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FOREWORD

We are pleased to present the APEC Energy Demand and Supply Outlook, 6th Edition. This Outlook aims to help inform policy makers about the major trends and challenges facing the energy sector in the APEC region.

The energy choices made in this region will have global impacts on energy security and environmental sustainability. The Business-as-Usual Scenario clearly highlights that current policies and trends do not adequately address the regions energy challenges with APEC missing both the energy intensity and renewables target. As a result, the Asia Pacific Energy Research Centre (APERC) developed three alternative scenarios (Improved Efficiency, High Renewables and Alternative Power Mix Scenarios) to outline how APEC can meet its energy goals and transition towards a more sustainable energy system.

To improve energy security and address climate change, the APEC region will need to accelerate both energy efficiency improvements and measures aimed at decarbonising energy supply. The analysis presented in this Outlook identifies major barriers towards implementing energy efficiency and switching to lower carbon fuels as well as possible solutions to overcoming these obstacles.

This report is the flagship work of the Asia Pacific Energy Research Centre. It is an independent study, and does not necessarily reflect the views or policies of the APEC Energy Working Group or individual member economies. However, we hope that it will serve as a useful basis for discussion and analysis of energy issues both within and among APEC member economies.

I would like to express a special thanks to the many people outside APERC who have assisted us in preparing this report, as well as to the entire team here at APERC. This publication coincides with the celebration of APERC's 20th anniversary and we hope that the analysis will help guide the mapping of the APEC region's energy future.



Takato Ojimi
President
Asia Pacific Energy Research Centre (APERC)

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We also would like to thank members of the APEC Secretariat, APEC Energy Working Group (EWG), the APEC Expert Group on Energy Data and Analysis (EGEDA), and the APERC Advisory Board, along with numerous government officials, for their helpful information and comments.

PROJECT MANAGER

Cecilia Tam

COORDINATOR

Naomi Wynn

LEAD AUTHORS

Muhamad Izham Abd Shukor ● Chrisnawan Anditya ● Luis Camacho Beas ● Martin Brown-Santirso ● Alexey Kabalinskiy ● Fang-Chia Lee ● Juan Roberto Lozano Maya ● Choong Jong Oh ● Takashi Otsuki ● Hooman Peimani ● Tran Thi Lien Phuong ● Dk Nur Afifah Atikah Pg Hj Ismail ● Michael Ochoada Sinocruz ● Dmitry Sokolov ● Maren Stachnik ● Atit Tippichai ● Linmin Xia

OTHER CONTRIBUTORS

Du Bing ● Elvira Torres Gelindon ● Jia Hao ● Kazutomo Irie ● Kensuke Kanekiyo ● Yeong-Chuan Lin ● Aishah Mohd Isa ● Parminder Raeewal ● Kirsten Smith ● Wanhar

EDITORS

Marilyn Smith ● Kristine Douaud ● Andrew Johnston ● Erin Crum

ADMINISTRATIVE SUPPORT

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EXTERNAL EXPERTS

Australia: Matthew Deady, Gary James, Tanya Kavanagh, Richard Niven, Kate Penney, and Arif Syed, Department of Industry, Innovation and Science; Katie Eberle, Department of the Environment • **Brunei Darussalam:** Abdul Matiin bin Hj Md Kasim, Noor Dina Zharina Hj Yahya, Abdul Salam bin Hj Abdul Wahab and Andi Tabrani, Energy and Industry Department, Prime Minister's Office • **Canada:** Department of Natural Resources Canada and National Energy Board • **Chile:** Ministry of Energy • **Hong Kong, China**: Cho-yee IP, Electrical and Mechanical Service Department, The Government of the Hong Kong Special Administrative Region • **Indonesia:** M. Teguh Pamudji and Susetyo Edi Prabowo, Ministry of Energy and Mineral Resources; Satry Nugraha, National Energy Council • **Japan:** Shinichi Kihara, Shinji Ishii, and Kazuhiro Karumi, Ministry of Economy, Trade and Industry; Naoko Doi, Peck Yean Gan, Takao Ikeda, Asamu Ogawa, Tohru Shimizu, Kan Sichao, Kaoru Yamaguchi, The Institute of Energy Economics, Japan • **Korea:** Young Joon Joo and Jung-Lim Noh, Ministry of Trade, Industry and Energy; Moon-sun Choi and Gue Jae Jeong, Korea Energy Economics Institute • **Malaysia:** Loo Took Gee, Aswita Sazmin Ismail and Falisya Noor Azam, Ministry of Energy, Green Technology and Water; Zuliana Azrin and Zaharin Zulkifli, Energy Commission • **Mexico:** Leonardo Beltrán Rodríguez, Rafael Alexandri Rionda, Alejandro Amerena Carswell, José Alberto Bravo López, Javier Flores Durón Lizaola, Leslie Mildred González Amezquita, Juan Herrera Romero and Giselle del Rocío Pérez Zazueta, Ministry of Energy • **New Zealand:** Clem Arlidge, Marcos Pelenur and Bryan Field, Ministry of Business, Innovation and Employment; John Duncan, Caroline Parlane and Elizabeth Yeaman, Energy Efficiency and Conservation Authority • **Peru:** Omar Chambergo Rodriguez, Rosa Luisa Ebentreich Aguilar, and Raul Perez-Reyes, Ministry of Energy and Mines • **The Philippines:** Jesus T. Tamang, Carmencita A. Bariso and Ma. Victoria B. Capitoe, Energy Policy and Planning Bureau of the Department of Energy • **Papua New Guinea:** Martin Bonou, Kepsy Puyei and Vore Veve, Department of Petroleum and Energy; Rebecca Kiage, Department of Public Enterprises • **Russia:** Talyat Aliev, Mariya Volkova, Ministry of Energy; Boris Saneev, Energy Systems Institute, Siberian Branch Russian Academy of Sciences • **Singapore:** Violet Chen, Kang Yang Chia, Faith Gan, Agnes Koh, Erica Liu, Wei Chian Poh, Kejia Ren, Lueneng Tan, Derek Wu and Lyana Yeow, Energy Market Authority • **Chinese Taipei:** Jyuung-Shiauu Chern and Su-Fang Chen, Bureau of Energy, Ministry of Economic Affairs; Jen-Yi Hou, Taiwan Research Institute • **Thailand:** Supit Padprem, Vichien Tantiwisarn, Munlika Sompranon, Thammayot Srichuai and Chawalit Pantaros, Ministry of Energy • **United States:** Elena Thomas-Kerr, Department of Energy; Erin Boedecker, Linda Doman, Mindi Farber-DeAnda, Perry Lindstrom, John Maples, Chris Namovicz, Kelly Perl, John Powell, Michael Schaal, Mark Schipper, Kay Smith, John Staub and Jim Turnure, U.S. Energy Information Administration.

Contact

For comments and questions, please contact:

Cecilia Tam
Special Adviser
Asia Pacific Energy Research Centre
Phone: (+81)3 5144 8551
E-mail: cecilia.tam@aperc.ieej.or.jp

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SCENARIOS IN THE 6TH EDITION

Recognising the rapid changes underway across the energy sector, the 6th edition of the APEC Energy Demand and Supply Outlook examines the Business-as-Usual (BAU) Scenario (the reference scenario) against three alternatives. The BAU reflects current policies and trends within the APEC energy sector; thus, its projections largely extend the past into the future. The alternatives are target-based and demonstrate what could be achieved under different policy frameworks. The Improved Efficiency Scenario supports the APEC goal of reducing energy intensity by 45% between 2005 and 2035. The High Renewables Scenario supports the APEC goal of doubling the use of renewable energy sources between 2010 and 2030. The Alternative Power Mix Scenario evaluates trade-offs among the use of cleaner coal, gas and nuclear energy in the electricity sector.

Table I ● Outlook scenario descriptions

	Business-as-Usual Scenario	Improved Efficiency Scenario	High Renewables Scenario	Alternative Power Mix Scenario
Definition	Current policies and trends	Enhanced energy efficiency policies and measures	Doubling of renewable energy use in electricity and transport	Four power mix cases evaluating cleaner coal, high gas and high nuclear
Purpose	Outlines likely energy future if no significant changes occur	Identifies further energy efficiency improvements	Outlines a pathway to achieve the APEC goal of doubling renewables	Evaluates trade-offs among the use of cleaner coal, gas and nuclear in the electricity sector
Limitations	Assumes minimal changes in energy demand and supply trends	Renewables shares maintained at BAU levels	Energy efficiency initiatives maintained at BAU levels	Limited to power sector, with energy efficiency and renewables maintained at BAU levels

ALTERNATIVE ENERGY FUTURES TO SUPPORT APEC ENERGY COMMITMENTS

Recognising their vital role in the global energy system, APEC economies have shown strong leadership in the development of a more sustainable energy system by committing to two important goals. In 2012, the St. Petersburg Declaration introduced an enhanced 'aspirational goal to reduce aggregate energy intensity of APEC economies by 45% from 2005 levels by 2035' (APEC 2012). In 2014, the Beijing Declaration introduced an 'aspirational goal of doubling the share of renewables in the APEC energy mix, including in power generation, from 2010 levels by 2030' (APEC 2014). These goals are the basis for two of the three alternative scenarios APERC developed for this 6th edition of the APEC Energy Supply and Demand Outlook.

APEC 45% Energy Intensity Reduction Goal

The APEC Energy Intensity Goal aims to reduce energy intensity for APEC as a whole by 45% over the period 2005 to 2035, but does not set out any economy-specific targets. It is a follow-on to the Sydney Declaration (2007), which aimed to reduce energy intensity by '25% from 2005 levels by 2030'. Stimulated by the realisation in 2010 that the initial goal would be far surpassed, APEC Energy Ministers pushed for the more ambitious goal agreed to under the 2012 declaration. Significant improvements in energy efficiency and conservation measures in many APEC economies have already demonstrated the clear benefits of enhanced efforts to reduce energy consumption.

Under the BAU Scenario, the 45% energy intensity goal is not achieved until 2037. The Improved Efficiency Scenario evaluates the impact of more stringent energy efficiency policies and measures in buildings, industry and transport, applied across all APEC economies, to illustrate the potential for an even more ambitious energy intensity reduction goal. Wider adoption of existing and already commercial end-use technologies, along with the development and deployment of new, more efficient technologies, are potential areas for further APEC cooperation.

The energy denominator for such a target is still under discussion: it could be primary energy, final energy or final energy excluding non-energy use. To develop the Improved Efficiency Scenario in this Outlook, APERC chose final energy and final excluding non-energy use as the basis for evaluating improvements in energy intensity.

APEC Doubling Renewables Goal applied to power and transport

The High Renewables Scenario is driven by APEC's goal of doubling the regional share of renewable energy. The goal includes the use of hydropower in its definition of renewables, but excludes the use of traditional biomass. Because of data and modelling limitations for projecting additional renewables use in industry, buildings and agriculture, the High Renewables Scenario covers only the power and transport sectors and is applied based on final energy.

The High Renewables Scenario assumes that all announced government targets on renewables will be achieved. For the power sector, it uses a least-cost model to determine the remaining additions of renewables needed to achieve the APEC doubling renewables goal. The model also assumes that the level of variable renewables (solar PV and wind) would be limited to 30% in generation in developed economies[1] and 20% in developing economies. In the transport sector, the High Renewables Scenario assumes that the supply of biofuels expands as the land available for feedstock production is maximised; land productivity is also assumed to increase. Under this scenario, rising biofuels supply potential leads to higher biofuel blend rates. In economies where no blend rates currently exist but additional biofuels production is possible, a minimum blend rate is set to meet potential production based on feedstock availability.

EVALUATING TRADE-OFFS IN DETERMINING A SUSTAINABLE POWER MIX

To reconcile economic growth with environmental sustainability, APEC member economies are looking for ways to decouple their energy needs from rising greenhouse gas emissions. In particular, the predominance of fossil fuels in the region's electricity mix calls for generation portfolios with lower carbon dioxide (CO_2) intensities. Despite rising shares of renewable electricity and the considerable share of hydropower in some APEC economies, the reality is that coal, natural gas and nuclear energy account for most of the region's electricity generation–and are expected to remain dominant in 2040.

The Alternative Power Mix Scenario assesses four different cases. The Cleaner Coal Case assumes that, as a minimum, all new coal plants built from 2020 in the BAU Scenario will be equipped with supercritical (SC) or ultra-supercritical (USC) technologies; from 2030, all will be equipped with carbon capture and storage (CCS). The High Gas 50% and High Gas 100% Cases assume that all new coal plants will be replaced by combined cycle gas turbines (CCGT) at replacement rates of either 50% and 100%. The High Nuclear Case assumes an expansion of nuclear energy in nine APEC economies, plus continued use of nuclear energy in Mexico and Chinese Taipei.

This scenario provides a quantitative assessment of the trade-offs among the use of clean coal technologies, higher shares of natural gas and the expansion of nuclear energy in APEC's electricity generation as compared with BAU results. It evaluates the effects of the different power generation portfolios in terms of installed capacity, fuel use and CO_2 emissions. The scenario highlights policy implications of the alternatives, providing valuable findings for policy makers in APEC economies.

[1] Australia is an exception to this: Variable renewables reach 44% as 18 GW of energy storage is assumed to be deployed together with rooftop PV.

STRUCTURE OF THE 6TH EDITION OF THE OUTLOOK

As with previous editions, this 6th edition of the APEC Energy Demand and Supply Outlook comprises two volumes. Volume I examines major energy trends within APEC overall, while Volume II is a compendium of outlooks for each of the 21 APEC economies.

Volume I is split into two parts. Part 1 reviews the APEC energy and demand supply outlook under the BAU Scenario, which assumes current policies and trends continue. It comprises three chapters covering energy demand (Chapter 2), energy supply (Chapter 3) and the electricity sector (Chapter 4). Part 2 explores alternatives to the BAU, devoting a chapter to each of the newly developed scenarios: Improved Efficiency Scenario (Chapter 5), High Renewables Scenario (Chapter 6) and Alternative Power Mix Scenario (Chapter 7). An expanded investment analysis (Chapter 8) under the BAU and alternative scenarios, and a final chapter analysing the energy security and climate change impacts of the various scenarios (Chapter 9) rounds out Part 2.

Volume II provides a detailed review for each economy, examining major energy demand and supply trends under the BAU Scenario and evaluating how different policy drivers influence the three alternative scenarios. The implications of these various scenarios are then evaluated in terms of investment needs and how they might affect energy security and climate change. Each economy chapter concludes with a section highlighting recommendations for further policy action that would enhance energy security and sustainable development.

1. AUSTRALIA

KEY FINDINGS

- **Australia is one of the largest energy producers in APEC over the Outlook period.** It is the world's third- and APEC's second-largest uranium producer, fourth-largest coal producer and sixth-largest gas producer. Its coal export resources are abundant and of high quality.

- **Australia has high renewable energy potential, with some of the best solar and wind resources in the world.** Its target is to increase non-hydro renewable generation to 33 TWh in 2020, and the economy's generation mix is shifting away from coal towards renewables under the BAU Scenario. The High Renewables Scenario exceeds this target by 80%.

- **Electricity demand declined in 2010-15 due to high roof-top solar uptake, high electricity costs, energy efficiency measures and closure of industrial and manufacturing plants.** Despite decreased demand under the BAU, electricity prices remain elevated due to high network costs.

- **Energy intensity drops 41% from 2005 to 2035 under the BAU Scenario, contributing to the APEC regional target, while energy demand grows 28%** from 81 Mtoe to 104 Mtoe from 2013 to 2040. The Improved Efficiency Scenario reduces energy intensity 49% from 2005 to 2035 and energy-related CO_2 emissions 19% compared with the BAU, achieving the energy productivity target.

ECONOMY AND ENERGY OVERVIEW

Exports to Japan, China, Korea and India have driven Australia's energy resource development. The economy has grown year-on-year since 1992 (at an average annual growth [AAGR] of 3.2% from 1992 to 2013) and was largely resistent to the most recent economic crises thanks to economic stimulus and high commodity exports to China (Table 1.1). As China's commodity consumption declines with slower economic growth, Australia's economic growth is likely to decelerate (ABS, 2015a). Mining-related investment that underpinned economic growth during the height of the mining boom is now in decline, falling 40% from 2010 to 2014 (BIS, 2014). Non-mining sectors are showing improvement, but not strong enough to fully offset the slower growth in the mining sector. In energy, the electricity generation mix has been changing with increased renewables[1] and less coal-fired generation. Abundant natural resources (coal, liquefied natural gas [LNG], iron ore, etc.) will keep the mining and energy sectors growing to 2020 as sustained investment in new capacity translates into higher production.

Table 1.1 • Australia: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	467	644	876	953	1 179	1 553	2 008
Population (million)	17	19	22	23	26	30	34
GDP per capita (2012 USD PPP)	27 342	33 698	39 506	40 941	45 281	51 568	59 199
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	86	108	124	129	134	140	144
TPES per capita (toe)	5.1	5.7	5.6	5.5	5.1	4.7	4.2
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	57	70	76	81	89	98	104
Final energy intensity per GDP (toe per 2012 USD million PPP)	121	108	87	85	76	63	52
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	260	335	385	389	391	393	382
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	100	100	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

ENERGY RESOURCES

Australia's large domestic energy resources provide long-term energy security for the economy (Table 1.2). In 2014, proven reserves of coal were 76 400 million tonnes (Mt), equivalent to 155 years of production at 2014 rates. Oil resources are diminishing as large oil fields mature, and although Australia has proven and untested condensate and liquefied petroleum gas (LPG) resources offshore, they are not under exploration. Conventional gas reserves were 3.7 trillion cubic metres (tcm) in 2014, or 68 years at 2014 production.

Australia has some of the world's best wind and solar energy resources. Annual solar radiation is 1 385 240 million tonnes of oil equivalent (Mtoe) covering hundreds of kilometres of land, and wind energy potential is highest along the south-western, southern and south-eastern land areas (BREE, 2014). Wave and tidal hydro potential is also high, but conventional hydro is limited as Australia is the driest inhabited continent. It is therefore unlikely that existing mature hydro will expand.

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

Table 1.2 ● Australia: Energy reserves and production, 2014

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Coal (Mt)[a]	76 400	155	8.6	4th	4th
Oil (billion bbl)[a]	4.0	24	0.23	25th	7th
Gas (tcm)[a]	3.7	68	2.0	11th	3rd
Uranium (kt U)[b]	1 174	185	32	1st	1st

Notes: [a]Total proven coal/oil/gas reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions. [b]Uranium reserves are 'reasonably assured resources'; reference year for uranium reserves and production is 2013.
Sources: For oil, coal and gas, BP (2015); for uranium, NEA (2014).

ENERGY POLICY CONTEXT

The Department of Industry, Innovation and Science (DIIS) administers energy and resource policy and the Department of the Environment oversees climate and renewable energy policy. In April 2015, DIIS released the government's new Energy White Paper, which sets out an energy policy framework to deliver competitively priced and reliable energy to domestic and international markets. The main objectives are to increase competition to keep prices down; improve Australia's 'energy productivity' [2] by 40% between 2015 and 2030; and attract investment in energy resource development and energy technologies. This third Energy White Paper since 2004 marks a change in direction for climate policy. Australia's economy-wide target to reduce greenhouse gas (GHG) emissions by 26% to 28% below the 2005 level by 2030 also forms the basis for its Intended Nationally Determined Contribution (INDC).

The National Energy Productivity Plan (NEPP), launched in December 2015, is expected to contribute more than a quarter of the savings required to meet Australia's 2030 GHG emissions reduction target. Several programs also encourage innovation and investor confidence in energy-use sectors: the AUD 5 billion (USD 4.5 billion)[3] Asset Recycling Initiative encourages states and territories to privatise state-owned electricity assets to free up capital for investment in new infrastructure (roads, ports and rail projects related to energy market competiveness). The AUD 188.5 million (USD 170 million) Industry Growth Centres raise competitiveness and productivity in the oil, gas and energy resources sector, and in mining equipment, technology and services. The AUD 476 million (USD 429 million) Industry Skills Fund helps develop the highly skilled workforce needed to adapt to new business opportunities, rapid technological change and market-driven structural adjustment. It also provides funding to train the oil, gas and energy resource industry's workforce in mining equipment, technology and services for small- and medium-sized enterprises.

BUSINESS-AS-USUAL SCENARIO

This section summarises the key energy demand and supply assumptions under the Business-as-Usual (BAU) Scenario (Table 1.3). Definitions used in this Outlook are different from the government targets and goals published in 2015 (such as the above-mentioned INDC/GHG emissions reduction target). It does not include new policies from 2015, such as the NEPP energy productivity target.

[2] An Australian government term that encompasses energy efficiency and reducing energy intensity and energy costs while promoting economic growth and competitiveness. The government defines it as 'the economic value created for every unit of energy consumed (GDP/PJ primary)'.
[3] All AUD figures use 2014 World Bank official exchange rate USD 1: AUD 1.11.

Table 1.3 • Australia: Key assumptions and policy drivers under the BAU Scenario

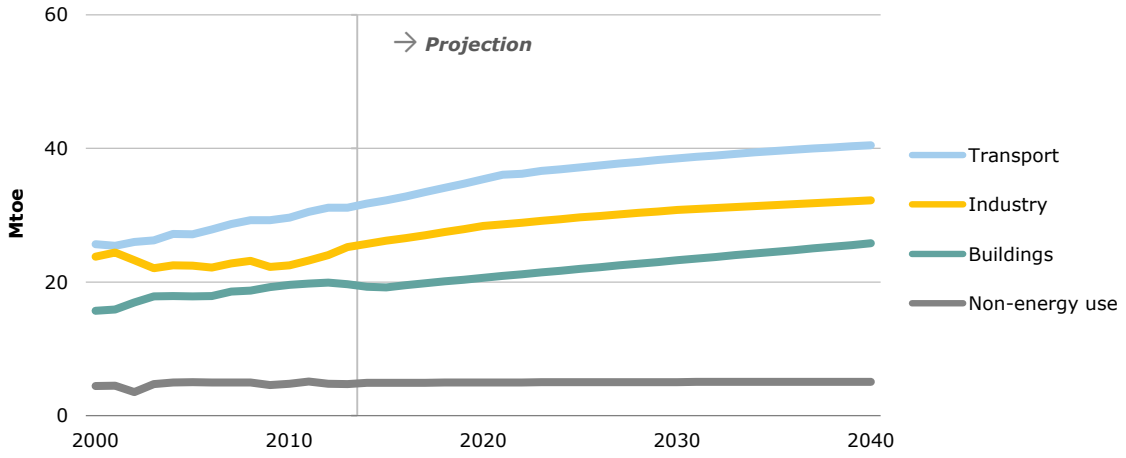
Buildings	• Minimum energy performance standards (MEPS) and labelling programs maintained at current levels.
Transport	• Slow deployment of hybrid cars and electric vehicles (EVs).
Energy supply mix	• Oil imports continue to increase. • No new oil reserves developed.
Power mix	• No new coal or hydro power plants. • No nuclear policy.
Renewables	• High growth in other renewables.
Energy security	• No oil stockpiles. • Self-sufficiency in coal, gas and renewables.
Climate change	• Work towards the INDC and emissions reduction target to reduce GHG emissions by 26% to 28% below 2005 level by 2030.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Under the BAU Scenario, final energy demand grows at an AAGR of 0.92%, from 81 Mtoe in 2013 to 104 Mtoe in 2040, an overall increase of 29%. Growth occurs in all sectors, with the largest AAGR in the buildings sector at 1% (Figure 1.1). However, domestic transport retains its dominant share of 39% (31 Mtoe) in 2013, peaking at 40% (35 Mtoe) in 2020 and remaining at 40 Mtoe until 2040. Industry follows at 31% (25 Mtoe) in 2013, 32% (26 Mtoe) in 2015 and 32 Mtoe in 2040.

Figure 1.1 • Australia: Final energy demand by sector, 2000-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

Given the importance of the transport sector in total final energy demand, oil remains the main fuel consumed, accounting for 50% of total demand over the Outlook period. Gas increases from 17% in 2013 to 21% in 2040, an increase of 62% from 13 Mtoe in 2013 to 22 Mtoe in 2040. Coal is the only fuel that declines, from a share of 4.1% (3.3 Mtoe) in 2013 to 2.5% (2.6 Mtoe) in 2040. Electricity demand decreased in 2013 because of increased energy efficiency, significant uptake roof-top solar, high electricity prices and the end of the mining boom. However, projections show demand growth from 2016 with the start of three new LNG projects in Queensland; in the longer term, population and economic growth drive demand.

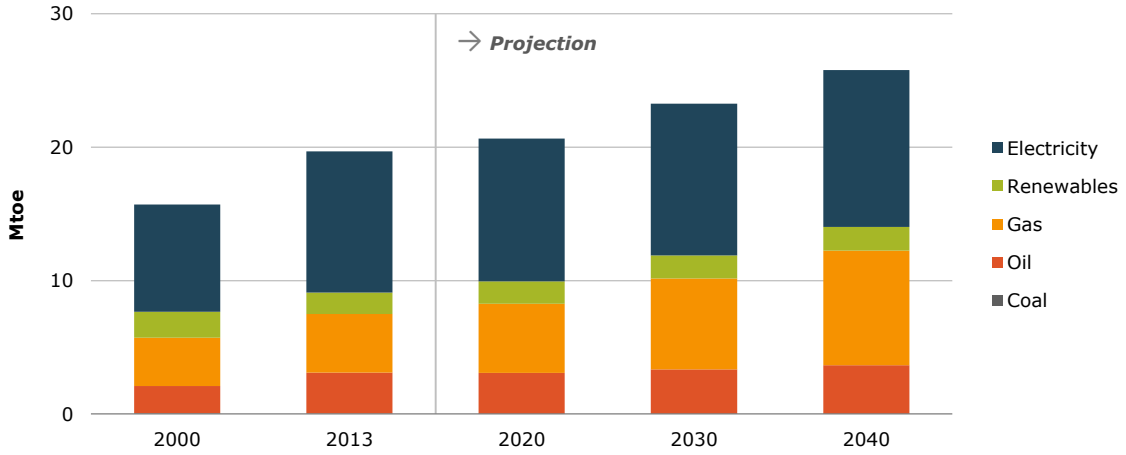
Despite increased demand, energy intensity (final energy demand per GDP) declines from 85 tonnes of oil equivalent (toe) per 2012 USD million PPP in 2013 to 57 toe per 2012 USD million PPP in 2035 and 52 toe per 2012 USD million PPP in 2040. Over the Asia-Pacific Economic Cooperation (APEC) energy

intensity goal period (2005-35), Australia's energy intensity falls by 41% and remains at this level through to 2040.

Buildings energy use: Efficiency improvements keep growth moderate

The buildings sector is electricity intensive, but high electricity prices as well as solar photovoltaic (PV) uptake and greater energy efficiency in this sector are partially responsible for the unexpected drop in grid electricity demand from 2011. Growth in population and average household income leads to continued increase in energy consumption in this sector, from 20 Mtoe in 2013 to 26 Mtoe in 2040, an increase of 32% (Figure 1.2). The residential sub-sector's 53% (11 Mtoe) share of the buildings sector's demand in 2013 increases to 57% (15 Mtoe) in 2040. Commercial sub-sector demand declines slowly from a 2010 peak of 36% (7 Mtoe) to 30% (7.8 Mtoe) by 2040, thanks to greater energy efficiency. The share of agriculture energy demand rises slightly from 11% in 2013 to 12% in 2040.

Figure 1.2 ● Australia: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Australia's wide range of well-established programs to promote energy efficiency in the residential and commercial sub-sectors include MEPS, energy rating labels, building codes and standards, a Nationwide House Energy Rating Scheme (NatHERS), an HVAC High Efficiency Systems Strategy and the Commercial Building Disclosure program. In South Australia 25% of homes have a solar PV system, in Queensland 21% do and in Western Australia the rate is 18% (APVI, 2015). Energy efficient appliances are also widespread thanks to stricter standards across a range of products.

Although appliances, electrical gadgets and space cooling already have high penetration rates in Australia, residential demand grows slowly and steadily with increased household numbers and economic growth. Demand for gas peaks in the winter months, as it is used for space and water heating in colder states such as Victoria.

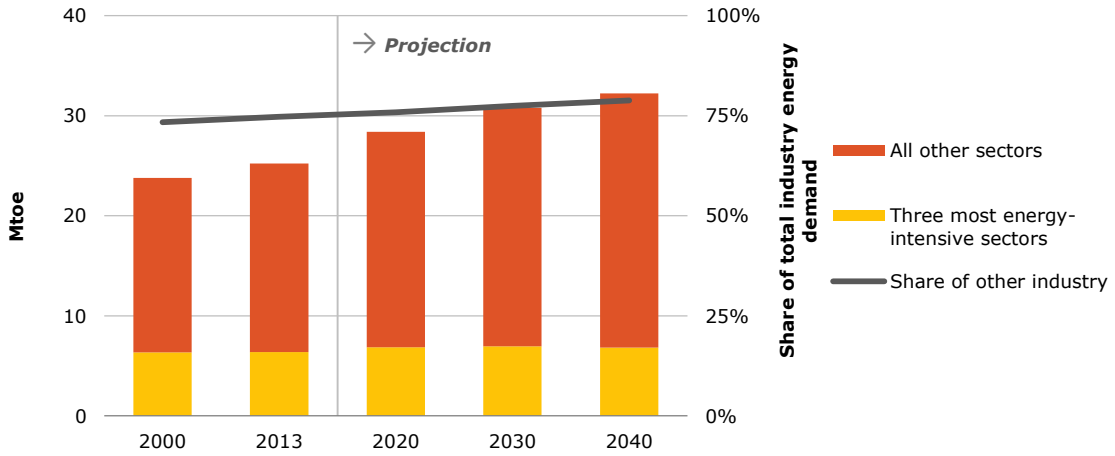
Within overall energy demand in the buildings sector, electricity demand increases to 12 Mtoe in 2040 from 11 Mtoe in 2013, while gas demand increases to 8.6 Mtoe in 2040 from 4.4 Mtoe in 2013.

Industry energy use: Slower growth

Industrial energy demand is projected to grow at an AAGR of 0.91% from 2013 to 2040, rising from 25 Mtoe to 32 Mtoe (Figure 1.3). The two largest energy consumers are non-ferrous metals (34% of total industrial energy use in 2013), and metal and quarry mining (16%). With the recent mining boom, the share of metal and quarry mining's energy use rises to 20% by 2040 (6.5 Mtoe), while the share of non-ferrous metals falls slightly to 33% (11 Mtoe). Of the three most energy-intensive industrial sub-sectors in the APEC region—iron and steel, chemicals and petrochemicals, and non-metallic minerals—only non-

metallic minerals is among the three largest energy consumers in Australia. Energy use in the three most energy-intensive sectors rises only moderately to 2040.

Figure 1.3 • Australia: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.

Sources: APERC analysis and IEA (2015a).

The mining sub-sector, until recently focused on infrastructure-related investments such as off-grid electricity generation, now turns to increasing production. This development, combined with the closure of several energy-intensive manufacturing plants, contributes to a drop in the industry energy demand AAGR from 2.4% from 2010 to 2020 to 0.82% from 2020 to 2030.

Box 1.1 • Australia: The Energy Efficiencies Opportunities (EEO) Program

As industry is one of the most energy-intensive sectors, the government implemented the Energy Efficiencies Opportunities (EEO) Program in 2006 requiring large energy users (more than 0.5 petajoules [PJ] or 11.9 kilotonnes of oil equivalent [ktoe] per year, equivalent to the consumption of about 10 000 Australian households) to undertake an energy use audit and report on all potential energy savings. The participants, which included transportation and large commercial building corporations, accounted for 56% of Australia's total energy use. Potential energy savings equivalent to 2.7% of annual energy demand, or 3.9 Mtoe, were identified. In the program's first cycle, 54% of the identified savings potential was implemented for annual net financial benefits of AUD 808 million (USD 728 million) and energy savings of 2.1 Mtoe, equivalent to total chemical and petrochemical sub-sector energy use in 2013. The program led to a 40% energy efficiency improvement within the Australian industrial sector.

Transport energy use: Road energy demand continues to dominate

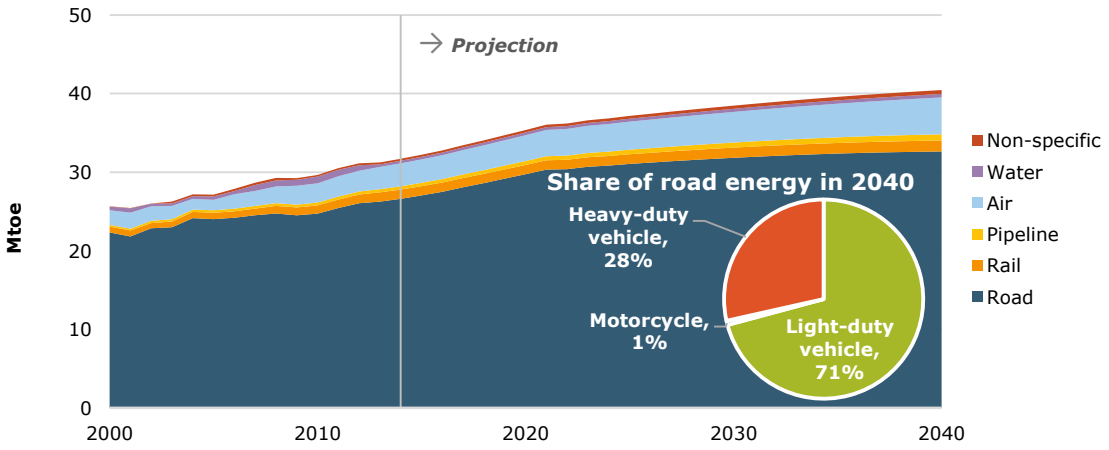
Domestic transport is the largest energy consumer, with a share averaging 39% over the projection period. Energy demand increases from 31 Mtoe in 2013 to 40 Mtoe in 2040 (Figure 1.4), and oil dominates at 96% of energy used in 2013. The uptake of biofuels and EVs results in fuel switching and the share of oil declines to 93% by 2040.

Energy consumption increases as transport demand rises with population growth and reliance on road vehicles for both freight and passenger transport. Australia's geography means that goods must be transported vast distances between major cities; as a result, heavy-duty vehicle energy demand rises by 1.1% per year, or 33% from 2013 to 2040. Additionally, urban sprawl is problematic for public transport

networks, with people favouring cars over public transport in most instances. Iron ore and coal dominate rail transport, accounting for 80% of total rail demand (BREE, 2014).

Australia does not have any fuel economy standards, and new vehicle imports are restricted to manufacturer and dealer networks. However, pollution standards and energy efficiency policies have led to fuel economy improvements as well as labelling on new cars and the online Green Vehicle Guide. Implementing efficiency standards and removing restrictions on vehicle imports would also help improve fuel efficiency.

Figure 1.4 ● Australia: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

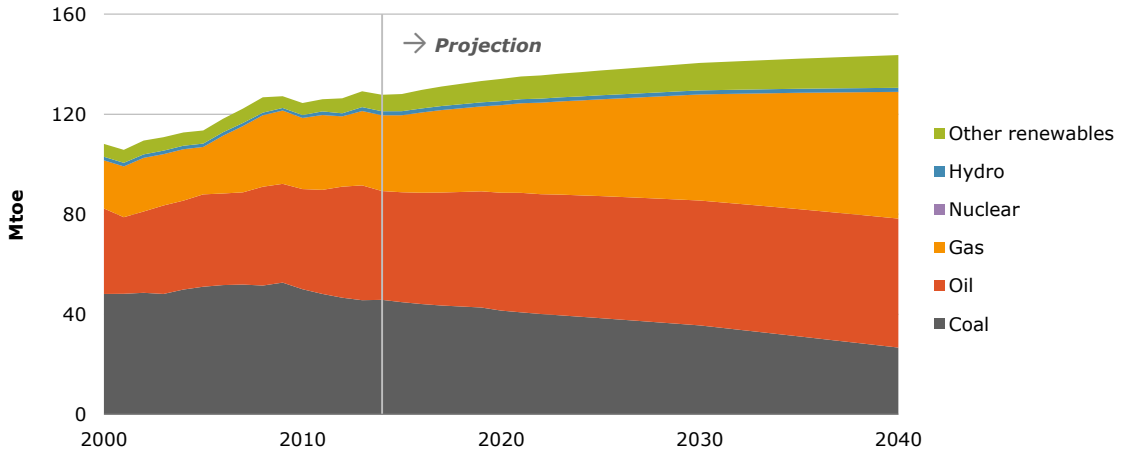
In 2013, total primary energy production was 344 Mtoe, and according to projections it will increase 27% to 436 Mtoe by 2040. Coal accounts for the largest share of production, peaking at 77% of total energy production in 2013 and declining to 72% in 2040. Gas replaces coal, its share rising from 15% in 2013 to 23% in 2040; this increase represents a near doubling in gas production, from 52 Mtoe to 102 Mtoe. With an AAGR of 2.5% from 2013 to 2040, gas production has the second-highest annual growth rate, after other renewables at 2.7%. Production from other renewables doubles from 6.3 Mtoe in 2013 to 13 Mtoe in 2040. Oil production declines significantly from the 2001 peak of 35 Mtoe to 20 Mtoe in 2013 and 6 Mtoe in 2040. Domestic oil production supplied 44% of oil consumption in 2013, but it meets just 12% by 2040. Australia's oil comes from mature fields with declining yields, and while there are unexplored offshore fields with potential for extraction, these resources have limited application and future oil consumption will therefore rely increasingly on imports. Australia currently exports over 75% of its oil production (BREE, 2014).

Primary energy supply: Away from coal towards gas and renewables

From 2013 to 2040 total primary energy supply (TPES) increases 14%, from 129 Mtoe to 144 Mtoe (Figure 1.5). Coal dominates TPES at 46 Mtoe in 2013, down from 52 Mtoe in 2007, and drops further to 30 Mtoe in 2040. Its percentage share drops from its peak in 2007 of 43% to 35% in 2013, and 20% in 2040. The decline in coal consumption is largely due to reductions in coal-based electricity and decreased use in the iron and steel sector, which uses large amounts of coal for the production of primary steel and for electricity production. The Australian iron and steel sector is contracting due to global overcapacity resulting in weak steel prices. Oil increases from 46 Mtoe in 2013 to 52 Mtoe in 2040. Transport used 72% of Australia's oil supply in 2013, so oil imports increase as transport demand continues to grow over the projection period. Gas has the second-highest AAGR at 2% from 2013 to 2040. Electricity generation is the largest gas consumer, followed by manufacturing. Gas supply increases from 30 Mtoe in 2013 to 51 Mtoe in 2040. The share of other renewables more than doubles from 6.3 Mtoe in 2013 to 13 Mtoe in

2040, to support the APEC renewable energy doubling goal in the 2010-30 period (4.8 Mtoe to 11 Mtoe). The short-term increase is linked to large wind farms that come online in 2018-19 and the significant uptake of solar PV.

Figure 1.5 ● Australia: Total primary energy supply by fuel, 2000-40

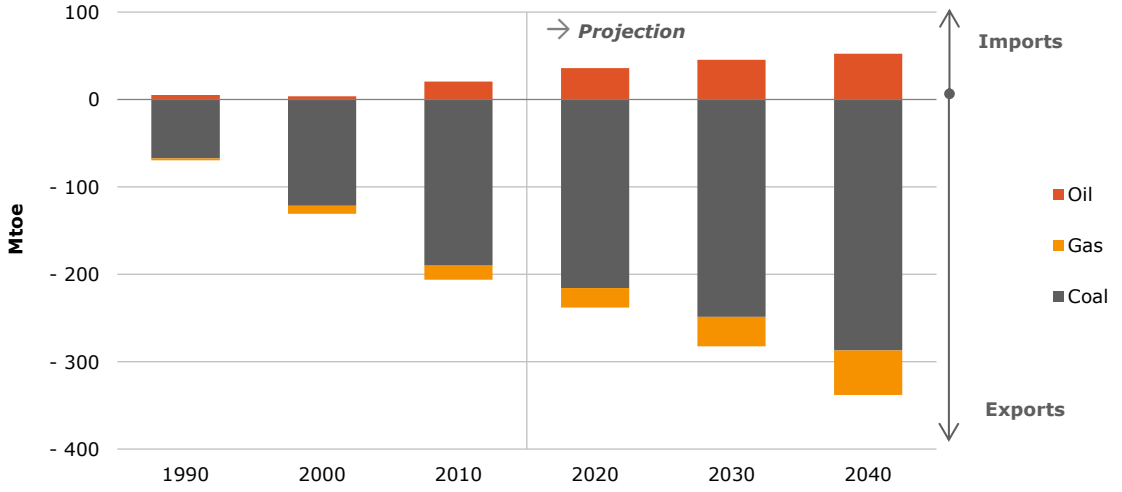


Sources: APERC analysis and IEA (2015a).

Energy trade: Rising coal and gas exports more than offset rising oil imports

Net energy exports (exports minus imports) grow 27% from 210 Mtoe in 2013 to 286 Mtoe by 2040 (Figure 1.6). According to the government, in 2014 energy exports accounted for 31% of total commodity exports at a value of AUD 72 billion or USD 64 billion (BREE, 2014). Energy exports are the second-largest export earner after resources. In 2013, energy exports increased by 14% from 2012, thanks to increased coal, uranium and gas exports. In contrast, energy exports rose by only 2% in 2014 largely due to a decline in crude oil and uranium exports (DIIS, 2015b). Oil remains Australia's only energy import over the Outlook period. As mature oil fields deplete, imports increase by 75%, from 30 Mtoe in 2013 to 52 Mtoe in 2040. Increased transport demand is responsible for oil imports doubling, as is the remote offshore location of the producing oil fields, the relocation of refining offshore, and oil field maturation. However, the economy has an estimated 356 Mtoe of undiscovered crude oil in four proven basins and 3 444 Mtoe of identified immature oil shale deposits (GA, 2014). Exploring and developing these resources would reduce import dependence.

Figure 1.6 ● Australia: Net energy imports and exports, 1990-2040



Sources: APERC analysis and IEA (2015a).

The largest energy exports, and second- and third-largest exports overall, are coal and gas (iron ore is the overall largest) (ABS, 2015b). Australia's largest coal market is Japan, but its largest expanding market is China. Gas exports go mainly to Japan (18 Mt), China (3.4 Mt) and Chinese Taipei (0.1 Mt) (IGU, 2015). Coal exports will depend on demand from China and India; Chinese imports are uncertain at present due to recent weaker than expected growth and policies directed at constraining coal use, but future demand from India is potentially high.

Gas exports have grown significantly, from 2.4 Mtoe in 1990 to 22 Mtoe in 2013, and are projected to grow 127% to 51 Mtoe by 2040. Australia is expected to have the largest liquefaction capacity in the world by 2018, overtaking both Qatar and Malaysia with a total capacity of 58 Mt per year.

Power sector trends: Rapid growth in renewables diversifies the power sector

The electricity network consists of the National Energy Market (NEM), which services the south and eastern seaboard (Queensland, New South Wales, Victoria, South Australia and Tasmania) and supplies 85% of energy consumed. The South-West Interconnected System (SWIS) in Western Australia accounts for 10% of electricity consumed, while the remaining 5% of electricity comes from regional networks serving remote households, businesses and communities, and the energy and resources sector (CSIRO, 2014).

Under NEM, electricity prices vary depending on region, spot price and whether the electricity is purchased wholesale or retail. Wholesale electricity prices fluctuate depending on spot prices; however, over the last five years (2010-15) spot prices have remained relatively stable, avoiding the large peaks of prior years. By comparison, retail electricity prices more than doubled for households from 2008 to 2014 and increased by 82% for businesses. Investments in transmission and distribution to repair ageing assets and improve reliability during peak demand contributed to the price increase (BREE, 2014). With hotter summers each year, peak demand occurrences are increasing (BREE, 2014).

Australia currently has a 20% oversupply of electricity capacity, and demand has fallen since 2009 (ESAA, 2015). The Australian Energy Market Operator (AEMO) forecasts that Australia needs no new generating capacity in the NEM until 2019-20 and instead prioritises replacing ageing transmission network infrastructure (AEMO, 2015a). The SWIS in Western Australia, covering Perth and the southwest, is projected to be the same. Electricity generation from large-scale centralised power generators fell in recent years due to lower industrial production, the spread of small-scale solar systems, improved energy efficiency and higher electricity prices. The recent decline occurred in the NEM, whereas the SWIS and other regional markets grew due to the mining boom (BREE, 2014). Over the projection period, total electricity generation grows at an AAGR of 0.83%, from 249 terawatt-hours (TWh) to 311 TWh (Figure 1.7) due to several LNG projects coming online in Queensland and a slight recovery in electricity consumption in the buildings sector due to population growth (AEMO, 2015b). Electricity generation varies widely from region to region (Box 1.2). In some states renewables are the dominant electricity generation source; in others it is coal or gas. Different regions will also increase generation at different rates depending on industry demand.

Box 1.2 • Australia: Primary generation fuel by state

In 2013, Victoria produced 21% of Australia's total electricity generation, with brown coal used for 86%. Queensland provided 25% of generation and New South Wales (including the Australian Capital Territory) 28%; both relied mainly on black coal at 71% and 81% respectively. Tasmania's 5.3% of Australia's generation relied primarily on hydro at 82%. Finally, South Australia produced 5.4% of generation and Western Australia 14%, and they relied mostly on gas at 53% and 52% respectively (DIIS, 2015b).

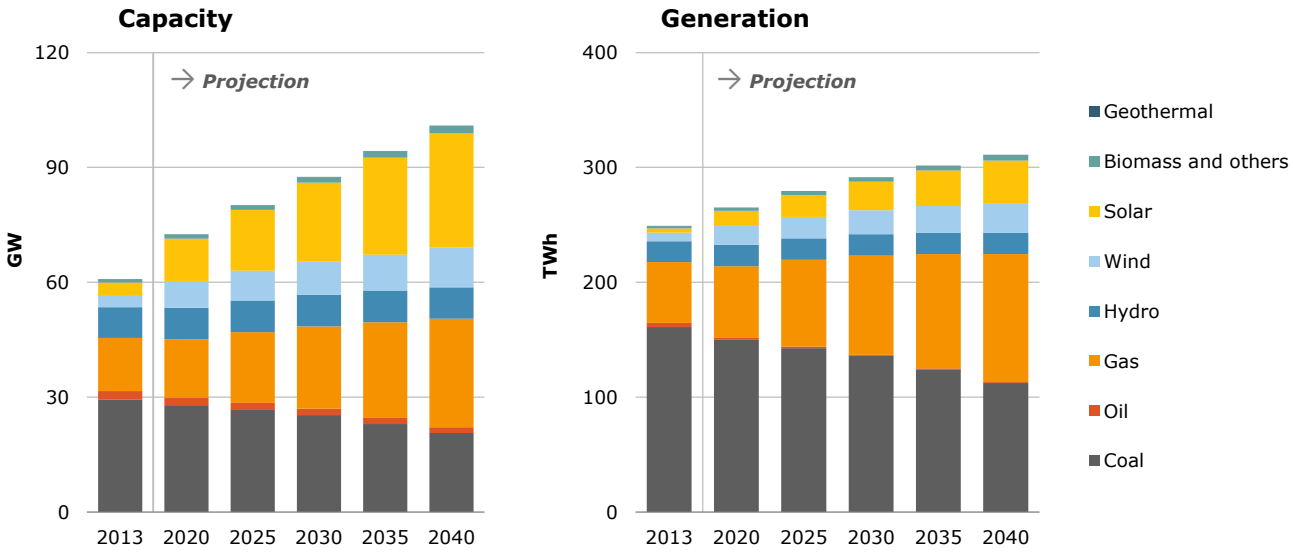
South Australia plans to increase renewables from a 25% share in 2013 to 50% by 2025, Queensland from 9% to 50% by 2030 and Victoria from 13% to 20% by 2020 (BREE, 2014).

The power mix continues toward a higher penetration of renewables over the projection period. Under the BAU the share of coal in capacity declines from 49% to 21%, and conversely other renewables increases from 12% in 2013 to 42% in 2040. Coal-fired generation declined from 187 TWh in 2007 to 161 TWh in 2013 due to the relative cost of coal-powered production and the uncertainty of Australia's carbon policy (DIIS, 2015b), and it is projected to decline further to 112 TWh by 2040. Overall generation declined further over 2010-15 as a result of downsizing in the iron and steel and manufacturing sub-sectors.

Renewables overtake coal as the largest capacity source in 2021 due to no new builds and only life extensions in coal-fired generation, while wind and solar generation ramp up. Coal capacity declines from 29 gigawatts (GW) in 2013 to 21 GW in 2040, total wind capacity increases 219% from 3.2 GW in 2013 to 10 GW by 2040, and solar grows 815% from 3.3 GW to 30 GW. In 2001 the government introduced a renewable energy target (RET) of 9.5 TWh of other renewables generation by 2010; in 2011 this was extended to 45 TWh by 2020, but was then reduced to 33 TWh in 2015. Under the BAU Scenario the economy falls short of the revised target, but when hydro is included generation reaches 38 TWh. Residential and commercial solar PV grows with reduced panel and installation costs, loans and renewable certificate programs, high electricity prices, 70% home ownership and consistent solar radiation levels (AEMO, 2015b; 2015c). Utility solar increases with improvements in storage technology and uptake by remote mines, and thanks to financing from the Clean Energy Finance Corporation and the Australian Renewable Energy Agency (AEMO, 2015c; ARENA, 2015).

While gas capacity increases steadily from 14 GW to 28 GW, gas generation falls in the short term due to higher costs for gas-based electricity and removal of the carbon price in 2014, which incentivised gas and renewable generation over that of coal.

Figure 1.7 • Australia: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

All three Alternative Scenarios apply to Australia.[4] The Improved Efficiency Scenario leads to the most significant reductions in energy demand at 17% (17 Mtoe) more than under the BAU Scenario in 2040, and the highest energy-related CO_2 emissions reductions, at 19% (308 million tonnes of CO_2 [$MtCO_2$]) more. The High Renewables Scenario leads to an 18% reduction in energy-related CO_2 emissions beyond the BAU Scenario. Within the Alternative Power Mix Scenario, only the Cleaner Coal and High Gas Cases are applicable, as Australia has no plans for nuclear generation.

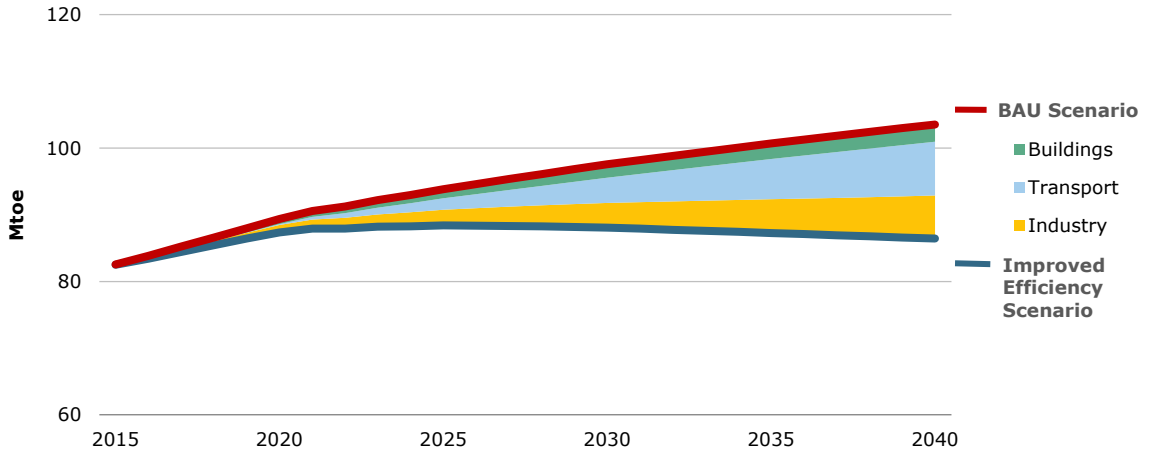
[4] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

While the APEC goal of reducing energy intensity by 45% by 2035 from the 2005 level is a collective rather than economy-specific target, under the BAU Scenario Australia's energy intensity decreases 41%.[5] The Improved Efficiency Scenario achieves a reduction of 49% in 2035 and 55% by 2040 (Figure 1.8).

Projections show that energy consumption can be reduced across all sectors. Transport demonstrates the largest reduction, 45% (6 Mtoe) of the total 13 Mtoe of savings by 2035 relative to the BAU, increasing to 47% (8.1 Mtoe) by 2040. The industry share amounts to 38% in 2035 and 2040, while the residential and commercial sub-sector share decreases from 21% (2.3 Mtoe) of savings in 2035 to 15% (2.6 Mtoe) in 2040.

Figure 1.8 • Australia: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Sources: APERC analysis and IEA (2015a).

Industry sector projections show energy reductions across all industrial sub-sectors; however, as non-ferrous metals has the largest share of energy consumption in both the BAU and Improved Efficiency Scenarios, it contributes the largest energy savings at 1.9 Mtoe in 2035 and eventually 2.4 Mtoe in 2040. Industry savings can be achieved through greater energy efficiency and higher rates of electrification.[6]

In transport, further reductions in road energy consumption can be achieved with more fuel-efficient heavy- and light-duty vehicles as well as urban planning that provides for efficient public rail transport. In the Improved Efficiency Scenario, road energy use peaks in 2021 at 30 Mtoe and declines to 24 Mtoe in 2040 for a 27% greater reduction than under the BAU. Increased deployment of EVs and improved public transport also reduce energy demand. Light-duty vehicle numbers fall from 25 million under the BAU in 2040 to 22 million under the Improved Efficiency Scenario, and the share of advanced vehicles (EVs and plug-in hybrid EVs) within the light-duty vehicle stock doubles to 17% by 2040 under the Improved Efficiency Scenario, from just 8.5% in the BAU Scenario.

Projected end-use savings in the residential sub-sector under the Improved Efficiency Scenario reach 1.2 Mtoe in 2040 and represent a 7.9% reduction compared with the BAU Scenario. Air conditioning shows the largest savings in 2035 (21%), followed by refrigerators at 18% and stand-by energy at 17%. Water heaters are the most energy-intensive appliance in 2035, at 68% of energy use, followed by air

[5] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.
[6] The Australian government provides information on improving industrial energy efficiency at the Energy Efficiency Exchange website (http://eex.gov.au/); for example, switching mining trucks to conveyor belts.

conditioners at 10%.[7] Projections for the modelled end uses show that the commercial sector can save 1.4 Mtoe by 2040 compared with the BAU Scenario with more efficient commercial appliances.[8]

As the recently released NEPP covers all energy consumption, including electricity, gas and transport fuels, it supports the Improved Efficiency Scenario. The NEPP incorporates energy market reforms to promote consumer choice and increase competition and innovation in the energy market, and energy efficiency measures that support better energy use in buildings, equipment and vehicles.[9]

The NEPP includes both existing policies considered under the BAU Scenario and new initiatives that support more productive consumer choices when selecting energy services through, for example, cost-reflective prices, smart meters and access to information, and labels. The NEPP also supports more productive energy services through innovation and competition by reducing market entry barriers for new technologies and service options, and through more efficient minimum standards for equipment, appliances and buildings.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

The doubling renewables goal proposes a doubling of renewable energy in APEC by 2030 from the 2010 level across all sectors.[10] In 2010 Australia's renewables generation was 22 TWh, and under the BAU Scenario it increases significantly to 51 TWh in 2020, 68 TWh in 2030 and 86 TWh in 2040. Other renewables (biofuels) in transport more than double under the BAU, from 0.2 Mtoe in 2010 to 0.54 Mtoe in 2030, and more than triple to 0.71 Mtoe in 2040.

In 2015, the government revised the RET from 41 TWh to 33 TWh by 2020 (other renewables only). The revised target is achieved in the High Renewables Scenario: other renewables electricity grows more than tenfold from 13 TWh (5.3% of total generation) in 2013 to 59 TWh (22%) in 2020, 135 TWh (46%) in 2030 and 164 TWh (52%) in 2040 (Figure 1.9). This is an additional 97 TWh of other renewables by 2040, or a 14% difference from the BAU. Hydro's contribution remains largely unchanged and wind overtakes hydro in 2018 as the largest renewable energy source at 10% (23 TWh) of the electricity generation mix, growing to 31% (81 TWh) in 2030 and 33% (89 TWh) in 2040 at an AAGR of 9.7% from 2013 to 2040. Solar grows from 1.5% (3.8 TWh) of the generation mix in 2013 to 15% (43 TWh) in 2030 and 20% (64 TWh) in 2040.

Investment in capital infrastructure (replacing network distribution and transmission infrastructure) has caused electricity prices to rise for consumers, accounting for 61% of retail price increases (AEMC, 2013). Consumers are therefore paying more for servicing the grid than for the actual fuel costs. This creates a paradox in Australia's electricity markets, as small businesses and residences are installing small-scale solar power generation at one of the highest rates in the world to reduce their grid consumption and the corresponding electricity bills. However, the reality is that the electricity bills still increase despite reduced grid consumption, as the costs for servicing apply regardless of how much fuel is consumed to produce the electricity. Therefore, in some instances it is less expensive for consumers to go completely off-grid using solar plus storage, than to remain connected to the network.

High retail- and geography-related delivery costs are motivating a trend in Australia toward a less centralised and more distributed electricity sector. The high cost of using centralised power in remote areas is becoming less favourable than a decentralised model using rooftop solar, local generation and

[7] The Improved Efficiency Scenario for the residential sector does not model all appliances, nor does it account for heating in Australia, and the figures represent energy savings potential. For example, in 2012, heating and cooling were the most energy-intensive sources of energy consumption at 40% of energy use in households, followed by water heating at 21% and fridges at 5.9% (http://www.yourhome.gov.au/energy/appliances). However, the savings demonstrated in the Improved Efficiency Scenario is a good indication of savings potential, especially given Australia's extreme climate and the increasing number of household air conditioners resulting from rising population and house size.

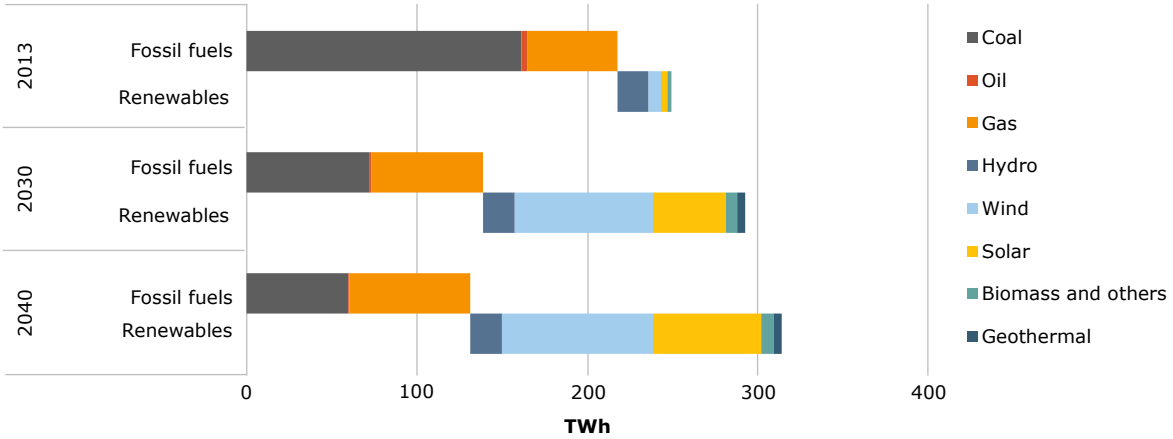
[8] The Improved Efficiency Scenario for the commercial sector only models energy use for lighting, cooling, refrigeration and ventilation. It does not model equipment, water heating, space heating or cooking. From 1999 to 2012, commercial building heating, ventilation and cooling accounted for 43% of energy use, followed by lighting at 26% and equipment at 20% (P&S, 2012).

[9] NEPP uses different assumptions from the Improved Efficiency Scenario, such as different GDP growth forecasts.

[10] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

storage thanks to increasingly competitive PV equipment, installation and storage costs, and high solar radiation levels. As a result of increased renewables, storage will form a larger part of energy infrastructure costs.

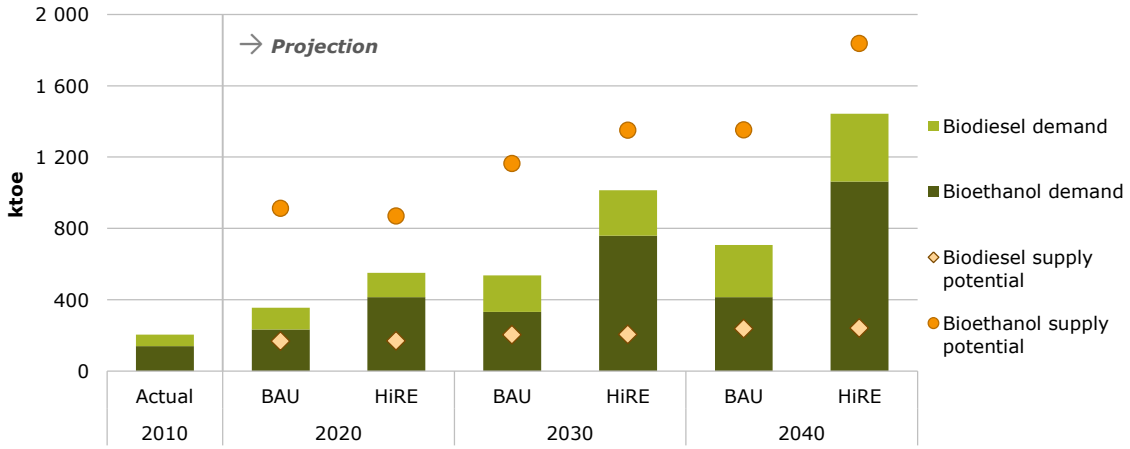
Figure 1.9 • Australia: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

Under the High Renewables Scenario, bioethanol demand more than quintuples from 0.14 Mtoe in 2010 to 0.76 Mtoe in 2030 and 1.1 Mtoe in 2040 (Figure 1.10). Biodiesel demand increases nearly fourfold from 0.07 Mtoe in 2010 to 0.25 Mtoe in 2030, and almost six times to 0.38 Mtoe in 2040. Bioethanol supply potential increases from 1.4 Mtoe in 2030 and 1.8 Mtoe in 2040. Biodiesel supply potential increases from 0.2 Mtoe in 2030 to 0.24 Mtoe in 2040. Under these projections, Australia has enough bioethanol supply potential to meet demand, but will need to import biodiesel as supply potential falls short of demand.

Figure 1.10 • Australia: Biofuels demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is for the Outlook period only; HiRE = High Renewables Scenario.
Sources: APERC analysis, IRENA (2014), FAO (2014) and IEA (2015a).

ALTERNATIVE POWER MIX SCENARIO

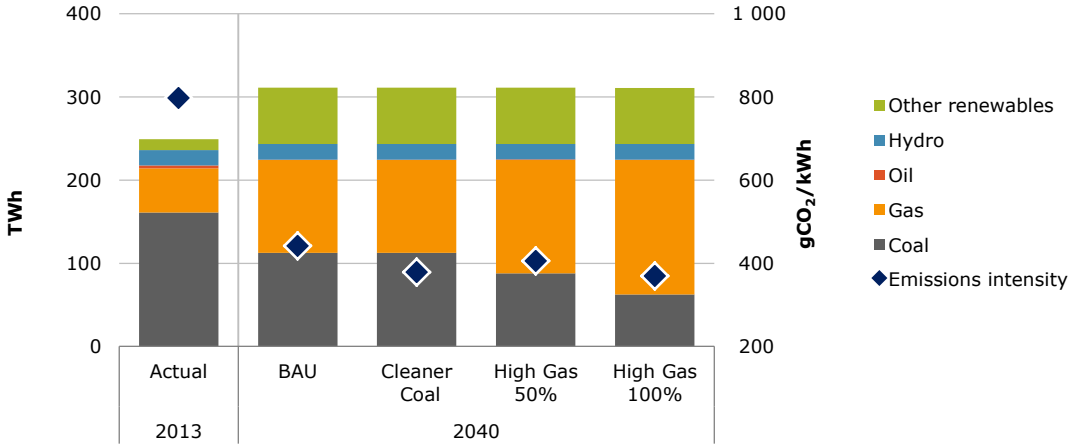
The Alternative Power Mix Scenario focuses on alternative supply options in the electricity sector. Only three of the four cases apply to Australia—the Cleaner Coal, the High Gas 50% and the High Gas 100%—as there are no economy-wide plans for nuclear development.

The Cleaner Coal Case assumes that all new coal-based electricity capacity in Australia is advanced ultra-supercritical (A-USC) or integrated gasification combined cycle (IGCC) with a minimum efficiency of 45% to 50% from 2020 onwards. From 2030, all new plants are additionally equipped with carbon capture and storage (CCS); currently 70% of Australia's coal-based capacity is sub-critical. The Cleaner Coal Case results in an additional 12.3 gigawatts (GW) of A-USC/IGCC by 2030 and 11.3 GW of A-USC/IGCC with CCS by 2040. The share of coal in generation declines to 36% by 2040 from 65% in 2013 (Figure 1.11).

The High Gas 50% Case assumes that 50% of what would have been new coal-based electricity capacity is replaced by gas, and the High Gas 100% Case assumes that all new capacity is replaced by gas. Under the High Gas 50% Case, the share of gas-based generation reaches 44% in 2040, from 36% in the BAU Scenario, and under the High Gas 100% Case the share of gas reaches 52%. The High Gas 100% Case results in the lowest power sector CO_2 emissions intensity by 2040 (369 grams of CO_2 per kilowatt-hour [gCO_2/KWh]) compared with the BAU, but has the highest average generation cost at USD 0.16/kWh. The Cleaner Coal Case demonstrates the second-largest change in emissions intensity at 378 gCO_2/KWh, or a 14% reduction compared with the BAU.

The major barriers to the Cleaner Coal, High Gas 50% and High Gas 100% Cases are high gas prices, the need for a consistent carbon policy in Australia and the high levelised cost of electricity (LCOE) for gas power plants compared with non-CCS coal. The former carbon price encouraged switching from coal to gas for baseload power when coal became more expensive than gas, but with rising retail gas prices and declining electricity consumption, gas-powered generation is likely to decline marginally in the short term and increase only slightly in the long term (AEMO, 2014). Additionally, increasing gas exports compound rising gas prices as the exports compete with the domestic gas market.

Figure 1.11 • Australia: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Upstream developments dominate energy investments from 2015 to 2040, at 39% of total cumulative investments under the low-cost estimate and 50% under the high-cost estimate (Table 1.4). The bulk of investments are in gas production, due to several gas facilities coming online by 2020, followed by coal, due to increasing exports within APEC and to India. This includes large mine developments such as the 60-Mt Carmichael Project and the 55-Mt Project China Stone in Queensland (DIIS, 2015c). Gas transport, largely pipeline, makes up the majority of total energy transport investment (78% in the low-cost estimate and 87% in the high-cost estimate). The power sector claims between USD 165 billion (29% of total low-cost estimate) to USD 246 billion (20% of high-cost estimate) to finance 40 GW of additional

capacity from utility and PV solar, wind and gas, replacing and upgrading transmission and distribution lines, and storage.

Table 1.4 • Australia: Projected investments in the energy sector in the BAU Scenario, 2015-40

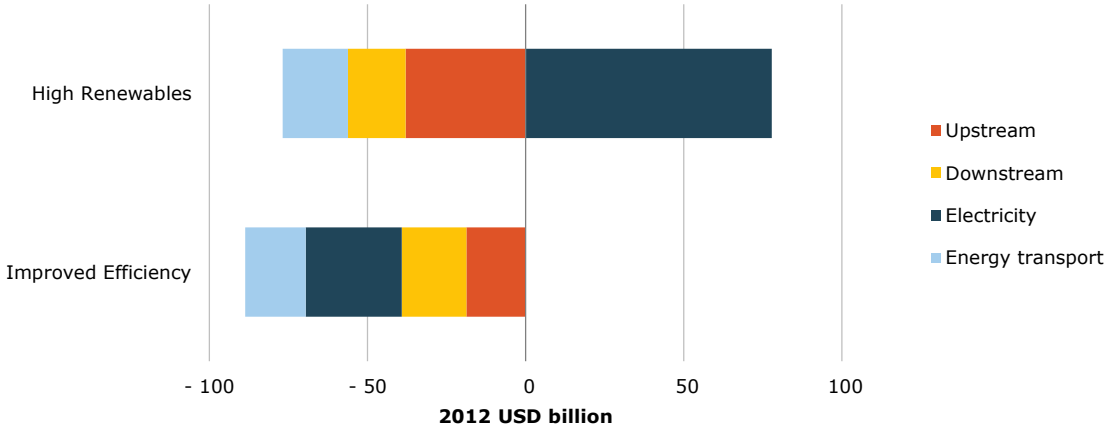
2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	45	67
	Gas	73	219
	Coal	106	345
	Subtotal	224	631
Downstream	LNG import terminals	0.4	0.4
	LNG export terminals	108	194
	Biofuels refinery	0.3	0.4
	Subtotal	109	195
Electricity	Coal	34	41
	Gas	14	24
	Hydro	0.2	0.3
	Wind	16	38
	Solar	60	85
	Biomass and others	6.5	8.6
	Geothermal	0.5	0.5
	Transmission lines	18	21
	Distribution lines	15	28
	Subtotal	165	246
Energy transport	Oil	12	14
	Gas	59	163
	Coal	4.8	10
	Subtotal	75	187
	Total	**573**	**1 259**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

A demand decrease of 17% in the Improved Efficiency Scenario by 2040 (reducing expenditure across all sectors) leads to total investment savings of 15% (Figure 1.12). However, while the High Renewables Scenario demonstrates savings in the upstream (17%), downstream (17%) and energy transport sectors (27%), power sector investment grows by 47% compared with the BAU, effectively negating any advantage over the BAU low-cost estimate. As more capacity in other renewables is added, more storage for the variable power sources is also needed, along with expansion and refurbishment of transmission and distribution lines for solar.

Figure 1.12 ● Australia: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

Enhancing energy security: High self-sufficiency and increased fuel diversity

Australia has high energy self-sufficiency for all fossil fuels except oil, and it is in non-compliance with the International Energy Agency (IEA) 90-day stockpile treaty (DIIS, 2015a). While Australia has agreed in principle to comply, maintaining the stockpile costs billions of dollars.

Under the BAU Scenario, primary energy supply diversity measured against the Herfindahl-Hirschman Index (HHI) improves from 0.31 in 2013 to 0.30 in 2040 (where a lower number indicates greater diversity) due to higher shares of natural gas and renewable energy and a lower share of coal (Table 1.5). Primary energy supply fuel balance is therefore considered good. Fuel input diversity in electricity generation improves over the projection period, from 0.58 in 2013 to 0.37 in 2040. This is due to coal's share in electricity generation decreasing from 65% to 36% while that of gas increases from 21% to 36% and renewables increase from 21% to 36%.

Table 1.5 ● Australia: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040					
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%
Primary energy supply diversity (HHI)	0.31	0.30	0.29	0.28	0.30	0.31	0.33
Primary energy supply self-sufficiency (%)	80	69	70	67	68	69	68
Coal self-sufficiency (%)	100	100	100	100	100	100	100
Oil self-sufficiency (%)	44	12	15	12	12	12	12
Gas self-sufficiency (%)	100	100	100	100	100	100	100
Electricity generation input fuel diversity (HHI)	0.58	0.37	0.35	0.33	0.36	0.36	0.39

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

Energy security improves by 2040 due to better oil self-sufficiency under the Improved Efficiency Scenario, in which there is a lower demand for oil (15%) compared with the BAU (12%). The High Renewables Scenario shows better diversity for electricity generation input fuel (0.33) compared with the BAU (0.37).

Climate change impacts and risks: High exposure and policy uncertainty

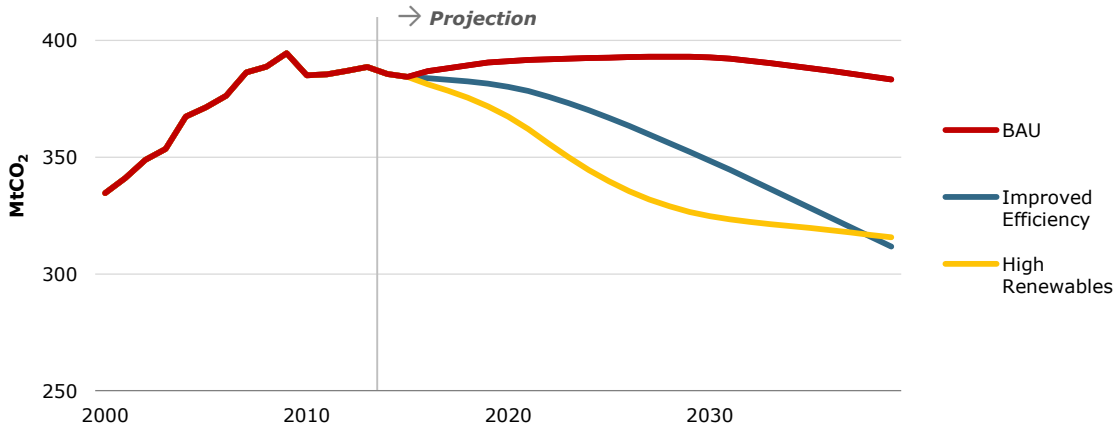
Australia is highly exposed to climate change impacts. It is the most arid inhabited continent on earth and is subject to extreme climate-induced events, including high-intensity bushfires and firestorms, floods, cyclones, droughts and out-of-trend weather such as snow in typically warm areas. The government estimates that more than AUD 266 billion (USD 240 billion) in coastal commercial, industrial, road and rail, and residential assets are exposed to flooding and erosion hazards at a sea level rise of 1.1 metres (DOE, 2011).

While Australia has a suite of climate change policies, its current flagship GHG emissions policy is an 'Emissions Reductions Fund,' which operates as a reverse auction in which the government purchases emissions reductions on eligible projects; it is an AUD 2 550 million (USD 2 297 million) fund (CER, 2015). In the two fund auctions so far, the government has purchased over 92 Mt of GHG emissions reductions from 275 projects at an average price of AUD 13.12 (USD 11.82) per tonne of abatement.

Climate policy has undergone many changes in recent years: in 2007 the Rudd Government announced a Carbon Pollution Reduction Scheme, which the parliament rejected. In 2010, Gillard took over Rudd's electoral term as prime minister, and in 2011 the Gillard Government implemented a carbon pricing mechanism or 'carbon price' and an associated whole-of-economy Clean Energy Plan. However, in 2013 the Abbott Government abolished the carbon price and Clean Energy Plan. The Abbott Government reintroduced the Emissions Reduction Scheme and released the 2015 Energy White Paper, which promotes CCS from 2030 and otherwise does not refer to climate change. Another change of prime minister in September 2015 created further uncertainty about Australia's carbon policy.

The energy-use sectors account for half of total GHG emissions (DOE, 2015). Within the energy-use sectors, electricity generation is the highest contributor to emissions due to coal dependence under the BAU Scenario; however, total emissions decline marginally at an AAGR of 0.064% over the projection period, from 388 $MtCO_2$ to 382 $MtCO_2$ as the uptake of renewables reduces coal's share in the power generation mix (Figure 1.13).

Figure 1.13 ● Australia: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

The Improved Efficiency Scenario offers the largest emissions reductions in the energy sector—19% compared with the BAU in 2040, at 308 $MtCO_2$. Under this scenario, energy-related CO_2 emissions decrease largely due to improved transport efficiency and decreased electricity demand. The High Renewables Scenario provides the most significant improvements from the beginning of the projection period, achieving greater energy-related CO_2 emissions reductions than the Improved Efficiency Scenario from 2013 to 2037, and continuing to decrease to 315 $MtCO_2$ in 2040.

RECOMMENDATIONS FOR POLICY ACTION

Australia's recommended policy priorities are renewables and energy efficiency, and reviewing the applicability of CCS in 10 years when the financial viability of cleaner coal becomes apparent. A strong climate change policy that encourages energy efficiency and renewables, and reduces coal consumption in the electricity sector, could dramatically reduce emissions per capita. This policy could take a whole-of-economy approach, addressing different sectors and implementing fuel economy standards and better public transport in the transport sector; penalties for high emitters and energy efficiency tax incentives in the industrial and electricity sectors; and renewable energy and green building requirements for new and existing buildings. These measures would help achieve the Improved Efficiency and High Renewables Scenarios, and assist developers in electricity generation to plan for storage and a more diversified, less centralised grid.

Australia already has in place a mandatory consumer information program that requires fuel efficiency labelling on new cars, as well as a voluntary program through the Green Vehicle Guide to help consumers make informed decisions. Under the Improved Efficiency Scenario, implementing efficiency standards and removing restrictions on vehicle imports would both improve fuel efficiency and reduce energy-related CO_2 emissions. Formed at the end of 2015, the Ministerial Forum and associated working group for implementing Euro 6, fuel quality standards, fuel efficiency measures for light-duty vehicles and emissions testing arrangements will help to achieve this scenario, along with the NEPP.

To reduce oil import growth, Australia could explore and develop the estimated 356 Mtoe of undiscovered crude oil in four proven basins and 3 444 Mtoe of identified immature oil shale deposits (GA, 2014).

2. BRUNEI DARUSSALAM

KEY FINDINGS

- **The oil and gas industry dominates Brunei Darussalam's economy at two-thirds of GDP.** The government aims to reduce over-reliance on oil and gas by expanding less-developed sectors such as agriculture and industry by 2035.

- **Brunei Darussalam is significantly more energy-intensive than other economies in the APEC region.** It will be difficult to contribute to intensity reduction targets without implementing energy efficiency and conservation practices, and deploying renewable energy.

- **By 2040, Brunei Darussalam will be the only energy self-sufficient economy in South-East Asia according to projections.** It is currently the fifth-largest oil producer in South-East Asia and exports more than three-quarters of its natural gas production as LNG. Remaining gas is used domestically, mainly to generate electricity and town gas.

- **Solar power has the greatest renewable growth potential.** Solar electricity is generated mainly through utility-scale solar PV installations and rooftop PV systems.

- **Restructuring energy prices and fuel subsidies is a sensitive issue.** However, current low global oil prices could help phase out fuel subsidies, as has been done in neighbouring economies.

ECONOMY AND ENERGY OVERVIEW

Brunei Darussalam is a small sovereign state on the northern coast of Borneo, 422 kilometres (km) north of the equator. It has a land area of 5 765 square kilometres (km^2) and a 161-km coastline that borders the South China Sea. The economy relies on revenue from its oil and gas sector, primarily crude oil and liquefied natural gas (LNG) exports, for two-thirds of its gross domestic product (GDP).

In 2013, the economy's GDP was USD 21 billion (Table 2.1). With a small population of about 410 000 in 2013 and very high GDP per capita (USD 50 878), the standard of living is high compared with other South-East Asian economies. Medical services and education up to university level are free, while fuel, food and housing are highly subsidised and citizens pay no taxes.

Table 2.1 ● Brunei Darussalam: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	15	18	20	21	23	25	29
Population (million)	0.3	0.3	0.4	0.4	0.5	0.5	0.6
GDP per capita (2012 USD PPP)	56 446	54 541	51 730	50 878	48 408	48 641	51 304
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	1.7	2.4	3.2	3.0	4.0	4.4	5.0
TPES per capita (toe)	6.7	7.2	8.2	7.4	8.5	8.5	8.8
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	0.4	0.6	1.3	1.1	2.0	2.1	2.2
Final energy intensity per GDP (toe per 2012 USD million PPP)	24	32	64	52	89	83	77
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	3.3	4.4	6.9	6.9	6.8	7.9	9.0
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	100	100	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Source: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

Because economic growth depends on the oil and gas sector, Brunei Darussalam is vulnerable to fluctuations in energy prices. Remaining GDP comes from the agriculture, forestry and fishery, industrial, and services sectors. Policies on economic diversification have long been in place, but have met with limited success. GDP per capita is expected to slide marginally to around USD 51 304 by 2040 due to rapid population growth and dependence on the energy sector, which is forecast to grow more slowly than population.

In energy sector development, policies encourage energy security, diversification of energy supply, energy efficiency and conservation. These policies are in line with the National Vision 2035–known as Wawasan Brunei 2035–to develop the economy's sustainable future.

ENERGY RESOURCES

Brunei Darussalam is one of the very few Asian economies to have self-sustaining energy production and reserves in recent decades. In 2014, it was estimated that the oil and natural gas reserves should last for more than 20 years, and in tonnes of oil equivalent (toe) per capita, energy reserves are the highest in South-East Asia.

As of 2014, total proven oil reserves were nearly 1.1 billion barrels, while total proven natural gas reserves were estimated at 0.3 trillion cubic metres (tcm) (Table 2.2). These oil and gas reserves should last approximately 23 years, and new recovery technologies and possible onshore and deep-water fields could extend this lifespan. The economy ranked 11th out of 21 Asia-Pacific Economic Cooperation (APEC) economies for both oil and gas reserves, but placed 43th among world oil reserves and 40th for world gas reserves, accounting for 0.06% of total world oil reserves and 0.15% for world gas reserves in 2014 (Table 2.2).

Significant high-quality coal resources lie within the economy's interior. Commercial opportunities are being assessed for possible impacts on the Heart of Borneo area.[1]

Table 2.2 ● Brunei Darussalam: Energy reserves and production, 2014

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Oil (billion bbl)	1.1	24	0.06	43rd	11th
Gas (tcm)	0.28	23	0.15	40th	11th

Notes: Total proven coal/oil/gas reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions.

Source: BP (2015).

ENERGY POLICY CONTEXT

Increasingly aware of growth in both global and local energy demand, Brunei Darussalam is taking measures to further strengthen its energy sector. In March 2014, the Energy and Industry Department of the Prime Minister's Office published the first Energy White Paper setting out a framework for strategic actions to ensure a more sustainable energy sector. One of the targets is to boost the energy sector's contribution to a sustainable future; this will require the growth of upstream and downstream oil and gas acitivities through aggressive exploration, to maintain the reserve replacement ratio[2] to at least above 1. The government aims to increase oil and gas production from about 372 000 barrels per day (bbl/d) in 2013 to 650 000 bbl/d in 2035 (EIDPMO, 2015). The government also aims to reduce energy intensity 45% by 2035 (from the 2005 level) to ensure long-term sustainability of the energy sector, in line with the APEC target. This entails increasing the share of renewable energy in the power generation mix to 10% by 2035.

At the United Nations (UN) Climate Summit in September 2014, Brunei Darussalam announced its goal to reduce total energy consumption 63% by 2035 (RTB News, 2014); the government has therefore intensified energy efficiency and conservation initiatives. Measures include a 30-year Energy Efficiency and Conservation (EEC) roadmap that identifies action plans, particularly in the five major sectors: power, commercial, residential, transport and industry. This initiative will reduce the amount of fossil fuel needed for inland energy use, redirecting it downstream and to other economic activities.

One recent policy is the Ministry of Development's new EEC Building Guidelines for non-residential buildings, launched in May 2015, which sets a standard Energy Efficiency Index (EEI) baseline of 175 kilowatt-hours per square metre (kWh/m^2) for all government buildings. For primary schools, however, the EEI baseline is set at 40 kWh/m^2, and for secondary schools at 60 kWh/m^2 (Brunei Times, 2015a). The aim is to reduce energy consumption 50% from the previous year through the use of energy-efficient inverter air conditioners and energy-efficient lighting.

[1] 'The Heart of Borneo area' is a joint initiative between Brunei, Malaysia and Indonesia to conserve nearly 25 million hectares of rainforest and protect the island's diverse flora and fauna.

[2] 'Reserve replacement ratio' is a metric used by investors to judge the operating performance of an oil and gas exploration and production company. It measures the amount of proven reserves added to a company's reserve base during the year relative to the amount of oil and gas produced. The ratio must be at least 1 for the company to sustain its business in the long-term.

BUSINESS-AS-USUAL SCENARIO

The Business-as-Usual (BAU) Scenario assumes that no new policies are implemented during the Outlook period, other than the existing policies related to energy demand and supply mentioned in the Energy White Paper. The main policies assumed within the BAU Scenario are summarised in Table 2.3.

Table 2.3 ● Brunei Darussalam: Key assumptions and policy drivers under the BAU Scenario

Buildings	• Government standards and labelling programs implemented.
Industry	• Demand in industry is assumed to grow at an average annual growth rate (AAGR) of 0.92%.
Transport	• Significant increase of hybrid cars and electric vehicles (EVs).
Energy supply mix	• Increased oil and gas production, to 650 000 bbl/d by 2035. • Remain as an energy exporter to at least 2035.
Power mix	• Natural gas continues to dominate the power generation mix. • Work towards but not achieve the 10% renewable energy generation target.[3]
Renewables	• Installed renewable energy capacity of 10 megawatts (MW) from biomass by 2020. • Additional solar photovoltaic (PV) capacity of 1.5 MW by 2040.
Energy security	• Oil and gas self-sufficiency. • Improved power generation efficiency, to above current level of 23%, by converting simple-cycle natural gas power plants to combined-cycle gas turbines (CCGTs).

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

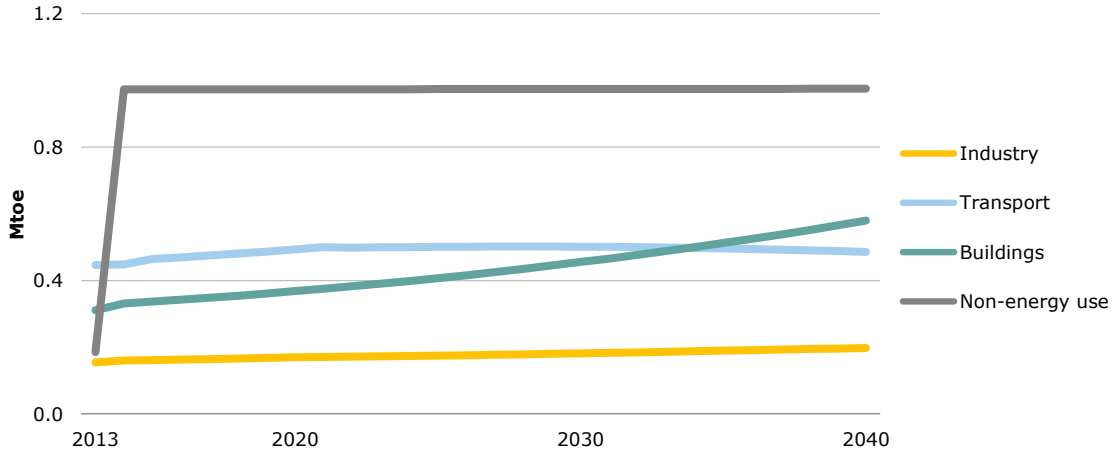
Because oil and gas have dominated the economy, the production of renewables,[4] although increasing, is very small. Under the BAU Scenario, final energy demand is expected to increase from 1 097 kilotonnes of oil equivalent (ktoe) in 2013 to 2 238 ktoe in 2040, an AAGR of 2.7%. When the methanol plant started production in 2010, the non-energy sector began to take a larger portion of final energy demand (compared with none in previous years) (Figure 2.1).[5] However, its share dropped from 54% in 2012 to 17% in 2013 due to several unplanned methanol plant shutdowns. This led the buildings and domestic transport sectors to become the main energy consumers in 2013, with domestic transport claiming approximately 41% of total final energy demand and buildings 28%, followed by non-energy use at 17% and industry at 14%.

By 2040, non-energy use is expected to be the highest energy consumer at nearly 44% or 975 ktoe of final energy demand. However, energy use in buildings is projected to almost double the 2013 level, to 579 ktoe by 2040 while consumption in the transport sector peaks in 2025 at 501 ktoe (from 446 ktoe in 2013) and subsequently decreases marginally to 486 ktoe by 2040 thanks to fuel economy improvements.

Energy demand growth over the Outlook period means that substantial natural gas will be needed to fuel industry and as feedstock for methanol production. Natural gas therefore accounts for the largest share (44%) by 2040, followed by oil at 32% and electricity at 24%.

[3] The BAU analysis projects the government target of 10% renewables generation in the power mix will not be realised by the end of the Outlook period because other potential renewables are still at the feasibility study stage. Only under the High Renewables Scenario is this target achieved by the end of the Outlook period.
[4] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.
[5] According to the APEC Expert Group on Energy Data and Analysis (EGEDA) definition of total final energy demand, natural gas used as feedstock for the production of methanol is reflected under total final energy demand, though all methanol is exported and not used domestically.

Figure 2.1 ● Brunei Darussalam: Final energy demand by sector, 2013-40



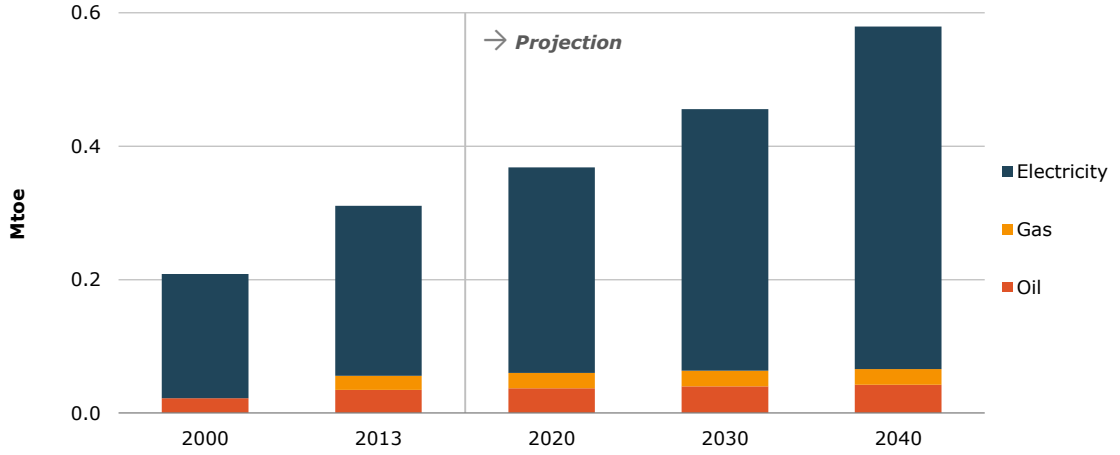
Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

Buildings energy use: Electricity dominates due to high space cooling requirements

Energy demand in the buildings sector is expected to grow 2.3% annually over the projection period, to 579 ktoe in 2040 from 311 ktoe in 2013. With electricity as the main energy source, this sector shows the highest growth rate, as the population is 38% higher in 2040 than in 2013. The electricity share therefore reaches 89% over the forecast period, from 82% in 2013, while the shares of both oil and natural gas continue to fall (Figure 2.2).

Electricity use, especially for air conditioning in practically every building, is high because of the economy's tropical climate and fairly low electricity tariffs. On 1 January 2012, the government reformed electricity tariffs for the residential sector to make them progressive rather than regressive. In a regressive system, the average cost per kWh goes down with higher consumption; the purpose of the new progressive tariff is to reduce electricity consumption and hence promote energy savings. These reforms should eventually be applied to the commercial and other sectors as well. The Energy and Industry Department of the Prime Minister's Office and the Brunei National Energy Research Institute are developing a Standards and Labelling Order to promote highly energy-efficient appliances and equipment in the buildings sector, and air conditioning and lighting in particular have been targeted by the EEI system. Brunei Darussalam's Intended Nationally Determined Contribution (INDC) states that implementation of these measure is expected in late 2016.

Figure 2.2 ● Brunei Darussalam: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

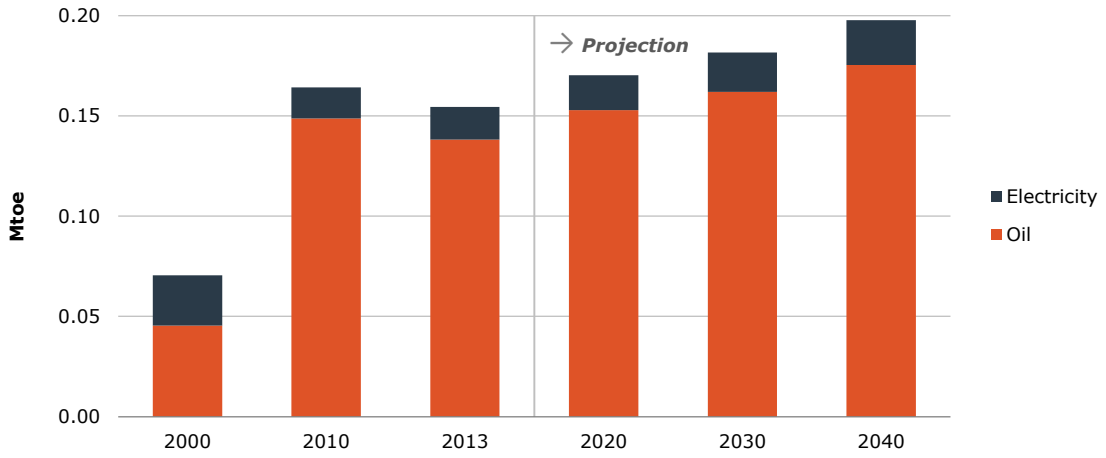
Industry energy use: Oil continues to dominate energy demand

Industry consumed 154 ktoe in 2013, mainly in the oil and gas sectors (not including refining), followed by construction and the textile industry (Figure 2.3). The growth of new downstream activities, and oil and gas services such as a marine supply base and a fabrication yard located at a new industrial site in Pulau Muara Besar (PMB), are expected to drive demand in the industry sector. Other projects in PMB are a 2.7-km bridge connecting the mainland to the western shore of PMB, roads, and utilities such as power and telecommunications lines (Borneo Bulletin, 2015).

Industry energy demand grows at an AAGR of 0.92% to reach 198 ktoe over the Outlook period. Industry remains the sector with the lowest energy demand, with oil (diesel) as its primary energy source. Oil consistently accounts for an 89% share of industrial energy demand, with approximately 138 ktoe consumed in 2013 and a projected consumption of 175 ktoe in 2040. Electricity demand increases to about 22 ktoe in 2040 from 16 ktoe in 2013. Electricity therefore accounts for the remaining 11% of overall industrial energy demand.

Final energy demand in the non-energy-use sector declined in 2013 to 186 ktoe from 477 ktoe in 2010. This sector comprises the economy's only existing downstream methanol production industry, the Brunei Methanol Company (BMC). It is located at Brunei Darussalam's first petrochemical industrial site, Sungai Liang Industrial Park (SPARK). Several downstream projects are in the feasibility study phase, including an ammonia and urea plant, and the production of some methanol derivatives such as formaldehyde and polyoxymethylene (POM).

Figure 2.3 • Brunei Darussalam: Industry sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Transport energy use: Sector to experience a slowdown after 2025

Demand in the domestic transport sector has grown the fastest historically. This trend continues until energy demand peaks in 2025, then remains flat until 2030 and subsequently decreases at annual rate of 0.31% to 2040 (Figure 2.4). Growth in domestic transport energy demand is motivated by population increase, rising incomes, affordable fuel prices and a lack of public transport. Brunei Darussalam has relatively high fuel subsidies for the APEC region; these subsidies covered just over 3% of the economy's GDP in 2013, encouraging greater energy consumption and higher per capita carbon dioxide (CO_2) emissions.

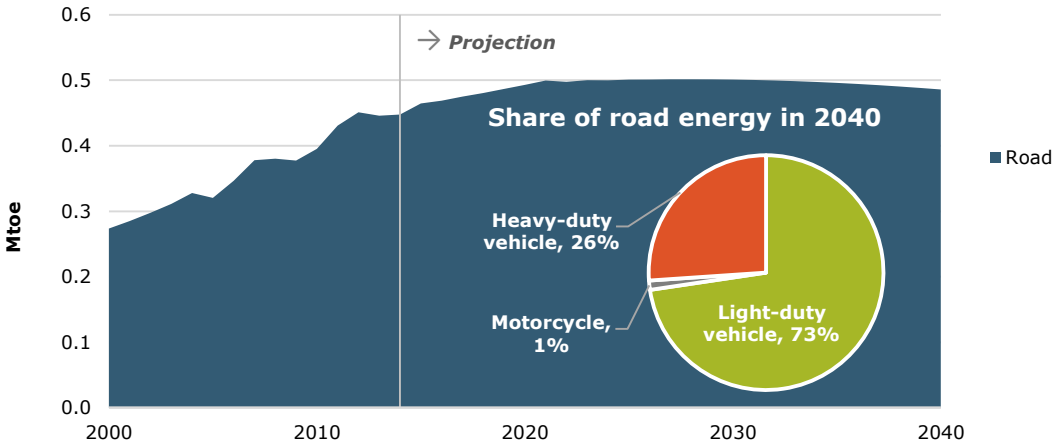
Domestic transport per capita CO_2 emissions are substantially higher than the APEC average and so Brunei Darussalam has begun promoting more extensive energy efficiency initiatives: in December 2014, the Ministry of Communications launched the Land Transport White Paper (LTWP) to provide a long-term policy framework for land transportation up to 2035 (MC, 2014). Aims include transitioning from private

to public transport to reduce dependency on cars; improving current modes of transport through emissions standards for all new vehicles; and minimising the carbon footprint by conserving energy.

The Energy and Industry Department of the Prime Minister's Office is also working with the Ministry of Communications to achieve a 'green' environment. To promote fuel-efficient vehicles, the government is developing a fuel economy regulation (FER) for new vehicles. This initiative aims at a weighted average fuel economy of 17.2 kilometres per litre (km/L) by 2020 and 21.3 km/L by 2025, similar to EU targets for 2016 and 2025. Other plans proposed in the LTWP are a light rail transit (LRT) system (assuming it is justified by potential commuter usage as population rises) and revised fuel subsidy policies. As Brunei Darussalam is a highly vehicle-saturated economy, the share of more efficient engines and new types of vehicles, such as hybrid and battery EVs, is expected to increase from nil to 21% by 2040 under the BAU Scenario.

Vehicle stock grows by nearly 40% by 2040 under the BAU, from 170 000 vehicles in 2013 to 236 000 in 2040. In 2040, energy demand for light-duty vehicles account for 73% of all vehicles and motorcycles account for 1%, up from 71% and 0.27% in 2013. In contrast, the heavy-duty vehicle share drops from 29% in 2013 to 26% in 2040.

Figure 2.4 • Brunei Darussalam: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Dominated by gas

Oil and gas are the predominant energy sources in Brunei Darussalam. Natural gas is used mainly for electricity generation and town gas,[6] as well as for feedstock for downstream industries. Oil is used primarily for petroleum products. In 1990, natural gas accounted for 97% of total primary energy supply (TPES); this share declined to about 80% by 2013, and oil was used for the remaining share of TPES (Figure 2.5). This reduction in gas and increase in oil resulted from increased oil demand in the transport sector–the government estimates AAGR for new vehicles is 9% (MC, 2014). Under the BAU Scenario, natural gas shares increase to 84% by 2040 due to power sector expansion and declining oil demand in the transport sector. Natural gas demand reaches 4 158 ktoe by 2040, from 2 457 ktoe in 2013.

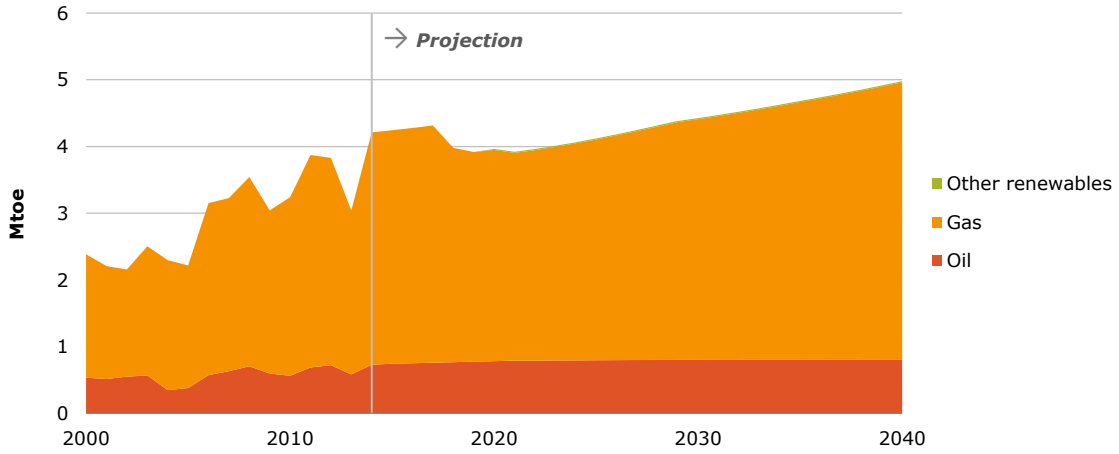
The projections also assume improvements in power generation efficiency, from 23% in 2013 to approximately 45% by 2020, achieved by replacing open-cycle power plants with more efficient CCGTs in 2018 to reduce gas consumption and make more gas available for export. The sharp decline in TPES in 2013 reflects poor downstream activity in that year.

[6] 'Town gas' is manufactured locally using naphtha and natural gas as feedstock (Towngas, 2014).

A refinery and petrochemical complex is currently under construction at the new petrochemical industrial hub at PMB. It is one of the largest foreign direct investments of a private Chinese company, Hengyi Industries. This export-oriented refinery has an intake capacity of 175 000 bbl/d and is expected to begin operations in early 2018. Brunei Darussalam intends to shift to greater consumption of crude oil and the export of petroleum products when the new facility is operational.

Fossil fuels made up nearly 100% of TPES in 2013. A study assessing the government's plan to generate 10% of power from renewable energy sources by 2035 is under way. In the BAU Scenario, shares of renewable energy increase to only 0.33% of TPES by 2040; the renewables target is assumed to be met only under the High Renewables Scenario.

Figure 2.5 ● Brunei Darussalam: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

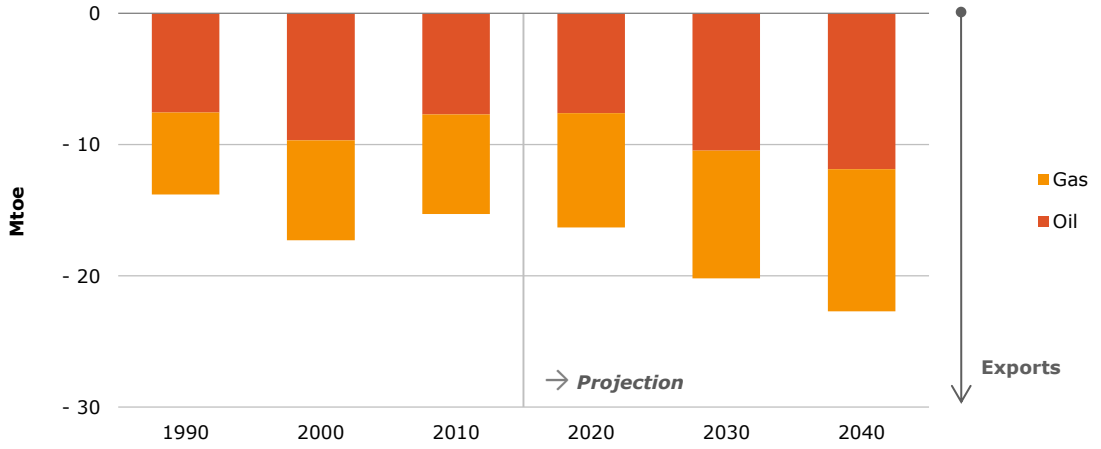
Energy trade: Only economy to remain a net energy exporter in South-East Asia

Brunei Darussalam is an energy-exporting economy, exporting oil and gas since the 1970s. Along with the other APEC economies of Australia, Malaysia and Indonesia, Brunei Darussalam was the largest supplier of LNG in the world until the mid-2000s. It exports LNG primarily to Japan and South Korea.

In 2013, Brunei Darussalam exported LNG spot cargoes to other Asian economies and countries such as Chinese Taipei and India in an effort to diversify export destinations. At the same time, it developed its customer base by signing a 10-year contract with Petronas of Malaysia. LNG spot trade grew in 2014, with China as the largest customer. As the main driver of rising energy demand globally, China is one of Brunei Darussalam's short-term LNG export destinations. Brunei Darussalam is also seeking other regional buyers to secure short-term contracts.

As a result of a natural decline in oil and gas production, Brunei Darussalam exported 12% less in 2010 than in 2000 (Figure 2.6). In 2013 it produced nearly 17 million tonnes of oil equivalent (Mtoe) of fossil fuels; 18% of production was consumed locally while the rest was exported. Under the BAU, by 2040 fossil fuel production increases nearly 65% to 28 Mtoe with aggressive exploration and production. While other economies in South-East Asia are expected to be net energy importers by 2040, Brunei Darussalam could remain the only energy self-sufficient one.

Figure 2.6 • Brunei Darussalam: Net energy imports and exports, 1990-2040



Sources: APERC analysis and IEA (2015a).

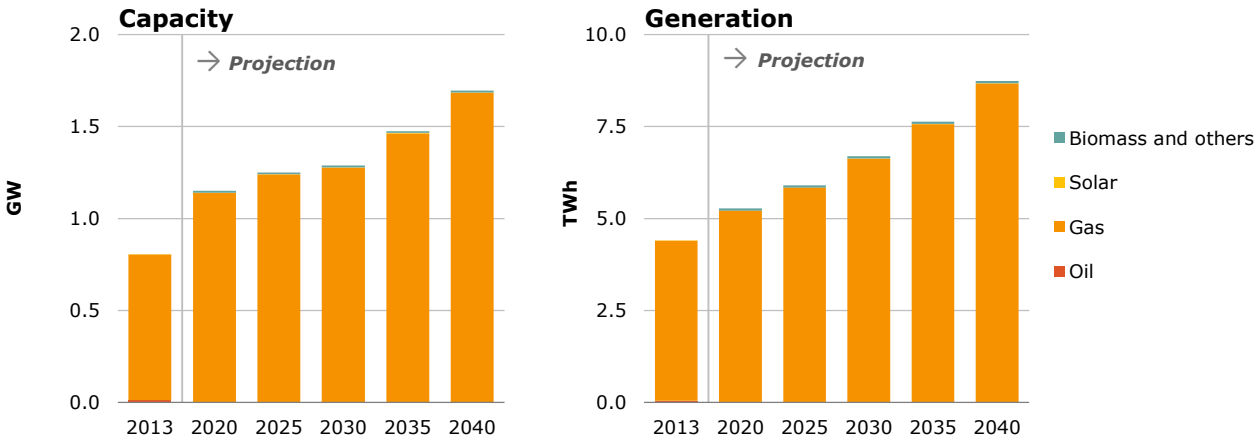
Power sector trends: Remains gas-dependent

The Department of Electrical Services (DES), established in 1921, fulfils the regulatory functions for the power sector; its mission includes managing and developing the electricity sector. The two electrical utilities in Brunei Darussalam are the DES and the Berakas Power Management Company (BPMC). BPMC is owned by the Brunei Investment Agency and operates as a private company.

Of the total installed capacity of 806 MW in 2013, electricity generation is almost entirely natural gas-fired: the only exceptions are the 12 MW diesel power station at Belingus and the 1.2 MW Tenaga Suria Brunei (TSB) solar PV demonstration plant. A new cogeneration power plant at PMB, scheduled to be operational by 2018, should significantly improve average power generation efficiency and reduce gas consumption. This is part of the action plan for improving power generation energy efficiency to greater than 45% by 2020.

In 2013, natural gas made up 98% of power generation capacity, and oil and renewables made up the rest (Figure 2.7). As diesel based power will be decommisioned by 2020, natural gas capacity shares are expected to increase slightly by 2040, and renewable energy capacity's share also increases to 0.75% (13 MW) from only 0.15% (1.2 MW) in 2013, thanks to a new waste-to-energy facility.[7] Among renewable energy sources, biomass grows the most, to 10 MW, followed by solar at 3 MW.

Figure 2.7 • Brunei Darussalam: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

[7] See Footnote 3.

ALTERNATIVE SCENARIOS

Of the three alternative scenarios used for analysing energy futures in this Outlook, only the Improved Efficiency and the High Renewables Scenarios apply to Brunei Darussalam.[8] Due to the economy's atypical dependence on natural gas for electricity, none of the cases in the Alternative Power Mix Scenario are applicable. The Improved Efficiency Scenario contributes to the reduction in energy demand (9.6%) and offers the greatest reduction in energy-related CO_2 emissions (11%) by 2040 between the two applicable Alternative Scenarios, compared with the BAU. The High Renewables Scenario leads to a 4.6% reduction in energy-related CO_2 emissions by 2040 compared with the BAU by 2040.

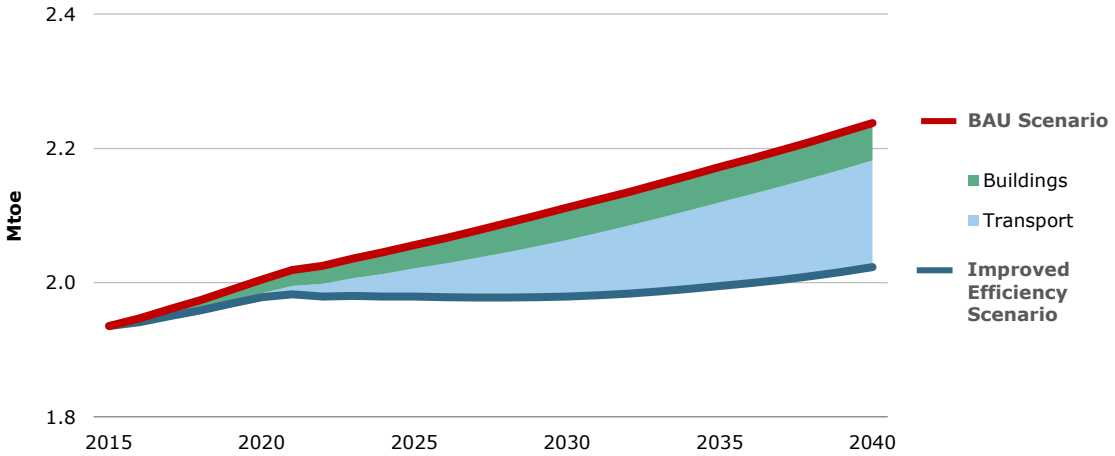
IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

The APEC energy intensity goal is a 45% reduction in energy intensity (final energy in toe per unit of GDP) from 2005 to 2035 across all APEC economies.[9] Since the goal is a collective effort, Brunei Darussalam has intensified its efforts to reduce energy intensity. However, its energy intensity is projected to increase significantly between 2013 and 2040, from 52 toe per USD million to 77 toe per USD million under the BAU Scenario, or to 69 toe per USD million under the Improved Efficiency Scenario. The increase is due primarily to the growth of downstream industry, especially the methanol plant that became operational in 2010. Energy efficiency action plans and measures initiated in the Energy White Paper may, however, offset some of this increase.

Energy consumption is 9.6% less in the Improved Efficiency Scenario than under the BAU by 2040 (Figure 2.8). Transport accounts for 0.16 Mtoe of these savings, and the buildings sector the remaining 0.06 Mtoe.

Under the Improved Efficiency Scenario, the vehicle stock in 2040 is projected to be 40 000 less, or 17% lower than under the BAU. As more efficent urban planning and improved public transport reduce vehicle demand, overall growth in transport energy demand declines by 33%. Meanwhile, the aggressive deployment of standards and labelling for electrical appliances contributes to energy savings from buildings, notably in lighting and air conditioning.

Figure 2.8 • Brunei Darussalam: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Note: An estimate for savings potential in industry was not calculated due to lack of data and hence the Improved Efficiency Scenario underestimates the potential savings from enhanced energy efficiency.

Source: APERC analysis.

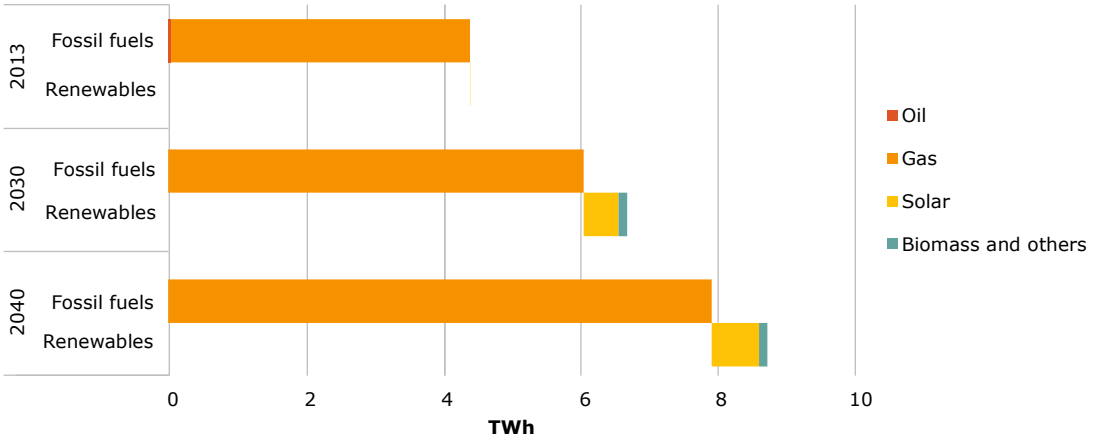
[8] For more details about the Alternative Scenario assumptions, see Chapters 5 through 7 in Volume I.
[9] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified; this Outlook uses final energy demand for analysis.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

The High Renewables Scenario models the APEC doubling renewables goal but focuses on renewables in power generation and for fuel in the transport sector.[10] Under the BAU projections, renewable energy increases from 2 gigawatt-hours (GWh) to 66 GWh by 2040, with the addition of 12 MW of new capacity in solar and biomass.

The government's goal to reach 10% renewables in the power generation mix by 2035 is realised under the High Renewables Scenario, thanks to solar energy capacity of 350 MW in 2035 and 400 MW in 2040 (Figure 2.9). Under the High Renewables Scenario, electricity generated from renewable resources rises to 816 GWh by 2040; this assumes a solar contribution made up of one-quarter rooftop PV and three-quarters utility-scale PV. The main impediment to this scenario could be in allotting the land required for the utility-scale PV installations. The rooftop PV would be deployed on approximately 16 000 buildings, and it is presumed that any challenges would be overcome through government support and other incentives to encourage rooftop PV installations on homes and other buildings.

Figure 2.9 ● Brunei Darussalam: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Projected total energy sector investment requirements are between USD 73 billion and USD 161 billion from 2015 to 2040 (Table 2.4). Upstream developments claim the bulk of total investments, to expand oil and gas exploration in deep-water areas and to increase production activities. In both the low- and high-cost estimates, total upstream investment covers more than three-quarters of the total over the Outlook period: USD 52 billion in the low-cost estimate and USD 97 billion in the high-cost estimate.

Energy transport claims the second-largest share of total investments at USD 14 billion in the low-cost estimate and USD 39 billion in the high-cost estimate. Investments are mainly for the oil and gas pipelines needed to transport increased upstream production. Meanwhile, the downstream sector is allotted an 8.8% share of the total low-cost estimate, the majority being required for refining–specifically to construct the 175 000 bbl/d committed refinery project. The remainder of investment would be used for additional LNG export terminal capacity of 3.0 million tonnes per year (Mt/y).

[10] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

The power sector is allotted the smallest share (approximately 1.3%) of the total low cost-estimate, for the construction of an additional 926 MW of generation capacity (natural gas power plants and expanded transmission and distribution networks) needed to meet future power requirements.

Table 2.4 ● Brunei Darussalam: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	39	58
	Gas	13	39
	Subtotal	52	97
Downstream	Refinery	3.5	18
	LNG import terminals	3.0	5.3
	Subtotal	6.5	23
Electricity	Gas	0.7	1.1
	Biomass and others	0.01	0.02
	Transmission lines	0.1	0.2
	Distribution lines	0.1	0.5
	Subtotal	1.0	1.8
Energy transport	Oil	0.1	0.2
	Gas	14	39
	Subtotal	14	39
	Total	**73**	**161**

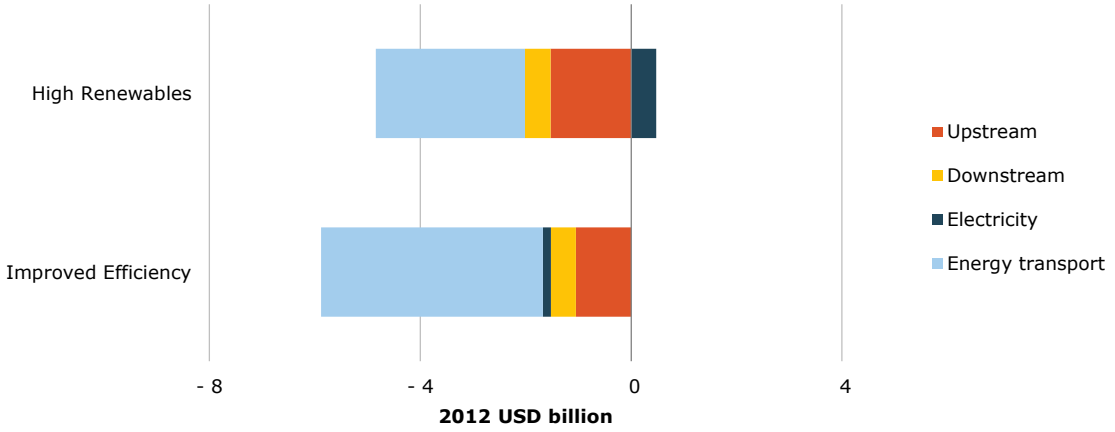
Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

Investments under the Improved Efficiency Scenario are projected to drop by 8% from the BAU Scenario to USD 67 billion from 2015 to 2040 (Figure 2.10). The energy transport sector is the greatest contributor to these savings, with an investment allotment of USD 4.2 billion less than under the BAU projections. The upstream and downstream sectors follow, contributing USD 1 billion and USD 0.47 billion investment savings. These savings are the result of 20% (602 000 tonnes per year) less additional LNG terminal capacity than under the BAU. A 15%, or USD 0.15 billion, investment savings in the power sector occurs with the displacement of 175 MW of capacity additions from the BAU Scenario.

In the High Renewables Scenario, investment projections also fall by 6%, to approximately USD 69 billion. Investment in the power sector, however, rises due to renewable capacity additions increasing thirty-fold to 400 MW, from 13 MW in the BAU Scenario. Total investments in upstream operations under the High Renewables Scenario are 3% lower than under the BAU, with lower gas production resulting in renewable energy displacing natural gas power plants. In addition, the decrease in gas production curtails capacity additions for LNG export terminals and further reduces investment needs.

Figure 2.10 ● Brunei Darussalam: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

Enhancing energy security: Energy self-sufficiency level to remain high in 2040

Brunei Darussalam's level of self-sufficiency is one of the highest in APEC, and it is expected to remain an energy exporter throughout the Outlook period. Within APEC, it has had the least diverse energy supply mix since the 1990s; nonetheless, it moved away from natural gas as its primary energy supply in the early 2000s in response to increasing oil demand. The Herfindahl-Hirschman Index (HHI) declined from 0.94 in 1990 to 0.69 in 2013 and is projected to rise to 0.72 by 2040 under the BAU Scenario (Table 2.5). The increased share of renewable energy contributes moderately to the energy mix, and in electricity generation natural gas retains the largest share throughout the forecast period.

Table 2.5 ● Brunei Darussalam: Energy security indicators under the different Scenarios, 2013 and 2040

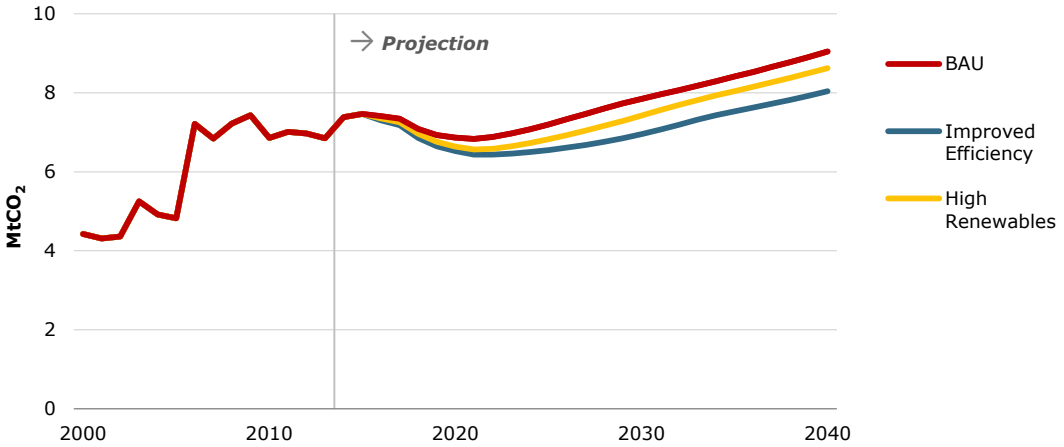
	2013	2040		
	Actual	BAU	Improved Efficiency	High Renewables
Primary energy supply diversity (HHI)	0.69	0.72	0.75	0.69
Primary energy supply self-sufficiency (%)	100	100	100	100
Oil self-sufficiency (%)	100	100	100	100
Gas self-sufficiency (%)	100	100	100	100
Electricity generation input fuel diversity (HHI)	0.98	0.98	0.98	0.89

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

Climate change impacts and risks: Emissions rising due to heavy reliance on fossil fuels for electricity generation

Because of its small population, Brunei Darussalam ranks among the highest in per capita CO_2 emissions in APEC. Even so, the economy contributes only 0.016% of global emissions (UNFCCC, 2015). Gas for the electricity generation and the other transformation sectors account for the majority of energy-related CO_2 emissions, causing the high energy-related CO_2 intensity. Under the BAU, the 2013 level of 6.9 $MtCO_2$ increases to 9 $MtCO_2$ in 2040 (Figure 2.11). Energy-related CO_2 emissions declines by 11% or 1 $MtCO_2$ by 2040 under the Improved Efficiency Scenario, and by 4.6% or 0.42 $MtCO_2$ in the High Renewables Scenario.

Figure 2.11 • Brunei Darussalam: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

RECOMMENDATIONS FOR POLICY ACTION

BP has estimated that Brunei Darussalam's energy reserves will be depleted in 23 years; the economy is therefore committed to diversifying its energy mix to meet the growing demands of its population. While the economy can benefit from solar power and a waste-to-energy facility, the Energy and Industry Department of the Prime Minister's Office is also exploring the potential to import power from the anticipated hydroelectric dam project with Sarawak Energy Bhd (SEB) in neighbouring Malaysia (Brunei Times, 2015b). This could minimise domestic natural gas consumption, freeing up more gas for LNG exports or for use as feedstock for downstream industries.

Present implementation of energy efficiency measures in Brunei Darussalam is minimal. Priority for energy efficiency and conservation programs should be placed on the rapidly growing buildings sector, where energy demand is weighted heavily towards electricity. Improved efficiency of electrical appliances, especially air conditioners, would slow demand growth in this sector. This would reduce natural gas consumed for electricity generation and consequently reduce investment requirements.

Brunei Darussalam has one of the highest vehicle per capita levels in the world. The number of new vehicles on the road rose by almost 20% over the 2011-13 period (Brunei Times, 2015c and DEPD, 2015). Though the economy has announced EU-equivalent fuel economy regulations on new vehicles by 2020 (UNFCCC, 2015), it is encouraged to adopt the strictest fuel economy regulations by 2018. Considering the transition time for new vehicles to replace the old, early policy action on vehicle efficiency is possible if the government gives incentives for new vehicles to enter the market. Accurate data are also essential to formulate EU-equivalent regulations that conform to EU targets.

Recent drops in global oil prices have led to growing uncertainty about the long-term stability of the economy, which relies wholly on oil and gas for two-thirds of its GDP. Although efforts to diversify the economy show little result as yet, Brunei Darussalam is exploring structural reforms for economic diversification and the investments identified in the Wawasan 2035 to sustain its revenue. The current slump in oil prices creates an opportunity to reform heavily subsidised fuel prices. These subsidies could be invested in other initiatives in the transport sector to support low-income groups. It is recommended that Brunei Darussalam implement reforms on energy pricing gradually, drawing on the successful experiences of other economies.

3. CANADA

KEY FINDINGS

- **Canada is rich in energy resources, with the largest oil reserves in APEC and second-largest in the world**. Energy exports are projected to rise 59% over the Outlook period to 294 Mtoe. Oil leads growth in energy exports, accounting for nearly three-quarters of total energy exports in 2040.

- **Canadian natural gas exports to the United States have fallen sharply due to recent technological advances in shale gas and oil development.** Asian markets are being explored for export diversification to replace falling US demand.

- **Energy intensity is projected to fall more than 31% over the Outlook period under the BAU Scenario.** Implementation of cost-effective efficiency measures under the Improved Efficiency Scenario leads to a 38% energy intensity improvement and energy savings of 13% over the BAU.

- **Wind power holds significant potential.** Wind capacity is projected to more than triple under the High Renewables Scenario, with renewables accounting for over 77% of total generation by 2040 compared with just 67% under the BAU.

- **Although Canada has set ambitious targets to reduce GHG emissions, energy-related CO_2 emissions still rise in the BAU Scenario.** To significantly reduce emissions, implementation of energy efficiency measures and renewable energy deployment will need to be accelerated.

ECONOMY AND ENERGY OVERVIEW

Canada has the second-largest land area in the Asia-Pacific Economic Cooperation (APEC) region and had a population of 35 million in 2013. From 2013 to 2040, gross domestic product (GDP) is projected to grow about 57%, with population growth of 19% (Table 3.1). Canada is an energy-intensive economy, with heavy industry and manufacturing contributing 13% to GDP. Major industries are forestry, mining, agriculture, chemicals, metal products, machinery and energy (Statistics Canada, 2015).

Canada is endowed with a rich energy resource pool of both non-renewable and renewable[1] resources, including oil and natural gas, coal, uranium, hydro, solar and biomass. Natural resource development has supported growth of the Canadian economy. According to Natural Resources Canada, in 2013 energy contributed CDN 175 billion (USD 170 billion)[2] to nominal GDP and accounted for 10% of total GDP (NRCan, 2015a). Total direct and indirect energy supply accounted for close to one million jobs, or 5% of total Canadian employment (NRCan, 2015a). In resource-rich areas of the economy such as Alberta and British Columbia, the economy is integrated with the resources sector. In Alberta, for example, the energy sector accounts for 25% of provincial GDP (Alberta Government, 2015).

Canada has traditionally been very dependent on the United States as its primary market. The development of natural gas deposits in the United States has made it self-sufficient in gas supply, which has had a dramatic effect on Canadian exports. Canada is under pressure to diversify export markets, so the energy industry and its resource markets may undergo significant changes over the Outlook period.

Table 3.1 • Canada: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	856	1 137	1 381	1 467	1 674	1 962	2 300
Population (million)	28	31	34	35	37	40	42
GDP per capita (2012 USD PPP)	30 935	37 041	40 474	41 648	45 033	49 247	54 921
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	209	252	251	253	292	304	316
TPES per capita (toe)	7.5	8.2	7.4	7.2	7.8	7.6	7.5
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	159	189	191	199	215	224	230
Final energy intensity per GDP (toe per 2012 USD million PPP)	186	166	138	136	129	114	100
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	419	516	515	536	545	552	551
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	100	100	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.
[2] Exchange rate calculated using 2013 figures, USD 1: CDN 0.97.

ENERGY RESOURCES

As the world's second-largest land area and fifth-largest energy producer, Canada has abundant and diverse natural resources. Primary non-renewable resources are oil, natural gas, coal and uranium, and renewable resources are hydro, biomass, wind, solar and tidal power (NRCan, 2015a).

Western Canada holds the majority of Canada's 174 billion barrels (billion bbl) of proven oil reserves. The recent technological advances in horizontal drilling, multi-stage hydraulic fracturing and pad drilling that have developed the shale oil and gas deposits throughout North America could increase Canadian reserves to over 300 billion barrels (NRCan, 2015a). Alberta's oil sands account for 97% of proven reserves, with 134 billion barrels recovered through *in situ* (non-conventional) methods and 34 billion bbl through conventional mining (NRCan, 2015a). Current proven reserves are sufficient to meet Canadian energy demand for the next 140 years at current production rates (NRCan, 2015c), and given the potential for shale reserves this figure may grow significantly.

In natural gas, proven reserves could increase up to 20 times, from 2.13 trillion cubic metres (tcm) to 57 tcm thanks to recent technological developments, making Canadian gas resources 5.5% of the world total (NRCan, 2015a). Natural gas deposits are found primarily in the Western Canadian Sedimentary Basin (WCSB) situated in British Columbia, Alberta and Saskatchewan, with small areas stretching into Manitoba, the Northwest Territories and Yukon. Shale gas resources are also found in these areas of western Canada, but other deposits are being developed in Ontario, Quebec and the Maritime provinces of New Brunswick and Nova Scotia (NRCan, 2015a). Canada has a sophisticated pipeline structure to move natural gas throughout Canada and the United States.

High-concentration uranium deposits are located in the Athabasca Basin of Saskatchewan, and significant coal resources are located in the three western provinces as well as Ontario, Nova Scotia, New Brunswick and unexplored mines in northern Canada (NRCan, 2015a). Having substantial renewable resources used for electricity, heat and fuels, Canada is the world's third-largest producer of hydropower, has the ninth-largest generation capacity for wind power, and ranks fifth-largest in the production of biofuels (NRCan, 2015a).

Canada is historically one of the world's largest energy producers, and its ample resource base indicates continued development over the Outlook period.

Table 3.2 ● Canada: Energy reserves and production, 2014[3]

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Coal (Mt)[a]	6 582	95.7	0.74	15th	6th
Oil (billion bbl)[a]	173	110	10	3rd	1st
Gas (tcm)[a]	2.0	13	1.1	15th	6th
Uranium (kt U)[b]	358	38	9.7	2nd	2nd

Notes: [a]Total proved coal/oil/gas reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions. [b]Uranium reserves are 'reasonably assured resources'; reference year for uranium reserves and production is 2013.

Sources: For oil, coal and gas, BP (2015); for uranium, NEA (2014).

ENERGY POLICY CONTEXT

The energy industry and its policies are shaped by both the federal and provincial governments. The federal government outlines three primary policy principles: a responsive and market-oriented energy industry; the authority of provincial governments for energy development within their respective borders;

[3] The BP Statistical Review of World Energy 2015 and the Nuclear Energy Agency's Uranium 2014 is used as standardised sources of energy reserves and production for comparative purposes.

and central government intervention to meet specific objectives, such as environmental regulations (NRCan, 2014a).

Recent developments in policy and in the energy sector as a whole could shift the structure of the industry over the Outlook period. Policy developments in the electricity market, specifically in coal and renewables, demonstrate Canada's commitment to addressing climate change, and federal and provincial governments and the private sector continue to develop resource deposits and associated infrastructure to strengthen export market diversification; energy efficiency policies are discussed later in this chapter.

Strict regulations on coal-fired electricity have banned the construction of traditional coal plants and will accelerate the closure of existing coal-fired generation facilities. Under the Canadian Environmental Protection Association (CEPA), this federal regulation applies to all coal generation plants built after 1 July 2015 and to existing plants reaching retirement. All coal plants must meet the performance standard of natural gas combined-cycle (NGCC) emissions intensity of 420 tonnes per gigawatt-hour (t/GWh) (GOC, 2013). For plants to remain below this emissions intensity level, they must be built or refitted with carbon capture and storage (CCS) technology. Plants not meeting this target must cease operations at a lifetime of 50 years, in 2019 or 2029 depending on the date of commissioning. As a result, older, less efficient coal-fired plants will be phased out and CCS will be installed on more efficient coal plants. Canada has constructed the world's first large-scale CCS demonstration plant for coal-fired generation with a 1 million tonne per annum (Mtpa) capacity at Boundary Dam in Saskatchewan.

Further impetus for cleaner electricity generation is given through tax incentives for the development of renewable resource generation. The Economic Action Plan 2014 has expanded the accelerated capital cost allowance (CCA) for renewable technologies to include water-current energy equipment and a wider variety of waste gasification equipment (Economic Action Plan, 2014). The CCA tax support is available to any business investing in clean energy generation and energy efficiency projects. Since its inception, the program has expanded to include heat recovery and district energy equipment, waste heat sources for generation purposes, biogas production equipment, and equipment used to treat gases from waste (Economic Action Plan, 2014).

BUSINESS-AS-USUAL SCENARIO

This section summarises the key energy demand and supply assumptions under the Business-as-Usual (BAU) Scenario (Table 3.3). The definition of the BAU Scenario and the modelling assumptions used in this Outlook are different from those used by the government for its projections, targets and analysis.

Table 3.3 • Canada: Key assumptions and policy drivers under the BAU Scenario

Buildings	• Minimum energy performance standards (MEPS) and labelling programs maintained at current levels.
Industry	• Implementation of cost-effective technology improvements.
Transport	• Slow deployment of hybrid cars and electric vehicles (EVs). Marginal contribution at the end of the Outlook period. • Mandated biofuel blend rates of 5% renewable fuel content for gasoline and 2% for diesel. • Stringent greenhouse gas (GHG) emissions standards for heavy-duty vehicles.
Energy supply mix	• Oil exports continue throughout the Outlook period; less coal and nuclear in the primary supply mix. • Growth in natural gas production, supplemented by shale oil and gas reserve development.
Power mix	• Decrease in traditional coal-fired generation, development of CCS technology, refurbishment and retirement of nuclear facilities. • Significant growth of gas and renewables.
Energy security	• No explicit energy security policies and targets. • Self-sufficiency in oil, gas, coal and renewables.

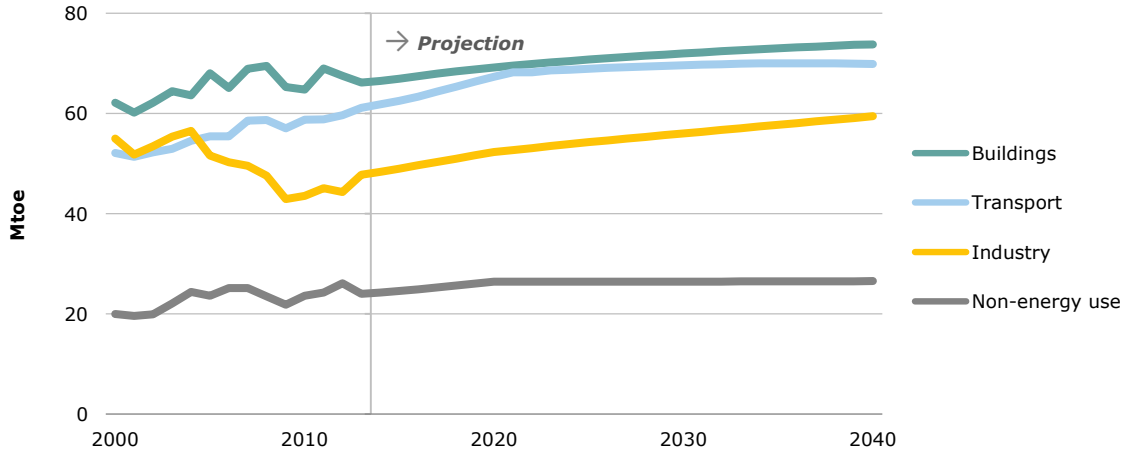
Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Energy demand under the BAU Scenario is projected to grow modestly over the Outlook period, rising over 15% to about 230 million tonnes of oil equivalent (Mtoe) from 199 Mtoe in 2013, an average annual growth rate (AAGR) of just 0.53%. In 2013, domestic transport consumed 31% and buildings 33% of total final energy, with industry and non-energy use accounting for the remainder (Figure 3.1). In the recovery period following the global economic decline of 2008 and the recent shifts in energy prices, industry energy demand rises at a slower rate but regains momentum and shows a slightly higher AAGR than the other two sectors by the end of the Outlook period. By 2040, buildings account for the largest share of energy demand (32%), followed by domestic transport (30%) and industry (26%).

To address climate change, the government has introduced a variety of energy efficiency programs. Already, CDN 5 billion (USD 4.5 billion) has been invested in ecoENERGY initiatives, and the Efficiency and Alternative Transportation Fuels program contributed an additional CDN 195 million (USD 189 million) between 2011 and 2016 in measures to improve energy efficiency in housing, buildings, equipment, industry and vehicles (NRCan, 2014a).

Figure 3.1 ● Canada: Final energy demand by sector, 2000-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

Buildings energy use: Efficiency improvements keep growth moderate

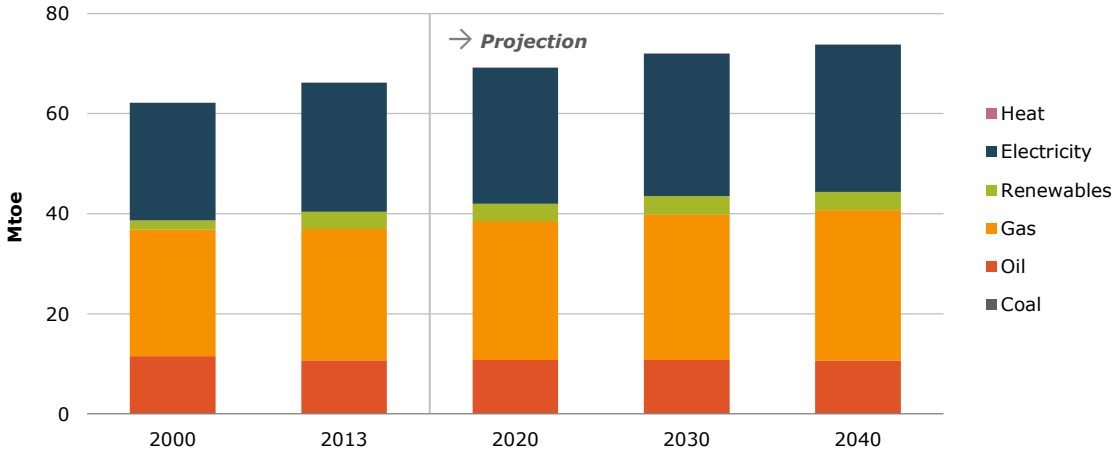
Energy consumption in the buildings and agriculture sector is projected to grow 0.4% annually from 66 Mtoe in 2013 to 74 Mtoe in 2040 (Figure 3.2). Despite declining oil use, higher gas and electricity consumption results from rising population and growing cities. Demand for space conditioning will be the primary driver in overall growth; although appliance and equipment penetration also increases, the pace is slower due to household appliance and equipment saturation. Due to temperature extremes, Canada's energy use for buildings is among the highest in APEC.

EcoENERGY and other related programs have been introduced in the commercial and residential sectors. In 2011, the National Energy Code for Buildings (NECB) was introduced; it is a 25% improvement from the previous building code and outlines minimum energy efficiency requirements in new buildings (NRCan, 2015b). Initiatives originally designed for commercial buildings have also benefited the residential sector by setting high standards for energy efficiency improvements (NEB, 2013).[4] Natural Resources Canada has also developed the Federal Buildings Initiative, which is a retrofit program for federally owned buildings. Since its introduction in 1991, the initiative has resulted in cumulative energy savings of CDN 500 million (USD 486 million), an average of 15% to 20% which is expected to continue over the

[4] Data based on Canada's Energy Future 2013 as Canada's Energy Future 2016 was not available at the time of modelling and drafting. For more recent government projections, see: https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016/index-eng.html.

Outlook period (NRCan, 2015b). Finally, in 2014 the Federal Energy Efficiency Act was adjusted to increase MEPS on home appliances and initiate a phase-out of inefficient lighting (NEB, 2013).[5] Further amendments to the act are expected by 2017 (NRCan, 2015c). These programs for energy efficiency are expected to slow the overall growth of final energy demand in the buildings and agriculture sector.

Figure 3.2 ● Canada: Buildings sector final energy demand, 2000-40



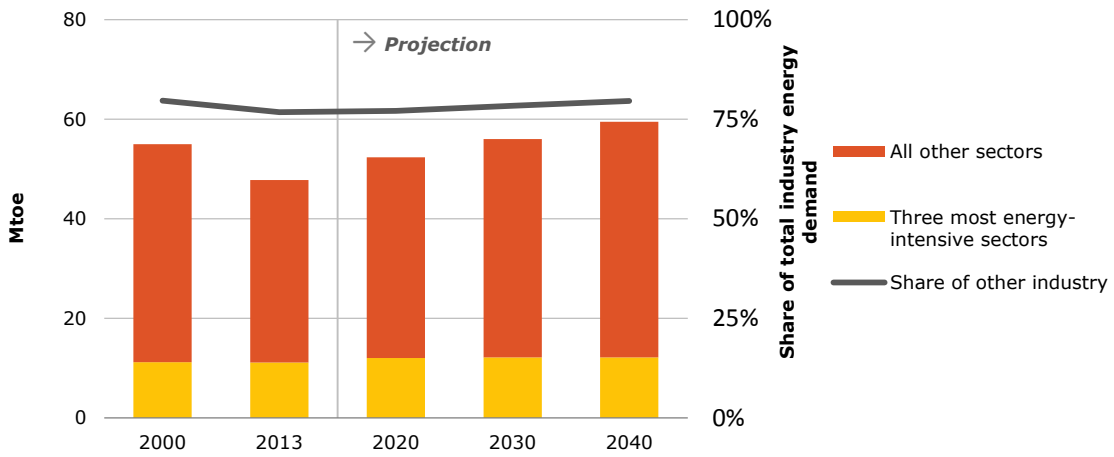
Sources: APERC analysis and IEA (2015a).

Industry energy use: The fastest growth of all end-use sectors

Industry demand grows at an AAGR of nearly 0.81% over the Outlook period, the fastest-growing sector in final energy demand (Figure 3.3). Industry has been recovering since the economic downturn in 2008, but with the recent drop in global energy prices, the mining sector (Canada's largest industry) has suffered a significant slowdown.

Production in natural resources is expected to rise significantly, more than 34%, from 55 Mtoe in 2013 to 74 Mtoe by 2040. Recovering production rates foster growth in other industrial sectors: the increase is small in iron and steel, chemicals and petrochemicals, and non-metallic minerals (slightly more than 20%), while machinery, food and tobacco, and pulp and paper and printing account for the bulk of growth (over 80%), registering an AAGR of 0.95%.

Figure 3.3 ● Canada: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.
Sources: APERC analysis and IEA (2015a).

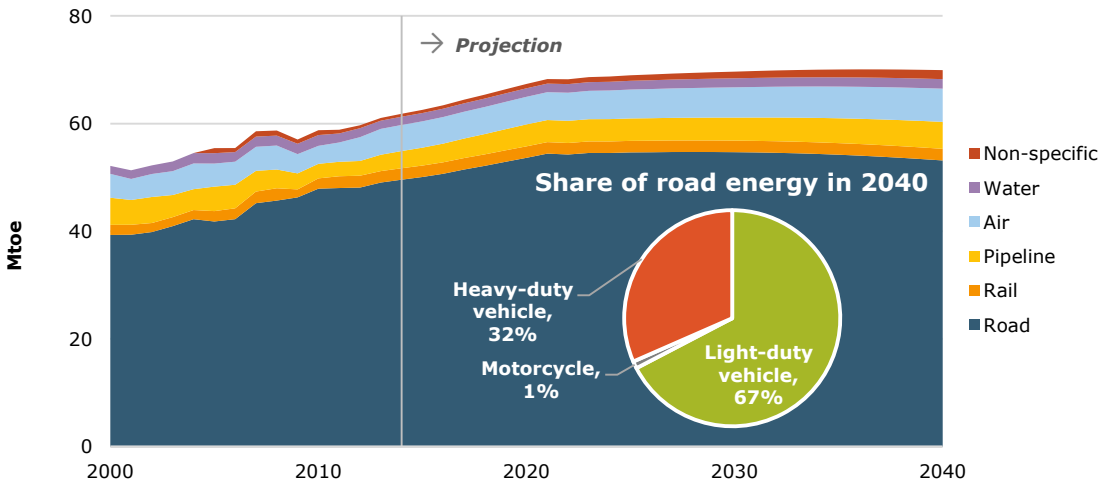
[5] See Footnote 4.

Various industrial demand programs at both the federal and provincial levels focus on energy savings for this sector (NEB, 2013).[6] EcoENERGY works with a variety of organisations to promote programs for energy efficiency and the reduction of GHG emissions in industry, and support is provided through the Canadian Industry Program for Energy Conservation to cover ISO 50001 Energy Management Systems, the implementation of effective energy management projects and the exchange of best practices, training workshops and toolkits, industry networking opportunities, and newsletters (NRCan, 2013).

Transport energy use: Road transport continues to dominate

Domestic transport energy demand is projected to grow 0.5% annually between 2013 and 2040, significantly slower than the historical trend of 1.6% per year from 1990 to 2010. Canada's vast land area, large distances between urban centres, sprawling resource deposits and lack of significant public transportation infrastructure ensure that road transport dominates transport energy consumption over the Outlook period. While overall transport energy demand grows at an AAGR of 1.1% between 2013 and 2020, stricter fuel economy standards and other initiatives to improve energy efficiency in transport lead to a plateauing of energy demand by 2020 (67 Mtoe), after which time only modest annual growth is expected (Figure 3.4). By 2040, total domestic transport energy demand reaches 70 Mtoe, 14% above the 2013 level (61 Mtoe).

Figure 3.4 ● Canada: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

The share of fuel-efficient vehicles (for example EVs and plug-in hybrids) is expected to rise as a result of rebate programs, pilot projects, funding for research projects and the commercialisation of sustainable vehicle technologies (NRCan, 2014a). Of total car sales, low-emissions vehicles account for close to 10% in 2040, up from only 0.3% in 2012. Stricter GHG emissions standards for light- and heavy-duty vehicles and an updated mandate for renewable fuel content in both gasoline (5%) and diesel (2%) increase biofuels use in transport from 2.9% to 3.6% and electricity from 0.65% to 2.9%.

[6] See Footnote 4.

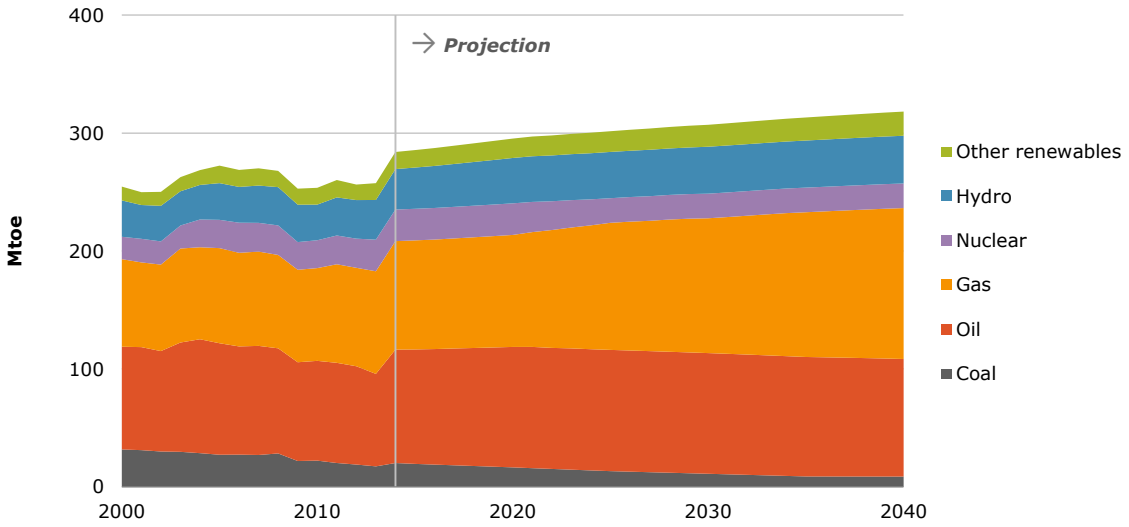
RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Natural gas and renewables replace coal and nuclear

Since 1990, growth in all energy sectors has been steady. Despite a slight decline in the early 2000s, all fuels except coal increased steadily. Since 2000, the share of coal in TPES has declined, a trend that is expected to continue over the Outlook period given the phase-out of coal generation.

In 2013, Canada's primary energy supply was largely fossil fuel-based with a share of over 34% of natural gas, 31% oil and 6.9% coal; renewables made up over 19% of the supply; and nuclear the remaining 13% (Figure 3.5). The energy supply mix shifts over the Outlook period under the influence of government initiatives, policies on GHG emissions in various sectors, and technological advances in the oil and gas industry.

Figure 3.5 ● Canada: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

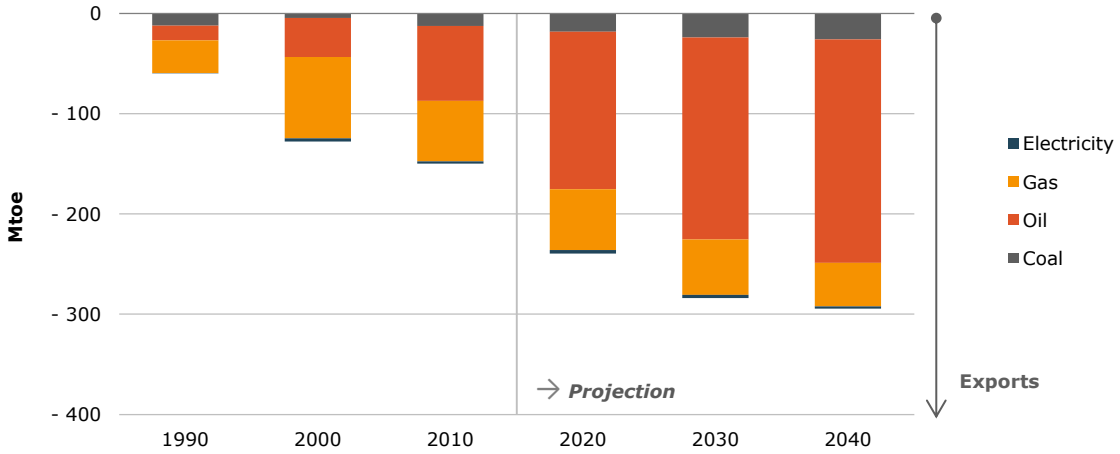
TPES grows annually by 0.82% from over 253 Mtoe in 2013 to 316 Mtoe in 2040. The share of natural gas increases at an AAGR of 1.4% to 128 Mtoe by 2040. Incentives and tax cost allowances for the development of renewables are expected to contribute to the 27% combined growth of hydro and other renewables to 61 Mtoe. Growth in natural gas and renewables offsets decreases in coal and nuclear for an overall net increase in TPES of 63 Mtoe. Coal declines by 50%, falling to just 8.7 Mtoe in 2040 from 17.4 Mtoe in 2013 due to phase-out of high-emitting plants. Nuclear declines by 22% as older nuclear facilities are retired or cease operations for refurbishment. As hydro, other renewables and natural gas are abundant and accessible, capitally intensive nuclear facilities and costly refurbishments are less competitive for energy supply and generation capacity.

Energy trade: Growth due to rising oil and coal exports

With rich natural resources and a comparatively low domestic energy demand, Canada is one of APEC's largest energy exporters. Net energy exports were 185 Mtoe (37% of energy production) in 2013, oil constituted 62% and gas 25% (Figure 3.6). By 2040, oil production reaches 324 Mtoe and gas 171 Mtoe (NEB, 2016).[7] These projections are subject to considerable uncertainty, however, as production is highly dependent on future prices.

Based on these production estimates, exports increase by 60% to 294 Mtoe in 2040. Exports are driven mainly by oil and to a lesser extent gas. Oil exports show a steady increase to 223 Mtoe by 2040, compared with 116 Mtoe in 2013. Gas exports rise until 2023, when higher domestic consumption causes exports to decline. However, depending on the development of liquefied natural gas (LNG) projects and global gas demand, gas production could rise significantly and offset this decline. Coal exports climb to 26 Mtoe in 2040, an increase of 43% from 2013 (18 Mtoe) due to the fall in domestic consumption and rising demand in Asia.

Figure 3.6 • Canada: Net energy imports and exports, 1990-2040



Sources: APERC analysis and IEA (2015a).

Canadian exports were valued at CDN 128 billion (USD 124 billion) in 2013, of which 92% went to the United States (97% of crude oil exports, 92% of petroleum products and 100% of natural gas) (NRCan, 2015a).

Advances in shale technologies that have nearly doubled Canadian resources have also benefited the United States. The United States had proven natural gas reserves estimated at 9.7 tcm in 2013, 40% of which was shale gas (EIA, 2014), and is projected to become a net exporter of gas by 2017 (EIA, 2015a). Increased production in the US primary market has directly displaced Canadian gas; natural gas exports have decreased over 25% and production volumes have decreased 13% since 2005 (EIA, 2015b).

[7] See Footnote 4.

Box 3.1 • Canada: Proposed LNG export terminals

Canada has a stable and massive natural gas supply, and exporting to the growing Asia-Pacific region and other APEC economies would diversify Canada's markets. Six pipeline expansion projects have been proposed in British Columbia to connect LNG terminals (NRCan, 2015a). There are currently 10 terminals proposed for the west coast and one for the east coast; under ideal circumstances, the first projects would come on line around 2020.

Facility	Size (Mtpa)	Location	Estimated time	Ownership	Status
Pacific Northwest LNG	12	Prince Rupert, BC	2019	Petronas (62%), Japex (10%), Sinopec (10%), Indian Oil Co. (10%), Petroleum Brunei (3%), Huadian (5%)	Gave conditional positive Final Investment Decision (FID) Waiting for Canadian Environment Assessment Act (CEAA) approval (September, 2015)
LNG Canada	12	Kitimat, BC	2020+	Shell (50%), Mitsubishi (15%), PetroChina (20%), KOGAS (15%)	Received British Columbia Processes for Reviewing. Environmental Assessment Act (BCEAA) and CEAA approval FID planned for 2016
Douglas Channel Floating LNG (FLNG)	0.55	Kitimat, BC	2018	Alta Gas/Idemitsu (33.3%), Exmar (33.3%), EDF (33.3%)	FID expected at the end of 2016 this year Needs National Energy Board (NEB) export licence
Kitimat LNG	11	Kitimat, BC	2020	Chevron (50%), Woodside (50%)	All certifications acquired FID planned for 2016
Prince Rupert LNG	14	Prince Rupert, BC	2021+	BG Group	Shell-BG merger puts project on hold indefinitely
Woodfibre LNG	2.1	Squamish, BC	2019	Pacific Oil and Gas	Sold 1 Mtpa/25 years to Guangzhuo, China Recently granted extension for environmental review
WCC LNG	15	Prince Rupert, BC	2024	ExxonMobil Canada (50%), Imperial Oil (50%)	BCEAA pre-application, CEAA substituted by BCEAA, NEB approved
Aurora	24	Digby Island, BC	2023	CNOOC (60%), Inpex (20%), JGC (20%)	FID in 2017 BCEAA pre-application, CEAA substituted by BCEAA, NEB approved
Wespac Tilbury	1.5	Delta, BC	2020	Wespac Midstream LLC	Brownfield, using existing infrastructure of Fortis BC LNG storage facility Export licence received
Triton LNG	2.3	Kitimat, BC	2020+	Alta Gas/Idemitsu (33.3%), Exmar (33.3%), EDF (33.3%)	Export licence received Not yet applied for Environmental Assessment EA
Goldboro	10	Nova Scotia	2020	Pieridae Energy Canada Ltd	Received all approvals - supply from US (requires Department of Energy (DOE) approval for export)

Sources: Various company websites.

Power sector trends: Continued high renewable generation

Generation capacity reaches 161 gigawatts (GW) by 2040, an increase of 24% from 2013 (130 GW) (Figure 3.7). The share of non-fossil power generation capacity, including nuclear, reached 78% in 2013. As such, Canada has one of the lowest-emitting electricity systems among APEC economies and G20 members (UNFCCC, 2015). Non-fossil energy's share is projected to decrease slightly by 1.8% in 2040, although the overall amount rises to 122 GW from 101 GW in 2013; of this, the share of nuclear declines from 11% (14 GW) to 7% (11 GW).

Renewable power continues to hold the majority share of capacity, with hydropower accounting for more than half of the economy's total capacity. The capacity of other renewables almost doubles from 8.2% in 2013 to 15% in 2040: biomass more than doubles (from 1.6 GW to 4 GW), solar quadruples (from 1.2 GW to 5.1 GW), and wind nearly doubles (7.8 GW to 15 GW). The renewables share of total installed capacity reaches 69% by 2040, slightly above the share of over 67% in 2013.

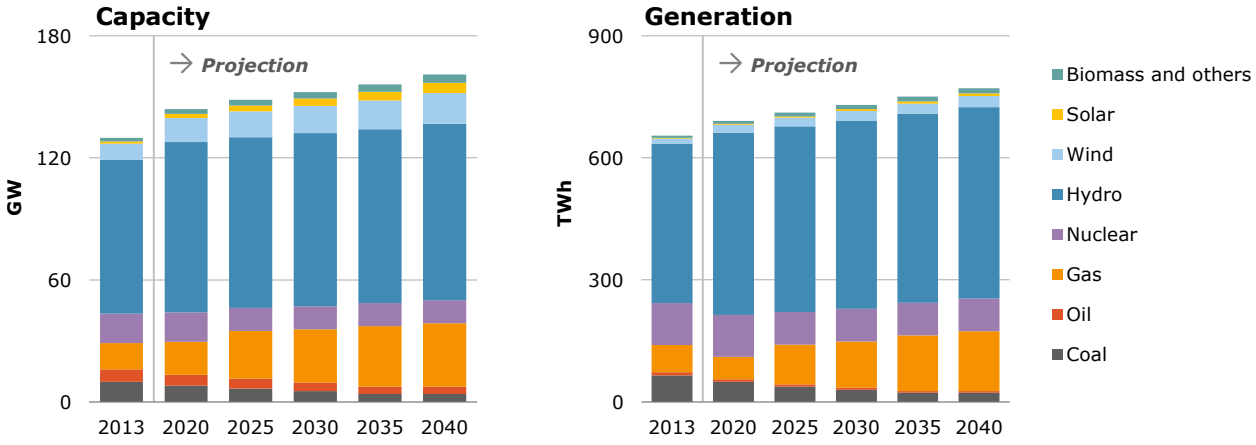
The share of coal capacity declines substantially from 7.6% in 2013 (9.9 GW) to 2.4% in 2040 (3.9 GW) and that of oil follows suit, from 4.8% in 2013 (6.2 GW) to 2.3% in 2040 (3.7 GW). However, gas capacity increases from 10% in 2013 (13 GW) to 19% in 2040 (31 GW).

Power generation is projected to increase by 18%, from 652 terawatt-hours (TWh) in 2013 to 771 TWh in 2040. Non-fossil energy remains dominant, decreasing slightly from 79% in 2013 to 78% in 2040. The share of renewables rises from 63% in 2013 to 67% by 2040. Coal generation declines steadily over the Outlook period.

The retirement and refurbishment of nuclear facilities result in a 22% decrease in nuclear capacity, from 11% in 2013 to 7% in 2040. No nuclear facilities are scheduled for construction over the Outlook period. Renewables and natural gas compensate for the loss of coal and nuclear capacity.

Coal represents 2.9% of the generation power mix in 2040, a significant decrease from 10% in 2013; the oil share also declines from 1.2% to 0.56%. Considerable domestic production, new shale resources and a temporary decrease in exports make natural gas competitive for electricity generation. Its share of generation therefore rises from 10% in 2013 to 19% by 2040.

Figure 3.7 • Canada: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

Of the three Alternative Scenarios, only the Improved Efficiency and High Renewables Scenarios are applicable to Canada.[8] Because no new nuclear or coal additions are anticipated and more than half of Canada's electricity generation by 2040 is met by hydropower, the Alternative Power Mix Scenario is not applicable.

Canada's policies for energy efficiency, its commitment to GHG emissions reduction and programs for sustainability are significant and should reduce energy consumption resulting from population growth, extreme temperatures, a vast land area and considerable heavy industry. The Improved Efficiency

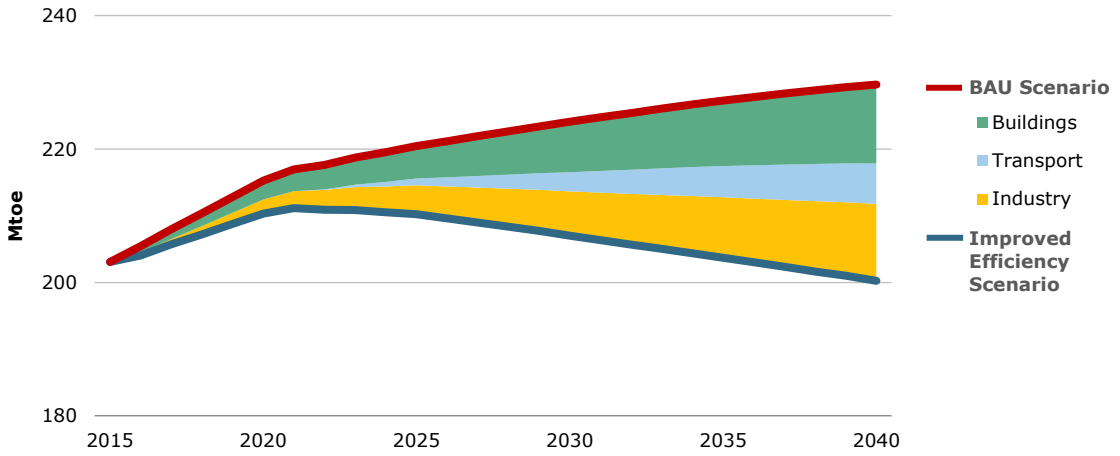
[8] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.

Scenario demonstrates the greatest impact on energy use: managing energy demand with ambitious energy efficiency targets and programs, investments and policies reduces energy intensity, energy demand and emissions and achieves domestic and international climate change targets.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

The APEC Energy Intensity Goal is a 45% reduction in energy intensity (final energy in tonnes of oil equivalent [toe] per unit of GDP) from 2005 to 2035 across all APEC economies.[9] Over this period, Canada's energy intensity under the BAU Scenario falls by 31%—short of the regional target due to rising industry energy demand. Under the Improved Efficiency Scenario, energy intensity declines by more than 38% between 2005 and 2035. Total projected savings under this scenario reach 29 Mtoe in 2040, a 13% greater reduction in energy demand than under the BAU Scenario (Figure 3.8).

Figure 3.8 • Canada: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Source: APERC analysis.

Energy savings are largest in the buildings sector (12 Mtoe), just above those of industry. Given Canada's cold climate and high use of space heating, more than half of all residential and commercial savings can be attributed to improvements in space heating and insulation. More efficient building envelopes, replacement of electric residence heaters with gas condensing boilers, advances in water heating technology (such as heating pump water heaters) and more efficient appliances offer significant savings potential.

As the industry sector is highly energy-intensive, the potential for energy savings is a significant 12 Mtoe, 19% greater than in the BAU Scenario. Nearly half of all estimated savings come from efficiency improvements in the pulp and paper and mining industries, the two largest energy-consuming sectors in 2040.

Savings in transport under the Improved Efficiency Scenario are estimated to be 8.7% (6.1 Mtoe) greater than under the BAU by 2040 because of increased penetration of efficient vehicles and better urban development. As a developed economy, Canada already has high levels of vehicle saturation and developed urban centres. Vehicle stock, including light- and heavy-duty vehicles, increases to 31 million units by 2040 under the BAU, but to only 28 million under the Improved Efficiency Scenario thanks to improved public transportation and urban development. Furthermore, the share of advanced vehicles in the Improved Efficiency Scenario is expected to reach 24%, compared with 13% in the BAU Scenario.

[9] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

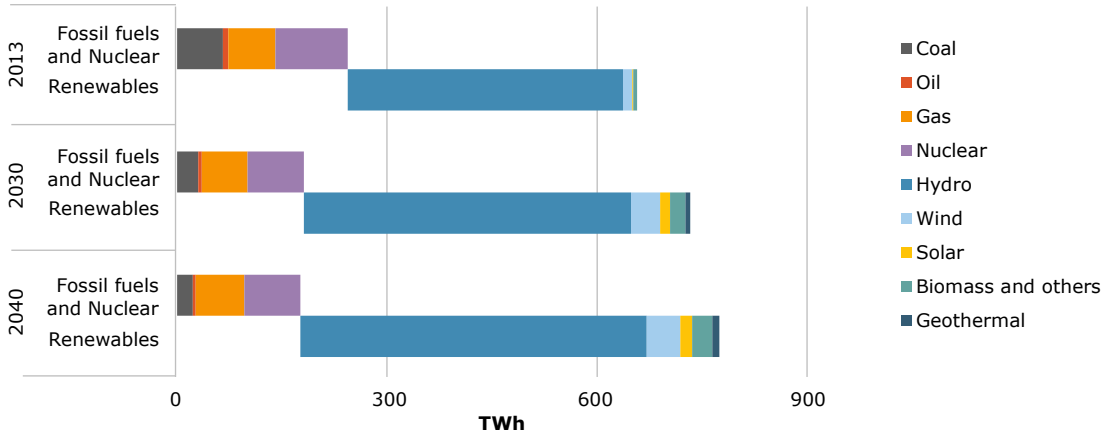
HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

In 2010 APEC announced the goal to double the share of renewables in the APEC region's energy mix, including in power generation, by 2030.[10] Asia Pacific Energy Research Centre (APERC) analysis focuses on renewables in power generation and fuel use in the transport sector.

Under the BAU Scenario, renewable power generation is projected to increase from 409 TWh in 2013 to 501 TWh by 2030 (69% of total generation) and 518 TWh by 2040 (67% of total generation). Given Canada's high level of renewable deployment and incentives promoting renewable generation, the share of renewable generation is predicted to reach 75% under the High Renewables Scenario by the end of 2030 (550 TWh), and 77% in 2040 (596 TWh) (Figure 3.9).

The largest growths in the High Renewables Scenario are in solar (from 1.4 TWh to 14 TWh), biomass (5.5 TWh to 22 TWh) and wind (13 TWh to 41 TWh) by 2030. By 2040, generation from solar reaches 17 TWh, biomass 29 TWh and wind 48 TWh.

Figure 3.9 • Canada: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

In 2014, Canada ranked sixth worldwide in new capacity additions (CanWEA, 2015) thanks to an additional 1.9 GW of w ind capacity, making it the ninth-largest wind energy producer globally. Although 63% of wind power is in the eastern provinces of Ontario and Quebec, there is great potential for wind power development inland on the prairie and in coastal areas (NRCan, 2014b). The Canadian Wind Energy Association (CanWEA) is urging the government to create more incentives for manufacturers, to streamline permit and approval processes for wind projects, and to enhance wind energy procurement. The organisation hopes that with government support, wind energy can supply 20% of electricity demand by 2025 (CanWEA, 2015).

Finally, the High Renewables Scenario projects a greater use of biofuels, with both supply potential and demand increasing significantly. In the BAU Scenario, the demand for biofuels rises at an AAGR of 1.5% from 1.8 Mtoe in 2013 to 2.6 Mtoe in 2040 (Figure 3.10). Canada's vast land area offers great potential for supply growth. In the High Renewables Scenario, biofuel supply potential more than triples; current mandates for renewable fuel blends are expected to push biofuel demand. The federal government mandates an average 5% renewable content for gasoline and 2% for diesel, but higher blend rates exist at the provincial level, with targets as high as 8.5% in Manitoba (USDA, 2014). In the High Renewables Scenario, blend rates of 6.5% for bioethanol and 3% for biodiesel are assumed by 2040. Biofuel demand grows 2.8% annually, from 1.8 Mtoe to 3.1 Mtoe over the Outlook period.

[10] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

Figure 3.10 ● Canada: Biofuels demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is for the Outlook period only; HiRE = High Renewables Scenario.
Sources: APERC analysis, IRENA (2014), FAO (2014) and IEA (2015a).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Total projected investments in the energy sector are between USD 1.2 trillion in the low-cost estimate and USD 2 trillion in the high-cost estimate from 2015 to 2040. Given Canada's significant production levels, 62% of the total low-cost estimate and 63% of the high-cost estimate will be required for the upstream sector (Table 3.4). The bulk of these investments will be allocated for the production of onshore and offshore oil, followed by gas and coal production.

After the upstream sector, the second-largest share of energy investments is allocated to the energy transport sector (16% of low-cost estimate and 13% of high-cost estimate), with oil pipelines (including export pipelines) absorbing the bulk of investment.

Electricity claims the third-largest investment share (12% of low-cost estimate and 14% of high-cost estimate). Electricity sector investments go towards additional capacity requirements for grid development, including transmission and distribution lines, and natural gas and renewables generation.

The downstream sector's share is the smallest in both the low-cost estimate (9.3%) and the high-cost estimate (10%), with oil refineries and regasification facilities accounting for the bulk of investment demand.

Investment requirements under the Improved Efficiency Scenario decrease in all four sub-sectors, with cumulative savings estimated at USD 118 billion, a 9.8% decrease from the BAU Scenario in the low-cost estimate (Figure 3.11). The largest investment reduction potential is in the upstream sector (USD 49 billion) as oil, gas and coal production slow to accommodate lower energy demand. Savings potential in the power sector follows at USD 46 billion, with improved efficiency of existing infrastructure sharply reducing investment requirements for power generation. Energy transport investment savings of USD 22 billion reflect 15% lower gas consumption, making existing gas transport infrastructure sufficient to meet future demand. Downstream investment savings potential under the Improved Efficiency Scenario is the lowest (USD 1.3 billion) owing to the highly capital-intensive nature of the oil refinery and LNG facilities.

Table 3.4 • Canada: Projected investments in the energy sector in the BAU Scenario, 2015-40

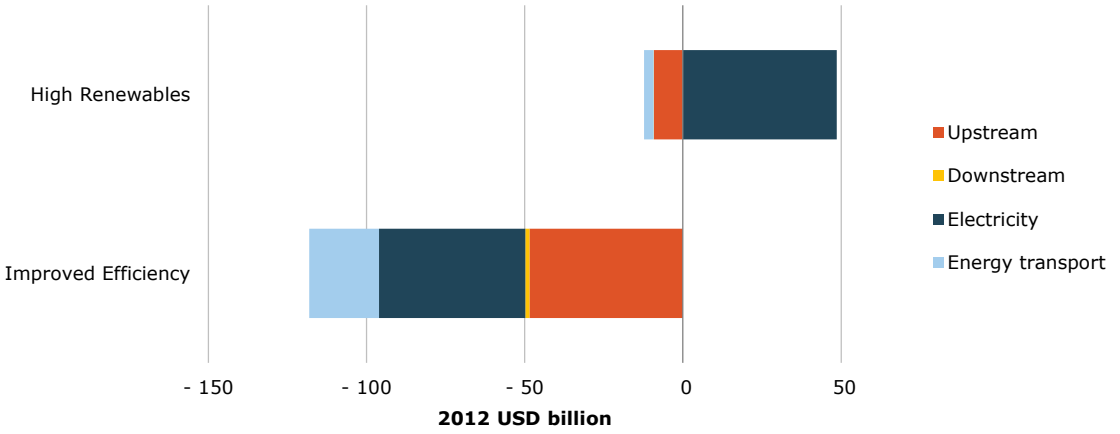
2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	649	974
	Gas	88	264
	Coal	13	42
	Subtotal	750	1 280
Downstream	Refinery	2.5	13
	LNG import terminals	0.5	1.0
	LNG export terminals	108	194
	Biofuels Refinery	0.6	0.8
	Subtotal	111	208
Electricity	Coal	4.4	12
	Gas	14	24
	Hydro	7.4	45
	Wind	21	53
	Solar	14	16
	Biomass and others	3.6	7.9
	Transmission lines	57	71
	Distribution lines	27	52
	Subtotal	149	282
Energy transport	Oil	166	206
	Gas	24	66
	Coal	0.5	1.0
	Subtotal	190	273
	Total	**1 201**	**2 043**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

Investment requirements for the High Renewables Scenario are marginally higher (3% or USD 36 billion) than under the BAU Scenario in the low-cost estimate. Higher investments in the power sector of USD 49 billion are needed for hydro, wind, solar and biomass capacity to meet the increased demand for these renewables. Savings are demonstrated for the upstream (USD 9.2 billion), downstream (USD 67 million) and energy transport (USD 3 billion) sectors. Greater savings in upstream and energy transport result from lower demand for fossil energy and thus reduced investment requirements for production and distribution.

Figure 3.11 ● Canada: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC Analysis.

SUSTAINABLE ENERGY FUTURE

Enhancing energy security: High energy self-sufficiency and fuel mix diversity

Canada's vast and diverse supply of natural resources is expected to not only meet domestic energy needs, but support growth of the energy sector through exports of oil, coal and natural gas. The Improved Efficiency Scenario demonstrates increased efficiency, lower domestic consumption and the export of excess energy. Under the High Renewables Scenario, over 77% of electricity generation (2040) is from domestic renewable resources. Domestic fossil fuel consumption decreases, allowing greater export opportunities. The policy to reduce coal consumption weakens coal demand over the projection period, resulting in coal production four times greater than domestic demand; similarly, oil production exceeds demand by 3.3 times. As it has one of the highest self-sufficiency levels in APEC, Canada is expected to continue being a major energy exporter beyond 2040.

Canada possesses one of the most diverse energy supplies among APEC members, with energy self-sufficiency expected to improve over the projection period. In 2013, the Herfindahl-Hirschman Index (HHI) for primary energy supply diversity was HHI 0.24; by 2040, the HHI deteriorates slightly to HHI 0.29 due to increasing reliance on natural gas (a lower number indicates greater diversity) (Table 3.5). This rating improves to HHI 0.26 under the Improved Efficiency Scenario and HHI 0.25 under the High Renewables Scenario, due to a more diversified renewable energy supply. Canada is fully self-sufficient in oil, gas and coal, and electricity generation input fuel diversity was HHI 0.26 in 2013, indicating a high level of diversification of its power mix (both fossil and non-fossil energy, particularly hydro).

Table 3.5 ● Canada: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040		
	Actual	BAU	Improved Efficiency	High Renewables
Primary energy supply diversity (HHI)	0.24	0.29	0.26	0.25
Primary energy supply self-sufficiency (%)	100	100	100	100
Coal self-sufficiency (%)	100	100	100	100
Oil self-sufficiency (%)	100	100	100	100
Gas self-sufficiency (%)	100	100	100	100
Electricity generation input fuel diversity (HHI)	0.26	0.28	0.36	0.27

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

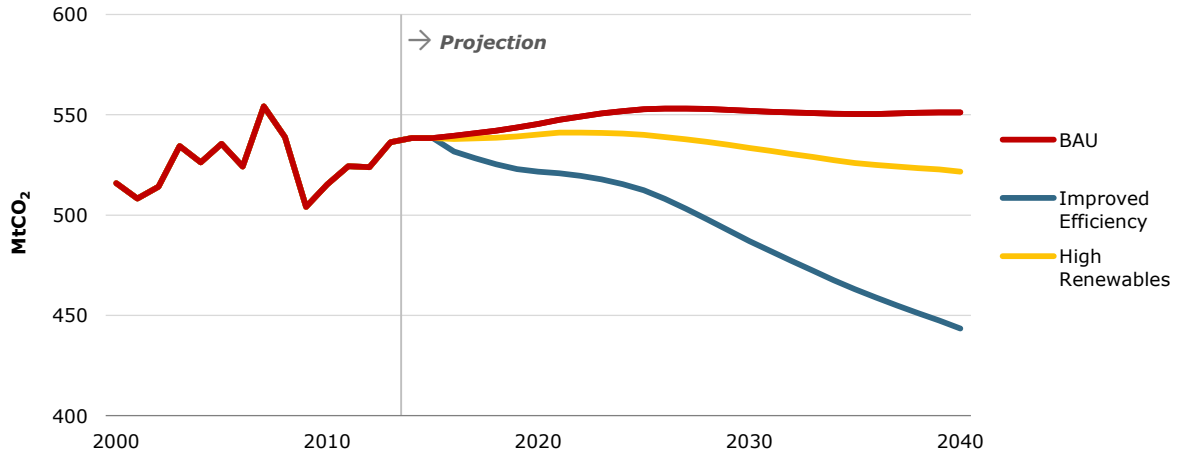
Climate change impacts and risks: Potential for emissions reductions in industry and transport

Canada accounts for 1.6% of the world's GHG emissions (INDC, 2012), and in 2013 fossil fuel production was the largest contributing sector at 26% of emissions (NRCan, 2015a). Under the BAU Scenario, energy-related CO_2 emissions grow from 536 million tonnes of carbon dioxide ($MtCO_2$) in 2013 to 551 $MtCO_2$ by 2040.

Canada has set an economy-wide target to reduce GHG emissions to 30% below the 2005 level by 2030, to 430 $MtCO_2$. However, the Outlook shows energy-related CO_2 emissions growing to 551 $MtCO_2$ in 2030, well above the economy-wide GHG emissions targets for all sectors. To reach its economy-wide goal and ensure a sustainable energy future, provincial and federal governments, and agencies such as the Canadian Council of Ministers of the Environment, have committed to the development of clean energy technologies and new policies to address climate change (INDC, 2015). Since 2006 the federal government has invested more than USD 10 billion in environmentally sustainable infrastructure and technologies, smarter grids, programs for energy efficiency and the promotion of cleaner fuels (INDC, 2015). Similar investments are also expected in the future.

Under the Improved Efficiency Scenario, energy-related CO_2 emissions decrease to 444 $MtCO_2$ in 2040 (Figure 3.12). In the High Renewables Scenario, energy-related CO_2 emissions are 522 $MtCO_2$ in 2040. The largest potential for reducing energy-related CO_2 emissions is in the industry and transport sectors. Although many aspects of Canadian industry are energy-intensive, industrial demand-side management programs and improvements in the energy efficiency of equipment would help curb energy-related CO_2 emissions (NEB, 2013).[11] Expanding public transportation systems to reduce the use of private vehicles and increasing the share of biofuels could significantly decrease transport's energy-related CO_2 emissions. Sector-by-sector government initiatives for emissions reductions would also aid in reaching the economy-wide emissions reduction goal as well as the APEC Energy Intensity Goal.

Figure 3.12 • Canada: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

[11] See Footnote 4.

RECOMMENDATIONS FOR POLICY ACTION

If Canada is to remain competitive in the international energy sector, further development of infrastructure for oil and natural gas exports is needed to facilitate the shipment of surplus fossil fuels to international markets, particularly in the Asia-Pacific region.

With concerted efforts in renewable energy development, Canada could be powered almost entirely by renewable electricity. The expected retirement of coal plants over 2019 to 2029 is an opportunity to further accelerate renewables deployment. However, policies are needed to address non-economic barriers, such as streamlining permitting and approval procedures for renewable projects and offering additional support mechanisms to attract greater investment in renewable power.

Improving energy efficiency across all end-use sectors offers significant savings potential. Tighter regulation of building codes, MEPS and fuel efficiency, as well as incentives and support measures to facilitate investments in energy efficiency in industry, are needed to help realise these potential savings.

4. CHILE

KEY FINDINGS

- **Under the BAU Scenario[1] Chile's final energy demand grows 67% from 27 Mtoe in 2013 to 45 Mtoe in 2040.** A member of the OECD since only 2010, Chile is transitioning to developed economy status. The industry sector grows by 102% over the Outlook period, followed by non-energy use (88%), buildings (59%) and domestic transport (35%).

- **With limited domestic fossil fuel resources and no plans for nuclear energy, Chile's net energy imports double under the BAU Scenario over the projection period.** Primary energy supply self-sufficiency deteriorates under the BAU from 39% in 2013 to 29% in 2040, but a significant increase in renewable capacity under the High Renewables Scenario improves self-sufficiency to 40%.

- **Energy intensity drops 25% from the 2005 level by 2035 under the BAU Scenario.** Under the Improved Efficiency Scenario, however, energy efficiency programs and policies lead to a 35% reduction by 2035.

- **Energy-related CO_2 emissions grow from 82 $MtCO_2$ in 2013 to 149 $MtCO_2$ in 2040—an 81% increase.** The Improved Efficiency Scenario demonstrates the greatest energy sector CO_2 emissions reductions, at 26% less than under the BAU in 2040. The High Renewables Scenario offers the second-largest emissions reduction at 23% lower than under the BAU. Energy efficiency, conservation and renewables deployment should continue to be priorities.

[1] In late 2015 the government released its long-term energy strategy, Energy 2050, which aims to transform Chile's energy outlook. It sets a goal of 70% renewables generation by 2050 and prioritises energy efficiency and conservation. The new strategy's targets are not included in the BAU Scenario, as it only includes existing policies enacted prior to October 2015.

ECONOMY AND ENERGY OVERVIEW

Chile, bordered by Peru to the north, Bolivia to the north-east and Argentina to the west, has a land area of 756 102 square kilometres (km^2). Its Pacific coastline is 6 435 km long and it has an average width of 175 km. Its geography makes energy, trade and transport interconnections among northern, central and southern parts of the economy difficult. The north is a desert, and mining dominates energy demand in the region; fossil fuel imports satisfy this demand despite high solar energy potential. In central and southern Chile, hydro and biomass resources are abundant and are the main energy sources.

Administratively, Chile has 15 regions headed by regional governors (intendentes) appointed by the president. In 2013 the population reached just over 18 million, with 87% living in urban areas (INE, 2013); 40% reside in Santiago, the capital. In 2013, gross domestic product (GDP) reached USD 327 billion (2012 USD purchasing power parity [PPP]) (Table 4.1), an increase of 4.3% from 2012, led by retail sales (7.2%), mining (6.1%) and business services (3.5%). Copper accounted for nearly 93% of mining exports and 41% of total exports (BCL, 2014). Foreign direct investment, closely related to mining investment, decreased by 35% to USD 17 billion in 2013 due to lower commodity prices (UNCTAD, 2015). Economic activity has a high correlation with final energy consumption: the mining and industry sectors accounted for 35% of final consumption and 25% of economic activity in 2013 (BCL 2015).

Table 4.1 ● Chile: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	104	190	281	327	429	559	663
Population (million)	13	15	17	18	19	20	20
GDP per capita (2012 USD PPP)	7 891	12 545	16 486	18 648	23 137	28 516	32 992
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	14	25	31	39	49	59	65
TPES per capita (toe)	1.1	1.7	1.8	2.2	2.6	3.0	3.2
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	11	20	24	27	34	41	45
Final energy intensity per GDP (toe per 2012 USD million PPP)	107	107	85	81	80	73	68
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	29	49	69	82	105	131	149
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	95	99	99	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments throughout this chapter are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

ENERGY RESOURCES

Fossil fuel reserves are limited, so nearly the entire fossil fuel supply is imported—around 61% of total primary energy supply (TPES) in 2013. Chile imports 97% of its oil and 80% of its gas, but despite high oil and gas import dependence, hydro and biomass contributed about 30% of TPES in 2013.

Rising demand for electricity, combined with policy incentives, makes renewables[2] an attractive option for increased domestic generation, especially solar because of high solar radiation in the north. Capacity potential is about 1 200 gigawatts (GW) in solar photovoltaic (PV) and 548 GW in concentrated solar

[2] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

power (CSP), which is sufficient to cover local electricity demand. Additionally, wind potential is estimated at 37 GW and hydro at 12 GW (MEC, 2014a).

Oil production declined from 15 million barrels (bbl) in 1981 to 1.1 million bbl in 2013 (Agostini, 2009; ENAP, 2014), maintaining proven oil reserves of 150 million bbl in 2014. The government is now focused on the promotion of oil and gas exploration and production through the National Petroleum Company (ENAP) to double hydrocarbons production by 2020 (ENAP, 2015).

ENERGY POLICY CONTEXT

In September 2015 the Ministry of Energy presented the Energy Roadmap 2050 setting out energy policy up to 2050 (MEC, 2015a). The main goals are to reduce emissions and have a competitive cost of energy by 2050. Energy 2050, released in December 2015, describes the four pillars of Chile's energy policy: 1) energy security and energy supply quality; 2) energy as a development engine; 3) environmental compatibility; and 4) energy efficiency and education (MEC, 2015b). Nuclear energy is not a short-term option under Energy 2050, but it is proposed that further research be considered in the next review of the energy policy. Energy 2050's main goals are summarised in Table 4.2.

Table 4.2 ● Chile: Energy 2050's main goals, 2035 and 2050

By 2035	By 2050
Interconnection with other Andean Electric Interconnection System members (Peru, Ecuador, Colombia and Bolivia) and with other South American economies and countries, particularly Mercosur economies and countries (Brazil, Paraguay, Uruguay, Argentina, Bolivia and Venezuela).	Energy sector greenhouse gas (GHG) emissions below limits established in the economy-wide goal.
Energy disruption reduced to less than four hours per year.	Energy disruption reduced to less than one hour per year.
Continuous and reliable access to energy services for all new vulnerable dwellings.	Universal and equitable access to reliable and modern energy services.
All projects developed have associativity mechanisms between project developers and communities to foster local development and better performance.	Territorial, regional and local planning and management tools conforming to the energy policy are in place.
Be among the five OECD economies and countries having lowest residential and industry energy costs.	Be among the three OECD economies and countries having lowest energy costs.
At least 60% of electricity generation from renewable sources.	At least 70% of electricity generation from renewable sources.
30% emissions intensity reduction in comparison with 2007.	Energy consumption decoupled from GDP growth.
All large energy consumers (industry, mining and transport) to apply energy efficiency measures.	100% of new buildings constructed under the Organisation for Economic Co-operation and Development (OECD) standards of efficient construction and smart systems of energy management.
All municipalities to adopt regulations declaring traditional biomass as solid fuel, thus included in GHG emissions levels.	100% of the main categories of appliances in the Chilean market are energy efficient.
All new passenger vehicles to be evaluated under energy efficiency standards.	Energy efficiency practiced at all levels of society.

Source: MEC (2015b).

BUSINESS-AS-USUAL SCENARIO

This section summarises the key energy demand and supply assumptions under the Business-as-Usual (BAU) Scenario (Table 4.3). As promoting economic development with limited energy resources is a major challenge, long-term goals are needed to increase energy efficiency, reduce energy dependency and energy costs, and improve productivity in the whole economy (MEC, 2015a).

Table 4.3 • Chile: Key assumptions and policy drivers under the BAU Scenario

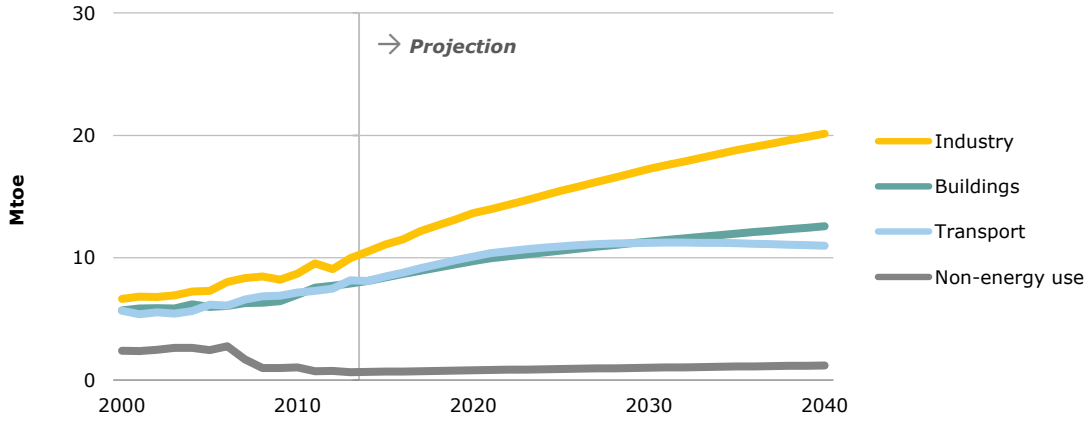
Buildings and industry	• Energy demand reduced 20% by 2020 through energy efficiency policies.
Transport	• Improved public train and bus transport. • Private car ownership close to saturation level (85%). • Biofuels not considered under the Energy Agenda 2014.
Energy supply mix	• No nuclear energy considered under the Energy Agenda 2014. • Coal remains as one of predominant sources and solar power expands in power generation (MEC, 2015c).
Renewables	• Committed renewable energy projects and historical capacity trends considered. • 20% of electricity generation from non-conventional renewable sources by 2025.
Energy security	• Expanded oil and gas exploration. • Renewable energy development. • Energy efficiency plan implemented.
Climate change	• Work towards the United Nations Framework Convention on Climate Change (UNFCCC) Intended Nationally Determined Contribution (INDC) target of GHG emissions intensity 30% lower than in 2007 by 2030.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Final energy demand grows robustly over the Outlook period under the BAU Scenario, rising 68% from 27 million tonnes of oil equivalent (Mtoe) in 2013 to 45 Mtoe in 2040, an average annual growth rate (AAGR) of 1.9% (Figure 4.1). In 2013, the industry sector consumed 37% (10 Mtoe) of total final energy, domestic transport 31% (8.2 Mtoe) and buildings[3] 30% (7.9 Mtoe); non-energy use accounted for the remaining 2.4% (0.63 Mtoe). By 2040, the industry share grows to 45% (20 Mtoe), whereas the buildings share declines to 28% (13 Mtoe) and transport to 24% (11 Mtoe).

Figure 4.1 • Chile: Final energy demand by sector, 2000-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

[3] 'Buildings' includes residential, commercial and agriculture energy demand; however, as agriculture accounts for only 0.85% of total final energy demand in 2013, it is not addressed separately.

Energy demand in industry grows at an AAGR of 2.6%, non-energy-use at 2.4%, buildings at 1.7% and transport at 1.1% (Figure 4.1). Transport energy demand peaks in 2031 and decreases thereafter due to expanded public transport infrastructure in Chile's major cities.

The government promotes energy efficiency measures in industry and mining, transport, buildings, end-use devices and heating through the Action Plan on Energy Efficiency 2020, which aims to reduce final energy demand 20% by 2020 (MEC, 2012) (Table 4.4).

Table 4.4 • Chile: Action Plan on Energy Efficiency 2020

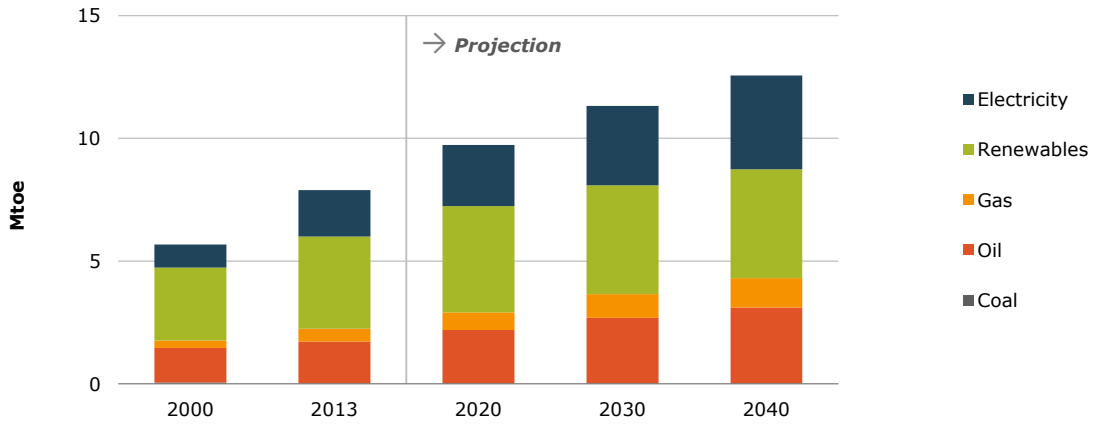
Industry and mining	• Promote energy management systems. • Promote energy cogeneration. • Encourage efficient technologies.
Transport	• Improve energy efficiency standards for light- and heavy-duty vehicles. • Use new transport technologies in heavy-duty vehicles. • Promote public transportation.
Buildings	• Encourage energy efficiency management in new buildings. • Promote building labelling.
End-use devices	• Enhance appliance labelling. • Establish minimum efficiency standards. • Establish minimum lighting efficiency standards.
Heating	• Encourage new technologies in the use of firewood. • Improve firewood quality. • Introduce thermal isolation standards in new residences.

Source: MEC (2012).

Buildings energy use: Sustained demand growth to 2040

Energy consumption in the buildings sector grows 1.7% annually, from 7.9 Mtoe in 2013 to 13 Mtoe in 2040 (Figure 4.2). By 2020, six of Chile's 15 regions are projected to have populations of over 1 million and energy demand therefore increases primarily in residential areas. Easy access to the grid in these growing urban residential areas increases energy demand for appliances and other residential uses (Agostini, 2010). In 2013, renewable energy was the largest fuel source in residential and commercial buildings at 3.8 Mtoe (48% share). However, the renewables share declines to 35% (4.4 Mtoe) by 2040 due to increased residential consumption of electricity (2.6% AAGR) and gas (3.1% AAGR) for space and water heating and cooking, due to rising population and urbanisation.

Figure 4.2 • Chile: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Gas accounted for 6.6% (0.4 Mtoe) of residential demand in 2013 and is projected to reach 11% by 2040 (0.9 Mtoe) under the BAU. Further use of gas is limited by the size of the distribution network, and

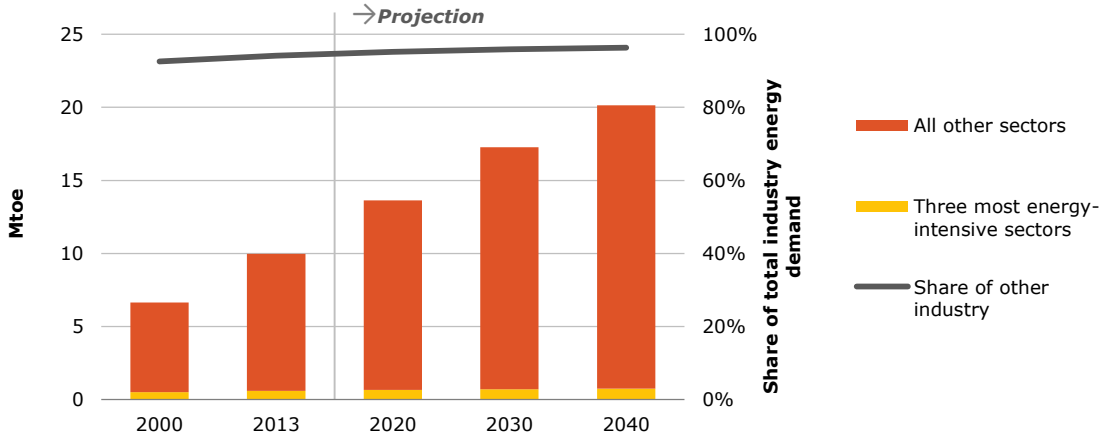
traditional firewood substitutes gas for heating and cooking in southern regions where it is cooler and forests are abundant (Galetovic and Sanhueza, 2015). Through the Energy 2050 policy, and the draft of the Use of Firewood for Heating Act, the government seeks to promote the responsible production and consumption of firewood used for heating, mainly in the southern region of the economy. These policies address building efficiency, sustainability and quality of firewood, other energy uses of the firewood, efficient heating technologies, institutions and education (MEC, 2015d). Residential energy consumption is lower in northern regions due to a milder climate and low population density.

Industry energy use: Demand increases with mining and manufacturing

Energy demand in industry grows the most quickly of all sectors, doubling from 10 Mtoe in 2013 to 20 Mtoe by 2040—an AAGR of 2.6% (Figure 4.3). This increased demand is prompted by the mining and manufacturing sub-sectors, which represent around 90% of industry GDP (BCL, 2014). The largest shares of industry energy use are in the mining and quarrying sub-sector with a 40% share in 2013 and 44% in 2040 (3% AAGR), the 'other industry' sub-sector at 32% in 2013 and 33% in 2040 (2.8% AAGR) and pulp, paper and printing at 23% in 2013 and 20% in 2040 (2.1% annual average decline).

Oil consumption increases from 33% (3.3 Mtoe) of total industry consumption to 36% (7.3 Mtoe) over the Outlook period, while electricity demand rises from 37% (3.7 Mtoe) in 2013 to 42% (8.4 Mtoe) by 2040. Already the world's largest copper producer (USGS, 2014), Chile plans to develop another 24 mining projects in the north between 2015 and 2024 at an estimated cost of USD 31 billion (Cochilco, 2015). Energy 2050 plans for large consumers in mining, industry and transportation to implement energy management systems and use efficient technologies. The government established the Chilean Energy Efficiency Agency (AChEE) to promote energy efficiency measures; it is responsible for training, energy audits, technological change, energy management system implementation and optimisation, and tools and capacity building programs for initiatives such as the ISO 50001 Energy Management System Standard and Optimisation Frameworks program (AChEE, 2015).

Figure 4.3 • Chile: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.
Sources: APERC analysis and IEA (2015a).

Transport energy use: Demand to peak and then decline

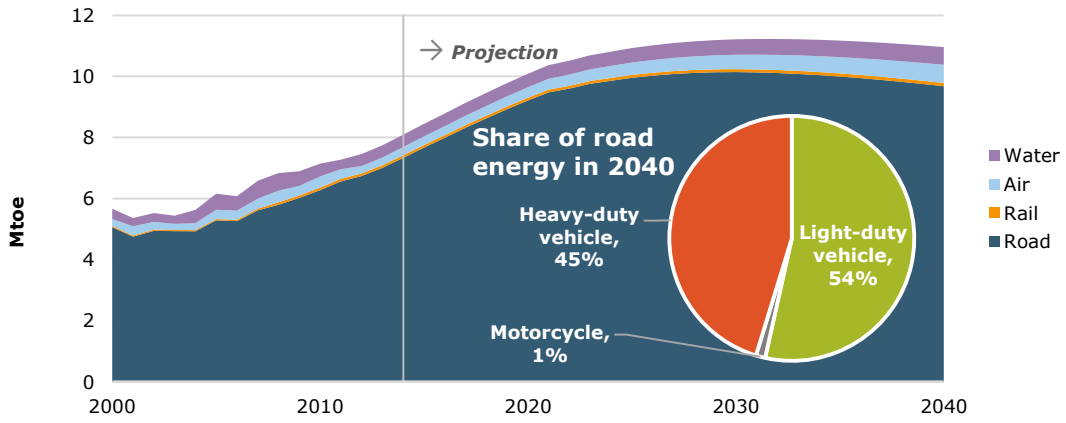
Due to Chile's uniquely narrow and long topography (6 435 km long), road transport connecting the north and south dominates transport sector energy consumption. Road transport consumed 91% (7.4 Mtoe) of transport sector energy in 2013 (Figure 4.4). Under the BAU Scenario, road transport consumption peaks in 2031 before declining to an 88% (9.7 Mtoe) share in 2040. Shipping is the next largest mode at 5.2% (0.4 Mtoe) of transport energy in 2013, and it maintains a 5.3% share on average over the projection period. Domestic air transport's share increases from 3.4% in 2013 to 5.4% in 2040.

Freight transport in the mining sector consumes the majority of oil within the transport sector, and the copper industry alone accounted for 5% of total road transport fuel demand in 2013 (Cochilco, 2014). Rivers are a key medium for goods exchange among all regions of Chile, and in the south they are the fastest and most reliable means of transport. Shipping by river and sea is therefore extensive in Chile, and about 20% of port cargo was domestic in 2012 (CMPC, 2013).

Chile is a net importer of oil, used mainly in the transport sector; demand for oil declines over the projection period, however, due to improved public transport and energy efficiency in transportation. A policy measure that contributes to this reduction is a green tax on new light-duty vehicles implemented in 2014, which targets pollution-intensive diesel vehicles. This tax aims to reduce emissions from vehicles with higher-polluting technologies.

Light-duty vehicle energy consumption declines from 2035 due to slower GDP growth, increased public transport infrastructure and increased congestion in Chile's major cities. In 2012, the Ministry of Transport and Telecommunications launched the Transport Master Plan 2025, a list of infrastructure projects and transport management plans to improve mobility and promote economic growth in 31 cities. It includes the Master Plan for the City of Santiago that provides nearly USD 23 billion in investments to 2025: 41% of the budget is allocated to the subway system, 36% to road concessions, 14% to road projects and 2% to cycle paths. These projects are expected to reduce travel times, and therefore energy use.

Figure 4.4 ● Chile: Domestic transport sector final energy demand, 2000-40



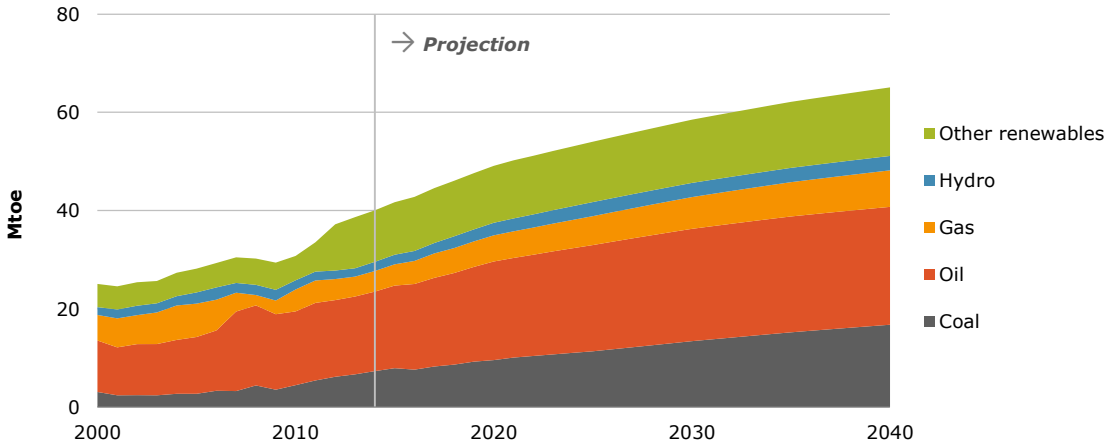
Sources: APERC analysis and IEA (2015a).

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Increased renewables and oil exploration

TPES decreased slightly in 2008 and 2009 due to the global economic recession. The economic slowdown of China had a great impact on the Chilean economy, as China received around one-third of Chile's overall exports and 35% of its copper specifically (Cochilco, 2015). The Chilean economy bounced back to 2007 levels by 2010, however, as it recovered from the recession. Fossil fuels continue to dominate the primary energy supply, rising from 69% (27 Mtoe) in 2013 to around 74% (48 Mtoe) in 2040 (Figure 4.5). With an AAGR of 2.3% over the projection period, the share of natural gas increases from 10% (4.1 Mtoe) in 2013 to 11% (7.4 Mtoe) in 2040. Concurrently, the share of coal rises from 17% (7 Mtoe) in 2013 to 26% (17 Mtoe) in 2040. This increase is the result of higher energy demand by the mining sub-sector in northern Chile. Other renewables increase from 10 Mtoe in 2013 to 14 Mtoe in 2040, and total renewable energy including hydro is 26% (17 Mtoe) of the 65 Mtoe TPES by 2040, down 5 percentage point from 31% (12 Mtoe) in 2013.

Figure 4.5 • Chile: Total primary energy supply by fuel, 2000-40



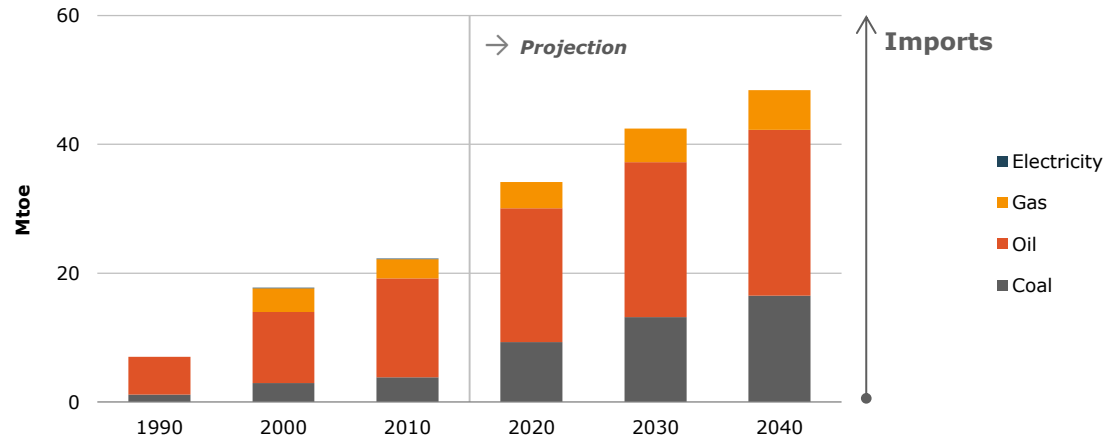
Sources: APERC analysis and IEA (2015a).

The government seeks to develop clean and domestic energy sources under the Energy Roadmap 2050, and the new role of ENAP is to increase domestic hydrocarbon resource exploration.

Energy trade: Imports to increase

Fossil fuel imports nearly double over the projection period, growing from 25 Mtoe to 48 Mtoe, accounting for 97% of supply in 2013 and 96% in 2040 under the BAU (Figure 4.6). Coal imports nearly triple from 6 Mtoe to 17 Mtoe over the projection period to meet coal-based electricity generation demand for industry and buildings. Coal demand peaks towards 2040, however, as mining activity slows. Meanwhile, oil imports are tied to growth in the transport sector. The AAGR for oil imports declines after 2025, from 1.5% to 0.6% by 2040 with reduced oil consumption in the transport sector—accounting for 65% of total energy imports in 2013 and 53% in 2040. Since 2012, 95% of gas imports come from Trinidad and Tobago, which has abundant natural gas and provides long-term contracts. However, as dependence on one sole source for gas threatens energy security, and as US exports are coming online and the Panama Canal has been expanded, Chile plans to secure the majority of its gas from the United States by 2016 (CDEC, 2015).

Figure 4.6 • Chile: Net energy imports, 1990-2040



Sources: APERC analysis and IEA (2015a).

Power sector trends: More renewable capacity

The electricity market in Chile consists of two main unconnected grids: the Northern Interconnected System (SING) and the Central Interconnected System (SIC). The SING supplies to northern consumers,

half of which support the mining industry and make up 7% of the population, while the SIC covers around 90% of the total population. There are also two smaller grids, the Aysen Grid and the Magallanes Grid, which serve their regions only. From 2014, a tax of USD 5 per tonne of carbon dioxide equivalent (tCO_2e) was applied to the power sector, which will in turn increase the relative price of electricity and encourage energy consumers to implement energy efficiency measures and low carbon technologies (MEC, 2015a).

Electricity generation grew at an AAGR of 5.2% from 1990 to 2013, one of the highest rates in the Asia-Pacific Economic Cooperation (APEC) region, from 18 terawatt-hours (TWh) to 73 TWh. The AAGR drops to 3% over the projection period under the BAU Scenario, and generation more than doubles to 161 TWh in 2040 (Figure 4.7).

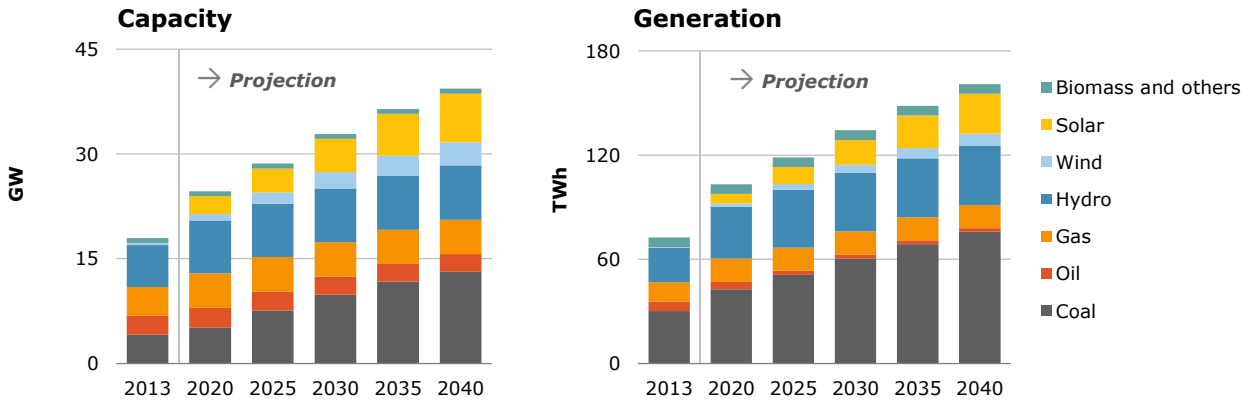
Coal-fuelled electricity capacity is 34% of total electricity capacity in Chile by 2040, compared with 23% in 2013—a threefold increase from 4.1 GW to almost 13.2 GW. Coal is used mainly in the northern mining and industrial region, where in 2015 50% of power capacity and 75% of generation came from coal, and is expected to increase as mining projects expand (Cochilco, 2015).

In 2013 gas accounted for 23% of total capacity and 15% of total generation, and by 2040 it accounts for 12% of capacity and 8% of generation. Hydro capacity was 34% of total capacity in 2013 and, although it decreases to 20% in 2040, total capacity increases by 30% from 6 GW in 2013 to 7.8 GW by 2040. However, the variability of hydro resources poses a supply risk: in a very wet year over 81% (41 TWh) of generation can be supplied by hydro plants, but this drops to 27% under dry conditions—a reduction of 13 TWh (Galetovich and Munoz, 2011). The 2015 El Niño rainfall filled water reservoirs for energy generation in the near future (CIIFEN, 2015).

Renewables capacity was 39% of total capacity in 2013 and increases to 48% in 2040. Total generation based on renewables, which was 36% in 2013, increases to 43% by 2040. In 2013, Law No. 20.698 decreed that 20% of electricity sold by 2025 must come from other renewable sources. According to Chile's Centre for Innovation and Development of Renewable Energies (CIFES), installed capacity of other renewables reached 2.1 GW at the end of 2014, 11% of the economy's total installed capacity, with wind accounting for the largest share (40%), followed by biomass (22%), solar (20%) and mini-hydro (17%) (CIFES, 2015).

Coal power generation costs are lower in the SING system than in the SIC, so interconnection of the systems will reduce average energy prices for final users of both systems. In 2015 the North Transmission Line project began the interconnection process, with an estimated investment cost of USD 1.1 billion (MEC, 2015e).

Figure 4.7 • Chile: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

All three Alternative Scenarios—Improved Efficiency, High Renewables and Alternative Power Mix—apply to Chile.[4] The Improved Efficiency Scenario achieves the greatest energy sector CO_2 emissions reductions, a 26% reduction compared with the BAU by 2040, and the greatest reduction in final energy demand, 16% (7.2 Mtoe) less than under the BAU. The High Renewables Scenario results in the second-largest reduction in CO_2 emissions at 23%, followed by the High Gas 100% Case at 16% and the High Gas 50% Case at 8%.

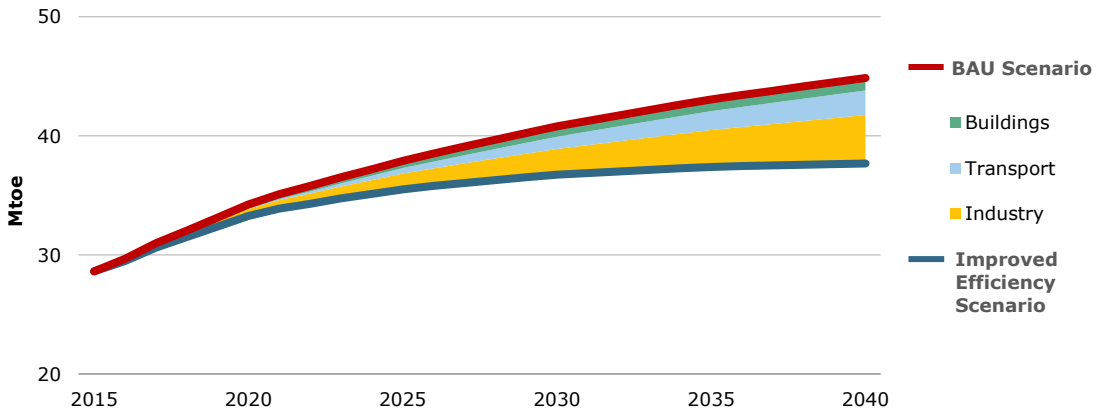
IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

Final energy demand under the Improved Efficiency Scenario is 16% (7.2 Mtoe) lower than under the BAU Scenario over the Outlook period. Under the BAU, Chile's energy intensity falls 26%, contributing to the APEC-wide energy intensity target of a 45% regional reduction by 2035 from the 2005 level.[5] However, under the Improved Efficiency Scenario energy efficiency improvements lead to a 35% reduction in energy intensity by 2035, offering a more significant contribution to the APEC goal.

As final energy consumption is concentrated in industry, the potential for savings is largest in this sector. Savings of 4.1 Mtoe in 2040 are demonstrated, amounting to 57% of total potential energy savings under this scenario (Figure 4.8). Savings in transport amount to 2.1 Mtoe, as the Improved Efficiency Scenario assumes a higher penetration of efficient vehicles and better urban development. Vehicle stock increases to 4.6 million units under the BAU Scenario, but to only 3.7 million under the Improved Efficiency Scenario. These assumptions correspond with the Ministry of Transport's plans to implement structural reform in Santiago, increasing investment in public transportation and as a result reducing light-duty vehicle stock to 4.2 million under the BAU by 2040, or to 3.5 million under the Improved Efficiency Scenario. Also, the share of advanced vehicles increases from 15% under the BAU to 31% under the Improved Efficiency Scenario by 2040, with a projected 25% (1.3 Mtoe) reduction in energy use by light-duty vehicles compared with the BAU.

Under the Improved Efficiency Scenario, energy savings potential in the residential sector is 8.3% (1 Mtoe) higher than under the BAU. This sector covers seven end uses: refrigerators, air conditioners, televisions, washing machines, lighting, water heating and stand-by energy. Around 60% of total residential energy savings under the Improved Efficiency Scenario are from refrigerators, lighting and water heating, with an average savings of 20% each compared with under the BAU.

Figure 4.8 • Chile: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Source: APERC analysis.

[4] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.
[5] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

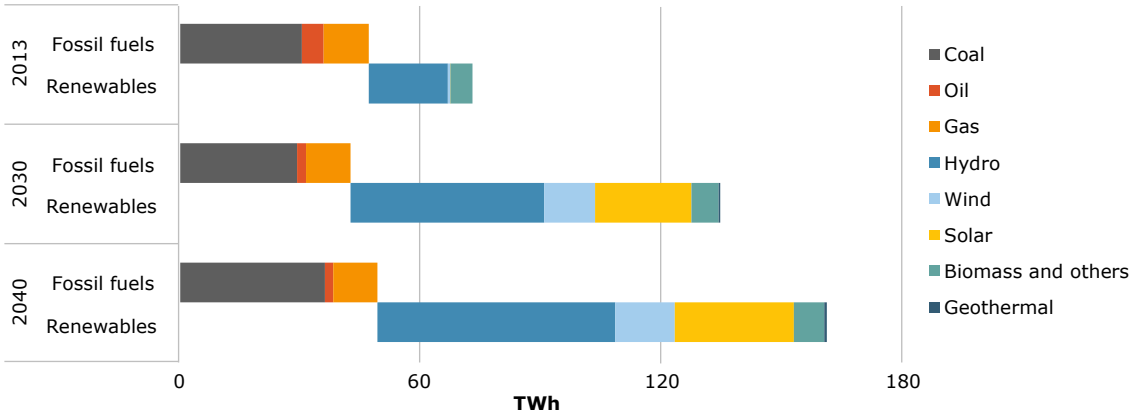
The government is implementing the Action Plan for Energy Efficiency 2020, and in 2014 it approved the Minimum Energy Efficiency Standards Act that applies to refrigerators and lamps. New regulations on vehicle labelling and water heating were also approved.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

The High Renewables Scenario models a doubling of renewables in the power generation and transport sectors by 2030 from the 2010 level, in line with the APEC-wide renewable energy goal.[6] According to the CIFES, installed capacity from other renewables doubled from 2012 to 2014, based on solar PV growing from 4 megawatts (MW) in 2012 to 402 MW in 2014 and wind from 205 MW to 836 MW (CIFES 2015).

Under the High Renewables Scenario, power generation from renewables increases from 36% (26 TWh) in 2013 to 68% (92 TWh) in 2030 and 70% (112 TWh) in 2040 (Figure 4.9). In 2040, hydro accounts for 37% (59 TWh) and other renewables around 33% (53 TWh), compared with hydro at 21% (34 TWh) and other renewables at 22% (35 TWh) under the BAU. Over the projection period, solar, wind and geothermal overtake biomass, with solar reaching 18% of total power generation by 2040, followed by wind (9.2%) and biomass and others (4.7%). In the BAU Scenario, solar reaches a share of only 14% of total power generation, followed by wind (4.2%) and biomass and others (3.5%). Geothermal remains undeveloped under the BAU Scenario, as the investment required is between USD 6 billion and USD 8 billion.

Figure 4.9 ● Chile: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

ALTERNATIVE POWER MIX SCENARIO

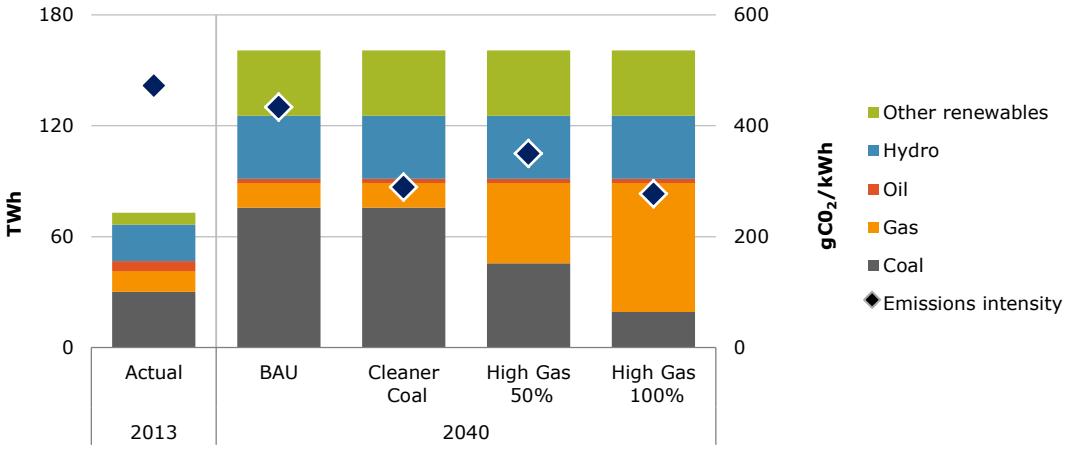
The Alternative Power Mix Scenario evaluates the effects of high-efficiency coal technologies (the Cleaner Coal Case), higher shares of natural gas (the High Gas 50% and the High Gas 100% Cases) and expanded nuclear power (the High Nuclear Case) in the power sector. Of the four cases, only the Cleaner Coal, the High Gas 50% and the Gas 100% Cases apply to Chile, as the economy has no plans for nuclear development.

The Cleaner Coal Case assumes that more efficient generation technologies such as advanced ultra-supercritical (A-USC) or integrated gasification combined cycle (IGCC) replace new coal generation capacity in the BAU Scenario from 2020, and are equipped with carbon capture and storage (CCS) from 2030. This case therefore shows a similar power generation mix as the BAU Scenario but with lower emissions (Figure 4.10). The High Gas 50% and High Gas 100% Cases assume that new coal-based generation capacity in the BAU Scenario is replaced either 50% or 100% by combined cycle gas turbine (CCGT) technology from 2020.

[6] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

Under the Cleaner Coal Case, electricity generation-related CO_2 emissions fall by 33% compared with the BAU by 2040, decreasing from 70 million tonnes of CO_2 ($MtCO_2$) under the BAU to 46 $MtCO_2$. Under the High Gas 50% Case, the substitution of gas for coal affects the SING grid in the north. In the High Gas 50% Case, electricity generation-related CO_2 emissions reach 56 $MtCO_2$ in 2040, a reduction of 19% from the BAU, whereas under High Gas 100%, CO_2 emissions are 36% below the BAU at 45 $MtCO_2$. Liquefied natural gas (LNG) generation increases fivefold under the High Gas 100% Case (70 TWh) compared with the BAU (13 TWh) in 2040. The additional gas generation will require a substantial increase in gas imports from LNG terminals and pipelines.

Figure 4.10 • Chile: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

With limited indigenous fossil fuel resources, a growing population and a rapidly developing economy, Chile's estimated energy investments from 2015 to 2040 range from USD 74 billion under the low-cost estimate to USD 138 billion under the high-cost estimate (Table 4.5). With electricity capacity projected to more than double under the BAU Scenario, investments will fund the 21 GW of additional capacity as well as transmission lines. Because of limited domestic energy resources, the government is focusing on power mix diversification, incorporating renewable sources to improve energy security. Electricity dominates investments, at 84% of total requirements under the low-cost estimate and 72% under the high-cost estimate. Within electricity investments, USD 21 billion (low-cost estimate) to USD 36 billion (high-cost estimate) is claimed by renewables. Transmission investments are needed to complete the grid interconnection project by 2020, as well as to connect renewables to the grid.

The Improved Efficiency Scenario results in an investment of USD 54 billion, 28% below the BAU low-cost estimate, the largest reduction being in the electricity sector with savings of USD 17 billion (Figure 4.11). Lower energy demand reduces generation capacity requirements by 5.8 GW compared with the BAU. Downstream investments decline by USD 1.7 billion as required LNG import terminal capacity falls from 5.3 Mt per year in BAU to 4 Mt per year.

Table 4.5 ● Chile: Projected investments in the energy sector in the BAU Scenario, 2015-40

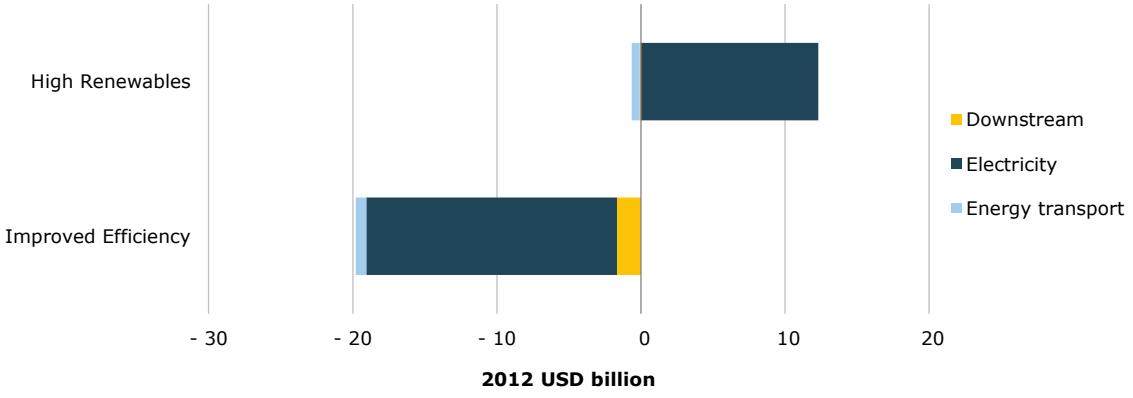
2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	1.5	2.3
	Gas	0.8	2.4
	Coal	0.2	0.6
	Subtotal	2.5	5.2
Downstream	Refinery	4.5	20
	LNG import terminals	0.3	0.7
	Subtotal	4.8	21
Electricity	Coal	22	27
	Gas	0.8	1.1
	Oil	0.04	0.07
	Hydro	1.4	4.4
	Wind	4.2	10
	Solar	15	22
	Biomass and others	0.1	0.1
	Transmission lines	14	26
	Distribution lines	4.6	8.8
	Subtotal	62	100
Energy transport	Gas	4.1	11
	Coal	0.3	0.7
	Subtotal	4.3	12
	Total	**74**	**138**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

Required electricity investment under the High Renewables Scenario increases by USD 12 billion compared with the BAU low-cost estimate due to renewable energy investments in hydro, wind and solar and the required transmission infrastructure. However, the increased use of renewable sources reduces additional energy transport capacity requirements, mainly for the transportation of gas, and lowers investments by USD 0.55 billion.

Figure 4.11 ● Chile: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low cost estimate only.

Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

Enhancing energy security: More renewables to improve self-sufficiency

In the face of Chile's high fossil fuel import dependence, the High Renewables Scenario improves primary energy supply self-sufficiency to 40% (compared with 29% in the BAU and 35% in the Improved Efficiency Scenario) by 2040. Table 4.6 demonstrates Chile's high dependence on imported energy resources across all scenarios. It is for this reason that the CIFES was established to support sustainable development policies and projects financed by the government, and the government is also promoting investment in renewable energy, specifically other renewables, to increase the share of renewables to 45% of new electricity generation by 2025. The High Renewables Scenario results in 61% of total generation from renewables by 2025.

Chile has one of the more diverse fuel supply mixes in APEC. In 2013, primary energy supply diversity under the Herfindahl-Hirschman Index (HHI) was 0.28, and it improves to 0.26 by 2040 under the BAU, where a lower number indicates greater diversity. Though Chile has diverse fuel options, it lacks fossil fuel self-sufficiency due to low energy reserves.

Table 4.6 • Chile: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040					
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%
Primary energy supply diversity (HHI)	0.28	0.26	0.26	0.27	0.26	0.26	0.28
Primary energy supply self-sufficiency (%)	39	29	35	40	29	30	30
Coal self-sufficiency (%)	24	1	2	3	1	2	6
Oil self-sufficiency (%)	3	3	3	3	3	3	3
Gas self-sufficiency (%)	20	17	19	18	17	9	7
Electricity generation input fuel diversity (HHI)	0.28	0.39	0.31	0.30	0.40	0.27	0.31

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

Fuel diversification in electricity generation is expected to deteriorate from the low value of 0.28 in 2013 to 0.39 in 2040 under the BAU Scenario. This is due to coal replacing hydro in electricity capacity, growing from 23% in 2013 to nearly 34% by 2040 and leading to increased dependence on coal for electricity generation. Under the High Renewables Scenario, electricity generation diversification improves to 0.30 by 2040 in comparison with 0.39 under the BAU, offering the best trade-off of the Alternative Scenarios.

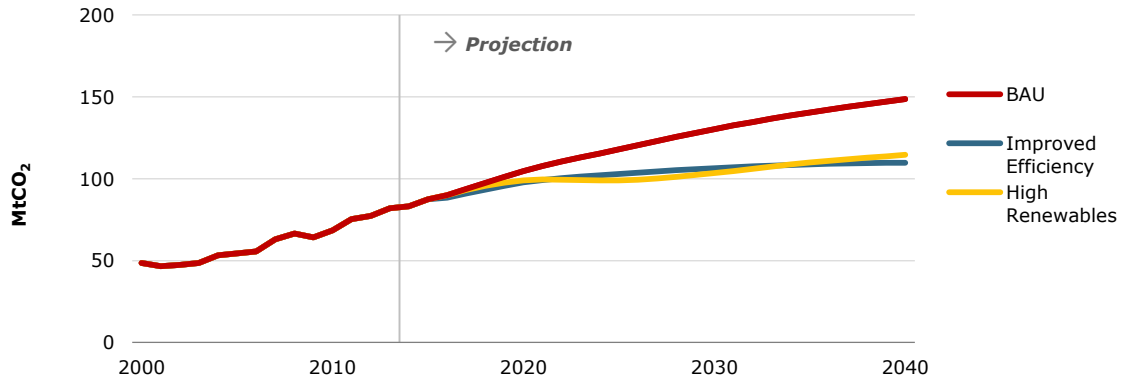
Climate change impacts and risks: Mitigation through energy efficiency

According to Environmental Ministry (MMA) vulnerability studies, climate change impacts include decreased precipitation (in some regions up to 75% less); temperature increases of up to 1.5%; and a decrease in the streamflow rate to 77% in some regions. The Biodiversity Climate Change Adaptation Plan, approved in 2014, contains 50 measures to reduce and mitigate the effects of climate change on biodiversity. The plan identifies hydroelectric resources, food production, urban and coastal infrastructure, and energy supply as the four areas most vulnerable to climate change, and in which adaptation is required.

The government's INDC is to reduce GHG emissions 30% by 2030, based on the 2007 level, and INDC options are established on intensity-based targets. The Ministry of Energy is responsible for developing energy efficiency policies and guidelines, and the Chilean Energy Efficiency Agency implements them. To reach the INDC and ensure the sustainability of Chile's energy future, the government is preparing the National Action Plan for Climate Change 2016-2021 to reduce the marginal cost of energy by 30%, to ensure 20% of the energy mix is renewable energy and to reduce energy consumption 20% by 2025.

Chile produces just 0.11% of the world's GHG emissions (CAIT, 2012). Under the BAU, energy-related CO_2 emissions are projected to nearly double from 82 $MtCO_2$ in 2013 to 149 $MtCO_2$ by 2040 (2.2% AAGR) (Figure 4.12). In the Improved Efficiency Scenario, energy-related CO_2 emissions decrease to 110 $MtCO_2$ in 2040, 26% below the BAU level. The High Renewables Scenario registers emissions of 115 $MtCO_2$, a savings of 23% over the BAU. Of the two scenarios, the Improved Efficiency Scenario shows the greatest reduction in the long term. Policies to increase renewable energy also achieve a reduction in CO_2 emissions, but do not curb the overall upward trend in emissions over the Outlook period. Policies combining renewables and energy efficiency ultimately have the greatest impact.

Figure 4.12 • Chile: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

RECOMMENDATIONS FOR POLICY ACTION

Developing and implementing programs to support the goals set out in the Energy Roadmap 2050 will be integral for Chile to address the challenges of improving energy efficiency, increasing renewables, promoting regional grid integration and mitigating energy security concerns.

Implementing stringent minimum energy performance standards across a wide range of appliances and equipment, as well as building codes, tougher vehicle fuel economy standards and programs to reduce energy use in industry will be needed to limit growth of energy consumption. Energy efficiency programs should include procedures for enforcement and monitoring of such standards and codes as well as regular review and tightening of these measures. The Improved Efficiency Scenario illustrates the energy security and CO_2 reduction benefits of reducing energy demand, and also lowers additional energy sector investment needs.

While Chile is lacking in fossil energy resources, it has abundant renewable energy potential, especially in significant solar energy resources well-suited to early deployment of concentrating solar power (CSP). Expanding CSP in the SING could help reduce both energy imports and CO_2 emissions. Chile has ambitious renewable energy goals which will require further policy support if they are to be achieved.

Investments in the grid as well as additional flexibility options such as energy storage and demand-side management will be needed to facilitate a higher share of variable renewables.

Greater regional integration with neighbouring economies could also help develop energy exchange, improve energy security, reduce energy costs and facilitate the integration of higher shares of variable renewables. This includes Chile's potential to export solar to neighbouring economies.

5. CHINA

KEY FINDINGS

- **China's energy demand increases along with economic growth under the BAU Scenario, but energy consumption per capita in 2040 remains slightly below the APEC average.** TPES grows 1.7% annually, mainly in the transport and buildings sectors.

- **In the Improved Efficiency Scenario, energy demand peaks in China by 2029, six years earlier than in the BAU.** Estimated energy savings reach 322 Mtoe in 2035 and 396 Mtoe by 2040, 14% lower than the BAU levels. Lower energy demand also helps energy-related CO_2 emissions peak earlier (in 2025) leading to a 22% reduction in 2040 emissions and highlighting the importance of energy efficiency in reaching climate objectives.

- **Rapid renewables deployment in the BAU leads to a cleaner power mix in China over the Outlook period.** By 2040, China's installed renewable energy capacity reaches 1 250 GW, triple the current levels, making China the leader in renewables development in APEC. Under the High Renewables Scenario, the share of renewable electricity generation reaches 36% by 2040, compared with 27% in the BAU.

- **To reach the INDC target for CO_2 peaking and non-fossil fuel use, substantial efforts are needed to improve energy efficiency and decarbonise energy supply.** Priority should be placed on decarbonising the power sector through greater deployment of cleaner fossil generation, renewables and nuclear power.

ECONOMY AND ENERGY OVERVIEW

With a population of 1.4 billion in 2013 and a land area of 9.6 million square kilometers (km^2), China is the largest emerging economy in the Asia-Pacific Economic Cooperation (APEC). After reforming and opening up its economy in 1978, China entered a period of rapid growth. In the decade between 2000 and 2010, the economy expanded 2.7 times as measured by gross domestic product (GDP, calculated as 2012 USD in purchasing power parity or PPP) (Table 5.1). The GDP per capita in 2013, however, was USD 9 722 (2012 USD PPP) compared with the average of USD 17 047 (2012 USD PPP) across APEC. In short, China still has a long way to go to develop its economy, reduce poverty and increase living standards.

The share of different sectors in GDP evolved somewhat differently between 2000 and 2013, with a noticeable slowdown in primary (15% in 2000/9% in 2013), a slight dip in secondary (45%/44%) and strong expansion in tertiary (40%/47%) (NBS, 2015). The tertiary sector gradually came to dominate economic development, reflecting China's efforts to move away from its traditional role as the 'world's workshop' and become the 'world's intellectual and creative centre'. Urbanisation reached 53% in 2013 (up from only 36% in 2010), which also contributed to the increase of the tertiary sector share.

China is rich in energy resources, including fossil fuels and renewables.[1] The reserves per capita, however, are relatively low, with coal at 84 tonnes (68% of world average), oil at 13 barrels (bbl) (5.6%) and gas at 2 569 cubic meters (m^3; 9.9%). An additional challenge is that China is energy resource-rich in the western regions, while population and energy demand are concentrated in the central and eastern regions.

China has become a global leader in renewable energy; in 2013, it installed more renewable capacity than all of Europe and the rest of the Asia-Pacific region combined (IRENA, 2014). Energy intensity in China has declined faster than the APEC average over the period 2000 to 2013 (Figure 5.1), while carbon dioxide (CO_2) emissions per unit of GDP in 2014 are 34% lower than 2005 levels (UNFCCC, 2015).

Table 5.1 • China: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	1 449	3 867	10 441	13 246	21 786	35 126	48 184
Population (million)	1 155	1 270	1 341	1 363	1 388	1 393	1 361
GDP per capita (2012 USD PPP)	1 255	3 045	7 786	9 722	15 698	25 215	35 406
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	871	1 161	2 469	3 009	3 974	4 553	4 693
TPES per capita (toe)	0.8	0.9	1.8	2.2	2.9	3.3	3.4
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	664	815	1 526	1 943	2 571	2 859	2 875
Final energy intensity per GDP (toe per 2012 USD million PPP)	458	211	146	147	118	81	60
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	2 184	3 259	7 095	8 977	11 171	12 238	12 016
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	94	98	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

Looking into the future, China has set its stragetic goal to build a moderately properous society (in an all-around way) by 2020. Key actions towards this goal include transforming the economic development pattern, promoting an ecological civilisation, and establishing within its policy orientation a development path that is green, low-carbon and energy efficient, and also has recycling as a core principle. APERC projections show that, with continuous efforts in energy structure optimisation as well as energy efficiency improvement and conservation, by 2040 China could reduce total final energy demand by around 60 tonnes of oil equivalent (toe) per unit of GDP (2012 USD million PPP).

ENERGY RESOURCES

China is rich in energy resources, particularly coal. According to recent estimates, China had recoverable coal reserves of around 114 500 million tonnes (Mt), proven oil reserves of 18 billion bbl and proven natural gas reserves of 3.5 trillion cubic meters (tcm) at the end of 2013 (Table 5.2). The lifespan of proven reserves varies, with coal expected to last for 30 years, oil around 12 years and gas as much as 25 years. A huge potential in unconventional resources, particularly shale gas, may help to prolong China's fossil fuel reserves.

Table 5.2 ● China: Energy reserves and production, 2014

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Coal (Mt)[a]	114 500	30	13	3rd	3rd
Oil (billion bbl)[a]	18	12	1.1	14th	4th
Gas (tcm)[a]	3.5	26	1.8	13th	4th
Uranium (kt U)[b]	120	83	3.2	10th	5th

Notes: [a]Total proven coal/oil/gas reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions. [b]Uranium reserves are 'reasonably assured resources' (RAR); reference year for uranium reserves and production is 2013.

Sources: For oil, coal and gas, BP (2015); for uranium, NEA (2014) and WNA (2015).

China also has a large technical potential of renewable energy resources, the quality of which is on par with the average level in APEC. Considering the wind speed, for example, average capacity factors of wind power place China in 9th ranking in the APEC region; the overall quality is undermined by the fact that some resources are located in remote areas.

ENERGY POLICY CONTEXT

China recognises that energy underpins modernisation. Thus, the economy is optimising its economic development pattern, while also establishing basic state policy for resource conservation and environmental protection. To balance economic and environmental aims, China is focusing on securing its energy supply, transforming energy development and optimising the energy infrastructure. It also aims to put in place the necessary management and regulatory mechanisms and systems, improve energy efficiency, promote clean energy development and effectively mitigate greenhouse gas (GHG) emissions.

In January 2013, the government issued the 12th Five-Year Plan (2011-2015) for Energy. With domestic energy supply expected to reach 3 660 tonnes of coal equivalent (tce) in 2015 while installed generation capacity reaches 1 490 gigawatts (GW), the plan has three main aims in conventional energy sources: to develop coal mines safely and efficiently, building large-scale coal bases and retiring outdated production capacity; to accelerate development of conventional oil and gas; and to boost efforts in unconventional oil and gas. The plan also aims to actively expand hydro power, develop nuclear power safely and efficiently, and accelerate renewable energy development. In the area of energy transformation, the plan calls for cleaner and more efficient coal-fired generation along with promoting coal washing and demonstrating deep processing and upgrading. In parallel, it promotes intensive development of the oil processing industry and orderly development of gas power. To support energy conservation, the plan will

determine a total energy consumption target, optimise the structure and locations of industry, roll out a comprehensive campaign to push energy conservation and efficiency, and enhance energy management systems (SCC, 2013).

Controlling air pollution is an urgent—and Herculean—task in China. In September 2013, the State Council issued the Action Plan on Prevention and Control of Air Pollution, which will serve as the guide for efforts to prevent and control air pollution. The plan defines ten measures, including: developing 'new energy vehicles'[2]; upgrading the quality of fuel oil; adjusting and optimising the industrial structure; accelerating the pace of transforming the energy structure; increasing the supply of clean energy; controlling total coal consumption, etc. The State Council signed target responsibility letters with all provincial governments and will conduct annual evaluations.

In November 2014, China and the United States issued a joint announcement on climate change, with both presidents outlining their respective post-2020 actions. China intends to achieve peak CO_2 emissions around 2030 (and to make best efforts to peak earlier) and to increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030. President Xi Jinping and President Barack Obama committed to working together, and with other economies and countries, to adopt a protocol, another legal instrument or an agreed outcome with legal force under the United Nations Framework Convention on Climate Change (UNFCCC), applicable to all Parties, in the context of the Paris Conference in 2015 (SCC, 2014c). In June 2015, China submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC, which demonstrates its efforts to tackle climate change. In addition to the overall CO_2 emission reduction and non-fossil fuel targets, China also determined to reduce CO_2 emissions per unit of GDP by 60% to 65% from 2005 levels (UNFCCC, 2015).

The 12th Five-Year Plan came to an end in 2015. In advance, the 18th Communist Party of China (CPC) Central Committee held its fifth plenary session, and unveiled a proposal for formulating the 13th Five-Year Plan. The proposal called for a system to control consumption of energy, water and construction land. It promised an 'energy revolution' with clean, safe resources (wind, solar, biomass, water, geothermal and nuclear) replacing fossil fuels, in parallel with exploring deposits of natural, shale and coal-bed methane. Energy-intense industries, such as power, steel, chemicals and building materials will be subject to CO_2 emission control regulations.

BUSINESS-AS-USUAL SCENARIO

This section illustrates energy demand and supply in the Business-as-Usual (BAU) Scenario and summarises the key assumptions from existing government policies (Table 5.3). The definition of the BAU Scenario and the modelling assumptions used in this Outlook are different from those used by the government for its projections.

[2] New energy vehicles are defined as vehicles utilising advanced technologies and new structures, which use unconventional vehicle fuel as the power source.

Table 5.3 • China: Key assumptions and policy drivers under the BAU Scenario

Buildings and industry	• Promote green buildings standard, to be executed first in government and large-scale public buildings. • Continually optimise industrial structures, with iron and steel, cement, and chemicals being key sectors.
Transport	• Develop further public transport such as intercity rail, high-speed railways, subways and light railways. • Manage the saturation level for vehicles at 320 cars per 1 000 inhabitants, reaching saturation by 2040. • Enforce continually stricter fuel economy standards for vehicles and phase out low-efficiency vehicles. • Promote the use of advanced vehicles.
Energy supply mix	• Increase shares of renewable energy and nuclear energy. • Increase share of gas in line with the growth of domestic supply and import availability. • Boost diversity of primary energy supply with renewables and nuclear displacing coal.
Power mix	• Promote non-fossil fuel generation; scale up wind and solar power; promote hydro power; develop nuclear in a safe manner. • Expand gas generation and substitute some coal generation; retire existing oil generators and avoid building new ones.
Renewables	• 2020 targets for wind (200 GW) and solar (100 GW).
Energy security	• Expand oil and gas imports to satisfy domestic demand.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

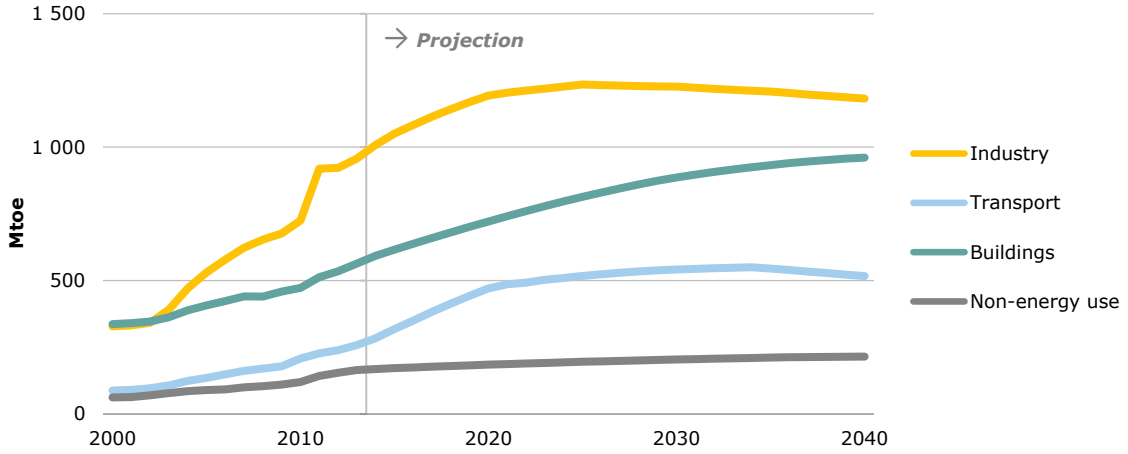
RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

In 2013, final energy demand in China was 1 943 million tonnes of oil equivalent (Mtoe). Under the BAU Scenario, it increases at an average annual growth rate (AAGR) of 1.5% to reach 2 875 Mtoe by 2040, in line with relatively rapid social and economic growth. Following a curve of rapid industrialisation and urbanisation, China's final energy demand per capita would be 8% below the APEC average by 2040, a dramatic change from being 24% below in 2013.

A series of actions enabled China to reduce its energy intensity by 23% over the period 2005 to 2013, three of which warrant special mention. A mandatory standard system of quotas for energy per unit of product was introduced in key industries (e.g. iron and steel, petrochemicals, non-ferrous metals and building materials), which helped phase out outdated facilities. Key energy-saving projects for combined heat and power were undertaken, along with construction of enterprise energy control centres. Energy service companies (ESCOs) were established and encouraged to provide total energy solutions for industrial energy users. Taking these actions forward under the BAU, energy intensity in China drops a total of 63% from 2005 to 2035, far exceeding the APEC-wide goal of a 45% reduction by 2035 (compared with 2005 levels).

Under the BAU, by 2040 the bulk of China's energy consumption will be in industry (41%), followed by buildings (33%), domestic transport (18%), and non-energy use (7.5%) (Figure 5.1). Energy consumption in industry and domestic transport over the Outlook period initially shows a growth trend but drops before 2030 as economic development continues in a context of continuous structure optimisation and efficiency improvement. Buildings show a relatively rapid energy demand growth throughout the Outlook period, mainly reflecting higher electricity and gas consumption as incomes rise and urbanisation expands. Non-energy use remains roughly the same, as demand itself is relatively stable.

Figure 5.1 ● China: Final energy demand by sector, 2000-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

In terms of supply, APERC analysis shows that by 2040 the two dominant sources are electricity (30%) and oil (23%); the former mainly satisfying the needs of residential and commercial consumers and the latter supplying expanding light-duty vehicle (LDV) and heavy-duty vehicle (HDV) fleets.

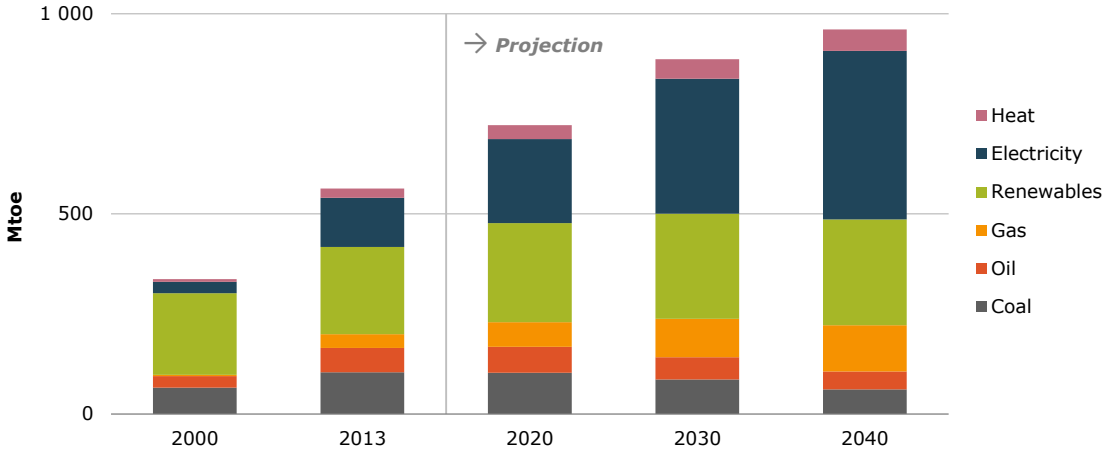
Buildings energy use: Electricity demand grows, but coal use declines

In 2013, China's per-capita energy consumption in the buildings sector was 0.41 toe, substantially lower than the APEC average of 0.59 toe, largely because consumption at the household level is still low compared with more developed economies. Over the Outlook period, the trend typically seen in more developed economies is anticipated as higher income levels drive up energy consumption, for example with fewer inhabitants living in larger homes and greater overall access to energy services.

Anticipating this trend, the government is promoting energy saving in buildings. Government buildings and large-scale public buildings, for example, are required to execute the green buildings standard. China plans an increase of 300 million m^2 in new green buildings and renovation of 300 million m^2 in the northern regions by 2015 (SCC, 2014b). In addition, energy labelling schemes implemented in 2005 promote the adoption of energy efficient products, currently covering 28 product categories and more than 570 000 product models.

Under the BAU Scenario, the buildings sector consumes an estimated 961 Mtoe annually by 2040, representing an AAGR of 2% (Figure 5.2). Electricity consumption would more than double (from 22% in 2013) to comprise a 44% share in 2040. Average energy consumption per capita in the sector reaches 0.71 toe, almost equal to the APEC average of 0.73 toe.

Figure 5.2 ● China: Buildings sector final energy demand, 2000-40

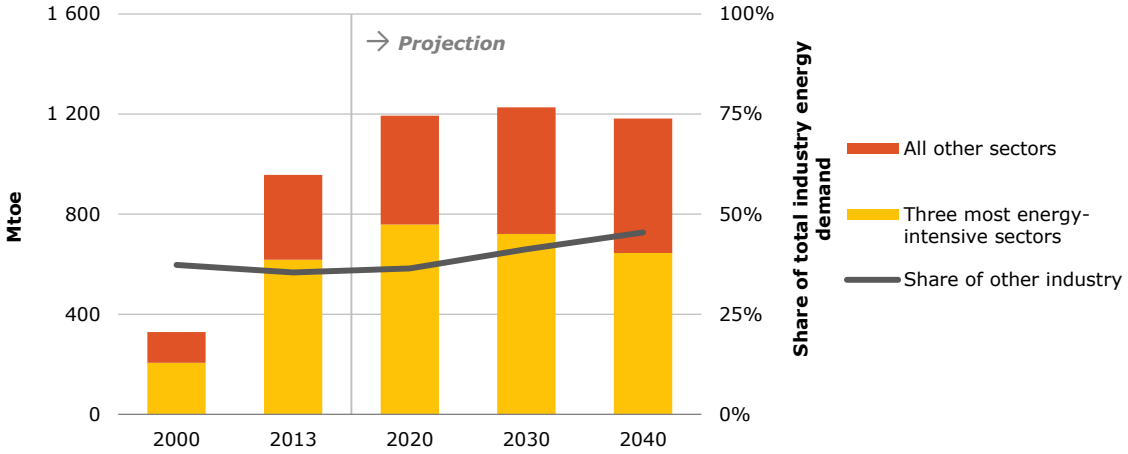


Sources: APERC analysis and IEA (2015a).

Industry energy use: Consumption peaks around 2030 as less energy-intensive sub-sectors gain share

Industry is the largest energy user in China. To develop a circular economy and promote energy efficiency in this sector, China continues to optimise the traditional industrial structure. In the iron and steel sector, a series of policies have been implemented: total production capacity is controlled and outdated production capacity is being phased out; products are upgraded and heat resources produced in the industrial processes are comprehensively re-utilised. The cement sector now uses fly ash produced in coal power plants and industry residues to replace clinker (an energy- and CO_2-intensive product). In the chemical and petrochemicals sector, a series of production processes and feedstock shave been optimised. The combination of supportive government policies and access to capital from different sources (government, local enterprises and foreign investors) have encouraged energy efficiency improvements in industry (NDRC, 2014). The BAU projections show that the rate of growth of industrial energy consumption will slow from 2013 to 2030 compared with rapid growth seen from 2000 to 2010 (Figure 5.3). In fact, consumption would peak at 1 235 Mtoe in 2025 and decline thereafter.

Figure 5.3 ● China: Industry sector final energy demand, 2000-40



Note: The three largest energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.

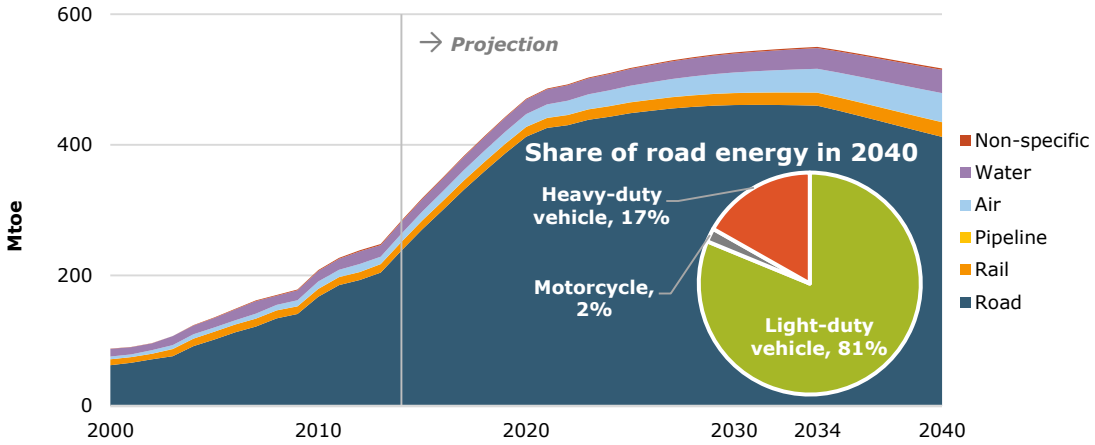
Sources: APERC analysis and IEA (2015a).

China's industry structure is expected to gradually migrate from the most energy-intensive sectors to less intensive manufacturing. APERC forecasts that shares of the three most energy intensive sub-sectors in the APEC region (i.e. iron and steel, chemical and petrochemicals, and non-metallic minerals) gradually decline as the share of other, high value-added industry (such as machinery manufacturing) rises from 35% in 2013 to 45% by 2040.

Transport energy use: Vehicle ownership quadruples, but more public transport curbs energy demand to double level

China's transport energy consumption is projected to rise rapidly, peaking around 2034 at 550 Mtoe, and then decline (Figure 5.4). In terms of structure, road transportation will continue to dominate energy consumption in the transport sector, even though shares of shipping and air transportation increase.

Figure 5.4 • China: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

In 2013, vehicle ownership in China was 90 vehicles per 1 000 inhabitants, about one-ninth that of the United States (812:1 000) and about one-third the APEC average (237:1 000). Vehicle ownership (and associated fuel consumption) expands exponentially over the Outlook period; even a projected rise to a ratio of 313:1 000 would add about 306 million units to the vehicle stock by 2040 (with most being added before 2030). Currently, the fuel consumption of vehicles manufactured in China is 6.9 litres per 100 km (L/100 km); implementation of tougher fuel economy policies could reduce the figure to below 5 L/100 km by 2020 (slightly above developed economies). Measures shown to be effective include: fuel economy standards for LDVs and HDVs with new models required to meet these standard before entering the market; demonstration of new energy or energy-saving models in public sector vehicle fleets; and financial incentives to encourage private consumers to purchase more efficient vehicles (SCC, 2012b).

To stem energy demand in transport, the government is committed to improving public transport by developing intercity rail and encouraging green commuting. By 2020, it aims to have public transport account for 30% of total motorised transportation in large and medium cities (UNFCCC, 2015). Integration is a key element, with intercity railway systems being built so that passengers can choose trains to travel among medium or large cities and also connect to urban transport systems (e.g. subways and light railways) within large cities. High-speed railway systems will also be expanded quickly. Economy standards for vehicles continually become more stringent and old vehicles are retired.

In order to improve energy efficiency and reduce CO_2 emissions, China is fostering advanced vehicle adoption. In June 2012, the State Council of China published a plan to develop domestic transport energy savings and the advanced vehicle industry. China also set an ambitious target to have 5 million electric vehicles (EVs) and fuel cell electric vehicles (FCEVs) by 2020 (SCC, 2012b). China has rolled out a set of measures to promote the use of advanced vehicles, including tax exemptions, subsidies for car purchases

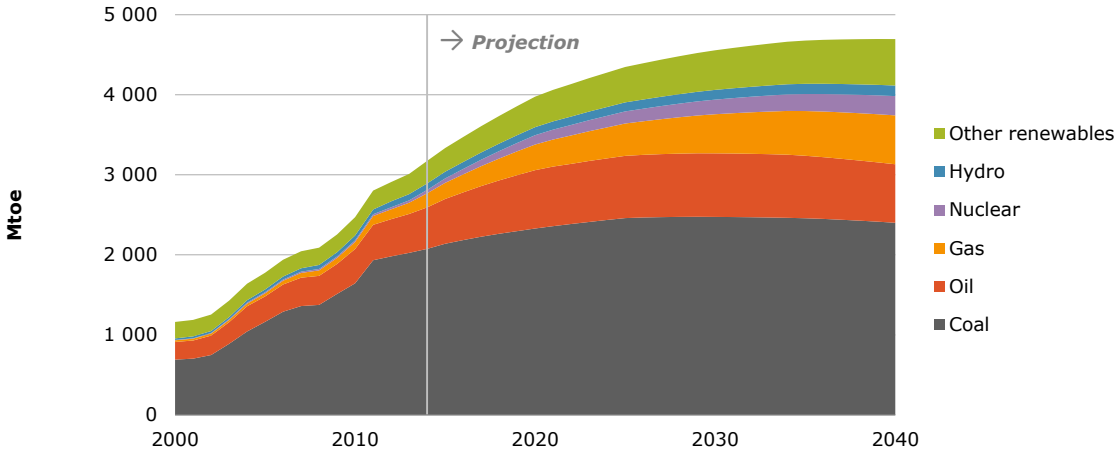
and requirements for the government car fleet to constitute more advanced vehicles. Collectively, these efforts could offset the increased energy consumption, especially fossil fuel use, in transport.

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Non-fossil fuel and gas gain shares, oil remains steady while coal declines

China's TPES under the BAU increases at an AAGR of 1.7% to reach 4 695 Mtoe by 2040 (Figure 5.5). Coal remains the dominant source, but its share drops from 67% in 2013 to 51% by 2040, for several reasons. Two major sub-sectors, iron and steel, and non-metallic minerals, reduce coal consumption as industry switches to higher value-added products. In parallel, direct coal consumption in the buildings (both residential and commercial) and agriculture sector also declines significantly as coal is replaced by gas and electricity. APERC analysis shows the share of gas increasing rapidly, from 4.7% to 13% over the Outlook period. As policy drives wider adoption of renewables, the shares of hydro and other renewables in TPES also increase. Nuclear power could also grow to meet electricity demand, potentially accounting for 5.1% of TPES by 2040.

Figure 5.5 ● China: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

Energy production: Coal and oil production steady, non-fossil fuel and gas grow sharply

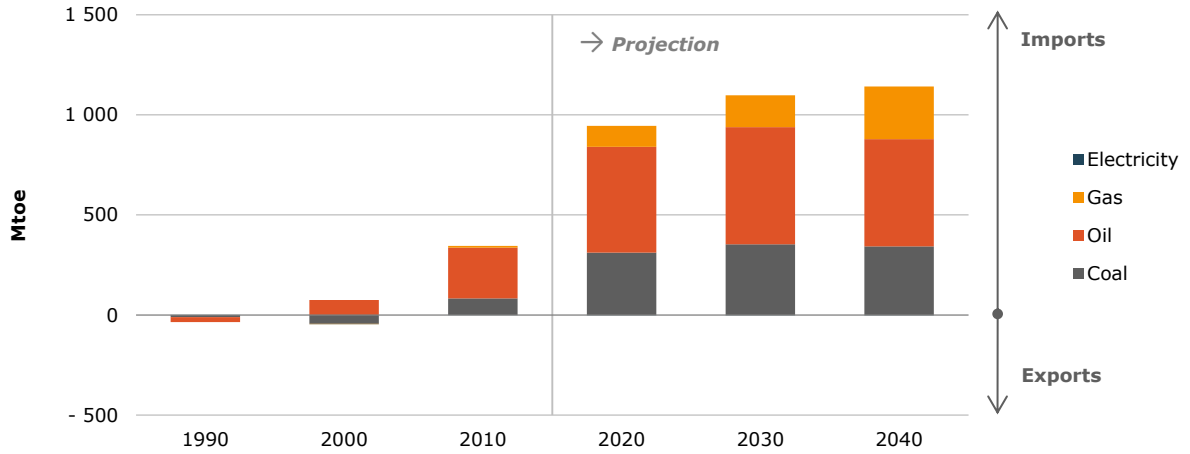
By 2040 under the BAU, China's primary energy production reaches over 3 613 Mtoe, reflecting an AAGR of 1.3%. The economy is already vigorously promoting development of renewable energy production: in 2013, it ranked first in the world for wind and hydro generation capacity, for the collector area of solar water heaters and for the number of biogas users (NDRC, 2014). By 2040, APERC projects China will add 594 Mtoe of non-fossil fuels to its TPES, accounting for 80% of non-fossil fuel growth across APEC.

China's annual coal production is around 2 050 Mtoe, while oil is much lower at 250 Mtoe. Effort is underway to increase production of natural gas, especially unconventional gas and coal-bed methane (CBM). At the end of 2011, the government declared shale gas an 'independent' mineral resource, in order to detach it from the administrative procedures for conventional natural gas production and to nurture participation of private capital in shale projects. The government also announced adjustments to the Guidance Catalogue of Foreign Investment and Industry to categorise foreign participation in shale gas projects as an 'encouraged' investment, which means that such projects are entitled to preferential administrative and fiscal measures. Rights to access shale gas resources for exploration purposes have been granted through two dedicated bidding rounds (June 2011 and October 2012). By the end of 2014, China had issued 52 exploration rights, covering an exploration area is 164 000 km^2. At time of writing, 374 wells have completed drilling, and the 2D seismic area has reached 20 000 km^2. APERC forecasts that natural gas production will reach 347 Mtoe by 2040, resulting in a gradual increase of the gas share of total energy production (APERC, 2015; UGF, 2015).

Energy trade: Fossil fuel imports account for 20% of energy supply with oil the major requirement

China is promoting international cooperation in energy for mutual benefit. In the early 1990s, China was a net energy exporter; by the 2000s, oil imports exceeded the volume of coal exported, making the economy a net importer. Subsequently, China began to import all fossil fuels to meet domestic energy demand. Under the BAU, net energy imports continue to grow over the Outlook period (Figure 5.6). By 2040, China imports 1 142 Mtoe of fossil fuels—about 24% of TPES—though the level of import dependence varies for each fuel. Oil imports double between 2010 and 2020, which may influence global oil markets. As for coal, which China began to import in 2010, imports peak around 2025, then decline sharply from 2030 to 2040 due to rapid uptake of renewables and nuclear, and the switch away from coal-fired power plants. Gas imports grow steadily as it is used to replace coal to reduce environmental impacts and accelerate green growth.

Figure 5.6 ● China: Net energy imports and exports, 1990-2040



Sources: APERC analysis and IEA (2015a).

Energy imports come mainly from five regions: Russia and Central Asia, the Middle East, Africa, America and Asia-Pacific. The Silk Road economic zone (Bangladesh–China–India–Myanmar) and the China–Pakistan economic corridor are to be further developed as key importing channels (SCC, 2014a). On 21 May 2014, Chinese and Russian authorities signed an agreement to transport natural gas from Russia to China through the East pipeline, and also a trading contract for natural gas between China Natural Petroleum Corporation (CNPC) and Gazprom. The contract sets 2018 as the target for putting the pipeline into operation, with a final capacity of 28 billion cubic metres (bcm) per year (NEAC, 2014).

Power sector trends: Growth of renewables leads to near tripling of installed capacity

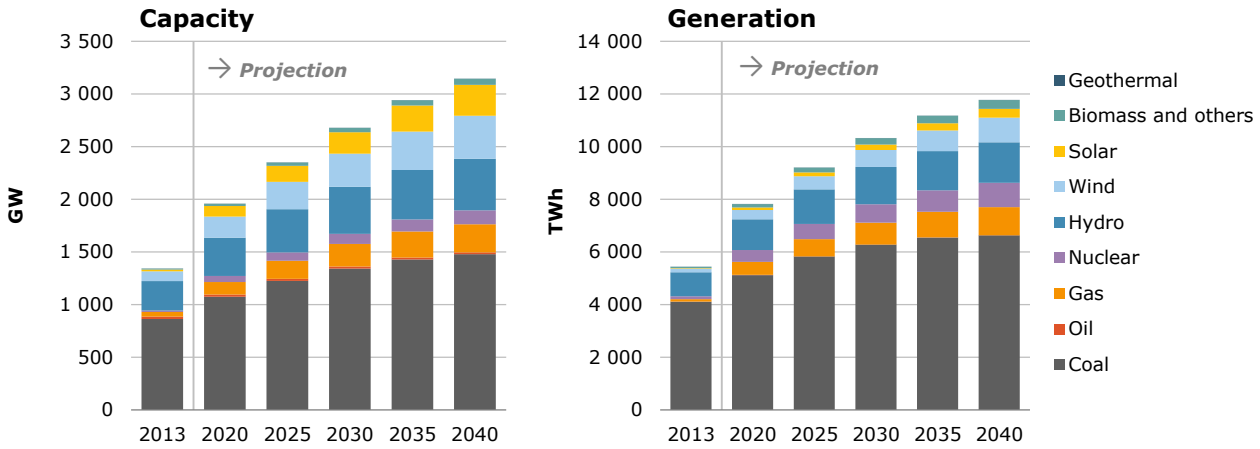
APERC projections show a rapid increase in electricity demand in China, with per-capita demand rising from 3.1 megawatt-hours (MWh) in 2013 to 5.7 MWh by 2040, and total demand rising from 5 437 terawatt-hours (TWh) to 11 775 TWh. Spurred by this rapid growth, China is taking the opportunity to optimise the power sector structure. In the fossil fuel power sub-sector, leading up to 2012 some 80 GW of small-scale thermal generators were replaced by much more efficient plants, leading to savings of more than 60 Mt of coal every year (SCC, 2012a). Additional gas-fired capacity has been added and the fleet will be expanded further.

In the deployment of clean power technologies, China faces economic pressures similar to those in other economies. The levelised cost of electricity (LCOE) for wind and solar power is still higher than for coal and gas. In addition, large-scale grid upgrading is necessary to connect renewables from remote areas. In an effort to move towards low-carbon and sustainable development, China invested nearly USD 90 billion in clean energy in 2014, exceeding the total amount of all other economies in Asia

(Bloomberg, 2015). By 2014, China had put into operation 23 GW of wind and 10.6 GW of solar photovoltaic (PV) (Ren21, 2015).

By 2040, China's total installed capacity is estimated to reach 3 145 GW, with coal generation capacity accounting for 47% (Figure 5.7). Two main drivers will stimulate the shift away from coal-fired plants: environmental concern and the declining cost of renewable power. Over the Outlook period, the projected 970 GW of new non-fossil fuel capacity in China will make up 74% of total new non-fossil fuel capacity across the APEC region. Clearly, China plays an important role in determining the APEC energy mix; its continued leadership in the development and deployment of renewables is vital. China's electricity fuel mix becomes more diversified under the BAU, a significant shift from 2013 when coal held a 76% share. The anticipated newly installed clean energy capacities will contribute 2 841 TWh in 2040, potentially replacing about 596 Mtoe of coal or 559 bcm of natural gas for power generation.

Figure 5.7 • China: Power capacity and generation by fuel, 2013-40



Note: Pumped storage is included in hydro.
Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

The Improved Efficiency, High Renewables and Alternative Power Mix Scenarios all apply to China, including the four cases making up the Alternative Power Mix Scenario.[3]

China faces diverse choices for its energy future. The Alternative Power Mix Scenario demonstrates that fossil fuel generation could remain a mainstay if a shift were prompted towards cleaner, high-efficiency coal technologies and more gas generators. Alternatively, renewable generators or nuclear generators could replace fossil fuel generators and still keep pace with growing electricity demand.

The Improved Efficiency Scenario contributes most in terms of reducing CO_2 emissions and increasing oil and gas self-sufficiency while the High Renewables and Alternative Power Mix Scenarios are valuable for primary energy diversification. Ultimately, a combination of these scenarios may be a good choice.

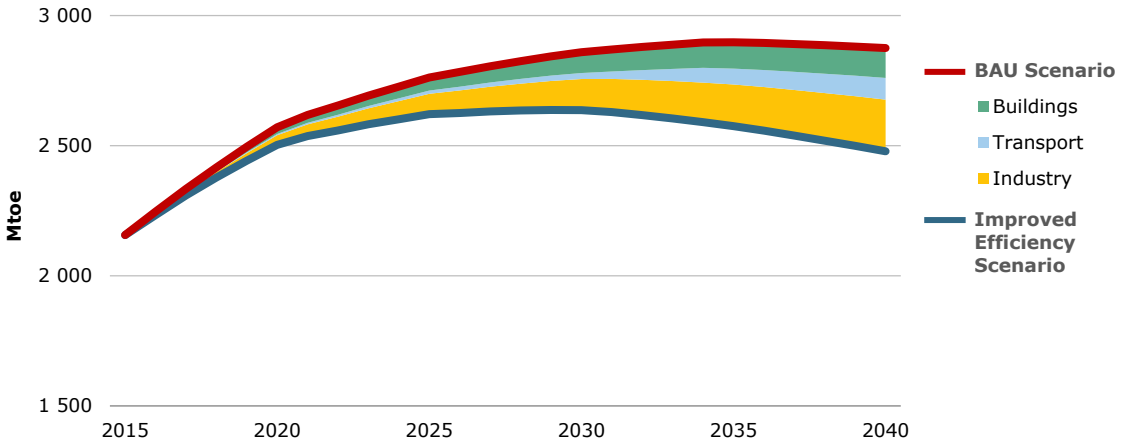
IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

The Improved Efficiency Scenario models the APEC energy intensity goal. Under the Improved Efficiency Scenario[4] China is projected to realise energy savings of 322 Mtoe by 2035 and 396 Mtoe by 2040, compared with the BAU (Figure 5.8). Industry has the largest potential, around 50% of total energy savings by 2040, as all sub-sectors contribute through improvements in energy efficiency and higher

[3] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.
[4] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

rates of electrification. Transport contributes 21%, mainly through more fuel-efficient HDVs and LDVs, as well as through more efficient urban planning to reduce demand for vehicles even as the urbanisation process advances rapidly. Buildings (residential and commercial) contribute 29% of total energy savings, mainly through more stringent efficiency targets and appropriate labelling schemes for electric appliances. Together, such measures also contribute to China reaching peak energy-related CO_2 emissions around 2025.

Figure 5.8 ● China: Potential energy savings in the Improved Efficiency Scenario, 2015-40

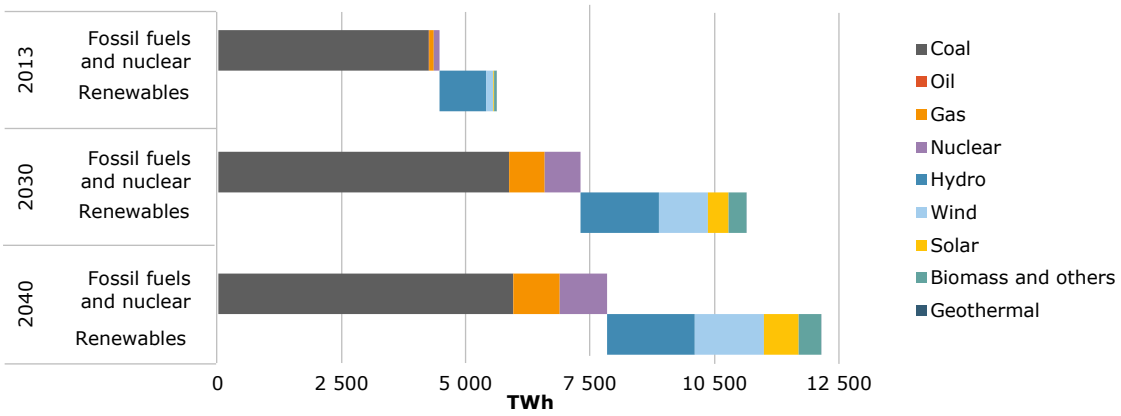


Source: APERC analysis.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

In 2014, APEC Leaders agreed to an aspirational goal of 'doubling the share of renewables in the APEC energy mix, including in power generation, from 2010 levels by 2030'.[5] China is an important and active participant in achieving this APEC target. Under the High Renewables Scenario, APERC projects China will contribute about 46% of APEC total renewable power generation by 2030. Total renewables generation reaches 3 241 TWh in 2030 (31% of generation) and 4 183 TWh by 2040 (36% of generation) (Figure 5.9). The highest growth rates are in solar (which more than doubles from the BAU level) and wind (increase of 45%).

Figure 5.9 ● China: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

Substantial energy research and development (R&D) underpins China's current leadership in renewable energy. In 2012, China's R&D intensity (i.e. R&D funding as a proportion of GDP) was 2%, matching that

[5] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

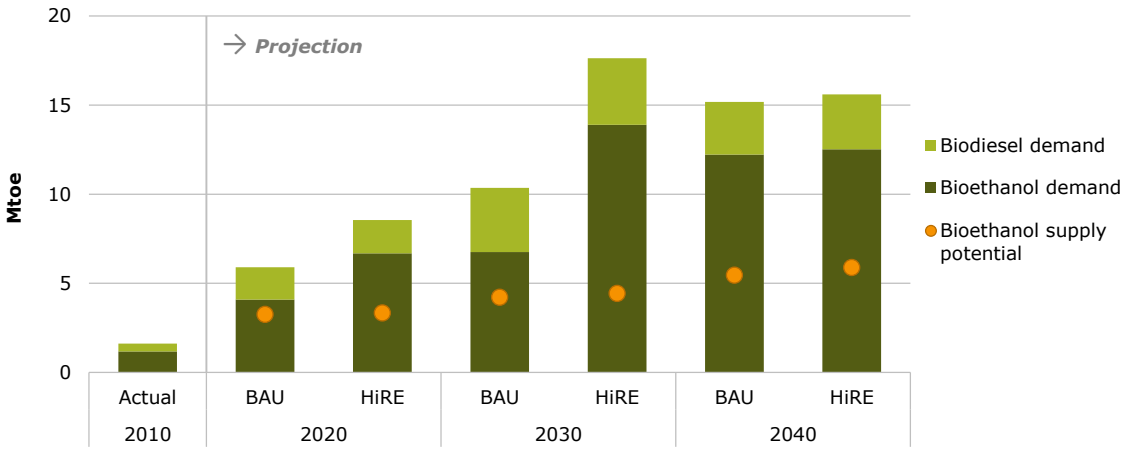
of the European Union (EU) for the first time. The rate increased to 2.1% in 2013 for total funding of USD 192 billion. Notably, private enterprises account for 77% of total R&D spending. China also shows rapid growth in patent applications across energy technologies, especially in wind and solar power, heating, insulation, and transmission and distribution (T&D). Many challenges still need to be addressed to achieve the ambitious goal of doubling the share of renewables, including grid extensions to support new renewable energy capacity and the development of suitable business models to support investments.

Box 5.1 • China: Pathway to realising rapid wind and solar power developement

Several factors underpin China's impressive scaling up of wind and solar power. First, public support and government determination to improve the quality of the environment provide stable supporting policies. This reassures investors that the drive for renewables will be continually maintained. Second, a portion of investment capital is directed towards research on how to manufacture state-of-the-art technologies at competitive prices. Third, a feed-in-tariff system supports quick and large-scale deployment. Finally, the rapid increase of electricity demand creates the need to deploy wind and solar power generators.

Under the High Renewables Scenario, biofuels demand in China increases at an AAGR of 8.5% over the Outlook period, to 15 Mtoe in 2040 (Figure 5.10). Government policy to increase the blend rates for bioethanol (20%) and biodiesel (30%) could lead to a bioethanol supply potential of 4.4 Mtoe in 2030 and 5.9 Mtoe in 2040. China's policy, it should be noted, is to prioritise food supply over bioethanol production, in part reflecting a lack of arable land for growing bioethanol feedstock. As China has no potential to produce biodiesel, its use will increase only modestly.

Figure 5.10 • China: Biofuels demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production; Supply potential is shown for the projection period only; HiRE = High Renewables Scenario.

Sources: APERC analysis, Ren21 (2014), IRENA (2014), FAO (2014) and IEA (2015a).

ALTERNATIVE POWER MIX SCENARIO

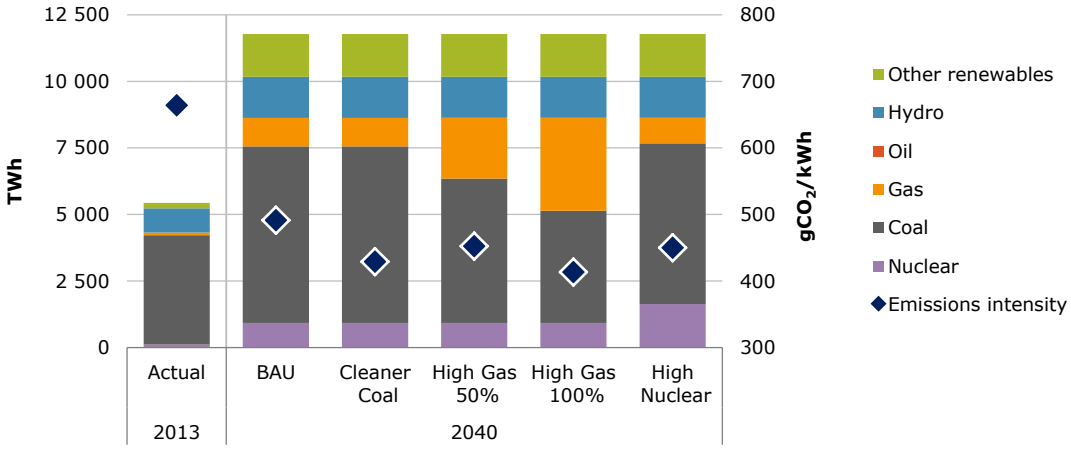
All four Alternative Power Mix Scenario cases—the Cleaner Coal, the High Gas 50%, the High Gas 100% and the Nuclear Case— apply to China.

The Alternative Power Mix Scenario shows diverse possible paths for China. Under the Cleaner Coal Case, which demonstrates increased use of technologies such as advanced ultra-supercritical (A-USC) or integrated gasification combined cycle (IGCC) with carbon capture and storage (CCS), coal consumption declines by 44 Mtoe, with a reduction of 0.73 gigatonnes (Gt) of CO_2 emissions. Considerable uncertainty remains, however, as to the economic feasibility of CCS and issues regarding storage and use of CO_2

must be resolved; without CCS, the potential for China to reduce emissions while continuing to use coal is very limited.

Under the High Gas 50% Case assumptions, in which gas-fired power plants replace the coal-fired additions projected under the BAU, a 50% replacement would mean newly installed gas generators produce 1 215 TWh more electricity than in the BAU (Figure 5.11). Under the High Gas 100% Case, all new coal capacity is replaced with gas and produces an extra 2 425 TWh of gas generation. The coal-to-gas replacement strategy would lead to additional gas demand of 239 bcm (High Gas 50% Case) or 477 bcm (High Gas 100% Case). Since gas generators are more efficient and have lower energy-related CO_2 emissions, this scenario allows China to reduce its emission intensity to 452 grammes of CO_2 kWh (gCO_2/kWh) (High Gas 50% Case) or 413 gCO_2/kWh (High Gas 100% Case) by 2040. A shift to higher levels of gas in power generation has energy security impacts, however, as it is uncertain whether this gas would be sourced from imports or domestic sources. Development of unconventional gas resources would likely be needed to pursue a significant shift to gas-fired capacity, but this also remains uncertain. Thus, the availability of gas—either domestic or imported—at competitive prices is an overarching challenge for the potential of the High Gas Cases.

Figure 5.11 ● China: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

Under the High Nuclear Case, nuclear power produces 1 634 TWh by 2040, an increase of about 700 TWh compared with the BAU, while the CO_2 emission intensity is reduced to 450 gCO_2/kWh. Nuclear power also has a lower cost, making it an attractive option for China. China has more than 30 years of experience in nuclear research, design, manufacture, construction and operations, including mastering the imported M310 technology and absorbing the advanced Generation III technology (AP1000, EPR and AES-2006). It also applied learning from Japan's Fukushima nuclear accident to develop Generation III technology for ACP1000 and ACPR1000 with completely independent intellectual property rights, merging these two technologies into 'HualongOne' (Kang Xiao-wen, 2014). The High Nuclear Case helps to diversify China's power mix at a competitive power cost while enabling the economy to become a leading manufacturer—all of which make nuclear an attractive option. This case depends on adding many nuclear generators, however, which implies substantial building and operational challenges. Public acceptance is also a challenge, particularly for plants that would be located inland.

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

APERC bases investment estimates on the lowest (low-cost estimate) and highest (high-cost estimate) cost per unit of energy facility/infrastructure. Investments are also categorised into four sub-sectors: upstream, downstream, power and energy transport. To meet the energy infrastructure requirements between 2015 and 2040, China's total investment needs fall between USD 5.9 trillion (low-cost estimate) and USD 13 trillion (high-cost estimate) (Table 5.4).

About 50% of the economy's energy investment needs are associated with rising demand for power: the 1 804 GW additional generation capacity needed (including T&D expansion) will cost between USD 3.4 trillion (low-cost estimate) and USD 5.3 trillion (high-cost estimate). The upstream sub-sector accounts for 38% of total investment needed, primarily for coal mining and production. A 2.4% share for downstream investment would be directed towards additional refinery capacity (3.5 million bbl/d) and the construction of a liquefied natural gas (LNG) import terminal (additional capacity of 146 Mt per year). Domestic energy transport for oil, gas and coal (from source to ports or facilities) requires a 2.6% share of total investment.

Table 5.4 • China: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	547	820
	Gas	274	822
	Coal	1 447	4 703
	Subtotal	2 267	6 344
Downstream	Refinery	104	420
	LNG import terminals	26	32
	Biofuels refinery	14	19
	Subtotal	144	471
Electricity	Nuclear	193	254
	Coal	463	579
	Gas	90	148
	Hydro	229	370
	Wind	498	662
	Solar	475	617
	Biomass and others	65	91
	Geothermal	0.2	0.2
	Transmission lines	1 257	1 414
	Distribution lines	97	1 161
	Subtotal	3 367	5 299
Energy transport	Oil	32	48
	Gas	117	326
	Coal	3	11
	Subtotal	152	386
	Total	**5 930**	**12 499**

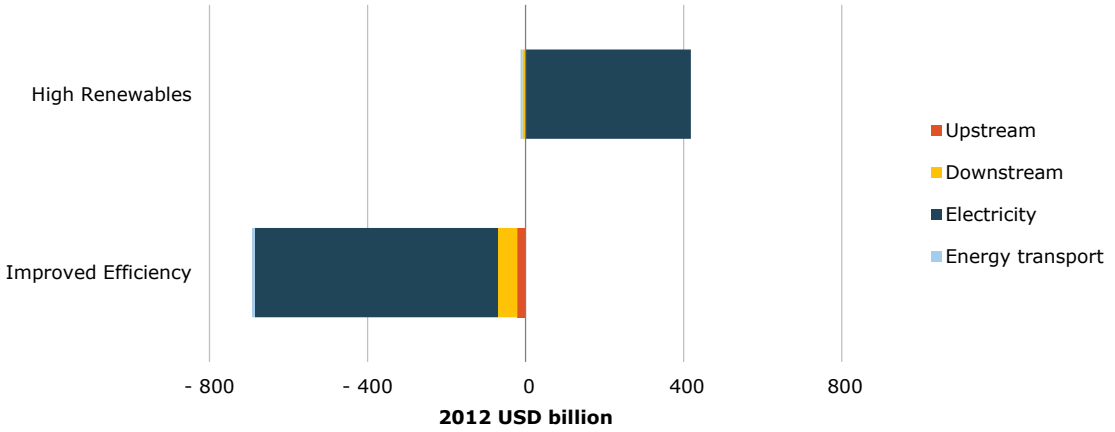
Notes: Investment is estimated based upon range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport only includes pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

Under the Improved Efficiency Scenario, total investment needed in China is USD 5.2 trillion from 2015 to 2040, a savings of 12% from the BAU level (Figure 5.12). Power shows the largest investment savings, of USD 615 billion or 18% below the BAU investments, as less generation capacity and fewer T&D lines need to be added. Important savings can also be seen in downstream investments (USD 49 billion) as less LNG import terminal capacity will be required and upstream (USD 21 billion) as less investment is needed to expand energy production.

In the High Renewables Scenario, total investment increases by 6.8% corresponding to the entry of substantially more renewable capacity—1 215 GW—in the generation mix (from only 851 GW in the BAU). Such a huge increase of renewables would decrease downstream investment by 5.4% (about USD 8 billion) reflecting lower requirements for LNG import terminal capacity. However, as grids need to be expanded to connect the installed renewable capacity, power infrastructure needs will drive up investment by 12% (USD 418 billion).

Figure 5.12 ● China: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

To enhance energy security, China will accelerate the optimisation of its economic structure while also improving energy efficiency—that is, the government aims to support relatively high social and economic development while consuming less energy. The government promotes domestic energy production as a major channel of energy supply, supports exploration and development of domestic energy, and continually improves energy substitution and the stock system. China will also enhance international cooperation with a view to promote energy trade and investment while further diversifying supply routes.

China holds the view that climate change is a shared global challenge and attaches great importance to addressing it through an aggressive economy-wide strategy that promotes green and low-carbon development as important components of the ecological civilisation process. On 30 June 2015, China submitted its INDC to the UNFCCC, outlining its efforts to tackle climate change at home and contributing its views on the 2015 agreement to be negotiated at the climate change talks in Paris (UNFCCC, 2015).

Enhancing energy security: Supply becomes more diverse, but oil and gas self-sufficiency decline

Although China has significant fossil fuel resources, the government intends to ensure that renewables and nuclear energy play more important roles in the future. An overriding challenge, however, is that the economy's energy resources are inadequate to meet demand. Under the BAU, net energy dependency rises from 15% in 2013 to 23% by 2040. With oil dependency projected to increase from 57% in 2013 to

65% by 2040, China is seeking to secure oil supply by diversifying its suppliers, drawing imports from the Middle East, Russia and Central Asia, Africa, and Latin America. By 2040, China will rely on imports for nearly 43% of gas supply, an increase of 28% from 2013 (at which time imports came from at least 10 economies) (IEA, 2014). China could reduce its oil and gas import dependence by intensifying exploration and production, particularly of unconventional oil and gas.

Table 5.5 ● China: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040						
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%	High Nuclear
Primary energy supply diversity (HHI)	0.49	0.32	0.30	0.30	0.32	0.29	0.26	0.30
Primary energy supply self-sufficiency (%)	85	77	88	82	78	78	74	80
Coal self-sufficiency (%)	94	86	100	94	87	97	100	90
Oil self-sufficiency (%)	43	35	41	35	35	35	35	35
Gas self-sufficiency (%)	72	57	79	60	57	41	32	60
Electricity generation input fuel diversity (HHI)	0.73	0.45	0.41	0.39	0.44	0.36	0.30	0.39

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

Energy supply diversity in China is expected to improve significantly over the Outlook period. In 2013, China's primary energy supply as measured on the Hirchmann-Herfindahl Index (HHI) was HHI 0.49 due to high dependency on coal; by 2040, the increased shares of other fuels bring it down to HHI 0.32, where a lower number indicates improved diversity (Table 5.5). Electricity will benefit the most from China's efforts to diversify input fuels: in 2013, heavy reliance on coal drove the HHI for electricity as high as HHI 0.73; by 2040, increased use of renewables, nuclear and gas bring the HHI to 0.45, on par with most developed economies in APEC.

Of the Alternative Scenarios, the Improved Efficiency Scenario shows the best results across most indicators. The High Renewables Scenario and High Nuclear Case deliver reduced import dependency; as consumption of fossil fuels decreases, less gas needs to be imported from other economies. The High Gas 50% and the High Gas 100% Cases help to diversify primary energy supply and electricity generation (both positive trends) but gas self-sufficiency declines to 41% in the High Gas 50% Case and to 32% in the High Gas 100% Case, which may lead to energy security concerns.

Climate change impacts and risks: CO_2 emissions expected to peak before 2035

The actions China has set out to 2030 to contribute to global climate change goals, as set out in its INDC, are based on its circumstances, the state of economic and social development, a sustainable development strategy and international responsibility. They include two overarching goals: increasing the share of non-fossil fuels in primary energy consumption to around 20% and reducing CO_2 intensity (CO_2 per unit of GDP) by 60% to 65% from the 2005 level (UNFCCC, 2015).

Box 5.2 ● Lower carbon development in China

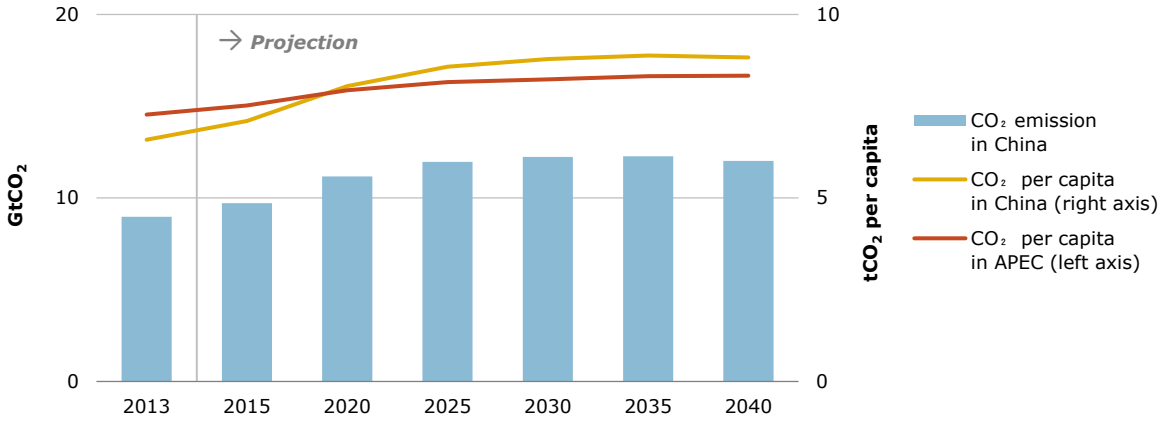
Although still in the early stages, China has implemented many effective means to advance towards a low-carbon economy, such as optimising the industry structure, improving efficiency and developing non-fossil fuel energy.

If China successfully trail-blazes a low-carbon development path, other developing economies at the early stage of industrialisation and urbanisation could benefit from its experience. Collectively, such efforts would contribute to the challenge of addressing climate challenge.

China's development and climate change ambitions highlight the importance of exploring a new mode of low-carbon development, tailored to its current context. China has enacted and implemented multiple relevant initiatives: the National Program on Climate Change; the Work Plan for Controlling Greenhouse Gas Emissions during the 12th Five-Year Plan period; and the National Plan on Climate Change (2014-2020), among others. China has established CO_2 emission trading pilots in seven provinces and cities, and initiated low-carbon development pilots in 42 provinces and cities. The government has also set 'Phase' objectives, such as the aims to, by 2020, achieve installed capacities of wind (200 GW) and solar (100 GW), and expand use of geothermal to reach total capacity of 50 Mtoe (UNFCCC, 2015).

During the period 2013 to 2030 under the BAU, non-fossil fuel supply increases by 439 Mtoe. APERC analysis shows that CO_2 emissions peak at 12.3 $GtCO_2$ in 2034 and by 2040 reach 12 $GtCO_2$, with a per-capita level of 9 tCO_2 (Figure 5.13).

Figure 5.13 ● China: Final energy-related CO_2 emissions per capita in APEC and China under the BAU, 2013-40

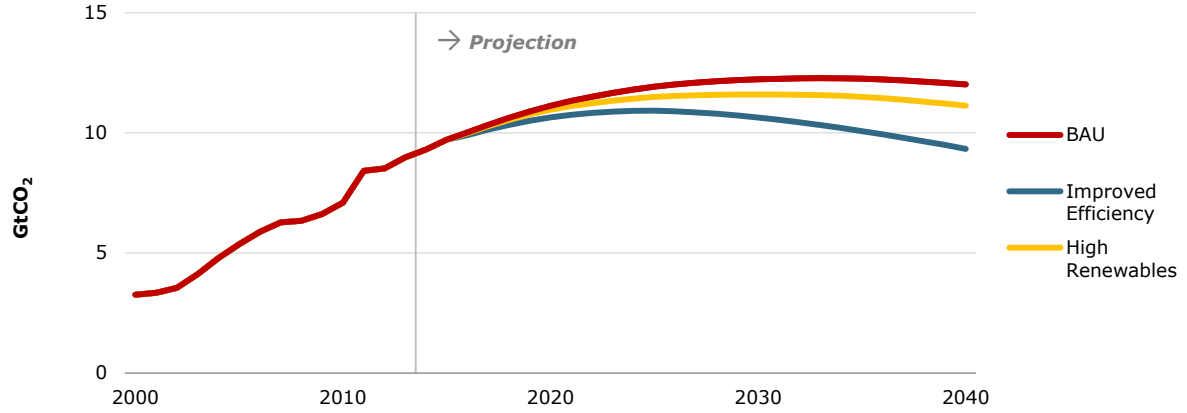


Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).

Sources: APERC analysis and IEA (2015b).

Emissions decline under the Improved Efficiency (savings of 2.7 $GtCO_2$) and High Renewables (savings of 0.88 $GtCO_2$) Scenarios, compared with the BAU (Figure 5.14). This difference highlights the importance and urgency of implementing energy efficiency improvements and shows that all sectors can contribute. In terms of crossover between energy sub-sectors and economic sectors, emissions reduction in industry reflects lower use of coal and less demand for electricity, transport emissions reduction comes from lower use of oil, and buildings emissions reduction reflects lower electricity demand.

Figure 5.14 ● China: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and LULUCF.

Sources: APERC analysis and IEA (2015b).

RECOMMENDATIONS FOR POLICY ACTION

Opportunity exists for China to strengthen efforts on energy efficiency improvements in both the short and long term. In industry, smaller enterprises and less energy-intensive industry could be encouraged to install efficient motor and steam systems, as well as deploy energy management systems. Meanwhile, regular energy audits could play a significant role in reducing energy consumption in these rapidly growing industries. In the buildings sector, tougher enforcement of building codes could help to improve the energy efficiency of buildings, while more stringent standards for appliances and equipment would help to reduce the need to add new electricity generation capacity.

Over the next decades, China is expected to add more than 320 million vehicles, putting pressure on both energy demand and the environment. To reduce oil demand and thus lower import dependency, additional policies and measures are needed to promote public transportation and cleaner cars. High-speed rail, subway and light rail could substitute for LDVs to satisfy demand for commuting and travel. Measures to increase sales of advanced vehicles (e.g. EVs and FCEVs) would also contribute to reducing the environmental impact of energy use in transport.

Greater efforts on renewable energy R&D are needed to further optimise China's energy structure and to take advantage of the energy security and environmental benefits of wider adoption of renewable energy sources. Priority should be given to reducing the manufacturing cost of wind and solar power equipment in order to accelerate deployment of renewables and increase total installation while also helping to address climate change issues worldwide. A quicker reduction in renewable technology costs could help the economy to make an earlier switch away from coal.

Support for CCS development and deployment is also needed as China continues to add coal-fired capacity throughout the Outlook period. Policies aimed at improving the efficiency and/or limiting the emissions or energy intensity of new coal-fired plants are particularly important over the next decade. Additionally, they need to ensure that added capacity can be retrofitted with CCS as it becomes more widely deployed.

6. HONG KONG, CHINA

KEY FINDINGS

- **Hong Kong is a highly advanced economy with the lowest energy intensity of the APEC economies**—only 18% of the projected 2020 average for the APEC region. In its Energy Saving Plan 2015-2025+, it has committed to reduce energy intensity by 40% of the 2005 level by 2025. Actions to meet this target include comprehensive energy efficiency improvements.

- **Hong Kong's primary energy supply diversity improves from HHI 0.44 in 2013 to HHI 0.41 in 2040 under the BAU.** However, the Improved Efficiency Scenario has the potential to improve TPES diversity to HHI 0.35. As the economy is energy import-dependent, diversifying the fuel mix and energy sources is a priority.

- **The public transport system is mature; car ownership is relatively low but close to saturation level.** With efficiency improvements over the projection period, fuel consumption in domestic transport decreases 20%.

- **As a world-class financial, trading and business centre, international transport energy demand in Hong Kong is high.** It is projected to reach 15 Mtoe in 2040, more than 8 times larger than projected domestic transport energy demand.

ECONOMY AND ENERGY OVERVIEW

Hong Kong is a special administrative region of the People's Republic of China. It is a global financial, trading and business centre of 7.1 million people located at the south-eastern tip of China. In 2013, the per capita gross domestic product (GDP) of Hong Kong was USD 52 340 (2012 USD purchasing power parity [PPP]), among the highest in the Asia-Pacific Economic Cooperation (APEC) (Table 6.1).

Table 6.1 ● Hong Kong: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	159	235	342	375	441	551	672
Population (million)	5.8	6.8	7.0	7.2	7.8	8.5	8.9
GDP per capita (2012 USD PPP)	27 417	34 575	48 897	52 340	56 522	64 947	75 062
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	9	14	14	14	14	15	14
TPES per capita (toe)	1.5	2.0	2.0	1.9	1.8	1.7	1.5
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	5.2	9.4	7.3	7.3	8.0	8.3	8.6
Final energy intensity per GDP (toe per 2012 USD million PPP)	33	40	21	19	18	15	13
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	33	40	42	46	42	42	35
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	100	100	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

The services sector drives overall economic growth, accounting for about 90% of GDP in 2013 (World Bank, 2015). The four main economic sectors are trading and logistics (24% of GDP in terms of value-added GDP in 2013), tourism (5%), financial services (17%), and professional services and other producer services (12%). The six industries which have development potential are cultural and creative services, medical services, education services, innovation and technology, testing and certification services, and environmental industries, which together accounted for 9.1% of GDP in terms of value-added GDP in 2013 (HKTDC, 2015). Hong Kong has a high population density, and much of the high-GDP economy is controlled from high-rise buildings (EB, 2015).

Hong Kong is restructuring to stay competitive and to attain sustainable growth while meeting the challenges of globalisation. The Closer Economic Partnership Arrangement (CEPA) of Hong Kong and China is a manifestation of the 'One Country, Two Systems' policy. As part of the liberalisation of trade goods under CEPA, Hong Kong manufacturers have tariff-free access to Chinese markets. China's support under CEPA and other policies such as the Framework Agreement on Hong Kong/Guangdong Co-operation reinforces Hong Kong's status as an international centre for financial services, trade and shipping, as well as advanced global manufacturing and modern services[1] (Policy Address 2013, 2014).

Lacking fossil fuel resources, almost all energy is imported. A substantial share of imported energy is converted into secondary energy such as electricity and gas for final consumption. Owing to its highly

[1] Modern services is a new concept from China, where service providers are operating in the context of more sophisticated technologies and/or newer forms of management.

developed and service-dominated economy, energy intensity is the lowest in APEC. In 2013, final energy intensity per unit of GDP was 82% below the APEC average, and it is projected to be 80% below the APEC average by 2040. In addition, total primary energy supply (TPES) per capita is projected to decline in comparison with the APEC upward trend over the projection period. TPES per capita decreases to 1.5 toe by 2040, 57% below the APEC average. Along with energy structure optimisation, more gas and renewables[2] are energy is substituted for coal, while more electricity is imported from mainland China. The economy's total energy-related carbon dioxide (CO_2) emissions are projected to decrease to 35 million tonnes of CO_2 ($MtCO_2$) by 2040 from 46 $MtCO_2$ in 2013.

ENERGY POLICY CONTEXT

Key energy policy objectives are to safely and efficiently meet energy needs at a reasonable price while minimising the environmental impact of electricity generation; to this end, the government promotes energy efficiency and conservation.

The primary target is to reduce energy intensity by 40% below the 2005 level by 2025 (EB, 2015). Being 'energy aware' and 'energy wise' is promoted by the government through the key measures of reducing energy-related CO_2 emissions and improving energy efficiency by using cleaner fuels such as gas and renewable energy; promoting energy efficiency in buildings and production; promoting renewable energy, including waste-to-energy; seeking input from the community to improve energy efficiency; and enhancing electricity demand management.

Detailed actions include optimising the fuel mix by purchasing more power or using more natural gas for local generation. In 2014 the government conducted a public consultation on the future fuel mix for electricity generation. Proposed changes include reducing the amount of coal-fired power and keeping coal-fired plants at very low utilisation levels or as reserve generation, such that coal would account for no more than 10% of the fuel mix; maximising the use of natural gas secured from the mainland, to increase its share in the fuel mix to 40%; and substantially increasing the share of non-fossil, low-emitting fuels, such that renewable energy would constitute 3% to 4% of the fuel mix, and the remaining 50% would be met by imported nuclear power (EPD, 2014).

The government plans to continue investing in mass transportation systems and improving public transport, as well as encouraging electric vehicle (EV) manufacturers and agents around the world to introduce a greater variety of EVs (EPD, 2010, 2014). Hong Kong also aims to maximise energy efficiency in the buildings sector through periodically reviewing, expanding and/or tightening relevant energy-related standards such as the Buildings Energy Efficiency Ordinance (BEEO), the Building (Energy Efficiency) Regulation (B[EE]R), and the Energy Efficiency (Labelling of Products) Ordinance (EELPO). The government itself intends to lead the energy savings and green buildings transformation in government buildings, public housing and public sector development (EB, 2015).

BUSINESS-AS-USUAL SCENARIO

This section illustrates energy demand and supply in the Business-as-Usual (BAU) Scenario and summarises the key assumptions from existing government policies (Table 6.2). The definition of the BAU Scenario and the modelling assumptions used in this Outlook are different from those used by the government for its projections, targets and analysis.

[2] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

Table 6.2 • Hong Kong: Key assumptions and policy drivers under the BAU Scenario

Buildings and industry	• Continued implementation of energy intensity reduction target (40% below 2005 level by 2025). • Efficiency in public and private buildings improves as higher standards are imposed. • Code of practice on energy labelling of products tightens with technology development.
Domestic transport	• Public transport further developed. • Private car ownership close to saturation.
Energy supply mix	• Coal consumption continues to drop, substituted by gas. • Gas and electricity imports grow to satisfy needs.
Power mix	• No new coal or nuclear power plants built. • Gas generators replace some retiring coal generators.
Renewables	• Continued promotion of wind as a major renewable source.
Energy security	• Continued imports of electricity and gas directly from the mainland.
Climate change	• Continued efforts to reduce CO_2 emissions intensity by 50% to 60% by 2020 (from 2005 level).

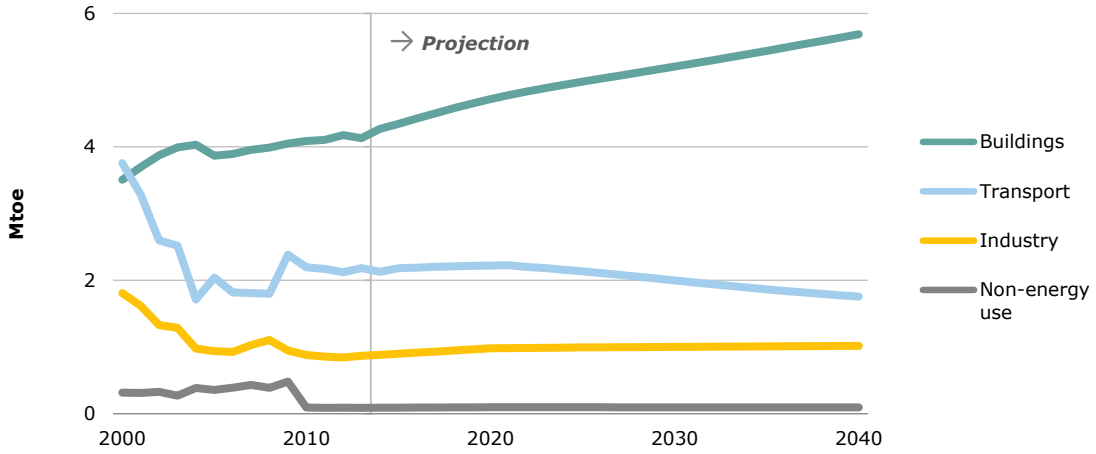
Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Total final energy demand is projected to increase to 8.6 million tonnes of oil equivalent (mtoe) in 2040, from 7.3 Mtoe in 2013. The majority of the increase comes from the buildings sector, owing to population growth and further development in services. Final consumption in industry rises only slightly, pushed by higher value-added sectors. Consumption in domestic transport increases initially with increased car ownership, but then decreases gradually thanks to efficiency improvements.

The buildings sector maintains the dominant share of final energy demand at 66% in 2040, followed by domestic transport at 21% and industry at 12% (Figure 6.1). Electricity remains the primary energy source for final energy demand, increasing from 50% in 2013 to 59% in 2040, followed by oil at 30% (down from 40% in 2013).

Figure 6.1 • Hong Kong: Final energy demand by sector, 2000-40



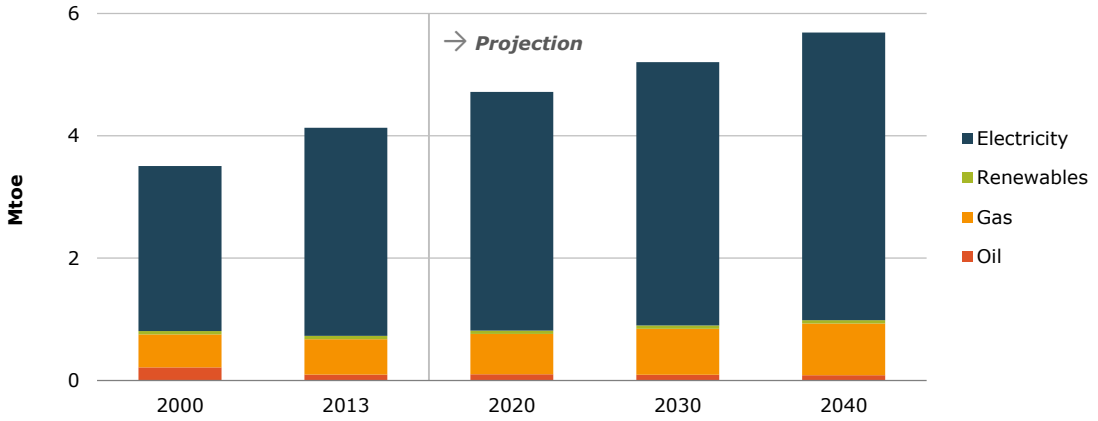
Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

Buildings energy use: Electricity-dominated buildings improve energy efficiency

The buildings sector consumes the most energy, accounting for 93% of the economy's total electricity demand over the projection period. The rise in energy demand is driven by population and income growth, but the government has committed to enhancing the regulatory system for building energy efficiency, promoting water-cooled air conditioning systems which are more efficient than air-cooled ones, and

implementing a voluntary energy efficiency labelling scheme (VEELS) as well as a mandatory energy efficiency labelling scheme (MEELS) (Box 6.1). Considering both energy demand increase and efficiency improvements, consumption in this sector is projected to reach 5.7 Mtoe in 2040, from 4.1 Mtoe in 2013 (Figure 6.2).

Figure 6.2 • Hong Kong: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Hong Kong is a high-GDP economy dominated by sophisticated services, with a large population living and working mostly in high-rise buildings in a subtropical climate. All these factors contribute to significant electricity usage, which continues to dominate the energy mix over the projection period, accounting for 83% of the buildings sector's total energy consumption by 2040 (82% in 2013). While natural gas and liquefied petroleum gas (LPG) are the main gaseous fuels used, another product available is 'town gas', which is manufactured locally using naphtha and natural gas as feedstock (Towngas, 2014). The Asia Pacific Energy Research Centre (APERC) forecasts a slight increase in gas consumption, to 15% (0.84 Mtoe) of buildings final energy demand by 2040, compared with 14% (0.58 Mtoe) in 2013.

Box 6.1 • Hong Kong: Energy efficiency labelling scheme

Hong Kong has developed an improved energy efficiency labelling scheme to cover more appliances, has introduced mandatory schemes and has tightened energy efficiency grading standards.

In 1995, Hong Kong launched VEELS. It now covers 22 types of household and office appliances, among which are 13 types of electrical appliances, 7 types of office equipment and 2 types of gas appliances. VEELS was extended to gasoline passenger cars in 2002 (EMSD, 2012a).

To further assist the public in choosing energy-efficient appliances and to raise energy savings awareness, the government introduced MEELS through the EELPO. MEELS Phase I was launched in 2009, covering room air conditioners, refrigerating appliances and compact fluorescent lamps. In 2011, washing machines and dehumidifiers were covered in MEELS Phase II. These five types of appliances account for 60% of annual electricity consumption in the residential sub-sector. Under MEELS, energy efficiency performance labels are required on all products for sale in Hong Kong (EMSD, 2012b).

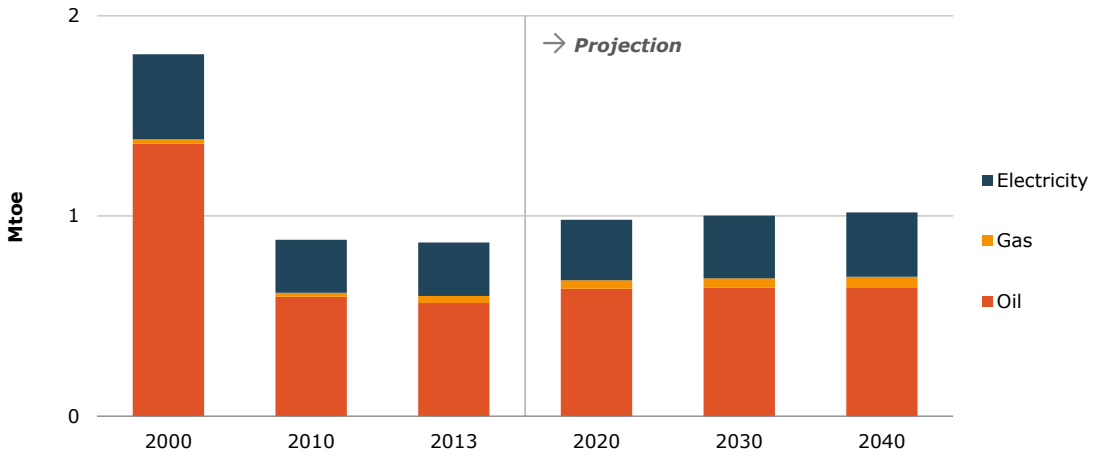
In light of technological developments, the grading standards of room air conditioners, refrigerating appliances and washing machines (together accounting for half of domestic electricity consumption) have been raised through revision of the Code of Practice on Energy Labelling of Products (November 2015). It is estimated that raising the grading standards will effect annual energy savings of 300 million kilowatt-hours (kWh) and reduce CO_2 emissions by 210 kilotonnes (EMSD, 2012b; EB, 2015).

Industry energy use: High value-added industry contributes to relatively low energy consumption

Through economic restructuring, Hong Kong has moved the majority of its labour-intensive operations to China and other low-cost economies in the region. It maintains and develops some higher value-added and knowledge-intensive activities such as research and development (R&D), prototype production, innovative design, technological applications, supply chain management, logistics, and marketing—mainly in the areas of automotive parts and accessory systems, communications technologies, and bioenergy. Hong Kong has assumed the role of strategic control centre to oversee its relocated manufacturing operations (TID, 2015).

Industry final energy demand is projected to increase to 1 Mtoe by 2040, from 0.87 Mtoe in 2013 (Figure 6.3). Oil remains the main resource, accounting for more than 63% (0.64 Mtoe) of total industry energy demand in 2040, compared with 65% (0.57 Mtoe) in 2013, owing to more value-added activities.

Figure 6.3 • Hong Kong: Industry sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

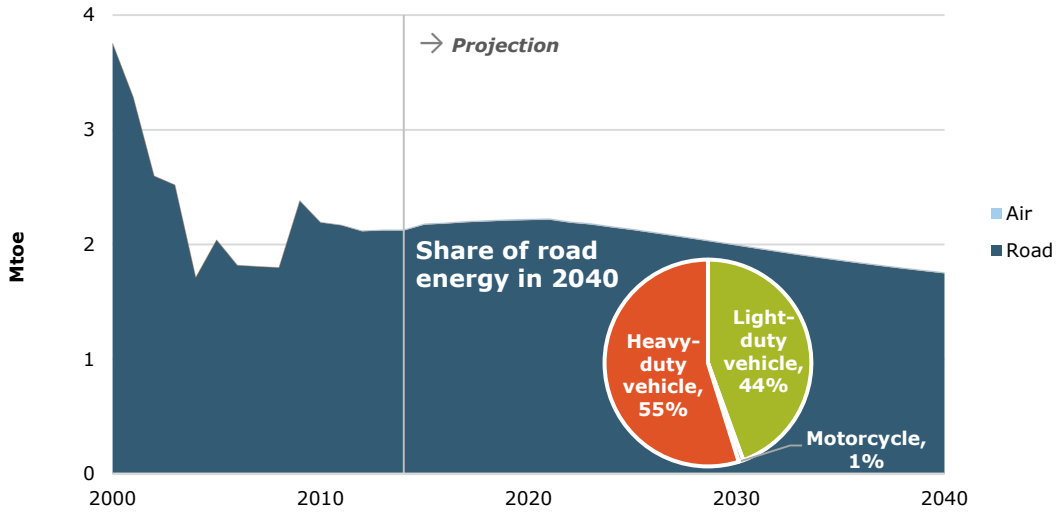
Transport energy use: Mature public transport keeps car ownership low

Hong Kong is expanding public transport and promoting low-emitting vehicles to reduce energy consumption and CO_2 emissions in domestic transport. The already extensive and energy-efficient public transport system, composed of the Mass Transit Railway (MTR), buses and ferries, is used by 90% of commuters. The MTR currently consumes 1 425 gigawatt-hours (GWh) (118 kilotonnes of oil equivalent [Ktoe]) of energy per year. Four new railway projects are under construction to increase the existing network by 25% (EB, 2015), and pedestrian areas and covered walkways are being improved to better integrate passive and active transport.

Car ownership is close to saturation level at present, though it is relatively low compared with other economies because of the highly developed public transportation system and the relatively high cost of private cars. Low-emitting vehicles and EVs are actively promoted; for example, the First Registration Tax of EVs is waived until the end of March 2017. Furthermore, enterprises which procure EVs are allowed a 100% profits tax deduction for the capital expenditure on EVs in the first year of ownership. At the end of January 2016, there were 4 464 EVs for road use in Hong Kong (EPD, 2016). The Pilot Green Transport Fund encourages the transport sector to test green and innovative means of transport and technology. Hong Kong plans to have 30% of private cars and 15% of buses and commercial vehicles hybrid or electric (or of similar performance) by 2020.

Although population increases over the projection period, fuel consumption in domestic transport decreases to 1.8 Mtoe by 2040 from 2.2 Mtoe in 2013 thanks to fuel efficiency policies and improved public transport systems (Figure 6.4).

Figure 6.4 • Hong Kong: Domestic transport sector final energy demand, 2000-40



Note: Electricity consumption of the MTR is not included.
Sources: APERC analysis and IEA (2015a).

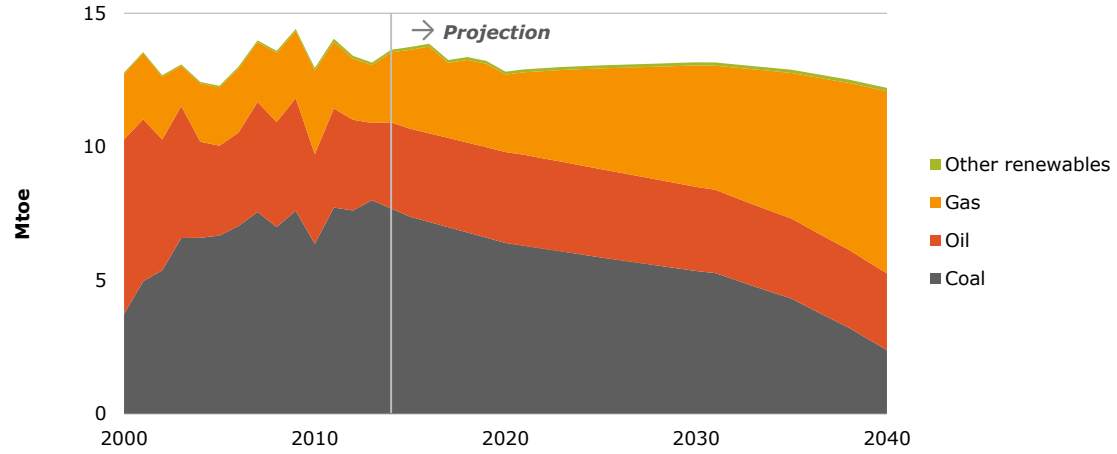
Being a global business centre and regional aviation hub, Hong Kong's international air and marine transport energy demand exceeds total final energy demand. In 2013, fuel consumed in international transport was 6.6 times that of domestic transport. Globalisation of economic activities is expected to continue raising air and shipping freight volumes; international aviation energy demand therefore reaches 6 Mtoe in 2040 (from 5.9 Mtoe in 2013), and marine demand rises to 8.9 Mtoe (from 8.6 Mtoe).

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Stable supply with gas share increasing and coal diminishing

Although Hong Kong's TPES varied slightly according to the economic situation in the 2005-15 period, it is projected to remain stable at 14 Mtoe over the projection period as energy efficiency improvements offset population increase (Figure 6.5).

Figure 6.5 • Hong Kong: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

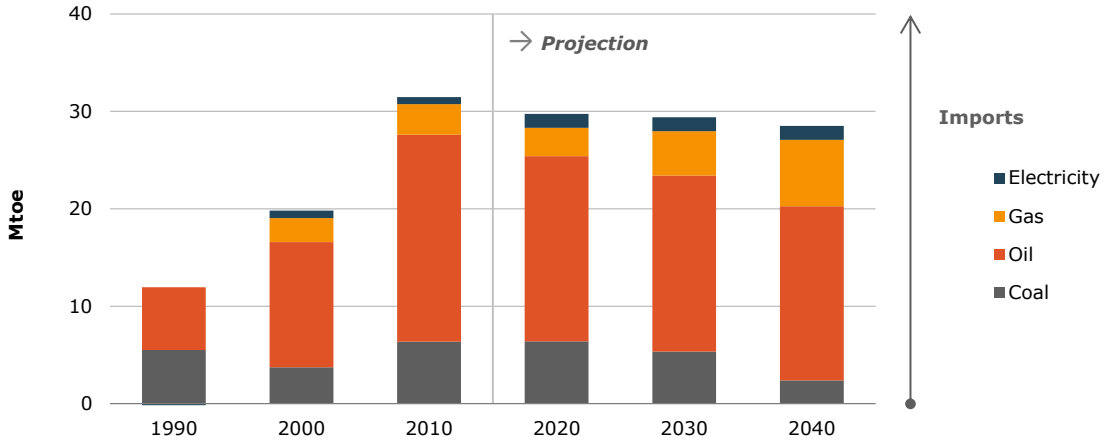
While TPES remains stable, the fuel mix shifts from coal to gas. The share of gas is projected to increase to 50% by 2040 in comparison with 16% in 2013. Meanwhile, the share of coal decreases from 57% in 2013 to 18% by 2040. The share of oil decreases as a result of efficiency improvements in heavy- and light-duty vehicle fleets, through investment in equipment and maintenance; better demand management by bus companies and the government; and promotion of good driving practices (ED, 2015). Under the BAU Scenario, the TPES fuel mix is more balanced by 2040, however the increased share of gas by 2040, may pose energy security concerns by exposing the economy to fluctuations in gas prices and disruptions in gas supply.

Energy trade: Almost all energy demand relying on imports

Hong Kong imports almost all of its primary energy from other economies—oil mainly from Singapore, and gas from China. It also imports electricity through a joint venture and supply contract with Guangdong Daya Bay Nuclear Power Station (CSD, 2014).

Energy imports are projected to increase slowly to 29 Mtoe by 2040 (Figure 6.6). Oil imports fluctuate slightly due to domestic transport consumption declining while that of international aviation and marine increases. The trend of coal import growth between 2000 and 2010 (to serve increased coal demand in electricity and industry) is expected to change over the projection period as gas and imported electricity gradually replace coal in the power sector. In contrast, gas imports increase to 6.8 Mtoe (triple the 2.2 Mtoe in 2013), mainly due to increased gas demand in the power sector. Hong Kong plans to import more electricity from China, possibly by increasing its share of contracted nuclear power or through direct electricity imports from the China Southern Power Grid.

Figure 6.6 • Hong Kong: Net energy imports, 1990-2040



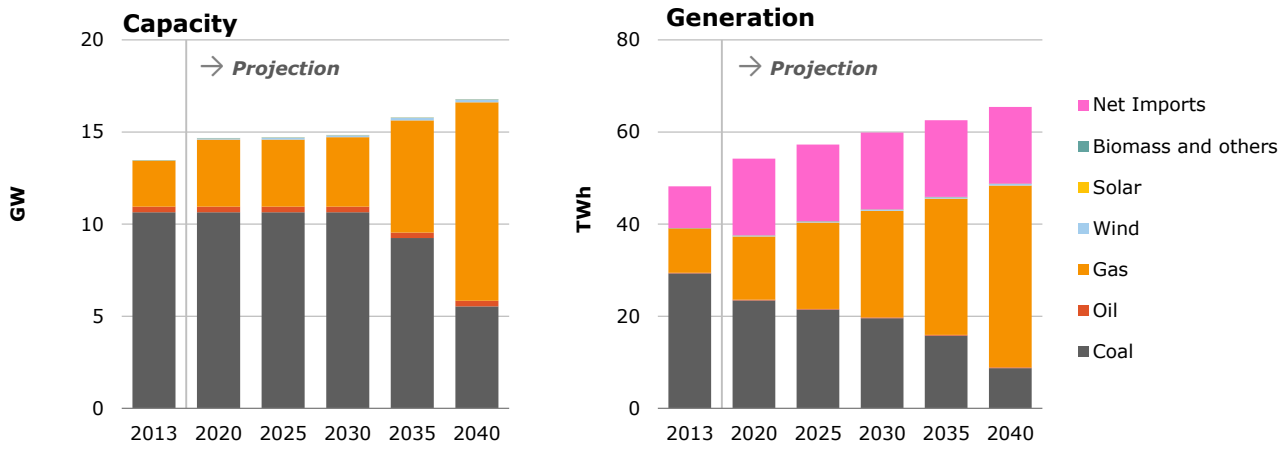
Sources: APERC analysis and IEA (2015a).

Power sector trends: Gas generation gradually dominates

Total installed and contracted electricity generating capacity in Hong Kong was 13 gigawatts (GW) in 2013. Almost all locally generated power is thermal power; CLP Power Hong Kong Limited (CLP Power) and the Hong Kong Electric Company Limited (HKE) are the main suppliers. CLP Power supplies electricity from two large plants fuelled by coal and gas and a smaller diesel-gas plant, while HKE supplies power from its large coal-fired plant. In addition, there are some small wind turbines and solar photovoltaic (PV) systems (PAH, 2013a, 2013b). In 2012, CLP Power contracted to purchase 70% of the electricity generated by pressurised water reactors at the Guangdong Daya Bay Nuclear Power Station in China, which can satisfy around 23% of the total electricity demand in Hong Kong (CLP, 2012a). Electricity imports reduce fossil fuel consumption in Hong Kong and help reduce power sector related CO_2 emissions by 0.13 $MtCO_2$ annually.

Domestic electricity supply expands to meet demand over the projection period. Total installed capacity is projected to reach 17 GW by 2040, a 25% increase in comparison with 2013, and generation output reaches 66 terawatt-hours (TWh) a 36% increase from 2013 (48 TWh) (Figure 6.7). The electricity supply structure changes over the projection period, with gas replacing coal as the major source of electricity. The share of coal was 79% (11 GW) of capacity in 2013 and is projected to fall to 33% (5.5 GW) by 2040; conversely, the share of gas rises from 19% (2.5 GW) to 64% (11 GW). The majority of coal-fired power plants in Hong Kong came into operation in the 1980s, and they will gradually be retired in conformation with a 1997 law prohibiting new coal-fired power plants for environmental reasons.

Figure 6.7 • Hong Kong: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

Despite geographical and natural constraints in developing wind energy, Hong Kong has started to explore offshore wind farm projects. For example, HKE plans to install up to 33 offshore wind turbines with a total generation capacity of 100 megawatts (MW), expecting to produce 175 GWh of electricity yearly. Biodiesel is being considered for use in a 'distributed' renewable energy source for tri-generation in buildings such as the Zero Carbon Building (EB, 2015). The installed capacity of renewable power continues to increase from 16 MW in 2013 to 166 MW in 2040, although its share in the local electricity supply reaches only 0.6% by 2040. An optimised electricity structure could reduce both carbon intensity and air pollutant emissions.

ALTERNATIVE SCENARIOS

Of the three alternative scenarios developed, only the Improved Efficiency and the High Renewables Scenarios apply to Hong Kong.[3] The Improved Efficiency Scenario results in a larger reduction in energy-related CO_2 emissions than the High Renewables Scenario, as land constraints limit the potential for renewable resource development. The Alternative Power Mix Scenario is not applicable to Hong Kong, as there are no plans to develop nuclear power domestically, but to import nuclear-based electricity from China. Additionally, since Hong Kong has already decided to replace retiring coal generators with gas generators, neither the assumptions of the Cleaner Coal Case nor those of the High Gas 50% and the High Gas 100% Cases apply.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

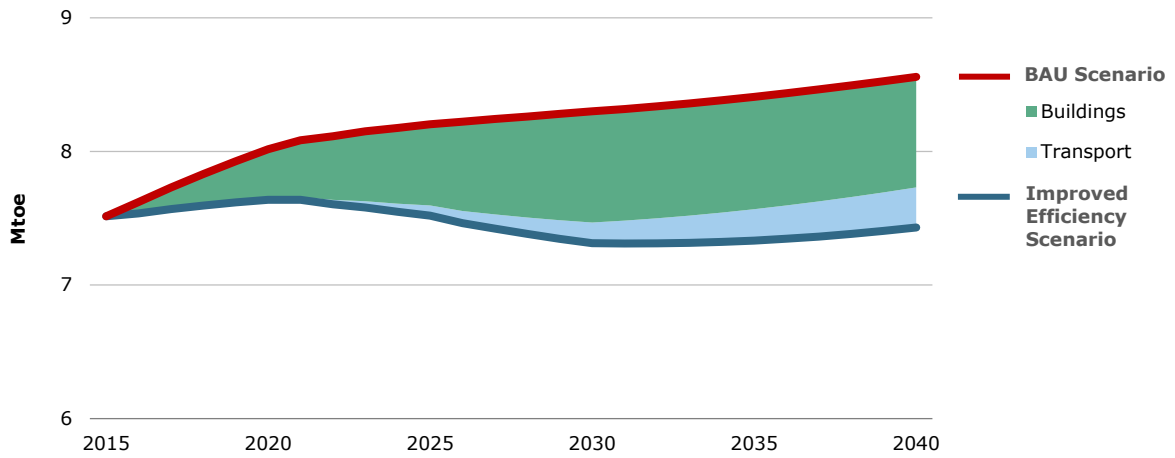
The Improved Efficiency Scenario explores energy efficiency opportunities to help meet the APEC energy intensity target.[4] Under the BAU Scenario, Hong Kong energy intensity declines 45% from 2005 to 2035.[5]

[3] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.
[4] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.
[5] According to government calculations in Hong Kong Energy End-use Data 2015, Hong Kong energy intensity dropped 23.9% in 2013 from the 2005 level (EMSD, 2015).

Energy intensity in 2035 is projected to be a mere 14 toe per USD million, one-fifth of the APEC average at 71 toe per USD million. In 2015, Hong Kong set a new target to reduce energy intensity by 40% of the 2005 level by 2025 through a series of actions, especially in buildings and transport, to save energy.

Further efficiency improvements impact energy demand in the buildings sector as well as transport, but the industry sector is excluded. The Improved Efficiency Scenario shows that 1.1 Mtoe of energy could be saved by 2040 compared with the BAU Scenario, or 13% of total final energy demand (Figure 6.8). Savings in the residential and commercial sub-sectors account for 73%, as electrical appliances and buildings become more energy efficient. Additional energy savings in transport are achieved with tighter fuel economy standards for heavy- and light-duty vehicles.

Figure 6.8 • Hong Kong: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Note: Energy demand in industry remains roughly stable with low growth over the Outlook period; projected savings in this sector is negligible under the Improved Efficiency Scenario.

Source: APERC analysis.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

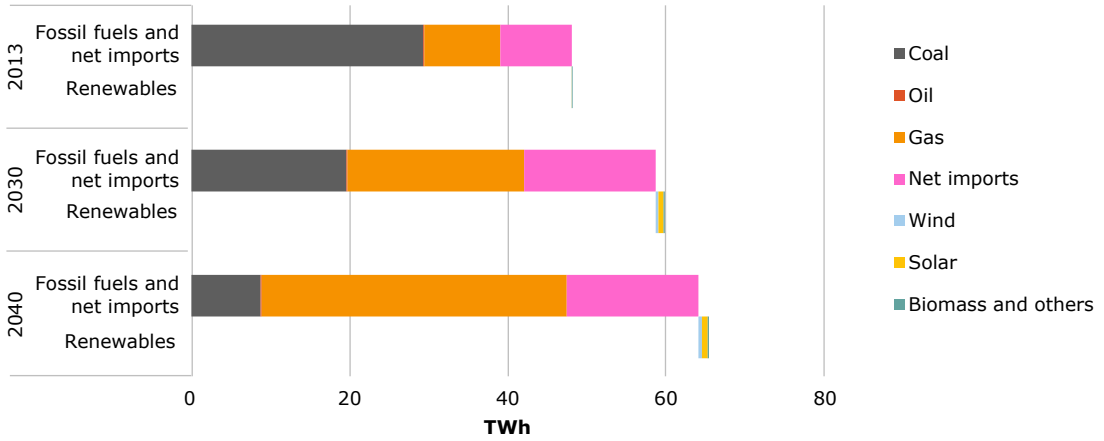
The High Renewables Scenario models the APEC doubling renewables goal within the power and transport sectors.[6] By 2030, 676 MW of renewable capacity is developed under the High Renewables Scenario, about five times more than under the BAU Scenario (Figure 6.9). Solar power reaches 501 MW in 2030 and 2040, while wind power increases to 151 MW in 2030 and 191 MW in 2040.

The primary challenge to this scenario, however, is Hong Kong's limited land area, which precludes a large-scale, industry-wide solar PV installation. Many buildings are relatively high, so rooftop PV systems are less efficient and economical due to overshadowing and high installation costs. There is wind power potential, but the levelised cost of electricity (LCOE) is high.

Hong Kong promotes biodiesel as a motor vehicle fuel. It adopted a duty-free policy for biodiesel in 2007 to facilitate its use in motor vehicles, then in 2010 introduced a regulatory control for motor vehicle biodiesel to help ensure its quality and to build driver confidence in the fuel.

[6] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

Figure 6.9 ● Hong Kong: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

By 2020, 4.6 ktoe of biofuel will be needed under the BAU Scenario, a 7% increase from 2013, and biofuel demand will remain stable if no further policies are implemented. Hong Kong will import almost all biofuel from other economies since no arable land is available to grow the feedstock. With no domestic biofuel production, only a small increase is assumed under the High Renewables Scenario.

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Total energy sector investments from 2015-40 range between USD 7.3 billion in the low-cost estimate and USD 14 billion in the high-cost estimate (Table 6.3). With no fossil fuel resources or downstream facilities, most of the investment is in power. More than 70% of the low-cost estimate and over 60% of the high-cost estimate is required for an additional 3.3 GW of power generation capacity, mainly gas but also some renewables, as well as expansion and refurbishment of transmission and distribution networks. The remaining investment is designated for support facilities for fossil fuel requirements and pipelines to ensure delivery of these resources.

Table 6.3 ● Hong Kong: Projected investments in the energy sector in the BAU Scenario, 2015-40

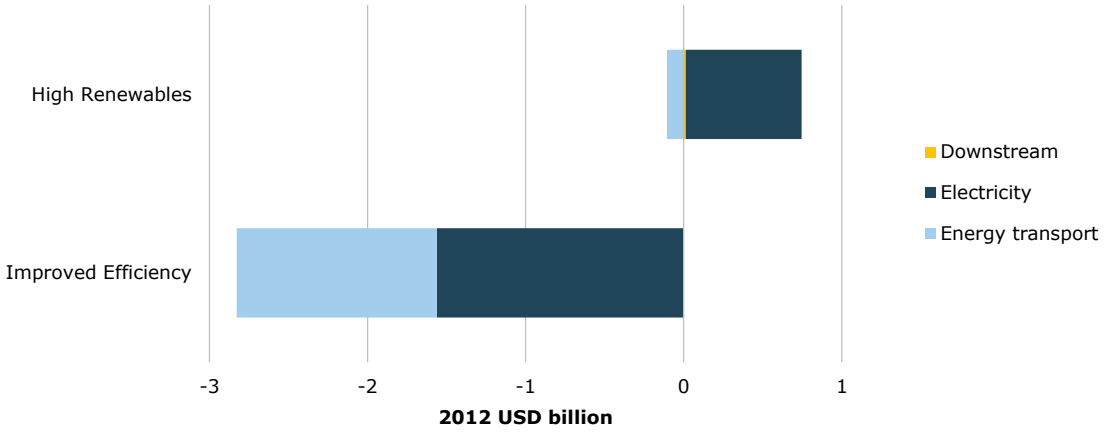
2012 USD billion PPP		Low-cost estimate	High-cost estimate
Electricity	Gas	3.2	5.3
	Wind	0.3	0.7
	Transmission lines	2.0	2.3
	Distribution lines	0.1	0.9
	Subtotal	5.6	9.2
Energy transport	Oil	0.02	0.1
	Gas	1.7	4.6
	Subtotal	1.7	4.7
	Total	**7.3**	**14**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities.

Source: APERC analysis.

The Improved Efficiency Scenario shows a potential energy investment savings of 39% in 2040 compared with the BAU Scenario (Figure 6.10). Of this savings, 28% is in the power sector due to 3.7 GW of deferred generation capacity, and lower energy demand likewise results in investment savings in energy transport. Under the High Renewables Scenario, investment savings of 8.8% from the BAU Scenario is achievable, primarily due to lower investment needs for energy transport which more than offset high investments in renewable generation capacity.

Figure 6.10 ● Hong Kong: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

The government of Hong Kong works with local electricity, oil and gas companies to maintain strategic reserves of coal, diesel, gas and naphtha. It also monitors the performance of power companies and other energy providers through the Scheme of Control Agreement.

The government is committed to working closely with the international community to combat climate change, and is pursuing measures set out in the Energy Saving Plan 2015-2025+ to reduce energy intensity by 40% of the 2005 level by 2025 (EB, 2015). Energy efficiency improvements in buildings and electrical appliances play an important role in this reduction.

Enhancing energy security: The transition from coal to gas

Reliance on imports for all fossil fuel needs is not expected to change in the near future. However, having modern and large ports, as well as strong marine transport capability, means Hong Kong can import oil products from numerous economies to increase energy security to some extent.

Table 6.4 shows energy structure optimisation over the projection period. Herfindahl-Hirschman Index (HHI) ratings improve in primary energy supply, from HHI 0.44 in 2013 to HHI 0.41 in 2040, and in electricity generation from HHI 0.69 to HHI 0.60, with a lower number indicating lesser reliance on a particular fuel. The main reason for this trend is the move from coal to gas. In addition, renewable energy development contributes to diversification of energy sources.

Table 6.4 • Hong Kong: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040		
	Actual	BAU	Improved Efficiency	High Renewables
Primary energy supply diversity (HHI)	0.44	0.41	0.35	0.39
Primary energy supply self-sufficiency (%)	1	1	1	2
Electricity generation input fuel diversity (HHI)	0.69	0.60	0.55	0.59

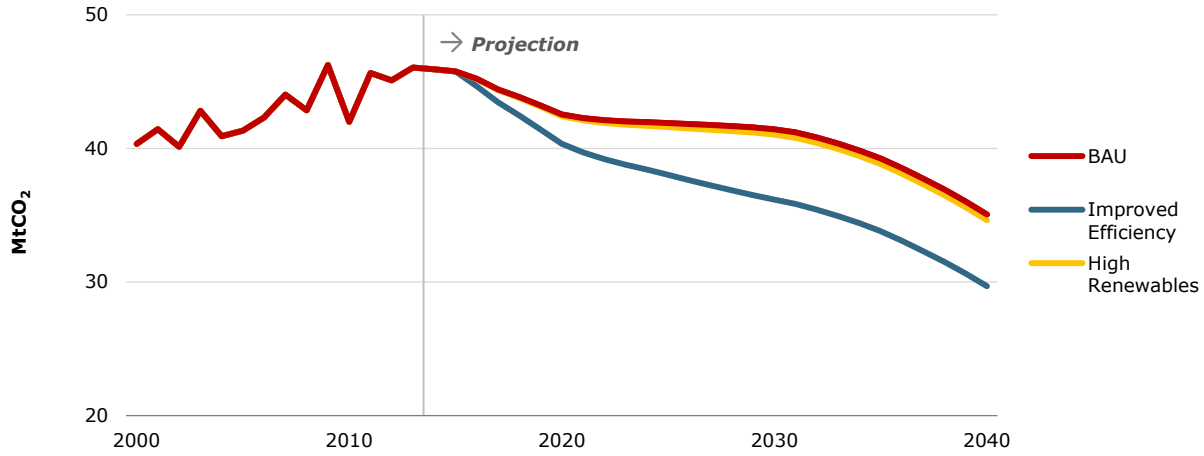
Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

Climate change impacts and risks: Power generation and domestic transport targeted

Climate change impacts on Hong Kong include rising temperatures, more frequent heavy rainfall, rising sea levels and more frequent extreme weather events. In 2010, Hong Kong set a CO_2 emissions intensity reduction target of 50% to 60% by 2020 (from 2005 level), CO_2 emissions intensity being the amount of CO_2 emissions per unit of GDP.

The primary contributors to final energy-related CO_2 emissions in Hong Kong are power generation and domestic transport. Energy-related CO_2 emissions under the BAU Scenario were 46 $MtCO_2$ in 2013 (Figure 6.11), the majority of which came from the electricity generation sector. Total final energy-related CO_2 emissions decrease 0.41% per year, to 35 $MtCO_2$ in 2040.

Figure 6.11 • Hong Kong: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

Hong Kong is implementing various policies to address greenhouse gas (GHG) emissions and climate change, such as decarbonising the fuel mix for power generation, enhancing building energy efficiency and making road transport more environmentally friendly. Corporations in Hong Kong also actively participate in combating climate change. CLP Power is exploring new technologies to make the power grid 'smarter', helping accommodate distributed renewable energy and EVs and opening up new opportunities for demand-side management (CLP, 2015). Under the BAU Scenario, final energy intensity is projected to fall to 13 tonnes per 2012 USD million PPP by 2040, from 25 tonnes in 2005 (50% reduction). In addition, energy-related CO_2 emissions per capita are projected to decline to 3.9 tonnes in 2040 from 6.4 tonnes in 2013.

CO_2 emissions from fuel use are lower under the Improved Efficiency and High Renewables Scenarios in comparison with the BAU Scenario projections. Under the Improved Efficiency Scenario, CO_2 emissions

from fuel use decrease 5.4 $MtCO_2$ by 2040, 15% lower than under the BAU Scenario. Under the High Renewables Scenario, CO_2 emissions decrease by only 0.43 $MtCO_2$, 1.2% below the BAU projections, since the economic potential of renewables in Hong Kong is limited.

RECOMMENDATIONS FOR POLICY ACTION

Hong Kong would benefit from developing its renewable power potential, especially solar PV and wind. Pollution and CO_2 emissions would decrease, and TPES would be more diverse. Incentivising policies like feed-in tariffs or renewable portable standards could encourage renewable energy development. Building or contracting with renewable power plants in China and importing the energy through the China Southern Power Grid could also be considered.

In energy-related CO_2 emissions reductions, Hong Kong benefits from importing nuclear-generated electricity from China. There has been considerable opposition to nuclear energy since the Fukushima accident, but public opinion now appears to be shifting.

The willingness of the population to make lifestyle changes demonstrates its concern about climate change. The Overall Thermal Transfer Value and B(EE)R have been gradually tightened since the mid-1990s, contributing substantially to energy efficiency improvements. Further tightening these rules is recommended to help achieve Hong Kong's energy intensity target. The use of low-emitting fuels for motor vehicles could also be further promoted.

7. INDONESIA

KEY FINDINGS

- **From 2013 to 2040 Indonesia's final energy demand increases at an AAGR of 2.9%** under the BAU Scenario.

- **Long-term energy security remains a challenge for Indonesia in the BAU Scenario, even though diversity of primary energy supply improves by 2040 compared with 2013.** Conversely, primary energy supply self-sufficiency drops from 84% in 2013 to 64% in 2040 due to rising oil and gas imports.

- **The High Renewables Scenario delivers the best energy security and the Improved Efficiency Scenario gives the best trade-offs in the power sector** with lower average generation costs, lower energy-related CO_2 emissions and a better HHI rating for Indonesia in 2040 compared with the BAU. The High Gas 100% Case offers the lowest power sector-related CO_2 emissions.

- **Under the BAU, Indonesia's energy intensity improves by 42% between 2005 and 2035, contributing to the APEC energy intensity goal** due to continuous and intensive efforts to improve energy efficiency in the transport and buildings sectors.

- **Indonesia has the potential to further contribute to the APEC energy intensity goal, as the Improved Efficiency Scenario achieves a 49% energy intensity reduction from 2005 to 2035.** The High Renewables Scenario achieves domestic renewables targets and contributes to the APEC renewable energy goal, as renewables generation increases sevenfold from 2010 to 2030, compared with a threefold increase in the BAU.

ECONOMY AND ENERGY OVERVIEW

Indonesia is a large archipelago located southeast of mainland South-East Asia, between the Pacific Ocean and the Indian Ocean. Its territory of 7.8 million square kilometres (km^2) encompasses 17 508 large and small islands, as well as large bodies of water at the equator. The economy's total land area is about 1.9 million km^2 (KESDM, 2014a). The area includes Indonesia's exclusive economic zone. The population in 2013 was 251 million, showing an annual average growth rate (AAGR) of 1.4% from the 2005 population level of 227 million (Table 7.1). Indonesia is the world's fourth most populous economy, yet about half of the population still lives in rural areas and is involved mainly in agriculture-related activities. The Indonesian government projects that around 67% of the population will become urbanised by 2035 (DEN, 2015). Over the Outlook period, Indonesia's population growth is projected to slow to an AAGR of 0.5%, reaching 290 million by 2040.

Table 7.1 • Indonesia: Macroeconomic drivers and projections 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	429	647	1 068	1 281	1 770	2 707	4 070
Population (million)	181	212	242	251	265	280	290
GDP per capita (2012 USD PPP)	2 366	3 058	4 421	5 097	6 688	9 654	14 010
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	99	156	209	214	315	430	554
TPES per capita (toe)	0.5	0.7	0.9	0.9	1.2	1.5	1.9
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	80	121	150	162	212	283	354
Final energy intensity per GDP (toe per 2012 USD million PPP)	186	187	140	126	120	105	87
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	134	258	383	425	598	868	1 163
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	28	57	67	81	99	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015), KESDM (2013a) and DJK Statistik Ketenagalistrikan (2014) for historical data; APERC analysis for projections.

Indonesia, which is a member of the Group of Twenty (G20), is the largest economy in South-East Asia and the 16th largest globally (World Bank, 2015). Between 2005 and 2013, the economy had an AAGR of 5.9% and was even resilient during the 2009 global financial crisis. In 2013, Indonesia's gross domestic product (GDP) was around USD 1 281 billion, with a per-capita GDP of USD 5 097. The manufacturing industry was the largest contributor to GDP in 2013, accounting for 21%; agriculture, forestry, and fishing delivered a combined share of 13%. The economy's main export products are mineral fuels, lubricants and related materials products (31% of total export value), followed by machinery and transport equipment products (12%) (BPS, 2015). Over the Outlook period, APERC analysis projects Indonesia's economic growth will increase 4.4% annually to reach USD 4 070 billion of GDP by 2040.

ENERGY RESOURCES

Indonesia is a major fossil fuel producer and exporter. It is the world's largest coal exporter (and the fourth-largest coal producer) and the seventh-largest liquefied natural gas (LNG) exporter (tenth-largest gas producer) (IEA, 2015a). Most crude oil is produced onshore from the Minas and Duri oil fields (on the eastern coast of central Sumatra), two of Indonesia's largest fields and both of which are considered

mature. The Duri field has undergone one of the world's largest enhanced oil recovery (EOR) efforts (Jakarta Post, 2012). Indonesia's crude oil production trend generally decreases due to maturing oilfields combined with a slower reserve replacement rate and decreased exploration and investment in the industry.

To boost oil and gas production, the Indonesian government is promoting exploration further offshore and in frontier regions. The government is also providing incentives to reduce risk, for example by giving a better equity split between the government and the contractor (the entitlement of the contractor can be 30% to 35% for oil, up from the current entitlement of 20%, and 35% to 40% for gas, up from the current entitlement of 30%) along with an exemption of import duty and fiscal incentives. It has also taken steps to simplify the process of obtaining permits by establishing a 'one-stop service permit and licensing'. Three major oil projects are ongoing: Banyu Urip in Java with a maximum capacity of 165 000 barrels of oil per day (bbl/d); Bukit Tua with a maximum capacity of 20 000 bbl/d; and Ande-Ande Lumut with a capacity of 20 000 bbl/d (Widjonarko, 2013). As the number of new exploration and production projects has been small relative to oil demand, the economy is expected to remain an oil importer in the long term.

Indonesia's large natural gas reserves are located in six main areas: near Arun in Aceh, around Badak in East Kalimantan, South Sumatra, the Natuna Sea, the Makassar Strait, and Papua. Smaller, offshore gas reserves are found in West and East Java (EIA, 2015). At present, 14 major natural gas projects are in operation, primarily deep water fields in the eastern part of Indonesia such as Indonesia Deepwater Development (IDD) Bangka, IDD Gendalo Hub, and IDD Gehem Hub (Widjonarko, 2013). The government is also promoting, exploration of coal-bed methane (CBM), which is currently estimated at 17.2 trillion cubic meters (tcm), and shale gas, estimated at 4.3 tcm (DJMG, 2014). Contracts of CBM blocks, mainly in Sumatra and the Kalimantan islands, were first awarded to investors or developers in 2007. For shale gas, two contracts have been awarded to Pertamina (the state-owned oil and gas company) for the Sumbagut block in North Sumatra (IEA, 2015a). Further progress and success of these projects will depend on the regulation and support offered by the government. Without progress to increase gas production to meet high demand growth, Indonesia will begin to import natural gas in 2026 according to the APERC Outlook projection.

Indonesia is one of the world's leading coal producers, with lignite accounting for about 57% of total recoverable reserves, followed by sub-bituminous (27%), bituminous (14%) and anthracite (<0.5%) (Table 7.2). Most of the coal reserves are in South Sumatra and East Kalimantan, with relatively small deposits in West Java and Sulawesi. While Indonesian coal's heating value can range from 5 000 to 7 000 kilocalories per kilogram, it is generally distinguished by its low ash and sulphur content (typically less than 1%). Coal production in Indonesia grew at an AAGR of 14% in the past four years, with total production reaching 458 million tonnes (Mt) in 2014, of which some 83% was exported (the rest being used for domestic demand) (Gushka, 2015).

Table 7.2 ● Indonesia: Energy reserves and production, 2014[1]

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Coal (Mt)[a]	28 017	61	3.1	10th	5th
Oil (billion bbl)[a]	3.7	12	0.22	27th	9th
Gas (tcm)[a]	2.9	39	1.5	14th	5th
Uranium (kt U)[b]	6.3	N/A	0.17	24th	7th

Notes: [a]Total proven coal/oil/gas reserves are generally taken to be those quantities that geological and engineering information indicated with reasonable certainty can be recovery in the future from known deposits under existing economic and operating conditions. [b]Uranium reserves are 'reasonably assured resources' reference year for uranium reserve and production is 2013.
Sources: For oil, coal and gas, BP (2015); for uranium, NEA (2014).

[1] The BP Statistical Review of World Energy 2015 and the Nuclear Energy Agency's Uranium 2014 are used as standardised sources of energy reserves and production for comparative purposes.

Renewables are abundant in Indonesia.[2] Based on 2014 data from the Ministry of Energy and Mineral Resources, diverse sources show strong potential including geothermal (29 gigawatts [GW]), hydro (75 GW), wind (62 GW of commercial potential) and biomass for electricity (33 GW). Theoretical potential also exists for ocean wave (142 GW) and ocean thermal (4.2 GW), while solar potential irradiation is between 2.6 kilowatt-hours per square metre (kWh/m^2) and 5.8 kWh/m^2 (DJEBTKE, 2014).

ENERGY POLICY CONTEXT

Indonesia's current National Energy Policy (NEP) was formulated under Government Regulation No. 79 of 2014. The NEP is based on the principles that energy management should be equitable, sustainable and environmentally friendly, and should support energy self-reliance and energy resilience. To encourage the use of domestic resources to meet Indonesia's energy needs, the government uses policy instruments such as energy pricing, subsidies and incentives, particularly for renewables. It also supports research and development (R&D) to help commercialise specific energy technologies. To secure the economy's energy needs, the government will implement policies to gradually decrease fossil energy exports (particularly gas and coal) and also to reduce fuel oil and electricity subsidies.

The NEP also sets development priorities for energy resources, encouraging exploitation and use of renewables and coal, as well as optimising gas use while minimising oil use. The policy identifies nuclear as the last energy option, after carefully considering the safety factor. The NEP sets out the ambition to transform, by 2025 and 2050, the primary energy supply mix with shares as follows:

- new and renewable energy at least 23% in 2025 and at least 31% in 2050;
- oil should be less than 25% in 2025 and less than 20% in 2050;
- coal should be minimum 30% in 2025 and minimum 25% in 2050; and
- gas should be minimum 22% in 2025 and minimum 24% in 2050.

In addition, the NEP established an economy-wide target with several components including: reduce the energy elasticity target to less than 1 in 2025; reduce final energy intensity by 1% annually up to 2025; achieve an electrification rate of 85% in 2015 and nearly 100% in 2020; and achieve a gasification rate in households of 85% in 2015. According to 2014 data, the electrification rate was 84.4% (DJK, 2015) while the gasification rate still lagged behind the 81.7% target (PERTAMINA, 2014).

A new policy on fuel subsidies came into effect on 1 January 2015, which ends government subsidies for gasoline types with an octane number of 89 RON (called 'Premium' in Indonesia's market). The policy also applied a fixed subsidy (USD 0.07 per litre) for diesel oil types with an octane number of 48 (called 'Solar' in Indonesia's market). The government expects this policy will reduce fuel consumption, thereby helping to reduce fuel imports.

To better ensure that coal exports comply with the regulation and also optimise the state revenue from coal exports, the government has created a registry of coal exporters. Companies wanting to export coal must register and also pay the royalties before shipping coal. To better control actual shipping, the government also plans to reorganise the numerous coal ports into 14 official coal ports (to date, no progress on implementing this plan is evident). The value-added policy on coal includes the development of mine mouth power plant,[3] which the government is accelerating through special pricing that allows producers to add a 25% margin to total mining production costs. As part of increasing investment in the mineral and coal sector, the government has reduced the number of permits available from 62 permits to 18, to provide more investment and legal certainty to investors, and reduce approval times which previously experienced delays.

[2] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.
[3] Mine mouth power plant is the coal-fired power plant, which is using low-rank coal located around the coal mine mouth to eliminate coal transportation needs.

To accelerate development and use of geothermal energy for electricity generation, the government issued the New Geothermal Law No. 21/2014 on 17 September 2014, which removed a previous restriction on geothermal development in protected forest areas. Under the new law, the required permit has been changed from a 'Geothermal Mining Permit' to a 'Geothermal Permit'; this opens the possibility to obtain from the Ministry of Forestry an 'environmental service use permit', which can be applied to areas categorised as production, protection and conservation forests. The new regulation also gives the central government authority to set the tariff on geothermal electricity, to conduct tenders on geothermal working areas (GWA), to issue 'geothermal permits' and to offer incentives to developers. Previously, these activities and authorities were carried out by the central or local government, according to their respective jurisdictions.

BUSINESS-AS-USUAL SCENARIO

This section examines Indonesia's energy demand and supply under the Business-as-Usual (BAU) Scenario, which is based on key assumptions and existing policies that are expected to apply over the Outlook period (Table 7.3).

Table 7.3 • Indonesia: Key assumptions and policy drivers under the BAU Scenario

Buildings	• Implement energy performance standards and labelling programs currently being considered.
Industry	• Implement energy management systems and energy audit programs currently being considered. • Implement an economy-wide standard ISO 50001 on energy management system and system optimisation.
Transport	• Low saturation level of road vehicle ownership. • Limited deployment of hybrid and electric vehicles (EVs). • Increase biofuels blends, based on historical trends. • Apply fuel efficiency standards only for specific vehicles.
Energy supply mix	• Increase shares of renewables and coal. • Reduce share of oil.
Power mix	• Expand use of coal, gas and renewables. • Reduce use of oil. • Nuclear development is not considered.
Renewables	• No target set for renewable energy; construction will proceed on committed projects.
Energy security	• Optimise self-sufficiency for oil, gas and renewables.
Climate change	• Carbon dioxide (CO_2) emission reduction is considered within the implementation of energy efficiency and conservation programs.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

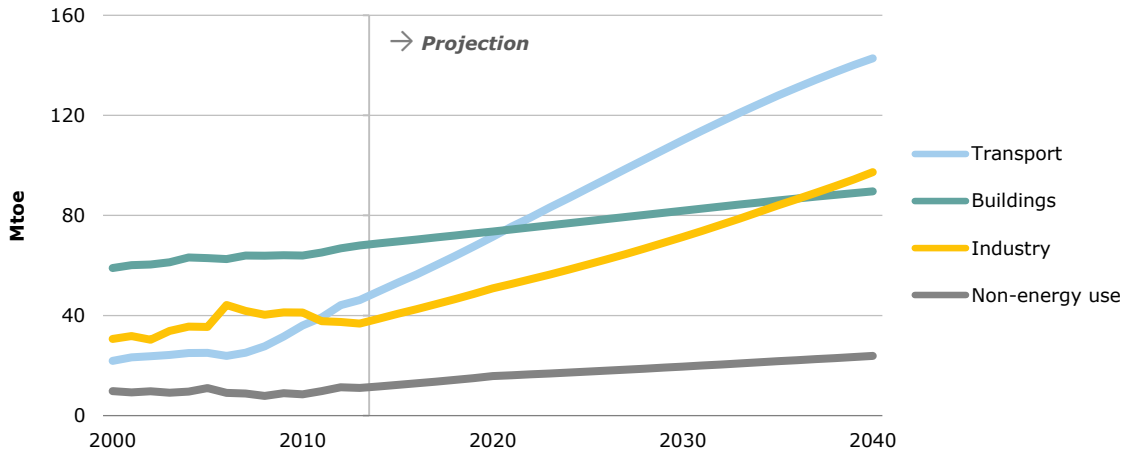
RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

According to the NEP, Indonesia aims to reduce energy final intensity by 1% annually up to 2025. The government is pursuing various energy efficiency and conservation programs across all sectors, including public awareness campaigns, standards and labelling, partnership programs for energy audits, smart street lighting, and human resource development. Those efforts will contribute to the Asia-Pacific Economic Cooperation (APEC) goal of reducing energy intensity by 42% in 2035 (from the 2005 level).

Considering that Indonesia's GDP grows 4.4% annually and final energy demand rises 2.9% over the period 2005 to 2035 under the BAU Scenario, the economy's final energy intensity of GDP falls from 166 tonnes of oil equivalent (toe) per unit of GDP to 96 toe in 2035. This translates to a 42% intensity reduction over the 30-year period, contributing to the regional APEC energy intensity goal.

In absolute terms, final energy demand under the BAU increases from 162 million tonnes of oil equivalent (Mtoe) in 2013 to 354 Mtoe in 2040 (an AAGR of 2.9%), with demand rising across all sectors. Demand shares, however, are expected to shift. With a share of 42%, buildings and agriculture was the largest end-use sector in 2013, followed by domestic transport (29%) (Figure 7.1). By 2040, domestic transport shows an AAGR of 4.3% and overtakes as the largest (40%) end-use, while industry AAGR of 3.7% bumps it to second place (28%). Stronger buying power of the population is boosting car ownership and driving the increase in domestic transport energy demand, along with expansion of automobile manufacturing and the recent launch of a low-cost green car policy (Bappenas, 2015). Industrial slowdown in Indonesia, reflecting on going recovery from the global economic crisis in 2009, has resulted in energy demand growth being lower in industry than in transport.

Figure 7.1 • Indonesia: Final energy demand by sector, 2000-40



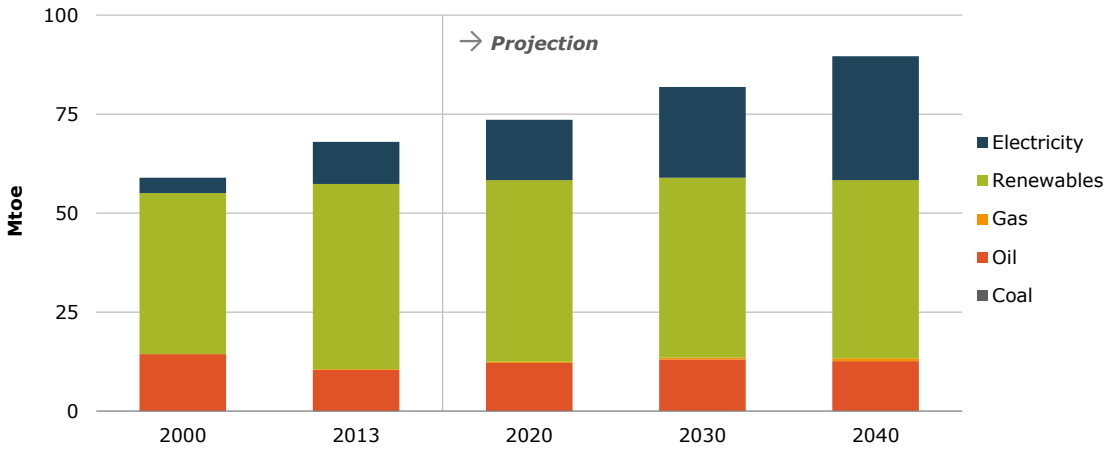
Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

Buildings and agriculture energy use: Biomass continues to dominate

Under the BAU, energy demand in the buildings and agriculture sector in Indonesia increases from 68 Mtoe in 2013 to 90 Mtoe in 2040, reflecting an AAGR of just 1% (Figure 7.2). Energy demand in residential buildings is below this average (0.6%), influenced by a similarly low (0.5%) AAGR in the population. As half of Indonesia's population still lives in rural areas, renewable biomass remains the primary residential energy source (DEN, 2015), even though the use of liquefied petroleum gas (LPG), natural gas and electricity grows. In line with a positive economic outlook, the commercial buildings sector grows more rapidly (AAGR 4.3%), primarily through development of hotels, offices and property. Demand will largely be met through electricity and oil. Oil will remain dominant in the agriculture sector, particularly for light equipment such as tractors and water pumps for irrigation.

In 2013, the share of renewables in buildings and agriculture was 69%, followed by electricity (16%), oil (15%) and gas (0.3%). The fuel demand mix for the sector changes over the Outlook period due to urbanisation. Estimating that around 67% of the population will become urbanised by 2035 (DEN, 2015), the government has implemented three programs targeting the residential sector: 1) a kerosene to LPG conversion program, which was started in 2007; 2) a city gas program, launched in 2009; and 3) an electrification program that aims to boost the access level to nearly 100% in 2020 (KESDM, 2014b). The most rapid demand growth (4.7%) is in gas (to reach 0.74 Mtoe) and coal (to 0.033 Mtoe) in 2040, followed by electricity (4.1% AAGR to reach 31 Mtoe). Both renewables and oil decline over the Outlook period. As a result, the shares of energy demand by fuel type will change dramatically by 2040 with renewables falling to 50% while electricity doubles to 35%; the share of oil declines slightly (14%) while gas (0.8%) and coal (0.2%) rise slightly from a low base.

Figure 7.2 ● Indonesia: Buildings and agriculture sector final energy demand, 2000-40



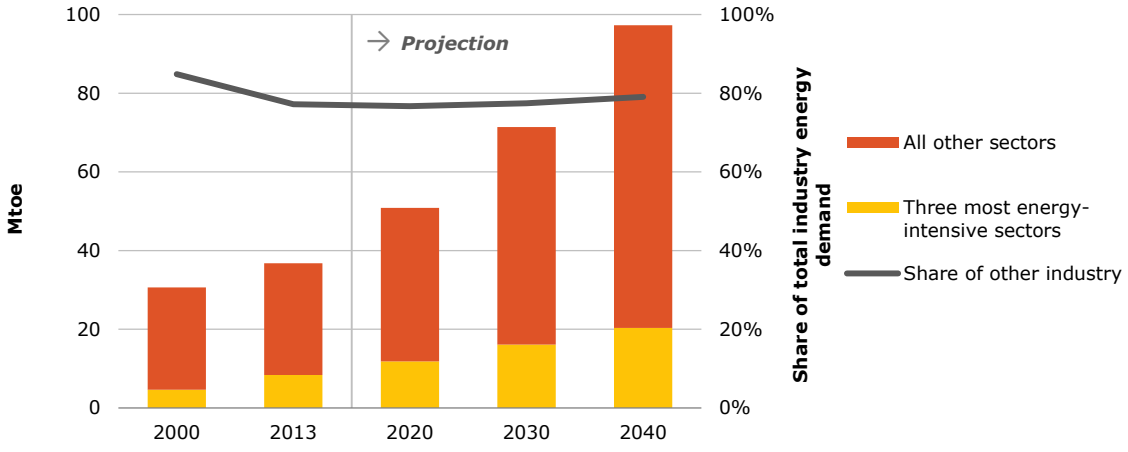
Sources: APERC analysis and IEA (2015a).

Industry energy use: Less energy-intensive industries drive demand growth

Industry plays a fundamental role in Indonesian economic growth, and could become more important in the future. Its contribution, particularly in non-oil and gas industry, to GDP reaches 30% by 2020 under the BAU (Kemenperin, 2015a). In 2013, the manufacturing industry was the largest contributor (21%) to the economy's GDP (BPS, 2015).

Industrial energy demand in Indonesia increases at an AAGR of 3.7%, from 37 Mtoe in 2013 to reach 97 Mtoe in 2040 (Figure 7.3). Less energy-intensive sub-sectors (textile and leather production, mining of metals and quarry, food and tobacco, and construction) dominate, consuming about 79% of total industry energy demand. Energy demand in the three most energy-intensive sub-sectors (iron and steel, chemical and petrochemicals, and non-metallic minerals including cement) grow 3.3% per year to reach 20 Mtoe in 2040.

Figure 7.3 ● Indonesia: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.
Sources: APERC analysis and IEA (2015a).

To stimulate energy efficiency and conservation (EE&C) in industry, the government has initiated different programs. Under an energy conservation partnership program, free energy audits were conducted of 805 companies in 2013-14. The government also provided support for certification of 151 energy managers and 74 energy auditors. With the support of the UN Industrial Development Organization (UNIDO), Indonesia has also implemented the ISO 50001 economy standard on energy

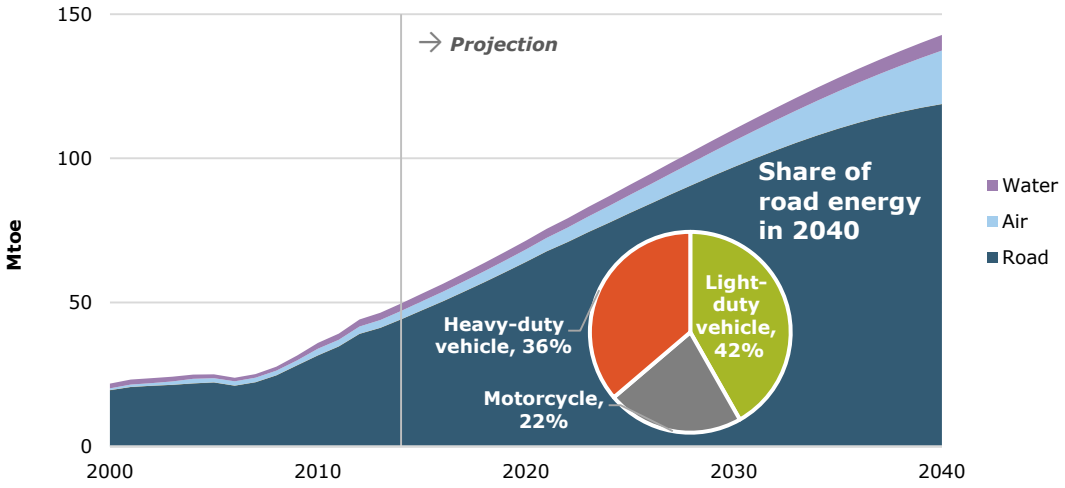
system management and system optimisation, targeting four industries (textiles, pulp and paper, food and beverage, and chemical). The program will be expanded to also cover the fertiliser, ceramic and glass, power generation, and automotive industries. In power generation and industry, the government intends to launch online reporting to monitor EE&C implementation and is preparing regulations to support development of energy service companies (ESCOs) (Feby Misnah, 2015).

Transport energy use: Green policies help counter impact of growing demand

In an effort to promote cleaner personal transportation, the Indonesian government launched (in 2012) a new policy called 'Low Cost Green Car' (LCGC). The program provides tax incentives (such as zero luxury goods tax and exemption from import duty) to reduce the price of cars that meet the minimum fuel oil (or other fuel equivalent) consumption of 20 km/litre and the minimum specifications Research Octane Number (RON) 92 for gasoline and Cetane Number (CN) 51 for diesel. The government also set up a small green vehicle class with a maximum price of around USD 7 000 (IDR 95 million) (Kemenperin, 2015b). Sales of LCGCs jumped from 51 180 vehicles in 2013 to 172 120 cars in 2014—an increase of 236%—accounting for 14% of sales (Gaikindo, 2015). At 84 vehicles per 1 000 people, the saturation of vehicle ownership in Indonesia was only 18% in 2013. As the economy accelerates, vehicle ownership increases at an AAGR of 5.8% to reach 384 vehicles per 1 000 people in 2040, with total vehicle stock rising to 112 million vehicles and saturation reaching 82%. As a result, transport energy demand increases more than threefold from 47 Mtoe in 2013 to 146 Mtoe in 2040 (Figure 7.4).

In 2013, road transport accounted for about 89% of domestic transport energy demand, with light-duty vehicles (LDVs) consuming 23%, heavy-duty vehicles (HDVs) (45%) and motorcycles (32%). The LDV percentage share increases to 42% by 2040, with HDV and motorcycle shares declining. Since the government introduced deregulation in air transport in 2001, rapid growth of low-cost airlines has suppressed water transport, which is increasingly used for freight or passengers only in areas not covered by airlines. By 2040, domestic air travel will account for 13% of transport energy demand, while water transport will have only a modest (4%) share.

Figure 7.4 ● Indonesia: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

In an effort to diversify fuels in the transport sector and address climate change, the Indonesian government has established a policy to promote, produce and use biofuels, which includes a minimum biofuels blend rate mandate and target. As of April 2015, the new minimum blend rate mandate is for 1% bioethanol with gasoline (E1) and 15% biodiesel with diesel (B15) (KESDM, 2015). By 2025, the blend rates will increase to E20 (20%) for bioethanol and B30 (30%) for biodiesel. To improve the competitiveness of biofuels with gasoline and diesel, the government has provided fiscal incentives such as exemptions on value-added tax (VAT) and on import duty; direct subsidies on retail prices for the transport sector; investment tax incentives; and interest rate subsidies for biofuel feedstock plantation.

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Oil maintains dominance, coal remains fuel of choice for new power plants

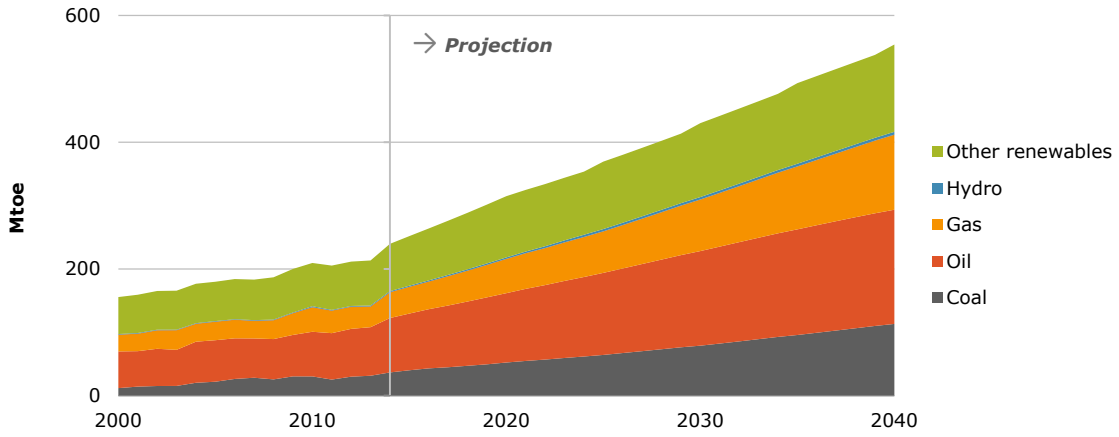
Data from the Ministry of Energy and Mineral Resource show that total primary energy supply (TPES) in Indonesia was 226 Mtoe in 2013, having had an AAGR of 3.8% since 2000. Oil (38%) still dominated the primary energy mix, followed by coal (25%), renewables (19%), natural gas (15%) and hydro (3%) (KESDM, 2014a). In line with rising final energy demand, the Outlook projects that Indonesia's TPES will more than double, reaching 554 Mtoe in 2040 (Figure 7.5). Oil (32%) will still dominate in 2040, but other shares will change as natural gas (21%) overtakes coal (20%), and the shares of renewables (25%) and hydro (1%) decline.

Natural gas grows the most quickly, at 4.9% AAGR, reaching 118 Mtoe in 2040, largely to meet demand in industry for chemical and petrochemical, textiles and power generation. Coal will have the second-fastest growth, at AAGR 4.8% to reach 113 Mtoe in 2040, mainly for power generation (coal-fired power plant capacity increases at 5% AAGR) and for cement, paper, and textile sub-sectors. While oil shows slower growth (3.2% AAGR to reach 180 Mtoe), it remains the dominant share of TPES, driven by rapid demand growth from transport.

Indonesia's archipelago geography and the dispersed nature of its gas reserves complicate fuel transport; this challenge is mitigated through a combination of LNG facilities and a localised pipeline network. Currently, Indonesia has three LNG liquefaction facilities in operation (Arun, Bontang and Tangguh) and one under construction (Donggi–Senoro). In anticipation of rising domestic demand, especially from islands lacking their own natural gas sources, two floating storage and regasification units (FSRU) are in operation (FSRU Lampung and FSRU Nusantara Regas), and 9 more will be constructed by 2030, along with 61 land-based regasification units (Cahyono Adi, 2015).

Indonesia's natural gas pipeline network is currently operated by three large gas transmission system operators: PGN and Pertagas (which are both state-owned), and Transportasi Gas Indonesia (TGI) (60% owned by PGN). PGN owns and operates the high-pressure pipeline network in South Sumatra, North Sumatra and West Java (total length of about 2 300 km). Pertagas owns and operates approximately 1 600 km of pipeline network across South Sumatra, West Java, Banten, East Java, North Aceh, North Sumatra and East Kalimantan. TGI operates the only cross-border natural gas pipeline, which runs from the Natuna Islands of Riau and South Sumatra across the Strait of Malacca to Singapore (IEA, 2015a).

Figure 7.5 • Indonesia: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

To capture the potential of its abundant renewable energy resources, Indonesia has set a target that renewables (including biomass) will have a 26% share in TPES by 2025. Hydro power under the BAU increases at an AAGR of 4.2% to reach 4.4 Mtoe in 2040; other renewables increase twofold from

71 Mtoe in 2013 to 137 Mtoe in 2040. Indonesia's target that new and renewable sources will reach at least 23% share in TPES by 2025 will be achieved under the Outlook projections.

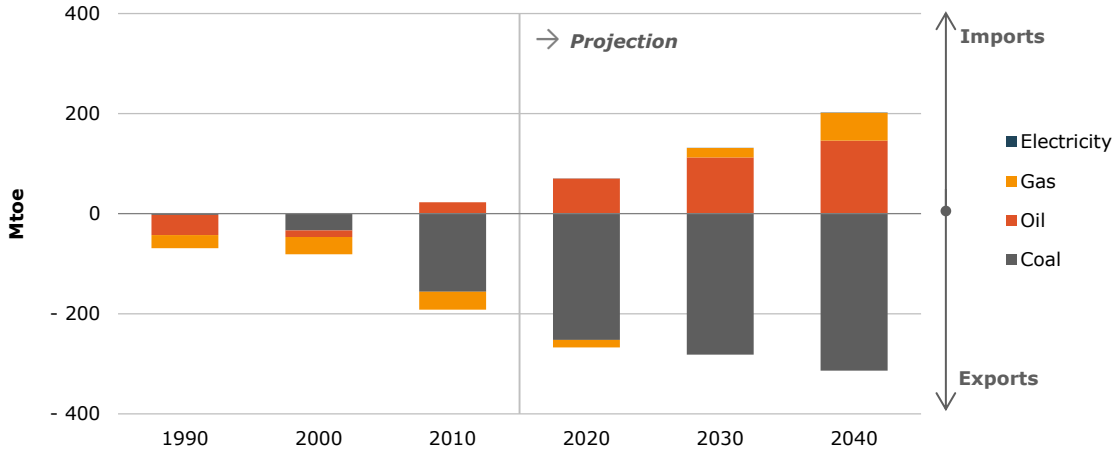
Energy trade: Coal exports remain vital as Indonesia becomes a gas importer after 2020

To keep pace with demand and reduce imports, the Indonesian government is actively increasing fuel production. Four new oil refineries will be developed by 2025, with total capacity of 518 000 bbl/d. Two new refineries, Cilacap and Eretan (212 000 bbl/d) will be located in Java islands, the Medan refinery (6 000 bbl/d) in Sumatra island, and the Bontang refinery (300 000 bbl/d) in Kalimantan island. Under this plan, Indonesia's refinery capacity could reach 1 687 000 bbl/d by 2025—about 44% above current capacity (Cahyono Adi, 2015).

Indonesia's crude oil production tends to decrease continually over the Outlook period. To meet the high oil demand projected under the BAU, Indonesia remains an oil importer. In fact, imports increase at an AAGR of 5.4% to reach 146 Mtoe in 2040 (from 35 Mtoe in 2013), at which time 81% of Indonesia's oil supply will come from imports (Figure 7.6).

Indonesia's gas supply shows a different situation under the BAU, as the economy continues to produce and export gas until 2025. Thereafter, Indonesia begins importing natural gas—unless the new gas projects now being developed show significant progress. In 2040, Indonesia is projected to require 118 Mtoe of gas while production is only 63 Mtoe, meaning 47% of gas demand will need to be imported. The main challenges of upstream gas development in Indonesia are offshore locations and deep sea exploration in the eastern region, which require large capital and advanced technology.

Figure 7.6 • Indonesia: Net energy imports and exports, 1990-2040



Sources: APERC analysis and IEA (2015a).

Coal production in Indonesia is strong due to high demand and large reserves. Reflecting recent implementation of a coal production control policy, over the Outlook period coal production grows (AAGR 1.6%) to reach 427 Mtoe in 2040 from 281 Mtoe in 2013. Considering domestic coal consumption is still lower than production, Indonesia remains a coal exporter over the Outlook period, with coal exports growing at 0.9% AAGR. In 2013, 85% of Indonesia's total coal production was exported, mainly to India, China, Japan and Korea (DEN, 2015).

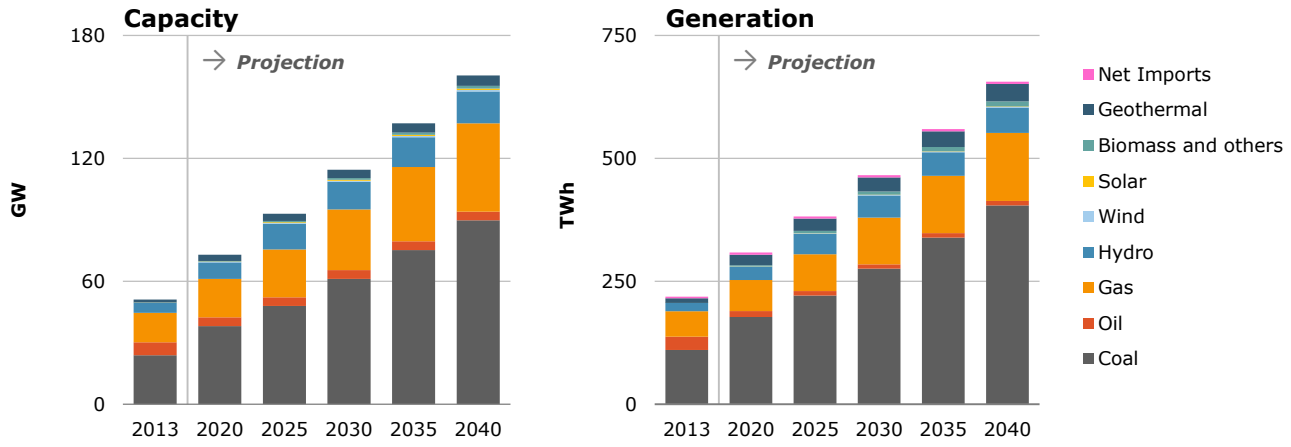
Power sector trends: Coal still the preferred investment choice for thermal power plants

Indonesia has among the lowest rates of electrification and per-capita electricity consumption in APEC. In 2014, 84.4% of households were electrified, but per-capita consumption remained low at only 865 kWh (DJK, 2015), compared with an APEC average of 5 032 kWh. Annual electricity consumption growth has been high (7.8%) over the past five years (2008-13) (DJK, 2014). Anticipating a surge in electricity demand, Indonesian authorities launched (in 2015, to be completed by 2019) a 35 GW Electricity Program for Indonesia, building on the success of the 10 000 megawatt (MW) Accelerated Power Program rolled out in 2006 (Phase 1) and 2010 (Phase 2). Considering that 7.4 GW of power plants are already under construction, the new project (actually 35.5 GW) boosts capacity to be developed by 2019 to 42.9 GW. Around 60% of the additional capacity will come from coal-fired plants.

To realise such an ambitious program, the government has put in place policies to support land acquisition for projects of public interest (which will be secured by the government according to the land law), to establish ceiling prices for electricity purchase, and to streamline the procurement and permitting processes.

Under the BAU, Indonesia's power capacity increases from 51 GW in 2013 to 160 GW in 2040, while power generation increases at an AAGR of 4.2% from 219 terawatt-hours (TWh) in 2013 to 656 TWh in 2040 (Figure 7.7). Coal and gas are the preferred investment choices for thermal power plants, especially since Indonesia has vast but under-utilised coal deposits. The economy is projected to add 66 GW of coal-fired capacity and 29 GW of gas-fired by 2040, boosting coal to the highest share in the generation mix (from 51% in 2013 to 62% by 2040) while drastically shrinking the share of oil (from 12% in 2013 to 1.4% by 2040). This aligns with the government policy to eliminate oil-based power plants, except in areas where no competitive alternative is available (isolated and remote areas as well as small islands) (PLN, 2015).

Figure 7.7 ● Indonesia: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

Policy for renewable energy development and use in Indonesia is mainly dedicated to enhancing energy security, sustaining socio-economic development and addressing climate change. To promote development of renewables and improve their competitiveness against fossil fuels, Indonesia has set medium- and long-term targets, a feed-in tariff (FiT) scheme for selected technologies, and fiscal incentives such as exemption from taxes. In line with government policy, hydro and other renewables (in the form of solar, wind, geothermal and biomass) are expected to contribute an increasing share to the generation mix over the Outlook period, reaching 16% by 2040. Electricity generation from hydro will grow at 4.2% AAGR, reaching 51 TWh in 2040, while other renewables grow at an AAGR of 6.1% to reach 48 TWh. Geothermal remains the second largest renewable generation source growing from 9 TWh in 2013 to 35 TWh in 2040.

ALTERNATIVE SCENARIOS

All three alternative scenarios, the Improved Efficiency Scenario, the High Renewables Scenario and the Alternative Power Mix Scenario apply to Indonesia, including all four cases of the Alternative Power Mix Scenario.[4]

Among the alternatives, the Improved Efficiency Scenario demonstrates the largest impact, delivering the lowest energy-related CO_2 emissions and having a relatively lower average generation cost for power. The power generation fuel input mix is also more diversified under this scenario than under the BAU.

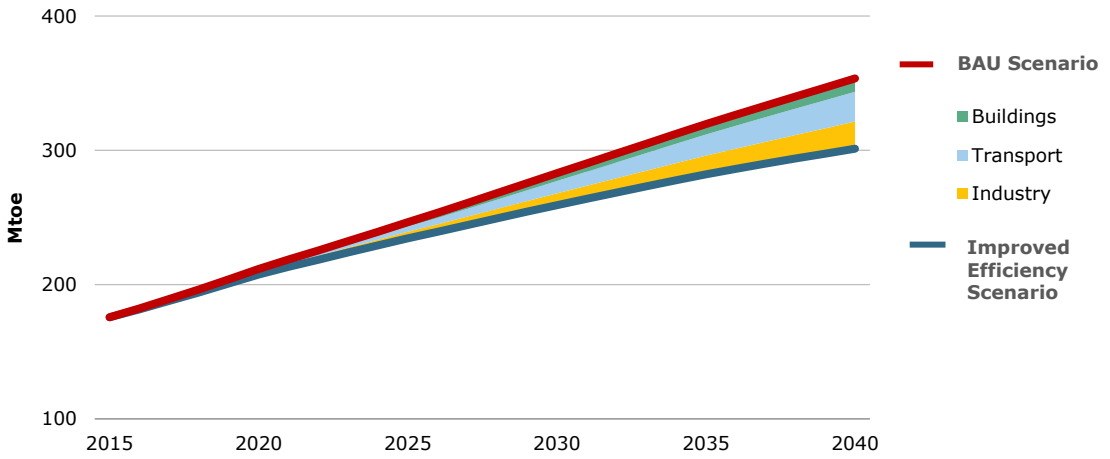
IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

The Improved Efficiency Scenario models the potential for the APEC region to achieve the APEC energy intensity goal.[5] The Improved Efficiency Scenario demonstrates energy demand savings of nearly 15% over the BAU Scenario. The largest savings (22 Mtoe) are in domestic transport, with vehicle stock being 24% lower than under the BAU in 2040 (Figure 7.8). These savings can be achieved only if Indonesia develops better urban planning, including better public transportation, to lower vehicle saturation and avoid congestion.

Industry provides the second-largest contribution (20 Mtoe) to total energy savings in 2040, through uptake of best available technologies, more effective energy management and increased efficiency in equipment. Other less intensive industry (e.g. textiles and food processing) delivers the largest share (88%) of industry energy savings, followed by chemicals and petrochemicals (4%), non-metallic minerals including cement (6%), and iron and steel (1%). Application of ISO 50001 Energy Management Standards and System Optimisation Frameworks, coupled with energy management services and energy audit programs, are vital measures to help realise these energy savings.

Adoption of more efficient appliances plays a key role in achieving 10 Mtoe of energy savings in the buildings sector in 2040. The larger share (72%) comes from residential, and the rest (28%) from commercial.

Figure 7.8 ● Indonesia: Potential energy savings in the Improved Efficiency Scenario, 2015-40



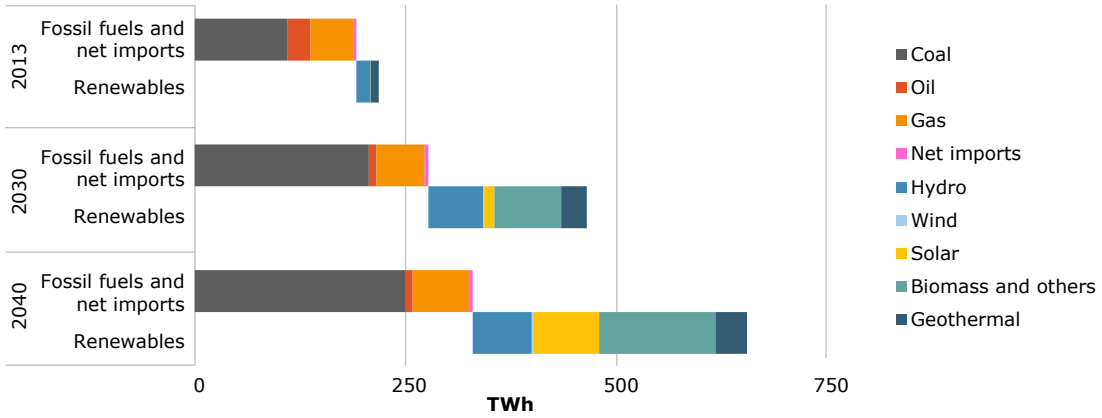
Source: APERC analysis.

[4] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.
[5] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

The High Renewables Scenario models the APEC doubling renewables goal, focusing on the power and the transport sectors only.[6] The High Renewables Scenario assumes that the government's renewable generation target is met and uses the levelised cost of electricity (LCOE) to identify potential for additional renewable generation. Under this scenario, LCOE is lowest for hydropower (USD 0.043/kWh), geothermal (USD 0.049/kWh) and biomass (USD 0.063/kWh), which contributes to a steady evolution in power generation. In 2030, hydro generation accounts for 14% of total generation under the High Renewables Scenario, compared with 9.6% under the BAU (Figure 7.9). Biomass accounts for 17% (1.4% under the BAU) in 2030 and geothermal 6.5% (6.1% under the BAU). As the costs of power generated from solar photovoltaic (PV) and wind decline globally, uptake increases although shares remain low in 2030 (2.6% for solar and 0.25% for wind) under this Scenario. In 2030, total renewables generation reaches 188 TWh under this Scenario compared with 81 TWh under the BAU, or 40% of total generation, compared with the BAU's 18%.

Figure 7.9 ● Indonesia: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

The target for renewable power generation in Indonesia remains unclear. Officials from the Directorate General of New, Renewable Energy and Energy Conservation (DGNREEC) state capacity targets of new and renewable power plants: hydro at 25.7 GW in 2030 and 27.4 GW 2040; geothermal at 5.2 GW in 2030 and 6.1 GW in 2040; biomass at 13.1 GW in 2030 and 26.7 GW in 2040; and solar at 9.8 GW in 2030 and 78 GW in 2040, with the addition of 1.5 GW of wind by 2040 (DJEBTKE, 2015). These targets (particularly for solar capacity) differ from National Energy Council projections, the agency responsible for preparing the NEP (DEN, 2014). As mentioned above, under the High Renewables Scenario, APERC assumes the DGNREEC capacity targets for 2030 and 2040 will be achieved. Electricity generation from renewables in the High Renewables Scenario reaches 326 TWh in 2040, from 100 TWh in the BAU, to account for 50% of total generation. Biomass accounts for 21% of total generation, followed by solar (12%) and hydro (11%).

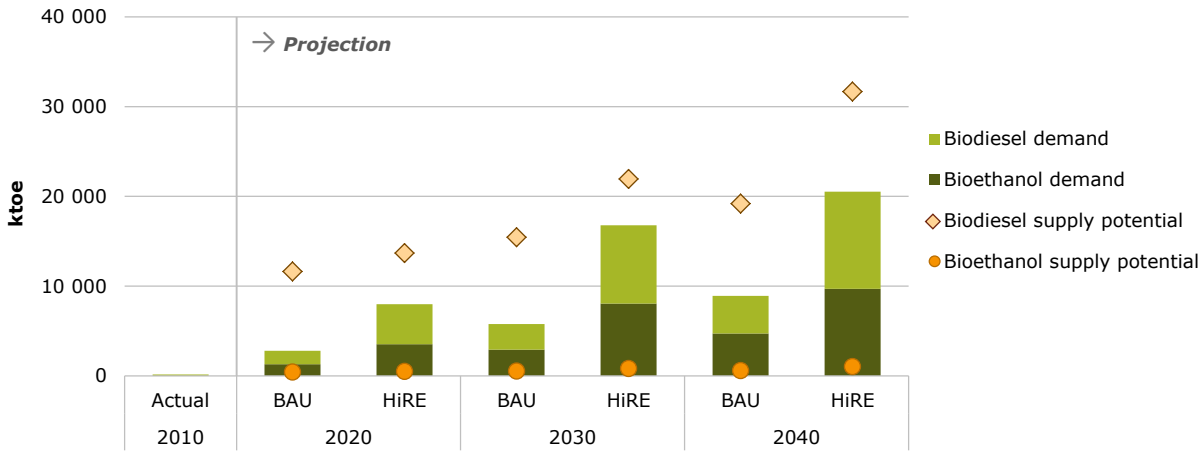
In transport under the BAU Scenario, the share of biofuels in total transport energy demand is 5.2% in 2030 (which follows the historical trend to achieve blend rates of 7% for bioethanol and 8% for biodiesel), and is significantly higher than the 0.48% in 2010 (Figure 7.10).

As of 2015, the Indonesian government's biofuel targets are 20% bioethanol blend and 30% biodiesel blend by 2025 (maintained through the Outlook period) (KESDM, 2015). Under the High Renewables Scenario biofuel's share of total transport energy demand increases by almost 8-fold to 15% in 2030

[6] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

from 2010 levels. Demand for biofuels will increase from 0.17 Mtoe in 2010 to 17 Mtoe in 2030 and 21 Mtoe in 2040, with biodiesel accounting for a slightly larger share (52% in 2030 and 53% in 2040). Both bioethanol and biodiesel register AAGRs of about 11% over the Outlook period. Indonesia has sufficient feedstock potential from agriculture to produce biodiesel at this rate, but not bioethanol. Government support is needed, however, to attract investors and developers to biofuels production (particularly bioethanol).

Figure 7.10 ● Indonesia: Biofuels demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is for the Outlook period only; HiRE = High Renewables Scenario.
Sources: APERC analysis, KESDM (2013b), FAO (2014) and IEA (2015a).

ALTERNATIVE POWER MIX SCENARIO

The Alternative Power Mix Scenario illustrates the potential impact of having cleaner coal, more gas and higher nuclear contributions in the power generation mix, and their respective impacts on energy-related CO_2 emissions. All four Alternative Power Mix Scenario Cases apply to Indonesia: Cleaner Coal, High Gas 50%, High Gas 100% and High Nuclear.

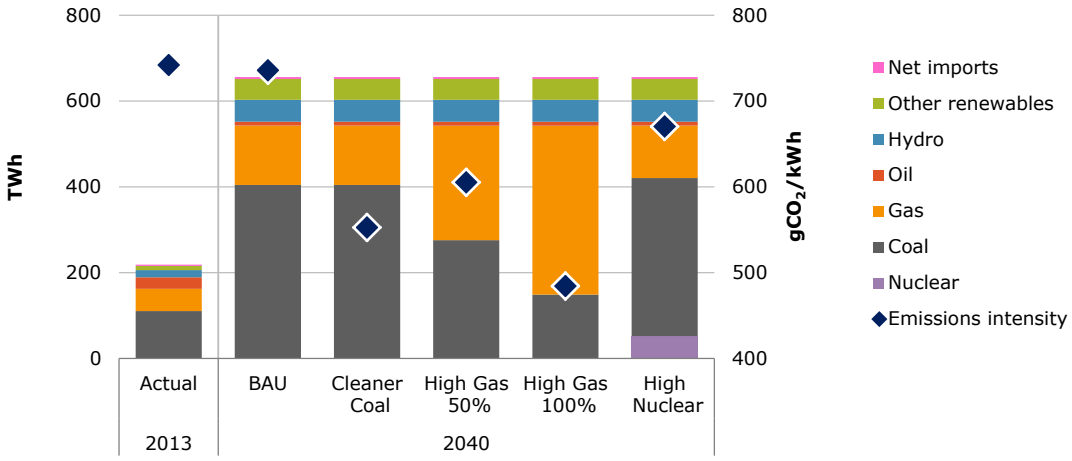
The Cleaner Coal Case assumes that from 2021 all new coal-based generation capacity is supercritical (SC) or ultra-supercritical (USC), and after 2035 all new coal plants have carbon capture and storage (CCS) capability. The share of coal in power generation remains the same as in BAU, reaching 60% by 2040, but these changes result in lower energy-related CO_2 emissions (Figure 7.11). Despite the higher capital cost of more advanced coal technologies, the average generation cost is projected to decrease from USD 114/MWh in 2013 to USD 104/MWh in 2040, the same as under the BAU. The decreasing average cost may reflect more efficient power generation, requiring lower fuel consumption. Under the Cleaner Coal Case, CO_2 emissions from electricity generation decrease to 360 $MtCO_2$ in 2040 compared with 479 $MtCO_2$ under the BAU.

The High Nuclear Case assumes that Indonesia will develop 1 GW of nuclear power by 2030 and then expand capacity rapidly to 3 GW by 2035 and 7 GW by 2040, compared with no nuclear in the BAU. At USD 91/MWh in 2040, this case delivers the lowest average generation cost. It also substantially reduces energy-related CO_2 emissions from electricity generation, which reach 436 $MtCO_2$ by 2040, or 9% lower than under the BAU.

From a base of 14 GW in 2013, gas capacity will need to be expanded substantially by 2040 to reach 69 GW in the High Gas 50% Case and 96 GW in the High Gas 100% Case. The share of gas to total power generation in 2040 will be 41% in the High Gas 50% Case and 60% in the High Gas 100% Case, compared with 21% under the BAU. Average generation costs of USD 110/MWh under High Gas 50% and

High Gas 100% are higher than in the BAU in 2040 but slightly higher 2013 average generation costs. In 2040, High Gas 50% will produce electricity generation CO_2 emissions of 394 $MtCO_2$, (18% lower than the BAU) while High Gas 100% produces only 315 $MtCO_2$ (34% lower than the BAU).

Figure 7.11 ● Indonesia: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

To achieve the lowest average cost of power generation, Indonesia would need to pursue nuclear power. However, the NEP clearly states this to be 'the last option' due to safety considerations (KESDM, 2014b). Higher use of gas presents its own challenges, particularly high costs (and thus high pricing) as gas reserves are predominantly offshore in the eastern region and gas infrastructure is lacking (SKK Migas, 2015). These factors are coupled with abundant coal reserves that can be developed at low cost, which are pushing Indonesia towards increasing coal-fired generation (DJK, 2015). To minimise the associated CO_2 emissions, the government has established a Roadmap of Clean Coal Technology in Indonesia with aims to develop SC/USC plants and also integrated gas combined cycle (IGCC) plants (DJK, 2015).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

To build up the infrastructure needed to meet growing energy demand, Indonesia requires total investment ranging from USD 661 billion to USD 1 684 billion from 2015 to 2040 (Table 7.4). The largest shares of investment need to be directed towards upstream production and development (61% under the low-cost estimate and 67% under the high-cost estimate) and power generation (26% and 18%, respectively).

The downstream sub-sector covers refinery capacity additions needed to maintain the current share (60% in 2013) of refinery production to total domestic oil demand over the Outlook period. Indonesia needs to construct new refinery capacity of 1.0 million bbl/d by 2040. Unless significant progress is made on projects currently under development, the economy might have to import natural gas. Energy transport for oil, gas and coal (from source to ports or end-use facilities) will demand around 7% of total investments in the low-cost and the high-cost estimates.

Table 7.4 ● Indonesia: Projected investments in the energy sector in the BAU Scenario, 2015-40

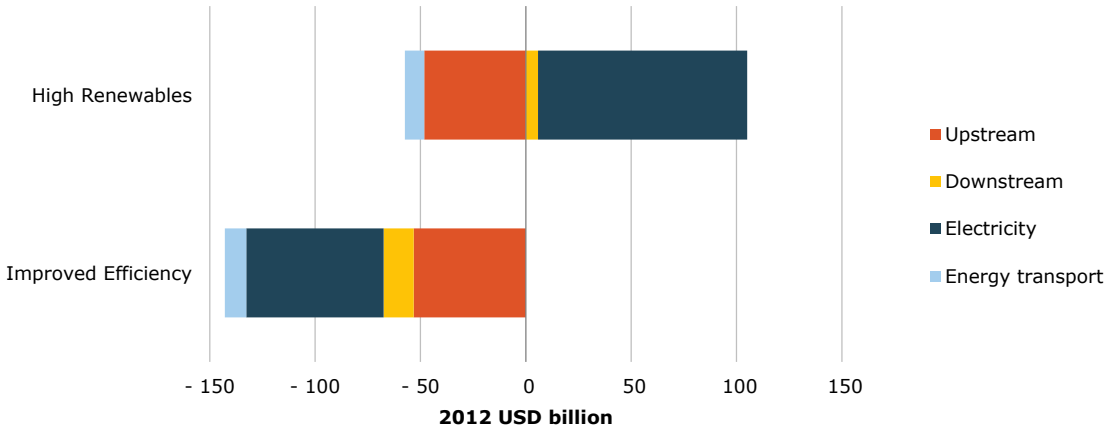
2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	98	148
	Gas	54	162
	Coal	253	823
	Subtotal	406	1 133
Downstream	Refinery	21	104
	LNG import terminals	4.1	9.0
	LNG export terminals	4.5	8.1
	Biofuels Refinery	7.6	11
	Subtotal	37	132
Electricity	Coal	84	129
	Gas	22	25
	Hydro	15	24
	Wind	1.3	1.6
	Solar	1.6	2.2
	Biomass and others	2.7	3.6
	Geothermal	7.9	10
	Transmission lines	18	44
	Distribution lines	19	62
	Subtotal	171	301
Energy transport	Oil	1.3	2.6
	Gas	23	64
	Coal	22	52
	Subtotal	47	119
	Total	661	1 684

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

With electricity generation projected to increase by about threefold, investment will be needed to fund 109 GW of additional capacity, including expansion and refurbishment of transmission and distribution (T&D) networks.

Figure 7.12 ● Indonesia: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.

Source: APERC analysis.

The Improved Efficiency Scenario leads to investment savings of USD 143 billion compared with the BAU low-cost estimate, primarily because the 15% reduction in final energy demand lowers the need for additional power generation capacity (requiring only 65 GW) (Figure 7.12). The need for additional T&D networks declines correspondingly.

The investment requirement rises by USD 48 billion under the High Renewables Scenario (compared with the low-cost estimate from the BAU), with power generation accounting for much of the increase due to additional renewables capacity. Required average investment in power jumps by 99 USD billion due to higher costs associated with increased generation capacity from renewables. Specifically, significant increases by 2040 in solar and biomass power will drive up investment needs, as will the need to invest in electricity storage capacity to optimise solar generation and biomass power.

Downstream investment requirements increase by USD 5.8 billion in the High Renewables Scenario as higher blend rates increase demand for biofuels and subsequently for additional refinery capacity of about 67 million litres per day, a 120% increase from the BAU.

SUSTAINABLE ENERGY FUTURE

Indonesia's NEP specifically states that energy management should be 'equitable, sustainable and environmentally friendly to the creation of the self-reliance of energy and energy resilience'. To this end, the government will encourage the use of domestic resources to meet domestic energy needs by supporting increased use of new and renewable energy, gradually decreasing fossil energy exports and reducing the subsidies allocated for oil and electricity. Additionally, the government has set targets to transform the primary energy mix by 2025 and 2050, focusing on minimising the development and use of oil, optimising coal and gas, and maximising renewable energy.

Enhancing energy security: Higher diversity, but substantial drop in self-sufficiency

In terms of primary energy supply diversity, higher renewable shares in the energy mix under the BAU Scenario will help improve the Herfindahl-Hirschman Index (HHI) rating from HHI 0.29 in 2013 to HHI 0.26 by 2040, where a lower number indicates improved diversity (Table 7.5). The economy's level of energy self-sufficiency, however, will drop significantly from 84% in 2013 to 64% by 2040 as sharply rising demand (particularly of oil and gas) means 36% of energy will need to be imported.

Table 7.5 ● Indonesia: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040						
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%	High Nuclear
Primary energy supply diversity (HHI)	0.29	0.26	0.26	0.28	0.25	0.26	0.28	0.25
Primary energy supply self-sufficiency (%)	84	64	68	70	64	59	53	65
Coal self-sufficiency (%)	100	100	100	100	100	100	100	100
Oil self-sufficiency (%)	55	21	24	22	21	21	21	21
Gas self-sufficiency (%)	100	53	68	63	53	43	36	55
Electricity generation input fuel diversity (HHI)	0.31	0.38	0.37	0.45	0.38	0.32	0.33	0.33

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

The NEP target to minimise the use of oil, particularly in transport, is well supported by mandates to increase minimum biofuel blend rates and phase out fuel subsidies. To counter declining gas self-sufficiency—from 100% to 53% under the BAU by 2040—the government needs to create an attractive investment climate to boost exploration and development of new gas resources.

Overall, the Improved Efficiency and High Renewables Scenarios both have higher energy supply self-sufficiency rates and provide greater energy security for Indonesia than the BAU or the Alternative Power Mix Scenarios. The government would do well to pursue a combination of these scenarios, which ultimately aligns with the NEP target to maximise renewable energy development and use to satisfy energy demand while also encouraging energy conservation through various programs.

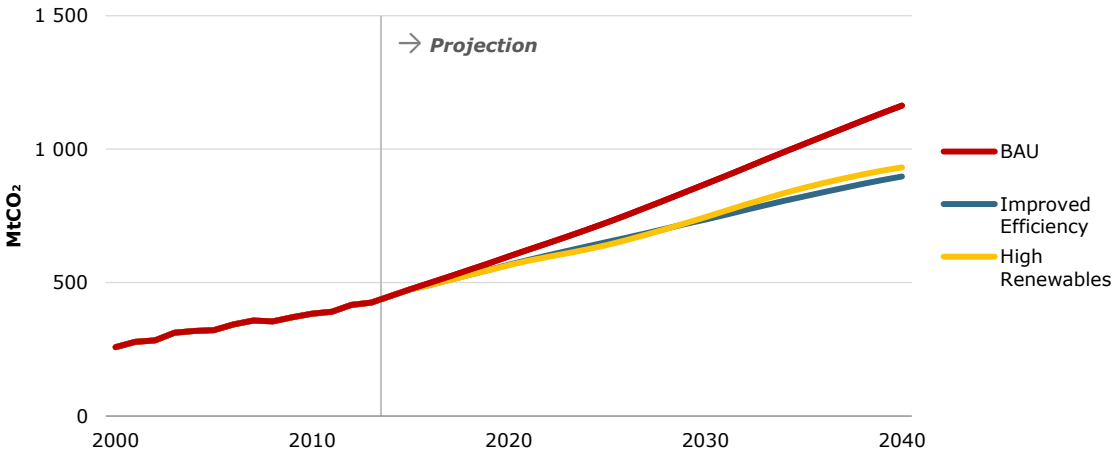
Climate change impacts and risks: Emissions rise with growing demand

Under its Intended Nationally Determined Contribution (INDC), Indonesia has unconditionally committed to reduce greenhouse gas (GHG) emissions by 26% by 2020 and by 29% by 2030 below 2010 levels (a proposed 41% reduction by 2020 is conditional on getting international support) (KLHK, 2015). The unconditional reduction is economy-wide; however, the agriculture, energy and transport, and industry sectors, which are the main energy consumers, contribute to only 6% (45 $MtCO_2$) of the total GHG emissions target of 767 $MtCO_2$ in 2020 (Bappenas, 2014). To achieve the INDC, the government needs to implement other measures since energy is not the main contributor to GHG emissions reduction.

Under the BAU Scenario, total energy-related CO_2 emissions from Indonesia's energy sector are expected to increase at an AAGR of 3.8%, from 425 $MtCO_2$ in 2013 to 1 163 $MtCO_2$ in 2040 (Figure 7.13). Continued dependence on coal makes electricity generation the highest contributor to rising CO_2 emissions at 41% of total emissions in 2040.

The Improved Efficiency Scenario delivers the greatest reduction in emissions at 23% (897 $MtCO_2$) compared with the BAU (1 163 $MtCO_2$) in 2040, followed by the High Renewables Scenario at 20% (931 $MtCO_2$). Within the Alternative Power Mix Scenario, the High Gas 100% Case provides the greatest reduction at 14% (999 $MtCO_2$), followed by the Cleaner Coal Case at 10% (1 043 $MtCO_2$).

Figure 7.13 ● Indonesia: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



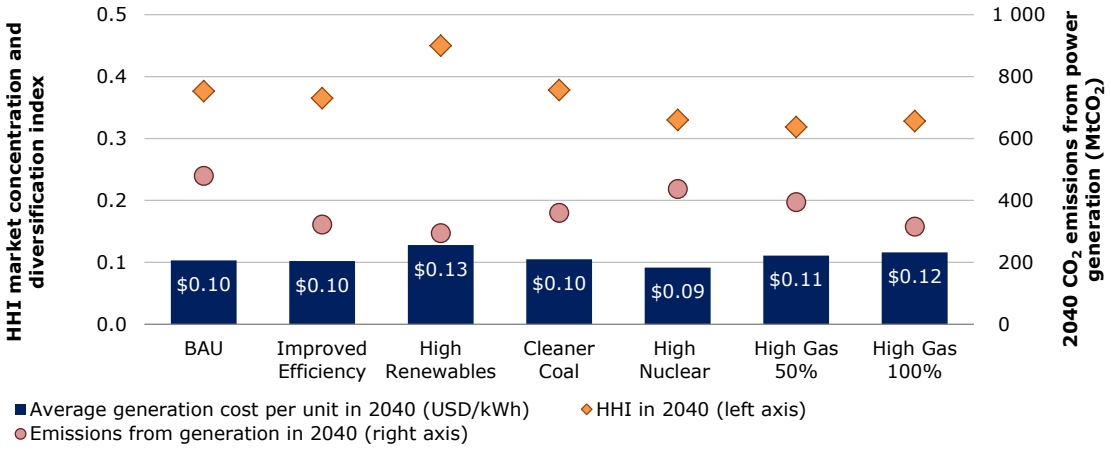
Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).

Sources: APERC analysis and IEA (2015b).

Trade-offs in the power sector in 2040: Improved Efficiency Scenario reduces costs and emissions

The scenarios presented in this Outlook provide insights into the trade-offs each represents in terms of average generation costs, emission level from the power sector and energy supply diversification (Figure 7.14). The High Gas 100% Case results in lower electricity generation CO_2 emissions, but has the second-highest generation costs. The High Renewables Case offers the lowest electricity generation CO_2 emissions level, while the need for storage for wind and solar pushes the average generation cost to the highest level. The Cleaner Coal Case offers the lowest generation cost, but with the second-highest HHI rating. The Improved Efficiency Scenario facilitates reduced energy demand; thus, even with the BAU fuel mix, it delivers lower generation costs and the second-lowest electricity generation CO_2 emissions level.

Figure 7.14 ● Indonesia: Generation trade-offs under the different Scenarios, 2040



Source: APERC analysis.

RECOMMENDATIONS FOR POLICY ACTION

Over the Outlook period, Indonesia's final energy demand will increase with oil remaining the dominant fuel, particularly in domestic transport. Considering the economy has become a net oil importer and import requirements are expected to increase, the government would do well to implement measures to reduce oil consumption, such as expanding the fuel efficiency standards that currently apply only to the 'Low Cost Green Car' program to other vehicles. Better urban planning, including better public transportation, could help restrain the expected rapid growth of vehicle ownership and thus road congestion.

In response to high electricity growth and to increase the electrification rate, Indonesia is likely to develop more coal-fired power plants under the BAU Scenario. To reduce associated GHG emissions, it is strongly recommended that Indonesia pursue clean coal technology, including CCS, both for new power plant projects and to replace old plants.

High installation and generation costs, particularly for solar and wind power, remain a hurdle to developing renewable energy in Indonesia. Policy support is needed to reduce generation costs and establish the renewable industry.

8. JAPAN

KEY FINDINGS

- **Total final energy demand is projected to fall** due to Japan's declining population and modest economic growth, as well as continuous, intensive efforts to improve energy efficiency in the transport and buildings sectors. Japan's energy intensity on a total final energy demand basis improves by 39% from 2005 to 2035.
- **The BAU Scenario implies long-term energy security challenges to Japan.** The economy's energy self-sufficiency rate (including nuclear as quasi-domestic energy) is projected to improve as nuclear power restarts and renewables expand. In the long term, however, nuclear retirements due to the '40-year lifetime rule' increase dependence on fossil fuels, lowering the self-sufficiency rate by 2040.
- **To meet Japan's INDC target, further policy actions are necessary to accelerate energy efficiency improvements and the deployment of low-carbon technologies.** The energy-related CO_2 emissions reductions in the BAU Scenario are well below the INDC target. However, Japan can achieve its target under the Improved Efficiency Scenario through additional energy efficiency and low-carbon measures.
- **Japan has the potential to contribute significantly to the APEC energy intensity goal and the APEC renewable energy goal.** The Improved Efficiency Scenario and High Renewables Scenarios respectively show the pathways towards '45% energy intensity improvements' by 2035 from 2005 levels and to 'more than doubling the renewables share in Japan's electricity and transport sector' by 2030 from 2010 levels.

ECONOMY AND ENERGY OVERVIEW

Japan's gross domestic product (GDP) reached USD 4 633 billion in 2013, the third-largest in the world after the United States and China (World Bank, 2015). The service sector accounted for approximately three-quarters of total GDP in 2013, followed by the manufacturing sector at about 20% (CAO, 2015a). Under the Business-as-Usual (BAU) Scenario, GDP is projected to grow, at 1.1% per year on average to 2040, while Japan's population, which has been declining since 2008, is expected to fall to 114 million by 2040 due to increasingly low birth rates. It is important to note here that the definition of the BAU Scenario in this Outlook is different from the Japanese Government's Long-Term Energy Demand and Supply Outlook (the government's outlook) published in July 2015 (for detail, see Energy Policy Context below). The BAU Scenario in this Outlook is based on existing policies, while the government outlook includes new policies and ambitious assumptions as well; for example, the projected GDP growth above is lower than the government's outlook as the government's outlook assumes a 'revitalised economy' (1.7% per year on average).

Despite being the third-largest economy in the world, Japan depends on other Asia-Pacific Economic Cooperation (APEC) economies and countries for its energy supply because its domestic energy sources are very limited. Diversifying fuel sources has been Japan's main strategy for improving energy security since the two oil crises in the 1970s. Japan lowered oil dependence from 72% of total primary energy supply (TPES) in 1970 to 41% in 2010[1]; coal's share of TPES grew to 23%, gas's share to 17% and nuclear's share to 15% by 2010 (IEA, 2015a).

Table 8.1 ● Japan: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	3 701	4 146	4 510	4 633	4 994	5 679	6 246
Population (million)	122	126	127	127	125	120	114
GDP per capita (2012 USD PPP)	30 273	32 976	35 419	36 488	40 017	47 241	54 625
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	439	519	499	455	454	439	410
TPES per capita (toe)	3.6	4.1	3.9	3.6	3.6	3.7	3.6
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	298	341	322	311	308	294	277
Final energy intensity per GDP (toe per 2012 USD million PPP)	80	82	71	67	62	52	44
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	1 049	1 157	1 126	1 235	1 088	997	970
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	100	100	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.
Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

The Fukushima Daiichi nuclear power accident in March 2011 made it more difficult for Japan to pursue its '3E+S' policy – 'Energy security, Economic efficiency and Environment on the premise of Safety'. After all nuclear plants were shut down because of the accident's impact, the energy self-sufficiency rate (including nuclear energy) declined from 20% in 2010 to 6% in 2013 (IEA, 2015a). Electric power utilities

[1] The most recent year before the Fukushima Daiichi nuclear power plant accident in March 2011.

raised residential electricity prices by about 20% and industrial prices by 30% from fiscal year[2] (FY) 2010 to FY 2013, primarily because of additional fuel costs (METI, 2015a). In addition, energy-related CO_2 emissions in 2013 increased by 18% from 1990 and 3% from 2005, to reach about 1 235 million tonnes of carbon dioxide $MtCO_2$/year (IEA, 2015b).

ENERGY RESOURCES

Japan has limited indigenous fossil fuel resources, resulting in its low energy self-sufficiency rate (6.1%). Japan's estimated domestic coal reserves are about 350 million tonnes (Mt), equivalent to only twice 2013 annual consumption, and natural gas reserves are 20 billion cubic metres (bcm), only one-fifth of 2013 annual consumption (BP, 2015).

Japan has a variety of potential renewable energy sources, including solar, onshore/offshore wind, geothermal and hydro. However, it faces technical, environmental and economic challenges to developing renewables.[3] Of onshore wind installation potential, 75% is in Hokkaido and Tohoku, far from the major electricity consumption areas (MOE, 2013). More than 70% of geothermal potential is within Japan's National Park Areas, where environmental regulations limit constructing facilities (MOE, 2012). Government authorities are discussing how to overcome these barriers. The Ministry of Economy, Trade and Industry (METI) has reviewed the operation rules of inter-regional transmission lines to utilise renewable energy as well as ensure a stable electricity supply (METI, 2015b). In addition, the ministry has estimated transmission costs from wind resource locations to demand centres for future infrastructure enhancements. METI also financially supports utilities' demonstration projects for large-scale battery systems for renewable energy integration, including a demonstration of a redox flow battery system (60 megawatt-hours [MWh]) in the Hokkaido area and a lithium-ion battery system (20 MWh) in the Tohoku area (METI, 2015b). As for geothermal, the Ministry of the Environment (MOE) relaxed regulations in 2012 to allow horizontal directional drilling in Class II and Class III National Park Special Zones[4] (MOE, 2012). In October 2015, further deregulation conducted by MOE also allowed for horizontal directional drilling in the Class I National Park Zone (MOE, 2015).

ENERGY POLICY CONTEXT

METI is responsible for designing Japan's energy policy. In April 2014, the cabinet approved the revised Strategic Energy Plan, drafted by the Strategic Policy Committee of the Advisory Committee for Natural Resources and Energy, which is an advisory panel of METI. This is the fourth plan based on the 2002 Basic Law on Energy Policy, and provides general policy direction for Japan's energy sector after the Great East Japan Earthquake and the subsequent nuclear accident in March 2011.

The revised plan states that the period from 2014 to around 2018 to 2020 is devoted to reforming the electricity and gas systems into a more liberalised and competitive energy market (METI, 2014a). Electricity system reform after the earthquake focuses mainly on three stages: 1) establishing the Organisation for Cross-regional Coordination of Transmission Operators (OCCTO)[5] in April 2015; 2) full retail competition from April 2016; and 3) legal unbundling of the transmission/distribution sector from 2020 and a transition to overall liberalisation of retail prices after the unbundling. To avoid a monopoly after retail liberalisation in 2016, retail tariffs of designated utilities will be regulated as a transitional measure, and then gradually deregulated after legal unbundling. Amendments to the Electricity Business Act for the three stages were enacted in November 2013, June 2014 and June 2015.

[2] The fiscal year in Japan starts on 1 April.
[3] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.
[4] National Park Areas are classified into three categories: Special Zone, Marine Park Zone and Ordinary Zone. Special Zone is further divided into Special Protection Zone, Class I Special Zone, Class II Special Zone and Class III Special Zone.
[5] OCCTO aims to promote the development of electricity transmission and distribution networks and to enhance the economy-wide function of balancing demand and supply in normal and emergency situations (METI, 2014b).

Amendments to the Gas Business Act were enacted in June 2015 to fully liberalise the gas retail market by about 2017 and to legally unbundle gas pipes owned by three city gas utilities, Tokyo Gas, Osaka Gas and Toho Gas, by April 2022 (METI, 2015c).

In general, however, market liberalisation leads utilities to pursue short-term gains. Without regulated tariffs, utilities are less inclined to make long-term investments in capital-intensive infrastructure, such as grid and nuclear power. In addition, future massive integration of renewables into the electricity market would lower the wholesale prices and capacity factor of fossil fuel plants, reducing the profitability of generation facilities and creating a further disincentive for investment. Japan needs to continue discussions about how to secure the long-term infrastructure capacity for a stable energy supply.

Under the latest Strategic Energy Plan, Japan will decrease nuclear dependence while strengthening energy efficiency and expanding renewable energy use. Accordingly, in July 2015, the Long-Term Energy Supply and Demand Subcommittee of the abovementioned Advisory Committee concluded Japan's Long-Term Energy Supply and Demand Outlook. The Committee projected energy demand to 2030 using macroeconomic indicators, and calculated total energy savings with a bottom-up estimation about sectorial savings potential. The government's outlook indicates an electricity mix, primary energy demand and supply, and energy-related CO_2 emissions (METI, 2015d), and aims to ensure the '3E+S' policy where 'Safety' is the foremost condition. It has three steps: 1) increase energy self-sufficiency (including nuclear as a quasi-domestic energy) to 24.3% from 6% in 2012; 2) lower electricity costs by 2% to 5% from 2013 fiscal year levels; and 3) reduce total greenhouse gas (GHG) emissions by 26% from 2013 fiscal year levels.

The government's outlook aims for a well-balanced power mix where nuclear accounts for 20% to 22% of total generated electricity, renewables for 22% to 24%, liquefied natural gas (LNG) for 27%, coal for 26% and oil for 3% (METI, 2015d). The share of nuclear is smaller than before the earthquake (when it was around 30%), thus lowering nuclear dependence. Within renewables, the two largest sources are hydro, accounting for 8.8% to 9.2%, and solar (7%).

The government's outlook assumes radical energy savings of 17% in electricity demand and 13% in final energy consumption from the baseline.[6] Economy-wide efforts—especially in the commercial and residential sub-sectors, which account for 47% of final consumption savings—are necessary to realise the government's outlook goals. Projected demand assumes a 1.7% economic growth rate based on the 'revitalised economy' policy (CAO, 2015b), which assumes higher growth than recent actual trends and the BAU Scenario in this Outlook.

[6] These savings are deducted from the denominator of the aforementioned energy and electricity mix in the government's outlook.

BUSINESS-AS-USUAL SCENARIO

The BAU Scenario in this Outlook is based on existing policies, which is different from the government's outlook published in July 2015 (METI, 2015d) that also includes new policies. For example, the BAU Scenario assumes a more conservative outlook for nuclear than the government's outlook (Table 8.2).

Table 8.2 ● Japan: Key assumptions and policy drivers under the BAU Scenario

Buildings	• Efficiency improvements of household and office appliances due to the Top Runner Program.
Industry	• Procurement boom in 2010s due to reconstruction from the Great East Japan Earthquake and Olympic Games. • Implementation of cost-effective technology improvements.
Transport	• Fuel economy improvements through Top Runner Program. • Biofuel supply mandate for oil refining companies.
Energy supply mix	• Continue policies to improve energy self-sufficiency.
Power mix	• Fossil fuel: gas-fired dominates new fossil fuel capacity additions based on power producer's plan as of 2015. • Nuclear: 40-year lifetime rule, except for reactors whose retirements have been announced or whose lifetime extensions are being examined by the Nuclear Regulation Authority (NRA) as of 2015. Additions of three new reactors under construction as of before the earthquake.
Renewables	• Feed-in tariff, but gradually reduce purchase prices.
Energy security	• Continue policies to decrease oil dependence and diversify fuel sources.
Climate change	• Work towards but not achieve the Intended Nationally Determined Contribution (INDC) target of 26% GHG emissions reduction (25% energy-related CO_2) by FY 2030 from FY 2013.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

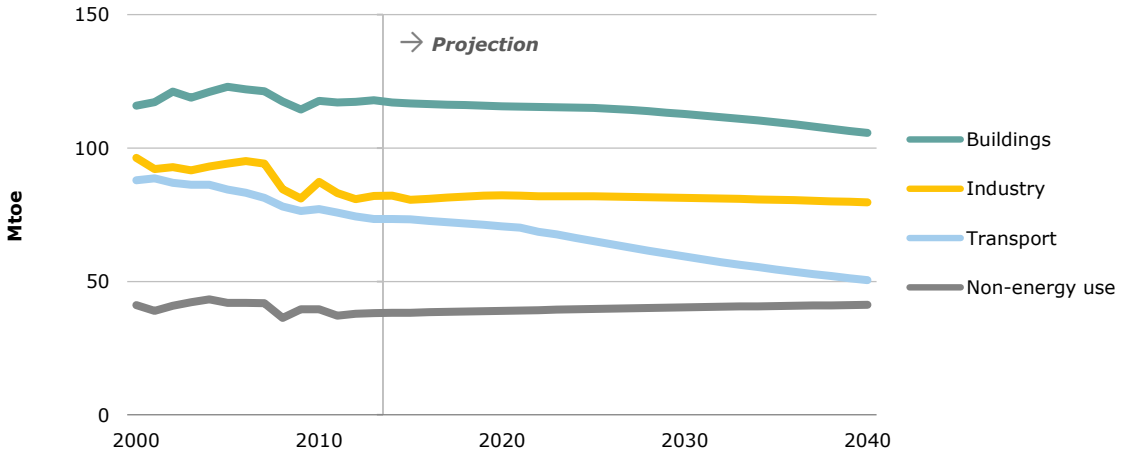
Japan relied heavily on oil for 72% of primary energy supply in 1970 (IEA, 2015a). During the oil crises of the 1970s, the government realised that its energy structure was fragile and that efficient energy use was vital. Japan therefore enacted the Energy Conservation Law in 1979, which contains energy efficiency standards. Final energy intensity improved by 35% from 1980 to 2012, due in particular to intensive efforts in industry. The industrial sector curbed final energy demand by 43% from FY 1973 to FY 2013, in terms of final energy demand per Indices of Industrial Production (IIP) (METI, 2015a). The buildings and transport sectors, by contrast, continuously increased final consumption except during the oil crisis periods (METI, 2015e). To further improve energy efficiency in these sectors, in 1998 Japan introduced the Top Runner Program, which covers more equipment and has higher standards than the Energy Conservation Law. Various kinds of appliances and equipment have shown large efficiency improvements.[7] Japan revised the Energy Conservation Law in 2013, widening the scope of the program to include construction materials[8] and energy-consuming equipment, such as refrigerators for commercial use, printers and light-emitting diode (LED) lamps. As of March 2015, the program expanded to 31 items, from 9 items in April 1998 when the program started (METI, 2015e).

Over the projection period, energy efficiency measures and modest economic growth result in a downward trend for final energy demand (Figure 8.1), from 311 million tonnes of oil equivalent (Mtoe) in 2013 to 277 Mtoe in 2040, at an average annual growth rate of -0.4%. This results in declining final energy intensity, from 67 toe per USD million in 2013 to 44 toe per USD million in 2040. Over the APEC energy intensity goal period (2005 to 2035), this reduction is equivalent to a 39% improvement,

[7] For example, from Japanese FY 2005 to Japanese FY 2010, electric refrigerators for residential use achieved a 43% efficiency improvement, larger than the initial expectation (21%). Although air conditioners (ACs) (non-ducted/wall-mounted AC units, 4 kilowatts [kW] or less) did not reach the expectation (22.4%), the appliance has shown a 16.3% improvement.
[8] The standards for insulation materials were specified.

contributing towards the APEC-wide target.[9] The demand decline is driven by the transport sector, in which demand decreases by 31% from 2013. Demand in the buildings sector also drops by 10%, but this sector still retains a dominant share at around 40% of total final demand. The industry sector shows small changes compared with the transport and building sectors.

Figure 8.1 ● Japan: Final energy demand by sector, 2000-40

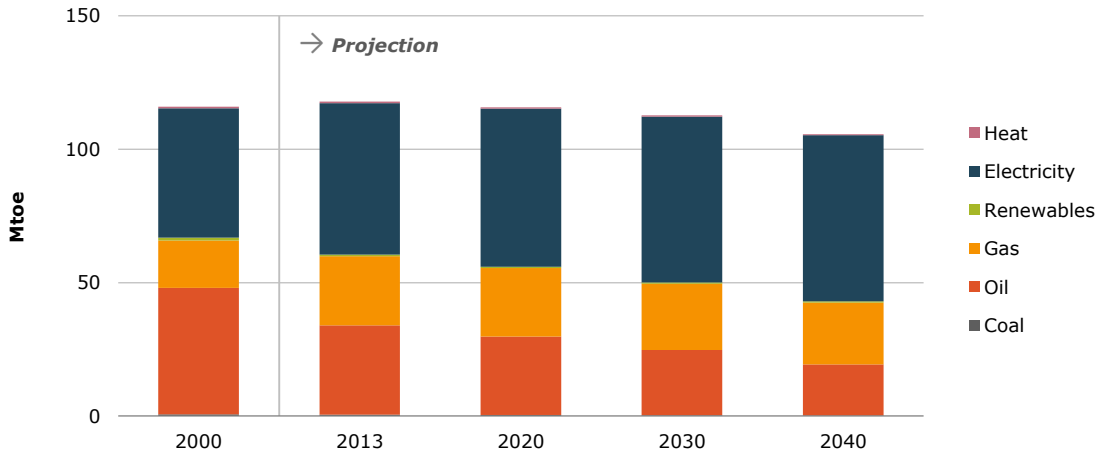


Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

Buildings energy use: Fuel shifts to electricity and efficiency measures succeed

The residential and commercial sub-sectors retain the dominant share of energy demand in the buildings sector, with residential buildings accounting for 39% (46 Mtoe) and commercial for 57% (67 Mtoe) in 2013 (IEA, 2015a). Other non-specified buildings and agriculture account for the remainder. The Top Runner Program has helped improve energy efficiency in buildings significantly.[10]

Figure 8.2 ● Japan: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

The Top Runner Program continues to curb overall energy demand over the projection period. By 2040, energy demand is expected to decline by about 16% in residential and by 4% in commercial buildings. Both the residential and the commercial sub-sectors become more electricity-intensive over the projection period. Buildings' share of electricity demand increases from about half in 2013 to 60% in 2040; in contrast, the sector's share of oil demand drops from about 30% to 20%. One of the main

[9] The APEC energy intensity goal is an APEC-wide collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.
[10] See Footnote 7.

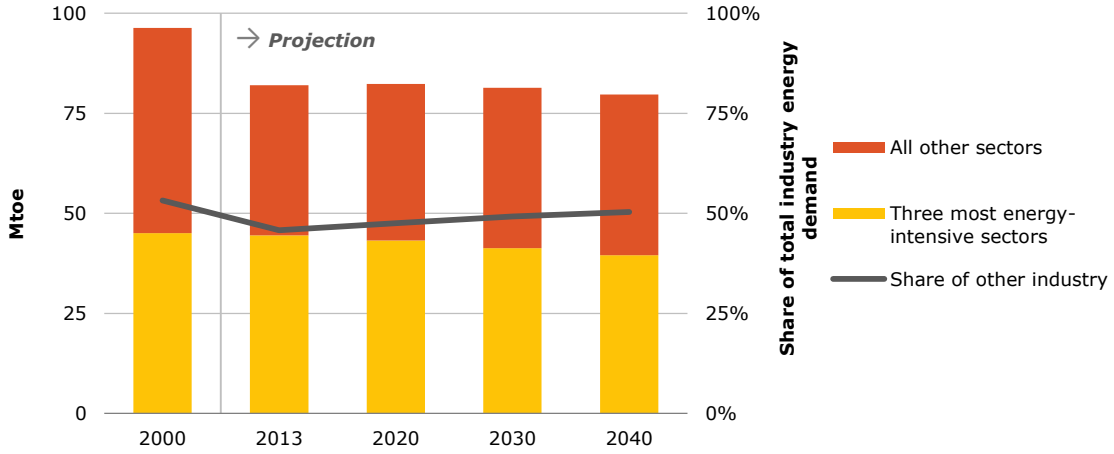
causes is energy source shifting, mainly for space heating, from oil products (such as kerosene for oil heaters) to electricity for air conditioning. Higher penetration of household appliances and office equipment also pushes up buildings' share of electricity. Gas consumption jumped from 18 Mtoe in 2000 to 26 Mtoe in 2013 due to the deployment of gas cogeneration facilities for air conditioning and hot water supply in the commercial sub-sector.

Industry energy use: Holding steady

Japan's industrial demand dropped from 2000 to 2013 mainly due to the global financial crisis in 2008 and the earthquake in 2011. Industrial demand declined in 2008 by 10% compared with the previous year, from 94 Mtoe to 85 Mtoe (IEA, 2015a). Demand recovered after the recession, but the earthquake pushed the sector's energy demand down again, to 82 Mtoe in 2013.

Industrial energy demand is projected to remain close to the 2013 level, with an increase of 0.054% per year from 2013 to 2020 and a decline of 0.16% on average per year from 2020 to 2040. Overall average annual growth rate (AAGR) is -0.11% per year. With the Tohoku area still under reconstruction after the earthquake and Tokyo preparing to host the 2020 Olympic Games, large infrastructure investments are planned over the next few years. Energy demand in the construction sub-sector shows an 8% increase by 2020, the largest growth among the sub-sectors. In contrast, when reconstruction and the Olympics are over, total industry energy demand flattens and then declines because of the economy's structural issues, including a shrinking working-age population and low birth rates.

Figure 8.3 ● Japan: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.

Sources: APERC analysis and IEA (2015a).

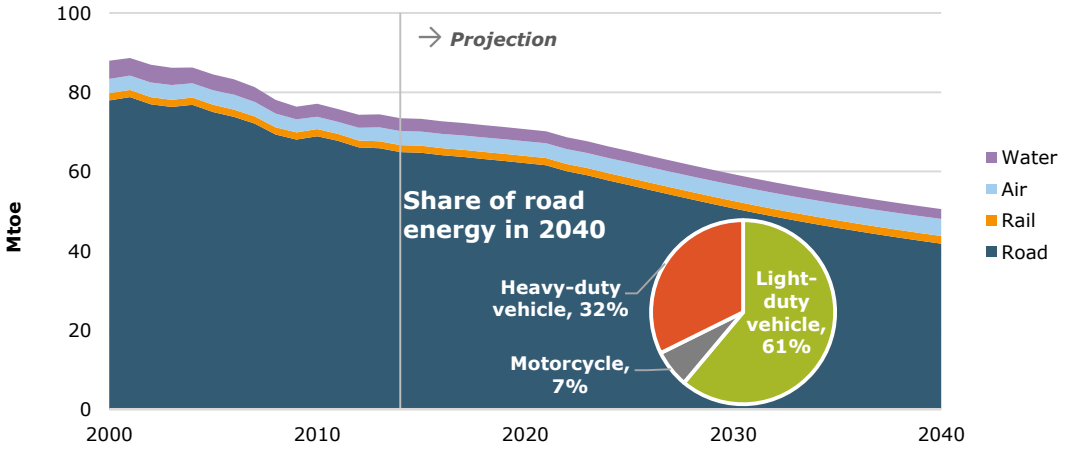
Transport energy use: Curbed thanks to fuel economy improvements

Road transport has been dominating transport energy demand in Japan. Over the last decade, fuel economy of both passenger and freight vehicles has shown large improvements under the Top Runner Program,[11] with transport energy demand peaking after 2001 (IEA, 2015a).

Over the Outlook period, further fuel economy improvements are expected under the program, while vehicle stock and average vehicle travel become saturated mainly due to the population structure. This results in the declining trend in total transport demand, in absolute terms, from 73 Mtoe in 2013 to 51 Mtoe in 2040, equivalent to an AAGR of -1.4%. In contrast with the changes in road transport, energy demand for water, air and rail transport remains close to current levels (together about 9 Mtoe).

[11] For example, from FY 1995 to FY 2010, fuel economy of passenger and freight vehicles improved by 48.8% and 13.2%, respectively.

Figure 8.4 ● Japan: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Gasoline and diesel fuel consumption declines in absolute terms, but still dominates total transport energy demand, at more than 90% over the projection period. Despite the modest impacts on total transport energy demand, gradual shifts to alternative-fuel vehicles[12] occur in light vehicles after 2020, reaching a share of 11% of light vehicle stock in 2040. The main alternative vehicle types are projected to be PHEVs and BEVs as they are compatible with existing infrastructure and as the economics of battery systems improve. Vehicle stock reaches 5.5 million for PHEV and 1.9 million for BEV by 2040.

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Continues to rely on fossil fuel

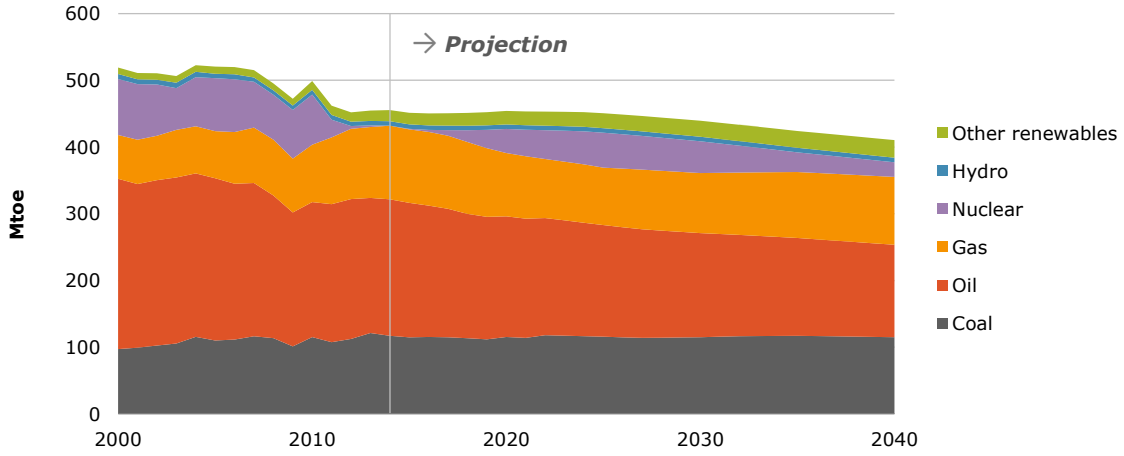
From 2000 to 2013, TPES showed two significant drops: in 2008 because of the economic recession and in 2011 because of the earthquake (IEA, 2015a). TPES decreased by 12% from 519 Mtoe in 2000 to 455 Mtoe in 2013. Non-fossil fuels, which accounted for 19%[13] in 2010, dropped to 5.4% in 2013 due to the earthquake and subsequent nuclear shutdown.

Under the BAU Scenario, Asia Pacific Energy Research Centre (APERC) analysis shows that continuous energy conservation efforts and energy efficiency improvements on the consumption side help to bring TPES down further, to 410 Mtoe by 2040. However, although Japan becomes a more energy-efficient economy and renewables expand in the electricity sector, the economy continues to rely on fossil fuels in the long term. The non-fossil share recovers to 18% in 2025 because of nuclear restarts, but the 40-year lifetime regulation for nuclear reactors is projected to push the share down to 13% by 2040. Renewables show strong growth in the power generation, driven mainly by solar photovoltaic (PV) power. This results in the increasing share of renewables in TPES, from 4% in 2010 to 7% by 2030 and 8% by 2040; however, the share still remains modest due to limited use of renewables in other sectors.

Among fossil fuels, oil supply decreases from 202 Mtoe in 2013 to 139 Mtoe in 2040, mainly because of fuel economy improvements in the transport sector, fuel shifting from oil to electricity in the buildings sector and a decline in oil-fired generation in the electricity sector. The trends in gas supply are driven by the power generation mix. Nuclear restart is expected to reduce the gas-fired generation currently utilised for base load, but again, nuclear retirements increase the need for gas after 2025.

[12] Plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), fuel cell vehicles, clean diesel vehicles, liquefied petroleum gas (LPG) vehicles and compressed natural gas (CNG) vehicles.
[13] Of which nuclear accounts for 15%.

Figure 8.5 • Japan: Total primary energy supply by fuel, 2000-40



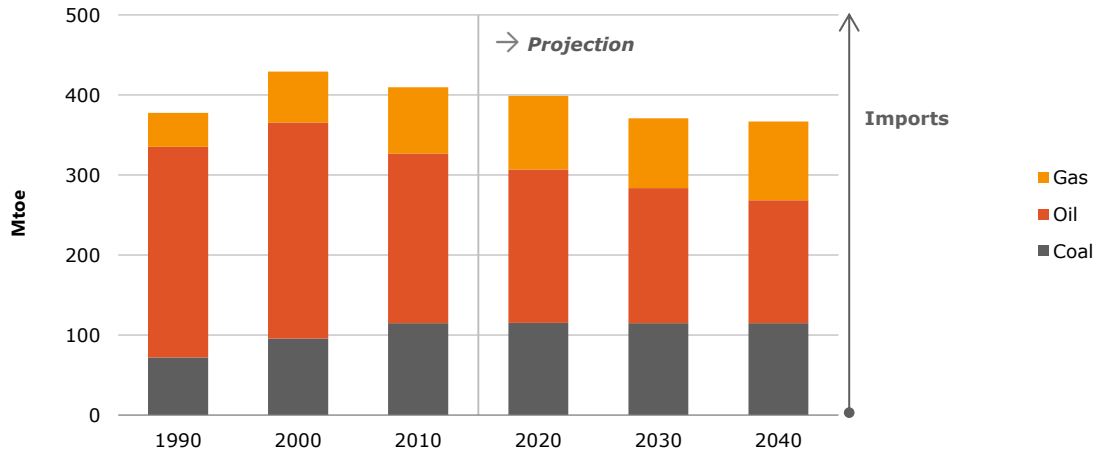
Sources: APERC analysis and IEA (2015a).

Energy trade: Imports shift from oil to coal and gas

Japan has been a net energy importing economy for more than 40 years. The energy self-sufficiency rate was 6.1% in 2013. Japan was APEC's (and the world's) third-largest oil consumer after the United States and China, and APEC's third-largest (and the world's fourth-largest) coal consumer after China and the United States in 2013.[14] Japan imports natural gas in the form of LNG, accounting for 37% of the total world LNG trade in 2013 (BP, 2015). Since the 1970s oil crises, Japan has been diversifying the origin of energy imports to enhance energy security. Japan still depends heavily on the Middle East for the bulk of its oil supply: 84% in FY 2013. (METI, 2015a); in contrast, the economy has strategically diversified gas and coal supplies, which are widely distributed across the world and in politically stable regions. For example, as for gas supply, Japan's dependence on the Middle East was 30% in FY 2013, much lower than oil (METI, 2015a).

Japan remains a major energy importer over the Outlook period, but the composition of imports shifts away from oil towards more diversified sources. Japan's net energy imports amounted to 437 Mtoe in 2013, of which net oil imports accounted for about half (212 Mtoe). By 2040, total net energy imports are projected to decline to 367 Mtoe, with a reduction in net oil imports to 154 Mtoe and slight increases in gas and coal. Oil's share of net imports declines to 42% in 2040.

Figure 8.6 • Japan: Net energy imports, 1990-2040



Sources: APERC analysis and IEA (2015a).

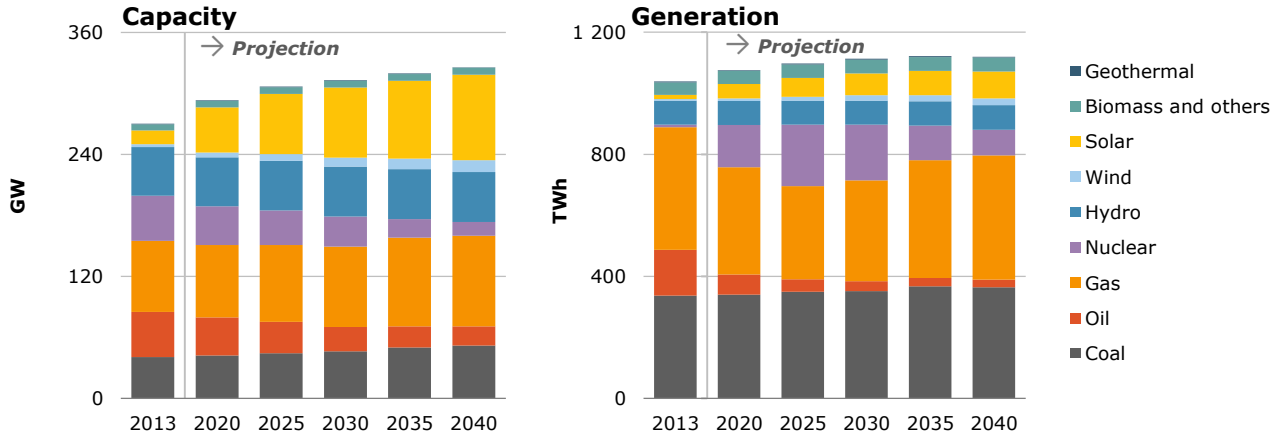
[14] India was the world's third-largest coal consumer in 2013.

Power sector trends: Growth in renewables

The BAU Scenario incorporates electricity market reforms, which aim to optimise economy-wide power generation. The BAU also includes policy directions and regulations, including the Strategic Energy Plan and the Nuclear Reactor Regulation Act, as well as power producers' power development plans. The Strategic Energy Plan established in 2014 emphasised that Japan will decrease nuclear dependence while strengthening energy efficiency and expanding renewable energy use (METI, 2014a). The Nuclear Reactor Regulation Act, amended in 2012, stipulates that the reactor lifetime is 40 years and operators can extend only once, up to 20 years with an approval from the NRA (e-Gov, 2014). The BAU assumes the '40 years rule' for all plants, except for five reactors that will be retired[15] (OCCTO, 2015) or reactors whose lifetime extensions are being examined by the NRA as of 2015 (NRA, 2015). The BAU also includes new installation of three reactors in the 2020s, which are currently under construction.[16] In August 2015, Sendai power plant became the first to restart under the new regulatory scheme. Nuclear reactors are expected to gradually restart from 2015 after receiving regulatory approval from the NRA. OCCTO is obliged to summarise power producers' supply plans and submit them to METI every year. As of mid-2015, gas-fired generation dominated new fossil fuel capacity additions in power producers' long-term plans, with 16 gigawatts (GW) out of approximately 22 GW[17] by 2028 (OCCTO, 2015). The BAU assumes these existing policies and plans continue over the projection period.

Under the BAU Scenario, Japan's electricity demand growth is one of the lowest in the APEC region, 0.3% per year, because of the mature economy and further energy efficiency improvements in end-use sectors. However, despite the modest growth in electricity demand, total power generation capacity grows by 21% due to expansion of variable renewable energy (solar and wind power) with low capacity factors. By 2040, the net increase[18] in variable renewables capacity amounts to about 80 GW, whereas that of fossil fuel-fired capacity is 4.9 GW. Solar PV drives the expansion of variable renewables as the feed-in tariff system improves investment opportunities. Solar PV capacity grows from 14 GW in 2012 to 69 GW by 2030 and 84 GW by 2040.

Figure 8.7 • Japan: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

In the short- to mid-term, nuclear restart reduces gas and oil generation in the power mix, which jumped after the nuclear disaster; in the long-term, however, dependence on gas-fired generation resumes as nuclear plants are retired. In 2030, the BAU power generation mix includes renewables (19%), nuclear (16%), coal (32%), gas (30%) and oil (3%). Driven by solar PV, renewables increase to 21% by 2040. In

[15] Tsuruga-I, Mihama-I, Mihama-II, Shimane-I and Genkai-I nuclear power plants.
[16] Shimane-III, Oma and Higashidori-I nuclear power plants.
[17] These values include plants currently under construction (fossil fuel fired total: 7.24 GW), plants in preparation for construction (7.47 GW) as well as long-term plans (6.40 GW).
[18] New capacity additions minus retirements.

2040, flexible generation such as gas and oil mainly satisfies the need to manage the intermittency from variable renewables such as solar and wind. The Strategic Energy Plan reaffirms the importance of coal for low-cost baseload generation. Under the BAU Scenario, coal accounts for more than 30% of annual supply over the period.

The share of renewables and nuclear in the generation mix does not reach the level in the Long-Term Energy Supply and Demand Outlook of the Japanese Government. Several renewables reach or are close to the level in the government's outlook in terms of generation; however, the government's outlook assumes lower demand due to drastic energy savings, resulting in a higher share for renewables than in the BAU Scenario. As for nuclear generation, the government's outlook projects about 217-232 terawatt-hours (TWh) in 2030, much higher than the BAU (183 TWh). To achieve the government's outlook level, further new reactor additions and/or lifetime extensions would be necessary. The BAU implies that the economy needs to focus on policies to promote energy savings as well as to increase public acceptance of long-term nuclear utilisation.

ALTERNATIVE SCENARIOS

This Outlook discusses three independent Alternative Scenarios—Improved Efficiency, High Renewables and Alternative Power Mix—in Japan.[19] The Improved Efficiency and the High Renewables Scenarios include the Japanese Government's targets for higher penetration of energy-efficient equipment and renewable energies, respectively. These scenarios discuss Japan's potential contribution to the APEC energy intensity goal and renewable energy goal. The Alternative Power Mix Scenario focuses on the electricity sector, and discusses the opportunities and challenges of alternative electricity supply options. Among these Alternative Scenarios, the Improved Efficiency Scenario achieves energy-related CO_2 emissions reduction close to Japan's INDC level. The High Renewables Scenario and the High Nuclear Case in the Alternative Power Mix Scenario largely improve the primary energy self-sufficiency rate.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

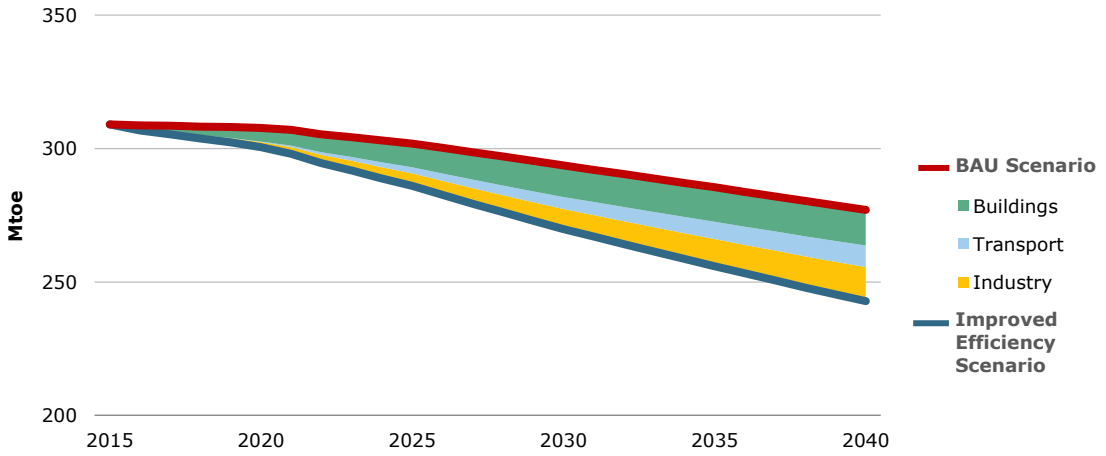
The Improved Efficiency Scenario explores energy efficiency opportunities to help APEC meet its target of reducing energy intensity by 45% between 2005 and 2035.[20] This scenario assumes Japan achieves its major targets for higher energy efficiency. In the buildings sector, this scenario includes the target for energy-efficient equipment; for example, the penetration of LED lights in residential and commercial sub-sectors is assumed to reach 100%, the level targeted by METI (2014a), which is much higher than the level in the BAU (about 25%). In the transport sector, this scenario assumes a higher share of 'next-generation vehicles'[21] in vehicle sales, reaching 50% by 2030, which is within the range (from 50% to 70%) targeted by METI (2014a) and much higher than the BAU (25%). In the industry sector, the scenario assumes energy efficiency upgrades mainly in the less energy-intensive industries because the more energy-intensive sub-sectors have already carried out energy efficiency upgrades.

The Improved Efficiency Scenario shows Japan's potential to contribute to APEC's energy intensity goal. In the BAU, Japan's energy intensity reduction of 39% on the basis of final energy demand is below the APEC-wide target level. Final energy demand decreases under the Improved Efficiency Scenario, for example, by 10% (-30 Mtoe from the BAU) in 2035 (Figure 8.8). These savings achieves a 45% reduction by 2035. In absolute terms, intensity falls from 78 toe per USD million in 2005 to 43 toe per USD million in 2035, an improvement of about 5 toe per USD million from the BAU. The Improved Efficiency Scenario shows the largest energy-related CO_2 emissions reduction across all Alternative Scenarios, -30% in 2030 from the 2013 level, achieving Japan's INDC level of a 25% reduction in energy-related CO_2 emissions.[22] This scenario implies that energy efficiency measures have a large potential to reduce energy-related CO_2

[19] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.
[20] See Footnote 9.
[21] Next-generation vehicles in this chapter include hybrid vehicles, PHEVs, BEVs, fuel cell vehicles, clean diesel vehicles, LPG vehicles and CNG vehicles.
[22] Japan's INDC is calculated on a fiscal year basis, while APERC's analysis uses calendar years.

emissions. All sectors contribute to energy savings. Of total savings in 2035, industry accounts for 34%, transport for 22% and buildings for 44% (Figure 8.8). These savings are equivalent to reductions from the BAU of 13% in industry (-10 Mtoe from the BAU), 12% in transport (-7 Mtoe) and 12% in buildings (-13 Mtoe). These results imply that continuous efforts are required across all sectors to achieve the regional goal level.

Figure 8.8 ● Japan: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Source: APERC analysis.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

The High Renewables Scenario focuses on the electricity and transport sectors, and shows a path to achieve the doubling renewables goal in the APEC region.[23] This scenario assumes that each APEC economy's targets for renewable energy are achieved, such as the government's outlook (METI, 2015d)[24], and in some economies exceeds the target, when it is cost-competitive and it assists the APEC region to meet the goal (see Chapter 6 in Volume 1 for a detailed explanation). In the transport sector, productivity improvements for biofuel feedstock are assumed as well. The High Renewables Scenario shows Japan's contribution potentially needed for doubling renewable energy in the APEC region.

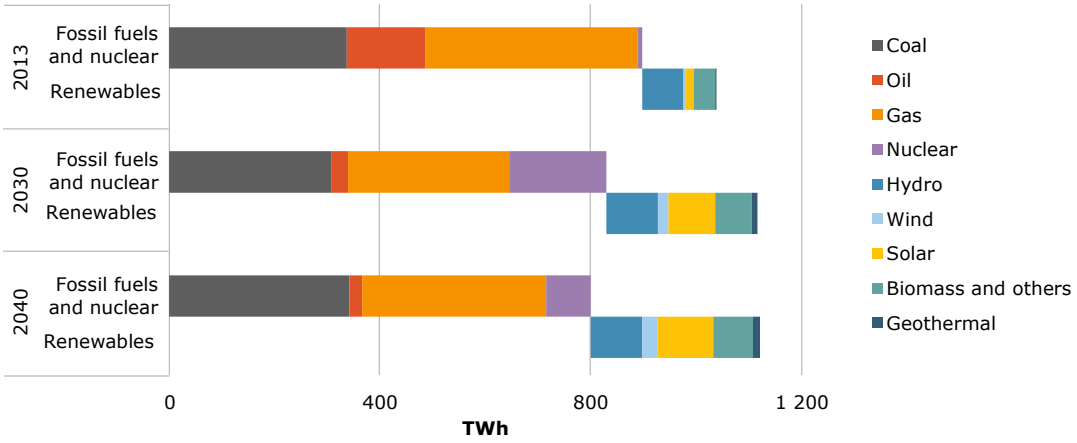
Under the BAU Scenario, the share of renewables increases, driven by solar PV, from 4% in 2010 to 7% in 2030 in TPES and from 12% to 19% in the power mix; however, the share does not meet the doubling level, and the total renewable generation does not reach the government's outlook. In the transport sector, the BAU projects limited demand for biofuels at 1% of transport energy demand in 2030. In 2009, Japan enacted the Law Concerning Sophisticated Methods of Energy Supply Structures, which requires oil refining companies to increase biofuel supply to 500 000 kilolitres (kl) per year (approximately 450 ktoe per year) by 2017. The BAU assumes that level of supply is reached by the target year.

Under the High Renewables Scenario, renewables show large growth both in the power mix and in transport. The share of renewables almost triples in TPES, from 4% in 2010 to 11% by 2030. This results in a more environmentally sustainable and self-sufficient energy system. Energy-related CO_2 emissions are about -23% from the 2013 level. The energy self-sufficiency rate improves from 6% in 2013 to 22% by 2030 and 19% by 2040, about three and five percentage points higher than the BAU, respectively.

[23] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro. The definition of this goal is under discussion at the Expert Group on New and Renewable Energy Technologies.

[24] The High Renewables Scenario assumes that each type of renewable's share reaches the range in the government's outlook.

Figure 8.9 ● Japan: Power sector under the High Renewables Scenario, 2013-40

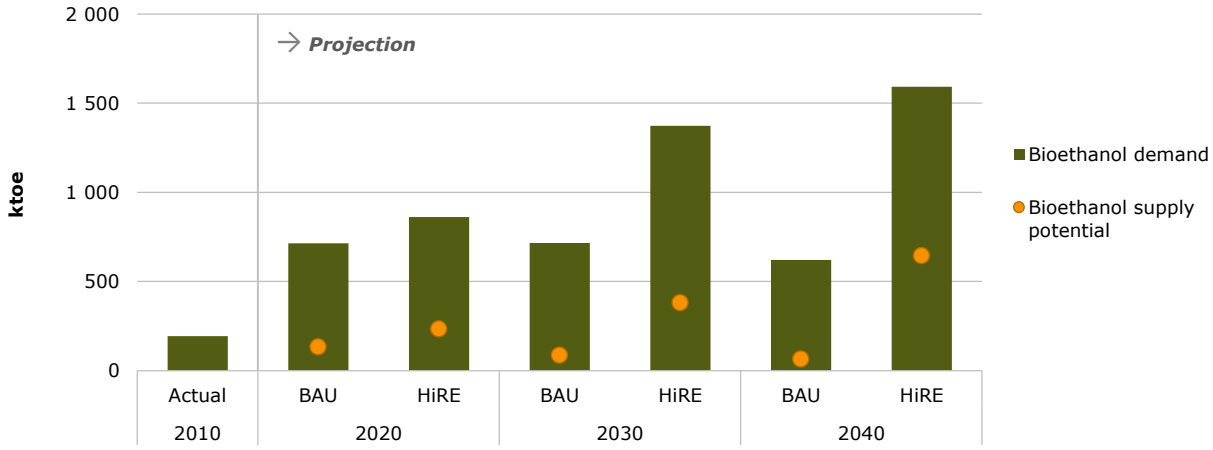


Sources: APERC analysis and IEA (2015a).

In the power mix, the share of renewables exceeds the doubling levels, reaching 26% in 2030 from 12% in 2010. The main driver is again solar PV, increasing its share from 1% in 2013 to 8% in 2030. Other types of renewables also grow; for example, hydro generation increases from 78 TWh in 2013 to 98 TWh by 2030 as the High Renewables Scenario assumes relaxation of generator siting constraints, including environmental regulatory barriers. However, compared with solar PV, other types of renewables show modest growth of one to two percentage points from 2013 to 2030 (and from the 2010 level as well), due to technical and economic challenges, including resource availability, regional resource imbalances and grid connection issues. Variable renewable power capacity reaches 95 GW in 2030 (85 GW solar and 10 GW wind). As in the BAU, flexible generation, such as gas and oil (total 95 GW), as well as pumped hydro storage, play a major role as a backup for variable renewable power.

In the transport sector, the High Renewables Scenario envisages a large jump in the use of renewables. To contribute to the APEC goal of doubling renewables' share, Japan needs to increase biofuel use to 1 370 ktoe by 2030 (up from 710 ktoe in the BAU). In the BAU, the number of cars using biofuels is assumed to be saturated after the biofuel target year (2017) because of cost-competitiveness issues in Japan, where sunshine hours are short for economical biofuel production. In addition, improved fuel economy reduces biofuel blended gasoline consumption, resulting in a declining trend in biofuel demand in the BAU. To increase biofuel consumption as illustrated in this scenario, Japan needs to widely use E3 (a fuel mixture of 3% bioethanol and 97% gasoline) as well as E10, which would require drastic changes in road transport fuel supply policies.

Figure 8.10 ● Japan: Bioethanol demand and supply potential in the BAU and High Renewables Scenarios, 2010-40

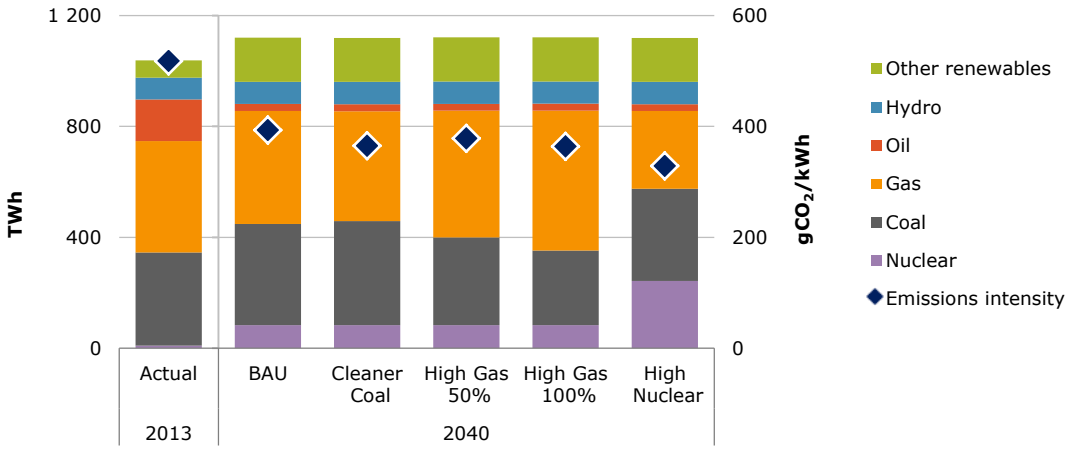


Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is for the Outlook period only; HiRE = High Renewables Scenario.
Sources: APERC analysis, PAJ (2012), FAO (2014) and IEA (2015a).

ALTERNATIVE POWER MIX SCENARIO

The electricity generation sector accounted for 45% of CO_2 emissions in APEC and 40% in Japan in 2013, due to a high share of fossil fuels in the power mix. In the BAU, fossil fuels, especially coal, are expected to remain a predominant source in APEC and Japan by 2040. Fossil fuels still account for about 60% of generation in 2030 in both the Improved Efficiency and the High Renewables Scenarios (and for 50% in the combined scenario[25]), suggesting the importance of cleaner use of coal as well as shifts to lower-carbon technologies (excluding renewables, which are discussed in the High Renewables Scenario). Therefore, APERC set up the Alternative Power Mix Scenario, aiming to evaluate the potential opportunities and barriers of lower-carbon alternatives with a focus on the three major thermal-based generation technologies: cleaner coal technologies for coal-fired generation (the Cleaner Coal Case), accelerated deployments of more efficient gas-fired technology (the High Gas 50% and the High Gas 100% Cases) and accelerated nuclear utilisation (the High Nuclear Case). All four cases apply to Japan.

Figure 8.11 ● Japan: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



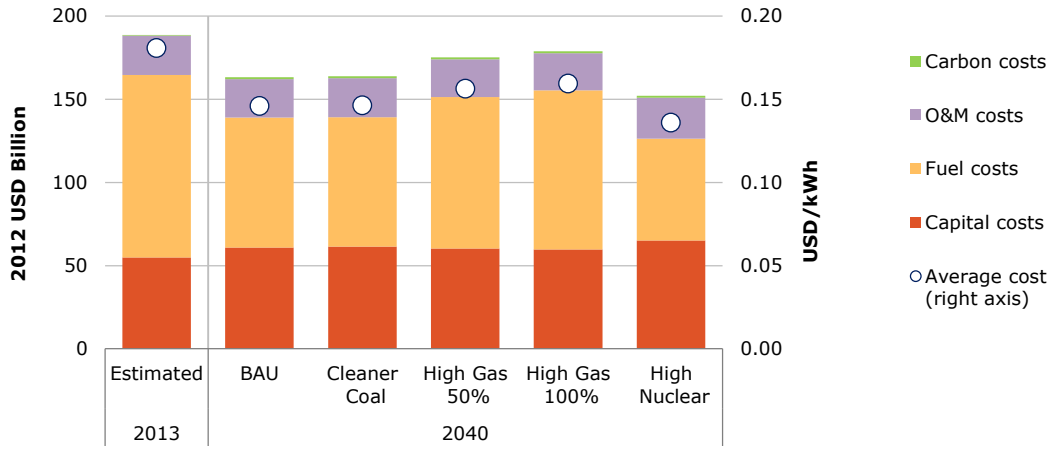
Sources: APERC analysis and IEA (2015a, 2015b).

The Cleaner Coal Case assumes that more efficient generation technologies such as advanced ultra-supercritical (A-USC) or integrated gasification combined cycle (IGCC) replace new coal generation capacity in the BAU from 2020 and are equipped with carbon capture and storage (CCS) from 2030. Thus, this case shows the similar power generation mix as the BAU but with lower emissions. New additions of advanced coal technologies (without CCS) amount to 2 GW in the 2020s and installation of CCS-equipped advanced coal reaches 6 GW by 2040. Large emissions reductions can be expected, especially after 2030, due to the use of CCS; annual emissions reductions in the electricity sector are estimated to be 0.24% in 2030 and to expand to 7.2% in 2040. Japan has a large electricity market (total capacity in 2030: 310 GW; total coal-fired: 46 GW) and average efficiency is already among the world's highest. So 2 GW of capacity with advanced technologies (but without CCS) improves average coal-fired conversion efficiency by less than one percentage point, resulting in modest reductions by 2030. These results imply that CCS would be the key technology for cleaner use of coal.

The High Gas 50% and the High Gas 100% Cases assume that new coal-based generation capacity in the BAU Scenario is replaced by combined-cycle gas turbines (CCGT) from 2020 at 50% and 100% levels of replacement respectively. Higher gas prices are applied to these cases as global gas demand and supply are assumed to be tighter. Although natural gas provides environmental benefits because its energy-related CO_2 emissions are lower, this fuel switch may weaken fuel diversification (Table 8.4). The share of gas-fired generation increases from 36% in 2040 in the BAU to as much as 45% in the High Gas 100% Case, resulting in reducing power sector emissions by 7% in 2040. However, this increases reliance on a single fuel and increases generation cost by 10% by 2040, mainly because of higher fuel costs.

[25] See Box 9.2 in Volume I for the APEC total trend in the combined scenario.

Figure 8.12 ● Japan: Power generation cost in the BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Note: Power generation cost does not include cost for transmission and distribution.
Source: APERC analysis.

The High Nuclear Case assumes that a 20-year lifetime extension is approved for all existing nuclear plants (except for five that are being retired). Assuming nuclear safety as a foremost condition, the High Nuclear Case shows a well-balanced power mix from the '3E+S' perspective, with the highest self-sufficiency rate (including nuclear) and the lowest emissions and power generation cost (Figures 8.11 and 8.12). Compared with the BAU, the nuclear share of the power mix increases from 16% to 25% in 2030 and from 8% to 22% in 2040. Installed nuclear capacity in the High Nuclear Case is about 46 GW in 2030 and 40 GW in 2040.[26] The larger nuclear share reduces fossil fuel-fired generation, resulting in self-sufficiency rate improvements in 2030, from 19% in the BAU to 24%. The rate in 2040 improves from 14% in the BAU to 24% in the High Nuclear Case. Energy-related emissions decrease by 20% in 2030 from 2013, the largest reductions among power mix cases. However, the Fukushima accident has significantly raised public concern about the safety of nuclear generation and made it more difficult to resolve plant siting issues, especially regarding a high-level radioactive waste disposal facility. Clear policy guidance as well as continuous economy-wide discussion about the benefits of long-term nuclear use is indispensable to gain public acceptance and realise the High Nuclear Case.

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Given Japan's limited indigenous fossil fuel resources, energy investment is mainly driven by the electricity sector, where the 2011 earthquake significantly changed the situation. The need for massive integration of renewables, enhancement of transmission and distribution networks, and replacement of ageing generation facilities creates large investment opportunities. From 2015 to 2040, investments in the energy sector amount to USD 430 billion (low-cost estimate) to USD 748 billion (high-cost estimate), of which around 90% is for electricity infrastructure in both cases. The remaining investment is shared by the other sectors—energy transport (from ports of importation to end-use facility), upstream and downstream.

[26] All Scenarios in this chapter include new installation of three reactors in the 2020s, which are currently under construction. See Footnote 16.

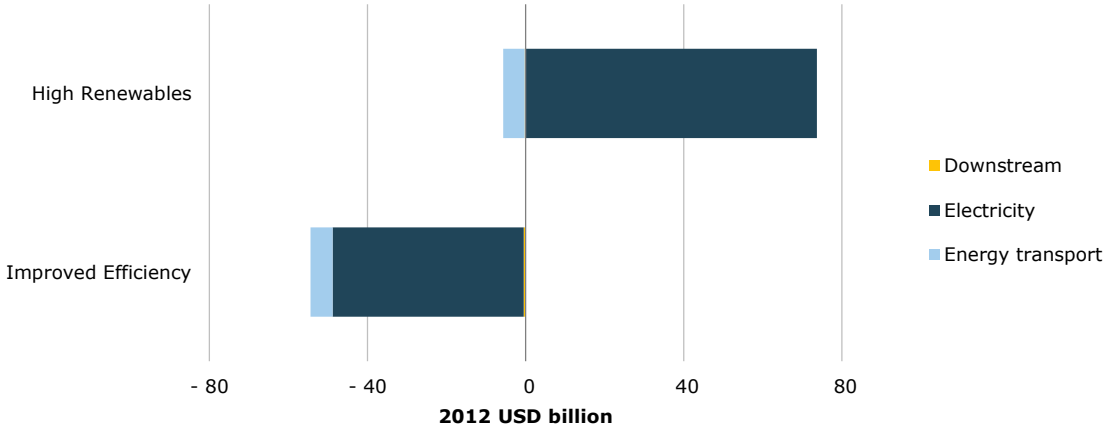
Table 8.3 ● Japan: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	1.7	2.6
	Gas	2.6	7.9
	Subtotal	4.4	11
Downstream	Refinery	4.5	18
	LNG import terminals	0.7	0.9
	Biofuels Refinery	0.01	0.01
	Subtotal	5.2	19
Electricity	Nuclear	13	16
	Coal	32	38
	Gas	39	64
	Oil	2.2	2.9
	Hydro	2.0	7.1
	Wind	22	38
	Solar	219	344
	Biomass and others	12	16
	Geothermal	2.7	3.5
	Transmission lines	28	38
	Distribution lines	8.2	98
	Subtotal	380	667
Energy transport	Oil	38	44
	Coal	2.7	7.5
	Subtotal	40	52
	Total	**430**	**748**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.
Source: APERC analysis.

Investment in the Improved Efficiency Scenario (low-cost estimate) amounts to USD 375 billion, leading to investment savings of USD 55 billion compared with the BAU, a reduction of 13%. The electricity sector shows the largest savings of USD 48 billion resulting from a displacement of 36 GW by 2040. In contrast, total investment expands in the High Renewables Scenario by USD 68 billion due to initial investments for renewables. Compared with the BAU, renewables capacity increases by 22 GW with an incremental investment of USD 74 billion (see High Renewables Scenario in Figure 8.13); meanwhile, lower oil demand because of higher biofuels blends brings investment savings in oil transport, amounting to USD 5.5 billion, partly offsetting the additional investment in renewables.

Figure 8.13 ● Japan: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

As discussed earlier in this chapter, since the 2011 earthquake, Japan has faced significant challenges in meeting its 3E and S (Safety) goals.

Enhancing energy security: The role of nuclear power

Nuclear plays a signficant role in the BAU and Alternative Scenarios in terms of energy self-sufficiency and fuel diversity.

Japan's primary energy supply self-sufficiency rate (including nuclear as quasi-domestic energy), already one of the lowest among the APEC economies, was pushed down further by the earthquake and the subsequent nuclear shutdown. Among the Alternative Scenarios, the highest primary energy supply self-sufficiency rate is reached in the High Nuclear Case, followed by the High Renewables Scenario and the Improved Efficiency Scenario.

Table 8.4 ● Japan: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040						
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%	High Nuclear
Primary energy supply diversity (HHI)	0.33	0.26	0.26	0.24	0.26	0.26	0.26	0.23
Primary energy supply self-sufficiency (%)	6	14	17	19	14	15	15	24
Oil self-sufficiency (%)	0	1	1	1	1	1	1	1
Gas self-sufficiency (%)	3	3	4	3	3	3	3	4
Electricity generation input fuel diversity (HHI)	0.30	0.28	0.25	0.25	0.28	0.28	0.29	0.25

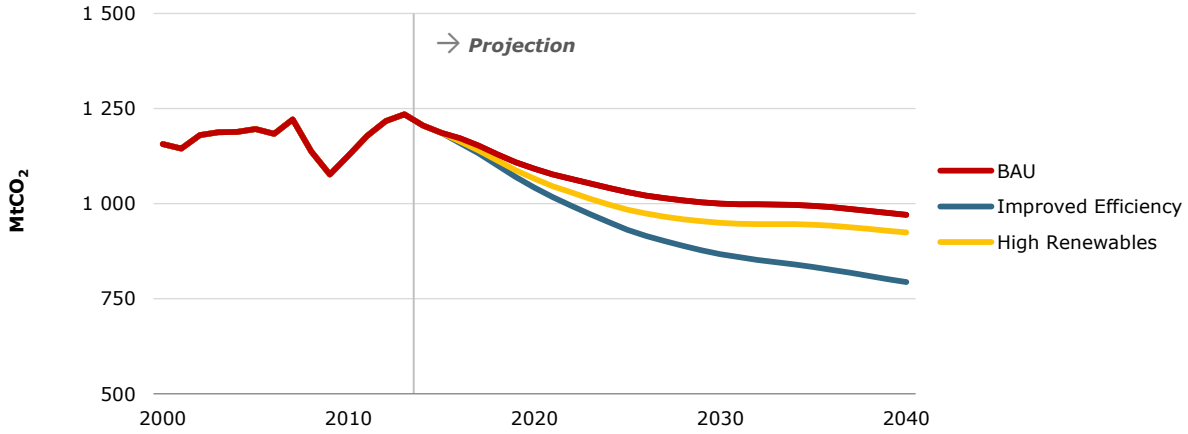
Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

In 2010, the most recent year before the Fukushima accident, Japan's primary energy supply diversity using the Herfindahl-Hirschman Index (HHI) was HHI 0.27, one of the lowest (that is, most diversified) among APEC members. In 2013, the index increased to 0.33 due to the temporary shutdowns of nuclear power plants, where a higher number indicates deteriorating diversity. However, Japan is expected to improve its primary energy supply diversity to HHI 0.26 by 2040 to almost the same level as before the Fukushima accident, because of the introduction of more renewable energy and a decrease in oil demand. Among the Alternative Power Mix cases, the High Nuclear Case shows the most diversified mix in terms of TPES as well as electricity generation fuel diversity.

Climate change impacts and risks: A combination of measures is necessary

The BAU Scenario does not meet Japan's INDC of a 26% GHG reduction and a 25% energy-related CO_2 reduction by FY 2030[27] from FY 2013 (UNFCCC, 2015). The Improved Efficiency and High Renewables Scenarios show larger reductions than in the BAU; however, only the Improved Efficiency Scenario achieves the economy's INDC level, showing the importance of additional energy efficiency improvements. The High Renewables Scenario and the High Nuclear Case follow the Improved Efficiency Scenario, but do not achieve the INDC level alone, implying that a combination of several low-carbon technologies is important to effectively reduce energy-related CO_2 emissions.

Figure 8.14 • Japan: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

RECOMMENDATIONS FOR POLICY ACTION

Existing policies largely improve energy efficiency, especially in the transport and buildings sectors, as well as expanding renewables in the electricity sector. However, these improvements are not enough to achieve the APEC-wide targets for energy intensity and renewables, or reach the levels in the government's Outlook and INDC.

This Outlook implies that additional measures have the potential to further improve energy efficiency, and suggests that there is no 'silver bullet' low-carbon technology for Japan to achieve these targets. It is important for the economy to promote several low-carbon technologies simultaneously—including renewable energy and nuclear energy—while considering the technical and economic compatibility of each alternative measure. For example, in the electricity sector, lowering electricity demand and utilising nuclear generation, which is relatively inflexible in grid operation, may reduce the room for variable renewable power integration. Japan needs to take into account the interrelationships among alternative policies.

[27] Japan's INDC is calculated on a fiscal year basis, while APERC's analysis uses calendar years.

9. KOREA

KEY FINDINGS

- **Total final energy demand is forecast to grow at an AAGR of 0.27% over the projection period,** along with economic growth of 2.2% under the BAU Scenario, mainly from high natural gas and electricity demand in the buildings and industry sectors.

- **Korea's energy security remains vulnerable,** although increased nuclear and renewable generation is projected to raise primary energy self-sufficiency to 23% in 2040 from 16% in 2013. Energy policies focus on ensuring a stable energy supply.

- **Nuclear energy retains a high share of the power generation mix over the Outlook period** in response to climate change and energy security pressures. The nuclear share increases from 26% in 2013 to 29% in 2040.

- **Additional policies will be needed to meet Korea's INDC.** APERC analysis shows CO_2 emissions need to be reduced by 7.3% over the BAU to be in line with the INDC. Korea needs to adopt a mixture of the Improved Efficiency and the High Renewables Scenarios, and the High Nuclear Case to reach the target.

- **Korea can contribute to the APEC energy intensity and renewable energy goals.** Under the BAU Scenario, Korea's energy intensity falls 43% from 2005 to 2035, contributing to the APEC-wide energy intensity target. Expanded wind and solar generation, and increased biofuels in transport, would achieve the renewable energy goal in both power generation and transport.

ECONOMY AND ENERGY OVERVIEW

Korea's population in 2013 reached 50 million, with an urbanisation rate of 82%. Population density is very high at more than 500 people per square kilometre (km^2). Almost half the population lives in the Seoul metropolitan area, which includes Seoul, Incheon and Gyeonggi province.

The population is projected to grow slightly in the period 2020-30 and decrease thereafter. In addition, Korea has a rapidly ageing population: after 2030, 24% will be over the age of 65—a substantial increase from 12% in 2013 (KOSIS, 2015). This change in population size and composition may negatively impact future economic growth by reducing domestic consumption, and a smaller labour force may threaten the supply capacity of the economy.

In recent decades, Korea has been one of Asia's fastest-growing and most dynamic economies. Gross domestic product (GDP) increased at an average annual growth rate (AAGR) of 5.1% from 1990 to 2013, reaching USD 1 660 billion (2012 USD purchasing power parity [PPP]) in 2013 (Table 9.1). GDP per capita income in 2013 was USD 33 303, 2.7 times higher than in 1990.

According to projections, GDP will increase to USD 2.9 trillion (2012 USD PPP) over the Outlook period, doubling from 2010. Total primary energy supply (TPES) per capita will increase to 5.9 tonnes of oil equivalent (toe) by 2040, 1.7 times the Asia-Pacific Economic Cooperation (APEC) average. Major industries include semiconductors, shipbuilding, automobiles, petrochemicals, digital electronics, steel, machinery, parts and materials.

Table 9.1 • Korea: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	529	977	1 521	1 660	2 066	2 569	2 999
Population (million)	43	46	49	50	50	51	49
GDP per capita (2012 USD PPP)	12 307	21 134	30 994	33 303	41 021	50 844	60 686
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	93	188	250	264	282	292	291
TPES per capita (toe)	2.2	4.1	5.1	5.3	5.6	5.8	5.9
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	65	127	158	168	179	182	180
Final energy intensity per GDP (toe per 2012 USD million PPP)	123	130	104	101	86	71	60
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	232	432	551	572	576	578	564
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	94	98	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

ENERGY RESOURCES

Korea has very limited domestic energy resources: oil resources consist of a small amount of condensate, and it has only 320 million tonnes (Mt) of recoverable coal reserves and 6 billion cubic metres (bcm) of natural gas (KESIS, 2015; EIA, 2014). To sustain high economic growth, Korea imports large quantities of energy products—about 89% of TPES in 2013. It was the world's fifth-largest importer of oil and liquefied natural gas (LNG) and third-largest importer of coal.

ENERGY POLICY CONTEXT

Energy policy in the past focused on ensuring a stable energy supply to sustain economic growth. The government is now seeking a new direction that supports sustainable development and fully considers the '3Es' (energy security, efficiency and the environment).

The past priority of keeping energy prices low in consideration of socioeconomic circumstances has caused inefficient use of energy, especially electricity as it was the most affordable. Lack of active demand control led to electricity replacing oil and gas in heating and cooling, creating over-dependence on electricity. This higher dependence causes additional transformation losses during generation, which does not occur when oil or gas is used as a heating fuel. The electricity boom also created supply instability, as it takes considerable time for an economy to expand its capacity.

On 14 January 2014, Korea launched the 2nd Energy Basic Plan covering 2014-35; it is the energy sector's main framework document (MOTIE, 2014a). The plan introduced policies on demand management, distributed power generation, energy sustainability, energy security and public acceptance. The share of nuclear in the economy's generation capacity is expected to be kept at around 29%, a decrease from the 41% set out in the 1st Energy Basic Plan in 2008. The 2011 Fukushima accident raised public environmental and nuclear safety concerns, heightening the importance of transparency and investment in safety measures. To ensure the safety of nuclear reactors, the government recently decided to retire the oldest reactor, Gori-1, in 2017 at the end of a 10-year life extension.

Increased renewables[1] has also been proposed. The government indicated 11% of TPES will be renewables by 2035 in the 4th New and Renewable Energies (NRE) Basic Plan of 2014, where 13.4% of total electricity will be renewables by 2035 with development of solar and wind as major energy sources (MOTIE, 2014c).

BUSINESS-AS-USUAL SCENARIO

The 7th Electricity Demand and Supply Plan for 2015-29 aims for the power capacity mix in 2029 to be 26.4% coal, 23.4% nuclear, 20.6% LNG and 20.1% NRE. Its targets are reflected in the Business-as-Usual (BAU) Scenario (Table 9.2).

Table 9.2 • Korea: Key assumptions and policy drivers under the BAU Scenario

Buildings	• Financial support for installing insulation in homes. • Stronger energy-savings design standards for new buildings.
Industry	• Demand management in energy-intensive industrial facilities. • Energy efficiency program such as Cloud FEMS (Factory Energy Management System) applied to industrial complexes.
Transport	• Mandated biodiesel blend rate of 2.5% in 2015, rising to 3% after 2018.
Energy supply mix	• Increased LNG, renewables and nuclear shares in TPES.
Power mix	• 29% share of nuclear in generation capacity in 2035.
Energy security	• Increased renewables in TPES, from 3.2% in 2013 to 11% in 2035. • Facilitated international joint stockpiling.
Climate change	• Enact policies that work towards achieving the Intended Nationally Determined Contribution (INDC) of 536 million tonnes of carbon dioxide ($MtCO_2$) by 2030. • Emissions trading system and target management system development.

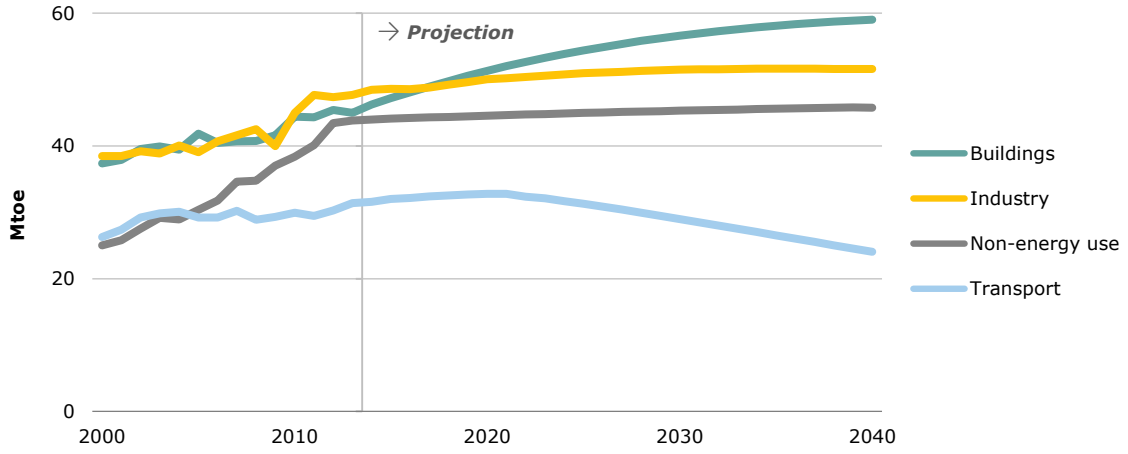
Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included; the Outlook's definition of renewables is different from 'new and renewable energy' in the government's plan.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Under the BAU Scenario, final energy demand grows at an AAGR of 0.27%, from 168 Mtoe in 2013 to 180 Mtoe in 2040—a 7.4% increase over the projection period. Growth occurs mostly in the buildings sector, at an AAGR of 1% (Figure 9.1) due to higher living standards with economic growth and a greater number of households, while industry increases slightly at the beginning but remains stable after 2020. Transport energy use declines as the efficiency of internal combustion engines improves and as the use of electric cars counterbalances the rise in vehicle stock. The government announced a plan to decrease energy intensity 30% from 2011 to 2035, an average annual decrease of 1.44%, through new demand-side management technologies, market schemes and stronger demand control policies in the electricity sector.

Figure 9.1 ● Korea: Final energy demand by sector, 2000-40

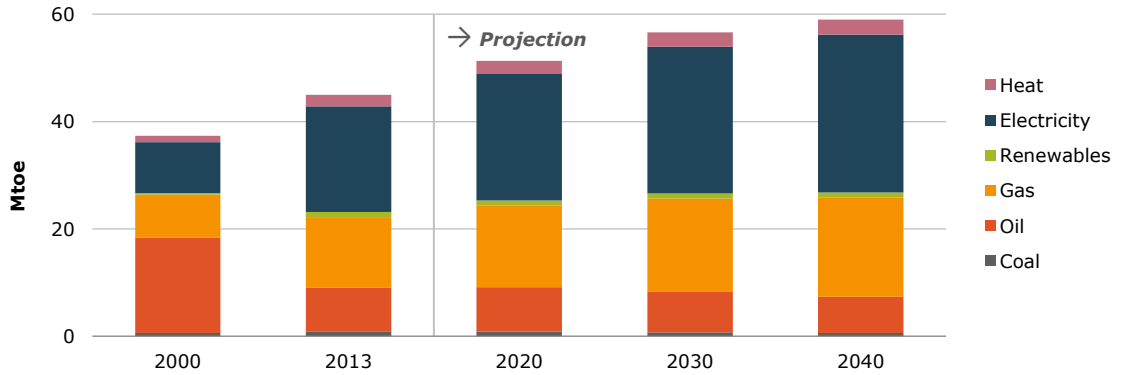


Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

Buildings energy use: Upward trend

The residential and commercial sub-sectors, at 20 Mtoe each, retain the dominant share (90%) of energy demand in the buildings sector in 2013. Energy demand in buildings is estimated to increase 31%, from 45 Mtoe in 2013 to 59 Mtoe in 2040 (Figure 9.2), mainly through a 49% increase in the commercial sub-sector to 31 Mtoe. Despite population reduction after 2029, energy demand in the residential sub-sector grows 21% to 25 Mtoe, and the number of households continues to grow by 22%, from 18 million in 2013 to 22 million in 2035, according to the Korean Statistical Information Service (KOSIS). About 75% of household increase is due to significant growth in one-person households, from 4.7 million in 2013 to 7.6 million in 2035. Policy measures to reduce building energy use are the Energy Efficiency Label and Standard Program, energy-saving design criteria for buildings, the building energy efficiency rating system, and the energy service company (ESCO) project.

Figure 9.2 ● Korea: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

With more appliances, electrical gadgets and space cooling resulting from economic growth, electricity's share in buildings sector energy demand almost doubled between 2000 and 2013 to replace that of oil. Increased large-scale heating, ventilation and air conditioning (HVAC) systems in buildings, together with relatively lower electricity prices, accelerated the electrification of energy consumption in the 2000s. Policy focus thus turned to energy demand management to prevent overuse of electricity.

Industry energy use: Modest increase

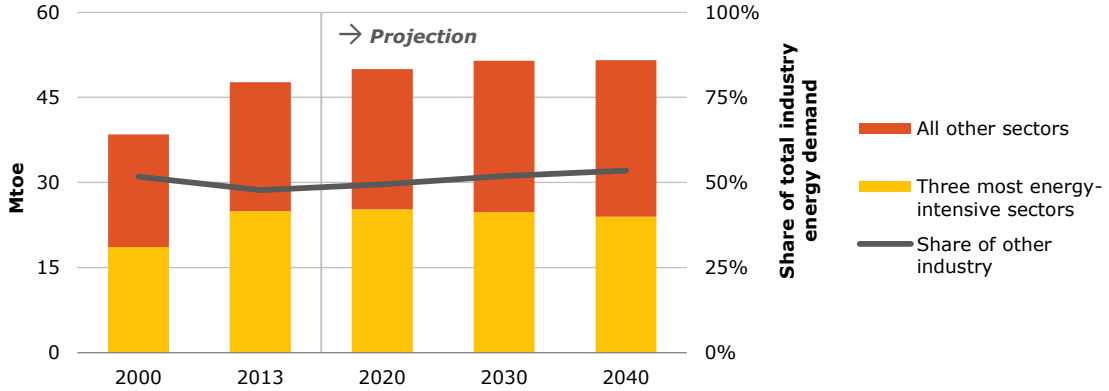
Industry energy demand increased significantly (24%) from 39 Mtoe in 2000 to 48 Mtoe in 2013, mainly due to rapid growth in iron and steel (53%) and chemicals and petrochemicals (44%), two of the three most energy-intensive sub-sectors. However, the 2nd Energy Basic Plan projects a slower AAGR of 1.3% between 2011 and 2035, significantly below the average of 3.3% for the whole manufacturing industry.

Industrial demand is projected to grow 8.1% (0.29% on average per year), from 48 Mtoe in 2013 to 52 Mtoe in 2040 (Figure 9.3). Industry energy use peaks in 2035 and is almost flat until 2040; increased energy use in all other sub-sectors balances that of the three most energy-intensive ones as demand decreases in steel, and chemicals and petrochemicals. Electricity and gas use increase continuously, from 22 Mtoe in 2013 to 25 Mtoe in 2040 for electricity and 9.8 Mtoe to 12 Mtoe for gas, while that of coal decreases 22%, from 8.1 Mtoe in 2013 to 6.4 Mtoe in 2040.

The three most energy-intensive sub-sectors in the APEC region—iron and steel, chemicals and petrochemicals, and non-metallic minerals—maintain their energy demand in absolute terms, but the share of industrial final energy demand declines from 52% in 2013 to 47% in 2040. While chemicals and petrochemicals grows continuously, from 9.1 Mtoe in 2013 to 10 Mtoe in 2040, iron and steel and non-metallic minerals peaked in the mid-2010s and decline thereafter. All other sub-sectors show 21% growth in energy use, from 23 Mtoe in 2013 to 28 Mtoe in 2040, mainly due to machinery (49% increase, from 7.4 Mtoe to 11 Mtoe).

Several programs facilitate efficient energy use in industry, including mandatory energy process consulting for large energy-consuming businesses, the ESCO project, tax incentives and soft loans.

Figure 9.3 • Korea: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.

Sources: APERC analysis and IEA (2015a).

Transport energy use: Consumption decreases with improved fuel efficiency

Transport energy demand decreases over the projection period with fuel efficiency improvements in road transport, which accounted for 96% of total domestic transport demand in 2013. Other domestic transport—air, rail and water—shows a modest increase, from 3.9% in 2013 to 6.4% in 2040, mainly due to expansion in rail transport.

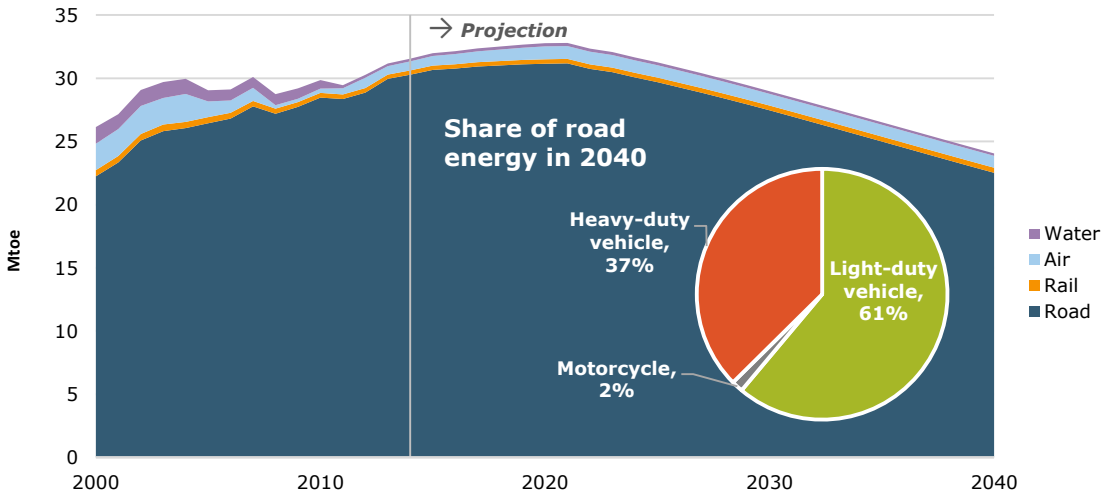
The number of vehicles increases under the BAU by only 0.68% AAGR over the projection period, reaching 23 million in 2040 (18% more than in 2013). The introduction of more efficient vehicles reduces domestic transport energy demand and more than compensates for stock increase. Total domestic transport energy consumption decreases by 23%, from 31 Mtoe in 2013 to 24 Mtoe in 2040 (Figure 9.4).

Gasoline and diesel dominate at over 80% throughout the projection period. Light-duty vehicles shift gradually to high-efficient vehicles (20% of light-duty vehicle stock in 2040). Hybrid electric vehicles lead, climbing from just 0.2% of light-duty vehicle stock in 2013 to 13% in 2040, thanks to improved battery technology and compatibility with existing infrastructure.

Mandatory blending of biofuels in diesel vehicles was introduced in 2012 to reduce carbon dioxide (CO_2) emissions, even though Korea has very limited biodiesel resources. The initial blend rate of 2% was raised to 2.5% in 2015. This will affect freight more than passenger transport, as diesel is more widely used in heavy-duty vehicles. The government recently mandated a 3% blend as of 2018 to increase the use of biodiesel as a transport fuel.

Korea's world-class public transport system is at the core of the economy's fast development. There are eight international and six domestic airports connecting Korean cities with almost anywhere in the world. Since 2004, Korea's KTX (Korean Train Express) high-speed rail network connects the economy's main cities, and almost all its towns are served by regional bus services. Getting around cities is easy and cost-effective thanks to subway systems in six major cities and extensive city bus systems. Improved public transport such as the expanding Intelligent Transport System (ITS) and universal cards that can be used in any buses, subways and trains will help curb future road transport demand.

Figure 9.4 ● Korea: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

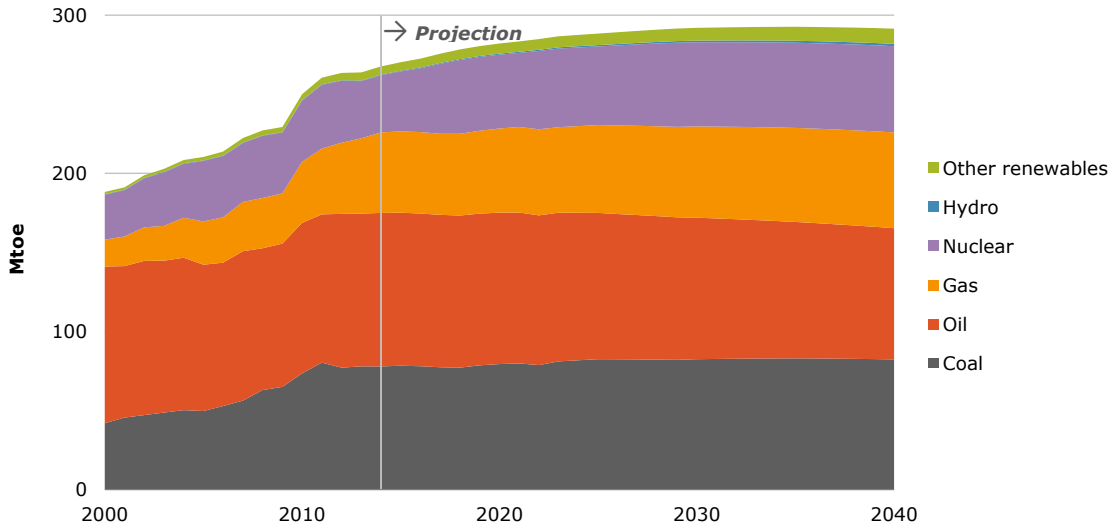
Primary energy supply: Continued reliance on imports to meet increasing demand

From 2013 to 2040, TPES increases by 11% from 264 Mtoe to 291 Mtoe (Figure 9.5) to meet increasing energy demand in buildings and industry. Oil's share drops but still remains the largest at 29% (83 Mtoe) in 2040, followed by that of coal, which rises to 28% (82 Mtoe) in 2040 due to increased coal generation. Nuclear rises from 14% (36 Mtoe) to 19% (55 Mtoe), contributing to Korea's INDC emissions reduction commitment. Renewables double from 5.5 Mtoe in 2013 to 11 Mtoe in 2040, raising their share in TPES from 2.1% to 3.8%.

Natural gas use has grown rapidly since the introduction of LNG in 1986. LNG has been replacing coal and oil for heating fuel since the introduction of pipeline networks in urban areas. Gas shares expand from 18% (48 Mtoe) in 2013 to 21% (61 Mtoe) in 2040.

Although the share of energy imports declines 5.9% with rising nuclear and renewables, 83% of TPES still relies on imports. Energy policy focuses on ensuring a stable energy supply to support high economic growth.

Figure 9.5 ● Korea: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

Energy trade: Gas and coal imports rise

Korea is among the most heavily energy import-dependent economies. Almost all of the fossil fuel supply is imported, and energy imports accounted for more than one-third of total import value in 2013. Energy imports are estimated to reach more than 241 Mtoe annually by 2040 (Figure 9.6).

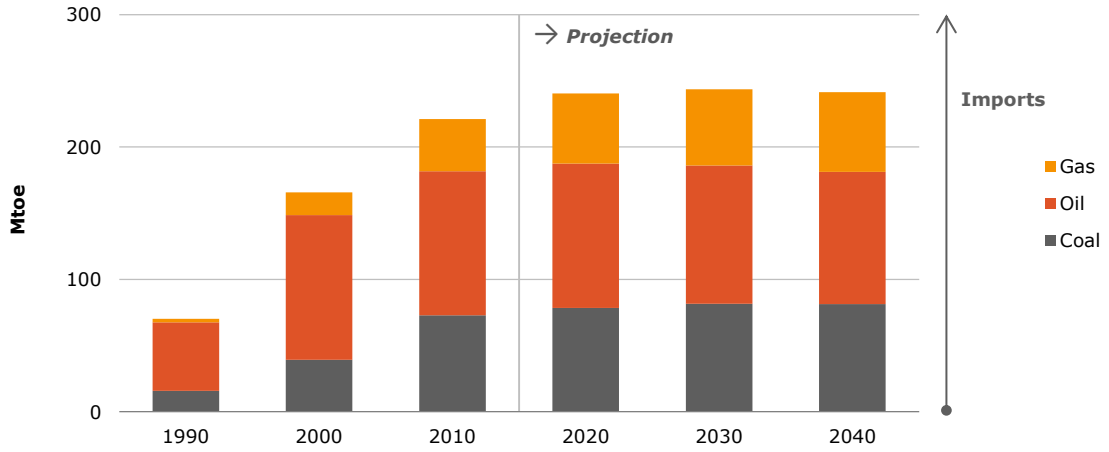
Korea will continue to import 99% of crude oil, mainly from the Middle East (KESIS, 2015). Net oil imports decrease by 8.5%, from 109 Mtoe in 2013 to 100 Mtoe in 2040, as transport energy demand declines, but it still accounts for 41% of net energy imports in 2040.

In coal, Korea is the world's third-largest importer of coking coal and fourth-largest importer of steam coal. Main coal imports come from Australia, Canada, China, Indonesia, Russia and the United States (KESIS, 2015). Imports increase by 5.1%, from 77 Mtoe in 2013 to 81 Mtoe in 2040, as the demand for coal in the electricity sector grows.

Gas imports also increase by 27%, from 48 Mtoe in 2013 to 60 Mtoe in 2040. Most LNG will come from Qatar, Indonesia, Oman, Malaysia, Brunei Darussalam and Australia (KESIS, 2015). Domestic natural gas production began in November 2004, but the Donghae-1 offshore field in the south-east produces only a small quantity.

Because economic growth is based on manufacturing, Korea has no choice but to import the energy resources it lacks domestically. However, its heavy dependence on the Middle East for oil, compared with diverse sources for coal and gas, is a threat to energy security. Development of domestic energy resources, such as renewables and nuclear, would enhance energy security.

Figure 9.6 • Korea: Net energy imports, 1990-2040



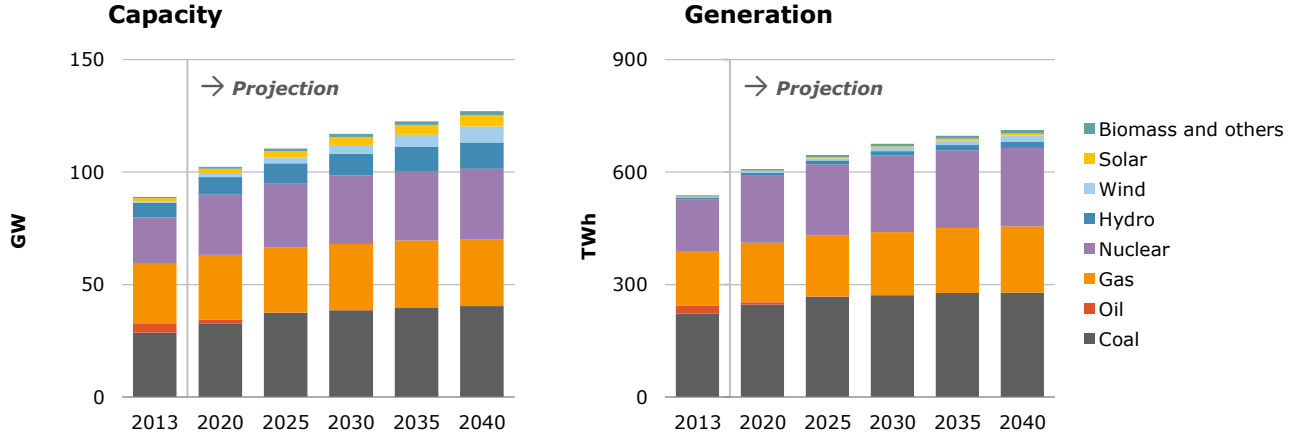
Sources: APERC analysis and IEA (2015a).

Power sector trends: Growth in nuclear and renewables

The AAGR of power generation is a modest 1%, with output of 538 terawatt-hours (TWh) in 2013 and 712 TWh in 2040 (Figure 9.7). Generation capacity rises 43% from 89 gigawatts (GW) in 2013 to 127 GW in 2040. The relatively high increase in both generation and capacity between 2013 and 2020 reflects the recent trend of using more electricity than other final energy sources. Rising electricity demand is the result of increased investment in—and production of—energy-intensive industries such as steel and petrochemicals, and the transition from other energy resources to electricity when it became the most affordable energy following the 2008 economic crisis. In 2011, continuous, rapidly increasing demand caused disruptions to electricity distribution in some districts for several hours. Since then, energy policy has been focused on securing necessary capacity and controlling electricity demand growth. A modest increase in generation and capacity after 2020 reflects efforts to stabilise the demand-supply balance.

Among fuel resources for electricity generation, coal continues to lead with a share of 39% in 2040, down slightly from 41% in 2013. Gas also declines from 27% in 2013 to 25% in 2040. Oil is phased out by 2030, from a share of 4% in 2013. Nuclear is projected to continue rising, from 26% in 2013 to 29% in 2040, in spite of the decision to reduce nuclear generation after the Fukushima accident. Shares of renewables rise almost fourfold: from 0.8% in 2013 to 2.4% in 2040 for hydro, and from 1% to 4.4% for non-hydro thanks to policies facilitating the use of renewables and increased private-sector investment.

Figure 9.7 • Korea: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

All three alternative scenarios—Improvement Efficiency, High Renewables and Alternative Power Mix—apply to Korea.[2] Of these three scenarios, the Improvement Efficiency Scenario demonstrates the most significant reductions in energy-related emissions (20%) and energy consumption (9.9%) compared with the BAU in 2040, relative to the other scenarios and cases.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

Under the BAU, energy intensity (based on final energy demand) falls 43%, contributing to the APEC-wide target of a 45% regional reduction between 2005 and 2035.[3] The Improved Efficiency Scenario, however, demonstrates a 47% reduction by 2035, an improvement of 5.5 toe per USD million over the BAU.

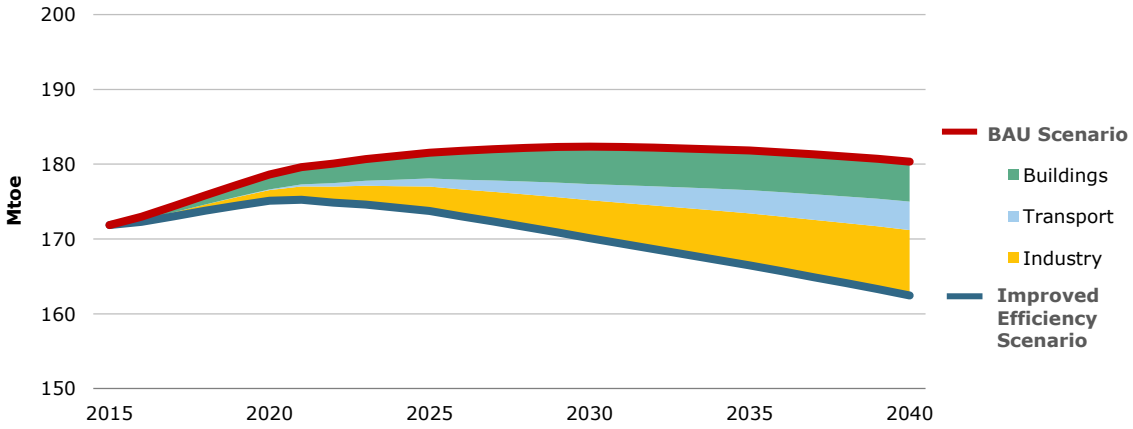
All sectors contribute to energy savings under the Improved Efficiency Scenario. Of the 18 Mtoe energy savings by 2040, industry accounts for 49%, transport 21% and buildings 30%. These results reveal room for additional savings; continuous efforts across all sectors are required to reach the regional goal.

Almost half of projected energy savings in the Improved Efficiency Scenario come from industry, at 6.9 Mtoe below the BAU level in 2035 and 8.8 Mtoe below in 2040 (Figure 9.8). Within industry, the sub-sectors with the greatest absolute reduction potential are machinery (2.5 Mtoe) and chemicals and petrochemicals (1 Mtoe). Paper, pulp and printing shows the highest efficiency improvement rate of 22% (0.53 Mtoe).

Buildings provides the second-largest savings of 5.3 Mtoe in 2040, 9.1% below the BAU. The residential sub-sector has the most potential (3 Mtoe), mainly from savings in water heating, television and air conditioning. Savings potential in the commercial sub-sector is 2.3 Mtoe, mostly from cooling and lighting.

Transport energy savings in the Improved Efficiency Scenario reach 3.8 Mtoe in 2040, below that of industry and buildings. As fuel economy policies and technical development trends are already reflected in the BAU Scenario, and the car industry is already technologically advanced, there is little potential for additional development in this sector.

Figure 9.8 • Korea: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Source: APERC analysis.

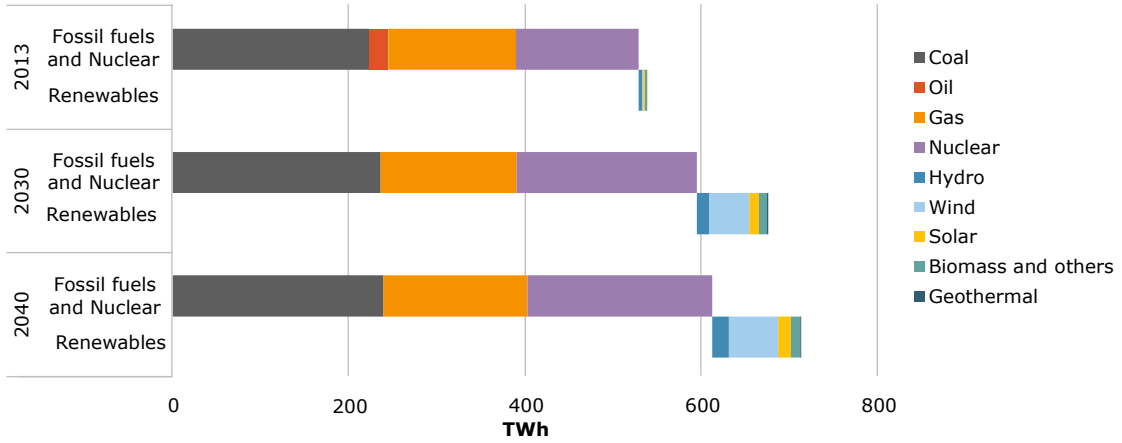
[2] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.
[3] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

The High Renewables Scenario models APEC's renewable energy goal, and under this scenario the share of renewables in power generation reaches 14% in 2040, more than double that of the BAU (6.8%).[4] Renewables reach 81 TWh in 2030 and 101 TWh in 2040 (Figure 9.9). Wind rises to 56 TWh (AAGR of 15%) and solar to 14 TWh (AAGR of 8.5%) in 2040, both from less than 2 TWh in 2010. These two sources contribute more than 88% of total additional renewable generation in 2030.

Average generation cost declines from USD 116 per megawatt-hour (MWh) in 2013 to USD 110/MWh in 2040 under the High Renewables Scenario, higher than the USD 109/MWh in 2040 projected under the BAU. The reduced average generation cost is the result of declining production costs of renewables, especially wind and solar, over the projection period.

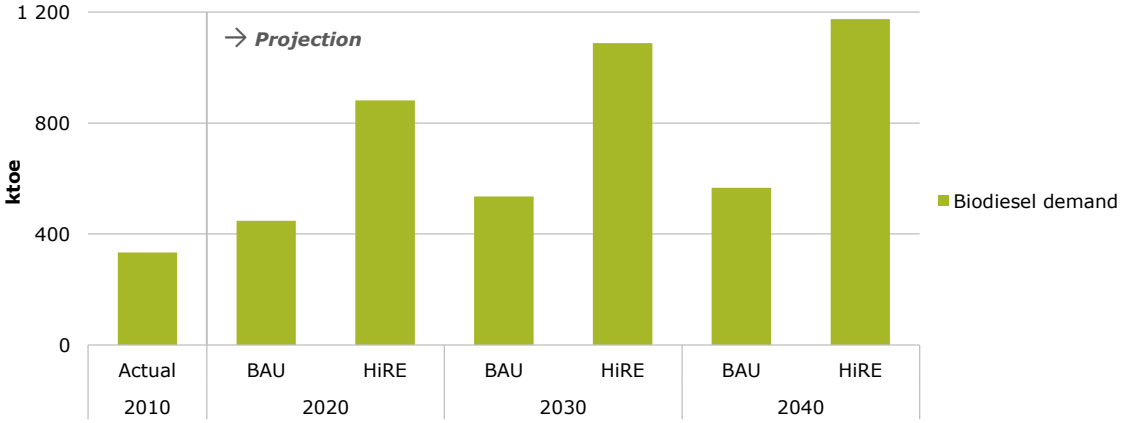
Figure 9.9 ● Korea: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

The share of biodiesel in total transport energy demand is expected to nearly double under the BAU, from 1.1% in 2010 to 1.8% in 2030, due to a mandated biodiesel blend rate of 3% by 2018. Under the High Renewables Scenario, the biodiesel mandate is assumed to increase to 10% in 2040, leading to a biodiesel share of 3.8% in 2030, a more than threefold increase from 2010. Although falling transport energy demand between 2030 and 2040 reduces growth, total biodiesel demand still increases from 1 088 kilotonnes of oil equivalent (ktoe) in 2030 to 1 175 ktoe in 2040 (Figure 9.10).

Figure 9.10 ● Korea: Biodiesel demand in the BAU and the High Renewables Scenarios, 2010-40



Note: HiRE = High Renewables Scenario.
Sources: APERC analysis, IRENA (2014) and IEA (2015a).

[4] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

ALTERNATIVE POWER MIX SCENARIO

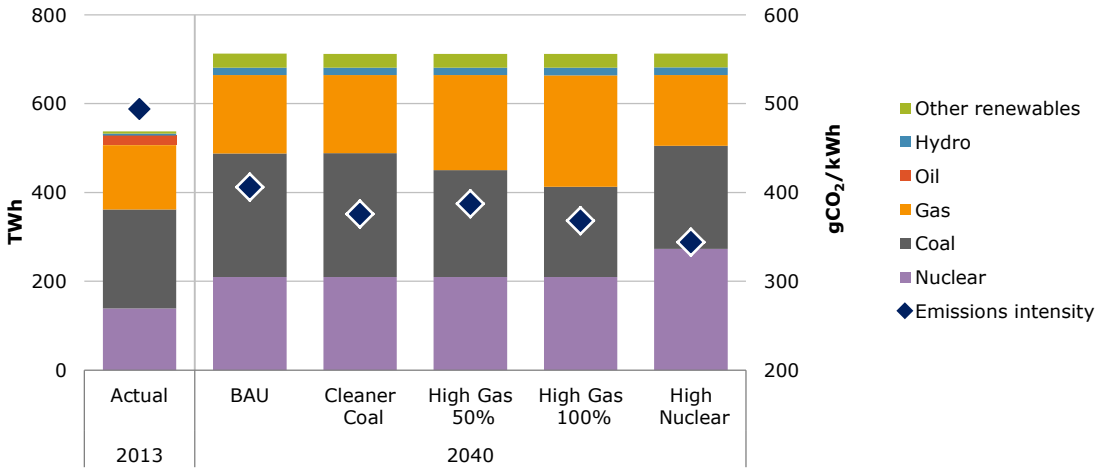
The Alternative Power Mix Scenario evaluates opportunities and barriers for applying cleaner coal generation technologies, increasing shares of natural gas and extending the life spans of existing nuclear power plants. All four Alternative Power Mix cases, the Cleaner Coal Case, the High Gas 50% Case, the High Gas 100% Case and the High Nuclear Case, apply to Korea.

The Cleaner Coal Case assumes that more efficient generation technologies such as advanced ultra-supercritical (A-USC) and integrated gasification combined cycle (IGCC) replace new coal generation capacity in the BAU Scenario from 2020, and are equipped with carbon capture and storage (CCS) from 2030. This case shows the same power generation composition as the BAU, but with 7.4% less CO_2 emissions per kilowatt-hour in 2040 thanks to CCS (Figure 9.11).

In the High Gas Case, the combined-cycle gas turbine (CCGT) replaces 50% or 100% of forecast coal capacity additions (the High Gas 50% and the High Gas 100% Cases). Substituting gas for coal-based capacity additions results in a more balanced power mix, and CO_2 emissions intensity declines significantly in the High Gas 100% Case (9.3% over the BAU in 2040). However, generation costs rise by 8.5% in 2040 compared with the BAU due to higher gas costs, which could reduce economic competitiveness and energy security.

The High Nuclear Case assumes that additional 20-year life span extensions are approved for all existing nuclear reactors except one, which will retire in 2017. The High Nuclear Case shows the most significant reduction in emissions intensity, at 15% less CO_2 emissions per kilowatt-hour than under the BAU in 2040. It is also the most competitive in generation cost: 10% less in 2040 than the High Gas 100% Case and 2.9% less than the Cleaner Coal Case. However, elevated public concern since the Fukushima accident makes it difficult to extend the life spans of existing reactors and introduce new ones.

Figure 9.11 • Korea: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Approximately USD 191 billion (the low-cost estimate) to USD 373 billion (the high-cost estimate) is required for energy infrastructure from 2015 to 2040 (Table 9.3). About 91% of energy investments will be devoted to power: investments are estimated between USD 174 billion (low-cost estimate) and USD 333 billion (high-cost estimate) for the 38 GW of additional generation capacity and transmission and distribution line expansion. Downstream investment is allotted a 3.8% share of total investments for

refinery capacity additions of 82 000 barrels per day, and LNG import terminal capacity of 26 million tonnes per day. Energy transport of oil, gas and coal (from source to ports or facilities) claims 3.5%. Meanwhile, upstream investment (mainly for oil exploration and production) takes 1.9% of total investments.

Table 9.3 ● Korea: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	2.7	4.1
	Gas	0.3	0.8
	Coal	0.7	2.3
	Subtotal	3.7	7.1
Downstream	Refinery	2.4	10
	LNG import terminals	4.7	5.7
	Biofuels Refinery	0.1	0.2
	Subtotal	7.2	16
Electricity	Nuclear	74	102
	Coal	31	37
	Gas	6.1	10
	Hydro	19	67
	Wind	17	29
	Solar	12	19
	Biomass and others	3.6	4.8
	Transmission lines	7.2	14
	Distribution lines	4.2	50
	Subtotal	174	333
Energy transport	Oil	0.3	0.6
	Gas	3.9	11
	Coal	2.5	5.9
	Subtotal	6.6	17
	Total	**191**	**373**

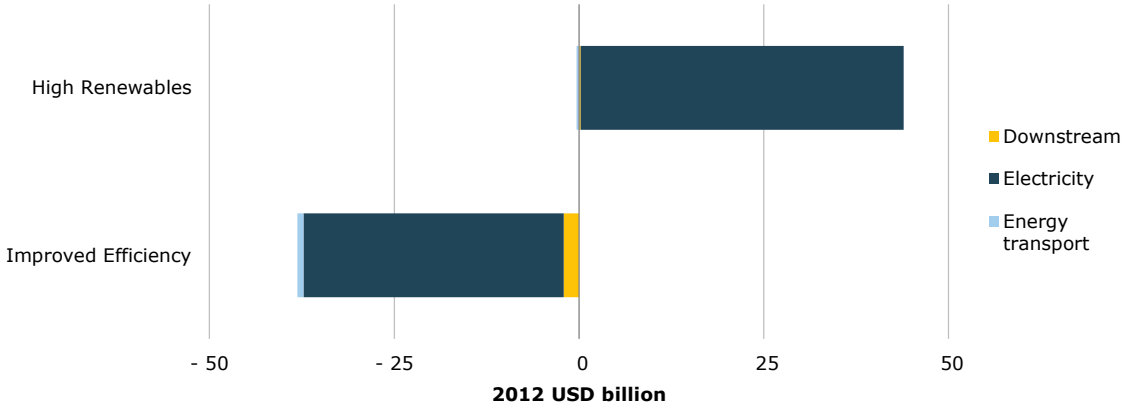
Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

Under the Improved Efficiency Scenario, total investment is 20% less than the BAU, at USD 153 billion from 2015 to 2040 (Figure 9.12). Power contributes significantly (93%) to the investment reduction, with the displacement of 18 GW of generation capacity and lower investment requirements for transmission and distribution lines. Meanwhile, downstream investment declines by 28% with lower capacity requirements in LNG import terminals (35% less) and refineries (12% less) than under the BAU due to decreased gas and oil demand.

In the High Renewables Scenario, total investment increases by 23% (additional USD 44 billion) due to 38 GW more renewable capacity in the generation mix, compared with only 17 GW in the BAU. Wind and solar together contribute more than three-quarters to renewable capacity additions.

Figure 9.12 • Korea: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.

Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

Since the two oil crises of the 1970s, Korea has been trying to diversify its energy import sources to meet quickly rising energy demand as the economy grows. The government has introduced incentives to reduce dependence on Middle Eastern crude and has also stockpiled crude and oil products with the private sector since joining the International Energy Agency (IEA) in 2002. As of the end of 2014, Korea maintains petroleum reserves to cover 116 days of imports. It continues to depend heavily on fossil fuel imports and will need to ensure a stable supply to support high economic growth over the Outlook period.

Box 9.1 • Korea: Business models to respond to climate change

In July 2014, the Ministry of Trade, Industry and Energy (MOTIE) created six new energy-related businesses, based on emerging business models, to reduce CO_2 emissions and increase energy efficiency (MOTIE, 2014b). MOTIE also established the Energy Efficiency and Climate Change Bureau for more efficient policy support. Plans for research and development (R&D) in related technology and regulation reforms were announced in December 2014 and April 2015 (Government of Korea, 2014b, 2015).

The six business models are:

1. Demand management service that collects electricity saved from buildings and factories using electricity-saving devices and sells it to the electricity trading market;
2. Integrated energy management service that connects finance, insurance and an energy management system and also provides system maintenance for companies;
3. Independent micro-grid that replaces diesel generators with NRE generators and an electricity storage system;
4. Photovoltaic equipment rental that lends photovoltaic equipment to households and receives payment through electricity gains;
5. Recharging service for electric vehicles that provides paid recharging; and
6. Used-heat recycling from thermal power plant that utilises used heat in diversified farming.

These business models focus on reducing the demand for fossil fuel electricity and increasing R&D investment to develop related technologies.

Enhancing energy security: Increased nuclear and renewables

Korea's primary energy supply self-sufficiency rate is one of the lowest in APEC, although it improves from 16% in 2013 to 23% in 2040 with rising nuclear and renewables production (Table 9.4). Primary energy supply diversity improves slightly, but electricity generation input fuel diversity remains similar to 2013 level. Given that domestic resources make up less than 2% of the fossil fuel supply, the fossil fuel self-sufficiency rate is low and demonstrates Korea's vulnerability to regional and global supply disruptions.

Of all Alternative Scenarios and associated Cases, the High Nuclear Case shows the best primary energy self-sufficiency and also lowers the average generation cost to 2.6% below that of the BAU, while the High Gas 50% Case raises it by 5.4% and High Gas 100% Case by 8.5% due to high LNG prices. In diversifying electricity generation input fuel, the High Renewables Case shows the greatest improvement, followed by the High Gas 100% Case.

Table 9.4 • Korea: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040						
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%	High Nuclear
Primary energy supply diversity (HHI)	0.27	0.24	0.24	0.23	0.24	0.24	0.24	0.24
Primary energy supply self-sufficiency (%)	16	23	26	26	23	23	23	29
Coal self-sufficiency (%)	1	1	2	1	1	1	1	1
Oil self-sufficiency (%)	1	1	1	1	1	1	1	1
Gas self-sufficiency (%)	1	0	0	0	0	0	0	0
Electricity generation input fuel diversity (HHI)	0.33	0.34	0.34	0.31	0.34	0.32	0.32	0.36

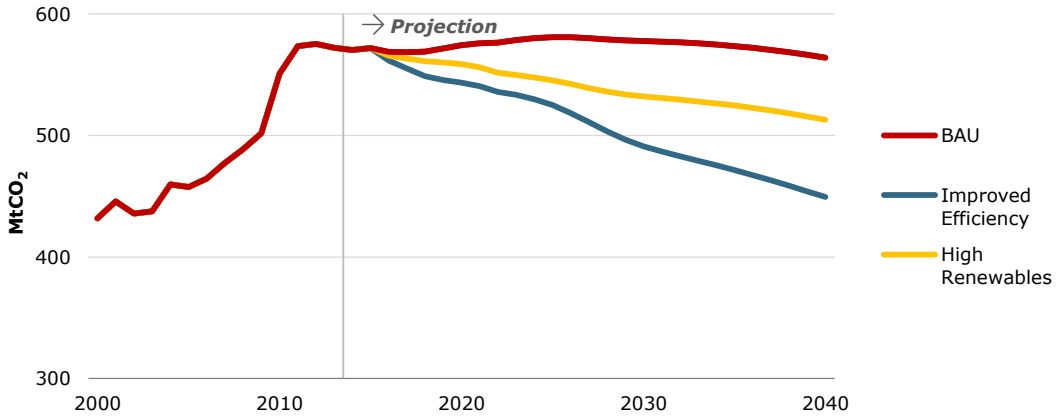
Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

Climate change impacts and risks: Combination of measures needed

In accordance with the Framework Act on Low Carbon, Green Growth, Korea is addressing climate change across all sectors and will strengthen efforts to achieve the 2030 mitigation target. It plans to reduce greenhouse gas (GHG) emissions to 536 million tonnes of carbon dioxide equivalent ($MtCO_2eq$) by 2030, a 37% reduction over the government's projected 851 $MtCO_2eq$ across all sectors, with the interim target of reducing emissions 30% below this projection by 2020 (UNFCCC, 2015).

Under the BAU Scenario, energy-related CO_2 emissions increase from 572 $MtCO_2$ in 2013 to 564 $MtCO_2$ in 2040—not meeting the INDC of 536 $MtCO_2$ in 2030 (Figure 9.13). The BAU cannot sufficiently offset the trend of rising emissions linked to growing energy demand to meet the INDC. The Alternative Scenarios and associated Cases show larger reductions: the High Renewables Scenario reduces energy-related emissions 51 $MtCO_2$ more than BAU in 2040, but energy-related CO_2 emissions only decline to 532 $MtCO_2$ in 2030—slightly lower than the INDC. The Improved Efficiency Scenario shows a reduction in energy-related CO_2 emissions to 490 $MtCO_2$ in 2030 and 449 $MtCO_2$ in 2040, below the 2030 target of 536 $MtCO_2$. However, since Asia Pacific Energy Research Centre (APERC) analysis does not include industrial process emissions or land use, land-use change and forestry (LULUCF), the Improved Efficiency Scenario may not meet the INDC on its own. A combination of alternative measures for non-energy-related CO_2 emissions is therefore necessary.

Figure 9.13 ● Korea: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).

Sources: APERC analysis and IEA (2015b).

RECOMMENDATIONS FOR POLICY ACTION

It will be challenging for Korea to achieve its INDC commitment to reduce CO_2 emissions. APERC analysis finds that no single scenario can meet all requirements to meet, but improving energy efficiency together with other alternatives such as deploying renewables is the best way forward.

Adoption of consumer-compatible expansion policies, such as eco-friendly energy towns and improved obligatory renewable portfolio standards (RPS) would increase renewable energy use. Shifting the renewable energy market from a government-led system to private partnerships through profit-based business models and easing of regulations would also expand usage.

Recent policy measures facilitate technology development and employ business models to increase energy efficiency. Developing energy management systems, accelerating smart-grid deployment, and R&D on energy-related technologies such as CCS and electricity storage systems would further improve energy efficiency. Increasing energy investment from both the public and private sectors is essential to accelerate progress in these activities. Reviewing restrictions on private investment in energy-related businesses and deregulating excessive ones may be necessary.

In addition to improving efficiency, facilitating renewables' deployment and securing public acceptance of nuclear energy are important in achieving the CO_2 emissions reduction target. These measures will help reduce dependence on imported fuels and lead to improved energy security.

10. MALAYSIA

KEY FINDINGS

- **Malaysia is expected to achieve high-income economy status in 2020.** Under the BAU Scenario, GDP grows by more than 4.2% per year from 2013 to 2040 while population increase is modest. Green growth has been identified as a high priority, reflecting an important shift in policy direction from 'grow first, clean up later' to sustainable development.

- **As it transitions to being a net energy importer, from 0.69 Mtoe of net energy export in 2013 to 68 Mtoe of the net energy import in 2040, Malaysia needs to secure future supply.** Oil supply is an immediate priority, as Malaysia became a net oil importer in 2013; it is expected to become a net gas importer around 2035, as production capacity falls short of growing demand.

- **Malaysia will reduce energy intensity by 41% in 2035 under the BAU, contributing to the APEC-wide goal of 45% reduction overall**; it could achieve a further 4.6% reduction in the Improved Efficiency Scenario. Over the next five years, setting a demand-side management master plan is a high priority for the government; this will further reduce energy intensity in the longer term.

- **Malaysia has the second-highest growth rate for renewable energy (AAGR of 3.5%) in APEC under the BAU**, with solar, hydro and biomass being key sectors. All three show even greater potential in the High Renewables Scenario.

ECONOMY AND ENERGY OVERVIEW

Malaysia, located in South-East Asia, has a total territory of about 330 803 square kilometers (km^2). The economy is separated by the South China Sea into two main geographical areas comprising Peninsular Malaysia in the west, and Sabah and Sarawak on the island of Borneo. The capital city of Malaysia is Kuala Lumpur while Putrajaya hosts the seat of the federal government (EPU, 2013). In 2013, the population was 29.5 million, an increase of 1.7% from 29 million in 2012 (World Bank, 2015).

Malaysia's gross domestic product (GDP) reached USD 514 billion in 2013, with GDP per capita around USD 17 446 (Table 10.1). The largest contributions to GDP were from services (55%) and manufacturing (25%) (MOF, 2014). In 2014, the main export products were electrical and electronic (E&E) products at about 33% of total exports, petroleum products at 9.2% and liquefied natural gas (LNG) at 8.4% (MATRADE, 2015). Projections carried out by the Asia Pacific Energy Research Centre (APERC) show Malaysia's GDP per capita increasing 2.9% annually to reach USD 37 981 by 2040.

Table 10.1 ● Malaysia: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	143	284	443	514	725	1 098	1 550
Population (million)	18	23	28	29	33	37	41
GDP per capita (2012 USD PPP)	7 846	12 121	15 754	17 446	21 978	29 454	37 981
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	22	49	74	89	103	127	149
TPES per capita (toe)	1.2	2.1	2.6	3.0	3.1	3.4	3.7
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	14	30	43	54	63	77	88
Final energy intensity per GDP (toe per 2012 USD million PPP)	98	105	97	105	87	70	57
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	49	114	188	207	248	306	363
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	93	96	99	100	100	100	100

Note: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.
Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

In May 2015, the government launched the 11th Malaysia Plan,[1] 2016-2020 as the final stage in realising Vision 2020, a long-term development plan launched in 1991 that set out to make Malaysia a fully developed economy—across all dimensions—by 2020. Six thrusts are central to the 11th Malaysia Plan; two thrusts, pursuing green growth for sustainability and resilience, and strengthening infrastructure to support economic expansion, have implications for energy initiatives (EPU, 2015).

ENERGY RESOURCES

Compared against other large economies in the Asia-Pacific Economic Cooperation (APEC), Malaysia's energy resources can be considered moderate in absolute terms. A 2013 survey shows that East Malaysian states hold nearly two-thirds of the economy's energy reserves; Peninsular Malaysia holds the

[1] The Malaysia Plan is a mid-term (5 years) economy-wide development plan that sets goals for economic growth and allocates part of the government budget to program development. It also underlines the role of the private sector. The First Malaysia Plan started in 1966 and the 11th Malaysia Plan covers 2016 to 2020.

rest. The Malaysian Energy Commission estimates oil reserves (including condensate) at 5.9 billion barrels, 40% of which is found in Peninsular Malaysia (Malay basin). Abundant natural gas reserves are estimated at 2.8 trillion cubic metres (tcm) or 98 trillion standard cubic feet, with nearly half found in the Sarawak basin. The coal reserves deposit, assessed at 1.9 billion tonnes, is located mostly in Sarawak and Sabah (EC, 2015).

In 2013, coal consumption reached more than 14 Mtoe (million tonnes of oil equivalent, or 21 million tonnes of coal), at which time Malaysia ranked as the ninth-largest coal importer in the world. This reflects rapid expansion of coal generation capacity, especially between 2000 and 2013 when coal consumption in the power sector swelled from 1.5 Mtoe per year (Mtoe/yr) to 13.6 Mtoe/yr. Coal generation capacity was expanded to meet increasing electricity demand and reduce dependence on natural gas, which previously dominated generation with shares as high as 70% in the 1990s (EC, 2015). Though Malaysia has 1.9 billion tonnes of proven coal reserves, most deposits are of poor quality and are located in protected areas in Sabah and Sarawak. With limited options to extract sufficient domestic coal to meet demand, Malaysia has become highly dependent on coal imports.

Table 10.2 ● Malaysia: Energy reserves and production, 2014[2]

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Oil (billion bbl)	3.8	15	0.22	26th	8th
Gas (tcm)	1.1	16	0.58	25th	7th

Note: Total proven oil/gas reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions.
Source: BP (2015).

At 2014 production levels, Malaysia's crude oil reserves will last for about 15 years (Table 10.2). Under the 11th Malaysia Plan, with an average overall resource replenishment ratio (ORRR)[3] of 1.94 achieved from 2011 to 2013, the government is cautiously optimistic that it is possible to prolong the lifespan of the reserves. This 'healthy' ORRR is attributed to continuous investments by Petroliam Nasional Berhad (PETRONAS), the state-owned oil company, in upstream exploration and production (EPU, 2015).

To boost the oil and gas reserves, PETRONAS is intensifying efforts in deep-water exploration. According to Bank Pembangunan Malaysia Berhad, Malaysia has approximately 615 100 km^2 of acreages available for oil and gas exploration. In 2011, production sharing contracts (PSCs) covered 36% of the total acreages, leaving almost two-thirds of the areas available for exploration (BPMB, 2012). This indicates potential for PETRONAS to expand existing proven hydrocarbon reserves, as was demonstrated in April 2015 with an oil discovery at the Bestari-1 exploration well in Deepwater Block R in Sabah (INPEX, 2015).

Located near the equator where sunshine is abundant, Malaysia has huge potential to develop solar power. The economy also has huge potential in biomass: as of 2013, it accounts for 39% of world palm oil production and 44% of the product's world exports (MPC, 2014). This creates abundant agricultural residue, particularly empty fruit bunches.[4]

Three major electricity grids provide power in Malaysia. The main grid in Peninsular Malaysia and the Sabah grid are both regulated by the federal government; the Sarawak grid is under the responsibility of state government. The main grid in Peninsular Malaysia is connected to Thailand's grid to the north (with capacity for power transfer of 380 megawatts [MW]) and to Singapore's main grid to the south (capacity

[2] The BP Statistical Review of World Energy 2015 is used for energy producing economies as a standardised source of energy reserves and production for comparative purposes.
[3] ORRR is an indicator to measure discovered reserves versus production; a ratio of 1.0 or above is considered 'healthy'.
[4] The process of palm oil production generates large amounts of residue, such as empty fruit bunches (EFB) of palm. The EFB is a type of woody biomass having a calorific value of 4 400 kcal/kg-dry; it is regarded as a safe and promising biofuel resource because it has very low chlorine content (Asia Biomass, 2009).

of 450 MW) (HAPUA, 2014). In East Malaysia, the Sarawak grid is connected to Kalimantan grid in Indonesia (capacity expected to reach 50 MW by the end of 2015) (SEB, 2015).

ENERGY POLICY CONTEXT

Malaysia's National Energy Policy, which was first formulated in 1979 and serves as the overall framework for the development of the energy sector, comprises three principal objectives:

- The supply objective: To ensure the provision of an adequate, secure and cost-effective supply of energy through the development of indigenous energy resources and diversification of energy supply from domestic and international sources;
- The utilisation objective: To promote efficient utilisation of energy and to discourage wasteful and non-productive patterns of energy consumption; and
- The environmental objective: To minimise the negative impacts of energy production, transportation, conversion, utilisation and consumption on the environment (KeTTHA, 2010).

In the past, the focus for economic growth was on quantity over quality. The 11th Malaysia Plan places greater emphasis on quality growth, taking into consideration the nation's natural resources and the impacts of their use on the environment. The 11th Malaysia Plan covers almost the entire spectrum of energy, of which this Outlook highlights a few notable strategies, initiatives and targets. To improve the existing green market, the 11th Malaysia Plan includes adoption of green buildings criteria and strengthens green certification. It also sets a target to increase the share of renewable energy[5] sources to 7.8% of total installed generation capacity in Peninsular Malaysia and Sabah by 2020, by exploring the potential for wind, geothermal and other renewables. Besides exploring other renewables potential, the economy plans to introduce a new market mechanism, which is net energy metering. Under this new mechanism, consumers that generate excess electricity through solar photovoltaics (PV) will be able to send electricity to the grid, and utility companies will compensate for transferred energy on a net consumption basis. By 2020, renewable energy capacity is expected to reach 2.1 gigawatts (GW), contributing 7.8% of total installed capacity in Peninsular Malaysia and Sabah (EPU, 2015).

To lower the cost of energy subsidies and reduce market distortions, the government will continue to institute market-based energy pricing. In December 2014, for example, the government abolished petroleum product subsidies. To boost energy security and improve liquidity in the energy market (particularly of natural gas), with the aim of creating a competitive gas market, Malaysia plans to introduce third-party access regulation that will facilitate new entrants into the gas business. The government is also exploring nuclear power as an alternative energy resource, and plans to establish an independent atomic energy regulatory commission in accordance with a new, comprehensive law for nuclear electricity generation (IAEA, 2015). Finally, developing a comprehensive demand-side management (DSM) master plan, which should include targets and strategies to save energy across all sectors, is a high priority for the government (EPU, 2015).

[5] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

BUSINESS-AS-USUAL SCENARIO

This section outlines energy supply and demand in the Business-as-Usual (BAU) Scenario, based on existing short-, mid- and long-term policies, beginning with a summary of key assumptions (Table 10.3). The BAU Scenario explores how the economy evolves based on actions and policies that are currently in place or expected to happen. The overall results in the BAU reflect an extension of current trends of supply and demand, however does not include all current government policies and targets.

Table 10.3 ● Malaysia: Key assumptions and policy drivers under the BAU Scenario

Buildings and industry	• Encourage the adoption of green building design. • Maintain DSM program. • Pursue 11th Malaysia Plan targets. • Abolish the Special Industrial Tariff (SIT) and introduce enhanced time-of-use (EToU) for electricity. • Expand minimum energy performance standard (MEPS), labelling programs and Efficient Management of Electrical Energy Regulations (EMEER 2008).
Transport	• Encourage high deployment of hybrid cars and electric vehicles (EVs). • Pursue efficient engine vehicle deployment as in National Automotive Policy (NAP).
Energy supply mix	• Pursue 11th Malaysia Plan targets. • Apply National Depletion Policy on oil and gas. • Maintain ORRR at greater than 1 for any given period. • Optimise self-sufficiency for oil, gas and renewables.
Power mix	• Expand use of renewables and coal. • Maintain Herfindahl-Hirschman Index (HHI) at less than 0.5.[6]
Renewables	• Achieve renewables targets set under the National Renewable Energy Policy and Action Plan 2010.
Climate change	• Work towards greenhouse gas (GHG) emissions intensity of GDP reduction by 45% by 2030 relative to 2005 level.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

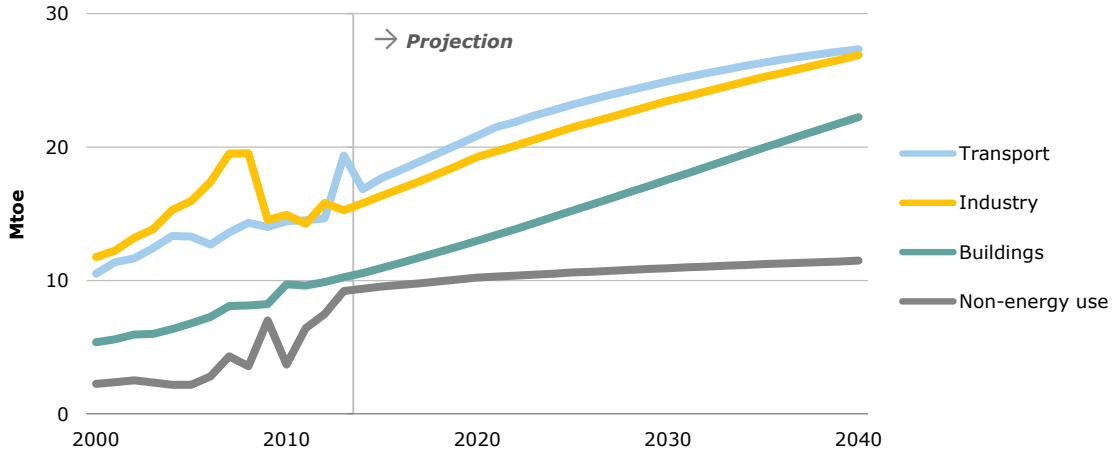
Over the last five decades, Malaysia has maintained one of the strongest economic growth records in Asia, with the availability and reliability of energy supply being a major contributing factor to its success. In the past, Malaysia managed to sustain high economic growth by focusing on resource-based and energy-intensive industry. This economic model is not sustainable in the long run, however, as both resources and energy—particularly fossil fuels—are finite.

In 2013, Malaysia's domestic transport sector consumed approximately 36% of total final energy, followed by industry (28%), and buildings and agriculture (19%). By 2040, the economic structure is expected to change rapidly from a manufacturing base to services; hence, the share of the buildings and agriculture sector in final energy demand is expected to increase from 19% in 2013 to 25% in 2040, while domestic transport sector shares decrease from 36% in 2013 to 31% in 2040. However, absolute demand increases in all sectors (Figure 10.1).

Under the BAU, by 2040 Malaysia's final energy demand is expected to rise by about 63% (34 Mtoe) compared with the 2013 level, reaching just below 88 Mtoe. This reflects an average annual growth rate (AAGR) of 1.8% (almost double the APEC average of 1%).

[6] Herfindahl-Hirschman Index (HHI) is a measure of energy market concentration and diversity. For Malaysia's case, an HHI of 0.5 (or lower) indicates no dependence on any particular fuel; an HHI exceeding 0.5 reflects overdependence on certain fuel resources.

Figure 10.1 • Malaysia: Final energy demand by sector, 2000-40



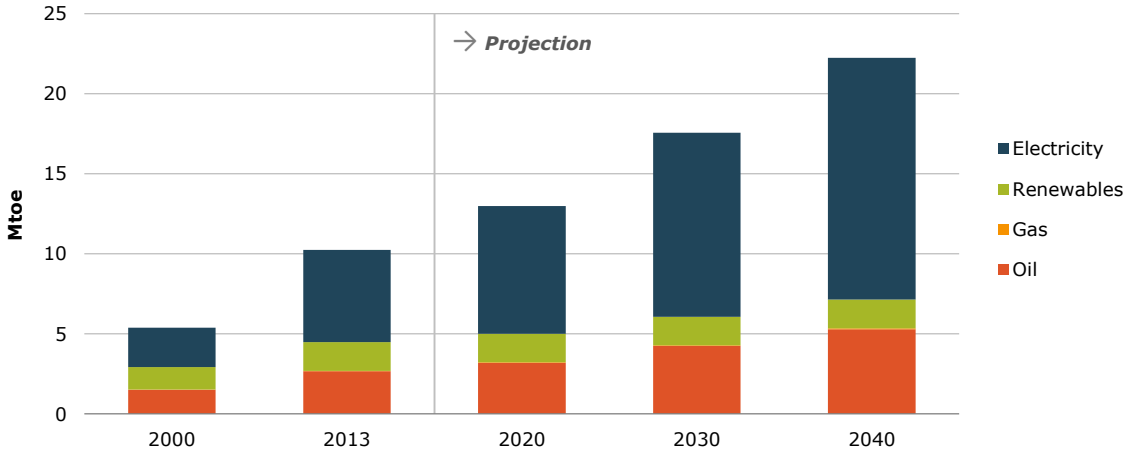
Notes: Transport refers only to domestic transport; Based on IEA Statistics 2015 data, a huge energy demand increase occurred in the transport sector from 2012 to 2013, which does not reflect historical trends. This is due to the historical data collection–particularly for 2013–having captured oil trade from recently completed oil storage as part of the statistics. The data has been adjusted to reflect trends prior to 2013 in transport sector.

Sources: APERC analysis and IEA (2015a).

Buildings energy use: Driven by demand for electricity

Energy consumption in Malaysia's buildings (commercial and residential combined) and agriculture sector is projected to grow 2.9% annually under the BAU, from around 10 Mtoe in 2013 to 22 Mtoe in 2040—one of the highest growth rates among economic sectors (Figure 10.2). Commercial activity has the highest share (57%) of final energy demand in this sector by 2040, while electricity (with a share of 68%) dominates energy demand. Other fuels, primarily oil and renewables, make up the rest of the shares in the agriculture and buildings sector.

Figure 10.2 • Malaysia: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Recognising the large potential for energy efficiency in the buildings sector, the government has set a priority for further improving DSM, continuing initiatives developed under the 10th Malaysia Plan, 2011-2015. Several targets have been set, including an increase in the number of Registered Electrical Energy Managers (REEM) under EMEER 2008, implementation of ISO 50001[7] in the private sector, and extending MEPS and labelling programs to a wider range of appliances (EPU, 2015).

[7] ISO 50001 is a voluntary international standard to provide organisations a recognised framework to manage and improve their energy performance.

In agriculture, government initiatives under the 11th Malaysia Plan that aim to improve the productivity and income of farmers (both in crop and livestock rearing) and fishermen are expected to drive up energy demand. These initiatives include promoting greater use of machines and mechanised equipment, upgrading and building more collection and distribution centres, and upgrading cold storage facilities.

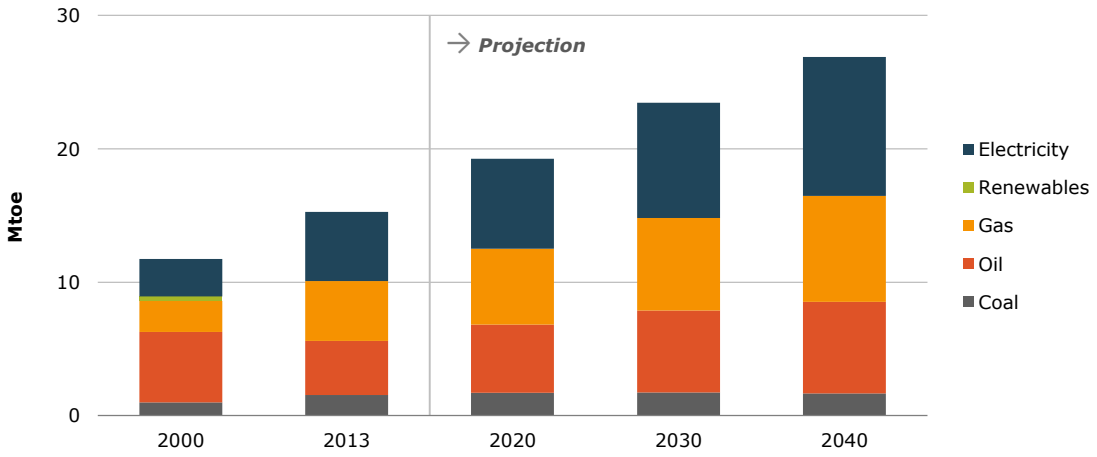
To encourage the adoption of green building design, the government will set itself as the market leader: all new government buildings will have to adopt green features and designs, while existing government buildings will be gradually retrofitted. Under the 10th Malaysia Plan, two government buildings were chosen as pilot projects for retrofitting through an energy performance contracting (EPC) concept. Data collected through these projects are promising: energy consumption in both buildings was reduced to the required level with payback periods of 1.6 years and 4.7 years. Under the 11th Malaysia Plan, the government aims to retrofit 100 government buildings (EPU, 2015).

Industry energy use: Modest growth as more complex manufacturing introduced

Energy demand in industry grows at an AAGR of 2.1% over the Outlook period, from 15 Mtoe in 2013 to 27 Mtoe in 2040 (Figure 10.3). Following the 10th Malaysia Plan, industry has made important contributions to GDP and accounts for the largest share of total exports. The establishment of the Sarawak Renewable Energy Corridor (SCORE), in which large hydro projects generate electricity for energy-intensive industries (including aluminium, steel and glass), will contribute to the increase in final energy demand (EPU, 2015).

During the Asian financial crisis in 1997-98, the Malaysian government introduced the Special Industrial Tariff (SIT) to help manufacturers stay competitive. Though launched as a temporary measure, as of 2015 the SIT was still in place. In line with the government policy to gradually remove energy subsidies, the SIT will be abolished in stages and fully by 2020. As part of interim measures prior to SIT abolishment, the government set new requirements for SIT applicants to implement EMEER 2008 regulations, such as appointing REEM and implementing energy saving measures. Its removal should encourage industry to be more energy efficient in the future (EPU, 2015).

Figure 10.3 • Malaysia: Industry sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

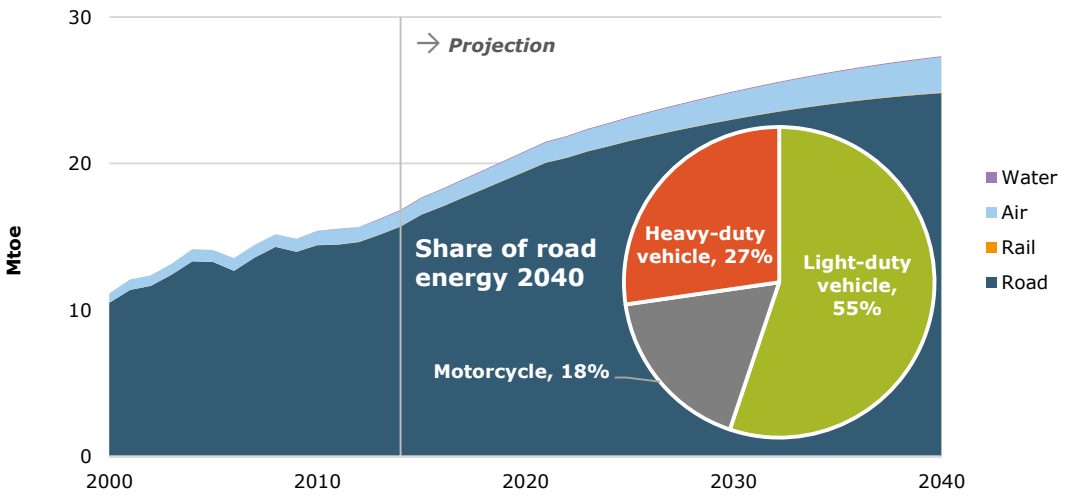
In parallel, power companies will introduce Enhanced Time-of-Use pricing with three different time periods. This will give industry flexibility to manage electricity demand and thus reduce peak demand, making it easier for power companies to manage supply and demand. By reviewing utility standby charges, the government plans to increase on-grid cogeneration capacity by more than 100 MW.

Transport energy use: Road transport continues to dominate

Malaysia's domestic transport final energy demand in the BAU is projected to grow at an AAGR of 1.3% from around 19 Mtoe in 2013 to over 27 Mtoe in 2040 (Figure 10.4). Lack of reliable public transport has been identified as a key factor that creates traffic congestion in Kuala Lumpur, which subsequently reduces productivity and leads to significant energy wastage. To rectify this situation, more than 150 km of mass rapid transit development has been planned in Kuala Lumpur, to be rolled out in three phases. The first phase of 50 km is expected to start operation in 2016, followed by the second and third phases towards the end of this decade and the start of the next. The recently launched National Automotive Policy (NAP) encourages the adoption of energy efficient vehicles (EEVs) (MAA, 2014). Such vehicles can help to reduce dependence on fossil fuel and fuel wastage, and also lower the emission of harmful gases and black smoke, thereby lowering transport's impact on the environment.

Malaysia's vehicle stock is expected to increase in tandem with the growing middle class; people are expected to travel more and to shift to more comfortable vehicles, such as personal cars (passenger light-duty vehicles or PLDVs). With high-quality highways, at least by South-East Asia standards, and new highway projects planned in East Malaysia and on the east coast of West Malaysia, people who own PLDVs are expected to travel more (previously, such travel was limited due to lack of public transportation options). In terms of fuel consumption, PLDVs are expected to continue to have the highest energy demand—around 14 Mtoe by 2040, followed by heavy-duty vehicles (HDVs) with 6.8 Mtoe.

Figure 10.4 • Malaysia: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Expected to be cleaner in the future

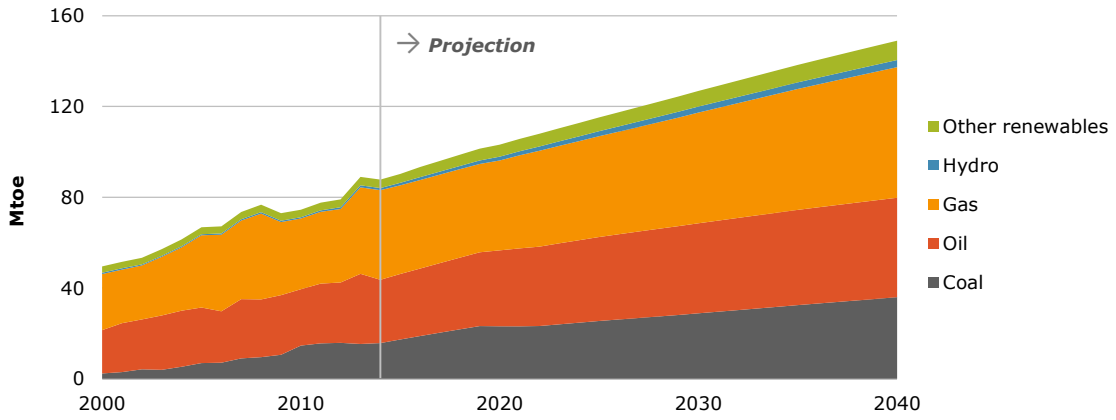
Malaysia has experienced a rapid expansion of its energy sector, with total primary energy supply (TPES) quadrupling from 22 Mtoe in 1990 to 89 Mtoe in 2013. Steady growth is evident across all fuels, with coal recording the fastest increase at an AAGR of nearly 13%. Since 2000, the share of oil has declined from 39% in 2000 to 35% in 2013, while natural gas dominated TPES with a share of 50% in 2000, subsequently falling to 43% in 2013, a trend that is expected to continue over the Outlook period.

Fossil fuels made up nearly 95% of TPES in 2013, with renewables (including big hydro) accounting for the remainder (Figure 10.5). APERC analysis projects that Malaysia's energy supply will move towards greener sources over the Outlook period, with government policies, targets and initiatives being the main drivers.

In tandem with high economic growth—Malaysia's GDP is expected to expand at an AAGR of 4.2%, from USD 514 billion in 2013 to USD 1 550 billion in 2040—TPES is projected to grow at 1.9% annually from

89 Mtoe in 2013 to 149 Mtoe in 2040. Strong growth is expected in renewable energy; at 3.5% annually, Malaysia is projected to have one of the highest renewable energy growth rates among APEC economies. Rapid expansion of the electricity sector, however, is expected to drive a parallel increase in coal demand, which increases by 21 Mtoe to reach 36 Mtoe in 2040 (against the 2013 level of 15 Mtoe). Malaysia imports almost all of its coal supply; by 2040, the economy will need to import roughly 51 Mt of coal annually, compared with 20 Mt in 2013. Natural gas supply is expected to reach 58 Mtoe over the same period, with Malaysia expected to become a net gas importer by 2035. In reality, Malaysia started to import LNG in 2011 due to the geographical mismatch between where gas is produced (East Malaysia) and the regions of highest demand (West Malaysia).

Figure 10.5 ● Malaysia: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

Energy trade: From energy exporter to major energy importer

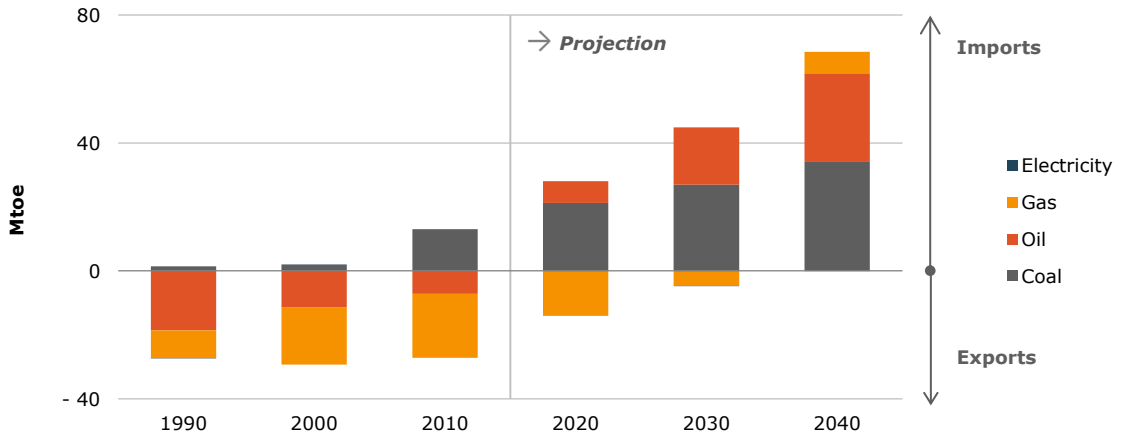
PETRONAS was established in 1974 as the custodian for Malaysia's oil and gas resources. The establishment of Malaysia LNG Sdn. Bhd. (MLNG), incorporated in 1978, led to the completion (in 1982) of the PETRONAS LNG Complex in Bintulu, Sarawak. This paved the way for Malaysia's entry into the LNG market, with its first cargo setting sail for Japan in 1983 (MNLG, 2015). These developments led to Malaysia becoming an energy-exporting economy in the early 1980s.

By 2013, Malaysia became the second-largest LNG exporter in the world, outsized only by Qatar (IGU, 2015). With seven projects now under construction (with total capacity of 58 Mt/yr), Australia is expected to overtake both Qatar and Malaysia to have the largest liquefaction capacity by 2018.

Malaysia shifted from a net energy exporter to become a net energy importer in 2014—largely due to rising energy demand (Figure 10.6). Recent expansion of coal power plants in the economy has caused a sharp increase in coal demand; but as Malaysia has limited indigenous coal production, coal imports have also increased steeply. Looking ahead to 2040, Malaysia's total energy production is expected to remain flat while energy demand is forecast to nearly double. Malaysia's long-term oil supply projection warrants special attention: under the BAU Scenario, net oil imports increase almost five-fold at an AAGR of 6%, from 5.7 Mtoe in 2013 to 28 Mtoe in 2040.

To ensure sustainable economic growth and security of energy supply, Malaysia is developing the Pengerang Integrated Petroleum Complex (PIPC), a large-scale project (covering approximately 9 100 hectares) that will pave the way for Malaysia to become the regional hub for oil storage and LNG (JPDC, 2015). Measures are also underway to introduce third-party access for gas supply; enforcement of amendments to the Gas Supply Act 1993 (Act 501), which are expected to be tabled in Parliament in 2016, will allow third parties to use the gas supply infrastructure. This will create a level playing field for new entrants to compete in the domestic gas supply market, complementing PETRONAS, which is currently the sole player (EPU, 2015).

Figure 10.6 • Malaysia: Net energy imports and exports, 1990-2040



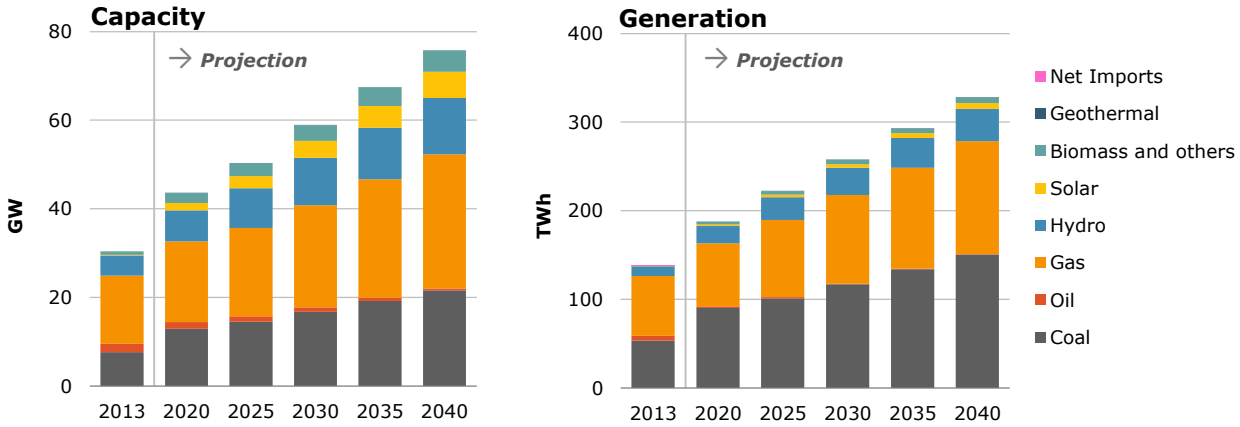
Sources: APERC analysis and IEA (2015a).

Power sector trends: Fossil fuel dependence continues, despite rising share of renewables

In 2013, fossil fuel generated more than 91% of Malaysia's electricity, with the remaining 9% coming from renewable energy sources (Figure 10.7). Three separate grid systems serve the economy, with total generated electricity at slightly below 139 terrawatt hours (TWh) in 2013. A mismatch between resource locations and load centres is a major challenge for Malaysia: while Peninsular Malaysia accounts for more than 85% of electricity demand, nearly two-thirds (64%) of fossil fuel production takes place in Sabah and Sarawak (EC, 2015).

By 2040, Malaysia's generation capacity is expected to reach nearly 76 GW, an increase of around 150% from the 2013 level of 30 GW. With the introduction of a feed-in tariff (FiT) system in 2011, renewable capacity is anticipated to increase by more than 18 GW, from 5.5 GW in 2013 to more than 23 GW in 2040. Solar power is expected to show an AAGR of about 15% as the goverment takes steps to boost solar PV capacity (including through mechanisms such as maintaining the FiT and introducing a net metering system). Biomass also expands rapidly under the BAU Scenario, at nearly 6.6% growth annually.

Figure 10.7 • Malaysia: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

As renewable energy generation capacity shows the highest growth among power sources, the share of electricity generated from fossil fuels falls from 91% in 2013 to about 85% by 2040. In terms of electricity generated, renewables expand fourfold by 2040 from 2013 levels. Malaysia makes a substantial contribution to the target to double the share of renewables in the APEC energy mix

(including in power generation) by 2030 (from the 2010 level), as renewable generation increases by more than four times over the same period.

Natural gas and coal are expected to continue their roles as main fuels for electrcity generation in Malaysia under the BAU. By 2040, generation capacity for natural gas increases by 15 GW from the 2013 level, while coal increases by more than 14 GW, leading to total generation capacity from fossil fuels of 52 GW or 69% of total capacity. The BAU Scenario assumes the reserve margin will be kept above 20%, though values for each of the three major grids may vary.

ALTERNATIVE SCENARIOS

All three Alternative Scenarios—Improved Efficiency, High Renewables and Alternative Power Mix—apply to Malaysia.[8] Within the Alternative Power Mix Scenario, all four cases apply and result in some reductions in energy-related CO_2 emissions. Among these Alternative Scenarios, the Improved Efficiency Scenario contributes the greatest reduction in energy-related CO_2 emissions, while improving energy self-sufficiency. The High Renewables Scenario and the High Nuclear Case in the Alternative Power Mix Scenario significantly improve fuel mix diversity and energy self-sufficiency, with some reductions in energy-related CO_2 emissions compared with the BAU scenario, but still higher than under the Improved Efficiency Scenario. The High Nuclear Case is applied to Malaysia due to power generation capacity projections by the Energy Commission in 2014 (EC, 2014).

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

The Improved Efficiency Scenario assumes a higher penetration of energy-efficient vehicles in transport and energy-efficient equipment in the buildings sector and demonstrates Malaysia's potential contribution to the APEC energy intensity goal.[9] Unlike most developed economies, which show a trend of falling energy demand, Malaysia's emerging economy status suggests rising energy demand. Still, the economy has been boosting efforts to meet the APEC energy intensity target. Under the BAU, energy intensity drops by nearly 40% by 2035, largely as a result of a voluntary target to reduce greenhouse gas (GHG) emissions intensity (GDP-based) by up to 40% by 2020 (compared with the 2005 level).

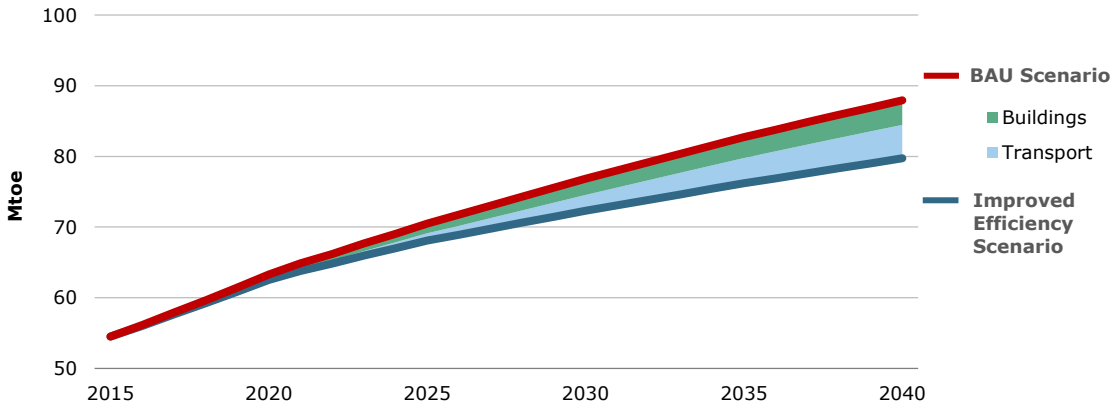
Assuming the government proceeds with subsidy rationalisation in the power sector, rising energy prices are expected to prompt residential and commerical consumers towards more efficient use of electricity. By applying the Improved Efficiency Scenario to Malaysia, APERC estimates a potential of 9.3% additional energy savings compared with the BAU by 2040 (Figure 10.8). Additionally, Malaysia's energy intensity declines by more than 46% in 2035 (from the 2005 level), compared with 41% under the BAU.

Under the Improved Efficiency Scenario, Malaysia's industry sector was not assessed due to a lack of detailed historical data, particularly for energy consumption in energy-intensive industry. Thus, the scenario modelling results likely underestimate the potential savings reduction and Malaysia may have potential to further reduce energy intensity.

Against the BAU, the Improved Efficiency Scenario demonstrates that transport contributes energy savings of 4.7 Mtoe, while the buildings sector contributes energy savings of 3.5 Mtoe. Improved fuel economy of new vehicles and efficient urban planning, with rapid expansion of rail transport in the capital, prompts a 10% reduction in vehicle stock. According to the Land Public Transport Commission, nearly 300 km of new rail will be added to the existing 280-km network in Kuala Lumpur/Klang Valley by 2025. Additionally, Malaysia expects to finish upgrading the existing railway to be fully electrified and high-speed by 2020. This will cut travel time to most major towns connected to the railway network by more than 50% compared with road travel (SPAD, 2013).

[8] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.
[9] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

Figure 10.8 • Malaysia: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Note: An estimate for savings potential in industry was not calculated due to lack of data and hence the Improved Efficiency Scenario underestimates the potential savings from enhanced energy efficiency.

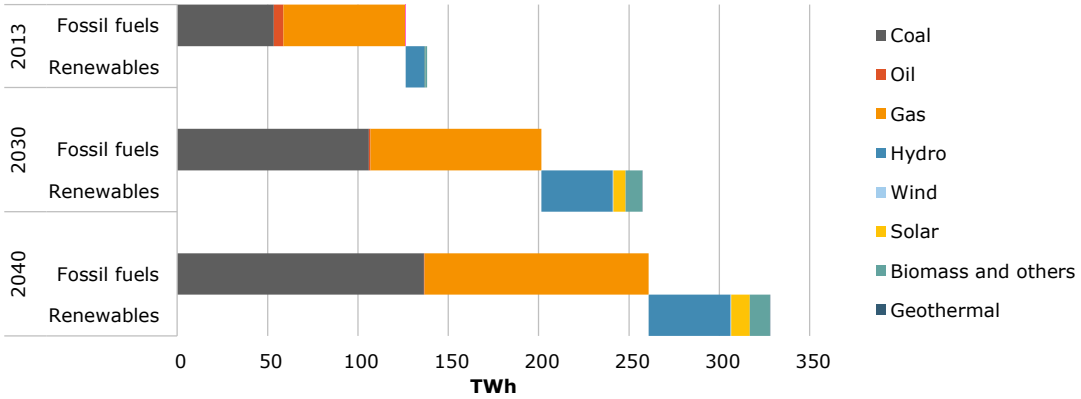
Source: APERC analysis.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

In 2014, APEC energy ministers agreed to a collective goal of doubling the share of renewable energy in the APEC energy mix, including the power mix, from the 2010 level by 2030.[10] The High Renewables Scenario focuses on the electricity and transport sectors to achieve a doubling of renewables in Malaysia. Under the BAU Scenario, renewables increase from 4.6 Mtoe in 2013 to nearly 12 Mtoe by 2040, with hydropower, solar and biomass increasing rapidly. Renewables generation rises from 12 TWh in 2013 to 40 TWh in 2030 and 50 TWh in 2040.

Under the High Renewables Scenario, Malaysia generates an additional 17 TWh from renewables, with biomass and hydro making the strongest contributions (Figure 10.9). Electricity generated from renewable resources reaches 67 TWh by 2040, more than five times the 2013 level (12 TWh). Electricity from hydropower increases by more than 8.6 TWh compared with the BAU, while solar's contribution increases by 3.8 TWh. In this scenario, wind power contributes 0.45 TWh in 2040, up from negligible generation in 2013.

Figure 10.9 • Malaysia: Power sector under the High Renewables Scenario, 2013-40



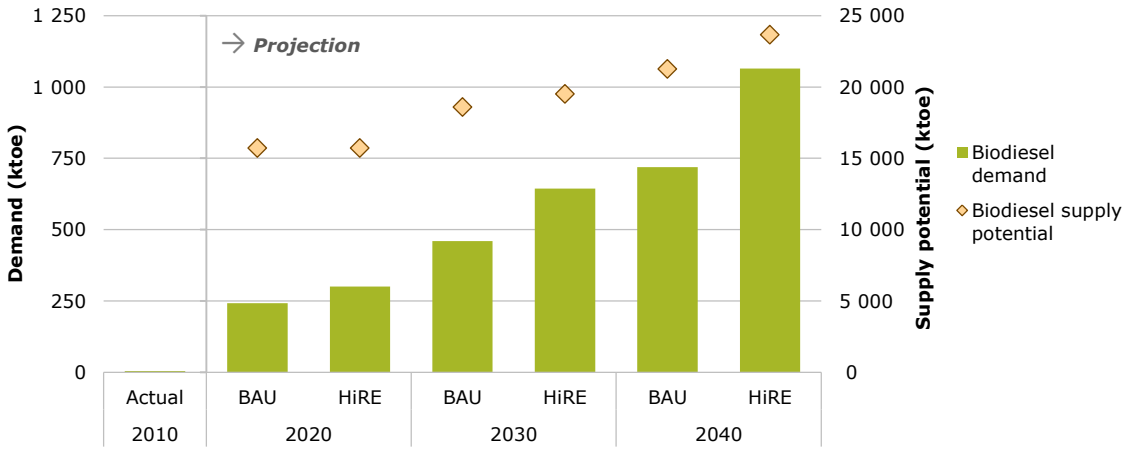
Sources: APERC analysis and IEA (2015a).

Under the BAU, biofuels demand in the transport sector increases from 0.13 Mtoe in 2013 to 0.46 Mtoe in 2030 and 0.72 Mtoe in 2040. The High Renewables Scenario shows strong potential for biomass in both electricity generation and transport, directly linked to Malaysia's status as one of the world's major exporters of palm oil. In 2011, the local palm oil sector generated an estimated 80 Mt of biomass; by

[10] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

2020, the volume is expected to increase to 100 Mt, primarily due to higher yields. Together with biomass produced in other agriculture sectors, this substantially increases fuel source options and volumes for biomass electricity generators (PEMANDU, 2011). Assuming Malaysia is able to produce enough palm oil for biofuels with a blend rate of 20% by 2020, the High Renewable Scenario shows that biofuel consumption rises to 1.1 Mtoe by 2040—accounting for 3.9% of total energy demand in transport (Figure 10.10).

Figure 10.10 ● Malaysia: Biodiesel demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is for the Outlook period only; HiRE = High Renewables Scenario.
Sources: APERC analysis, IRENA (2014), FAO (2014) and IEA (2015a).

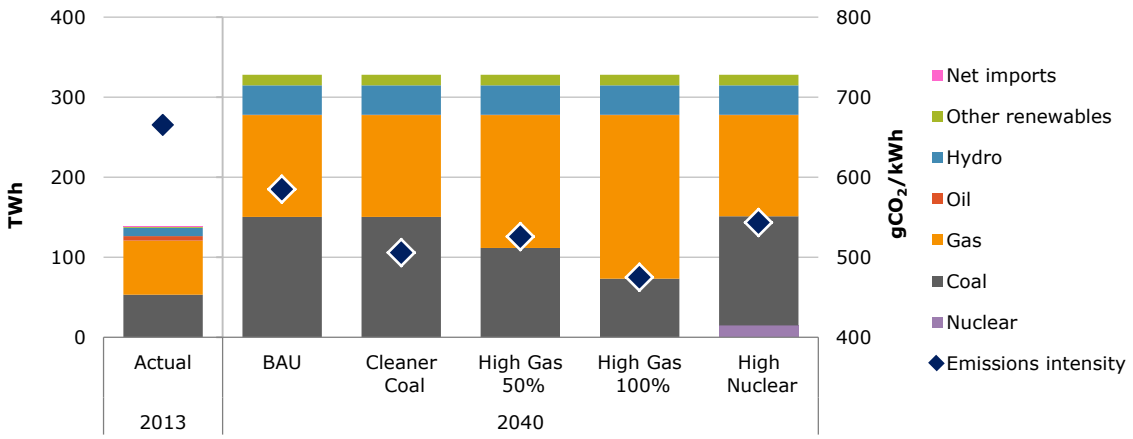
ALTERNATIVE POWER MIX SCENARIO

Four Alternative Power Mix cases evaluate the potential of deploying certain energy technologies (such as cleaner coal) or promoting fuel switching (as in the High Gas or High Nuclear Cases). This section examines options to adjust the fuel mix for power generation in Malaysia, including the trade-offs each option represents for generation costs, emissions and the fuel diversity index. The assessment improves understanding of CO_2 emission mitigation, cost of generation and diversity of fuels in the power sector.

The Cleaner Coal Case assumes that, from 2020 onwards, all new coal-based electricity generation capacity is ultra-supercritical (USC) with a minimum efficiency of 40%. By 2030, carbon capture and storage (CCS) is introduced in all new plants. The High Nuclear Case assumes that nuclear power is introduced to Malaysia's power mix in 2026. The High Gas Case assumes that new generation capacity up to 2040 is natural gas instead of coal. Two levels of replacement are considered: the High Gas 50% Case assumes half of new generation switches to gas while the High Gas 100% Case assumes all planned coal-fired plants transition to gas.

Under the BAU, natural gas contributes about 39% of power generation in 2040 with about 30 GW of installed capacity (Figure 10.11). The High Gas 50% Case installed capacity increases to 36 GW and the High Gas 100% Case shows installed capacity of 41 GW. The High Gas 100% Case delivers the lowest CO_2 emissions intensity by 2040, but has the highest generation cost per unit: high fuel costs would push generation costs to USD 154/MWh compared with USD 119/MWh in the BAU.

Figure 10.11 ● Malaysia: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

Natural gas supply in terms of Malaysia's TPES, which is 58 Mtoe in 2040 under the BAU, increases to more than 66 Mtoe under the High Gas 50% Case and to 76 Mtoe in the High Gas 100% Case. A major implication of the High Gas 100% Case is that Malaysia becomes a net gas importer by 2027—some eight years sooner than under the BAU (2035).

Under the Cleaner Coal Case, Malaysia's emissions intensity from electricity generation falls by nearly 14% as compared with the BAU Scenario, while under the High Nuclear Case, in which nuclear power is introduced in 2026 and reaches 2 GW by 2030, Malaysia's emissions intensity falls by 7.2% as compared with the BAU Scenario.

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

APERC analysed Malaysia's supply side investment needs to keep pace with energy demand, using both a low-cost estimate and a high-cost estimate, with neither having a discount rate. Under the BAU from 2015 to 2040, estimated investments are between USD 307 billion (low-cost estimate) and USD 658 billion (high-cost estimate) (Table 10.4). As its energy reserves are depleting, Malaysia will need to intensify upstream activity to replace oil and gas reserves; this accounts for 50% in the low-cost estimate and 47% in the high-cost estimate. Considering electricity generation increases more than twofold, the need to fund 45 GW of additional generation capacity will demand 28% in the low-cost estimate and 26% in the high-cost estimate. Investment for energy transport will account for 19% under the low-cost estimate and 21% under the high-cost estimate. The downstream sector has the lowest investment requirement, as only a small amount of additional capacity will be needed to accommodate domestic requirements.

With energy demand about 9.3% lower under the Improved Efficiency Scenario than in the BAU Scenario, this Scenario leads to 5.4% (to USD 290 billion) savings in investments in the low-cost estimate (Figure 10.12). Much of the investment savings is in the power sector, resulting from a 10% (7.8 GW) decrease or deferral in the need for additional capacity. The High Renewables Scenario shows an increase of 1.3% (to USD 311 billion) due to increased investments for electricity of 5.8% (to USD 92 billion) under the low-cost estimate; savings from investment needs for energy transport offset additional investment requirements in the power sector, particularly due to expansion of biomass and hydropower.

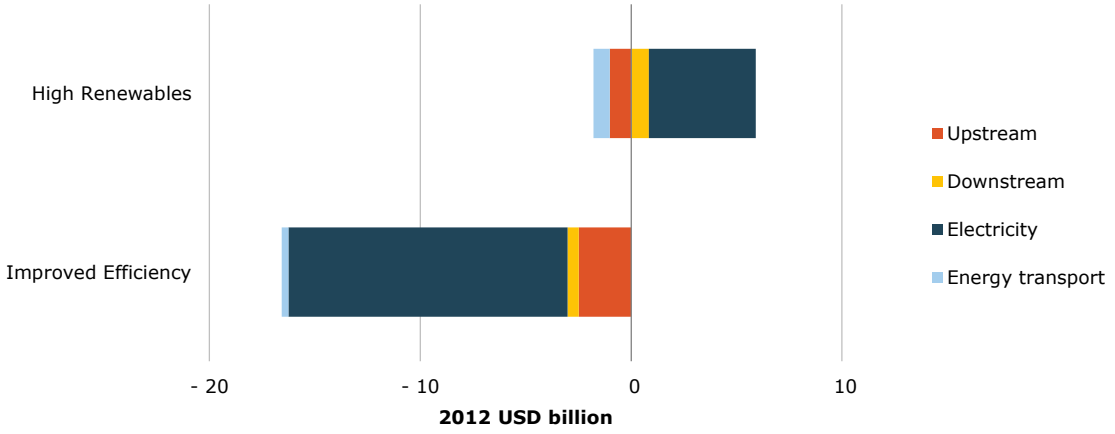
Table 10.4 • Malaysia: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	99	148
	Gas	54	163
	Coal	1.4	4.4
	Subtotal	155	316
Downstream	Refinery	6.4	30
	LNG import terminals	0.2	0.5
	Biofuels refinery	0.1	0.1
	Subtotal	6.7	31
Electricity	Coal	22	25
	Gas	11	17
	Hydro	7.4	24
	Solar	14	20
	Biomass and others	5.6	7.4
	Geothermal	0.1	0.1
	Transmission lines	8.8	21
	Distribution lines	18	60
	Subtotal	87	173
Energy transport	Oil	14	17
	Gas	42	118
	Coal	1.5	3.3
	Subtotal	58	138
	Total	**307**	**658**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

Figure 10.12 • Malaysia: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.

Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

Malaysia's National Depletion Policy (introduced in 1980) aimed to safeguard the exploitation of natural oil reserves as crude oil production increased rapidly by capping oil production at around 650 000 bbl/d. Subsequently, the Four Fuel Diversification Policy (introduced in 1981) aimed to prevent over-dependence on oil as the main energy resource. As result, oil shares in power generation dropped from a high of 80% in 1976 to 5.2% in 2000, replaced by coal, natural gas and hydropower (EC, 2015).

Enhancing energy security: Higher diversification but lower self-sufficiency

Under the 11th Malaysia Plan, the government introduced a fuel diversity index based on the Herfindahl-Hirschman Index (HHI). The Plan prioritises exploration of alternative fuels to optimise the fuel mix and reduce dependence on fossil fuels for electricity generation. Malaysia's HHI for 2014 was a healthy 0.45; the target for 2020 is to maintain an HHI of 0.5 (or lower), which APERC analysis shows to be achievable throughout the Outlook period.[11] High renewable energy penetration under the BAU helps achieve a higher diversity level of primary energy supply—from HHI 0.34 in 2013 to HHI 0.30 by 2040 (Table 10.5). Overall, however, Malaysia's level of energy self-sufficiency decreases from 84% in 2013 to 57% in 2040 under the BAU; better self-sufficiency levels are achieved under the Improved Efficiency and High Renewable Scenarios.

Under the Improved Efficiency Scenario, oil self-sufficiency in Malaysia improves to 53% (compared with 47% in the BAU). Among the APERC scenarios, the High Renewables Scenario produces the best results for diversity of TPES and of input fuel for electricity generation. In the High Gas 100% Case, however, the diversity index increases to HHI 0.36, which indicates less diversification in primary energy supply. Under the same case, Malaysia's gas self-sufficiency detriorates to the lowest level (67%) while the Improved Efficiency and High Renewables Scenarios maintain 90% or greater gas self-sufficiency through to 2040.

Table 10.5 • Malaysia: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040						
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%	High Nuclear
Primary energy supply diversity (HHI)	0.34	0.30	0.30	0.29	0.30	0.32	0.36	0.28
Primary energy supply self-sufficiency (%)	84	57	63	60	56	57	56	60
Coal self-sufficiency (%)	12	5	6	6	5	7	10	6
Oil self-sufficiency (%)	96	47	53	47	47	47	47	47
Gas self-sufficiency (%)	100	88	96	90	88	77	67	90
Electricity generation input fuel diversity (HHI)	0.44	0.42	0.41	0.39	0.43	0.42	0.47	0.37

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity. For example, Malaysia set a maximum 0.5 HHI for its power mix as a benchmark to show the level of diversity, where 0.5 (or lower) indicates no dependence on any particular fuel; an HHI exceeding 0.5 reflects overdependence on certain fuel resources. In 2013, APEC region power mix was 0.36 of HHI.

Sources: APERC analysis and IEA (2015a).

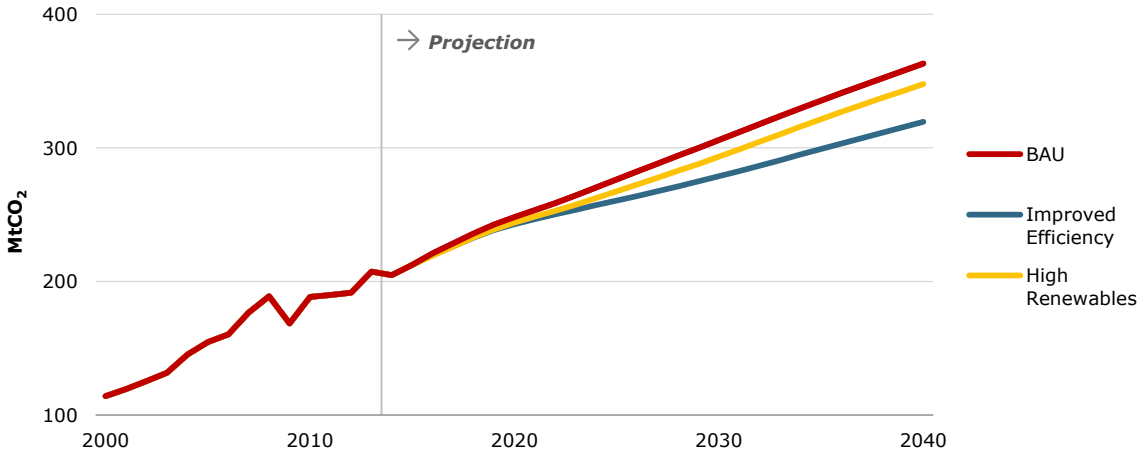
Climate change impacts and risks: With the right policy, emissions can be reduced

The energy sector accounts for about two-thirds of Malaysia's total emissions (MNRE, 2014). Malaysia's increasing dependence on coal under the BAU makes electricity generation the highest contributor to

[11] Based on Malaysia's definition, in the power sector, HHI of 0.5 (or lower) indicates no dependence on any particular fuel; HHI exceeding 0.5 reflects overdependence on certain fuel resources (EPU, 2015).

energy-related CO_2 emissions with an increasing majority share over the Outlook period. Total energy-related emissions under the BAU almost double over the Outlook period, from 207 million tonnes of CO_2 ($MtCO_2$) in 2013 to 363 $MtCO_2$ by 2040 (Figure 10.13).

Figure 10.13 ● Malaysia: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



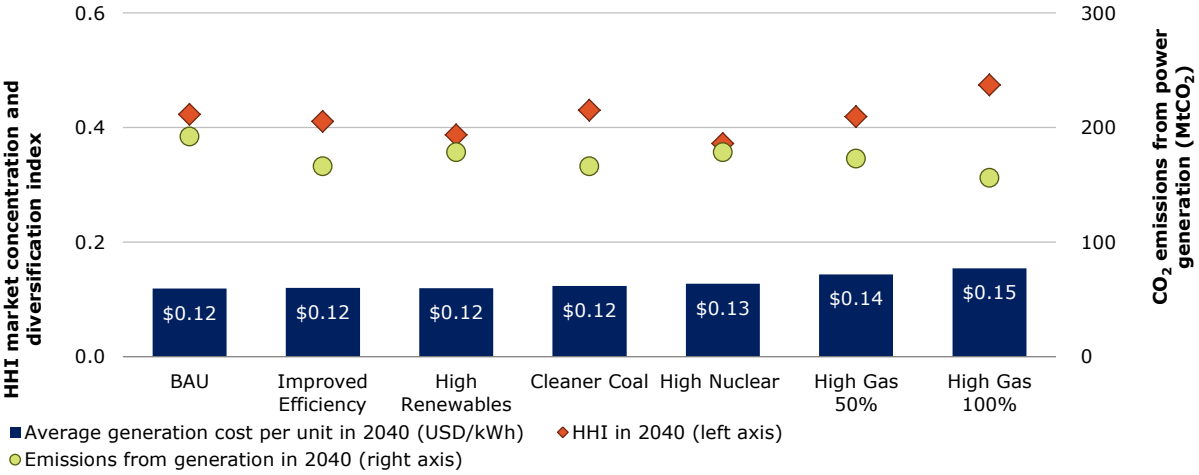
Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF). The drop in CO_2 emissions post-2010 is due to the historical data collection, especially in 2013, which included oil trade from the recently completed oil storage facility; the data was also adjusted to reflect trends prior to 2013 in transport sector.

Source: APERC analysis.

The Improved Efficiency Scenario offers the largest emissions reduction opportunity in the energy sector in 2040, at around 9.4% (329 $MtCO_2$ reflecting an AAGR of 1.6%) compared with the BAU (AAGR of 2.1%). The High Renewables Scenario shows emissions reaching 348 $MtCO_2$ by 2040 (AAGR of 1.9%), a savings of 15 $MtCO_2$ from the BAU Scenario. As there is potential for energy savings beyond those modelled under the Improved Efficiency Scenario, CO_2 emissions reductions could exceed APERC projections.[12]

Trade-offs in the power sector in 2040: Improved Efficiency may strike the balance in power sector

Figure 10.14 ● Malaysia: Generation trade-offs under the different Scenarios, 2040



Source: APERC analysis.

[12] The potential for energy savings in industry was not modelled due to lack of sectoral energy usage data. It is thus assumed that Malaysia should be able to reduce CO_2 emissions further than the current modelling demonstrates.

Using the combination of generation costs, power sector CO_2 emissions and the fuel diversity index to project potential outcomes of the energy sector by 2040, APERC analysis can gauge some of the trade-offs that Malaysia may need to consider under each scenario (Figure 10.14). The High Gas 100% Case and High Renewables Scenario have the lowest power sector CO_2 emissions, but generation costs in the High Gas 100% Case escalates and the fuel diversity index shows over-dependence on gas. By introducing nuclear power, fuel diversity for generation improves but power sector CO_2 emissions decrease only slightly compared with the BAU. The Cleaner Coal Case shows improvements in all aspects compared with the BAU, but some are less pronounced than in other cases.

RECOMMENDATIONS FOR POLICY ACTION

Malaysia's energy demand is expected to increase throughout the Outlook period. The APERC scenario analysis provides insights into different ways to balance rising demand with targets for increased energy efficiency, reduced energy-related CO_2 emissions and greater energy security. A high growth rate in renewable energy should allow Malaysia to contribute to the target to double the share of renewable energy in APEC's energy mix while also helping improve Malaysia's energy security. This is vital, as Malaysia is expected to import nearly 50% of its energy supply by 2040.

As Malaysia is making the transition from exporter to importer of oil—i.e. heading towards a 'new norm'—a more coordinated effort in energy planning will help ensure reliable and sustainable energy supply for future generations. Improving energy data collection is one area that Malaysia can work on immediately, particularly on the demand side (and particularly for industry) where the lack of historical data may hamper better energy planning.

Recent moves to rationalise energy subsidies demonstrate that Malaysia is heading in the right direction. Removing the subsidy on petroleum products while the oil price is low is wise; a similar approach should be applied to the power sector as soon as possible. Malaysia's inefficient fossil fuel subsidies lead to wasteful energy usage. An alternative to fossil fuel subsidies is fuel economy policies implemented through regulations under the Environmental Impact Assessment (EIA).[13]

The status of 'green growth' as one of the economic pillars in the 11th Malaysia Plan is an important change in direction, from 'grow first, clean up later' to sustainable development. Malaysia now needs to introduce robust policy to support this transformation, in areas such as fuel economy and clean energy. Considering the growing importance of coal in TPES, Malaysia has the opportunity to demonstrate that with the right technology, coal can help mitigate energy-related CO_2 emissions (as shown in the Alternative Power Mix Scenario). As it becomes commercially viable, CCS should be made compulsory for any future coal power plant. A levelised tariff of coal with CCS should be the benchmark in power planning and future projects.

Under the 11th Malaysia Plan, the government sets out various strategies and initiatives to improve the energy supply and demand equation. Executing such plans can, however, be challenging—particularly if the government lacks support from the sectors or if energy subsidies remain in place. Educating people about Malaysia's new reality as net oil importer may help build understanding of why consumers need to use energy wisely and efficiently.

[13] An EIA is a mandatory legislative requirement for project development and must be prepared in accordance with the guidelines issued by the Department of Environment. It must include an assessment of the impact on the environment and proposed mitigation measures.

11. MEXICO

KEY FINDINGS

- **A landmark energy reform enacted in late 2013 is expected to transform Mexico's energy outlook.** This reform broke a 75-year state monopoly in oil and gas with a new legal and institutional framework to accelerate hydrocarbon production and make the electricity sector more efficient by allowing private participation across the industry's value chain.

- **TPES is projected to grow in line with historical rates, with the share of fossil fuels remaining constant.** The share of coal and oil in TPES declines considerably while that of natural gas grows from less than one-third in 2013 to nearly half by 2040, mainly for electricity generation.

- **Higher reliance on natural gas erodes primary energy supply diversity from HHI 0.38 in 2013 to HHI 0.39 in 2040 and may threaten energy security.** Unless domestic gas production increases significantly, dependence on US imports will grow, at the risk of availability and competitive long-term pricing.

- **Despite being an emerging economy, Mexico is highly committed to tackling climate change. Under the BAU Scenario, energy-related CO_2 emissions grow from 451 $MtCO_2$ in 2013 to 695 $MtCO_2$ in 2040.** The Improved Efficiency Scenario demonstrates the greatest CO_2 emissions reductions in the energy sector, with 23% less emissions than the BAU Scenario in 2040. The High Renewables Scenario cuts emissions by barely 3% over the BAU.

ECONOMY AND ENERGY OVERVIEW

Mexico is a federal republic that is usually regarded as a Latin American economy due to its culture and history, although its geographical location and economic integration are within North America. Major reforms and free trade agreements since the 1990s have created macroeconomic stability and have expanded foreign direct investment, making Mexico one of the largest developing economies.

Population was over 118 million in 2013, and it was the eighth-largest economy in the Asia-Pacific Economic Cooperation (APEC) and 15th in the world (World Bank, 2015). Economic growth in the last two decades has been below the APEC average, so further structural changes have been required to stimulate the economy, including a sweeping energy reform enacted in 2013.

The services sector is the main contributor to gross domestic product (GDP) with a share of over 62%, followed by industry at 34% and agriculture at 4% (INEGI, 2015). Supported by a strong manufacturing industry, a growing services sector and accelerated development of energy resources, Mexico's economy is poised for robust growth over the Outlook period. In economic terms, mining, oil and gas, and electricity generation activities contributed barely 8.6% of GDP in 2013, but in energy terms they represented 34% of total primary energy supply (TPES) (INEGI, 2015; SENER, 2014). Nonetheless, overall energy intensity is expected to decline and remain slightly above the APEC average in 2040 (Table 11.1).

Table 11.1 • Mexico: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	956	1 352	1 640	1 803	2 314	3 133	4 038
Population (million)	86	103	119	118	127	137	145
GDP per capita (2012 USD PPP)	11 162	13 151	13 828	15 228	18 211	22 791	27 770
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	123	145	176	191	234	275	302
TPES per capita (toe)	1.4	1.4	1.5	1.6	1.8	2.0	2.1
APEC TPES per capita (toe)	2.1	2.3	2.7	2.8	3.2	3.4	3.5
Total final energy demand (Mtoe)	84	98	114	118	154	179	192
Final energy intensity per GDP (toe per 2012 USD million PPP)	88	73	69	66	66	57	48
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	260	344	414	452	556	645	695
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	96	98	99	99	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments throughout this chapter are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

ENERGY RESOURCES

With nearly 2 million square kilometres (km^2) of territory rich in natural resources, Mexico has abundant fossil and renewable energy resources. Proven reserves of fossil resources at the end of 2014 amounted to 1 211 million tonnes (Mt) of coal, 11 billion barrels (billion bbl) of oil, 0.35 trillion cubic metres (bcm) of natural gas and nearly 3 kilotonnes (kt) of uranium (Table 11.2), and inferred resources are of a large magnitude. In renewable energy, proven annual potential is 1 932 gigawatt-hours (GWh) of geothermal, 4 457 GWh of hydro, 15 307 GWh of wind, 8 171 GWh of solar and 728 GWh of biomass (SENER, 2015b). This combined potential is 60% above Mexico's current electricity generation from renewables.[1]

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

Table 11.2 ● Mexico: Energy reserves and production, 2014

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Coal (Mt)[a]	1 211	87	0.14	23rd	8th
Oil (billion bbl)[a]	11	11	0.65	18th	5th
Gas (tcm)[a]	0.35	6.0	0.19	33rd	10th
Uranium (kt U)[b]	2.9	N/A	0.08	30th	8th

Notes: [a]Total proven coal/oil/gas reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions.[b] Uranium reserves are 'reasonably assured resources' (RAR); reference year for uranium reserves and production is 2013.

Sources: BP (2015) for oil, coal and gas; NEA (2014) for uranium.

Mexico is a major crude oil producer with a yield of 2.5 million barrels per day (bbl/d) in 2013. Production began climbing in the 1990s and peaked in 2004 at 3.4 million bbl/d, mostly due to the productivity of the Cantarell supergiant oilfield, which by that year supplied as much as 61% of Mexico's output (SENER, 2015d). The accelerated depletion of Cantarell, the natural decline of other major fields, and the technical, legal and budgetary constraints faced by Pemex (Mexico's largest oil and gas company) led to a considerable drop in domestic crude oil and gas production.

With the recent energy reform, oil production is likely to improve in the medium and long term thanks to private capital stimulating more extensive development of oil and gas resources. It is expected that private companies will undertake the more costly and technologically complex exploration and production of frontier and unconventional hydrocarbon resources such as those in deep water and shale formations.

According to preliminary assessments (EIA, 2013), Mexico's hydrocarbon reserves in shale formations are among the ten largest in the world, roughly 15 trillion cubic metres (tcm). Even though the Mexican government had downsized the estimate in 2014 to 4 tcm, the magnitude of resources is still very large. The profitability of these shale formations is promising, as they are presumed to hold substantial volumes of crude oil (tight oil) and some of them extend into the United States, where commercial production is ongoing. Moreover, Mexico is one of the few economies to have undertaken actions conducive to large-scale development of its shale resources (see Pathways to Shale Gas Development in Asia-Pacific [APERC, 2015]).

ENERGY POLICY CONTEXT

Continued underinvestment, overstaffing and technology gaps within Pemex, along with the accelerated decline of many oil fields, have compromised the technical and financial viability of the oil and gas industry. Although the natural gas and electricity industries were partially deregulated in the 1990s and some legal changes were introduced in 2008 to give Pemex more operational flexibility under the previously rigid framework (Box 11.1), deterioration in Mexico's oil and gas industry could not be halted.

To improve the competitiveness of the energy sector and its social and economic contributions, the landmark reform of December 2013 introduced a completely new legal framework. Investments and capabilities of private competitors, especially in areas of great technical complexity, risk and capital, enhance the activities of state-owned energy companies.

In the oil and gas industry, the reform reaffirms state ownership of resources but allows private actors to undertake activities across the upstream and downstream segments to reverse the decline in domestic production and increase social benefits. Likewise, in the electricity industry, the private sector can now undertake generation and retail activities to create a more competitive market, reduce prices and improve service quality. Under the new institutional arrangement, regulators' mandates expanded to address industry challenges more effectively, while state-owned companies were conferred more flexibility to foster competitiveness, yet still ensuring transparency and concern for public interest.

Box 11.1 ● Mexico: The energy sector prior to the 2013 energy reform

For more than 75 years, Mexico's energy sector was unique in that it strictly blocked any form of private participation in its oil and gas industry. Expropriation of the oil and gas industry in 1938 by the federal government banned private agents from all activities across the industry's value chain, granting the economy's oil company Petróleos Mexicanos (Pemex) exclusive legal rights. With this legal monopoly, Pemex became Mexico's largest company and taxpayer: a very strong vehicle for development as well as a stable revenue source for the government. In 2013, oil exports accounted for little more than 10% of total export value, yet they provided 34% of total federal government revenue (Banxico, 2015).

The reform also included a 'Round Zero' mechanism whereby Pemex retained certain strategic oil and gas assets prior to any public tenders for private competitors; the aim was to give Pemex an advantage in the face of increased competition. The Round Zero resulted in Pemex keeping 83% of proven and probable reserves and 21% of prospective oil and gas resources. A subsequent 'Round One' followed Round Zero to tender available resources to private operators, and at present only two of the 14 tendered blocks have been awarded (SENER, 2015c), due largely to the disparity between the fiscal security originally established and the risks sensed by operators in the face of continued low oil prices.

Alongside institutional transformation in the oil, gas and electricity markets, the reform introduced legal instruments to decouple economic activity from greenhouse gas (GHG) emissions, including a more accelerated transition to low-carbon energy and environmental sustainability criteria for all energy sector projects and operations.

BUSINESS-AS-USUAL SCENARIO

This section describes the major energy supply and demand assumptions underpinning the Business-as-Usual (BAU) Scenario, on the basis of current short-, mid- and long-term policies (Table 11.3).

Table 11.3 ● Mexico: Key assumptions and policy drivers under the BAU Scenario

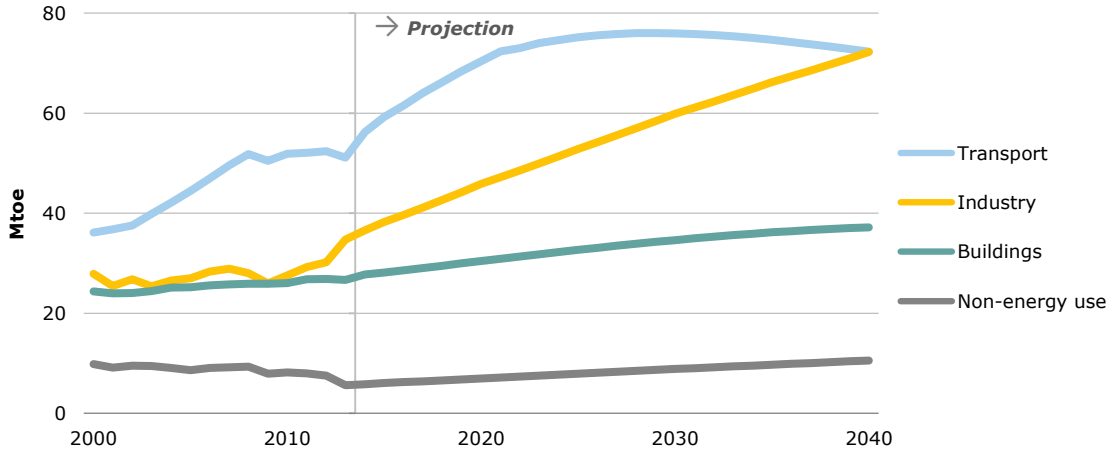
Buildings	• Energy performance and labelling programs maintained at current levels.
Industry	• Implementation of cost-effective technology improvements.
Transport	• Slow deployment of hybrid cars and electric vehicles with marginal contribution at the end of the Outlook period. • No specific growth or mandatory blend rate assumed for biofuels. • Indirect vehicle fuel efficiency standards, by means of a maximum GHG emissions standard for light-duty vehicles.
Energy supply mix	• Oil exports throughout the Outlook period. • More expensive development of oil and gas reserves in the medium term. Long-term shale gas (and oil) development probable.
Power mix	• No nuclear development. Current nuclear capacity expires by 2020 (reactor 1) and 2025 (reactor 2).
Renewables	• Renewable energy generation targets not reached.
Traditional biomass	• Ongoing displacement of traditional (non-commercial) biomass in households. The extent of displacement is subject to income improvement and wider distribution of liquefied petroleum gas (LPG) and natural gas.
Energy security	• No explicit energy security policies and targets. • Self-sufficiency in oil, but net importer of natural gas, coal and most oil-based fuels.
Climate change	• United Nations Framework Convention on Climate Change (UNFCCC) (INDC) target of 22% reduction of GHG emissions by 2030 (from 2013 level), much lower than Outlook projections under the BAU Scenario.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Under the Business-as-Usual (BAU) Scenario, final energy demand is projected to increase 63% over the Outlook period, from 118 million tonnes of oil equivalent (Mtoe) in 2013 to 192 Mtoe in 2040, an average annual growth rate (AAGR) of 1.8%. All sectors grow, but the largest increase is in industry: manufacturing, cement and construction energy demand more than doubles at an AAGR of nearly 2.8% to reach 72 Mtoe by 2040 (Figure 11.1). Non-energy use also grows robustly with increased production of chemicals and petrochemicals. Energy demand in the domestic transportation sector is also projected to climb to 72 Mtoe (AAGR of 1.3%) and the buildings and agriculture sector expands to 37 Mtoe (AAGR of 1.2%).

Figure 11.1 ● Mexico: Final energy demand by sector, 2000-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

Industry consumes nearly as much energy as transport by 2040, each accounting for 39% of total final energy demand. This significant shift reflects slower growth in transport sector energy demand, resulting from tighter fuel economy standards and vehicle saturation between 2030 and 2035. The buildings and agriculture sector remains the third-largest consumer; its share declining slightly from 23% in 2013 to 20% in 2040.

Buildings and agriculture energy use: Efficiency gains with higher shares of gas and electricity

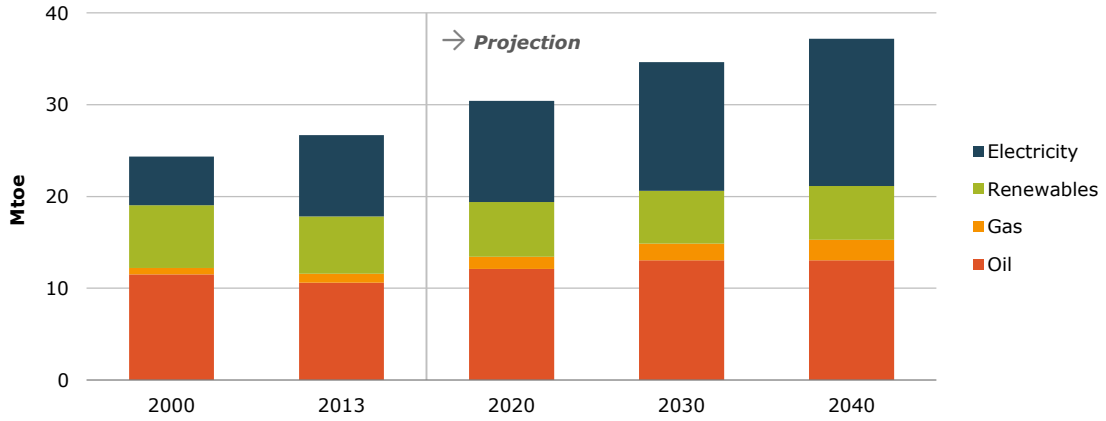
Buildings and agriculture energy demand is projected to grow more moderately over the Outlook period than it has historically. Energy demand rises 39% from 2013 to 2040 at an AAGR of 1.2%, the lowest AAGR among end-use sectors, thanks to numerous energy efficiency polices and measures targeting lighting and appliances in the residential sub-sector. The buildings component is the main energy consumer in this sector; agriculture accounts for around 15% of demand, mostly in the form of diesel.

In fuel composition, a decrease in the use of renewable energy results in its share dropping from 23% in 2013 to 16% in 2040, and oil decreases from 40% to 35% (Figure 11.2). Renewable energy and oil-based fuels in the form of non-commercial firewood and LPG are used primarily for cooking and water heating. Renewable energy demand in buildings is projected to decrease, whereas LPG demand grows moderately, the former being substituted with the latter as income levels increase and LPG supplies reach remote locations.

Natural gas demand grows the fastest among other fuels, by 1.3 times by the end of the Outlook period, at an AAGR of 3.2%. Despite this rapid pace, the share of natural gas increases from only 3.6% in 2013 to 6% in 2040, as actual demand growth hinges on development of transmission and distribution

infrastructure. Electricity shows the second-highest growth with an AAGR of 2.2% over the Outlook period. Short-term growth results from higher demand for appliances, but a more flexible and competitive electricity industry is likely to spur demand in the long term.

Figure 11.2 ● Mexico: Buildings sector final energy demand, 2000-40



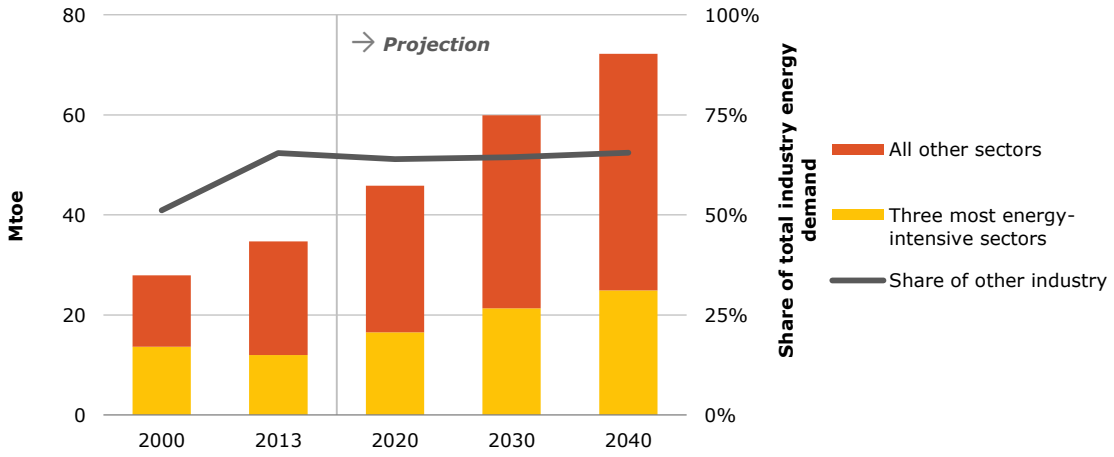
Sources: APERC analysis and IEA (2015a).

Even though Mexican law establishes the promotion of efficiency and savings measures, specific programs and actions are highly dependent on federal government priorities over its six-year administration. The current federal administration, in office until 2018, devised a working plan to capitalise on the energy efficiency potential in the buildings sector (CONUEE, 2015). With a potential 34 million users and 300 000 new homes, this plan aims to develop mechanisms and energy standards to be integrated in local construction regulations across Mexico. The plan also emphasises energy-saving behaviours, as well as the use of more energy-efficient equipment and renewable energy.

Industry energy use: More extensive use of natural gas

In Mexico's export-oriented economy, some of the most important industries—the manufacturing of automobiles, cement and chemicals—are highly energy-intensive. Industry energy demand is therefore projected to increase 1.1 times over the Outlook period (Figure 11.3).

Figure 11.3 ● Mexico: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.

Sources: APERC analysis and IEA (2015a).

The three most energy-intensive sub-sectors—chemicals and petrochemicals, non-metallic minerals, and iron and steel—account for one-third of final energy demand in 2040. With the exceptions of biomass and

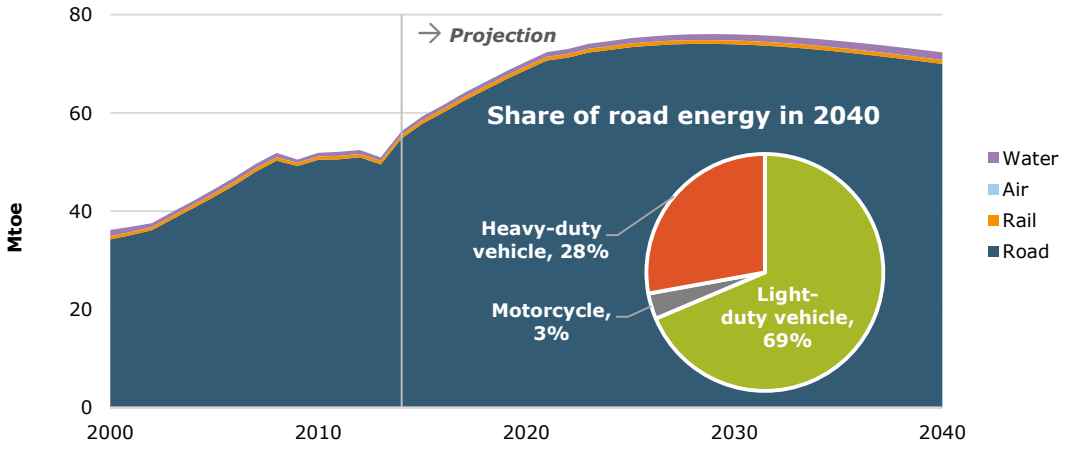
coal, demand for all fuels expands, but natural gas shows the largest growth at 3.3 times higher than in 2013. Natural gas displaces electricity to become the most used fuel in industry by 2040, largely due to the increasing availability of competitively priced imports from the United States. Natural gas represents nearly half of the sector's energy demand in 2040, and when combined with electricity the joint share is 83%.

While substantial structural changes in the industry sector are uncertain, it is possible that affordable natural gas from the United States would spur more intensive industrial activity in the medium and long term, and that ongoing energy efficiency programs could reduce energy demand (CONUEE, 2015).

Transport energy use: Little change expected, but vehicle saturation likely

Domestic transport remains Mexico's largest energy-consuming sector in the long term, but energy demand is projected to grow 43% (below historical rates), from 51 Mtoe in 2013 to 72 Mtoe in 2040 (an AAGR of 1.3%) (Figure 11.4). No significant changes are projected in the sector, with oil-based fuels (gasoline, diesel and LPG) accounting for 97% of total energy demand in 2040. Although the number of vehicles fuelled by natural gas, biofuels and electricity expands, the impact on energy demand is marginal.

Figure 11.4 ● Mexico: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Although the domestic transport sector expands with economic and population growth, energy demand peaks by 2030 and slowly declines thereafter due to vehicle saturation and the enforcement of fuel efficiency standards. In June 2013 the government released an official standard for maximum carbon dioxide (CO_2) emissions for light-duty gasoline and diesel vehicles; the indirect effect is calculated as a fuel-efficiency improvement of approximately 11% (ICCT, 2013). This standard indirectly encourages car manufacturers to improve vehicle fuel efficiency, and provides consumers the incentive to purchase more efficient vehicles. Another factor in peaking energy demand is rising gasoline prices that curb consumption.

Domestic air transportation shows the highest demand growth by mode (3.3 times), followed by water transportation (2.3 times). Road transport still dominates domestic transport energy demand, accounting for almost 97%. Rail, air and water transportation may have a larger share in transport energy demand in the long term, depending on federal government priorities and financial resources to develop and expand the infrastructure for these transportation modes.

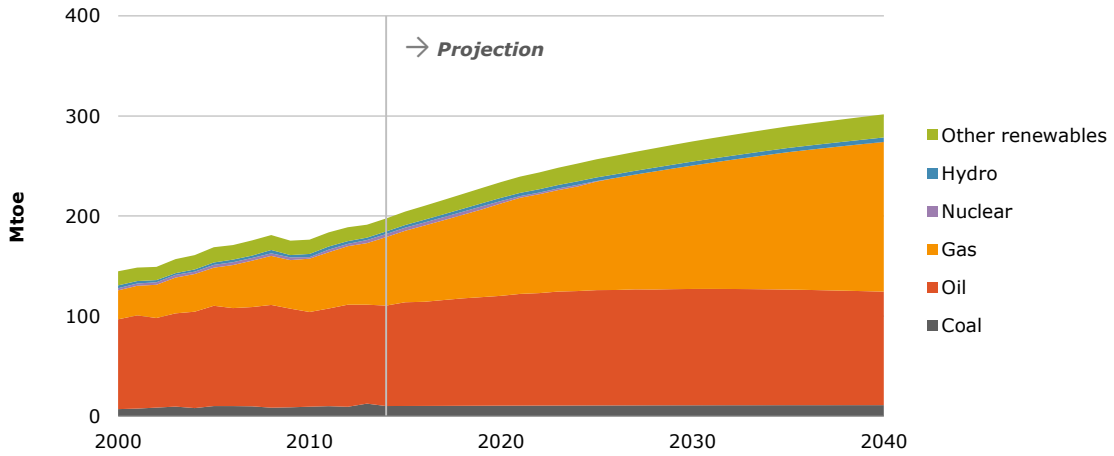
RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Growing share of natural gas

From 2013 to 2040, Mexico's TPES increases by 110 Mtoe to reach more than 302 Mtoe—an overall increase of 58% (AAGR of 1.7%), very close to historical rates (Figure 11.5). While little diversification is expected in TPES, the contribution of oil decreases considerably from 52% to 38% and that of natural gas increases from 32% to 50%. Although this shift reflects a structural change in the use of fossil fuels, the 91% share of fossil fuels in 2013 is forecast to prevail through to 2040. Consequently, the share of non-fossil fuels also remains constant throughout the Outlook period.

The fastest growing energy resource over the projection period is natural gas, which expands 2.4 times from 2013 to 2040. The use of natural gas has been bolstered by the large-scale replacement of oil-based electricity generation with gas-fired combined cycle technologies, much stricter environmental standards and the increased availability of competitively priced pipeline gas imports from the United States.

Figure 11.5 ● Mexico: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

Energy trade: The search for new oil export markets and growing dependence on US natural gas

With approximately 47% of domestic production sent out of the economy in 2013, Mexico is a net exporter of crude oil (SENER, 2015d). The United States is the primary market, receiving more than three-quarters of volumes exported; nevertheless, increasing self-sufficiency as a result of higher domestic light oil production from unconventional resources is pushing Mexico to find new export markets.

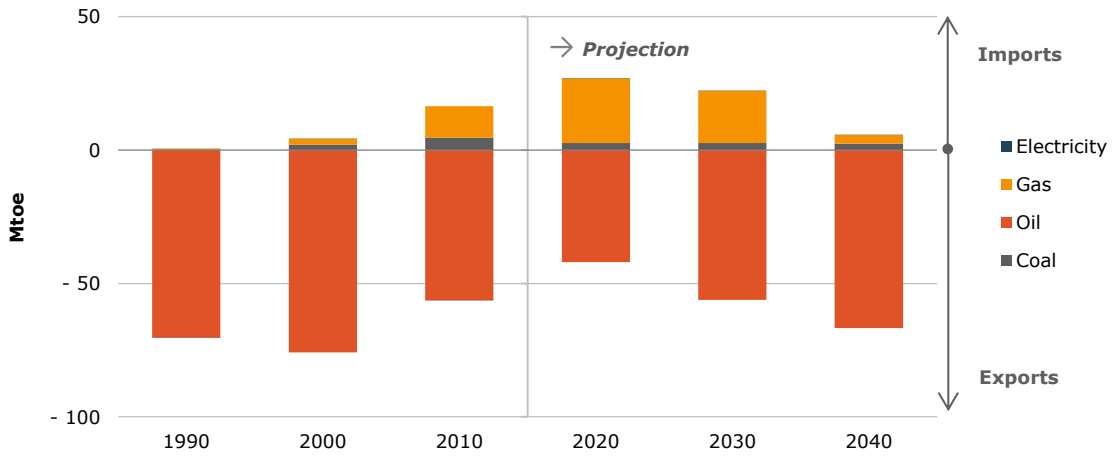
In August 2015, the US Department of Commerce authorised Mexico's request to trade up to 100 thousand bbl/d of Mexican heavy crude oil for light oil (SENER, 2015a). This exchange marks a shift in Mexico's long-established status as an exporter of crude oil exclusively, and also in the strict restrictions on US oil exports, which had previously been allowed to Canada only.

Mexico is a net importer of natural gas, as domestic production is insufficient to meet robust demand growth driven by the electricity and industrial sectors for the past decade. Natural gas imports were 5.6 times larger from 2000 to 2013 (Figure 11.6), and their share in total demand grew from 6% to 22% (Sener, 2015d). As a result, Mexico built three liquefied natural gas (LNG) import terminals, although increasingly available gas extracted from US shale formations has provided a more competitively priced source. Supply is constrained only by the physical capacity of cross-border pipelines, leading to their rapid expansion which will continue at least until the medium term.

Mexico is also a net importer of coal. In 2013, imports met 40% of total demand, sourced 70% from the United States and the remainder from Colombia, Australia and other economies (SIE, 2015; SENER, 2014). Demand is modest, mostly for electricity generation, and remains steady over the projection period.

According to energy trade projections, Mexico remains a net exporter of crude oil throughout the Outlook period; even though export volumes decline sharply in the medium term, they grow more rapidly with extensive resource development by private operators. In contrast, Mexico remains a net importer of natural gas, especially in the medium term thanks to cost-competitive US imports. In the long term, larger-scale domestic production, driven by non-associated conventional gas in particular and possibly shale gas, could substantially improve gas trade between 2030 and 2040.

Figure 11.6 ● Mexico: Net energy imports and exports, 1990-2040



Sources: APERC analysis and IEA (2015a).

Power sector trends: Overreliance on natural gas

The electricity system is well-developed, made up of a main grid spread across most of Mexico's territory and two other grids in the north and south of the Baja California Peninsula. The interconnection of the main and north Baja California grids programmed by 2018 is expected to optimise infrastructure and energy sources (CFE, 2014). Although the bulk of infrastructure was built up by the Comisión Federal de Electricidad (CFE), Mexico's largest state-owned utility, the number of private generators has grown over the last two decades. Private generation accounted for 42% of total electricity output, mostly from combined cycle technologies. With legal reform, this contribution is expected to grow and expand to other technologies, with emphasis on renewable energy.

Electricity generation expands 91% from 2013 to 2040, from 297 terawatt-hours (TWh) to 568 TWh (Figure 11.7). This AAGR of 2.4%, considerably lower than that of past years, requires 79 gigawatts (GW) of additional capacity. This relatively lower rate of generation is a result of more moderate economic and population growth, along with already high electrification rates. Fossil energy sources still dominate the electricity generation mix, but energy-related CO_2 emissions intensity is increasingly lower with larger shares of natural gas. Energy-related CO_2 emissions in the electricity sector increase 45%, from 144 million tonnes of carbon dioxide ($MtCO_2$) in 2013 to 210 $MtCO_2$.

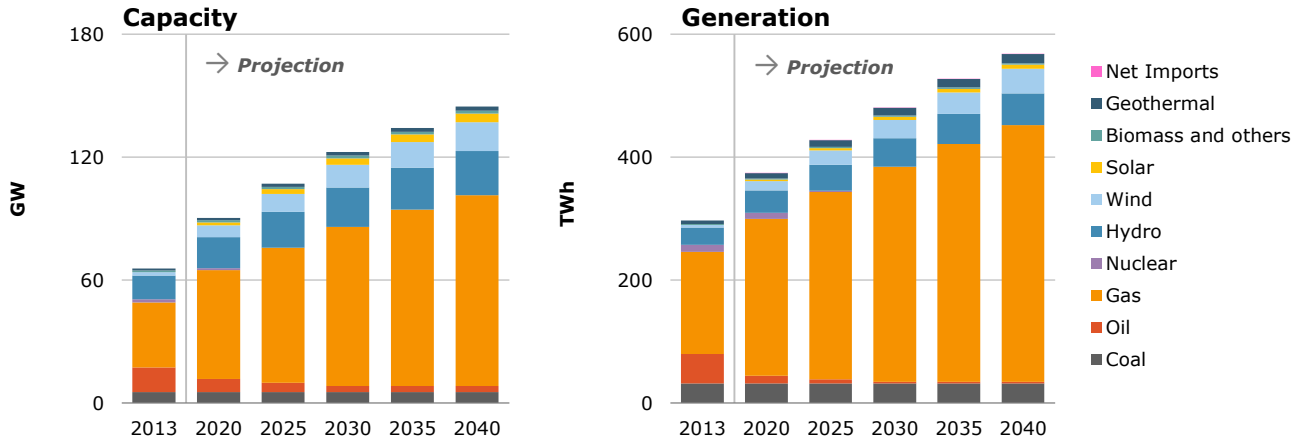
Oil-based electricity generation falls sharply at an annual rate of 10%, while coal generation remains flat. The combined share of both energy sources consequently declines dramatically, from 27% in 2013 to 6.1% in 2040. In contrast, public policies and technical and economic advantages favouring natural gas result in generation growth of 3.5% per year, to account for nearly three-quarters of all electricity production in 2040.

Under the BAU Scenario, other renewables are forecast to have the highest generation growth: 5.5 times, at an AAGR of 6.5%. The combined share of hydro and other renewables in electricity generation increases from 13% in 2013 to 20% by 2040.

Spurring this growth in renewable generation was the Law for the Use of Renewable Energy and Financing of Energy Transition, which mandated a maximum 65% share of fossil fuels in total electricity generation by 2024, 60% by 2035 and 50% by 2050. This law was overridden by the Law for Energy Transition passed in December 2015, but the clean energy goals were preserved in alignment with the Law for Climate Change, which mandates at least 35% non-fossil fuel electricity by 2024. Electricity generated from renewables and lower-emitting technologies is expected to increase thanks to these legal reforms, but under the BAU projections this growth would not be sufficient to achieve the Mexican government's goals, with 80% fossil fuel generation in 2024.

Mexico has not explicitly ruled out nuclear development, but neither has it signalled expansion of current capacity. Nuclear generation will cease by 2025 under the BAU if no further capacity is added. The 30-year operation licenses for the only nuclear plant (Laguna Verde) expire in 2020 (reactor 1) and 2025 (reactor 2). Legal reforms promoting participation of private generators exclude nuclear development, which remains reserved exclusively to the Mexican state; prospects for nuclear energy therefore remain low.

Figure 11.7 ● Mexico: Power capacity and generation by fuel, 2013-40



Note: In 2020 and 2025, nuclear-based electricity generation might appear incongruously larger than corresponding capacity due to the two reactors ceasing operations in those years if operating licenses are not renewed.

Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

Of the three alternative scenarios—Improved Efficiency, High Renewables and Alternative Power Mix—the Improved Efficiency Scenario demonstrates the deepest positive effect on Mexico's energy sector. By 2040, the Improved Efficiency Scenario leads to a 23% reduction in CO_2 emissions compared to the BAU Scenario, whereas the High Renewables Scenario shows a 2.6% reduction over the BAU. The effects of the Alternative Power Mix Scenario are minimal, as only the High Nuclear Case is marginally applicable and results in a reduction of just 2.4% in the power sector emissions.[2]

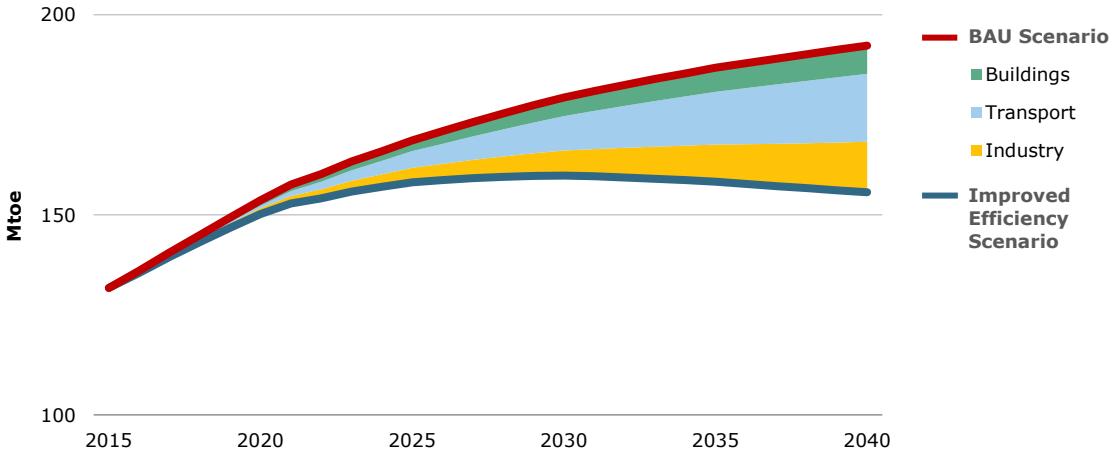
[2] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

Under the BAU Scenario, and within the framework of the APEC energy intensity goal to reduce regional energy intensity by 45% in 2035 from the 2005 level,[3] Mexico's energy intensity of primary energy demand decreases by 30% from 2005 to 2035, and final energy demand energy intensity decreases by 27%. In comparison, under the Improved Efficiency Scenario energy intensity of primary energy demand decreases by 42% from 2005 to 2035 and final energy demand intensity decreases by 38%, showing a greater contribution to the APEC energy intensity goal.

By 2040, the savings achieved through the Improved Efficiency Scenario compared with the BAU Scenario reach 37 Mtoe, with industry and transport together equally responsible for more than two-thirds (Figure 11.8). Energy efficiency programs have historically focused on the residential and commercial sectors, but must now shift to transport and industry, which have intensive energy demand profiles. As well, official vehicle energy efficiency standards have only indirect influence and could encompass a wider range of heavy-duty vehicles. More accelerated use of cogeneration systems in industry and of higher-efficiency equipment in electricity generation, especially from private companies, would also save energy.

Figure 11.8 ● Mexico: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Source: APERC analysis.

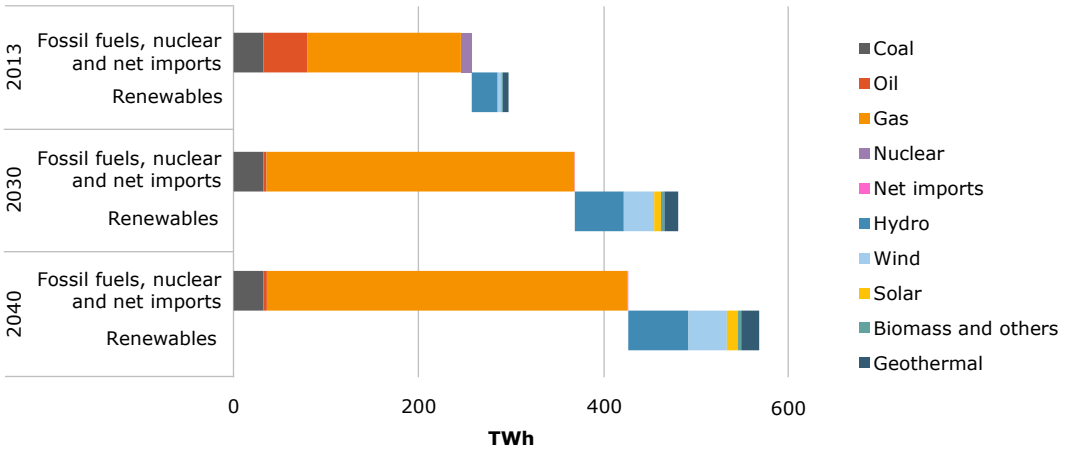
HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

The High Renewables Scenario is driven by the APEC goal to double the share of renewable energy in the region's electricity generation mix by 2030 (in comparison with 2010).[4] Renewable energy used to meet this goal includes large hydropower but excludes unsustainable non-commercial (traditional) biomass (APERC, 2015).

Policies prior to and included in the 2013 energy reform have not only fostered a wider use of renewable energy, but have aimed to accelerate deployment by strengthening market-based mechanisms and increased private competition in the electricity sector. With the energy reform, the first Geothermal Law was introduced and the Special Program for the Use of Renewable Energy set the goal of at least 24.9% of electricity generation based on renewable energy by 2018. Allowing private companies to generate electricity using any technology and fuel should expand and diversify economy-wide installed capacity, with the largest growth expected in renewables.

[3] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.
[4] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

Figure 11.9 • Mexico: Power sector under the High Renewables Scenario, 2013-40



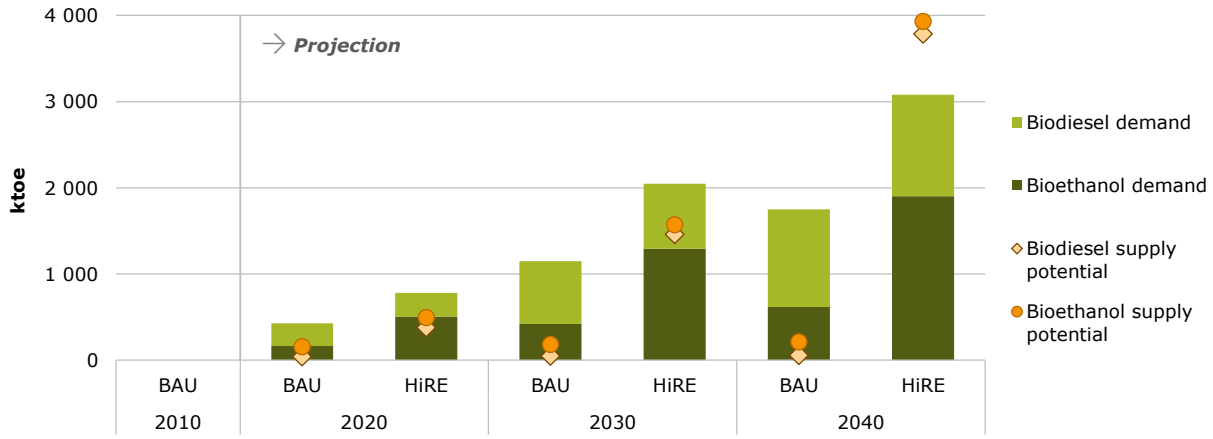
Sources: APERC analysis and IEA (2015a).

The High Renewables Scenario matches most closely the energy policy targets for renewable energy development. Under the BAU, electricity generation based on renewable energy (including hydro) grows from 13% in 2013 to 20% by 2030 and 2040; under the High Renewables Scenario it increases to 23% by 2030 and 25% by 2040 (Figure 11.9). According to levelised cost projections, the most cost-effective renewable technologies by 2040 are hydro, geothermal and wind (onshore), whereas the most expensive is solar, including concentrated solar power (CSP) and rooftop photovoltaic (PV).

Results for biofuel supply potential are drastically different in the BAU and High Renewables Scenarios: in the High Renewables Scenario, the volume of biodiesel is 19 times greater than under the BAU in 2040, and bioethanol is 67 times larger (Figure 11.10). Such expansion is plausible given the former constraints of Pemex's limited capacity and budget as sole market operator; however, biofuel development is still at the pilot project stage. The pace of biofuel development depends on: 1) the speed at which private companies enter into the downstream oil segment and promote biofuel production; and 2) the strictness of environmental standards requiring the blending of biofuels with gasoline and/or diesel. Considering how favourable its territory is for bioethanol and biodiesel production, whether through conventional or advanced methods, Mexico has exploited very little of its biofuel supply potential.

Given the environmental benefits of biofuels, demand is likely to be higher in major cities with high vehicle densities such as Mexico City, Guadalajara and Monterrey. According to projections, bioethanol demand grows 2.1 times by 2040 whereas biodiesel demand remains flat.

Figure 11.10 • Mexico: Biofuels demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is for the Outlook period only; HiRE = High Renewables Scenario.

Sources: APERC analysis, PEMEX (2013), FAO (2014) and IEA (2015a).

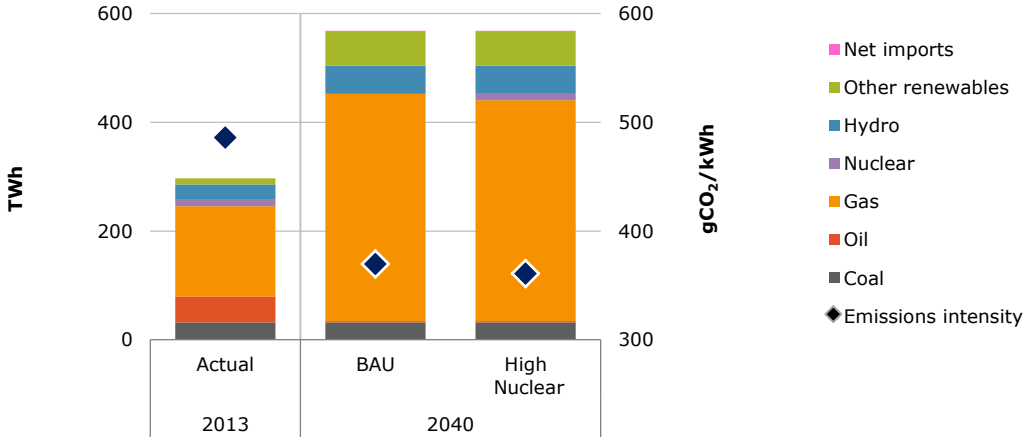
ALTERNATIVE POWER MIX SCENARIO

Of the four Alternative Power Mix Cases, only the High Nuclear Case is relevant to Mexico; assumptions of the Cleaner Coal and High Gas Cases are inapplicable due to Mexico's already high reliance on natural gas for electricity generation and its modest use of coal.

Since public policies do not indicate any explicit interest in further nuclear development, the High Nuclear Case does not assume capacity expansion, but rather minimal refurbishment of the existing nuclear power plant to keep it operational beyond 2025 to the end of the Outlook period. Nuclear-based generation therefore amounts to 12 TWh in 2040, equivalent to 2.1% of total electricity produced that year and to the amount of nuclear output in 2013 (Figure 11.11).

This minimal nuclear generation reduces power sector CO_2 emissions slightly in comparison with the BAU, avoiding around 2.4% of CO_2 emitted by 2040. The economic costs involved in keeping this share of nuclear energy would largely remain constant, but there would be a marginal decrease in the fuel costs incurred in Mexico's total electricity generation.

Figure 11.11 ● Mexico: The BAU Scenario and High Nuclear Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Total cumulative investments in Mexico's energy sector increase significantly, to between USD 877 billion (low-cost estimate) and USD 1 535 billion (high-cost estimate) between 2015 and 2040 (Table 11.4). Owing to the energy reform and the importance of oil and gas to the economy, the upstream segment of the oil and gas industry receives most of the capital inflow, in the range of USD 666 billion to USD 1 140 billion—76% of total energy sector investments in the low-cost estimate, or 74% under the high-cost estimate.

The electricity sector follows, claiming between USD 148 billion and USD 220 billion or 17% (low-cost estimate) and 14% (high-cost estimate) of total investments. The substantial investment in electricity results from increased participation of private companies which accelerates the development of renewable energy projects and associated transmission and distribution.

Decades of underinvestment under a state-owned monopoly have left Mexico's oil and gas transport infrastructure critically lagging behind in capacity and geographical coverage. Furthermore, a series of natural gas shortages from 2011 to 2013, and a higher frequency in theft of oil products and energy transport-associated accidents, have highlighted the urgency of upgrading transport infrastructure. This

has resulted in the government's renewed prioritisation of the midstream segment, particularly for the transmission of natural gas, which will receive large amounts of public and private capital, estimated at USD 47 billion (89% of total energy transport investments and 5.3% of total energy investments in low-cost estimate) to USD 130 billion (94% and 8.5%, respectively, in high-cost estimate).

Table 11.4 ● Mexico: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	574	861
	Gas	87	260
	Coal	5.9	19
	Subtotal	666	1 140
Downstream	Refinery	7.7	34
	LNG import terminals	0.4	1.0
	Biofuels refinery	1.2	1.8
	Subtotal	9.3	37
Electricity	Gas	60	61
	Hydro	8.7	28
	Wind	20	28
	Solar	9.0	13
	Biomass and others	1.3	1.7
	Geothermal	2.3	2.9
	Transmission lines	29	59
	Distribution lines	19	27
	Subtotal	148	220
Energy transport	Oil	5.6	7.6
	Gas	47	130
	Coal	0.1	0.2
	Subtotal	52	138
	Total	**877**	**1 535**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

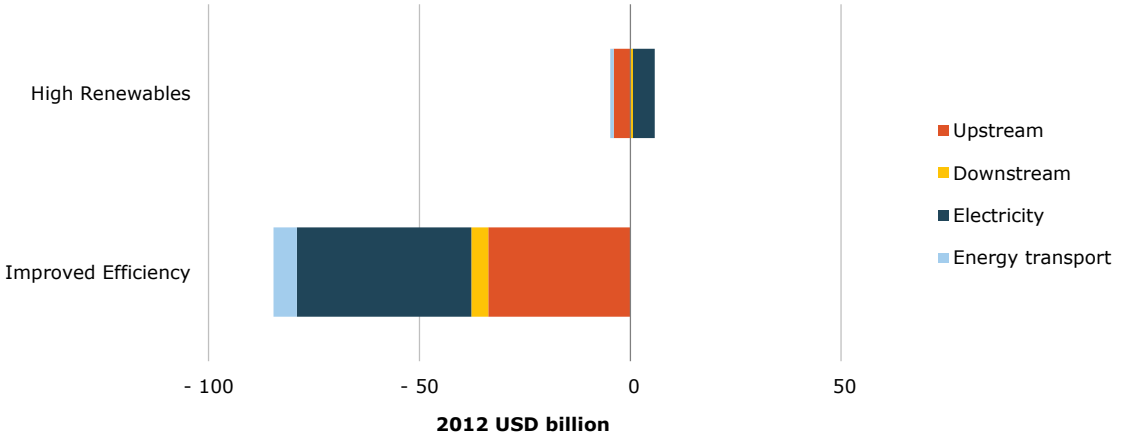
Source: APERC analysis.

The downstream segment of the oil and gas industry receives the lowest share of investments, in the range of USD 9 billion to USD 37 billion. While much of the capital requirement is to be raised from private investors who enjoy more flexibility since the energy reform, persistently low oil prices have raised uncertainty about energy sector investments, particularly in oil and gas. Furthermore, not only can the Mexican government not afford to fund many of these projects, but the fall in crude oil prices has weakened its budgetary capabilities.

While the amount of projected cumulative investments in the High Renewables Scenario is 0.12% higher than the BAU Scenario, under the Improved Efficiency Scenario this amount is 10% lower, at only USD 792 billion over the Outlook period, which represents a difference of USD 85 billion (Figure 11.12).

In the Improved Efficiency Scenario the downstream sector shows the largest reduction in investment needs (43% below the BAU) because lower gas demand (in both power and industry) displaces a significant amount of LNG import terminal capacity, and the cut in oil demand reduces refinery capacity. Followed by the power sector at 28% lower than the BAU. The investment requirement under the High Renewables Scenario is higher than under the BAU Scenario due to solar and wind generation costs as well as additional storage requirements for solar generation.

Figure 11.12 ● Mexico: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

Respecting natural ecosystems and complying with international environmental rules have become the pillars of Mexico's energy policy at the federal, state and local levels in the last decade. While changes to the oil and gas industry were central to the 2013 energy reform, the government enacted other laws oriented to the use of cleaner generation fuels in the electricity sector and the widespread promotion of energy efficiency measures across several economic sectors to ensure that the energy sector does not have permanent negative impacts for future generations. In addition, the Agency for Safety, Energy and Environment (ASEA in Spanish) was created as a new federal body to regulate and oversee industrial safety and environmental impacts of energy facilities.

Enhancing energy security: Short- to medium-term dependence on US natural gas imports

Mexico is endowed with abundant energy resources and is still a net exporter of oil, but self-sufficiency and trade balance for other fuels have deteriorated rapidly. Mexico has been a net importer of most oil-based products for several years, but since the shift away from fuel oil and other oil-based products in the electricity sector in the late 1990s, natural gas imports have increased considerably. These gas imports came in the form of LNG from several economies and countries, but now are mainly supplied by pipelines from the United States.

As a result, refining capacity and configuration is currently inadequate to meet growing demand for oil-based products. Mexico built its last refinery in 1979, and future investments in the downstream oil segment are likely to remain modest. This makes it very probable that imports will continue, but the market liberalisation in progress could be useful to diversify import sources and hence reduce costs. Regarding natural gas, it was hoped the energy reform would boost domestic supplies. The development of non-associated gas, and shale gas in particular, seems promising as Mexico has one of the largest resource bases in the world and is located next to the United States, home of the 'shale revolution'. Nevertheless, there are crucial technical, institutional and governance challenges that must first be overcome for shale gas resources to be produced economically and quickly enough to meet energy demand (APERC, 2015).

Until then, natural gas, oil-based products and other fuels like coal or even biofuels will continue to be imported to the detriment of Mexico's physical energy security. In the short term, the economy must remain dependent on external sources of fossil energy because of the chronic insufficiency of capital and

technological investments in its energy sector; however, a reversal of this situation is expected in the medium to long term with the legal modifications introduced in 2013.

Diversity in the primary energy supply is expected to remain nearly constant over the projection period, with a fuel diversity index for electricity generation measured by the Herfindahl-Hirschman index (HHI) between 0.37 and 0.39 by 2040 under different premises, where a lower number indicates greater diversity (Table 11.5). Nevertheless, fuel input for electricity generation may change drastically.

As high consumption and dependence on imported oil-based products and natural gas is expected to continue, the effects of most alternative scenarios on fossil fuel demand are remarkably similar to those of the BAU Scenario and therefore have little impact on energy security. The only notable exception is the Improved Efficiency Scenario, which projects a significant amount of energy saved and therefore less demand for fossil energy, especially natural gas. The decline in natural gas generation by 2040 in comparison with the BAU is estimated at 2.8% in the High Nuclear Case, 6.5% in the High Renewables Scenario and 35% in the Improved Efficiency Scenario.

Table 11.5 ● Mexico: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040			
	Actual	BAU	Improved Efficiency	High Renewables	High Nuclear
Primary energy supply diversity (HHI)	0.38	0.39	0.37	0.38	0.39
Primary energy supply self-sufficiency (%)	86	98	99	98	99
Coal self-sufficiency (%)	61	79	81	79	79
Oil self-sufficiency (%)	100	100	100	100	100
Gas self-sufficiency (%)	66	98	100	98	100
Electricity generation input fuel diversity (HHI)	0.34	0.56	0.45	0.50	0.52

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

Climate change impacts and risks: Alternative scenarios fall short of INDC emissions reduction

Mexico is rich in biological diversity and ecosystems, but its population and economy are vulnerable to the disastrous effects of climate change. Official estimates deem 46% of energy infrastructure, 30% of 400-kilovolt (kV) transmission lines and 32% of 205-kV transmission lines to be located in areas with high and very high risk of floods and landslides (Gobierno de la República, 2013).

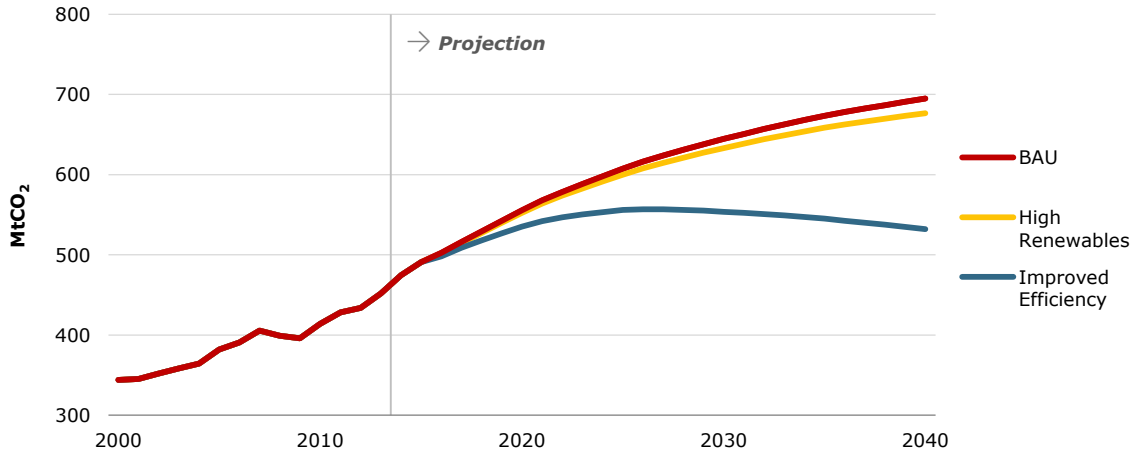
Mexico made significant efforts to decrease the carbon intensity of its economic development, in spite of its GHG emissions representing only 1.4% of the global total (UNFCCC, 2015). Mexico is one of the economies most devoted to addressing climate change, having issued its first specific strategy in 2000 and being the first developing economy to dedicate a law exclusively to this issue in 2012. Since then, numerous other policies on GHG emissions mitigation and climate change adaptation have been implemented, several addressing the energy sector and the most energy-intensive industrial processes. The energy sector is the largest source of economy-wide GHG emissions; according to the most recent official records, it alone accounted for 82% of the CO_2 and 67% of the GHGs emitted in Mexico during 2010 (SEMARNAT, 2013).

In March 2015 Mexico submitted its INDC of an unconditional 22% reduction (from the 2013 level) in GHG emissions by 2030. On a conditional basis, this share may increase to 36% if certain global measures to address climate change are in place (UNFCCC, 2015).

APERC, however, only models CO_2 emissions from energy use. Under the BAU Scenario, these energy-related CO_2 emissions grow from 451 $MtCO_2$ in 2013 to 645 $MtCO_2$ in 2030 (43% increase) and to 695 $MtCO_2$ in 2040 (54% increase) (Figure 11.13). In the Improved Efficiency Scenario, they reach 554 $MtCO_2$ in 2030 (23% increase) and 532 $MtCO_2$ in 2040 (18% increase), and under the High Renewables Scenario they rise to 633 $MtCO_2$ in 2030 (40% increase) and 676 $MtCO_2$ in 2040 (50% increase). The greatest reduction is therefore attained with the Improved Efficiency Scenario—23% less in 2040 compared with the BAU—whereas the High Renewables Scenario offers a 2.6% reduction compared with the BAU.

In the electricity sector alone, CO_2 emissions grow 45% above the 2013 level by 2040 under the BAU. Despite the marginal applicability of the High Nuclear Case to Mexico, there is a slight emissions reductions advantage, with approximately 2.4% of CO_2 emissions under the BAU avoided by 2040. Clearly, Mexico's INDC may be difficult to accomplish by 2030 under any of these scenarios.

Figure 11.13 • Mexico: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

RECOMMENDATIONS FOR POLICY ACTION

Well-supplied in fossil and renewable energy resources, Mexico has recently initiated a remarkable transformation of its energy sector to overcome chronic technical and financial hurdles, with the ultimate goal of maximising the value of its energy resources and supporting the transition towards a low-carbon economy. The recent and persistent fall in international oil prices has adversely affected the Mexican currency and economy, undermining the fiscal terms foreseen for upcoming oil and gas tenders. Furthermore, to reduce dependence on external fuel supply sources, Mexico is in critical need of a stronger downstream segment, especially since projections suggest it may not receive investments sufficient to respond to economy-wide demands.

Mexico is at a crossroads: while it is in a position to attract private capital to its energy sector, its focus is on the extensive development of fossil resources, crude oil in particular. This would contribute to sustained hydrocarbon dependency in the primary energy mix and in government revenue, hindering an effective energy transition and a more diversified economy. Approved in December 2015, the Law of Energy Transition will accelerate the transition towards renewable energy and other lower-emitting technologies, leveraging government and private sector financial aid as well as the technical expertise of academics and research institutions.

Mexico has the renewable resources necessary to promote less CO_2 emissions-intensive primary energy and electricity. The economy's strong reliance on natural gas could serve as a bridge to increased renewable energy; however, natural gas has become a mainstay. It may be advantageous in the short term to continue importing natural gas and oil based-products if it costs less than domestic production. Nevertheless, even though expanding US oil and gas production currently makes it cost-effective for Mexico to import natural gas, importing energy resources is intrinsically volatile. It constrains crude oil exports and, most important, it erodes energy self-sufficiency, physical energy security and hinders a more ambitious energy transition that effectively increases the use of energy sources with lower carbon emissions.

Promoting more effectively an energy transition that brings lower carbon emissions and enhanced energy security with a higher share of renewable energy, energy efficiency and technological solutions will depend on the Mexican government's closer coordination and collaboration with different stakeholders with the aim of developing expert and skilled human resources, exploring new capital mechanisms to ensure an adequate funding of the programs and initiatives designed, and especially enhancing interactions and cooperation with other economies and international organisations. With these actions, and in parallel to the advances in the oil and gas sub-sector, Mexico's federal institutions and industry operators could harness more rapidly the learning curve in their operations. Although the recent landmark reform could contribute strongly to the efficient development of Mexico's energy potential, longer-term effects on the economy and the population are uncertain. The success of the reform is largely contingent on the government's capacity to implement the changes through solid institutions and skilled human resources.

12. NEW ZEALAND

KEY FINDINGS

- **Renewable sources provided 74% of New Zealand's electricity in 2013—one of the highest rates in the APEC region.** The government's target is to reach 90% renewable power by 2025.

- **Total energy demand increases to 16 Mtoe by 2040, an increase of 19% from 2013.** The majority of demand increase comes from industry (oil) and the buildings sector (electricity).

- **Industry has the largest share of demand growth, at 59%.** The majority of growth is in non-energy-intensive industries such as food product manufacturing. Transport demand peaks in 2021, and by 2040 is 3.2% lower than in 2013 due to fuel efficiency gains.

- **The Improved Efficiency Scenario provides the greatest impact of all scenarios, with a 12% reduction in energy demand and a 5.9 $MtCO_2$ (19%) drop in energy-related CO_2 emissions compared with the BAU.** Strong transport and industrial efficiency policies are needed to obtain savings beyond the BAU.

- **Transport efficiency, EVs and biofuels are the most efficient means of reducing emissions.** Challenges to emissions reduction are posed by electricity generation, with its already high share of renewables, and by the agriculture sector, responsible for half of all GHG emissions in the economy.

ECONOMY AND ENERGY OVERVIEW

New Zealand is an island economy in the South Pacific, comprising the North Island, the South Island and numerous outer islands. With a land area of 269 652 square kilometres (km^2) (similar to the Philippines) and low population of 4.4 million, it is sparsely populated with over 86% of people in urban centres (World Bank, 2015). One-third of the population (1.4 million) lives in Auckland, the largest city (Stats NZ, 2013).

New Zealand's economy is mature and deregulated, based on the production and export of agricultural products. Exports account for 30% of gross domestic product (GDP) and agricultural commodities (dairy, meat and forestry products) dominate. It also has significant manufacturing and services sectors (New Zealand Now, 2015).

The economy was relatively insulated from the global financial crisis of 2008. It was growing at an average rate of 3.5% from 2000 to 2007; in 2008 growth was only 1%, and in 2009 the economy contracted 2% (Table 12.1). Since 2009 the economy has grown steadily to an annual growth rate of 3.3% in 2014, and the Treasury Department is forecasting a healthy AAGR of 2.8% over the next four years (NZ Treasury, 2015).

With a per capita GDP of about USD 32 500 in 2015 (World Bank, 2015), New Zealand has a high standard of living and well-developed energy infrastructure, with electrification rates and access to energy at near 100%. Not everyone is able to take full advantage of energy availability, however, especially in winter when home heating needs increase significantly.

Table 12.1 ● New Zealand: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	74	99	127	136	163	200	249
Population (million)	3.4	3.9	4.4	4.4	4.8	5.2	5.5
GDP per capita (2012 USD PPP)	21 840	25 567	29 115	30 976	33 985	38 547	45 304
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	13	17	18	20	20	22	24
TPES per capita (toe)	3.8	4.4	4.2	4.4	4.3	4.2	4.3
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	10	13	13	13	14	15	16
Final energy intensity per GDP (toe per 2012 USD million PPP)	131	130	100	96	88	75	62
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	22	29	30	31	31	31	32
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	100	100	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

New Zealand is self-sufficient in all energy sources except oil. It has vast renewable energy potential: in 2013 renewables[1] accounted for 74% of electricity generation, largely from hydro, geothermal and wind. For fossil energy resources, the remaining reserves are more modest: 128 million barrels (Mbbl) of oil and condensate, 59 billion cubic metres (bcm) of natural gas and liquefied petroleum gas (LPG), and 571 million tonnes (Mt) of coal at the end of 2012 (MBIE, 2015b; BP, 2015).

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

In international trade, New Zealand has one refinery to process crude oil, and it regularly exports high-grade coal, largely for steel manufacturing. Due to its remote location, it does not have electricity or pipeline connections to other economies, and it has no liquefied natural gas (LNG) terminals.

ENERGY RESOURCES

New Zealand is rich in energy resources, primarily coal and renewable energy. It also has oil and gas, but only modest quantities have been discovered to date. It is able to meet all domestic gas needs and one-third of oil demand.

All oil and gas produced in New Zealand comes from the Taranaki region on the south-west tip of the North Island. Significant hydrocarbon reserves may be held in other basins within New Zealand's exclusive economic zone, but they remain underexplored (GIC, 2013). In 2013, total oil production including condensates was just over 1.9 million tonnes of oil equivalent (Mtoe) and there were proven and probable reserves (2P or P50) of 18 Mtoe. Total gas production in 2013 was 5 Mtoe, with proven and probable reserves of 51 Mtoe (56 bcm). Unconventional (largely coal seam) gas resources of approximately 49 Mtoe (54 bcm) could also be developed to support the economy if no significant conventional discoveries are made soon (APEC, 2013).

Coal reserves are estimated in excess of 15 billion tonnes, around half believed to be recoverable (MBIE, 2015a). The majority of this resource (~80%) is in lignite and peat, having a lower energy value and higher moisture content. At 2013 production levels of 2.7 Mtoe (4.6 Mt of coal), there is enough coal for thousands of years. Current production is over 95% bituminous and sub-bituminous for export and local consumption. Most of the premium bituminous coal is exported for steel manufacturing.

Renewable energy potential is significant. In addition to 74% of electricity being renewable in 2013 (hydropower accounting for half of all generation), wind energy is being deployed without any government support, and geothermal energy is widely used in electricity generation and industry.

ENERGY POLICY CONTEXT

The Ministry of Business Innovation and Employment (MBIE) was created in July 2012 through the merger of four government ministries. MBIE is responsible for developing energy policies and strategies with assistance from other agencies, and it reports to the Minister of Energy and Resources.

In August 2011, the government released an overarching energy policy framework, the New Zealand Energy Strategy 2011-21: Developing Our Energy Potential (the NZES) (MBIE, 2011) to replace the 2007 New Zealand Energy Strategy. The new strategy focuses on four priorities: diverse resource development; environmental responsibility; efficient use of energy; and secure and affordable energy (Table 12.2). The Energy Strategy includes the New Zealand Energy Efficiency and Conservation Strategy 2011-16 (NZEECS), which replaces the 2007 version. A revised 2016 NZEECS is under development.

Oil and gas exploration and production activities are privately owned and open to competition, while minerals and underground wealth are owned by the government. New Zealand generally welcomes foreign investment in oil and gas exploration, and electricity generation and marketing are also open to competition. The electricity market is overseen by the New Zealand Electricity Authority, but this authority does not regulate electricity prices or the construction of new plants. Coal mining is dominated by Solid Energy, a state-owned firm, although there are small private operators as well. In 2015 Solid Energy entered into voluntary administration (bankruptcy management) due to depressed economic prospects from low coal prices.

Table 12.2 • New Zealand: Energy policies

Electricity	• Aspirational target of 90% electricity generation from renewables by 2025. • 49% privatisation of remaining state-owned electricity utilities. • National Policy Statement for Renewable Electricity Generation (2011) obliging government decision-makers to recognise economy-wide benefits of renewable electricity in plans and policies (MFE, 2011).
Oil and gas	• Government auction of numerous blocks for exploration, and support for acquisition of seismic data.
Energy efficiency	• An array of policies and programs: stronger home insulation requirements in building code, and home insulation program for existing dwellings; building rating program; expanded minimum energy performance standards (MEPS); compact fluorescent lamp (CFL) lighting program; heavy transport program; vehicle labelling scheme; and industrial energy audit subsidy.

BUSINESS-AS-USUAL SCENARIO

The Business-as-Usual (BAU) Scenario explores how the economy evolves based on actions and policies that are currently in place or reasonably expected to happen (Table 12.3). The overall results in the BAU reflect an extension of current trends of supply and demand.

Table 12.3 • New Zealand: Key assumptions and policy drivers under the BAU Scenario

Buildings	• Building code requirements, MEPS and labelling programs maintained at current levels.
Industry	• Implementation of cost-effective technology improvements. • Continued government support for industrial energy efficiency. • Highly intensive industries remain steady for the period. Gas discoveries assumed to support current consumption levels.
Transport	• Slow deployment of hybrid cars and electric vehicles (EVs). Marginal contribution at the end of the Outlook period. • Biofuel blend rates reach 2% renewable fuel content for gasoline and 3% for diesel. • Noxious emissions standards slowly updated. • Gradual improvement of fuel efficiency.
Energy supply mix	• Nuclear energy remains banned throughout the period. • Renewable energy policy statement obliges all levels of government to include economic benefits of renewable energy in planning processes.
Power mix	• Phase-out of coal generation. • Significant growth of wind and geothermal generation. • Gas discoveries assumed to support current level of consumption throughout the period.
Energy security	• No explicit energy security policies and targets aside from International Energy Agency (IEA) requirements.
Climate change	• Continue to work towards the Intended Nationally Determined Contribution (INDC) commitment to reduce greenhouse gas (GHG) emissions to 30% below 2005 levels by 2030. • Continue to work towards domestic target of 50% GHG emissions reduction by 2050. • Continue to work towards renewable energy target of 90% renewables generation by 2025.

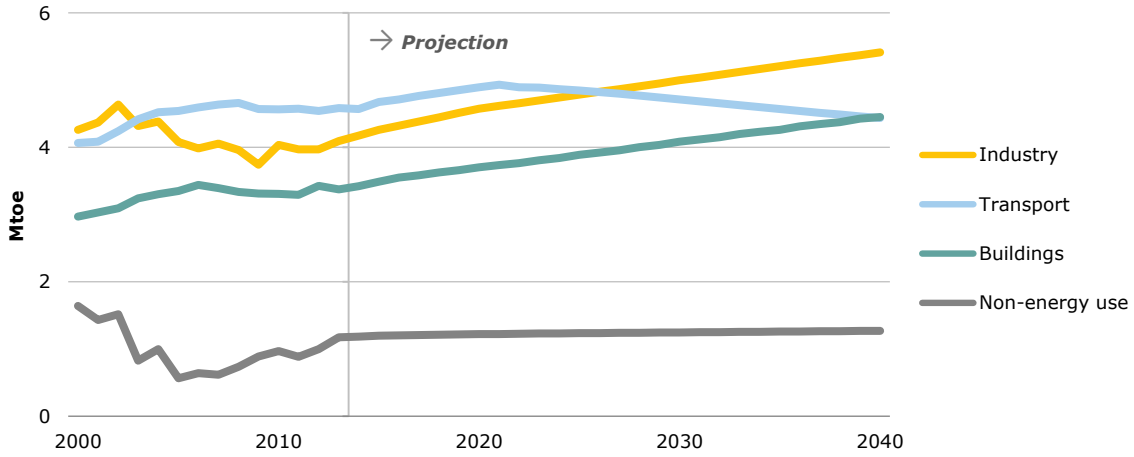
Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

TPES is projected to grow 21%, from 20 Mtoe to 24 Mtoe in the 2013-40 period, and final energy demand increases 18%, from 13 Mtoe to 16 Mtoe. This significant difference between TPES and final demand is due to the uptake of geothermal energy for electricity generation, which, despite New Zealand being more efficient than the rest of the Asia-Pacific Economic Cooperation (APEC), has a low efficiency factor of around 13% in 2013.

Industrial energy demand is projected to grow by 1.5 Mtoe (38%), accounting for 56% of net final demand increase in the period (Figure 12.1). The remaining increase is accounted for by the buildings sector at 1.1 Mtoe (40%) and non-energy consumption at 0.1 Mtoe. Transport energy demand increases early in the period, but peaks in 2025 and decreases through to 2040, resulting in an overall decrease of 3% compared with 2013 levels.

Figure 12.1 ● New Zealand: Final energy demand by sector, 2000-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

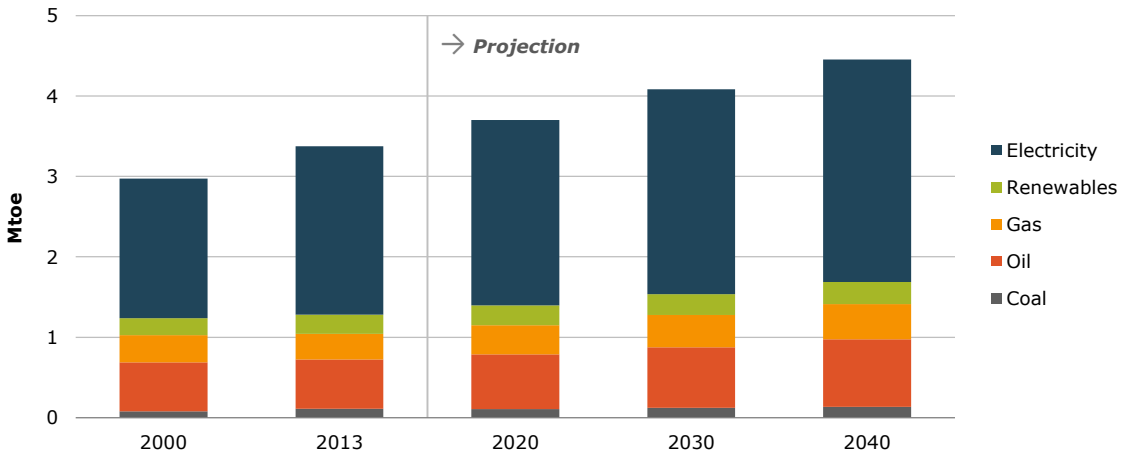
Buildings energy use: Demand grows despite efficiency measures

Demand in the buildings sector (residential, commercial and agriculture) is projected to grow 32% (Figure 12.2), due primarily to economic and population growth (demand for goods and services increases as a population becomes wealthier, which in turn affects other sectors). Population is expected to continue growing throughout the period, primarily through net migration, fuelling energy demand. Similarly, the total space area of the services sector increases, leading to higher energy requirements for the buildings sector.

Electricity is the key energy demanded, as most households rely on it for water heating, space heating and powering appliances. In the commercial sector as well, the main energy-consuming services (heating, ventilation and air conditioning [HVAC] systems, office equipment and lighting) are powered by electricity. Oil is used in the agricultural industry largely to power machinery such as tractors and harvesters, while gas is used for water heating, space heating and cooking for a small proportion of households and businesses.

Renewables used in the buildings sector are mostly in the form of biomass for residential space heating, in regulated wood burners (open fireplaces are banned in many areas of New Zealand). The increase in urbanisation and government efforts to control air quality effectively cap or discourage the use of biomass for energy. The use of solar energy is increasing, but the cost of installation remains high, and buy-back rates offered by utilities do not make it attractive for users to sell surplus generation back to the grid.

Figure 12.2 • New Zealand: Buildings sector final energy demand, 2000-40



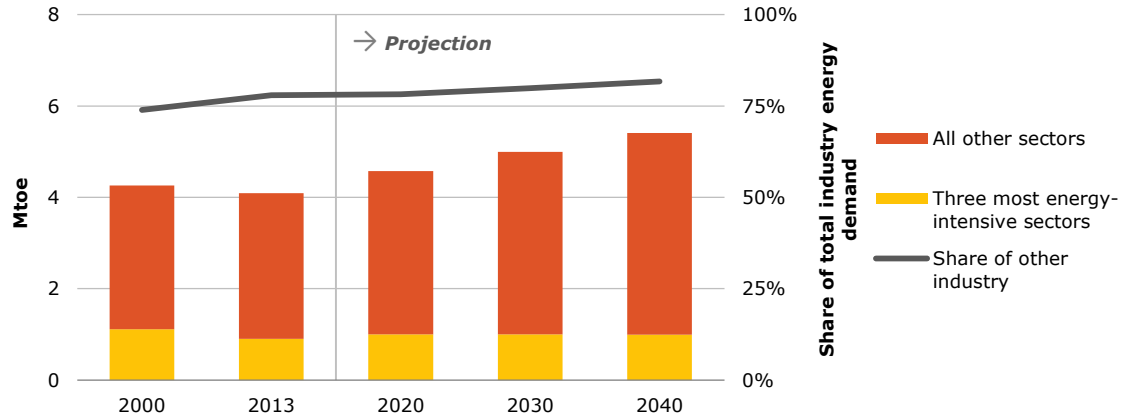
Sources: APERC analysis and IEA (2015a).

Energy efficiency programs aimed at appliances, buildings and consumer behaviour have played a role in slowing energy demand growth in recent years, but savings potential in this area remains significant.

Industry energy use: Recovery from financial crisis

Industry represents 30% of final energy demand and approximately 19% of New Zealand's GDP in 2013. During the Outlook period, energy demand is projected to grow 38% (Figure 12.3), largely from non-energy-intensive industries. The largest industry is food manufacturing. New Zealand is one of the largest dairy exporters in the world, and considerable amounts of energy are required to process and dry milk for export as powdered milk.

Figure 12.3 • New Zealand: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.

Sources: APERC analysis and IEA (2015a).

The industrial sector uses different forms of energy to meet this demand, including renewables in the form of biomass and direct application of geothermal steam. The growth in demand, however, is expected to be met largely by oil and electricity. As new gas discoveries are not guaranteed, limiting its availability, it is assumed that supplies remain constant over the modelling period.

Food manufacturing remains the most significant manufacturing industry over the Outlook period, growing with Asian demand for dairy products. The government wants to stimulate innovation in the high-tech industry, but this industry remains small. Energy demand in energy-intensive industries is expected to remain flat, as new plants are not foreseen. In the case of aluminium smelting, the plant may close due to consolidation of the resource sectors.

Transport energy use: Improved fuel efficiency leads to peak transport demand

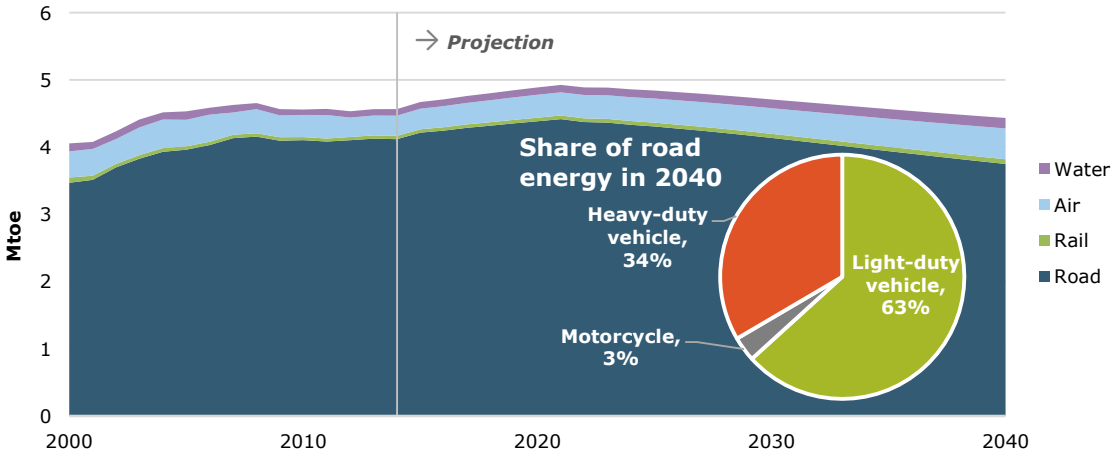
In New Zealand, as in the rest of the APEC region, road vehicles dominate transport energy consumption. Domestic transport accounted for 35% of final energy demand in 2013 at 4.6 Mtoe; the share declines but its value continues to increase early in the Outlook period, but as energy efficiency improves and vehicle ownership approaches the saturation point, total demand peaks in 2021 and decreases thereafter to 3% lower than in 2013 (Figure 12.4). Domestic air travel demand continues to grow as the population becomes wealthier, but not enough to counter decreased road transport demand. Domestic transport accounts for 28% of demand by 2040, reflecting this improvement.

Vehicle fleet efficiency is expected to increase over the period. The resulting overall energy demand reduction is achieved in several ways, including through technical improvement of the internal combustion engine and the adoption of new technologies. EV technologies—hybrids, plug-in hybrids and EVs—are expected to make up 12% of the vehicle stock by 2040.

Vehicle saturation towards 2040 limits fleet size growth and contributes to fuel demand reductions. Any fleet additions are the result of population growth rather than economic development.

Despite this trend, there is significant potential for further fuel efficiency improvements. The government is exploring ways to accelerate the deployment of new, advanced vehicles. The government's fuel efficiency labelling scheme informs consumers about a vehicle's fuel economy and requires vehicles to meet the Euro 4 or Japan 05 GHG emissions standards. The GHG emissions standard raises the efficiency of imported second-hand vehicles (five- to eight-year-old vehicles from Japan) which dominate the private light-duty vehicle fleet (MOT, 2015).

Figure 12.4 • New Zealand: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Renewables account for growing share of energy mix

TPES in 2013 was 20 Mtoe, an increase of 12% from 2000. Renewables, including hydro, is the largest component of TPES at 39% (Figure 12.5). This proportion is projected to increase to 48% by 2040 with growth in renewable electricity. Oil, which accounted for 33% of the energy supply in 2013, remains steady to finish the period with a 32% share in 2040.

Gas remains relatively flat throughout the period because demand is dominated by a small number of industrial users (including non-energy use in methanol production) and power generation, which are expected to remain at steady consumption levels, especially considering an existing long-term (10-year) supply contract for methanol manufacturing. Availability of gas for new demand will be limited by gas

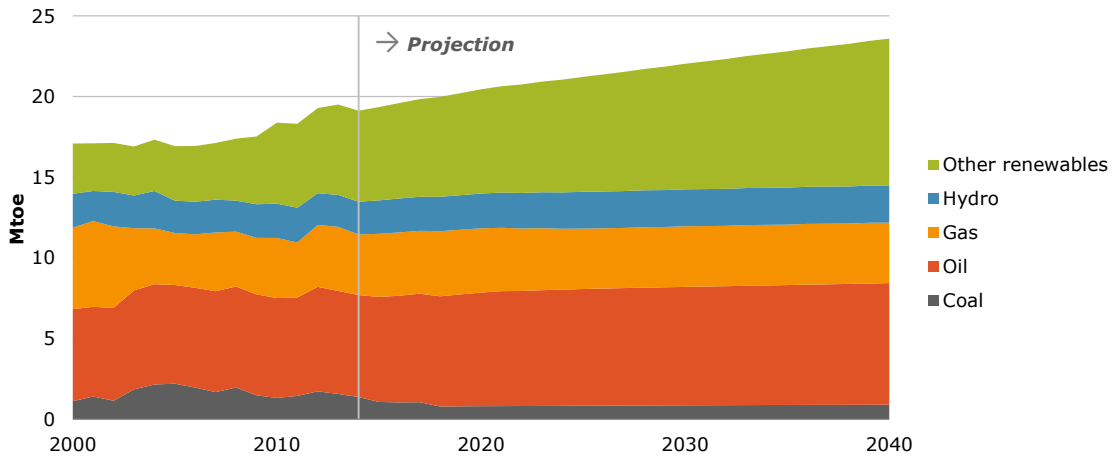
discoveries and the lead time required to bring them on line, so new discoveries are assumed to keep up with current demand throughout the Outlook period. Only significant discoveries would change this situation.

The share of coal in TPES is projected to decrease with decommissioning of the only coal-fired power plant by 2018. The Huntly power station, with four 250 megawatt (MW) units of dual coal/gas generation, initially commissioned in 1973, is being slowly decommissioned according to reserve needs. By the end of 2014 two of these units were decommissioned, and the remaining ones are scheduled to be permanently withdrawn from the market by 2018, unless the market makes it beneficial for them to be kept as operational reserve (New Zealand Herald, 2015).

Renewables are the key growth area, as wind and geothermal resources are increasingly deployed to meet the 90% renewable electricity goal. Solar energy is growing quickly—from a very low base—but once initial demand is filled, lack of government support may slow growth.

Overall, the fuel mix is diverse and the main objective for the future is to reduce reliance on fossil fuels in favour of renewables. This transition is lagging in the transport sector, which relies heavily on imported fossil fuels.

Figure 12.5 ● New Zealand: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

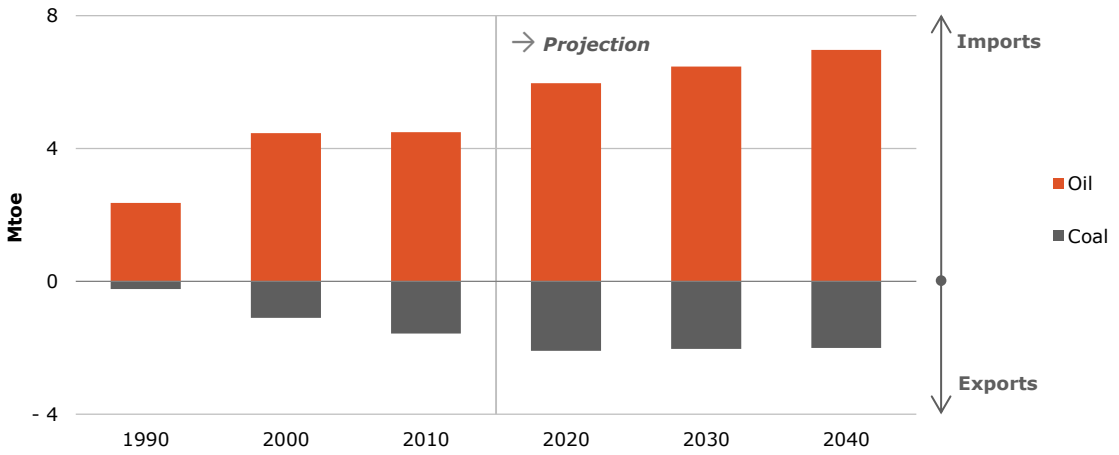
Energy trade: Oil imports dominate

While it has significant domestic resources, New Zealand is still heavily dependent on oil imports. Net oil imports were roughly equivalent to total oil demand in 2013 (5.9 Mtoe) (Figure 12.6). A significant find in the future is possible given its geology, but under current conditions New Zealand will remain dependent on foreign oil. This dependency makes it important to limit demand increases through transport efficiency policies or alternative resources such as biofuels.

New Zealand does not have LNG terminals to trade gas, but this option was considered in 2006 as the slow pace new gas discoveries generated fears of a shortfall by 2014 (Taranaki Daily Times, 2009). The project faced significant local opposition on safety grounds, and oil fields coming on line in 2008 alleviated medium-term supply concerns.

New Zealand trades coal internationally, exporting it mainly for steelmaking as it is very high-quality (low-sulphur, low-ash) coal that is ideal for coking. The export security for this high-quality coal does not extend to thermal coal, for which New Zealand must compete with the larger economies of scale achieved in Australia and Indonesia.

Figure 12.6 • New Zealand: Net energy imports and exports, 1990-2040

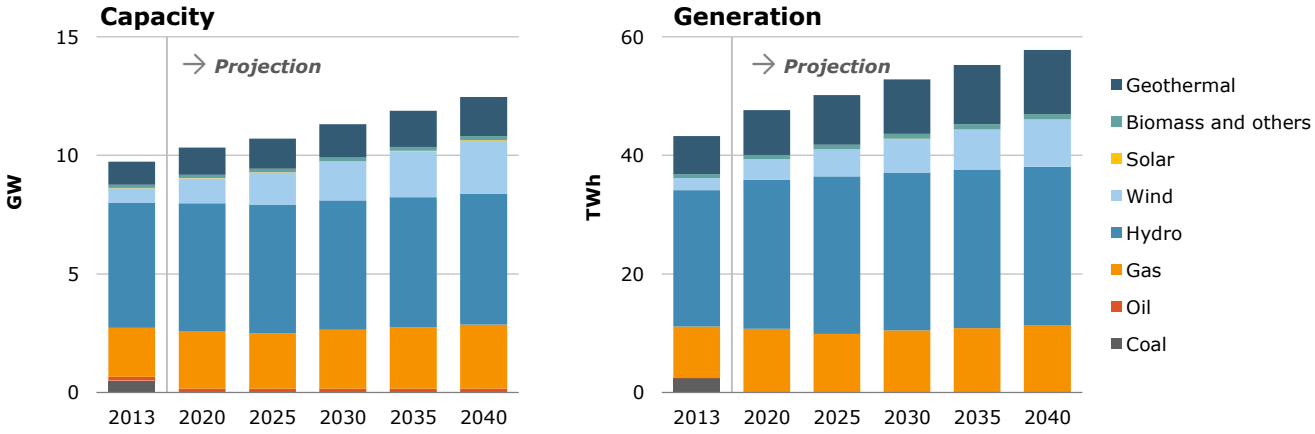


Sources: APERC analysis and IEA (2015a).

Power sector trends: Wind and geothermal to lead growth

Total generation capacity is expected to increase 28%, from 9.7 gigawatts (GW) in 2013 to 12 GW by 2040 (Figure 12.7) in response to residential and commercial sector demand increases. Electricity generation rises 34%, from 43 terawatt-hours (TWh) to 58 TWh.

Figure 12.7 • New Zealand: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

Two key trends stand out in the power sector. The first is that the majority of new capacity demand is expected to be met by geothermal and wind power in an effort to meet the 90% renewable electricity generation target by 2025. The second is the likely phase-out of coal, although there is no policy directive to do so. The sole coal-fired power plant is ageing and is scheduled for retirement by 2018, and there is strong public opposition to new coal projects. Coal generation after 2020 is expected to be limited to smaller cogeneration plants in industrial settings that are able to sell electricity to the grid, should electricity spot market prices be favourable.

Opportunities to increase generation from gas and hydro are restricted, as long-term gas availability is limited and all the large hydro opportunities have either been developed or encountered strong public opposition. This leaves the existing hydro, gas and growing geothermal generation to meet base-load requirements in winter when demand increases, and provide backup for increasing wind generation capacity.

Wind is a very viable resource in New Zealand; with a high capacity factor of over 40% on average (NZWEA, 2015), the extensive wind development in New Zealand is occurring without government support. Even so, total generation from renewables at the end of the Outlook period is projected to fall short of the 90% target (at 82%) because not all base-load demand can be covered by renewables, and keeping existing generation plants would be less costly than developing new renewable generation.

Transmission infrastructure is currently undergoing significant refurbishment in a number of areas to future-proof the system; however, an issue that made headlines recently is the viability of the aluminium smelter at the southern tip of New Zealand. The smelter consumes 15% of all electricity generated, supplied through a direct line from the 800 MW Manapouri hydro dam. Should the smelter be mothballed, a significant transmission project would be required to take electricity from the dam to market, and new generation would be pushed back for 9 to 10 years (MBIE, 2015a).

ALTERNATIVE SCENARIOS

Of the three alternative scenarios used for analysing energy futures in this Outlook, only the Improved Efficiency Scenario and High Renewables Scenario are relevant to New Zealand.[2] These two scenarios are used to assess the economic implications of the APEC intensity[3] and renewable energy[4] targets.

The Improved Efficiency Scenario has the largest impact: it provides the conditions necessary to reduce demand by 12% and energy-related CO_2 emissions by 19% in 2040 compared with the BAU. The High Renewables Scenario leads to only an 11% reduction in CO_2 emissions by 2040 compared with the BAU, as New Zealand already has a large proportion of renewable energy, which limits further renewable development.

The Alternative Power Mix Scenario was not applied to New Zealand because several key assumptions are irrelevant (such as nuclear power, which is banned by law), and further coal development is impractical as the economy and the government aim for renewable options.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

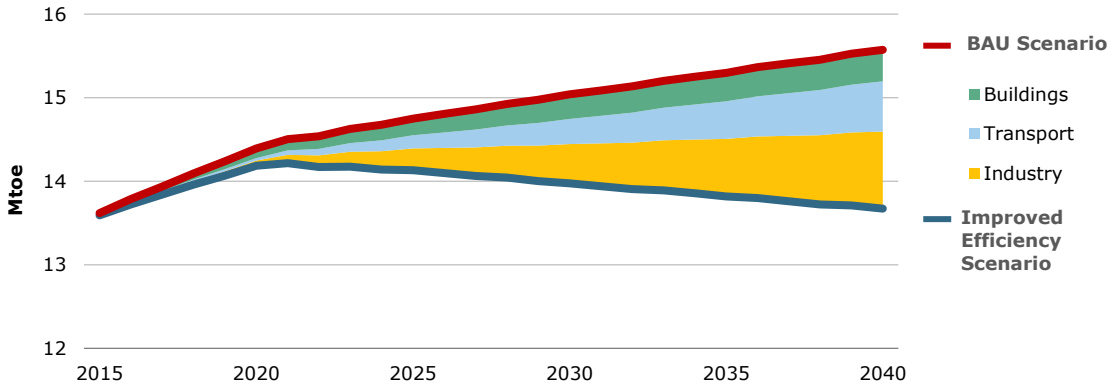
The goal of the Improved Efficiency Scenario is to decrease energy demand through energy efficiency policies in all major sectors. The key efficiency policies considered in this scenario are:

- Residential and commercial sector: MEPS for equipment and appliances;
- Transport: Fuel efficiency standards that significantly accelerate improvement over the period, and improved urban design to minimise transport demand; and
- Industry: Improved application of energy management principles, and highly efficient plant and fuel management.

Implementation of these policies results in estimated savings of 1.9 Mtoe, or 12% of total energy consumption by 2040 compared with the BAU Scenario (Figure 12.8). These savings cause energy demand to peak by 2021 and then decrease slowly until the end of the Outlook period.

[2] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.
[3] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.
[4] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

Figure 12.8 ● New Zealand: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Source: APERC analysis.

Industry accounts for 49% of savings by 2040, followed by transport (32%) and buildings (20%). Industrial energy consumption is the largest component of growth in the BAU Scenario. The projected 12% savings in industry under BAU slows overall demand growth, but not enough to counter the upward trend. The largest proportion of savings comes from non-intensive industries, dominated by food product manufacturing.

In the domestic transport sector, tighter fuel economy policies and improved urban design lead to an overall reduction in energy required per kilometre travelled, as well as in vehicle ownership. Total savings reach 0.6 Mtoe by 2040 compared with the BAU and, when combined with the existing downward trend, total transport energy demand is 16% lower than in 2013.

Efficiency gains from a number of major appliances in the residential sector results in a 0.4 Mtoe (8%) savings over the BAU. This excludes gains from improvements in space heating or building envelopes, which in New Zealand account for 40% of all residential energy consumption. Savings would increase significantly when space heating is included in the analysis.

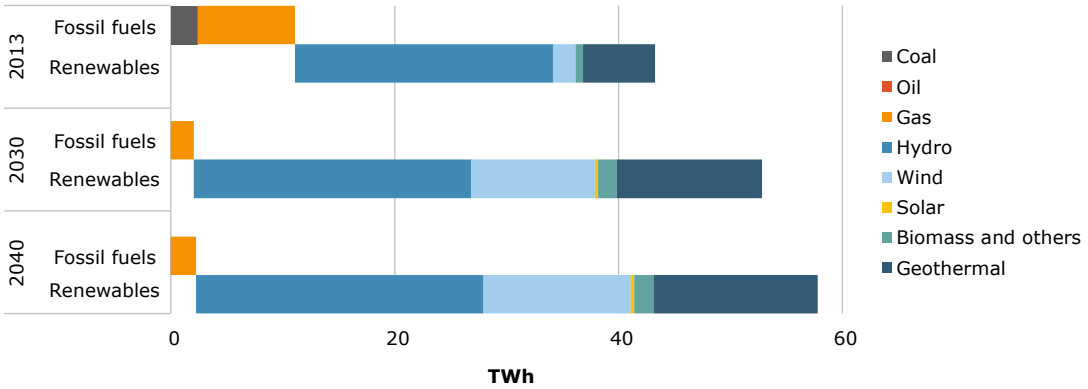
HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

This scenario explores how economies can increase renewable energy production—especially renewable electricity and biofuels—to meet the 2014 APEC renewable energy target. Given that New Zealand already has a large proportion of renewable energy, and that the BAU Scenario estimates the majority of new generation to come from geothermal and wind, the impact of the High Renewables Scenario is limited.

There is, however, potential for 13 GW of additional wind, solar and geothermal electricity generation. This is more than enough renewable energy to meet all of New Zealand's electricity demand by 2040 (Figure 12.9), but introducing all of it into the electricity market may be a challenge as the early retirement of operational gas generation may be required. In the High Renewables Scenario, renewable electricity increases to 96% in 2030 and remains stable until 2040, up from 74% in 2013. The majority of this electricity comes from hydro and geothermal, allowing for the integration of intermittent renewables.

The overall proportion of renewable energy in TPES in 2013 was 39%, from renewable electricity, and biomass and geothermal energy in the industrial sector. This share increases to 57% by 2040 in this scenario compared with 48% in 2040 under the BAU.

Figure 12.9 ● New Zealand: Power sector under the High Renewables Scenario, 2013-40

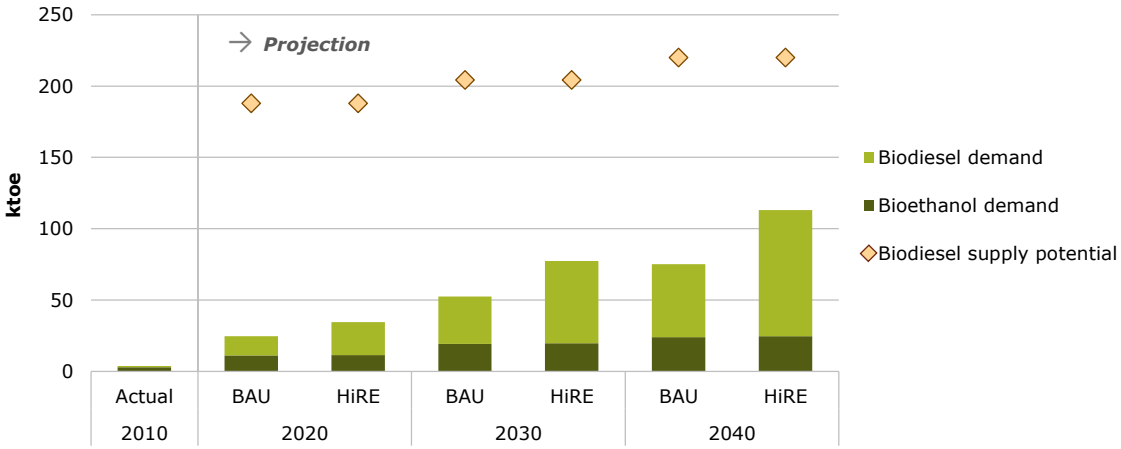


Sources: APERC analysis and IEA (2015a).

In biofuels, supply potential is very low and the government has lacked policy consistency. Different policy types have been implemented in recent years, for example a minimum sales obligation for fuel sellers, but it was repealed before it took effect when a new government came to power and replaced it with a subsidy scheme. The subsidy scheme, however, had the short expiration date of three years and was limited to NZD 1 million (around USD 830 000 [5]) per month, limiting its success and failing to spur long-term investment. The current approach is to support research and development (R&D) into advanced biofuels (made from woody biomass) through public-private partnerships.

New Zealand's limited biodiesel production relies on waste (or recycled) canola oil from restaurants and industrial food manufacturers. A new plant is being constructed to produce biodiesel from tallow (animal fat), a by-product of the meat industry. Ethanol is produced from whey, a by-product of the dairy industry, but is largely exported; only a small portion is used for domestic consumption.

Figure 12.10 ● New Zealand: Biofuels demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is for the Outlook period only; HiRE = High Renewables Scenario.
Sources: APERC analysis, MOT (2013), FAO (2014) and IEA (2015a).

Total biofuels demand is very small but is expected to grow: in the BAU Scenario, it grows to 75 kilotonnes of oil equivalent (ktoe), a small proportion of total transport demand (Figure 12.10). In the High Renewables Scenario, however, demand increases to 113 ktoe because of government policies. Production potential is based on the economy's ability to grow domestic feedstock for biofuel production without competing with food production.

[5] 2014 World Bank official exchange rate of USD 1: NZD 1.21.

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Total investment requirements are expressed in a high- and low-cost estimate range to allow for cost variations. The estimations are for four key areas: upstream fossil fuels, downstream fossil fuels, electricity and energy transport (Table 12.4). The total estimated investment needed to support energy demand growth in the BAU Scenario is between USD 31 billion in the low-cost estimate and USD 51 billion in the high-cost estimate from 2015 to 2040.

Electricity requires the highest investment from 2015 to 2040, at USD 18 billion to USD 24 billion, or 58% of total investment in the low-cost estimate and 48% in the high-cost estimate. Investment in electricity is used to fund 2.7 GW of additional generation capacity, as well as expansion of transmission and distribution networks. Upstream oil, gas and coal have the next largest investment requirement at USD 7.8 billion to USD 17 billion, or 25% in the low-cost estimate and 33% in the high-cost estimate, for the exploration and well development needed to maintain estimated levels of production. Energy transport for oil, gas and coal (from source to ports or end-use facility) requires around 15% of the total, while downstream has the smallest share at 1.6% to 4.7%.

Table 12.4 ● New Zealand: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	4.6	6.8
	Gas	2.0	5.9
	Coal	1.3	4.1
	Subtotal	7.8	17
Downstream	Refinery	0.5	2.3
	Biofuels Refinery	0.05	0.07
	Subtotal	0.5	2.4
Electricity	Gas	1.3	2.1
	Hydro	0.6	1.3
	Wind	5.1	5.3
	Solar	0.04	0.06
	Biomass and others	0.3	0.4
	Geothermal	2.8	3.5
	Transmission lines	5.5	6.7
	Distribution lines	2.4	4.6
	Subtotal	18	24
Energy transport	Oil	3.8	4.5
	Gas	0.9	2.6
	Coal	0.04	0.10
	Subtotal	4.8	7.2
Total		**31**	**51**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

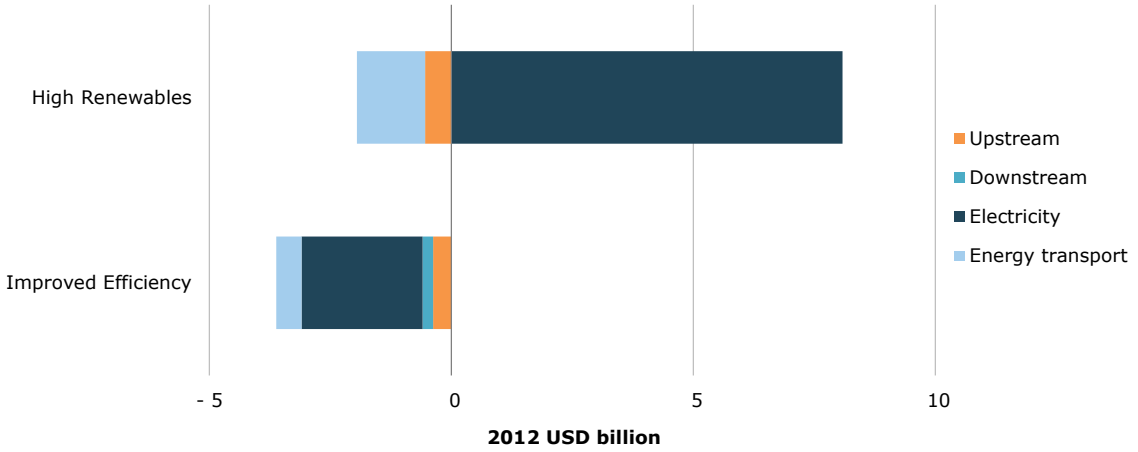
Source: APERC analysis.

Required investment is reduced under the Improved Efficiency Scenario due to lower energy demand and the associated costs of exploration, generation and distribution. The Improved Efficiency Scenario provides savings of USD 3.6 billion, largely concentrated in electricity infrastructure (USD 2.5 billion) (Figure 12.11). Reduced electricity demand also results in reduced gas generation in the power mix; consequently, upstream gas developments account for USD 0.4 billion less in investments.

In the High Renewables Scenario, net investment rises by USD 6.1 billion (20%) from new renewable electricity and the associated infrastructure. Investment in the power sector is up 45% from the BAU, with renewable capacity increasing by 3.1 GW compared with the BAU due to the lower capacity factors of renewable sources such as wind. The bulk of investment increases in this scenario is on renewable generation (USD 7.1 billion), largely wind and geothermal, with contributions from solar and biomass generation. Transmission investments increase (USD 2 billion), while gas generation investments decrease (USD 1 billion). The increase is partly offset by reductions in upstream and energy transport investments (USD 2 billion).

An assumed bioethanol blend rate of 5% increases downstream investment by 1.7% compared with the BAU. An additional 167 000 litres per day of bioethanol is needed to meet this blend rate. The overall investment required under the High Renewables low-cost estimate is USD 37 billion.

Figure 12.11 ● New Zealand: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.

Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

Two of the four key pillars of the NZES are energy efficiency and GHG emissions reductions. The NZES states an aspirational target of 90% renewable electricity by 2025, up from 74% in 2013, and GHG emissions reductions of 50% by 2050 compared with 2005. The strategy also sets out energy efficiency priorities and objectives.

The National Policy Statement on Renewable Energy (2011) further directs all policy makers at different levels of government to consider the benefits of renewable electricity in the project consenting process and to make provision for renewable electricity in regional and local plans and regulations.

Finally, the Resource Management Act of 1991 is the primary law that governs implementation of new developments. All power generation projects have to meet the requirements of this law, which include public consultations and environmental impact assessments, to obtain permits for development. In addition, the act empowers relevant parties to challenge resource consents through the Environment Court.

New Zealand is also active in international forums such as the United Nations Framework Convention on Climate Change (UNFCCC), to which it has committed a 30% emissions reduction by 2030, and the Global Research Alliance on Agricultural Greenhouse Gases (GRA) to establish cooperation and investment.

Enhancing energy security: Emphasis on geothermal and wind energy

Reliance on foreign oil for the transport sector is New Zealand's main energy security risk. Oil produced in 2013 was equal to 29% of domestic oil demand, but most of it is exported because it is a light sweet crude oil that commands a higher price in international markets. Transport oil import dependency is not reflected in the Herfindahl-Hirschman Index (HHI) value of HHI 0.25 in 2013, where a lower number indicates greater diversity (Table 12.5); one of the key weaknesses of the index is that individual sector dependency (such as transport) is not reflected in the evaluation.

Concerns over gas supply longevity have also been expressed. There have been no new gas discoveries in recent years, and at current production levels there is gas for approximately another 12 years (MBIE, 2015a).

Reliance on hydro resources for electricity generation is another energy security issue. Changing weather patterns (El Niño/La Niña in particular) significantly change rainfall, which affects hydro resource availability and disrupts the electricity market. In 2007 the government called for a conservation campaign to ensure that hydro reservoir supplies would last through the winter; commercial and industrial users were the most affected. The impacts of dry years have been mitigated through the introduction of dry-year electricity market requirements including demand-side management, asset management and liquidity of the hedge market (MBIE, 2015c).

The Improved Efficiency Scenario reduces exposure to energy security risks the most significantly by substantially reducing oil and gas demand and increasing deployment of alternative transport technologies. The High Renewables Scenario increases deployment of geothermal and wind energy, lowering the risk from hydro dependence. Although energy security remains vulnerable under these scenarios, the diversification index deteriorates from HHI 0.29 under the BAU in 2040 to HHI 0.34 under the High Renewables Scenario as the share of renewables becomes dominant. This is particularly evident in the electricity generation diversity index, which rises to 0.68 as coal is discontinued and the share of gas is reduced.

To reduce this exposure, the NZES has two pillars dedicated to energy security and diversity. The aim is to enhance oil and gas exploration and develop renewable energy with an emphasis on geothermal and wind, creating a demand-response system to cope with short-term electricity market disruptions. This measure is in addition to the 90-day reserve commitment in place through the IEA.

The future of oil and gas exploration is encouraging, as it is believed that some of the underexplored basins around New Zealand may be rich in hydrocarbons. With current low oil prices, however, exploration has slowed.

Table 12.5 ● New Zealand: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040		
	Actual	BAU	Improved Efficiency	High Renewables
Primary energy supply diversity (HHI)	0.25	0.29	0.30	0.34
Primary energy supply self-sufficiency (%)	77	78	80	80
Coal self-sufficiency (%)	100	100	100	100
Oil self-sufficiency (%)	29	32	36	32
Gas self-sufficiency (%)	100	100	100	100
Electricity generation input fuel diversity (HHI)	0.36	0.49	0.58	0.68

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

Although efforts have been made to enhance EV distribution and biofuel development, progress remains slow. Attention in biofuels is turning to advanced biofuels sourced from woody biomass, the production of which does not compete with food crops. This form of biofuel is not yet economically viable, and the government is supporting R&D in a joint venture with the industrial sector.

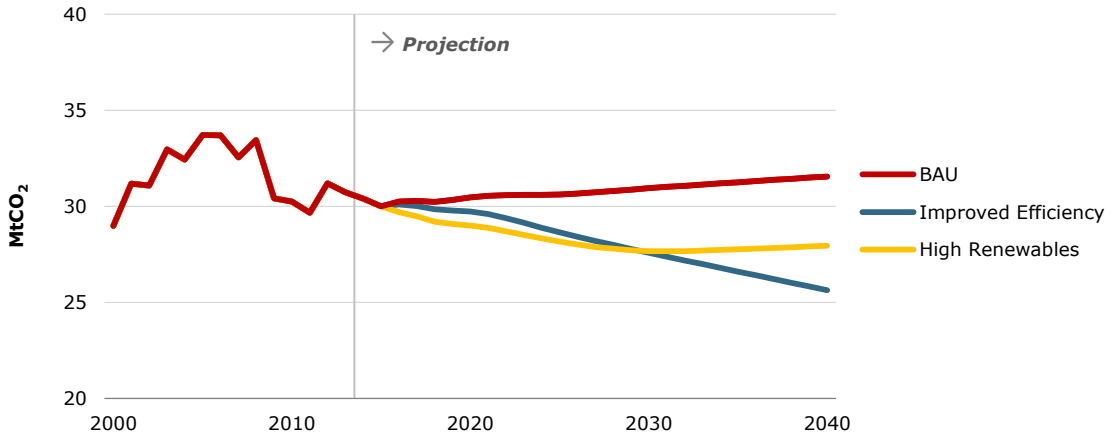
Climate change impacts and risks: Greatest emissions reduction potential in transport sector

New Zealand is exposed to climate impacts, and the Ministry for the Environment estimates an overall temperature increase of 1°C by 2050, reducing the days of frost and augmenting the number of hot days (MFE, 2012). This temperature change, however, is of little impact compared with the potential changes in rainfall patterns that would affect agriculture and power generation, and increase the frequency of extreme events such as droughts and floods.

Energy-related emissions are projected to continue increasing over the Outlook period, from 31 million tonnes of carbon dioxide ($MtCO_2$) in 2013 to 32 $MtCO_2$ in 2040 (Figure 12.12). This 3% rise, despite the phase-out of coal from electricity generation and overall decreased emissions from transport, is due largely to increased oil demand in the industrial sector.

The Improved Efficiency Scenario provides the largest emissions reduction, 26 $MtCO_2$ by 2040. This reduction of 17% from 2013 counters the BAU trend of increased emissions. Efficiency gains from industry and transport provide the key benefits through demand reduction of fossil fuels. Energy-related CO_2 emissions in the High Renewables Scenario are reduced through lower fossil fuel electricity generation, resulting in an overall reduction of 9% from 2013. As electricity generation is already dominated by renewables, the High Renewables Scenario has less impact on CO_2 emissions than the Improved Efficiency Scenario. Both scenarios do, however, provide significant overall reductions compared with the BAU (High Renewables Scenario, 11%, and Improved Efficiency Scenario, 19%).

Figure 12.12 • New Zealand: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).

Sources: APERC analysis and IEA (2015b).

The GHG emissions profile of New Zealand is unique among developed economies, as the agriculture sector is the largest source of GHG emissions at 48% (from livestock farming and fertiliser use) (MFE, 2014). It is followed by GHG emissions from transport, power generation and industry. Curtailing GHG emissions in agriculture is particularly challenging, as the same efficiency options as for energy-related emissions are not available.

Even so, the government volunteered an INDC of 30% less GHG emissions than in 2005 by 2030, and has a domestic target of 50% by 2050. The INDC target is economy-wide, across all sectors, and includes all sectors' GHGs.

According to scenario results, New Zealand will require more ambitious policies, particularly in transport and industry. It will also need to implement policies to reduce agriculture-related emissions, and the energy sector, which accounts for half of total GHG emissions, would need to reduce its emissions 60% to meet the economy's 30% reduction commitment.

RECOMMENDATIONS FOR POLICY ACTION

With electricity demand growth projected to be met through renewable sources, and half of domestic GHG emissions coming from agricultural activities, New Zealand's policy options to reduce energy-related CO_2 emissions are limited to the transport sector and the fossil components of industrial energy demand.

More ambitious energy efficiency policies are required to meet the INDC and other economy-wide targets. A number of areas in the domestic transport sector hold significant potential: improved efficiency of existing technologies; new technological development; and improved design of towns and transport systems. Policies that stimulate deployment of high-efficiency vehicles of the latest technology are needed to achieve the savings projected in the Improved Efficiency Scenario. Examples of these policies can be seen across APEC, including the stringent Corporate Average Fuel Efficiency (CAFE) standards in the United States that manufacturers must meet. Another example is an incentives system such as those applied in Korea and Japan for high-efficiency hybrids and EVs.

Biofuels are also an important means of reducing energy-related CO_2 emissions in transport and increases the renewables share within the energy mix. Biofuels and EVs together could provide the ideal energy mix for low-carbon transportation. Biofuel development remains limited, however, despite significant biomass resources: industry requires greater consistency from government to make long-term investments. While advanced biofuel[6] development is very challenging, as the technology is not yet market-ready and infrastructure needs to be developed, advances could be made with consistent government policies that foster sufficient demand for investment and modest support for infrastructure.

With growth in the residential and commercial sectors, more new dwellings and commercial floor space, and greater demand for appliances, comes increased demand for energy. There is an opportunity for a high-efficiency response to all this new energy demand, through high energy efficiency requirements in building codes and more numerous and stringent MEPS for appliances and equipment.

New Zealand can reduce dependence on imported resources, decrease emissions and improve productivity by scaling up energy efficiency in all sectors and developing domestic resources, both fossil and renewable.

[6] Biofuels nomenclature varies, but in this case advanced biofuels are those derived from wood or woody biomass, as opposed to food-related products.

13. PAPUA NEW GUINEA

KEY FINDINGS

- **Papua New Guinea's total final energy demand under the BAU Scenario increases fourfold,** from 1.6 Mtoe in 2013 to 5.7 Mtoe in 2040.

- **The economy's energy intensity is expected to fall by 40% by 2035 under the BAU (from the 2005 level)** and 45% under the Improved Efficiency Scenario. Improving energy efficiency is necessary to further decrease energy intensity and so Papua New Guinea has initiated policies to decrease energy consumption, improve energy efficiency and reduce CO_2 emissions, including the Papua New Guinea Vision 2050.

- **Despite the expansion of renewables capacity under the BAU by 238% over the projection period, the combined share of oil and gas in the power mix is expected to increase significantly,** from nearly 63% of total capacity in 2013 to close to 70% in 2040, mainly because of growing domestic gas production.

- **Papua New Guinea's power generation is projected to increase nearly fivefold from 3.6 TWh in 2013 to 18 TWh in 2040.** Gas replaces oil as the main fuel, with gas's share expanding to nearly 67% and oil's falling to 5.7%.

- **Papua New Guinea's growing gas production and LNG exports could double GDP and triple export revenues in the near term.** This leads to the energy sector's domination by gas.

- **Access to electricity is low (15%) and mainly confined to urban areas.** The economy's target is 1 970 MW of installed capacity by 2030, which is exceeded by 13% under the BAU Scenario.

ECONOMY AND ENERGY OVERVIEW

Papua New Guinea is a resource-based economy dominated by natural resources (particularly gold, copper, oil and increasingly gas), timber and agricultural exports (coffee, cocoa, tea, palm oil and copra) and a traditional subsistence sector in which most villages produce little or no surplus for trading (IRENA, 2013). Exports dominated gross domestic product (GDP) at 71% in 2008 (the latest year for which data is available), of which minerals made up the largest share at 77%, followed by agricultural products at 17% and forestry products at 5% (IRENA, 2013). GDP is projected to grow more than fivefold from USD 22 billion in 2013 to USD 115 billion in 2040, of which the natural resource sector has the largest share, particularly gas in the form of liquefied natural gas (LNG) exports. Papua New Guinea's population is expected to rise over 63% in the same period.

Papua New Guinea has small oil reserves (0.2 billion barrels) (EIA, 2015), which are rapidly depleting and will completely dry up in the 2020s (IRENA, 2013) unless new reserves are discovered. The economy imports an unknown amount of oil for its only refinery's crude oil requirements (ICLG, 2015a) while exporting a varying amount of oil annually.

Table 13.1 ● Papua New Guinea: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	8.0	12	17	22	35	66	115
Population (million)	4.2	5.4	6.8	7.3	8	10	12
GDP per capita (2012 USD PPP)	1 928	2 226	2 531	2 942	4 176	6 435	9 651
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	0.9	1.1	2.1	2.6	4.7	7.7	12
TPES per capita (toe)	0.2	0.2	0.3	0.4	0.6	0.8	1.0
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	0.5	0.9	1.2	1.6	2.3	3.7	5.7
Final energy intensity per GDP (toe per 2012 USD million PPP)	65	74	72	75	65	56	49
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	2.3	3.1	4.9	6.3	12	18	29
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	8	11	15	15	45	65	80

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: EGEDA (2015) and World Bank (2015) for historical data; APERC analysis for projections.

Papua New Guinea's significant gas reserves are mainly undeveloped. Thanks to the completion of its LNG liquefaction terminal in 2014, it began exporting LNG in May of that year, the only form of gas export for the island economy. Targeting spot markets, its main consumers are China, Japan and Chinese Taipei (Platts, 2014). Renewables, primarily hydro but also geothermal, account for slightly over 38% of the power mix, adding to diesel fuel and gas. The economy has known coal reserves and these are currently under exploration with a possibility of coal having a share in its energy mix (ER, 2015).

Mining, natural gas and oil extraction, agriculture, forestry and fisheries are the key drivers of economic development and energy consumption, with mining and gas extraction leading in both realms. LNG exports are expected to grow and significantly expand GDP, which will consolidate the mining sector's pre-eminence. Such exports could double GDP in the near term and triple export revenues (IM, 2014).

Papua New Guinea's energy consumption is projected to grow more than fourfold over the Outlook period. Total final energy demand (TFED) increases from 1.6 million tonnes of oil equivalent (Mtoe) in 2013 to 5.7 Mtoe in 2040, with the expansion of the mining sector, particularly gas, as the main contributing factor. Total primary energy supply (TPES) also grows over fourfold from 2.6 Mtoe in 2013 to 12 Mtoe in 2040. Oil loses its large share of TPES (almost 78% in 2013) by 2040 as its share falls to almost 47% while that of gas rises to 37% from nearly 5% in 2013.

ENERGY RESOURCES

Papua New Guinea has small reserves of oil and gas as well as coal reserves of unknown size. It has produced over 400 million barrels of light crude oil since 1992 (IRENA, 2013), reducing its oil reserves to 0.2 billion barrels in 2015 (EIA, 2015). Existing oil reserves are depleting rapidly and are expected to dry up in the 2020s. There are no reports of new oil discoveries.

Oil is the major component of the energy mix, as mentioned above. Oil production, while fluctuating, has been declining. From its three oil fields, Papua New Guinea produced roughly 30 100 barrels per day (bbl/d) in 2011, 27 500 bbl/d in 2012 and 28 250 bbl/d in 2013 (ICLG, 2015a). However, the LNG project is expected to add an extra 20 000 bbl/d of oil in the unspecified future (PCMP, 2015) as its by-product. The economy has been importing a fluctuating, but unknown, amount of crude oil annually to feed its only refinery, while exporting oil (around 6 080 bbl/d in 2013), (ICLG, 2015a) which accounts for a small share of the economy's mining exports.

Papua New Guinea's gas reserves of 0.2 trillion cubic metres (tcm) were largely undeveloped until May 2014, when the economy began exporting LNG (PL, 2015). Gas production began in 1991 from the Hides gas field, supplying electricity to the Porgera gold mine (ICLG, 2015b). The ExxonMobil-led joint venture invested heavily in its gas fields to produce gas in excess of the economy's domestic requirements to enable LNG exports (the only way to export gas, as piped exports are not an option for the island economy). The investment allocated for the current, initial phase of the LNG project is USD 19 billion (PL, 2015). LNG exports are expected to significantly increase the economy's export-generated revenue. For example, investing about PGK 8.9 billion (USD 3.6 billion) in the Gas to Queensland Project is expected to generate PGK 21.7 billion (USD 8.8 billion)[1] in exports over 28 years (ICLG, 2015b). LNG exports could triple the economy's export revenue from the USD 5.6 billion recorded in 2012 (Platts, 2014). The LNG project, the biggest investment in the economy's history, has the potential to double Papua New Guinea's GDP in the near term (Platts, 2014). Thanks to the LNG project, Papua New Guinea's gas production increased from 0.13 Mtoe in 2013 to 6.9 Mtoe in 2015 (DPEE, 2015).

Led by Esso Highlands Ltd (a subsidiary of ExxonMobil), the LNG joint venture involves Oil Search Limited, National Petroleum Company of Papua New Guinea (NPCP), Santos Limited, JX Nippon Oil & Gas Exploration, Mineral Resources Development Company Limited and Petromin PNG Holdings Limited (PCMP, 2015). The project receives gas from the Hides, Angore and Juha gas fields and from associated gas in the Kutubu, Agogo, Moran and Gobe Main oil fields (PCMP, 2015). The joint venture has liquefaction and storage facilities near Port Moresby with capacity of 6.9 million tonnes a year (PL, 2015). It will produce 6.6 million tonnes of LNG a year from two production trains once they are operating fully (PCMP, 2015). Around 95% of the project's LNG capacity is covered by long-term contracts with Sinopec, Tepco, Osaka Gas and CPC (Platts, 2014). InterOil and Total are working towards another LNG project, pending a final decision in 2017 (IOC, 2015).

ENERGY POLICY CONTEXT

Papua New Guinea is revising its energy policies, including the National Energy Policy, the Rural Electrification Policy and Strategy, the Geothermal Energy Policy, the Renewable Energy Policy and the Electricity Industry Policy (IRENA, 2013). As of 2015, there are no updates on the revised versions.

[1] All PGK figures use 2014 World Bank official exchange rate USD 1: PGK 2.46.

Other government policies that have a bearing on energy include the National Strategic Plan 2010-50. Announced in 2010, the plan covers 'seven pillars' of which two are related to energy (natural resources, and climate change and environmental sustainability). The Development Strategic Plan (DSP) 2010-30, initiated in March 2010, has five pillars, one of which is natural resources and environment (DNPM, 2010a). To address the low access rate of the economy's households to electricity (15% in 2015) (ER, 2015), the DSP set the following objective: 'All households are to have access to a reliable and affordable energy supply, and sufficient power is to be generated and distributed to meet future energy requirements and demands' (DNPM, 2010a). The economy's Medium Term Development Plan (MTDP) 2011-15 of October 2010 also focuses on increasing access to electricity for all households in the economy (DNPM, 2010b).

BUSINESS-AS-USUAL SCENARIO

This section illustrates energy demand and supply in the Business-as-Usual (BAU) Scenario and summarises the key assumptions and existing government policies included in the BAU analysis (Table 13.2). The definition of the BAU Scenario and the modelling assumptions used in this Outlook are different from those used by the government for its projections, targets and analysis.

Table 13.2 ● Papua New Guinea: Key assumptions and policy drivers under the BAU Scenario

Oil and gas reserves	• Rapid depletion of oil reserves to end production in the 2020s. • Small amount of oil-associated gas production to continue. • Expanding gas production of mainly undeveloped reserves.
Energy exports	• Small amount of oil exports since 2013. • LNG exports since 2014 to expand as investments continue.
Transport	• Road transport is dominant but still underdeveloped. • Plans as of 2012 to address infrastructural shortcomings.
Energy supply mix	• Expanding gas production to end heavy reliance on depleting oil.
Power mix	• No coal or nuclear power plants. • Mainly oil and hydro with a small amount of gas. • Expanding share of gas. • Small amount of geothermal.
Renewables	• Increasing the contribution of all renewables, including hydro and geothermal, by 2050.
Climate change	• Continue to work towards 2010 target to decrease greenhouse gas (GHG) emissions by at least 50% before 2030 to become carbon neutral before 2050.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

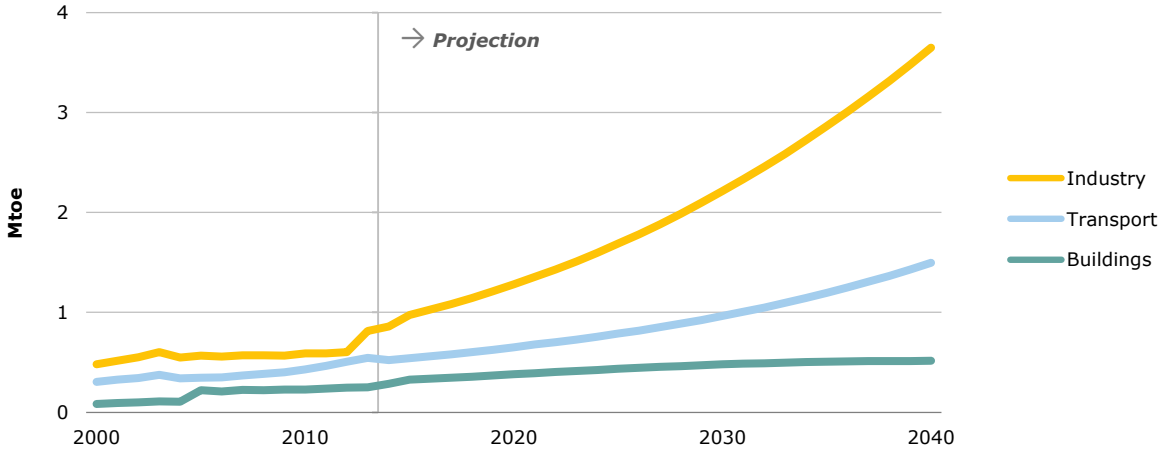
RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Papua New Guinea's TFED under the BAU increases more than threefold from 1.6 Mtoe in 2013 to 5.7 Mtoe in 2040, reflecting a significant average annual increase of approximately 4.8%. The growth of industry is the major contributing factor. Industry has the highest share of the economy's TFED through the Outlook period, rising from 51% in 2013 to 64% in 2040.

The buildings sector share decrease, from 15% to 9%, while domestic transport's share declines from 34% to just over 26%. Volume of energy consumption gradually increases in both sectors: oil and electricity in buildings, and oil in transport. Papua New Guinea also consumes biomass, especially in rural areas (IRENA, 2013).[2]

[2] There is no data on the actual volume of renewables and their share of Papua New Guinea's TEFD.

Figure 13.1 • Papua New Guinea: Final energy demand by sector, 2000-40

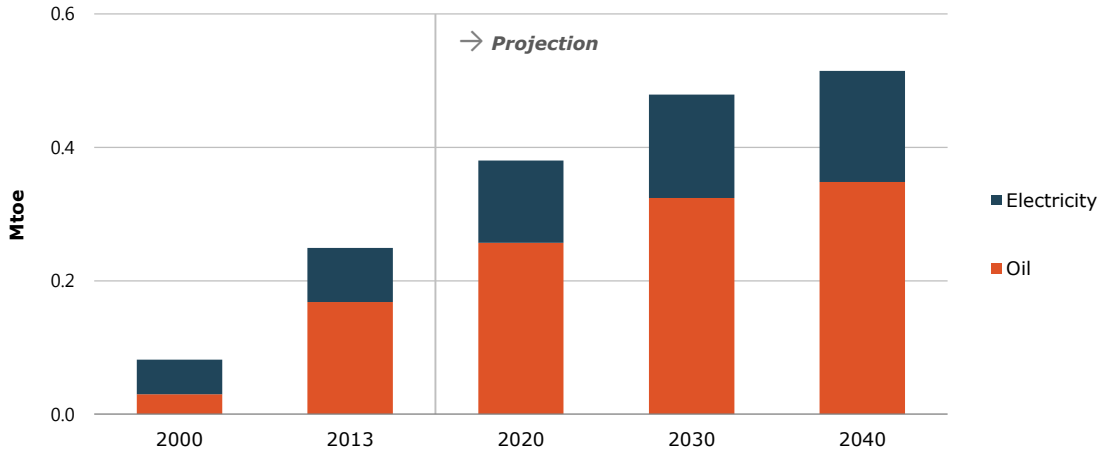


Note: Transport refers only to domestic transport.
Sources: APERC analysis and EGEDA (2015).

Buildings energy use: Phenomenal growth as access to energy expands

Energy demand from buildings (residential and commercial) and agriculture is projected to increase twofold from 0.25 Mtoe in 2013 to 0.51 Mtoe in 2040 (Figure 13.2). Oil's share increase from 67% in 2013 to 68% in 2040 (from 0.17 Mtoe to 0.35 Mtoe). Electricity's share decreases from 33% to 32% (0.17 Mtoe) although the economy expands access beyond the current 15% of the population through development plans such as the DSP. The DSP aims at augmenting power generation by substantially expanding hydro power, gas-based generation and renewable energy, while adding some coal-based generation and reducing diesel-based generation significantly (GPNG, 2010).[3]

Figure 13.2 • Papua New Guinea: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and EGEDA (2015).

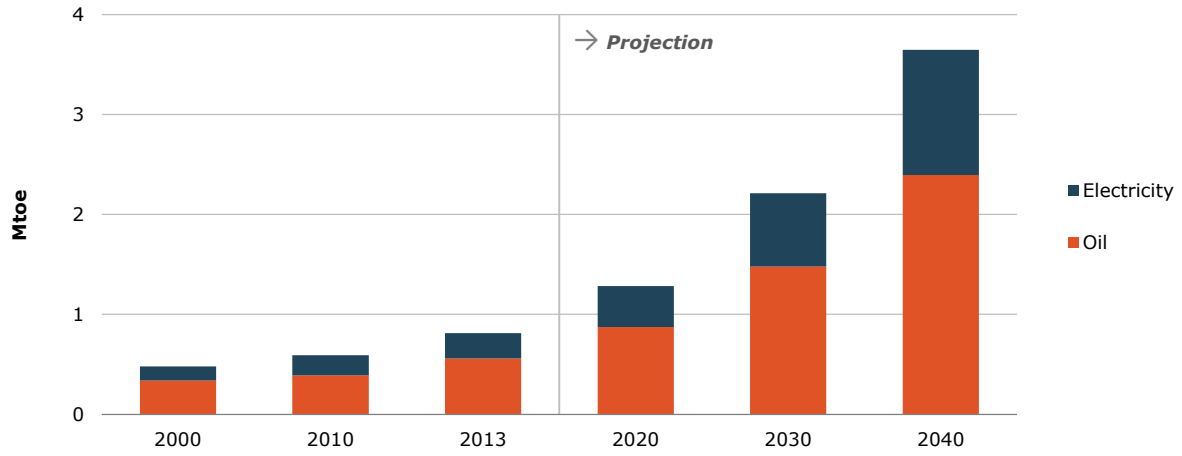
Industry energy use: Mining's leading role

Papua New Guinea's industrial energy demand is projected to increase more than fourfold from 0.81 Mtoe in 2013 to 3.6 Mtoe in 2040 with projected annual growth of over 15% (Figure 13.3). Contributing factors include mining (particularly gas extraction), light manufacturing (such as food) and agricultural processing industries that enable the economy to export its cash crops of coffee, palm oil, cocoa, copra, tea, rubber and sugar. Mining is the leading industry as its products, in particular copper, gold and LNG

[3] Only the total sectoral demand is available. Thus, the shares of buildings and agriculture are unknown.

(since May 2014), account for the bulk of exports, which are the economy's main source of revenue. Mining's contribution to GDP was 14% in 2014 (ANZI, 2015).

Figure 13.3 • Papua New Guinea: Industry sector final energy demand, 2000-40



Sources: APERC analysis and EGEDA (2015).

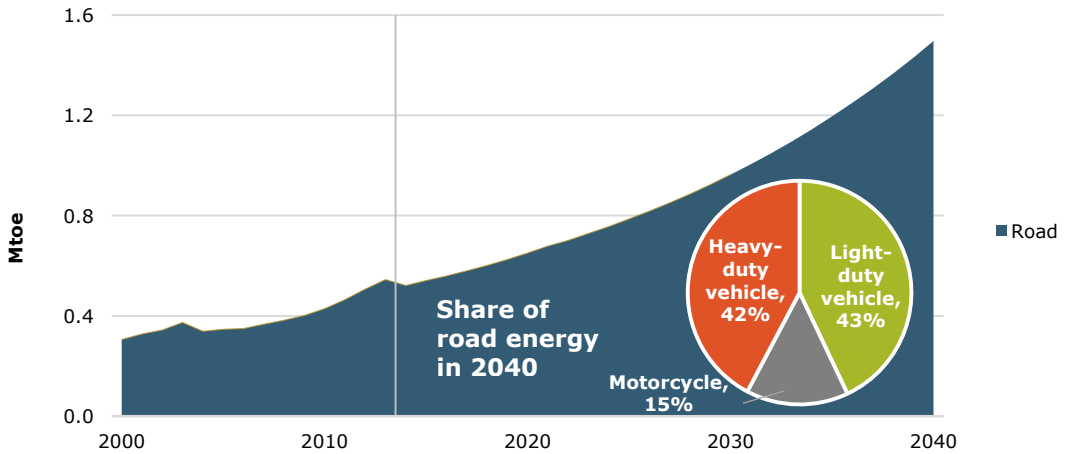
Mindful of industry's over-dependence on mining, the government is looking into expanding other industrial activities by attracting foreign investment. In July 2014, Max Rai, the head of the Department of Trade, Commerce and Industry's trade division, called on the government to provide incentives to attract foreign investment in other industries, through measures such as low corporate tax and individual income tax rates; tax holidays and other types of tax concessions; preferential tariffs; and creating Special Economic Zones and Export Processing Zones (BAP, 2014).

Transport energy use: Road transport and oil

The domestic transport sector's energy demand is projected to almost triple from 0.55 Mtoe in 2013 to 1.5 Mtoe in 2040 (Figure 13.4). Road transport accounts for 100% of the demand. The sector is not expected to experience major fluctuations, as demand increases gradually and steadily.

Oil accounts for 100% of the sector's energy demand during the Outlook period. There are no reports of plans to diversify the sector's energy mix by including electricity, gas—even though production is increasing substantially—or biofuels. The economy produces ethanol (around 0.3 million litres in 2013) but the bulk of it is exported to Australia (IRENA, 2013).

Figure 13.4 • Papua New Guinea: Domestic transport sector final energy demand, 2000-40



Note: Energy is also used for domestic air and shipping transport, but it is not currently modelled due to data limitations.
Sources: APERC analysis and EGEDA (2015).

The economy does not have a developed public transport system or firm plans for one during the Outlook period. Its transport sector suffers from infrastructural deficiencies; roads need modernisation, upgrading and expansion. The government has a program to rehabilitate existing roads and construct new ones by 2035 (DNPM, 2010a). Towards this end, in 2012 the leaders who make up the governing coalition agreed to 78 key statements, known as the Alotau Accord, underlying their vision to improve services delivery (IDAPO, 2015). Statement No. 43 stipulates establishing an Infrastructure Development Authority to 'take charge of overseeing major transport and public infrastructure projects for the next 5 years. The Authority will mobilise and negotiate financial resources and technical expertise' (IDAPO, 2015).

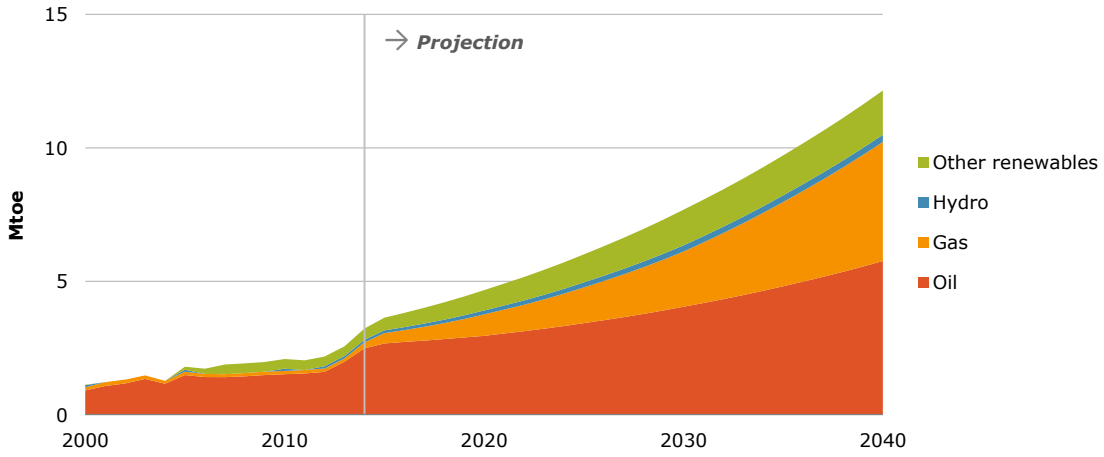
RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Fossil fuels dominate with more gas

Papua New Guinea's TPES is projected to grow more than four times from 2.6 Mtoe in 2013 to 12 Mtoe in 2040 (Figure 13.5). Oil and gas dominate supply, with a small contribution from renewables, primarily hydro, but also geothermal and biofuels. Oil and gas preserve their overall dominant role throughout the Outlook period, with their share increasing from nearly 82% in 2013 to over 84% in 2040.

The share and volume of gas rises significantly, from close to 5% (0.13 Mtoe) to 37% (4.5 Mtoe), thanks to the growing production of gas as oil reserves dry up. Oil's volume increases from 2 Mtoe to 5.8 Mtoe, but its share falls from almost 78% to about 45%.

Figure 13.5 ● Papua New Guinea: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and EGEDA (2015).

A major development in Papua New Guinea's TPES is the decline in the share of renewables from 18% in 2013 to 16% in 2040, even though its volume rises from 0.45 Mtoe to 1.9 Mtoe. Hydro is the single largest renewable energy source, accounting for 28% of electricity generation in 2013. Further expansion of hydro is planned, with its capacity share expected to grow from 30% in 2013 to 52% in 2030 (ADB, 2015a), to 69% in 2040. Hydro's share in TPES decreases from around 3.4% in 2013 to 2.2% in 2040 while that of other renewables,[4] including geothermal, declines from 14% to 13%. Biofuels consumption is limited as their bulk is exported (IRENA, 2013). Geothermal is mainly used by the mining industry for power generation. Papua New Guinea has no nuclear energy and no nuclear plans during the Outlook period.

Energy trade: Increased gas exports

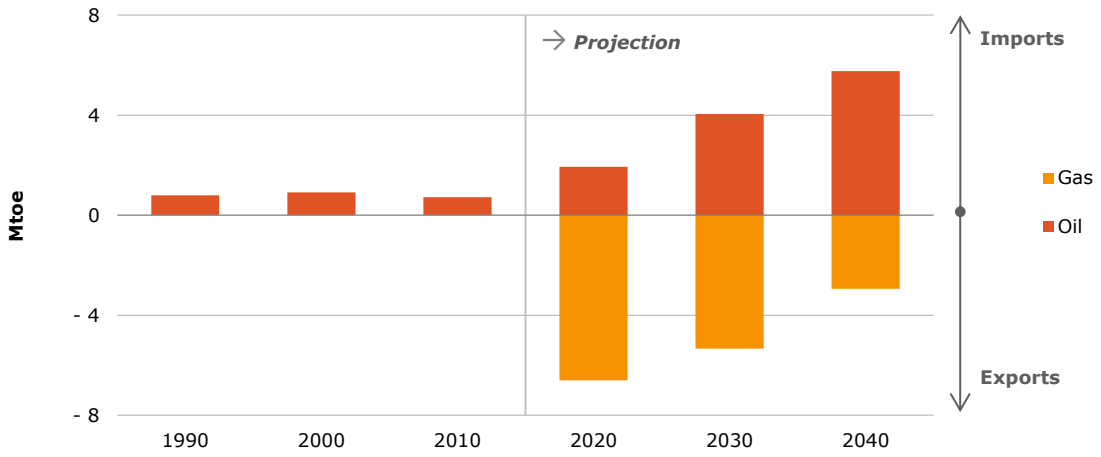
Papua New Guinea has coal reserves but the exact volume is unknown and its government supports coal exploration. However, the economy has proven oil and gas reserves enabling it to export oil since 2013

[4] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

and gas since 2014. Total energy trade volume of 2.3 Mtoe in 2013 reflects oil imports, as Papua New Guinea's own gas resources—which are mainly undeveloped—met its small demand for gas (Figure 13.6). Projected trade of 3.5 Mtoe in 2040 indicates the substantial LNG exports (2.4 Mtoe) that will result from recent investments in the gas industry, which enabled it to begin exporting LNG in May 2014.

Oil, which accounts for the bulk of Papua New Guinea's energy demand, moved from being an imported fuel in 2012 to being an export item in 2013 as well, when 0.3 Mtoe was exported. These exports are estimated to continue until 2025.[5] The projected total depletion of the economy's oil reserves ends its export capability, turning it into a net importer of oil from that date onwards with the exception of an unknown amount of oil to be produced as a by-product of gas extraction. Oil imports steadily increase from 2.3 Mtoe in 2013 to about 5.8 Mtoe in 2040. Oil remains the economy's dominant fuel, forming the largest share of the energy mix in all the sectors. Even now, with Papua New Guinea still exporting oil, an unknown portion of its oil refinery's crude oil requirements are imported from an unspecified supplier (ICLG, 2015a). Its likely future suppliers are unknown.

Figure 13.6 • Papua New Guinea: Net energy imports and exports, 1990-2040



Sources: APERC analysis and EGEDA (2015).

Gas is projected to follow an opposite export trend. LNG exports began in 2014, amounting to 0.3 Mtoe. These exports peak in 2015 at 7 Mtoe and then fluctuate before dropping to 2.9 Mtoe in 2040. The first shipment of LNG was exported in May 2014 to Japan, which remains a major importer along with other APEC economies, notably China and Chinese Taipei. LNG exports could exceed the projected figure if the ongoing ExxonMobil-led joint venture is supplemented by the proposed IntelOil-Total LNG project (7.6 million tonnes [Mt] per year to 10.6 Mt/year) during the Outlook period (Platts, 2014). These exports enable the economy to move from being from second-to-last gas producer in the APEC region in 2013 to 14th-largest in 2015 and 13th-largest by 2040.

Power sector trends: Increasing gas share

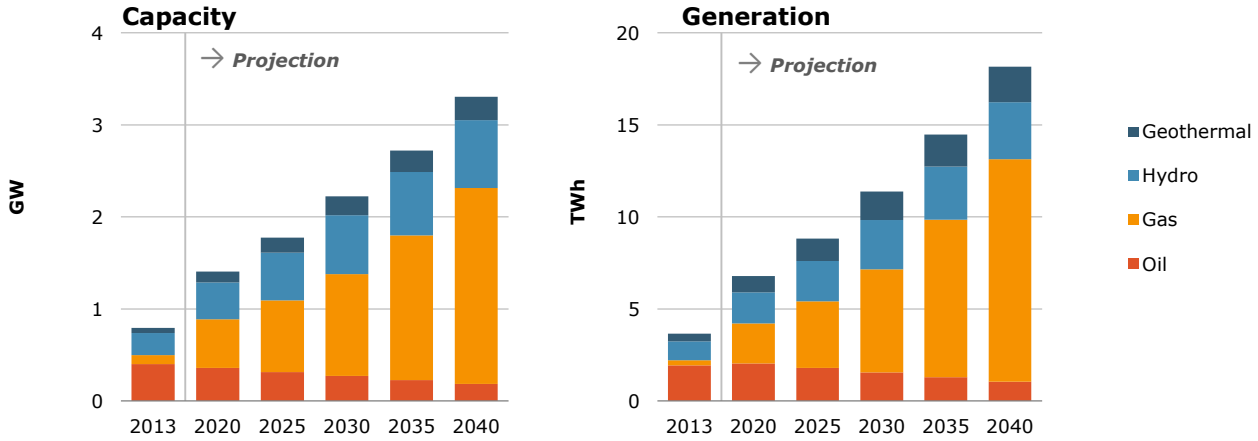
Papua New Guinea has an underdeveloped power sector. Only 15% of its people have access to electricity, the majority of whom live in urban areas (ADB, 2015b). Access to electricity in rural areas is about 3.7% (ADB, 2015a).

In 2010, Papua New Guinea had about 580 megawatts (MW) of installed generation capacity of which 230 MW was hydropower (40%), 217 MW diesel-generated (37%), 82 MW gas-generated (14%) and 53 MW geothermal (9%) (ADB, 2015b). The state-owned company PNG Power manages 300 MW; the remaining 280 MW is supplied by the self-generation systems of industrial facilities, including mining companies, and private-sector generators supplying the main grids or rural communities (ADB, 2015b).

[5] APERC assumes the economy's export of oil in excess of its demand.

The low reliability of on-grid supply is a major reason urban dwellers often resort to 'expensive high-maintenance, low-efficiency self-generation and back-up generation' (ADB, 2015b).

Figure 13.7 • Papua New Guinea: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and EGEDA (2015).

To meet the economy's growing demand for electricity, the government announced its Medium Term Development Plan (MTDP) 2011–2015 in October 2010, which focuses on increasing access to electricity for all households (DNPM, 2010b). The target for its ongoing plan is 1 970 MW of installed capacity by 2030 (ADB, 2015a).

Papua New Guinea's capacity of about 792 MW in 2013 is projected to rise to over 3 307 MW by 2040, an impressive increase (Figure 13.7). Although all the mentioned types of installed generators are projected to increase their capacity, oil's share of capacity is projected to decrease from about 51% of capacity in 2013 to 5.5% in 2040 and that of gas to increase from 12% to over 64% because of a large and growing increase in domestic gas production during the Outlook period. Renewables' share of capacity increases significantly by 2040.

Papua New Guinea's power generation is expected to increase five times from 3.6 terawatt-hours (TWh) in 2013 to slightly above 18 TWh in 2040 as all the contributing fuels increase their volumes. Oil's share of generation falls substantially from over 54% in 2013 to 5.7% in 2040 as a result of the availability of domestically produced gas. Gas substantially increases its share from 7.9% in 2013 to 67% in 2040 at the expense of renewables, as gas production grows. Renewables' share of generation increases substantially by 2040.

ALTERNATIVE SCENARIOS

Papua New Guinea has been assessed under the Improved Efficiency and the High Renewables Scenarios only; none of the cases in the Alternative Power Mix Scenario are applicable.[6] The Improved Efficiency Scenario has the largest impact, reducing energy use by 10% by 2040 and carbon dioxide (CO_2) emissions by 12% by 2040 compared with the BAU. Under the High Renewables Scenario CO_2 emissions reduce by 20% by 2040 compared with the BAU.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

In pursuit of APEC's region-wide goal of reducing energy intensity by 45% by 2035, Papua New Guinea has initiated policies to decrease energy consumption, improve energy efficiency and reduce energy-

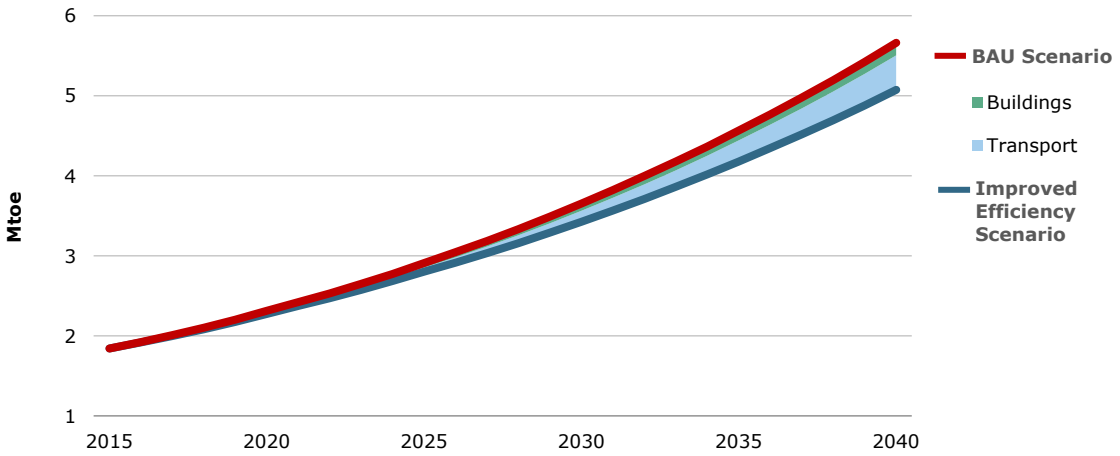
[6] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.

related CO_2 emissions.[7] The policies include the Papua New Guinea Vision 2050 (NSPT, 2010) consisting of seven pillars, of which three (natural resources, climate change and environmental sustainability) are related to the APEC energy intensity goal.

Under the BAU, Papua New Guinea reduces its energy intensity by 40% between 2005 and 2035 (Figure 13.8). It is an impressive reduction, reflecting a major improvement in energy intensity from 87 tonnes of oil equivalent (toe) per USD million to 52 toe per USD million. More efficient performance in all sectors, excluding buildings, is the reason for this drop in energy intensity.

Papua New Guinea's energy intensity reduction by the target date could improve further under the Improved Efficiency Scenario to reach 45% by 2035. The major gains in energy savings would be in transport (0.43 Mtoe) and the residential, commercial and agriculture sector (0.16 Mtoe).

Figure 13.8 • Papua New Guinea: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Note: An estimate for savings potential in industry was not calculated due to lack of data and hence the Improved Efficiency Scenario underestimates the potential savings from enhanced energy efficiency.
Source: APERC analysis.

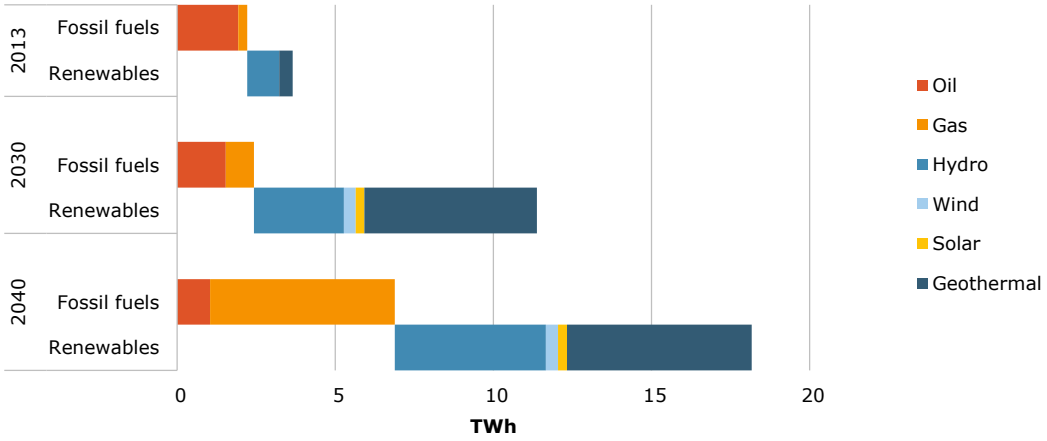
HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

APEC's doubling renewables goal envisages doubling the region's renewable energy across all sectors by 2030 from 2010 levels; the High Renewables Scenario only models increasing renewables in the transport sector and electricity generation.[8] Renewables account for close to half of Papua New Guinea's power generation in 2015 but are not used in the transport sector (ADB, 2015b). The economy produces a small amount of biofuels (bioethanol and biodiesel) but the bulk of these are exported to Australia (IRENA, 2013).

Papua New Guinea's renewable power generation in 2013 was 1.3 TWh (Figure 13.9). Hydro is the main contributor to renewables, followed by geothermal. Under the BAU, renewable generation is projected to increase threefold to 4.2 TWh by 2030 to surpass the APEC target. Hydro generation rises from 1 TWh to 2.7 TWh and geothermal generation almost quadruples, from 0.42 TWh to 1.6 TWh. By 2040, hydro grows to 3.1 TWh and geothermal to 1.9 TWh.

[7] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.
[8] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

Figure 13.9 • Papua New Guinea: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and EGEDA (2015).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

The total investment required to augment Papua New Guinea's energy infrastructure from 2015 to 2040 ranges from USD 15 billion (low-cost estimate) to USD 35 billion (high-cost estimate) (Table 13.3). Almost 30% of this is required for the upstream subsector, particularly for gas, in the low-cost estimate and more than 35% in the high-cost estimate. Power demands 34% of the total in the former and 26% in the latter to add 2.5 GW of generation capacity, and expand and refurbish transmission and distribution networks.

Table 13.3 • Papua New Guinea: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	0.7	1.0
	Gas	3.8	11
	Subtotal	4.5	12
Downstream	Refinery	1.3	6.7
	LNG import terminals	1.5	2.6
	Subtotal	2.8	9.3
Electricity	Gas	1.1	1.3
	Hydro	0.7	1.1
	Geothermal	0.4	0.5
	Transmission lines	2.7	5.0
	Distribution lines	0.3	1.0
	Subtotal	5.2	8.9
Energy transport	Oil	2.2	2.6
	Gas	0.6	1.5
	Subtotal	2.7	4.1
	Total	**15**	**35**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities.

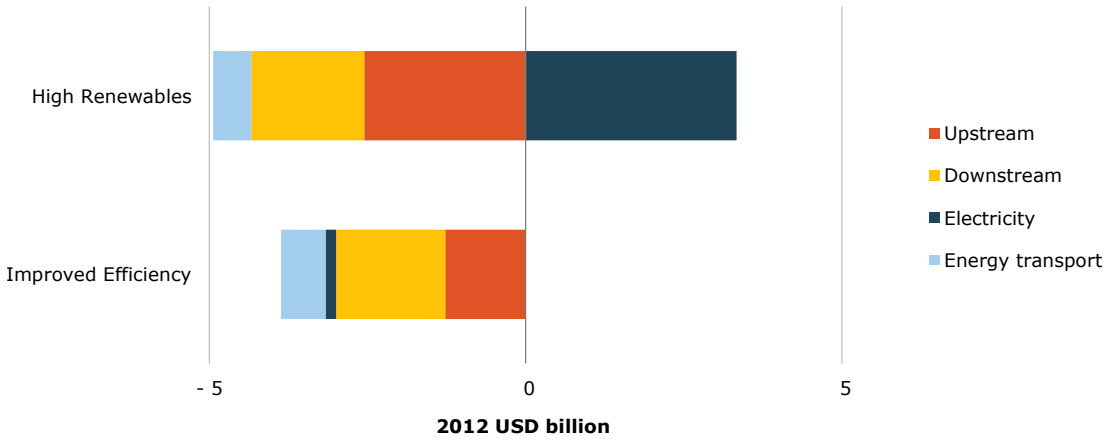
Source: APERC analysis.

Downstream investment requires 18% of the total in the low-cost estimate and over 27% in the high-cost estimate, for refinery and LNG export terminal capacity additions. The economy needs to add 67 000 bbl/d of refinery capacity and 1.5 Mt per year of LNG export terminal capacity. Domestic energy transport for oil and gas (from source to ports or facility) takes over 18% of the total in the low-cost estimate and more than 11% in the high-cost estimate.

The Improved Efficiency Scenario demonstrates total investment savings of 25% from the BAU levels, reaching USD 11 billion over the Outlook period (Figure 13.10). The downstream sector exhibits the largest contribution to the decrease, equal to 62% savings. Upstream shows a significant reduction of approximately 28% due to a cut in production requirements as a result of lower energy demand. Investment requirements in the energy transport sector also decline significantly, by 26% from the BAU levels. The power sector's investment requirements drop by 3.2%, as improvements in energy efficiency mean 309 MW of new generation capacity does not need to be built and little expansion is required for transmission and distribution systems.

Under the High Renewables Scenario, there would also be significant savings in energy investments with a reduction of almost 11% compared with the BAU, driven primarily by declines in upstream and downstream investment requirements as major investments in the LNG export terminals are not required. However, investment in the power sector escalates by 64% to enable renewable generation capacity to reach 2.3 GW compared with 0.99 GW in the BAU. Higher shares of variable renewable generation from solar and wind also lead to additional investment needs for energy storage. There is no need for additional investment in energy transport as the existing infrastructure meets the economy's needs.

Figure 13.10 ● Papua New Guinea: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

The Papua New Guinea government considers energy sustainability a major priority. This is reflected in its policies on addressing climate change and promoting renewables: one of the seven pillars of the Papua New Guinea Vision 2050 concerns climate change and environmental sustainability (NSPT, 2010). The government is also committed to decreasing GHG emissions by at least 50% before 2030 and becoming carbon neutral before 2050 to address global warming (UNFCCC, 2010).

Enhancing energy security: Gas plays a major role

Primary energy supply diversity in Papua New Guinea is projected to improve significantly under the BAU, with the Herfindahl-Hirschman Index (HHI) decreasing from HHI 0.62 in 2013 to HHI 0.38 by 2040, where a lower number indicates greater diversity (Table 13.4). This is the outcome of the economy moving away from heavy dependence on oil as gas's share of TPES increases substanitally and renewable energy's share shrinks. Of the alternative scenarios and cases, the High Renewables Scenario shows the best result in improving diversification, with an HHI of 0.35.

Papua New Guinea's level of primary energy self-sufficiency remains relatively unchanged (52%) from 2013 to 2040 under the BAU as the economy becomes dependent on imported oil for the bulk of demand while being self-sufficient in gas for most of the Outlook period. The High Renewables Scenario offers the highest level of primary energy supply self-sufficiency (58%) of the Alternative Scenarios.

In electricity fuel diversity, the economy has improved since 2000, when its HHI was 1 because of total dependence on oil. The index dropped to 0.39 in 2013, mainly because of growing gas production and expansion of renewables to almost half of the power mix. Electricity generation fuel input diversity deteriorates under the BAU from HHI 0.39 in 2013 to HHI 0.50 in 2040, with Papua New Guinea expected to rely heavily on domestically produced gas and a much smaller amount of oil for power generation. In 2040, 67% of power generated is from gas, a substantial increase from 7.9% in 2013, while oil provides only 5.7%, down from 53% in 2013. Renewables undergo a major decline, from over 38% in 2013 to slightly above 28% in 2040. However, High Renewables Scenario electricity generation input fuel have the same diversity level as the BAU.

Table 13.4 • Papua New Guinea: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040		
	Actual	BAU	Improved Efficiency	High Renewables
Primary energy supply diversity (HHI)	0.62	0.38	0.37	0.35
Primary energy supply self-sufficiency (%)	52	53	52	58
Oil self-sufficiency (%)	38	0	0	0
Gas self-sufficiency (%)	100	100	100	100
Electricity generation input fuel diversity (HHI)	0.39	0.50	0.47	0.50

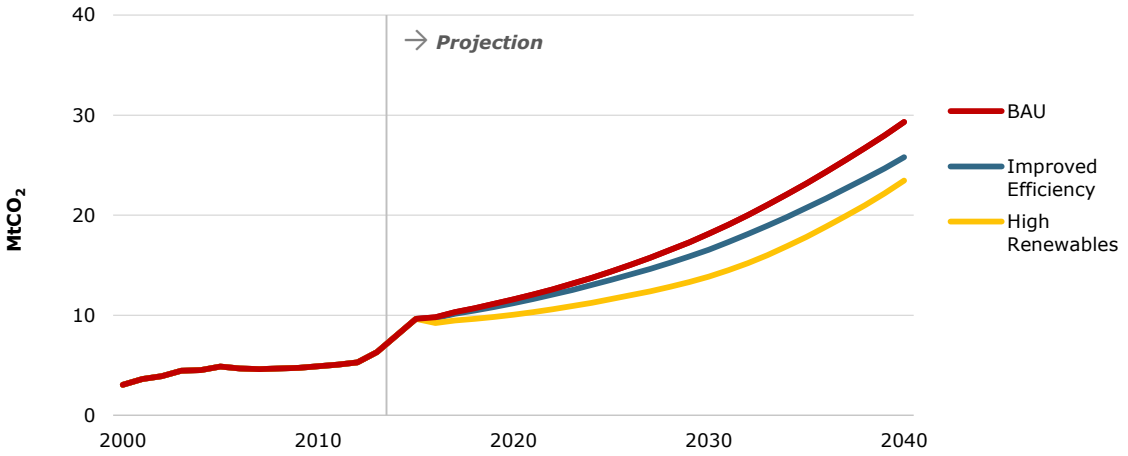
Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and EGEDA (2015).

Climate change impacts and risks: Ambitious targets

Papua New Guinea has aimed at decreasing its GHG emissions by 'at least 50% before 2030' and 'becoming carbon neutral before 2050', as part of its commitment to address global warming in its Copenhagen Accord response of 2 February 2010 (UNFCCC, 2010). Total energy-related CO_2 emissions under the BAU grow nearly five times from about 6.3 million tonnes of CO_2 ($MtCO_2$) in 2013 to approximately 29 $MtCO_2$ in 2040 (Figure 13.11).

Similar emissions reductions are shown for 2040 in the Improved Efficiency Scenario (26 $MtCO_2$ or 12% below the BAU) and the High Renewables Scenario (23 $MtCO_2$ or 20% below the BAU).

Figure 13.11 ● Papua New Guinea: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and EGEDA (2015).

RECOMMENDATIONS FOR POLICY ACTION

Papua New Guinea's energy demand increases over the Outlook period, with the share of gas increasing as oil's share decreases. The economy's total energy-related CO_2 emissions increase despite renewables maintaining a significant share of energy demand as a result of a substantial increase in consumption of domestically produced gas. This is a major challenge for the economy, which aims to decrease its GHG emissions by at least 50% before 2030 and become carbon neutral before 2050. Increasing renewables' share of energy demand and improving energy efficiency are two ways the economy could achieve its emissions reduction targets. Other measures that would be effective include developing the economy's public transport to reduce the current heavy reliance on private transport (cars and motorcycles), which is a major source of CO_2 emissions. Electricity-driven means of mass transport (e.g. buses and light rail) would be especially appropriate. Papua New Guinea's vast, but still mainly underdeveloped, hydro potential could be fully developed to supply environmentally clean power for transport. Run-of-river hydro should be considered as an inexpensive, non-polluting option for purposes such as addressing the economy's low rate of access to electricity in rural areas.

14. PERU

KEY FINDINGS

- **Final energy demand in Peru will increase by 185% under the BAU Scenario,** from 17 Mtoe in 2013 to 48 Mtoe in 2040, an AAGR of 4%.

- **Final energy intensity per GDP remains constant at 55 toe from 2005 to 2035 under the BAU.** Under the Improved Efficiency Scenario, estimated energy savings deliver a 19% reduction in energy intensity in 2035.

- **As gas production increases until 2040, Peru will become a net gas exporter, ranking fourth among APEC gas exporters; dependency on oil imports, however, will remain high.** This situation will challenge the economy to build markets for gas produced while also managing increased demand for imported oil (led by the transport sector).

- **Peru needs to invest in expanding its gas infrastructure, as new gas discoveries are expected in the future.** Infrastructure investments are needed to expand residential connections and to support the conversion of energy use in transport from diesel to gas.

- **To reduce projected growth in energy-related CO_2 emissions, Peru should facilitate investment in energy efficiency.** The Improved Efficiency Scenario leads to the largest emissions reduction in 2040 (23% lower compared with the BAU), largely through the implementation of energy efficiency standards and other support policies.

ECONOMY AND ENERGY OVERVIEW

Peru has a land area of 1.3 million square kilometres (km^2) and is divided into 25 political departments (administrative regions). In 2013, Peru had a total population of nearly 31 million, an increase of 1.1% from 2012 (INEI, 2014). Peru has an urbanisation rate of 76% (INEI, 2011); the city of Lima, with 9 million people, accounts for nearly one-third of the total population (INEI, 2013).

Between 1990 and 2014, gross domestic product (GDP) in Peru more than doubled as a result of increased foreign investments linked to the export of minerals, oil and gas, as well as strong growth in private consumption. During the global economic slowdown, Peru's annual GDP growth rate fell from 8.5% in 2010 to 2.4% in 2014. The economy is projected to nearly triple between 2013 and 2040, with population growth of 23% over the same period.

Peru is a market-oriented economy; in 2014, its key segments were services (48.7%), manufacturing and construction (21%), and mining (11.7%). The economy relies heavily on exports of raw materials; since 2010, it has been also an exporter of natural gas. Strong economic growth and an abundance of energy resources drove up energy demand in recent years, from 11 million tonnes of oil equivalent (Mtoe) in 2000 to 17 Mtoe in 2013. The annual average growth rate (AAGR) for gas has been particularly strong, at 30% between 2005 and 2013.

Access to energy has increased from 73% in 2000 to 91% in 2013, and is expected to reach 99% in 2025 (MEM, 2014). Lima is the first city with access to natural gas at the residential level, with 290 000 residential customers in 2015.

Table 14.1 • Peru: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	111	162	281	336	452	670	944
Population (million)	22	26	29	31	32	35	38
GDP per capita (2012 USD PPP)	5 103	6 267	9 583	10 985	13 945	18 864	25 072
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	10	12	19	22	33	48	60
TPES per capita (toe)	0.4	0.5	0.7	0.7	1.0	1.4	1.6
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	9	11	15	17	27	39	48
Final energy intensity per GDP (toe per 2012 USD million PPP)	77	65	54	50	59	58	50
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	19	26	41	46	76	114	143
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	69	73	85	91	97	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

ENERGY RESOURCES

Peru's proven gas reserves were 0.43 trillion cubic metres (tcm) in 2014, which is expected to increase to 0.8 tcm by 2025, based on information from the Ministry of Energy and Mines (MEM) (MEM, 2015). The Camisea gas project is the largest energy project in Peru, with a development cost of USD 2.7 billion since commencing operation in 2004. The project is located 500 kilometres (km) from Lima, in the region

of Cusco, and had proven reserves of 0.4 tcm in 2015. The pipeline has a length of 560 km and passes through the Andes from Las Malvinas plant (Cusco) to the liquefaction port in Pisco (130 000 barrels per day [bbl/d]). A second pipeline connects Las Malvinas plant to Ica and Lima (715 km) and is used to distribute gas to residential and industrial consumers (655 million cubic feet per day). A third pipeline, with a transport capacity of 1 500 million cubic feet per day, is under construction from Camisea to the regions of Arequipa and Moquegua in the south of Peru.

Table 14.2 ● Peru: Energy reserves and production, 2014[1]

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Oil (billion bbl)[a]	1.6	40	0.10	38th	10th
Gas (tcm)[a]	0.43	33	0.23	32nd	9th
Uranium (kt U)[b]	1.4	N/A	0.04	32nd	9th

Notes: [a]Total proven coal/oil/gas reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions. [b]Uranium reserves are 'reasonably assured resources'; reference year for uranium reserves and production is 2013.
Sources: For oil, coal and gas, BP (2015); for uranium, NEA (2014).

Oil reserves in Peru are 1.6 billion barrels, which is insufficient to keep pace with future demand. Additionally, this oil is largely unsuitable for refining in Peru, making the economy a net importer of oil. If 2014 production levels were sustained, proven oil reserves would be exhausted in 31 years (MEM, 2015). Proven reserves have been declining as a result of lower exploration investments and the evolution of global oil prices.

ENERGY POLICY CONTEXT

Peru needs to further develop energy resources to support its future economic growth. It also needs to build energy-related infrastructure to help access and develop resources. In 2014, the Peruvian government released the National Energy Plan 2014-2025 (MEM, 2014), which details the economy's energy policy and objectives. The plan sets out the aim of a reliable, continuous and sufficient energy system in Peru that can support sustainable development, in part by promoting investments in infrastructure (transport, refinery and production) and exploration.

Peru, which is a net importer, is looking to reduce its dependence on oil imports for two reasons. First, the economy's scarce oil resources and domestic production are insufficient to meet demand. Second, 85% of domestic crude oil production is of extra-heavy quality that several of Peru's domestic refineries are unable to process, and thus it is exported. In 2013, local oil production supplied just 40% of domestic demand. The government has begun a total overhaul of the state-owned refinery located in Talara (in northern Peru), with the aim of meeting local requirements through local oil production. Peru is promoting the exploration of new oil resources in the north and east; the government is reducing the time required to obtain exploration permits and facilitating communication with local communities to help reduce protests against exploration and production of extractive activities. According to government plans, oil production will increase to 153 000 bbl/d in 2025 (compared with 72 000 bbl/d in 2014).

Seeking to become an energy hub in the South American region, Peru is encouraging energy integration projects with Ecuador, Colombia and Chile (electricity), Brazil (hydro), and Bolivia (gas). Peru has electricity interconnection projects with Ecuador through two transmission lines (500 kilovolts [kV] and 220 kV). Agreements with Bolivia will support transportation of its gas to the liquefied natural gas (LNG) terminal in Peru, expected to begin operations by 2018. In the electricity sector, Peru and Bolivia are carrying out studies to assess the potential to interconnect their own power systems in order to jointly supply electricity to Chile. Finally, Peru and Brazil have a cooperation agreement to develop up to

[1] The BP Statistical Review of World Energy 2015 is used for energy producing economies as a standardised source of energy reserves and production for comparative purposes; The Nuclear Energy Agency is used for uranium producing economies.

6 000 megawatts (MW) of hydropower generation in Peruvian territory, which would be transmitted to Brazilian territory (MEM, 2010).

BUSINESS-AS-USUAL SCENARIO

This section examines Peru's energy demand and supply under a Business-as-Usual (BAU) Scenario and is based on key assumptions and existing policies that are expected to apply over the Outlook period (Table 14.3).

Table 14.3 • Peru: Key assumptions and policy drivers under the BAU Scenario

Buildings	• Use of the assumptions in the Reference Plan on Energy Efficiency, issued by the MEM in 2008.
Industry	• Use of the assumptions in the Reference Plan on Energy Efficiency, issued by the MEM in 2008.
Transport	• Limited deployment of hybrid cars, compressed natural gas (CNG) and electric vehicles. • Biofuel blends maintained at current levels of 5% for bioethanol blend and 2% for biodiesel blend. • No vehicle fuel efficiency standards.
Energy supply mix	• Major gas finds identified according to the National Energy Plan 2014-2025.
Power mix	• Least-cost options for power generation. • Committed renewable projects and historical renewable capacity trends considered. • No policy to develop nuclear.
Renewables[2]	• No target for renewables in total generation capacity is considered.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

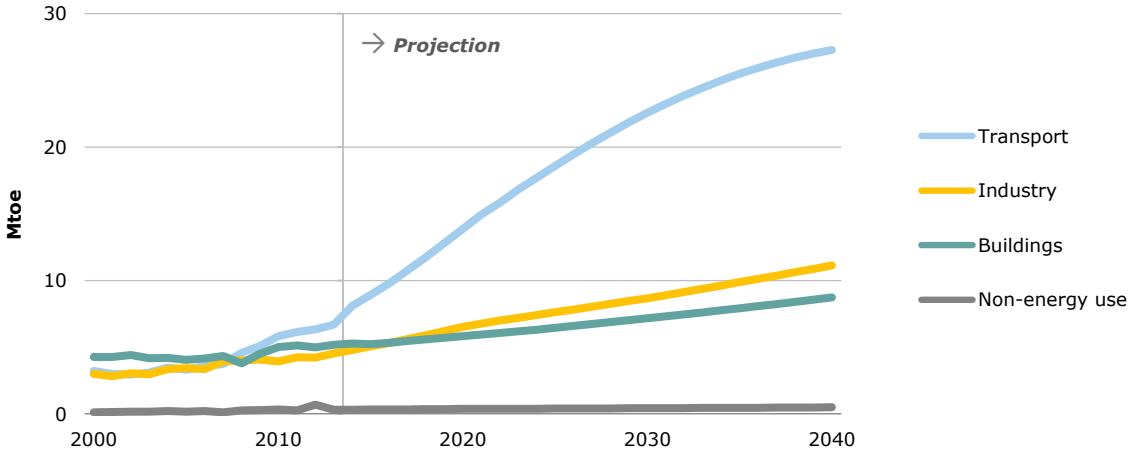
RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Energy demand in Peru under the BAU Scenario shows robust growth over the Outlook period, rising from 17 Mtoe in 2013 to 48 Mtoe in 2040 (185% increase), equivalent to an AAGR of 4%. In 2013, domestic transport consumed 40% of total final energy, followed by residential and commercial buildings (31%) and industry (27%), with non-energy use accounting for the remainder. Despite lower economic growth rates recently, domestic transport is expected to experience an AAGR of 5.3%; lower growth is seen for industry (3.4%) and buildings (2%). By 2040, domestic transport's share of final energy demand will grow to 57%, with corresponding declines in shares for industry (23%) and buildings (18%).

The transport energy demand growth reflects rapid development within Peru's cities and across the economy more broadly. Increasing purchasing power is driving new vehicle purchases, especially in coastal cities and major cities in the Andes region. Additionally, Peru's economy centres on Lima, which generates nearly 60% of the GDP and over 50% of manufacturing activity. Given the low penetration of rail transport, there is high demand for road transport to move goods to outlying areas.

[2] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

Figure 14.1 • Peru: Final energy demand by sector, 2000-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

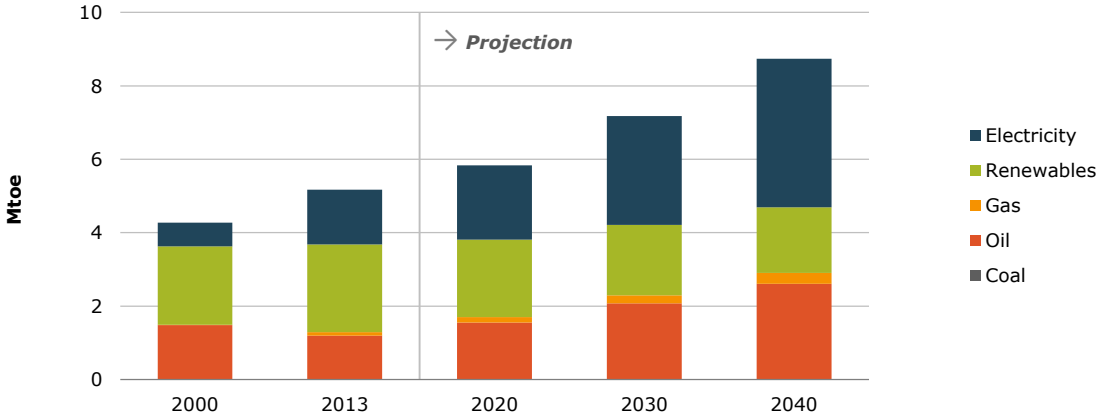
Buildings energy use: Sustained demand growth projected to 2040

Under the BAU Scenario, energy consumption in buildings in Peru will increase from 5.2 Mtoe in 2013 to 8.7 Mtoe in 2040, an increase of 69% with an AAGR of 2%. Oil consumption, which accounted for 23% in 2013, increases to 30% by 2040, while demand for renewables drops by half, from 46% in 2013 to 21% in 2040. This reduced share of renewables reflects the expected substitution effect between oil and gas against the use of renewables. In 2003 about 30% of households in Peru used firewood (renewable biomass) as their only source of energy for cooking and heating; by 2013, this had dropped sharply to only 14% while the share of households using liquefied petroleum gas (LPG) and firewood in combination rose from 14% to 33%. Over the Outlook period, the renewables share in buildings energy demand decreases 25%, from 2.4 Mtoe in 2013 to 1.8 Mtoe in 2040.

Electricity demand in buildings increases by 172% between 2013 and 2040 under the BAU, equivalent to an AAGR of 3.8%. The increases in the electrification coefficient and in urbanisation rates are the result of internal migration from rural areas to the main cities and of the greater purchasing power of the population. The migration process involves an important change in the type of energy used for cooking and heating. According to official statistics (INEI, 2013), only 5% of households in rural areas use LPG while 45% use firewood as a main energy source. In urban areas, by contrast, 50% of households use LPG and only 4% use firewood. The increase in purchasing power that comes with urban living is expected to increase demand for appliances (including refrigerators, washers, dryers, water heaters and air-conditioning [AC] equipment), which shows an AAGR of 3% between 2013 and 2030 (MEM, 2015). The largest increase will be in demand for AC equipment, with an AAGR of 17% until 2030, mainly concentrated in the cities of Lima, Arequipa, Ica, Trujillo and Piura, which have higher income levels. The combination of migration and higher purchasing power have prompted rapid growth in construction, and therefore a steady rise in residential energy demand—a trend that is expected to continue over the Outlook period.

Under the BAU Scenario, gas consumption in the buildings sector nearly triples from 0.1 Mtoe to 0.29 Mtoe between 2013 and 2040. This growth comes mainly from higher residential demand as residential connections increase in Lima and in the southern region (with the new pipeline expansion from Camisea to Moquegua and Arequipa).

Figure 14.2 ● Peru: Buildings sector final energy demand, 2000-40



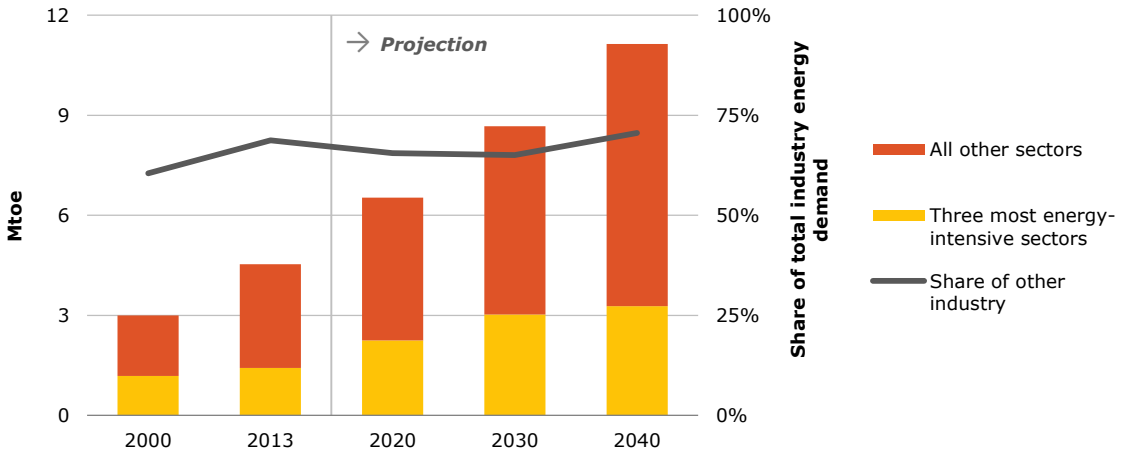
Sources: APERC analysis and IEA (2015a).

Industry energy use: Demand will evolve with mining and manufacturing

Peru's industry energy demand under the BAU shows an AAGR of 3.4% over the Outlook period, from 4.5 Mtoe in 2013 to 11 Mtoe in 2040, driven largely by the development of mining and manufacturing industries, which represent around 70% of industrial GDP (BCRP, 2014). In Peru, the potential portfolio of mining projects is USD 61 billion (MEM, 2015), as the economy is the world's third-largest producer of silver, zinc, copper and tin, and ranks fourth in lead and sixth in gold (USGS, 2014). The manufacturing sector, mainly related to construction materials, shows increasing demand reflecting a series of capacity expansion plans. These economic sectors are considered under the 'All other' category.

The MEM's 2009 plan, the Benchmark Plan for Efficient Use of Energy from 2009 to 2018, outlines various projects that are expected to be implemented in industry through 2018 with potential energy savings of 15% compared with a scenario without energy efficiency measures. This plan calls for the replacement of lighting systems, boilers and engines, as well as implementation of a labelling scheme for computers. To date, the plan's implementation has been delayed by a shortage of audit firms and a lack of incentives.

Figure 14.3 ● Peru: Industry sector final energy demand, 2000-40



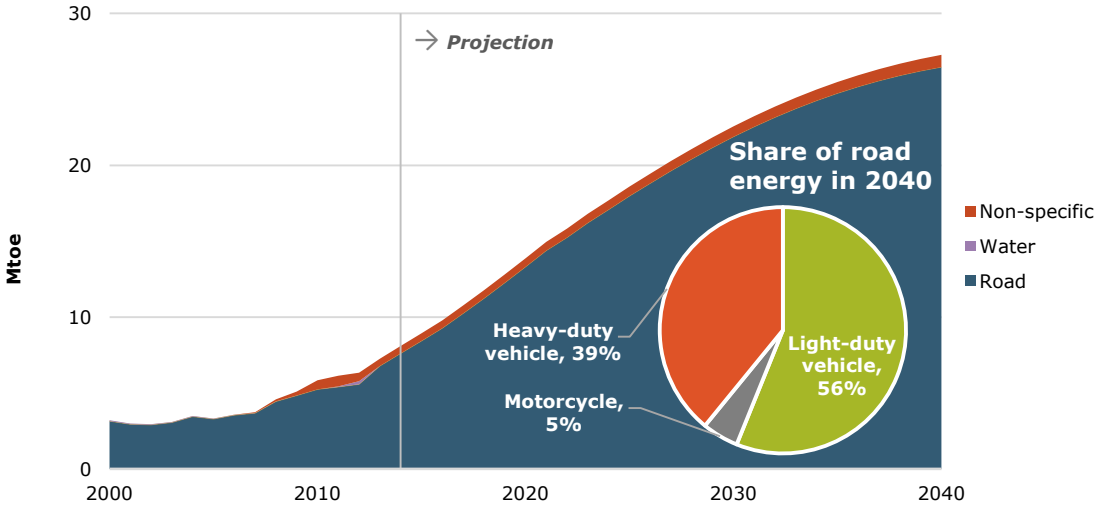
Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.
Sources: APERC analysis and IEA (2015a).

Transport energy use: Demand set to triple

In 2013, Peru's vehicle stocks for light-duty vehicles (LDVs) was largely met by gasoline (around 62%), diesel (25%) and CNG (7.3%). Under the BAU Scenario by 2040, these shares all decline—gasoline to 53%, diesel to 18%, and CNG to 7%—while hybrids and electric vehicles enter the market and reach a

share of 17%. Almost 100% of heavy-duty vehicles (HDVs) use diesel between 2013 and 2040. Over the Outlook period, an increase in vehicle stock pushes up oil demand—by 290% for both LDVs and HDVs—further increasing Peru's dependence on imports. The increased dependency is projected despite efforts to increase capacity of the Talara refinery in northern Peru to support refining of diesel and gasoline from domestically produced heavy oil. Domestic transport energy demand increases fourfold over the Outlook period, reaching 27 Mtoe by 2040.

Figure 14.4 ● Peru: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

The energy demand structure shows road transport is the most important sub-sector, as increases in public and freight transportation are both closely linked to the business cycle. Together, LDVs, HDVs and motorcycles accounted for 93% of domestic transport consumption in 2013, which will increase to 97% in 2040 under the BAU. Over the Outlook period, the rising number of vehicles will increase traffic congestion; however, the relatively low saturation level at present can accommodate the expected increase in the number of LDVs and HDVs until 2040.

Increased mining production, and a corresponding increase in transport of minerals on roads, generate a double effect on fuel consumption. The first impact is the greater number of vehicles on the Peruvian Central Highway (the main road in the mining region, which also connects Lima with the central Andes). The expected increase in congestion will also lead to more fuel consumption per vehicle on each trip.

The Peruvian government aims to expand the use of natural gas, as LNG and CNG, in transport (MEM, 2014). The Outlook, however, shows this aim being undermined by a lack of incentives for the conversion of heavy transport vehicles and a lack of supply points on the main roads.

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: New role for natural gas, stable outlook for oil

Currently, oil represents 45% of TPES in Peru, followed by natural gas with 27%. By 2040, both shares will increase, with oil showing stronger growth to 52% (driven by increasing transport energy demand) while gas rises to 33% (driven by major increases in industrial and residential demand, and a marginal increase in transport).

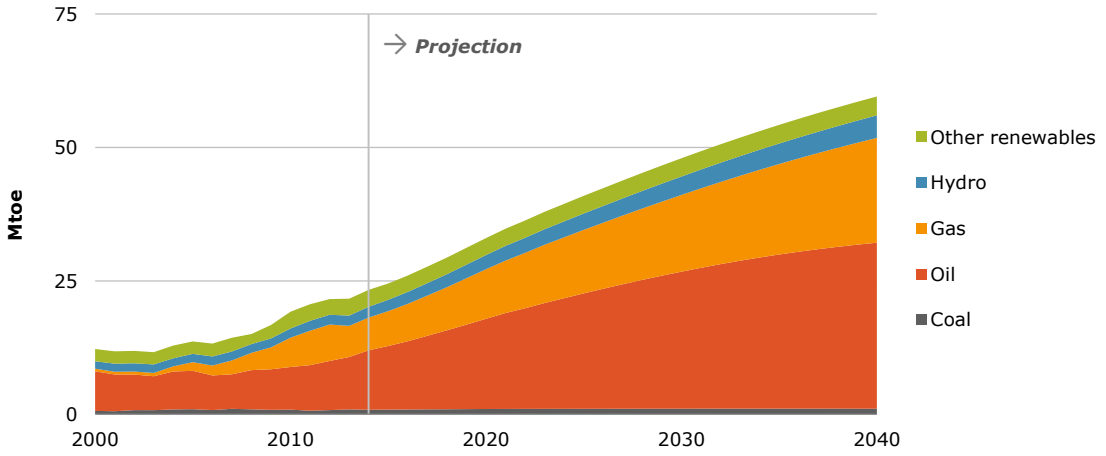
Peru became a gas producer in 2004. Production has increased significantly in recent years, a trend that will continue under the BAU with annual output rising from 12 Mtoe in 2013 to around 58 Mtoe by 2040, an AAGR of 6%. This volume will place Peru among the eight major gas producers in the APEC region.

The increase in gas production will redefine the current energy matrix, mainly in the industrial sector where gas replaces oil.

The pipeline from Camisea to Lima, along with future construction of a pipeline in southern Peru, will increase natural gas use in residential (replacing LPG) and industry (replacing oil). The process of substituting gas for oil will not, however, roll out at the same pace in transport, where it is stalled by few incentives and the lack of a distribution infrastructure.

As more emphasis is given to developing gas facilities, the share of renewables in Peru's TPES is expected to decrease from 24% in 2013 to 13% in 2040, even though the volume of renewables will rise from 5.1 Mtoe to 7.8 Mtoe, mainly due to a 2.3 Mtoe increase in hydro.

Figure 14.5 • Peru: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

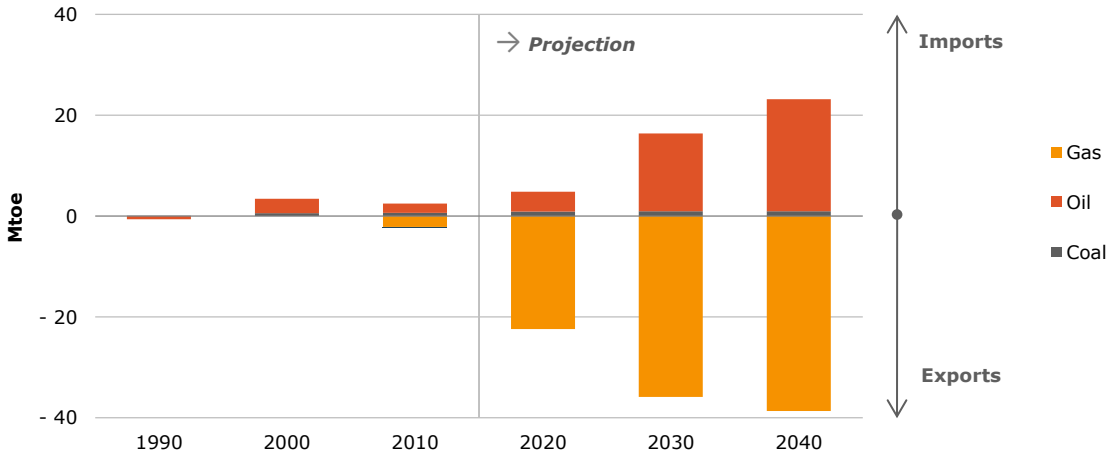
Energy trade: Oil imports versus gas exports in the long run

Peru's energy trade presents a mixed picture; the economy relies heavily on oil imports while exporting large volumes of natural gas. In 2014, natural gas exports were valued at around USD 0.7 billion, representing 60% of Peru's total hydrocarbon exports. In the same year, oil imports cost around USD 5.7 billion.

Due to high levels of natural gas production but relatively low domestic demand, Peru has been a net exporter since 2010. Until 2014, gas exports were destined mainly to Spain, Mexico, Japan and Korea. The production increase projected over the Outlook period is expected to boost exports up to 58 Mtoe in 2040 (from 12 Mtoe in 2013), creating the need to seek markets outside the APEC region and build alliances for energy cooperation among South American economies and countries. Development of the new southern pipeline from the Camisea gas field will increase power generation in southern Peru. This will facilitate the potential energy integration process with neighbouring economies and countries, which have much higher generation costs than Peru. Chile, for example, has an electricity generation cost of around USD 41 per kilowatt-hour (kWh) while in Peru it is around USD 19/KWh (BSantander, 2014).

On the oil side, Peru is a net importer, with supplies in 2014 coming from Ecuador (50%), Trinidad and Tobago (23%), Nigeria (19%), Colombia (5%) and others (3%). The BAU projections show Peru's oil imports increasing from 2.3 Mtoe in 2013 to 22 Mtoe in 2040. This aligns with government estimates that, despite the overhaul of Talara refinery to boost local refined oil production, growth in the transport sector will strongly push up oil demand over the Outlook period.

Figure 14.6 • Peru: Net energy imports and exports, 1990-2040



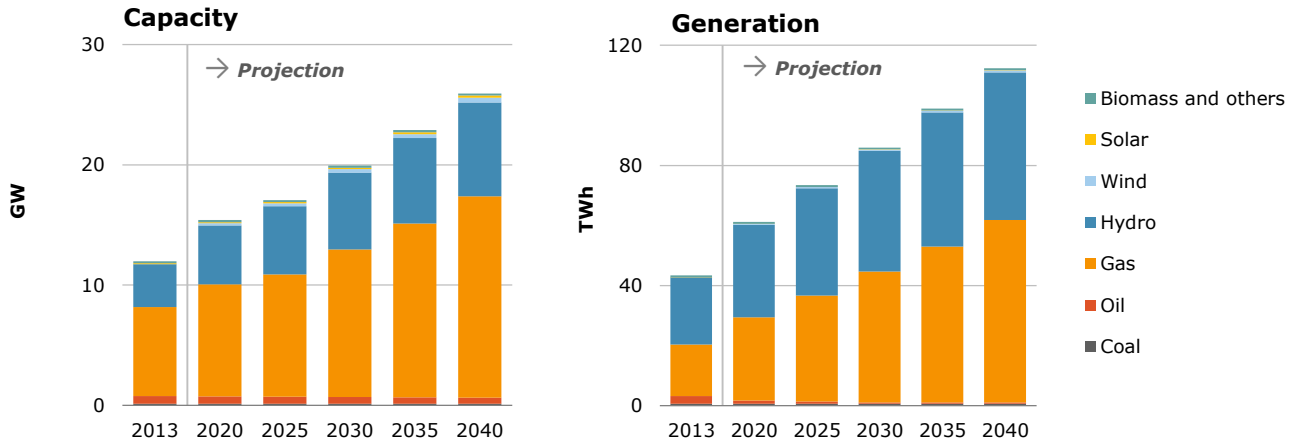
Sources: APERC analysis and IEA (2015a).

Power sector trends: Natural gas and hydro to provide majority share

Peru has two main electrical systems, the North-Central System (which includes Lima) and the Southern System. These systems are interconnected and form the National Integrated Electrical System (SEIN), which is fed by hydro and thermal power plants. Since 2012, the SEIN has also integrated solar, wind and biomass sources. In 2013, the SEIN accounted for 85% of the installed power in Peru and 93% of energy generation (MEM, 2014).

The National Energy Policy has a stated goal of developing the natural gas industry and expanding its use; it encourages projects for power generation, giving priority to the use of renewable energies (hydro) and natural gas. The next major energy project, a 2 000 MW generation plant using natural gas simple-cycle turbines and located in the southern region, will boost generation in the Southern System by around 150%. The project, representing an estimated investment of USD 3.6 billion, is linked to the extension of the pipeline from Camisea gas field in Cusco to Moquegua and Arequipa. This expansion is a necessary step to integrate Peru with other power markets in the region.

Figure 14.7 • Peru: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

The importance of natural gas in Peru's energy future is reflected in the strong focus on expanding both capacity and electricity generation. Natural gas accounted for 62% of total capacity and 40% of total generation in 2013; these shares will rise to 65% (capacity) and 54% (generation) by 2040. Over the Outlook period, oil-based generation capacity remains constant even though generation gradually declines as gas replaces oil in the power mix. Hydro capacity remains constant, around 30% between

2013 and 2040. Generation capacity of other renewables expands from 256 MW to 748 MW, an increase of 192% as solar generation capacity grows from 80 MW in 2013 to 178 MW in 2040. Despite this, other renewables represent only 2.9% of total generation capacity by 2040 (from 2.1% in 2013).

ALTERNATIVE SCENARIOS

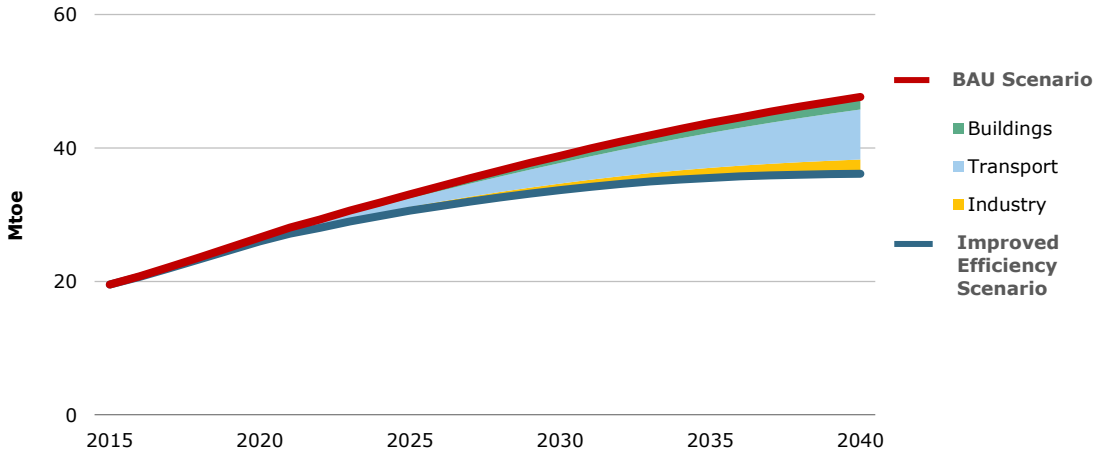
Of the three Alternative Scenarios developed in this edition of the Outlook, only the Improved Efficiency and High Renewables Scenarios apply to Peru.[3] The Alternative Power Mix Scenario was not deemed valid to Peru's electricity generation profile, as the economy does not have nuclear or coal-based power plants.

The Improved Efficiency Scenario offers the greatest reduction in final energy demand by 2040, decreasing by 24% (12 Mtoe) compared with the BAU, and the largest energy-related CO_2 emissions reductions at 30% or 43 million tonnes of CO_2 ($MtCO_2$) compared with the BAU in 2040. The High Renewables Scenario leads to only a 7.8% reduction in emissions.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

This scenario tracks APEC's progress towards the APEC energy intensity goal.[4] Energy demand in Peru under the Improved Efficiency Scenario is 24% (12 Mtoe) lower than in the BAU Scenario by the end of the Outlook period. Domestic transport offers the largest potential for savings, with energy demand declining by 27%, dropping from 28 Mtoe in BAU in 2040 to 20 Mtoe in the Improved Efficiency Scenario. Low levels of vehicle saturation, rapid growth in large urban areas such as Lima (9 million inhabitants), Arequipa, Trujillo and Chiclayo (almost 1 million each), and rising incomes are pushing the demand for personal transport. The vehicle stock in Peru under the Improved Efficiency Scenario estimates only 11 million vehicles by 2040, whereas the BAU estimates 13 million, and so the energy demand for domestic transport decreases.

Figure 14.8 ● Peru: Potential energy savings in the Improved Efficiency Scenario



Source: APERC analysis.

Under the Improved Efficiency Scenario, energy savings enable Peru to reduce final energy intensity per GDP by 19% by 2035 (from the 2005 levels), a sharp contrast from the energy intensity estimated under the BAU Scenario. Energy intensity is 45 toe/USD million GDP in 2035 in the Improved Efficiency Scenario, and decreases to 38 toe/USD million GDP in 2040, yielding a contribution to the APEC goal.

In 2010, the General Direction of Energy Efficiency (GDEE) was created within the MEM, with a mandate to create the legal framework for energy efficiency policy that will cover efficiency labelling for appliances

[3] For more details about the Alternative Scenario assumptions, see Chapter 5 to 7 in Volume I.
[4] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

and energy efficiency standards. Under the National Energy Plan (MEM, 2015), Peru expects to regulate energy efficiency labelling for water heaters, electric appliances and lighting, with an aim of reducing energy demand by 15% by 2025.

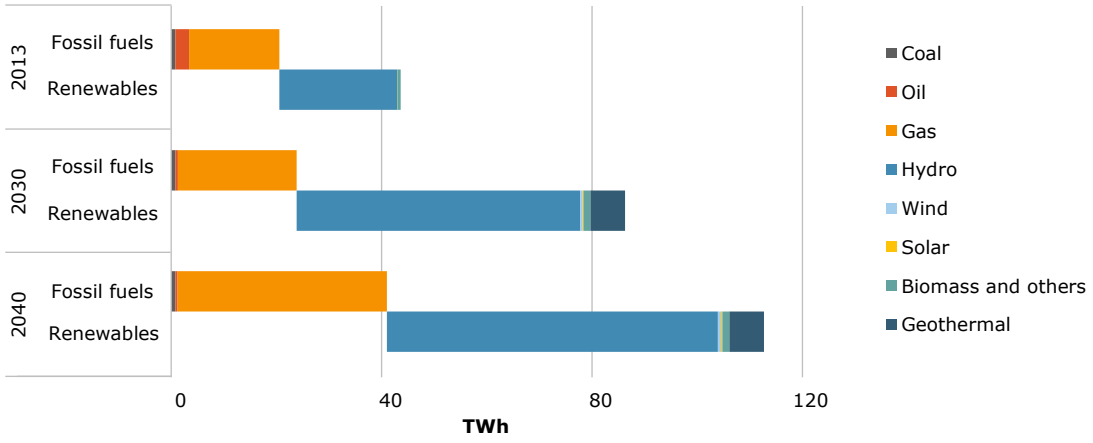
Energy savings in the buildings sector under the Improved Efficiency Scenario are projected to improve by 21% by 2040 compared with the BAU, with savings in water heating, lighting and AC. These numbers align with government demand projections to 2030, which anticipate an AAGR of 4% for refrigerators, 5% for water heaters, 14% for dryers and 10% for AC in the commercial sector (MEM, 2015). Industry shows a 19% reduction in energy consumption in the Improved Efficiency Scenario, driven by efficiency improvements in the mining, construction and manufacturing sub-sectors.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

The High Renewables Scenario models the APEC doubling renewables goal, though focusing on the power and the transport sectors only.[5] Under this scenario, the share of renewables in power generation rises to 64% by 2040 (compared with 45% in the BAU), with hydro rising almost threefold from 2013 to account for 56% of total generation. At the same time, the share of other renewables rises significantly from 1.6% in 2013 to 7.8% by 2040 (a sixfold increase over the BAU), with geothermal representing 75% of other renewables.

Peru does not, however, have a target for renewable electricity, largely because of cost implications: estimates suggest that a goal of 20% renewable energy could push up the average cost of generation by 20% (MEM, 2015). Despite not having a target, the government has used auctions to successfully boost other renewables capacity to 255 MW in 2013. While the current energy policy framework projects that other renewables will not exceed 5% of TPES by 2025, the High Renewables Scenario indicates potential to reach 7.6% of total capacity.

Figure 14.9 ● Peru: Power sector under the High Renewables Scenario, 2013-40

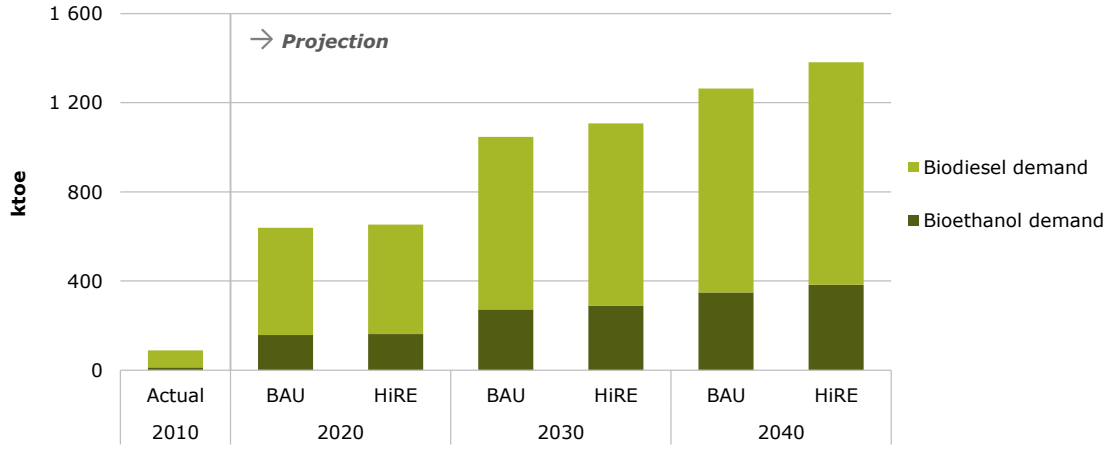


Sources: APERC analysis and IEA (2015a).

In the High Renewables Scenario, biofuels demand increases by 327% by 2040 compared with the 2013 level, higher than the 290% increase in the BAU. The BAU assumptions are based on the Biofuels Promotion Act, in which Peru establishes mandatory concentrations of 7.8% for gasoline and 5% for diesel (USDA, 2013). As Peru does not produce biofuels domestically, the higher demand in the High Renewables Scenario would force the economy to increase imports (that is become more dependent) compared with the BAU.

[5] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

Figure 14.10 ● Peru: Biofuels demand in the BAU and High Renewables Scenarios, 2010-40



Note: HiRE = High Renewables Scenario.
Sources: APERC analysis, MEM (2011) and IEA (2015a).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

To develop the energy sector under the BAU Scenario, Peru needs to invest in the range of USD 122 billion under the low-cost estimate to USD 342 billion under the high-cost estimate from 2015 to 2040. With the stated aim to increase production and exploration of oil and gas, upstream investments are projected at USD 57 billion to USD 126 billion, accounting for nearly 47% in the low-cost estimate and 38% in the high-cost estimate. Increased domestic demand and the government's goal to become an electricity exporter through regional integration will require that 17% of investments be directed to the electricity sector. The aim of boosting use of natural gas in southern Peru depends on the construction of the new pipeline from the Camisea field, which will require an investment of about USD 4.0 billion according to government estimates. The Outlook estimates that the investment related to gas distribution in the economy will be between USD 18 billion and USD 91 billion from 2015 to 2040 (this includes the new southern pipeline and the required investments to cover new industrial and residential demand until 2040).

The Improved Efficiency Scenario reduces the investment requirement by USD 39 billion compared with the BAU low-cost estimate, with USD 19 billion of potential reduction in upstream and downstream sectors, as lower demand leads to less production. Energy transport investment also decreases, by USD 11 billion, as gas demand for domestic transport and industry declines.

The High Renewables Scenario leads to a USD 17 billion investment savings compared with the BAU low-cost estimate, with the largest share (USD 14 billion) from energy transport and upstream (a reflection of lower fossil fuel demand). Under this scenario, the required investment for electricity will be USD 2.7 billion higher from the BAU, with investments in renewable sources accounting for 64% of total electricity generation investment. As stated above, Peru has a great potential to develop renewable sources, but is unlikely to do so given the high generation cost and lack of policy incentives.

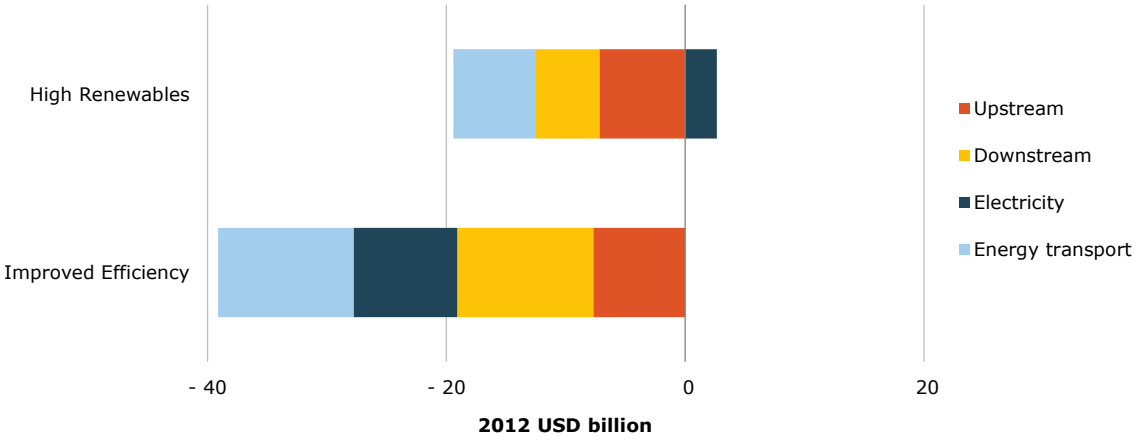
Table 14.4 • Peru: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	29	44
	Gas	28	83
	Coal	0.1	0.3
	Subtotal	57	126
Downstream	Refinery	9.3	42
	LNG export terminals	17	30
	Biofuels refinery	0.7	0.9
	Subtotal	27	73
Electricity	Gas	6.5	9.7
	Hydro	2.5	7.9
	Wind	0.6	1.3
	Solar	0.3	0.5
	Transmission lines	7.2	25
	Distribution lines	3.7	7.0
	Subtotal	21	51
Energy transport	Oil	0.2	0.3
	Gas	18	91
	Coal	0.02	0.07
	Subtotal	18	91
	Total	**122**	**342**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities.

Source: APERC analysis.

Figure 14.11 • Peru: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.

Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

In 2012, the Peru government published the 'Law to ensure energy security and to promote the development of the petrochemical industry' (OSINERGMIN, 2012), which aims to improve energy security by diversifying energy sources, reducing external dependence and boosting reliability of the energy supply chain. Peru has high energy self-sufficiency, based on domestic production of natural gas and the potential of hydro. Despite this, Peru is projected to become more dependent on oil imports as rapid

growth of transport pushes up demand. To address the challenge, the government is overhauling the Talara refinery's existing facilities so that heavy oil can be refined domestically. The project, with a cost of USD 3.5 billion, will increase refinery capacity from 65 000 bbl/d to 95 000 bbl/d. The government is also encouraging state-owned companies to become active in energy exploration and production projects.

Enhancing energy security: An aggregate high self-sufficiency

Peru is expected to experience moderate economic growth over the Outlook period, which affects energy demand. Peru's primary energy mix according to the Herfindahl-Hirschman Index (HHI) is expected to deteriorate from HHI 0.31 in 2013 to HHI 0.39 in 2040 under the BAU Scenario, where a lower number indicates greater diversity, due to the current reliance on oil and gas as the main energy sources. Under the High Renewables Scenario, the introduction of more renewables improves primary energy diversity compared with the BAU as renewables' share in the energy mix increases. Still, the biggest risk is associated with future dependence on imported oil as increasing transport activity sharply drives up oil consumption and imports.

Similarly, the diversity of fuels for electricity generation deteriorates under the BAU from HHI 0.37 in 2013 to HHI 0.54 in 2040, as most plants use gas and hydro. In the case of Peru, this is a low energy risk as the economy is a gas exporter and is rich in water resources. Projections made by the Committee for the Economic Operation of the National Interconnected System (COES, 2015) for the period 2015-18 state that the level of water reserves will be sufficient to meet hydro energy requirements even in the eventuality of a dry year. Both the Improved Efficiency and the High Renewables Scenarios improve electricity generation input fuel diversity compared with the BAU at HHI 0.44 and HHI 0.33 respectively.

Table 14.5 • Peru: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040		
	Actual	BAU	Improved Efficiency	High Renewables
Primary energy supply diversity (HHI)	0.31	0.39	0.39	0.34
Primary energy supply self-sufficiency (%)	73	67	72	68
Coal self-sufficiency (%)	19	11	13	11
Oil self-sufficiency (%)	49	39	51	39
Gas self-sufficiency (%)	100	100	100	100
Electricity generation input fuel diversity (HHI)	0.37	0.54	0.44	0.33

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

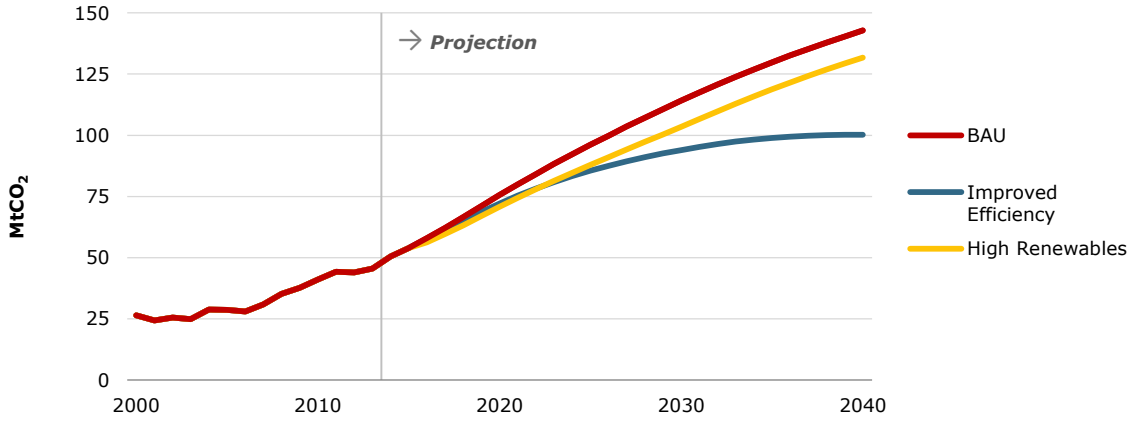
Climate change impacts and risks: Increased economic activity to push up emissions

Peru accounts for 0.11% of the world's greenhouse gas (GHG) emissions (CAIT, 2012). As stated in its Intended Nationally Determined Contribution (UNFCCC, 2015), Peru aims to reduce economy-wide GHG emissions in 30% by 2030 compared with 2010 levels. The absolute reduction is estimated at 90 $MtCO_2$, with 55% of this reduction being in the forestry sector, including land use, land use change and forestry (LULUCF). Under the BAU, Peruvian energy-related CO_2, emissions grows from 46 $MtCO_2$ in 2013 to 143 $MtCO_2$ by 2040, an AAGR of 4.3%. In the Improved Efficiency Scenario, energy-related CO_2 emissions still rise, but to only 100 $MtCO_2$, some 30% below the 2040 BAU level. In the High Renewables Scenario, energy-related CO_2 emissions reach 132 $MtCO_2$, down 7.8% compared with the BAU in 2040.

Sustained increase in economic activity, which began in 2000, will continue to drive up energy-related CO_2 emissions under the BAU, Improved Efficiency and High Renewables Scenarios. From a baseline of

1.6 tonnes of CO_2 (tCO_2) in 2013, per-capita emissions by 2040 increase to 4.1 tCO_2 in the BAU, 3.8 tCO_2 in High Renewables and 2.9 tCO_2 in the Improved Efficiency Scenario. This analysis highlights the importance of implementing energy efficiency measures in transport, residential buildings and industry. Increased use of hydro in electricity generation and of biofuels for transport facilitate energy-related CO_2 emissions reductions under the High Renewables Scenario, but the effect is overpowered by the expected increase in the number of LDVs and HDVs to 2040, causing energy-related CO_2 emissions to increase beyond the projection for the Improved Efficiency Scenario.

Figure 14.12 ● Peru: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).

Sources: APERC analysis and IEA (2015b).

RECOMMENDATIONS FOR POLICY ACTION

The Peruvian government needs to implement energy efficiency measures to reduce energy-related CO_2 emissions, which could be achieved by strengthening different programs outlined in the Energy Plan 2014-2025. The effectiveness of these programs will depend on government enforcement of new regulations and standards. Domestic transport has the highest potential to reduce energy consumption and energy-related CO_2 emissions but domestic transport demand is expected to grow sharply, thus stringent vehicle fuel economy standards are needed to curb the impacts of such growth.

The Outlook also highlights the potential for natural gas to replace the use of diesel and gasoline as an option to lower emissions in transport. This is particularly attractive for the freight sector, which uses diesel exclusively. To support the transition to lower-carbon transport, it will be vital to deploy distribution channels along main routes in Peru both along the coast (where flat terrain makes it easy to establish the distribution chain) and in the Andes (where the distance from the coast and difficult terrain present additional challenges) (PMEL, 2015).

With projected volumes rising quickly, Peru is set to become an important natural gas producer in the APEC region. The government would do well to diversify its energy export markets, both by encouraging energy integration in South America and seeking to enter other markets outside the APEC region. It should also expand its natural gas grid to the main cities, thereby encouraging use of natural gas in the residential sector.

Finally, the government should facilitate energy access to geographically remote or economically disadvantaged regions, as it is not currently possible for the private sector to supply energy to such areas. Effort should be made to tailor the energy access solutions to local characteristics and requirements, which would help to reduce the inefficient and unsustainable use of traditional biomass.

15. THE PHILIPPINES

KEY FINDINGS

- **The BAU Scenario poses energy security and environmental challenges for the Philippines, as the economy is highly dependent on coal for power generation.** Almost 69% of total power generation comes from coal in 2040, so policies requiring more advanced coal technology and quality improvements for domestic coal are indispensable.

- **Under the Improved Efficiency Scenario, energy savings of 14 Mtoe lead to a larger reduction in final energy intensity** than in the BAU in 2035, at 63% lower than the 2005 level.

- **While renewables' share in the generation mix decreases from 26% in 2013 to 16% in 2030 under the BAU, under the High Renewables Scenario, renewables' share increases to 38% by 2030.** This scenario leads to lower power sector CO_2 emissions than the BAU, and its power sector CO_2 emissions are higher than the Improved Efficiency Scenario, the High Gas 100% and the Cleaner Coal Cases.

- **Among the three alternative scenarios, the Improved Efficiency Scenario generates the lowest energy-related CO_2 emissions at 180 $MtCO_2$,** 31% lower than the BAU in 2040.

- **Total energy-related investments from 2015 to 2040 under the BAU are around USD 89 billion to USD 208 billion,** requiring an investor-friendly environment and policies to boost private sector confidence to attract sufficient capital.

ECONOMY AND ENERGY OVERVIEW

In 2013, the Philippines' gross domestic product (GDP) grew by 7.2% despite a string of natural disasters and the global economic slowdown (Navarro and Llanto, 2014) (Table 15.1). The Philippines' economic outlook is positive: the ratings agencies Standard and Poors, Fitch and Moody's have upgraded their credit ratings to 'stable outlook' (high quality with very low/minimal credit risks) (Official Gazette, 2014). The economy's ranking by the World Economic Forum has improved from 65th out of 144 economies and countries in 2012 to 59th out of 148 economies and countries in 2013 (Navarro and Llanto, 2014).

Table 15.1 ● The Philippines: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	179	239	377	446	663	1 231	2 143
Population (million)	62	78	93	98	110	126	142
GDP per capita (2012 USD PPP)	2 897	3 065	4 056	4 571	6 039	9 741	15 128
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	29	40	40	45	57	79	102
TPES per capita (toe)	0.5	0.5	0.4	0.5	0.5	0.6	0.7
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	20	24	24	26	34	48	64
Final energy intensity per GDP (toe per 2012 USD million PPP)	109	100	63	58	51	39	30
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	38	68	77	90	125	193	261
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%) (Household)	65	71	72	79	92	95	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015), DOE-Philippines (2015a) for historical data; APERC analysis for projections.

Over the Outlook period, the Philippines' economy is projected to continue rising at an average annual growth rate (AAGR) of 6%, with the service and industrial sectors contributing the largest shares to GDP. The service sector provided half of the economy's GDP in 2013, and nearly 60% of the growth posted (ADB, 2015). Growth in industry is expected to continue. The government established a Manufacturing Resurgence Program to revive the manufacturing sector under the Industry Development Program (IDP). The aim is to make economic growth more inclusive, generating more employment while helping the economy to benefit from the regional production network (DTI-BOI, 2014). Despite their large contribution to the economy, these sectors only consumed about 40% of energy demand in 2013. The economy's GDP per capita also increases by 4.5% during the Outlook period, reaching USD 15 128 per person in 2040.

In contrast to economic growth, population growth will slow to an AAGR of 1.4%, compared with 2.1% from 1990 to 2010, with the population reaching 142 million in 2040. In 2013, the population stood at 98 million, an increase of 1.7% from the previous year (World Bank, 2015).

ENERGY RESOURCES

The Philippines has modest energy resources, with proven reserves of around 76 million barrels (bbl) of oil (including condensate), 24 billion cubic metres (bcm) of natural gas, and 440 million tonnes (Mt) of coal (DOE-ERDB, 2015b). According to the Philippines Department of Energy, renewable energy sources (geothermal and hydro) made up 26% of total generation in 2013 and 32% of generation capacity in 2013 (DOE, 2014a). The government has a longstanding policy of harnessing domestic energy resources to improve and maintain the economy's energy self-sufficiency and reduce dependence on imported energy. In 2013, the economy produced 6 million bbl of oil (including condensate) and 3.5 bcm of gas (DOE, 2014c). Coal production in 2013 reached 7.8 Mt (DOE, 2014b) mostly sub-bituminous, a low-rank coal.

Since 1990, the Philippines has obtained almost half of its total energy supply from renewable energy sources, mostly geothermal, hydro and biomass (IEA, 2015a). Development and optimal use of renewable energy resources is one of the government's key policies to address climate change and increase energy security, sustainability and access to energy. A recent assessment found that vast amounts of renewables[1] are yet to be developed, including 11 gigawatts (GW) of new capacity that are already covered with renewable energy service or operating contracts (DOE, 2015c).

ENERGY POLICY CONTEXT

The Philippine Energy Plan 2012-2030 (PEP), part of the Energy Reform Agenda (ERA) of the Aquino Administration, is the central policy framework. It aims to ensure secure, sustainable, sufficient, affordable and environmentally friendly energy for all sectors of society. A central goal is to intensify the participation of the private sector and other stakeholders. The plan includes policies intended to expand energy access; promote a low-carbon economy; 'climate-proof' the energy sector; develop regional energy plans (local energy plans); promote investments in the energy sector; and identify and implement energy sector reforms (DOE, 2014b).

As fossil fuels are still the dominant sources of energy over the Outlook period, the government is continuing its drive to harness domestic fossil fuels. Through the Philippine Energy Conducting Round (PECR), the government is expected to award new service contracts for oil, gas and coal exploration and development. Under the PEP, around 95 wells are planned by 2030, which could provide 78 million bbl of additional oil production by 2030. Local coal production could double with the awarding of new coal operating contracts, thus attaining the government's target of a 100% increase in domestic coal production by 2030 and maintaining its contribution to total domestic coal consumption of about 30%. The government has likewise encouraged private sector participation to attain this target (DOE, 2014b).

In June 2011, the government developed the National Renewable Energy Program (NREP), which is a 'green energy roadmap' that sets out market penetration targets for each renewable energy resource and aims to increase renewable energy-based capacity threefold by 2030. The Renewable Energy Act of 2008 established four policy mechanisms that underpin the NREP: feed-in tariffs (FiT); a net metering policy; renewable portfolio standards (RPS); and the Green Energy option.

To accelerate renewable energy resource exploration and development, the Department of Energy (DOE) issued a circular in July 2015 prescribing policy for maintaining renewable energy's share of total power capacity at a minimum of 30% through FiT and other pertinent provisions under the Renewable Energy Act (DOE, 2015c). In August 2014, the DOE endorsed an increase in the FiT installation target for solar from 50 megawatts (MW) to 500 MW with application of a lower FiT rate for the additional capacity. The following year (April 2015) the wind FiT installation target was raised from 200 MW to 400 MW.

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

The government is exploring potential energy sources and promoting local energy security across the economy. The DOE has embarked on a multi-sectoral participative local power development planning program to help provinces attain adequate, reliable and affordable power supply in off-grid areas. The program involves local government units, the business sector, non-government organisations and tertiary institutions.

The government is committed to providing electricity to remote areas and expanded its electrification program through the Household Electrification Development Plan (HEDP) and the Sitio Electrification Program (SEP) by delivering electricity to households, as well as *sitios* (hamlets, or clusters of households). The program covers household lighting in off-grid areas and *sitios*, using mature renewable energy technologies such as photovoltaic solar home systems (PV-SHS), PV streetlights and micro-hydro systems. It aims to contribute to the government's goal of 90% household electrification by 2017. As of 2013, household electrification was 79% (DOE, 2014c).

BUSINESS-AS-USUAL SCENARIO

This section illustrates energy demand and supply in the Business-as-Usual (BAU) Scenario and summarises the key assumptions from existing government policies (Table 15.2). The definition of the BAU Scenario and the modelling assumptions used in this Outlook are different from those used by the government for its projections, targets and analysis.

Table 15.2 • The Philippines: Key assumptions and policy drivers under the BAU Scenario

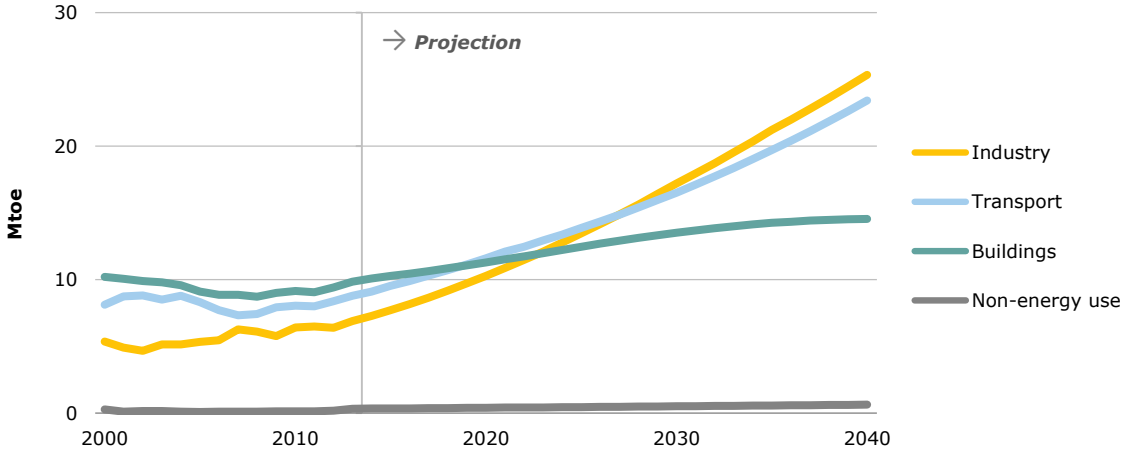
Buildings	• Minimum energy performance standards and labelling remain at current levels: household air conditioners with cooling capacity of up to 36 000 kilojoules per hour; refrigerators (5 to 8 cubic feet); compact fluorescent (CFLs), linear fluorescent and circular fluorescent lamps for general lighting; and ballast for fluorescent lamps.
Industry	• Maintain the current ISO certificate standards adopted by some manufacturing companies.
Transport	• Limited deployment of hybrid cars, compressed natural gas (CNG) and electric vehicles. • Biofuel blends maintained at current levels of 10% bioethanol blend and 2% biodiesel blend. • No vehicle fuel efficiency standards.
Energy supply mix	• No major gas finds identified.
Power mix	• Least-cost options for power generation. • Committed renewable energy projects and renewable energy historical capacity trends considered. • No policy to develop nuclear.
Renewables	• Target of 30% share of renewables in total generation capacity not considered.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

While projected economic growth during the Outlook period is high, at 6% per annum, final energy demand only grows by 3.4% annually, from 26 million tonnes of oil equivalent (Mtoe) in 2013 to 64 Mtoe in 2040. Under the government's manufacturing revival program, energy consumption in the industrial sector is project to rise nearly fourfold (Figure 15.1). Industry becomes the largest energy-consuming sector, accounting for about 40% of total final energy demand in 2040, up from 27% in 2013. Domestic transport's share of energy consumption increases slightly from 34% in 2013 to 35% in 2035 and then rises to 37% by 2040. The buildings and agriculture sector, which currently accounts for the largest share of energy consumption, is expected to exhibit modest growth, leading its share of total energy consumption to decline from 38% in 2013 to 23% in 2040.

Figure 15.1 • The Philippines: Final energy demand by sector, 2000-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

As the government embarks on energy efficiency and conservation programs as key components of its energy plan, energy intensity declines by more than half over a 30-year period, falling from 76 tonnes of oil equivalent (toe) of final energy demand per million USD of GDP in 2005 to 34 toe per million USD of GDP in 2035, an average annual improvement of 3.2%. In 2004, the government implemented the National Energy Efficiency and Conservation Program (NEECP), an umbrella program for energy efficiency initiatives carried out in partnership with stakeholders and technical assistance from donor institutions. The NEECP is a continuous effort and involves several measures, programs and projects, including the Energy Efficiency Standards and Labelling Program; Government Energy Management Program (GEMP); Energy Management Services and Energy Audits; the Fuel Conservation and Efficiency in Road Transport (FCERT); the Power Conservation and Demand Management (Power Patrol); and the Philippine Industrial Energy Efficiency Project (PIEEP) (DOE, 2014c). The DOE has been advocating for the passage of the Energy Efficiency and Conservation Bill, which now needs to gain endorsement from both legislative houses (DOE, 2015d).

Buildings and agriculture energy use: A modest increase in demand

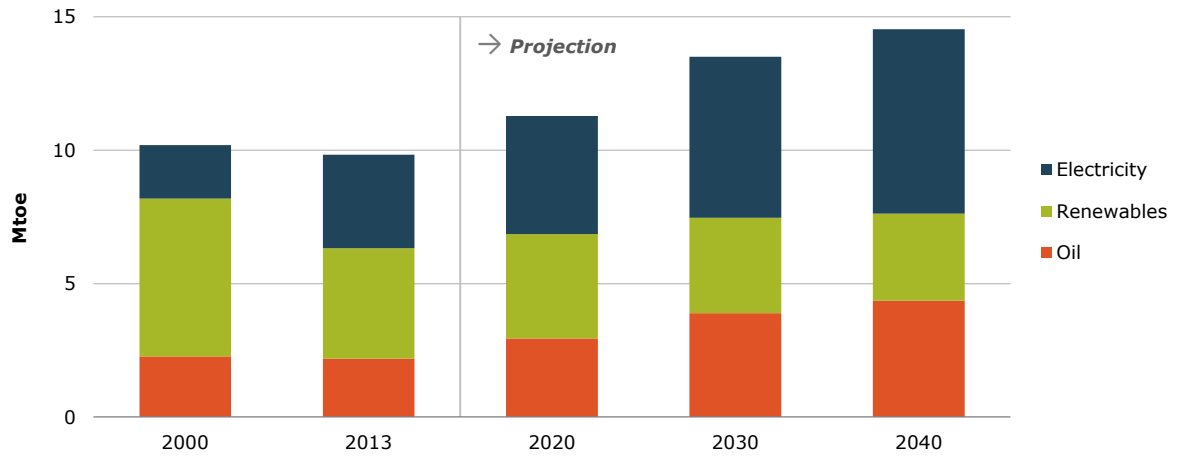
Final energy consumption in the buildings and agriculture sector increases by 1.5% annually from 9.8 Mtoe in 2013 to 15 Mtoe in 2040 (Figure 15.2). The increase in energy demand is modest because of a gradual decline in biomass consumption in the residential sector as urbanisation expands and household incomes improve, and a shift to more efficient fuels like liquefied petroleum gas (LPG) for cooking takes place. Oil consumption more than doubles by the end of the Outlook period.

The government's program on expanding access to energy, which aims to expand household electrification, pushes electricity consumption to increase more quickly, at an AAGR of 2.5% from 2013 to 2040, increasing its share to almost half of the sector's total demand. Demand from the service sector also pushes up electricity consumption, as the number of commercial buildings increases to cater for the tourism industry, and as the business process outsourcing industry grows. To generate energy savings, the government has implemented the Philippine Energy Efficiency Project, funded by the Asian Development Bank (ADB), to introduce energy-efficient lighting systems in the buildings sector. The estimated electricity savings from this project are around 260 gigawatt-hours (GWh) annually (DOE, 2014b).

The revised Energy Efficiency and Conservation Roadmap addresses energy demand in commercial buildings including energy efficiency measures in the building code and 'green building' ratings (DOE, 2015d). Building for Ecologically Responsive Design Excellence (BERDE) is a voluntary green building rating system initiated by the private sector and supported by the government. Developed by the

Philippine Green Building Council (PHILGBC), it measures, verifies and monitors building performance based on existing mandatory regulations and standards.

Figure 15.2 • The Philippines: Buildings and agriculture sector final energy demand, 2000-40



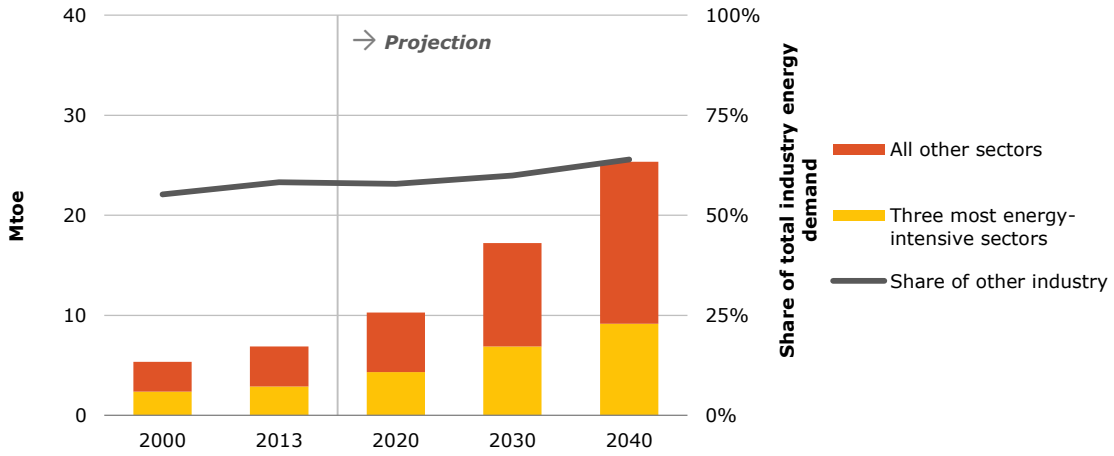
Sources: APERC analysis and IEA (2015a).

In the agriculture sector, energy consumption grows by an AAGR of 1.8% over the Outlook period, up from an AAGR of 0.82% between 1990 and 2012. Oil consumption increases annually by 2.2% and electricity consumption by 1.3% over the Outlook period due to mechanisation of agricultural processes.

Industry energy use: Rapid growth in sight

In 2013, the industry sector contributed about one-third of GDP, and grew by 9.5% from the previous year (PSA-NSCB, 2013). The manufacturing sector has started to show signs of recovery, contributing 2.3 percentage points to GDP growth in 2013, with value-added growth of 10% in the same year (Navarro and Llanto, 2014). Overall, the industry sector has the fastest growth in energy demand, growing at an AAGR of 4.9% on average, from 6.9 Mtoe in 2013 to 25 Mtoe in 2040 (Figure 15.3). This is significantly higher than the AAGR of 1.7% between 1990 and 2013.

Figure 15.3 • The Philippines: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.

Sources: APERC analysis and IEA (2015a).

The machinery subsector drives industry energy demand faster than the three most energy-intensive subsectors, with an AAGR of 6.6%, from 0.54 Mtoe in 2013 to 3.0 Mtoe in 2040. It is followed by the mining (metals and quarrying) sub-sector (5.3%), construction (5.2%) and food and tobacco (5%). Non-

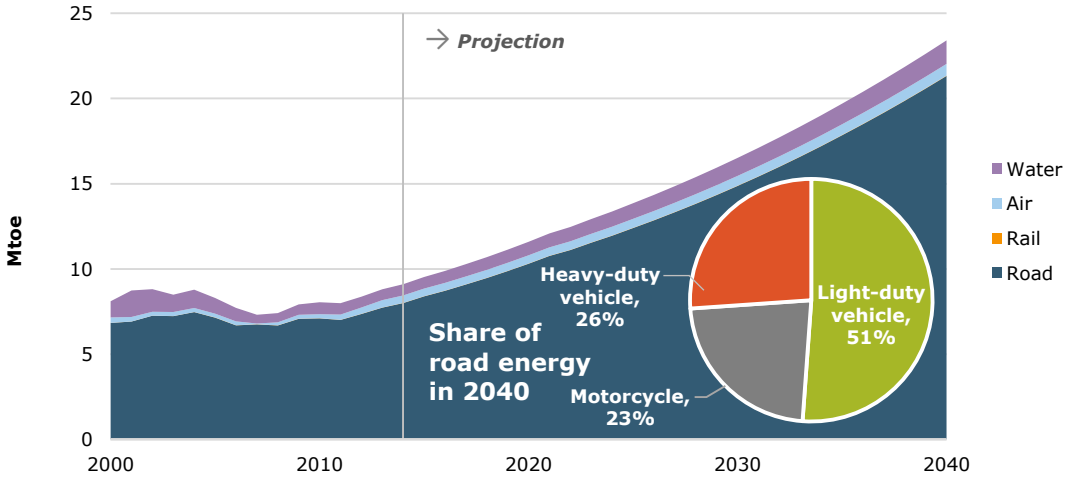
metallic minerals including cement grows by 4.6% a year, with energy consumption rising to 6.6 Mtoe in 2040 from 2 Mtoe in 2013. Iron and steel grows by 4.2% a year, while the chemical and petrochemicals subsector has the lowest growth at 2.6%. Growth in the non-metallic minerals and iron and steel subsectors are driven by much-needed infrastructure development, as well as domestic requirements for additional building and housing units. A quarter of total industry demand is consumed by the food and tobacco subsector over the Outlook period.

To improve energy management systems and energy efficiency in the industry sector, the government has implemented the Philippine Industrial Energy Efficiency Project in partnership with the United Nations Industrial Development Organisation (UNIDO), which is funded under the Global Environment Fund (GEF). The project intends to introduce and provide tools and capacity building for applying the ISO 50001 Energy Management Standard and System Optimisation Frameworks in the chemicals, food and beverages, iron and steel, and pulp and paper sub-sectors (DOE, 2015d). The government also conducts accreditation of energy service companies (ESCOs) to accelerate the implementation of energy efficiency and conservation initiatives.

Transport energy use: Road vehicles push up demand

Domestic transport energy demand grows by 3.7% a year, from 8.8 Mtoe in 2013 to 23 Mtoe in 2040 (Figure 15.4). The bulk of the sector's energy demand (90% on average) comes from road transport over the projection period, half from light-duty vehicles (LDVs) with the remaining half shared by heavy-duty vehicles (HDVs) and motorcycles. LDV stock grows at an AAGR of 5.2%, reaching 12.7 million vehicles in 2040, while HDV stock rises at an AAGR of 4.6% to reach 1.4 million. Motorcycle stock expands by 4.1% annually.

Figure 15.4 ● The Philippines: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Growth in domestic air transport energy demand is only modest, at 1.7% a year, down from 5.1% between 1990 and 2013. Marine transport—which plays an important role in the Philippines, an archipelago of 7 000 islands—posts a 2.9% annual growth rate, up from 0.48% between 1990 and 2013.

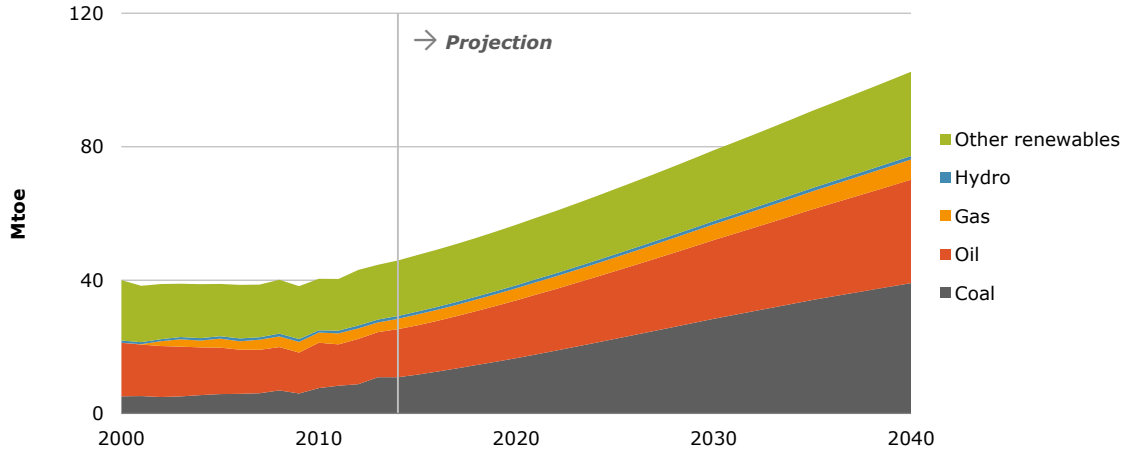
Due to the transport sector's large energy requirements, particularly for road transport, the government is looking at establishing a vehicle labelling program and fuel efficiency standards as part of the Energy Efficiency and Conservation Roadmap. In the long term, the government integrates urban planning and transport energy use policy to increase the efficiency of the transport system (DOE, 2015d).

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Coal share increases

The Philippines obtains more than half of its energy supplies from domestic resources. In 2013, local energy production stood at 26 Mtoe, or about 57% of TPES. Renewable energy sources were the biggest contributor, providing 18 Mtoe, more than two-thirds of indigenous energy production (DOE, 2014c) (Figure 15.5).

Figure 15.5 ● The Philippines: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

Among renewable energy resources, geothermal accounted for the largest share at 32% of total indigenous energy supply in 2013. Geothermal production is likely to increase, with several geothermal projects expected to be commissioned. Biomass, used as conventional fuel in the household sector for cooking and heating, as well as subsitute fuel in the industrial and commercial sectors, provided 29% of the indigenous energy supply. Biomass use in power generation expanded by 16% from the previous year (DOE, 2014a). With the intensified promotion of the use of renewables, 39 biomass projects were awarded in 2013 with an aggregate capacity potential of 250 MW (DOE, 2014c). The renewable resource assessment reveals that vast resources remain untapped. Despite this potential, the renewables share of TPES is projected to decline to 26% by the end of the Outlook period, from 39% in 2013, due to higher penetration of coal in the power sector.

Coal's share of TPES increases from 24% in 2013 to 38% in 2040 as coal's contribution to power generation accelerates. To lower dependence on imported coal, the government intends to formulate a policy to expand the use of indigenous low-rank coal and the adoption of local coal quality upgrading technologies like coal washing, preparation and blending to comply with environmental standards. The government has also explored alternative uses of coal through a project assessing the coalbed methane (CBM) potential of selected coal fields (DOE, 2014b).

Oil's share of TPES remains about 30% throughout the Outlook period, with levels rising at an AAGR of 3.1% to double current levels by 2040. The slower growth could be attributed to the introduction of alternative fuels and technologies, such as biofuels, as well as a reduced contribution of oil-based thermal plants to the power generation mix. Natural gas use also rises, with its share of TPES reaching 6.5% in 2040.

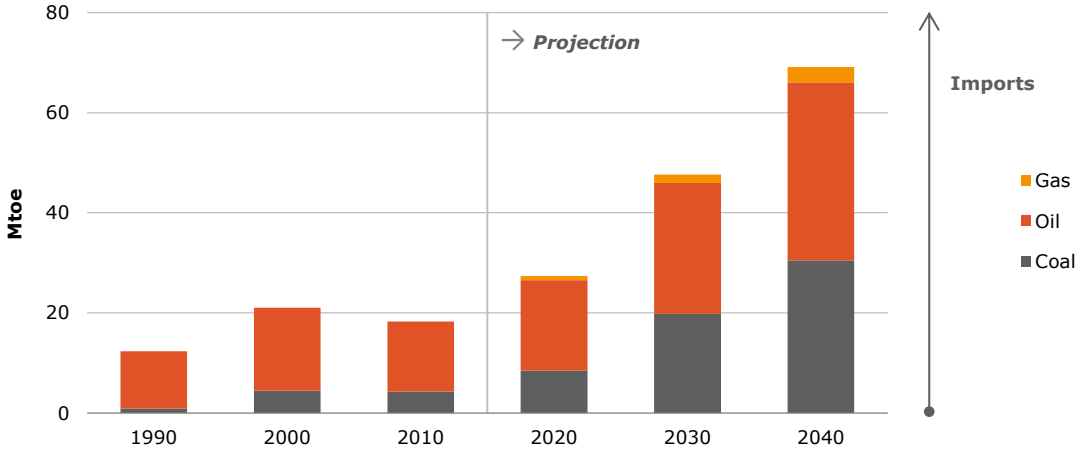
Energy trade: Oil and coal imports rise sharply

The Philippines is a net importer of crude oil, with domestic resources accounting for only 3.3% of crude oil supply in 2013. Around 76% of crude imports come from the Middle East and the rest from the APEC region, particularly from Malaysia and Russia (DOE, 2014d). The Philippines exports domestic oil and

condensate to Korea, Singapore and Thailand, or refines domestically at Shell's Tabangao Refinery (DOE, 2015d). Net oil imports fell in 2010 due to declines in oil demand as the economy reacted temporarily to continuous oil price increases (Figure 15.6).

Without any new oil wells, net oil imports are projected to continue to rise from 14 Mtoe in 2013 to 36 Mtoe in 2040, an AAGR of 3.5%. The Malampaya gas field will be depleted between 2022 and 2024, so net gas imports are expected to expand significantly by 16% a year, from 0.3 Mtoe in 2026 to 2.2 Mtoe in 2040, assuming no new large gas fields are identified. In anticipation, the government is considering building up liquefied natural gas (LNG) import terminals, including a floating storage regasification unit (FSRU) to receive LNG from other economies such as Australia, Brunei Darussalam and Indonesia.

Figure 15.6 • The Philippines: Net energy imports, 1990-2040



Sources: APERC analysis and IEA (2015a).

Despite producing coal, the Philippines will continue to be a net coal importer due to its high coal requirements for power generation plants. High-quality coal is mostly used in power plants, with some using small amounts of domestic coal for blending with imported coal. In 2013, 97% of coal imports came from Indonesia, and the rest from Australia and Viet Nam. Almost 90% of the Philippines' coal exports in 2013 went to China, and the rest to Thailand and Chinese Taipei (DOE, 2014d). As coal demand increases, net coal imports grow more than fourfold, from 6.7 Mtoe in 2013 to 30 Mtoe in 2040.

Power sector trends: Coal dominates

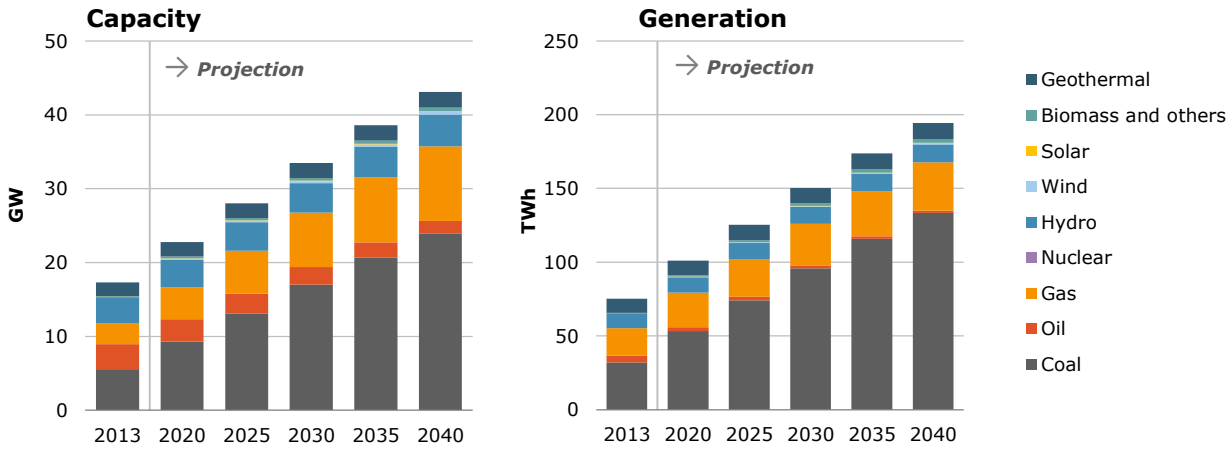
Although there is no government policy to increase use of coal for power, its low cost makes it an attractive source for baseload generation. Coal-fired capacity is projected to increase more than fourfold, from 5.6 GW in 2013 to 24 GW in 2040, reaching 56% of total generation capacity in 2040 from 32% in 2013 (Figure 15.7). Coal-based generation rises considerably to reach 133 terawatt-hours (TWh) in 2040 from only 32 TWh in 2013, an AAGR of 5.4%. By 2040, nearly 69% of total power generation comes from coal-based power plants. However, the use of coal for power is less socially acceptable due to environmental concerns.

Natural gas capacity more than triples over the Outlook period, growing at an AAGR of 4.8%. Nonetheless, the share of natural gas in power generation declines from 25% in 2013 to 17% in 2040, as coal generation rapidly increases.

Renewable energy capacity grows by 1.1% a year, from 5.5 GW in 2013 to 7.4 GW in 2040. Solar and wind capacity demonstrate the highest AAGR at 18% and 10%, respectively. As the increase in renewable energy generation capacity is slight, renewable energy's share of total power generation declines in 2040 to almost half of its 26% contribution in 2013.

Oil's share of power generation falls from 6% in 2013 to 0.8% in 2040, as no capacity is added and existing oil-based power plants are gradually retired.

Figure 15.7 • The Philippines: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

In June 2013, Retail Competition and Open Access (RCOA) commenced after a six-month transition period. RCOA enhances competition in power generation and supply through a competitive electricity tariff. Customers with an average load requirement of 1 MW in the previous 12 months will have the option to choose their own electricity suppliers (DOE, 2014c).

ALTERNATIVE SCENARIOS

All three alternative scenarios, the Improved Efficiency Scenario, the High Renewables Scenario and the Alternative Power Mix Scenario apply to the Philippines.[2] Of the four cases within the Alternative Power Mix Scenario (the Clean Coal, the High Gas 50%, the High Gas 100% and the High Nuclear Cases), only the High Nuclear Case does not apply to the Philippines. Despite its exclusion from the Outlook's analysis, the government is currently considering nuclear as a potential long-term option for power generation in the Philippines. The Improved Efficiency Scenario has the largest impact, with the greatest reduction in final energy demand, the lowest energy-related carbon dioxide (CO_2) emissions and lower average generation cost for power by 2040 compared with the BAU Scenario.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

Under the Improved Efficiency Scenario, final energy demand grows at an AAGR of 2.5% instead of 3.4% under the BAU (Figure 15.8). Lower demand growth generates total energy savings across different sectors of 9.3 Mtoe by 2035 and 14 Mtoe by 2040, translating to a 22% drop in energy demand by 2040 from the BAU. These savings enable the economy to reduce energy intensity in 2035 by about 63% (from the 2005 level) as compared with the BAU intensity reduction of 56%. This scenario yields energy intensity of 28 toe per 2012 USD million of GDP in 2035, contributing to the APEC energy intensity reduction goal.[3] The decrease in energy intensity can be attributed to the energy efficiency and conservation programs being implemented by the government, as well as structural changes including a growing contribution to GDP by the service sector, which is less energy-intensive.

The projected energy savings potential is consistent with the government's goal of achieving 10% energy savings across all sectors by 2030, as stipulated in the Philippine Energy Plan 2012-2030. The Energy

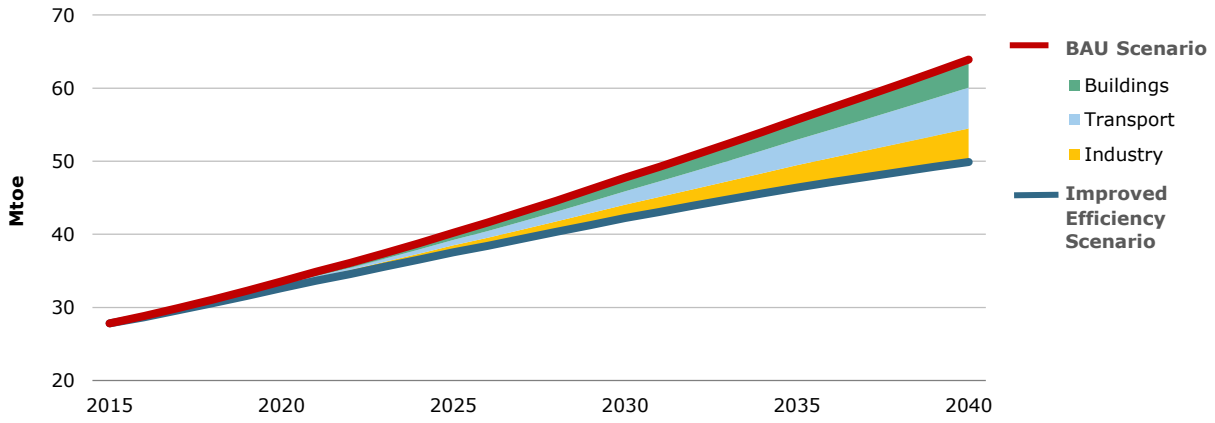
[2] For more details about the Alternative Scenario assumptions, see Chapter 5 to 7 in Volume I.
[3] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

Efficiency Roadmap sets a target reduction in energy intensity of 40% by 2030 based on the 2010 level (DOE, 2015d).

The transport sector accounts for the largest energy savings, of 5.6 Mtoe in 2040, or around 40% of total estimated savings. Of the energy savings in road transport, 70% is due to LDVs, while HDVs provide the rest with little share from motorcycles. This scenario assumes that the government meets its objective of implementing a fuel efficiency standard for all vehicles to reduce oil consumption and decrease the economy's dependence on oil imports. The transport sector consumes about 69% of total oil consumption in 2013.

Industry registers the second-largest energy savings of 4.6 Mtoe in 2040, or 33% of the total savings. The food and tobacco sub-sector accounts for 42% or 1.9 Mtoe of the industry savings potential in the Improved Efficiency Scenario, given its huge share of total industry energy demand as the largest-consuming industry sub-sector. Non-metallic minerals (17%) and machinery (14%) are the next largest contributors to energy savings in the industry sector. The application of ISO 50001 Energy Management Standard and System Optimisation Frameworks, as well as energy management services, are important measures to help realise the projected energy savings.

Figure 15.8 • The Philippines: Potential energy savings in the Improved Efficiency Scenario, 2015-40



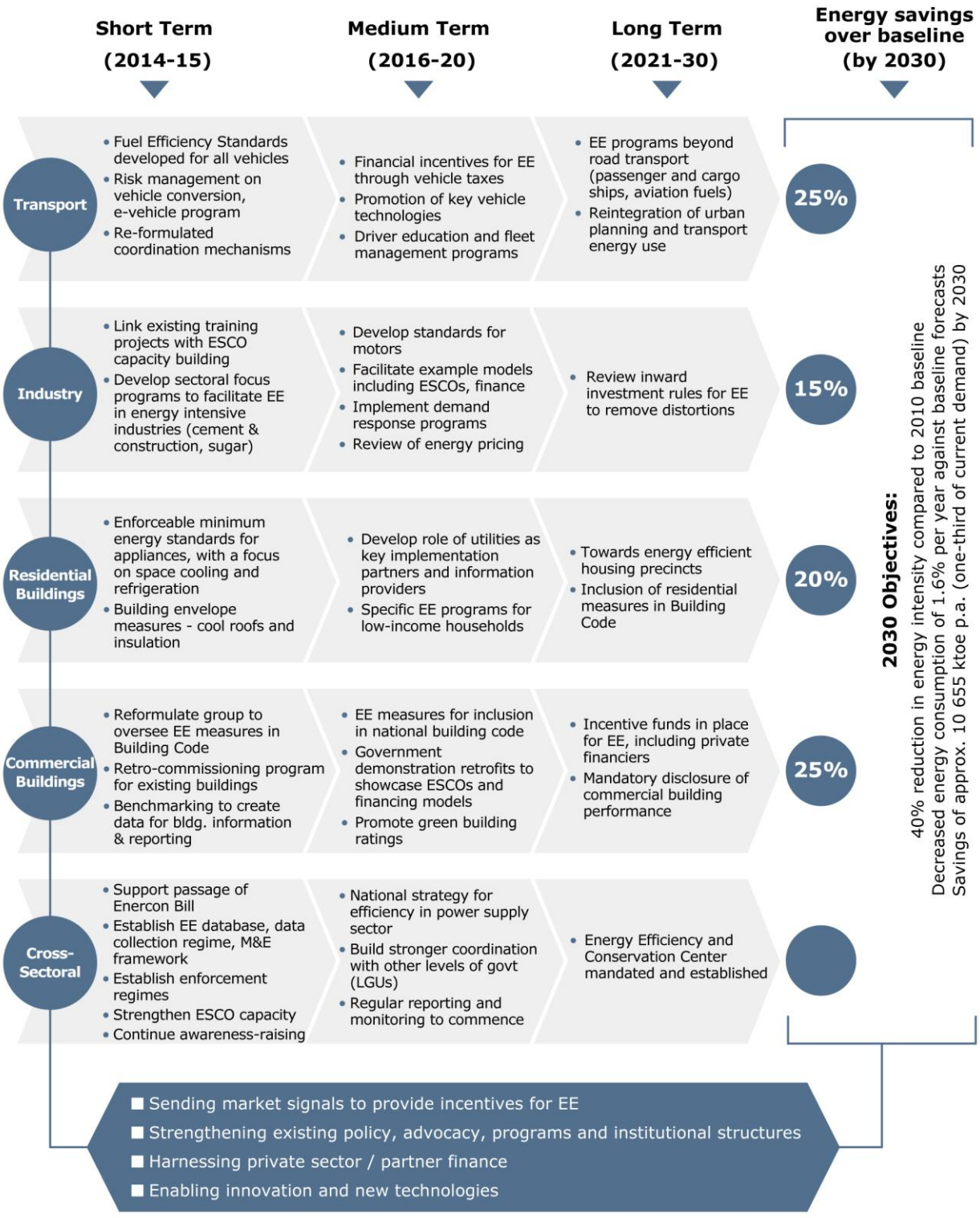
Source: APERC analysis.

Energy savings potential in the residential sector concerns seven end uses: refrigerators, air conditioners, televisions, washing machines, lighting, water heating, and stand-by energy. The savings from these end uses are projected to reach 3.8 Mtoe in 2040, representing 27% of total energy savings by end of the Outlook period and a reduction in energy use of 26% compared with the BAU. Air conditioners register the largest contribution to savings (27%) in 2040, followed by refrigerators (23%). Energy consumption for space cooling increases as rising incomes enable more households to purchase air conditioners to cope with the tropical climate. The remaining savings come from reductions in stand-by energy (15%), more efficient televisions (14%), lighting (12%) and washing machines (9%). Meanwhile, the commercial sector only accounts for 10% of total energy savings, with 60% of those savings coming from more efficient space cooling and 30% from lighting.

The Philippine government began implementing mandatory energy standards and labelling in 1999. Manufacturers and importers of consumer electrical and electronic products must comply with the minimum energy performance standard (MEPS) and energy-labelling requirement before selling their products. Currently, the program covers air conditioners; refrigerators (5 to 8 cubic feet); compact, linear and circular fluorescent lamps; and ballasts for fluorescent lamps (DOE, 2014c). As stipulated in the Philippine Energy Plan, the program may be expanded to cover other household appliances, industrial equipment such as fans and blowers, and even vehicles (DOE, 2014a).

Through the SWITCH-Asia policy support program, funded by the European Union, the government is revising the Energy Efficiency and Conservation Roadmap with the primary objective of promoting sustainable development (Figure 15.9). The government aims to strengthen economy-wide and regional policy frameworks to make consumption and production patterns more sustainable and increase resource efficiency. The roadmap will also provide long-term policy direction on energy efficiency and conservation (DOE, 2015d).

Figure 15.9 ● The Philippines: Energy Efficiency Roadmap



Source: DOE-Philippines (DOE, 2015d).

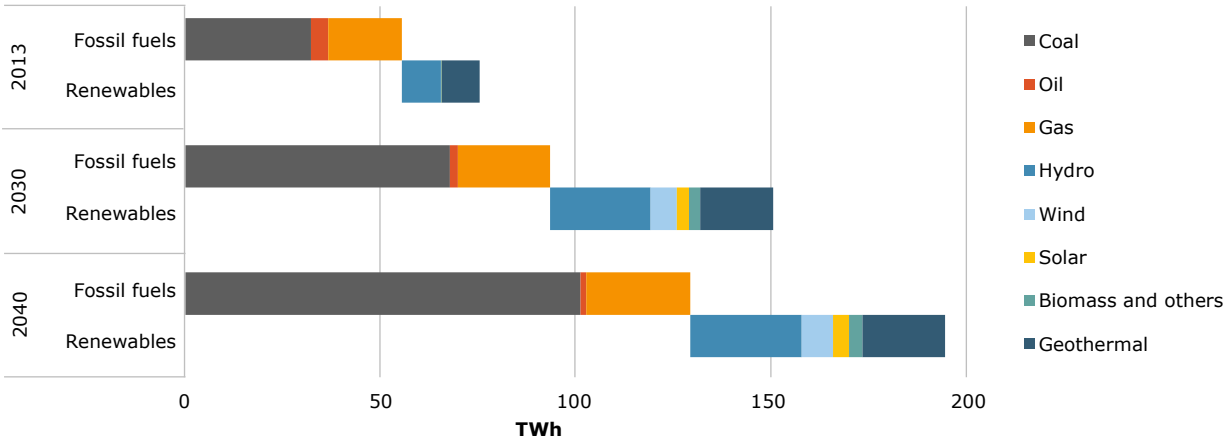
HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

The High Renewables Scenario models the APEC doubling renewables goal, but focusing on the power and transport sectors only.[4] Unlike the BAU, in which the renewables share of power generation declines, under the High Renewables Scenario it grows from 26% in 2010 to 38% in 2030. To keep the renewables share at this level, one of the highest in APEC, total power generation from renewables increases to 57 TWh in 2030 and 65 TWh in 2040 (Figure 15.10). Hydro and geothermal, which are more established technologies in the Philippines, provide the largest contributions to total renewables generation with shares of 44% (hydro) and 32% (geothermal) in 2040. Wind and solar technologies also need to be deployed to maintain the current share of renewables.

In this scenario, renewable capacity reaches 19 GW in 2030 and 21 GW in 2040. Wind capacity rises from just 0.03 GW in 2010 to 3.5 GW in 2040. Solar capacity also rises sharply, reaching 2.9 GW in 2040 from just 0.001 GW in 2010. These two technologies contribute to about 40% of total additional capacity from renewable energy in 2030. Such capacity expansion translates to AAGRs of 19% for wind and 34% for solar over the Outlook period.

Under this scenario, renewables account for 48% of total power generation capacity in 2030 and 43% in 2040, which is above the government target and policy agenda of maintaining renewables' share of total power generation capacity at 30%. The High Renewables Scenario results in a declining average generation cost of energy, from USD 104/MWh in 2013 to USD 97/MWh in 2040, as the levelised cost of electricity (LCOE) from renewables falls, especially for solar and wind. The scenario generates CO_2 emissions intensity of 545 grams/kWh in 2040, lower by 23% than the BAU levels.

Figure 15.10 ● The Philippines: Power sector under the High Renewables Scenario, 2013-40



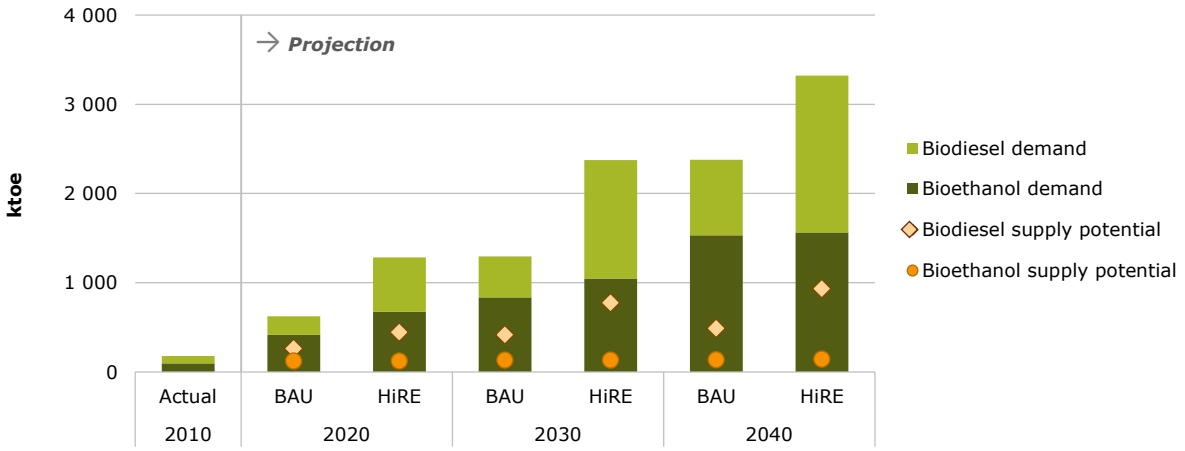
Sources: APERC analysis and IEA (2015a).

In the transport sector, renewables' share of energy demand already more than triples in the BAU, from 2.3% in 2010 to 7.8% in 2030. The BAU assumes increasing the current government-mandated biofuels blends of 10% bioethanol to 20% in 2040 and 2% biodiesel to 10% in 2040.

In the High Renewables Scenario, renewables' share of energy demand in the transport sector more than doubles from 2010 to 2030 and reflects the government's blend targets of 20% bioethanol by 2020 and 20% biodiesel by 2025 (DOE, 2014a). Biofuels' share of total transport demand increases about 13 times to around 14% in 2030 and at the end of the Outlook period (Figure 15.11). Demand for biofuels expands from 0.2 Mtoe in 2010 to 2.4 Mtoe in 2030 and 3.3 Mtoe in 2040. Bioethanol registers an AAGR of 7.5% and biodiesel an AAGR of 12% over the Outlook period.

[4] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

Figure 15.11 ● The Philippines: Biofuels demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



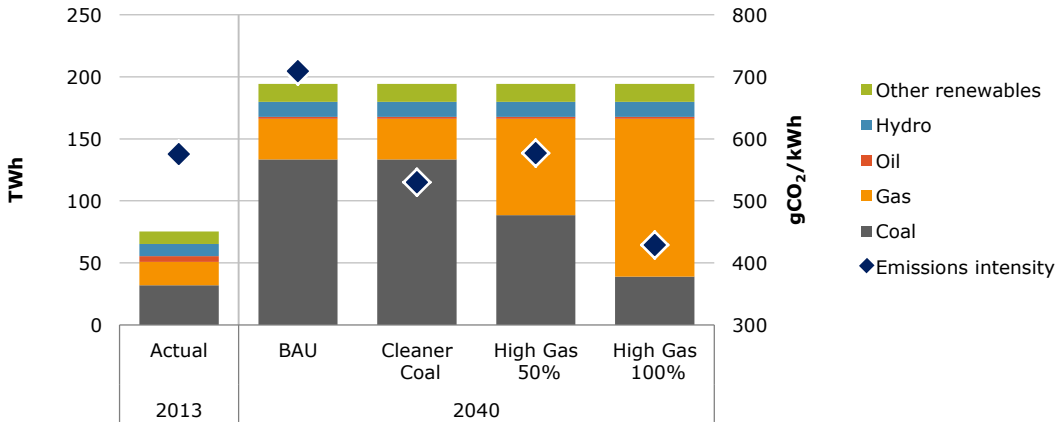
Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is for the Outlook period only; HiRE = High Renewables Scenario.

Sources: APERC analysis, DOE (2014b), FAO (2014) and IEA (2015a).

ALTERNATIVE POWER MIX SCENARIO

The Alternative Power Mix Scenario illustrates the potential impact of having cleaner coal, more gas and higher nuclear contributions in the power generation mix and their respective impacts on energy-related CO_2 emissions. Although the Philippines is still considering nuclear as a long-term option for power generation, the High Nuclear Case does not apply as the government has no clear policy yet on nuclear energy; the Cleaner Coal, High Gas 50% and High Gas 100% Cases apply.

Figure 15.12 ● The Philippines: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

The Cleaner Coal Case assumes that new coal-based generation capacity is supercritical (SC) or ultra-supercritical (USC) from 2021, and that after 2030 all new coal generation is fitted with carbon capture and storage (CCS). Under this case, the share of coal in power generation remains the same as in the BAU, reaching about 70% by 2040 (Figure 15.12). Total additional capacity from SC/USC is around 10 GW, while coal generation with CCS provides an additional 7.2 GW. With the higher capital cost of more advanced coal technologies, the average generation cost is projected to increase from USD 104/MWh in 2013 to USD 111/MWh in 2040, higher than the BAU average cost of USD 107/MWh in 2040. Energy-related CO_2 emissions intensity in the power sector (with CCS) decelerates at an AAGR 0.3%, to 530 grams of CO_2 per KWh (gCO_2/KWh) in 2040 from 570 gCO_2/KWh in 2013. Without CCS, CO_2 emissions intensity is 23% higher at 654 gCO_2/KWh.

The High Gas 50% Case results in gas capacity expanding from 2.9 GW in 2013 (BAU) to 19 GW in 2040 and the High Gas 100% Case to 27 GW. Under these cases the share of gas in total power generation reaches about 40% (High Gas 50%) or 65% (High Gas 100%) in 2040, from only 25% in 2013. The average generation cost is USD 120/MWh for the High Gas 50% Case and USD 129/MWh for the High Gas 100% Case in 2040, 12% and 21% higher than the BAU, respectively. The High Gas 50% Case yields a 577 gCO_2/kWh emission level, 19% lower than the BAU but 9% higher than cleaner coal (with CCS) due to conventional coal's contribution to the power generation mix. The High Gas 100% Case produces 429 gCO_2/KWh in 2040, which is 39% lower than the BAU and 19% below the Cleaner Coal Case.

The Philippines is considering enabling a high gas contribution to its power generation mix, formulating a Natural Gas Master Plan covering the establishment of investment and transactional frameworks focusing on LNG usage for power generation (DOE, 2014b).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

The Philippines requires investments ranging from USD 89 billion to USD 208 billion from 2015 to 2040 to provide the infrastructure necessary for its growing energy demand (Table 15.3). Among the sub-sectors, power and upstream require the largest shares, at 62% (power) and 15% (upstream) under the low-cost estimate, and 48% (power) and 18% (upstream) in the high-cost estimate.

Table 15.3 ● The Philippines: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	3.0	4.5
	Gas	4.5	14
	Coal	6.1	20
	Subtotal	14	38
Downstream	Refinery	8.4	42
	LNG import terminals	1.5	3.3
	Biofuels refinery	0.6	0.9
	Subtotal	11	46
Electricity	Coal	29	42
	Gas	5.4	8.0
	Hydro	0.7	2.3
	Wind	0.8	1.0
	Solar	0.3	0.5
	Biomass and others	0.6	0.7
	Geothermal	1.8	2.4
	Transmission lines	9.0	21
	Distribution lines	6.6	22
	Subtotal	55	99
Energy transport	Oil	0.5	1.9
	Gas	3.0	16
	Coal	6.6	7.5
	Subtotal	10	25
	Total	**89**	**208**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

With electricity generation projected to more than double, investment is needed to fund 26 GW of additional capacity, including expanding and refurbishing transmission and distribution lines. Despite having limited fossil fuel resources, the government is keen on intensifying its efforts to boost domestic production, particularly of gas, which requires 33% (low-cost estimate) to 36% (high-cost estimate) of the total upstream investment.

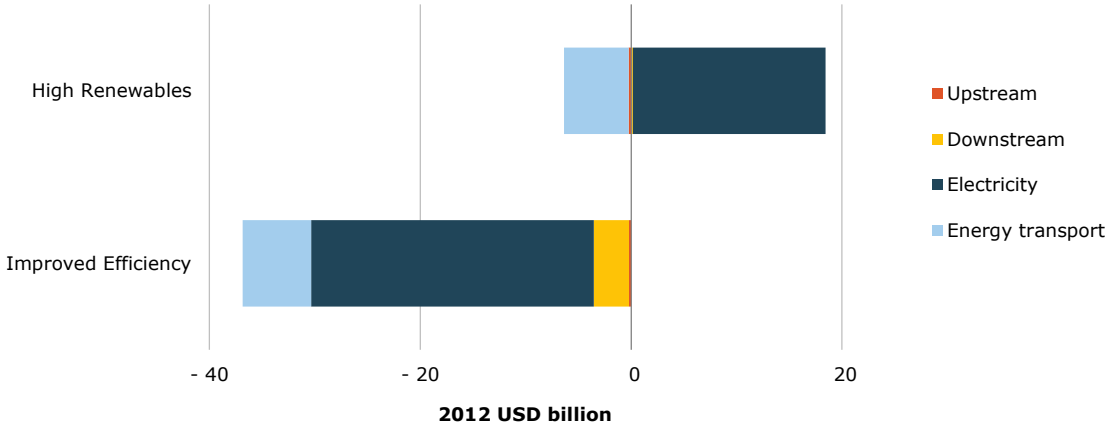
Investment in the downstream subsector is required to add 420 000 barrels a day (bbl/d) of new refinery capacity by 2040, and to maintain refinery production's share of total domestic oil demand, which stood at around 60% in 2013. The Philippines is also starting to build LNG infrastructure so that it can obtain natural gas from neighbouring producing countries as an alternative to depleting domestic natural gas resources. Energy transport for oil, gas and coal (from sources to ports or end-use facilities) demands around 11% of total investment in the low-cost estimate and 12% in the high-cost estimate.

The Improved Efficiency Scenario leads to a 41% savings in energy investment requirements compared with the BAU, necessitating only USD 52 billion (low-cost estimate) (Figure 15.13). The power sector achieves a 49% savings in investment, as lower demand reduces power generation capacity requirements by 15 GW, necessitating only 11 GW of capacity additions. Correspondingly, transmission and distribution network requirements fall following a decrease in generation capacity additions. The decline in oil demand by 19% in the Improved Efficiency Scenario results in a drop of 33% in investment requirements for downstream. About 283 000 bbl/d of new refinery capacity additions are needed, which is 33% lower than under the BAU.

Under the High Renewables Scenario, investment requirements rise by about 14% from the BAU levels, with power making up a large share of the increase. Investment in power is 33% higher than in the BAU because of the need to increase generation capacity from renewable energy and the additional transmission costs for solar and wind generation. Additional capacity from renewables reaches 16 GW, about nine times more than the 1.8 GW in the BAU. Solar expands significantly, at an AAGR of 34% instead of only 18% in the BAU, and wind grows at an AAGR of 19% instead of only 10%. Solar capacity reaches 2.9 GW in 2040 (up from 0.08 GW in the BAU), providing around 14% of total renewable capacity, while wind capacity stands at 3.5 GW in 2040 (up from 0.39 GW in the BAU), contributing 16% of the total.

Downstream investment also rises in this scenario, by about 1.5% from the BAU as higher blend rates increase demand for biofuels, requiring additional refinery capacity. Higher biofuels demand expands the requirement for additional refinery capacity to 9 million litres per day, an increase of 80% from the BAU.

Figure 15.13 ● The Philippines: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

Enhancing energy security: Energy self-sufficiency declines

The Philippines maintains a diversified primary supply mix and its Herfindahl-Hirschman Index (HHI)[5] of HHI 0.29 in 2013 only deteriorates to HHI 0.30 in 2040 under the BAU, where a lower number indicates greater diversity (Table 15.4). The High Gas 100% Case leads to the most diversified primary energy supply at HHI 0.26 in 2040 compared with the BAU, as it displaces all new coal additions over the projection period. However, with the expected depletion of the Malampaya gas field, the Philippines will need to import LNG to meet domestic gas demand, specifically for power, leading to the lowest self-sufficiency for gas under the High Gas 100% Case.

In terms of fuel diversity in power generation, diversity declines significantly under the BAU from HHI 0.33 in 2013 to HHI 0.49 in 2040. The Cleaner Coal Case also has the least diversified electricity generation input fuel mix due to the large shares of coal in the fuel mix for power generation. The fuel mix is diversified in the High Gas 100% Case at an HHI of 0.34.

Table 15.4 ● The Philippines: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040					
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%
Primary energy supply diversity (HHI)	0.29	0.30	0.29	0.29	0.30	0.27	0.26
Primary energy supply self-sufficiency (%)	55	37	48	50	38	40	41
Coal self-sufficiency (%)	34	22	35	27	22	30	50
Oil self-sufficiency (%)	6	1	2	1	1	1	1
Gas self-sufficiency (%)	100	49	92	76	65	31	19
Electricity generation input fuel diversity (HHI)	0.33	0.49	0.40	0.39	0.49	0.35	0.34

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

In energy security, the High Gas 100% case has more diversified supply sources for both total primary energy mix and electricity generation input fuel mix, and higher self-sufficiency for coal and oil but the least self-sufficiency for gas.

Climate change impacts and risks: Improved efficiency reduces CO_2 emissions significantly

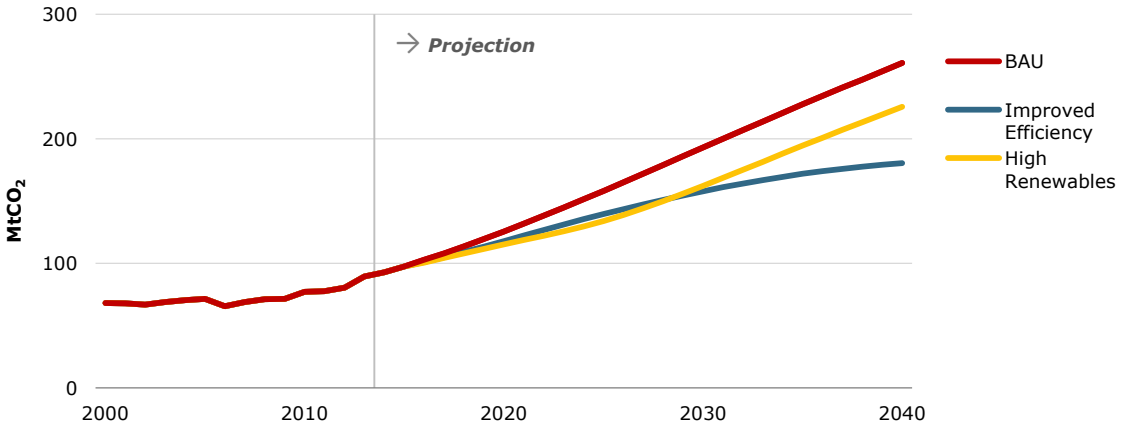
The Philippines is very vulnerable to the impacts of climate change. On average, 20 typhoons hit the economy per year. Although the economy's contribution to global GHG emissions is very small, the government created the Philippine Climate Change Commission (CCC) in 2009 to monitor and evaluate programs and action plans on climate change. The current administration established a Cabinet Cluster on Climate Change Adaptation and Mitigation to discuss policy issues. As the energy sector is the largest contributor to climate change, the government intensified its efforts on climate change mitigation, focusing on renewable energy, energy efficiency and conservation programs.

Among the different scenarios, the Improved Efficiency Scenario offers the largest reduction in energy-related CO_2 emissions, which reach 180 million tonnes of carbon dioxide ($MtCO_2$) in 2040, 31% below the BAU energy-related CO_2 emissions of 261 $MtCO_2$, highlighting the important contribution of energy efficiency to addressing climate change (Figure 15.14). This scenario in particular reduces growth in electricity consumption and its associated energy-related CO_2 emissions, which are particularly CO_2

[5] Lower HHI means less concentration or highly diversified sources.

emissions-intensive due to the future dominance of coal in the power mix. In the High Renewables Scenario, energy-related CO_2 emissions reach 226 $MtCO_2$ by 2040, 13% below the BAU—a more modest reduction, as coal still contributes significantly to power generation.

Figure 15.14 ● The Philippines: Final energy-related CO_2 emissions under the different Scenarios, 2000-40

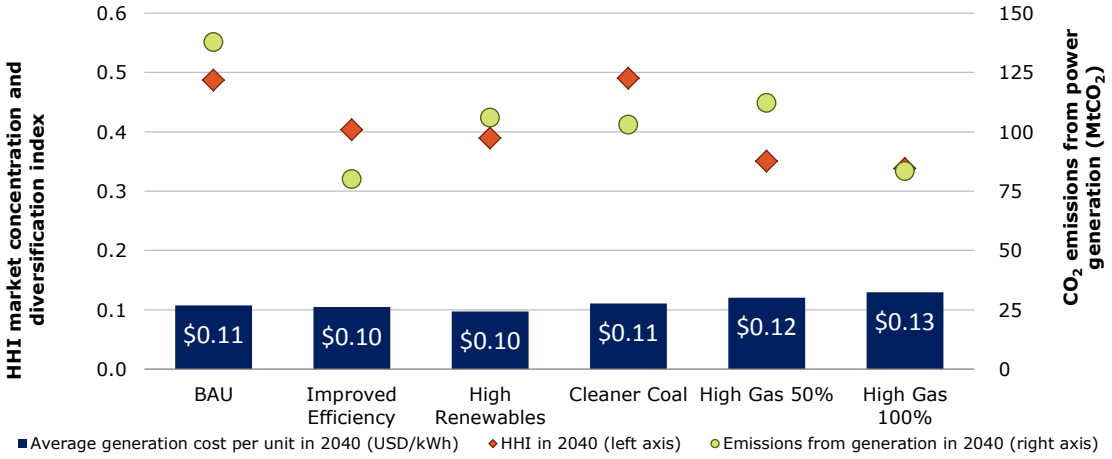


Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

Trade-offs in the power sector in 2040: Improved efficiency offers greater benefits

Trade-offs can be identified in each scenario based on generation cost, power sector CO_2 emissions level and energy supply diversification by 2040 (Figure 15.15). The Improved Efficiency Scenario offers the lowest power sector CO_2 emissions, with reduced energy demand and lower power generation costs compared with the BAU and the Alternative Power Mix Scenario cases. Both the High Gas 50% and High Gas 100% Cases result in the lowest power sector CO_2 emissions and fuel diversification index, but have the highest average generation cost in 2040 at USD 0.11/kWh.

Figure 15.15 ● The Philippines: Generation trade-offs under the different Scenarios, 2040



Source: APERC analysis.

The Cleaner Coal Case displays the third-lowest power-related emissions level, with generation costs lower than both the High Gas 50% and the High Gas 100% Cases but higher than the BAU and the High Renewables Scenarios, due to the cost of more advanced coal technology, including CCS. However, fuel diversification in the Cleaner Coal Case is the worst among the Alternative Scenarios, reaching the same level as the BAU.

The High Renewables Scenario produces the lowest average generation cost, compared with other scenarios, and improves diversity as renewables' share of the fuel mix increases. However, power sector CO_2 emissions are higher than in the Cleaner Coal and High Gas 100% Cases.

RECOMMENDATIONS FOR POLICY ACTION

The Philippines already has policies on renewable energy and biofuels to improve energy security and address environmental issues, and programs on energy efficiency and conservation. The government should also make it a priority to ensure that renewable energy projects are implemented smoothly and without delays. A policy declaring that renewable energy projects are important to the economy would help resolve issues such as conflicting policies between and among economy-wide and local government units, and lengthy processes for securing required permits and licenses, which delay implementation of these projects. Supporting policies that provide additional incentives may be necessary to encourage the private sector to develop and introduce second- and third-generation biofuels. The economy's bioethanol supply is insufficient to meet its domestic requirement for the existing 10% blend rate, and thus also its target blend rate of 20%.

To strengthen energy efficiency and conservation programs, the government should pursue passage of the Energy Efficiency Act, which is still pending in the Philippine Congress. Once enacted, it will institutionalise and mandate the energy efficiency program in all sectors, as identified in the Energy Efficiency Roadmap.

Since coal is a major source of fuel for power generation under the BAU, the government should develop policies or programs to construct more advanced coal-based power plants, using USC or advanced ultra-supercritical (A-USC) technology, and to develop and adopt CCS. In the Cleaner Coal Case, energy-related CO_2 emissions from power generation are significantly lower than BAU due to more advanced and efficient coal-based technologies with the inclusion of CCS. Provided there are both fiscal and non-fiscal incentives, investors will consider supporting these technologies. The government must also put forward policies and programs to address domestic coal quality by adopting technologies that reduce environmental impacts. This will promote greater use of indigenous coal and thus decrease dependency on imported coal.

As developing the natural gas industry remains a priority, as well as increasing the contribution of gas to the power generation mix, the government should intensify efforts to establish a comprehensive policy regulatory framework to govern the industry and develop its infrastructure and distribution systems.

16. RUSSIA

KEY FINDINGS

- **Russia will continue to hold a leading position in the world's energy markets.** Although the economy will need to overcome challenges in the years to come posed by low energy resource prices.

- **During the Outlook period (2013 to 2040), Russia cannot achieve economic growth solely by increasing production and export of energy resources,** as it did between 2000 and 2014 period. The economy needs to work on large-scale energy efficiency measures and invest in more efficient energy infrastructure and technologies for all sectors.

- **The Russian economy is under pressure to diversify its structure and modernise its energy industry,** bringing the industry, buildings, transport, heat and power generation sectors up to international standards and lowering their energy intensity and CO_2 emissions intensity.

- **Russia needs to invest heavily in oil and gas exploration and development in new frontier areas,** and in the necessary energy infrastructure, to service existing markets in Europe and new markets in the Asia–Pacific region.

- **Investment in the energy sector would be facilitated if Russia improved investor confidence** by normalising international relations with European and North American partners, and by ensuring the stability of Russian institutional arrangements and transparency of the energy markets.

- **Russia needs to foster investment in energy efficiency programs.** During the Outlook period, a low level of energy efficiency and a high level of energy losses, particularly in energy transportation and utilisation, pose obstacles to economic growth.

ECONOMY AND ENERGY OVERVIEW

Russia has the largest land area of any country or economy in the world and a population of 143 million in 2014 (GKS, 2015), which is projected to grow 5.2% to reach 151 million in 2040. Russia's major industries include oil and gas production, petroleum refining, mining, iron and steel, chemicals, machinery and motor vehicles. The energy sector is important not only to Russia's economic development but also to the survival of its population during its harsh winters.

Between 2000 and 2013 the economy developed strongly, growing by 4.4% a year on average, as world prices for oil and natural gas soared. In 2014 the energy sector's output accounted for 27% of Russia's gross domestic product (GDP), 53% of tax and customs duty payments, 70% of total exports and one-quarter of total investment in the economy.

Russia holds a leading position in each of the world's energy markets with 40% of uranium enrichment, almost 20% of nuclear reactor construction, 15% of spent nuclear fuel conversion, about 20% of natural gas trade, more than 10% of crude oil and petroleum products trade, and about 10% of coal trade.

In 2014, the global economic recovery was slower than expected, negatively affecting the Russian economy: GDP fell by 1.2% from 2013 to 2014 (Table 16.1). At the same time, industry has experienced serious challenges, including sanctions imposed by the European Union and the United States, a significant reduction in the prices of basic energy products, and worsening financial and economic conditions.

Table 16.1 ● Russia: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	2 126	1 436	2 317	2 516	2 850	3 272	3 696
Population (million)	148	146	143	143	147	149	151
GDP per capita (2012 USD PPP)	14 408	9 809	16 184	17 555	19 427	22 003	24 527
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	879	619	690	731	778	788	787
TPES per capita (toe)	6.0	4.2	4.8	5.1	5.3	5.3	5.2
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	625	418	446	434	469	491	504
Final energy intensity per GDP (toe per 2012 USD million PPP)	294	291	193	173	165	150	136
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	2 163	1 474	1 529	1 543	1 574	1 559	1 515
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	100	100	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

Over the Outlook period, Russia is under pressure to diversify its economy, energy industry and resource markets. The energy sector is expected to modernise comprehensively by improving energy efficiency to catch up with international standards for the industry, buildings, transport, heat and power generation sectors; by lowering the energy intensity and carbon intensity of these sectors; and by increasing the flexibility and diversification of energy exports.

ENERGY RESOURCES

In terms of proven reserves, in 2014 Russia held 17% of the world's gas reserves, 6.1% of its oil reserves and 18% of its coal reserves (BP, 2015). Even more resources are likely to be discovered, but obstacles of climate, terrain and distance hinder their exploitation.

Russia's oil resources in the traditional oil-producing regions are believed to be heavily depleted, with more than 50% of the economically recoverable resources already produced. In the Ural and Volga regions, resource depletion is believed to exceed 72%. The share of remaining resources that is hard to recover is constantly growing. Almost 80% of Russia's oil production comes from large fields with remaining resources of five to ten years at current production rates. Newly developed resources are often concentrated in middle- and small-size deposits, or in Arctic and Siberian areas.

The gas industry of Russia has a more favourable resource situation than the oil industry. Proven resources, estimated at 33 trillion cubic metres (tcm) (Table 16.2), should be adequate to meet both domestic market and export demands over the Outlook period.

Proven coal reserves amount to more than 157 billion tonnes. At current rates of coal consumption in the economy, these reserves will be sufficient for 441 years. Unlike the oil and gas sectors, the coal industry has no large state-controlled company and is almost 100% privatised.

Table 16.2 ● Russia: Energy reserves and production, 2014

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Coal (Mt)[a]	157 010	441	18	2nd	2nd
Oil (billion bbl)[a]	103	26	6.1	6th	2nd
Gas (tcm)[a]	33	56	17	2nd	1st
Uranium (kt U)[b]	217	69	5.9	6th	3rd

Notes: [a]Total proven coal/oil/gas reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions. [b]Uranium reserves are 'reasonably assured resources'; reference year for uranium reserves and production is 2013.
Sources: For oil, coal and gas, BP (2015); for uranium, NEA (2014).

Russia has enormous resource potential for renewables,[1] including 1 500 gigatonnes of oil equivalent (Gtoe) of solar; 620 Gtoe of wind, mainly along its Arctic and Pacific shores; 306 Gtoe of small hydro; technical potential of 100 million tonnes of oil equivalent (Mtoe) of bioenergy; and 22 Mtoe of geothermal in Kamchatka and the North Caucasus region (REA, 2012). Total technical potential is 3 150 Mtoe per year (ME, 2009). However, the use of this potential is constrained by the vast distances over which the energy would have to be transmitted to consumers.

ENERGY POLICY CONTEXT

Since 2014, the government has been revising its energy strategy for the period to 2035. The revised energy policy and strategy plans to be better adapted to an era of low global energy prices; however, the strategic objectives of Russia's external energy policy are unlikely to change. The objectives include: using Russia's energy potential to maximise its integration into the world's energy markets; strengthening its position in those markets; maximising the benefits of energy resources to the economy; and stimulating innovation in the energy sector.

To achieve these goals, Russia will implement measures to improve the security of its domestic energy consumption and energy export obligations, and make efficiency improvements along the entire energy supply chain. This will include developing new hydrocarbon projects in remote and offshore areas, and rehabilitating, modernising and developing energy infrastructure. Additional trunk oil and gas pipelines

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

will be constructed (Nord Stream 2, Power of Siberia, West Route to China, ESPO extension) to enhance the economy's energy export capacity (Gazprom, 2014). To better integrate Russia into world energy markets, export delivery markets will be diversified. It is anticipated that at least one-third of Russia's energy exports in 2030 will be delivered to the Asia–Pacific region.

BUSINESS-AS-USUAL SCENARIO

This section illustrates energy demand and supply in the Business-as-Usual (BAU) Scenario and summarises the key assumptions from existing government policies (Table 16.3). The definition of the BAU Scenario and the modelling assumptions used in this Outlook are different from those used by the government for its projections, targets and analysis.

Table 16.3 • Russia: Key assumptions and policy drivers under the BAU Scenario

Buildings	• Minimum energy performance and labelling programmes maintained at current levels.
Industry	• Implementation of cost-effective technology improvements.
Transport	• Slow deployment of new types of vehicles. • No development of biofuels. • No vehicle fuel efficiency standards.[2]
Energy supply mix	• Share of natural gas to be 50% of TPES by 2030. • Share of non-thermal energy to be 7% of TPES in 2030 from the 2008 level.
Renewables	• Renewable energy target of 2.5% by 2020, which excludes large-scale hydro.
Energy security	• 100% self-sufficiency for energy resources.
Climate change	• Work towards Intended Nationally Determined Contribution (INDC) of 25% to 30% greenhouse gas (GHG) emissions reduction from 1990 level by 2030.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

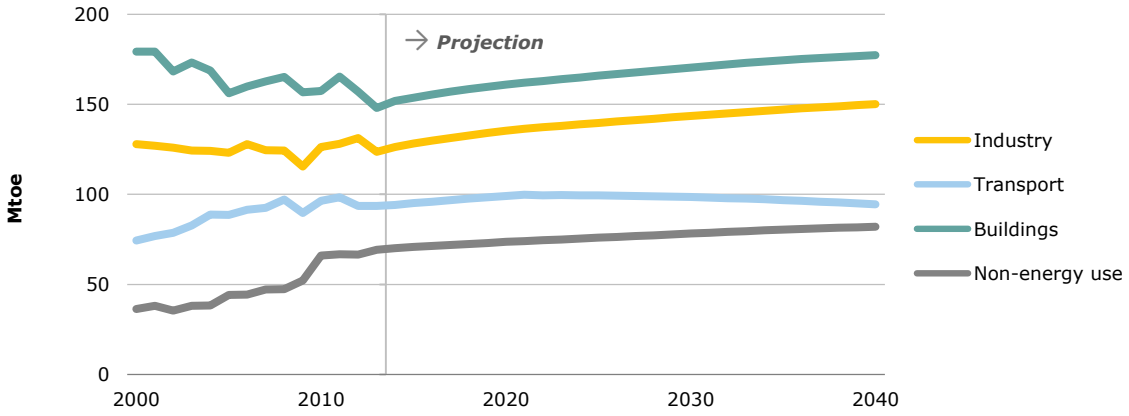
RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Under the BAU Scenario, Russia's final energy demand is projected to grow at an average annual growth rate (AAGR) of 0.55% from 2013 to 2040, an overall increase of 16% from 434 Mtoe to 504 Mtoe. The buildings and agriculture sector continues to be the largest energy user (Figure 16.1), with its share of demand increasing from 34% in 2013 to 35% in 2040. Industry's share of demand rises from 29% to 30%. Final energy demand in the domestic transport sector rises from 94 Mtoe in 2013 to 100 Mtoe in 2021 before declining to 95 Mtoe by 2040 as more fuel-efficient models dominate the vehicle fleet.

These projections show that under the BAU, Russia is neither on track to meet the goals adopted in the Energy Strategy 2030, nor the Energy Efficiency Federal Law target of a 44% reduction in energy intensity between 2005 and 2030.

[2] Decree of the Ministry of the Russian Federation No. AM-23-r of 14 March 2008 (amended 14 July 2015) establishes recommended fuel consumption rates for different vehicles.

Figure 16.1 ● Russia: Final energy demand by sector, 2000-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

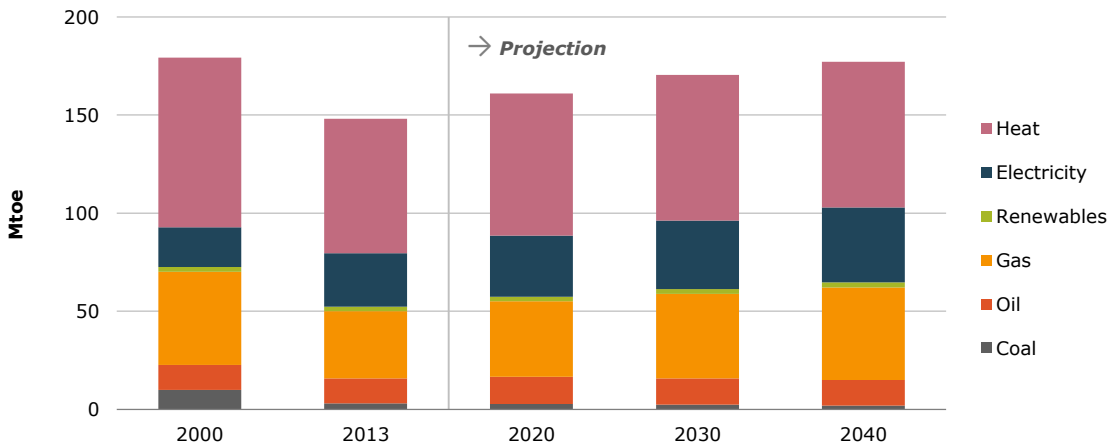
Buildings and agriculture energy use: More intensive energy efficiency and conservation programs needed

Due to Russia's extreme temperatures and cold winters, district heating is used for six to eight months each year, making energy use for buildings the highest in the Asia-Pacific Economic Cooperation (APEC) region. In 2013, 46% of final energy demand in the buildings and agriculture sector was for heating (Figure 16.2).

Russia's district heating system is characterised by insufficient heat metering: as of 2012, only 29% of buildings had heat meters (with a larger share in government buildings) (PNNL, 2012). A warmer than usual winter in 2013 and legislative obligations to install heat meters in new apartment buildings after January 2012 reduced consumption of heat, but energy consumption in buildings and agriculture is projected to increase by 20% between 2013 and 2040 despite existing energy efficiency and conservation programs.

Measures needed to reduce energy consumption in buildings include banning old lighting units and introducing LED lighting, promoting new technology platforms, encouraging the use of smart energy systems, implementing programs to improve heating use, and other energy efficiency measures in federal regions, mainly in heat supply (such as increasing penetration of heat meters and addressing 30% heat losses in district heating systems).

Figure 16.2 ● Russia: Buildings and agriculture sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

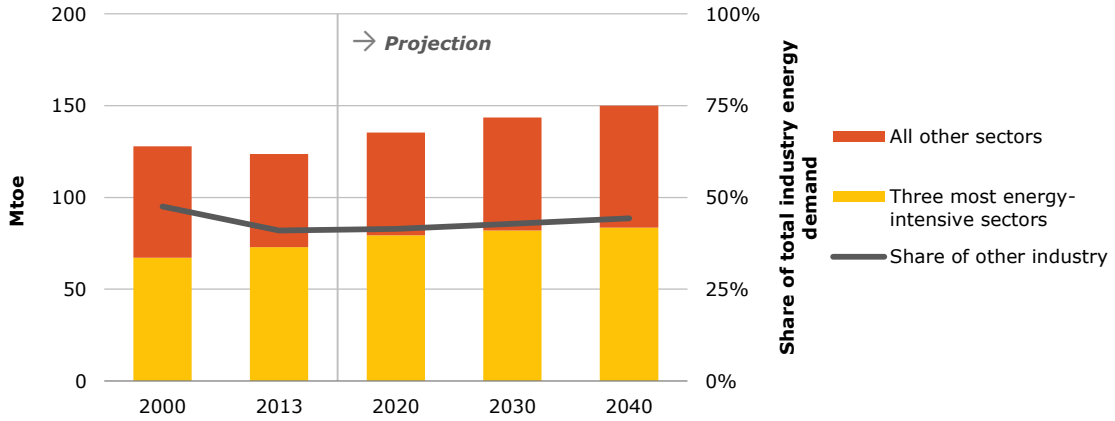
Russia has the world's largest and oldest district heating system, with centralised heat production and distribution networks in most major cities. The system has a high number of combined heat and power (CHP) installations, accounting for nearly a third of total global capacity. Given the obsolescence of the district heating infrastructure, a considerable amount of energy could be saved through relatively accessible technologies and cost-effective energy-saving practices. According to the Energy Strategy to 2030, the energy–saving potential in the district heating system is estimated to be 35% to 45% (IES, 2010).

Industry energy use: Share of the three most energy-intensive industries is one of the highest in APEC

Russia's final energy demand in industry grows by 21% over the Outlook period (Figure 16.3). Growth in the iron and steel, chemical and petrochemicals, and other industry sectors is expected to drive demand. The share of the three most energy-intensive industries in the APEC region (iron and steel, chemicals and petrochemicals, and non-metallic minerals) declines from 59% in 2013 to 56%, one of the highest shares in the APEC region.

Russia has traditionally had a strong iron and steel industry. As of 2013, it accounted for 5.6% of GDP and 4% of exports, and employed over 1 million people. In 2013, it consumed about one-quarter of industry's total final energy demand. Industrial productivity has risen sharply recently, but almost entirely on the back of higher capacity utilisation, not improved efficiency. During the Outlook period, iron and steel companies need to replace outdated, subscale steelmaking technology (such as open hearth furnaces) with more efficient technologies (such as basic oxygen furnaces and direct reduced iron).

Figure 16.3 • Russia: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.

Sources: APERC analysis and IEA (2015a).

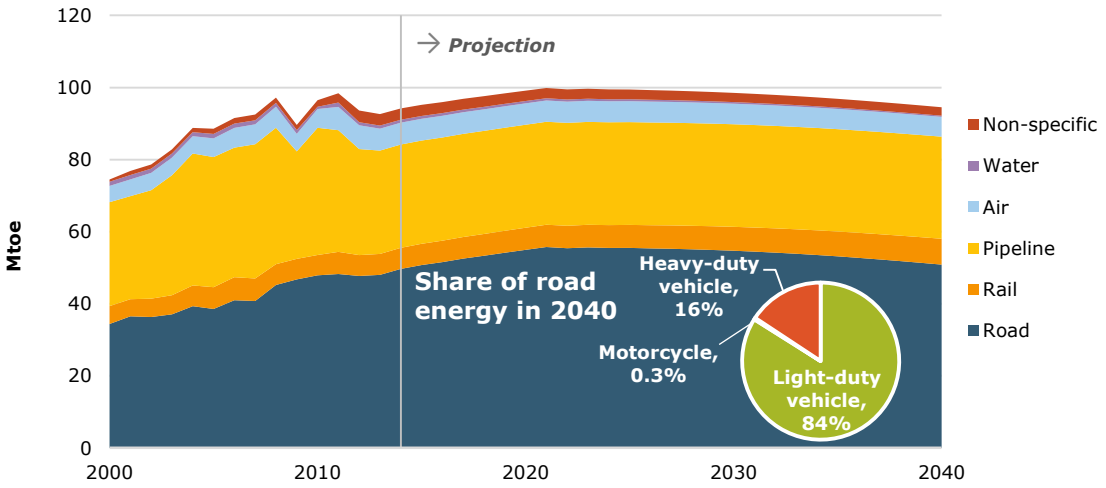
Modernisation of facilities in the cement industry, where wet kilns are still widely used, is expected to improve energy efficiency in the industry sector. Moreover, a firmly implemented policy to reduce energy subsidies and link domestic energy prices to global benchmarks is expected to provide a major stimulus for energy efficiency improvements in industry in the long term.

Stimulating the activity of energy service companies (ESCOs) in industry should be one of the major policy measures to improve energy efficiency. ESCO activities are primarily focused on public buildings and the market for industrial energy efficiency services is yet to be developed. The government should develop an appropriate infrastructure to coordinate management and monitoring of energy efficiency in industry.

Transport energy use: Energy use for pipelines is the highest in the world

Road transport continues to consume the largest share at 52% of the domestic transport sector energy demand in 2013, peaking at 56% in 2025, before declining to 54% by 2040 (Figure 16.4). Light-duty vehicles (LDVs) consume 84% of road energy in 2040. The improvement in living standards and increased vehicle ownership leads to a shift from public transport to individual passenger vehicles for commuting. Rising incomes gradually increase passenger vehicle ownership, from around 321 per 1 000 people in 2013 to about 511 per 1 000 in 2040.

Figure 16.4 ● Russia: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Pipeline transport, mainly export oil and gas pipelines, is the second-largest energy consumer in the domestic transport sector. It consumes 30% to 31% of total annual transport sector final energy demand between 2013 and 2040. Oil dominates the road transport sector, supplying 100% of energy used in 2013. As natural gas and electric vehicles become more common, oil's share declines to 98% by 2040. The underdevelopment of Russia's transport infrastructure—particularly airports and air transport facilities—poses challenges for the economy. Modernisation of air and rail transport is planned in connection with Russia's hosting of the 2018 FIFA World Cup the World Expo 2020.

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Energy production: Securing a larger share of international markets

Total primary energy production is projected to increase by 14% from 1 340 Mtoe in 2013 to 1 521 Mtoe in 2040. Natural gas accounted for the largest share of total energy production, at 42% in 2013, decreasing slightly to 41% in 2040. Large but undeveloped reserves of natural gas in remote regions of Siberia and the Far East are the reserve base for the production increase during the Outlook period.

West Siberia accounted for about two-thirds of oil production in 2013, while in 2040 most oil production is concentrated in the new deposits at prospective onshore oilfields in the Timano–Pechora and East Siberia regions, and offshore in the Arctic and Russian Far East seas and on the North Caspian shelf. With the development of new fields in these remote areas, oil production is likely to rise from 524 Mtoe in 2013 to 568 Mtoe in 2040.

Although the main coal-producing areas (the Kuznetsky and Kansko–Achinsky basins) are landlocked in the south of Siberia, 4 000 to 6 000 kilometres from the nearest coal shipping terminal for the Atlantic/Pacific markets, coal production continues to increase, exceeding 200 Mtoe a year from 2023 onwards. Enormous prospective coal deposits in Siberia, South Yakutia and the Russian Far East enable this production level to be maintained for the whole Outlook period.

Natural gas production increases at an AAGR of 0.41%, oil 0.29% and coal 0.73%. Meanwhile domestic final energy demand for gas and oil increases, while coal declines. As a result of these trends, Russia has more excess energy production in 2040 than in 2013.

Non-fossil fuel production is expected to expand by 1.4% on average per year, while fossil fuel production grows by 0.41%. Nuclear energy production is projected to grow the fastest at an AAGR of 1.9%, while other renewables have an AAGR of 0.5% and hydro an AAGR of 0.19%. With the largest land area in the world, Russia has the greatest untapped hydropower potential in the Far East, but this potential is unlikely to be developed within the Outlook period because of its remote location, far from demand centres.

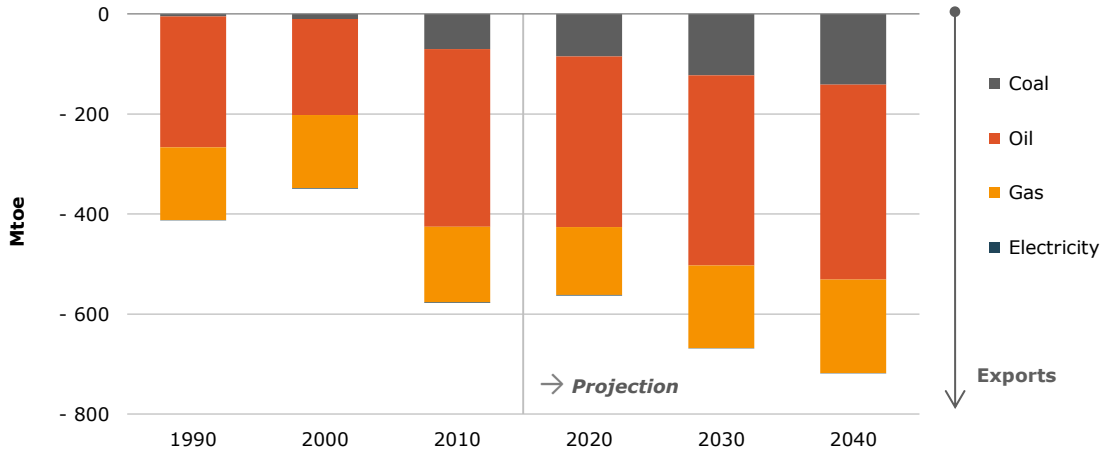
Energy trade: World's largest energy exporter

The Russian energy sector is crucial for the security of global energy supply. The economy is the world's largest exporter of energy overall, the largest exporter of natural gas, the second-largest exporter of oil, and the sixth-largest exporter of coal. In addition, Russian-produced nuclear fuel is used at more than 70 commercial reactors (or about 20% of the global market) and 30 research reactors in 17 economies and countries worldwide, and Russia provides over 40% of the world's uranium enrichment services.

In 2013, exports of crude oil, petroleum products and natural gas accounted for two-thirds of the economy's exports. Russia holds leading positions in each of the world's energy markets: 40% of uranium enrichment, about 20% of natural gas trading, almost 20% of reactor construction, 15% of spent nuclear fuel conversion, more than 10% of crude oil and petroleum products trading, and about 10% of coal trading.

Almost 90% of Russia's energy exports go to Western and Eastern Europe, including the Commonwealth of Independent States (CIS). To secure its future energy exports, since 2008 Russia has been diversifying its exports towards the Asia–Pacific region, aiming to deliver oil, natural gas and coal to China, Japan and Korea.

Figure 16.5 ● Russia: Net energy exports, 1990-2040



Sources: APERC analysis and IEA (2015a).

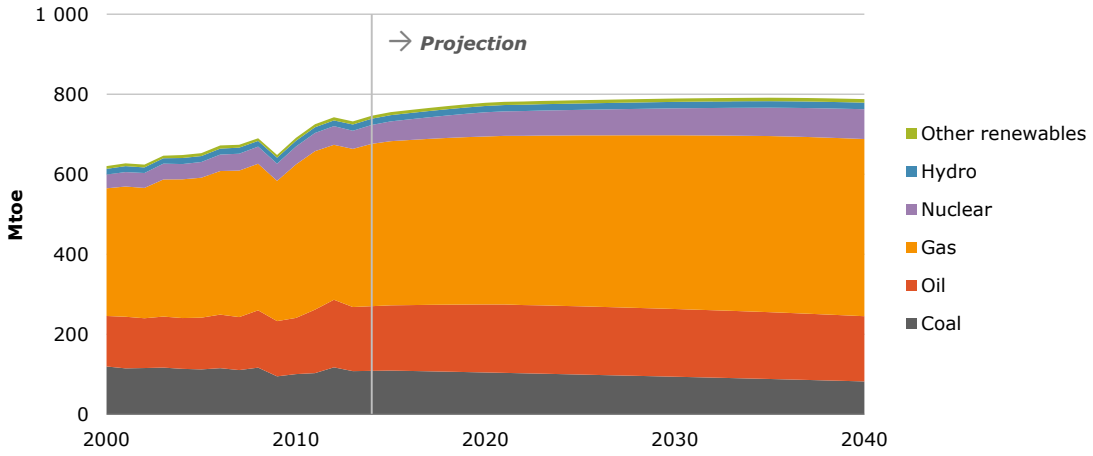
Russia is expected to continue to be one of the world's major energy exporters in the next few decades. Excess fossil fuel production is projected to be 719 Mtoe in 2040, an increase of 125 Mtoe from 2013. By 2040, Russia can supply to international markets up to 390 Mtoe of oil, 187 Mtoe of natural gas and 141 Mtoe of coal.

Given Russia's proximity to economies in north-east Asia that are expected to import most of their energy supply, there is a huge potential for Russia to meet energy demand in this region. Energy exports to Europe decline as demand falls.

Primary energy supply: Natural gas dominates TPES over the Outlook period

With the economic recession, TPES in Russia decreased from 690 Mtoe in 2008 to 647 Mtoe in 2009 before rising to 690 Mtoe in 2010 (Figure 16.6). TPES is expected to increase by 56 Mtoe over the projection period at an AAGR of 0.27%.

Figure 16.6 ● Russia: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

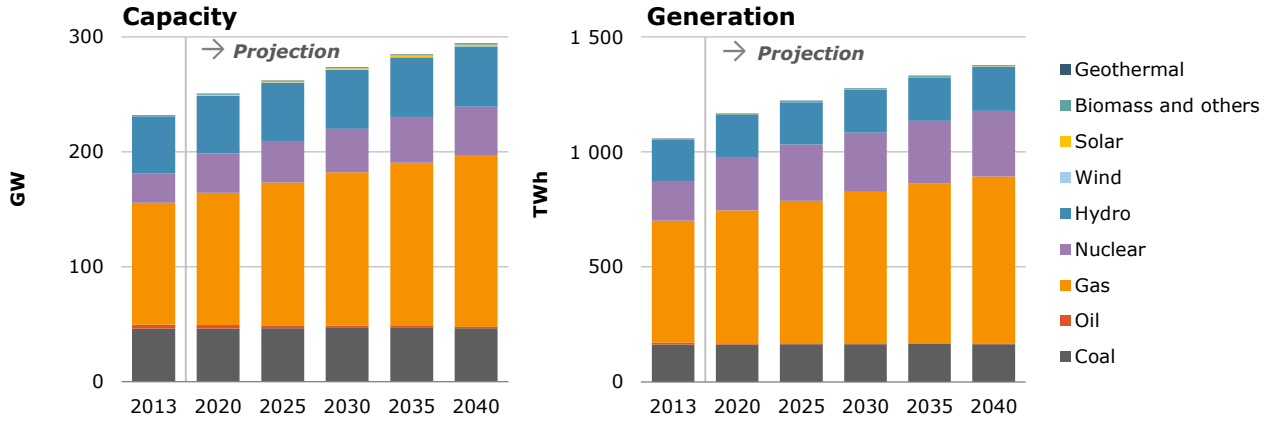
Natural gas dominates Russia's TPES at 54% in 2013, increasing slightly to 56% in 2040 at an AAGR of 0.42%. Coal consumption declines from 15% in 2013 to 11% in 2040, and oil's share declines slightly from 22% to 21% over the Outlook period. Other renewable energy expands at an AAGR of 0.52%, in contrast with coal supply which is expected to show an average decline of 1% annually.

Power sector trends: Renewables development is not sufficient

Electricity is projected to grow by 30% from 2013 to 2040. This requires the construction of 2.3 gigawatts (GW) of average annual capacity additions to increase installed generation capacity from 232 GW in 2013 to 294 GW by 2040 (Figure 16.7). Natural gas-fired generation accounts for 53% of the total power mix in 2040, followed by nuclear (21%), hydro (14%) and coal (12%). The share of electricity generated from other renewables increases from 0.32% to 0.46% over the projection period. Petroleum products conversely decline from 0.82% to 0.14% of electricity generation, but both fuel types remain the major fuel for generation in isolated areas, in particular for northern regions in the Far East. The nuclear energy share in generation increases from 16% in 2013 to 21% in 2040 as construction of projected nuclear plants is completed. Coal capacity remains flat, but electricity generation from coal rises slightly as outdated technology is replaced with more efficient units.

Under the BAU, Russia's target of a 2.5% share of renewable energy in 2020 outlined by the government is not met. Meeting these goals requires stronger measures to achieve renewable energy development targets and avoid implementation delays.

Figure 16.7 • Russia: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

All three alternative scenarios, the Improved Efficiency, the High Renewables and the Alternative Power Mix, as well as all four cases within the Alternative Power Mix Scenario, apply to Russia.[3] The four cases are the Cleaner Coal, the High Gas 50%, the High Gas 100% and the High Nuclear Cases.

The Improved Efficiency Scenario leads to the most significant reductions in energy consumption at 11% (55 Mtoe) compared with the BAU in 2040 and the highest energy-related carbon dioxide (CO_2) emissions reduction at 14% (209 million tonnes of carbon dioxide [$MtCO_2$]). The High Renewables Scenario decreases natural gas dependence by 4.9 percentage points. Within the Alternative Power Mix Scenario, the High Nuclear case has the greatest effect on CO_2 emissions intensity.

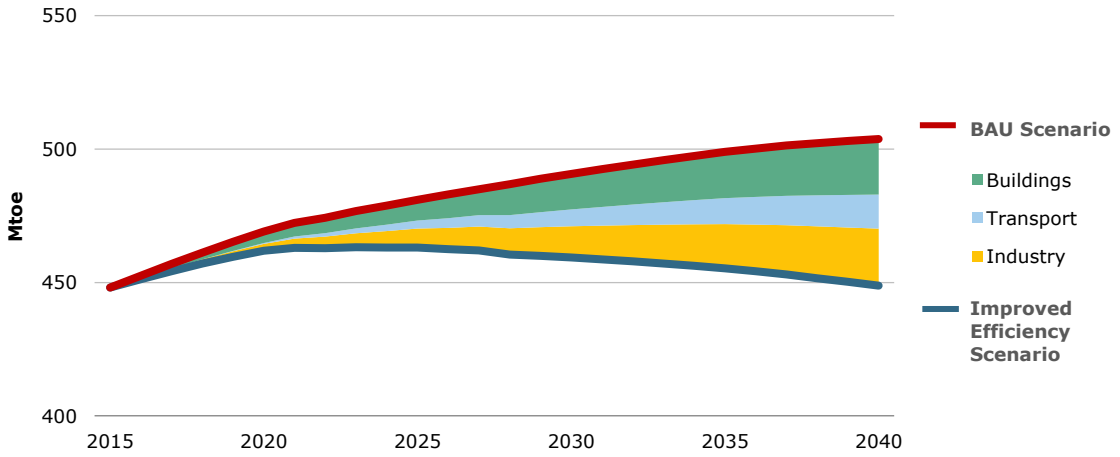
IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

The Improved Efficiency Scenario models the APEC energy intensity goal of a 45% reduction in energy intensity from 2005 levels by 2035 across all APEC economies, where energy intensity is measured as final energy in toe per unit of GDP.[4] Under the BAU, Russia reduces the energy intensity of its final energy demand by 33% between 2005 and 2035, contributing to the APEC energy intensity target. The Improved Efficiency Scenario achieves a 39% reduction by 2035 and a 43% reduction by 2040 (Figure 16.8). In absolute terms, intensity falls from 212 toe per USD million in 2005 to 130 toe per USD million in 2035 under the Improved Efficiency Scenario, an improvement of about 13 toe per USD million from the BAU.

Under the Improved Efficiency Scenario, strong energy efficiency policies across all sectors reduce energy use by 55 Mtoe by 2040, 11% lower than the BAU. The Improved Efficiency Scenario assumes higher penetration of efficient equipment in the buildings sector, mainly in the heat supply chain, with an increasing share of LED lights in the residential sub-sector. In the transport sector, savings after 2020 are due to fuel economy improvements, especially in heavy-duty vehicles, and improved road infrastructure. In the industry sector, energy use falls by 14% (21 Mtoe) compared with the BAU. The greatest savings occur in the three most energy-intensive sub-sectors (iron and steel, chemicals and petrochemicals, and non-metallic minerals), but increased energy efficiency through introducing efficient plants and equipment based on international standards is needed to achieve these savings.

[3] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.
[4] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

Figure 16.8 • Russia: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Source: APERC analysis.

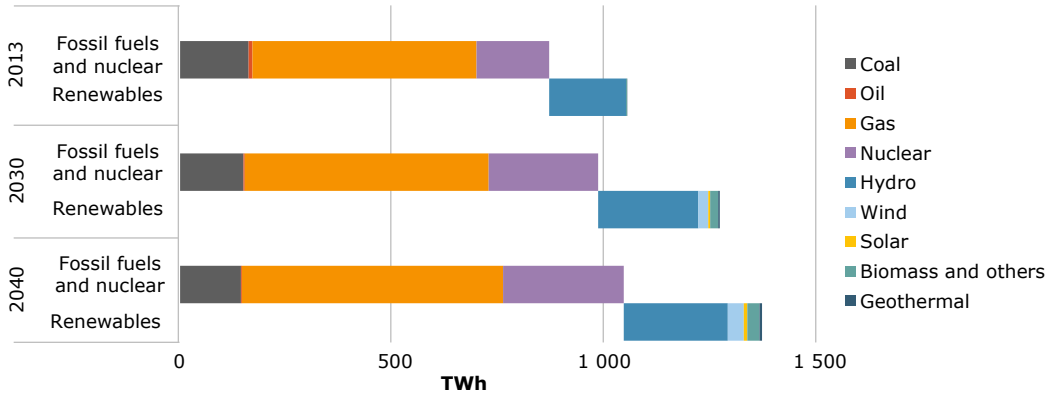
HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

The High Renewables Scenario models the APEC doubling renewable energy goal, but only for the power and transport sectors.[5] Under the BAU projections, Russia's other renewables generation increases from 3.3 terawatt-hours (TWh) in 2010 to 5.3 TWh in 2030 and 6.3 TWh in 2040.

The government's policy goals and mechanisms to promote renewable energy were first introduced in early 2009. According to the current Energy Strategy 2030, Russia's target is 4.5% of other renewables in the total generation mix by 2030. Greater support for renewable energy projects is needed to achieve the government's goals, as under the BAU other renewables only reach 0.46% of generation. Under the BAU, the share of hydro in Russia's power mix falls from 16% in 2010 to 15% by 2030 and 14% in 2040. Facilitating entrance to the wholesale electricity and capacity market and introducing power purchasing agreements for qualified renewable energy generators is forecast to result in an additional 18 GW of wind power, 5 GW of solar power, 7.2 GW of biomass power and 2.0 GW of small-scale hydro power by 2040 relative to the BAU (Figure 16.9).

Under the High Renewables Scenario, the share of renewables in TPES increases to 8.8%. In the transport sector, both the BAU and the High Renewables Scenarios project that biofuel demand reaches only 1.3% of road transport energy demand in 2040, as biofuels development has low priority in government energy policy.

Figure 16.9 • Russia: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

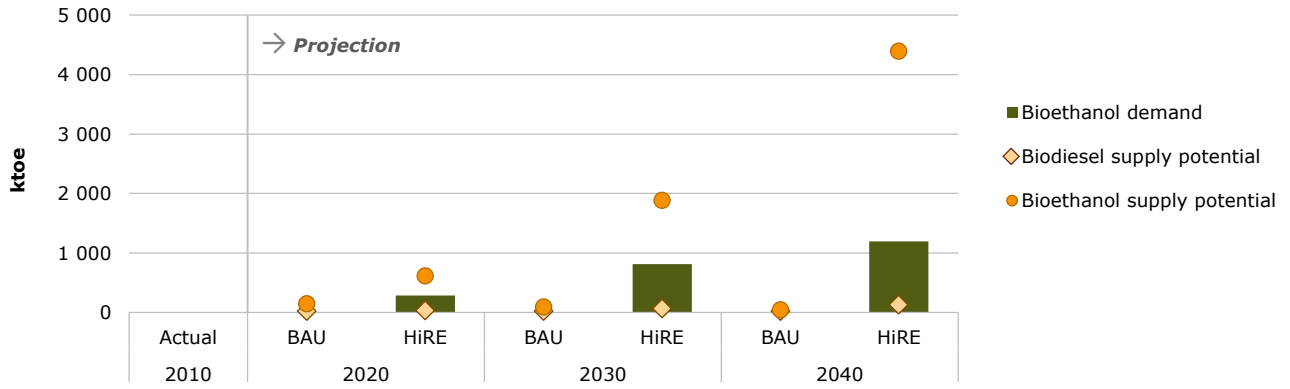
[5] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

The share of renewables in the power generation mix does not double, increasing from 17% in 2013 to only 23% in 2030 and 24% in 2040. The main growth drivers are wind with an AAGR of 31% and biomass with an AAGR of 8.8%; hydro has the highest share, rising from 17% in 2013 to 18% in 2040. Renewables development is prioritised in remote areas, where access to the centralised grid is unavailable; in areas where renewable energy generation is competitive with traditional generation; and in projects utilising the bioenergy feedstock from agriculture and farming.

Establishing a legislative base and a framework of financial incentives would support the development of renewables in power generation. A contract system should be introduced for delivery of renewable energy to the wholesale market. The government might establish a minimum level of renewable energy in generation companies' power mix, while subsidising the cost of connecting renewable energy generation facilities to the grid, with installed capacity of up to 25 megawatts (MW), especially in the Eastern Siberia and Far East regions. Regional tariff committees could regulate tariffs for purchasing electricity from renewable sources.

In the transport sector, the High Renewables Scenario does not envisage significant use of renewables. Bioethanol and biodiesel demand could reach a maximum of 4.4 Mtoe, but there are no drivers for biofuels over this level (Figure 16.10).

Figure 16.10 • Russia: Biofuels demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is for the Outlook period only; HiRE = High Renewables Scenario.

Sources: APERC analysis, FAO (2014) and IEA (2015a).

ALTERNATIVE POWER MIX SCENARIO

The Alternative Power Mix Scenario evaluates the impact of introducing high-efficient coal technologies, higher shares of natural gas (50% and 100% replacement of new coal capacity) and an expanded use of nuclear power within the electricity sector; all four cases are applicable to Russia.

The Cleaner Coal Case assumes that all new coal-based electricity generation capacity is advanced ultra-supercritical (A-USC) or integrated gasification combined cycle (IGCC) plants with a minimum efficiency of 45% to 50% from 2020. From 2030, all new plants are A-USC or IGCC and equipped with carbon capture and storage (CCS). New additions of advanced co al technologies (without CCS) amount to 17 GW in 2030, and installation of CCS-equipped advanced coal reaches 16 GW by 2040. CO_2 emissions from power generation in the Cleaner Coal Case are estimated to decline by 8.4% by 2040 compared with the BAU (Figure 16.11).

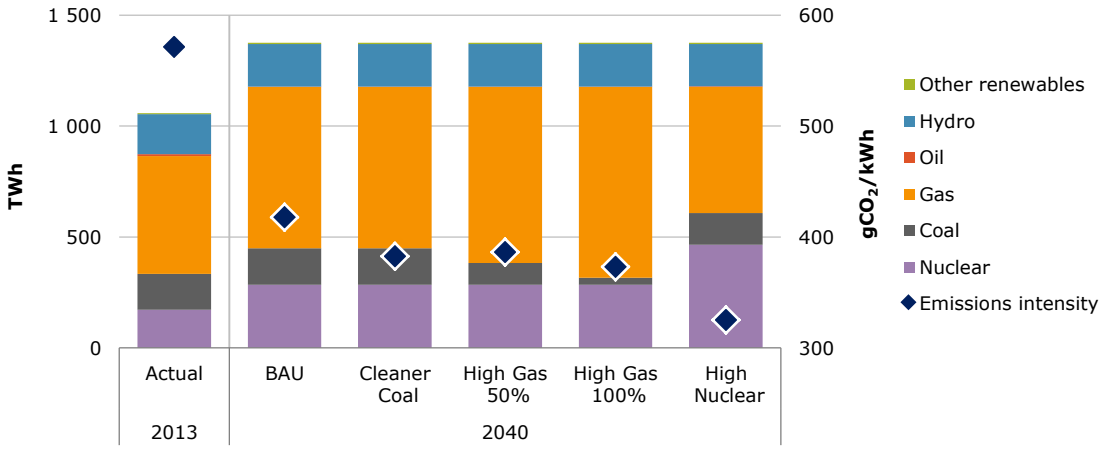
The High Gas 50% and the High Gas 100% Cases assume that new coal-based generation capacity is replaced with combined cycle gas turbines (CCGTs) from 2020, at either 50% or 100% replacement. Although natural gas provides environmental benefits because its emissions are about half those of coal, in Russia this fuel switch could weaken fuel diversification. The share of gas-fired generation in 2040

increases from 53% in the BAU Scenario to as much as 63% in the High Gas 100% Case, resulting in emissions reductions of 11%.

In the High Nuclear Case, Russia would maintain global leadership in advanced technologies, competencies and innovation—the stated goal of Rosatom, the key corporation in the Russian nuclear sector. Compared with the BAU, the share of nuclear in the power generation mix increases from 21% to 34% in 2040 under the High Nuclear Case, with installed nuclear capacity reaching 68 GW in 2040 compared with 42 GW in the BAU. The larger nuclear share would lower natural gas generation, reducing power sector related CO_2 emissions by 22% compared with the BAU in 2040.

Russia's average power generation costs would continue to be among the lowest in the APEC region, at USD 76 per megawatt-hour (MWh) by 2040 in the High Gas 100% Case, USD 73/MWh by 2040 in the Cleaner Coal Case and USD 72/MWh by 2040 in the High Nuclear Case.

Figure 16.11 ● Russia: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

The flow of investment into the energy sector would be facilitated if Russia improved investor confidence by normalising relations with European and North American partners, and by ensuring the stability of Russian institutional arrangements and transparency of the energy markets.

From 2015 to 2040, Russia's total investment ranges from USD 2 076 billion in the low-cost estimate to USD 4 009 billion in the high-cost estimate (Table 16.4). As Russia is one of the top producers of oil and gas, upstream requires 70% of the total investment. As a support facility to upstream, domestic energy transport for oil, gas and coal (from source to ports or end-use facility) receives 7.3% to 9.2% of the total. Power requires 16% to 19% of total investment to add 63 GW of new generation capacity and to expand and refurbish transmission and distribution networks. Investment in downstream obtains the smallest share at 3.4% to 5.1% to fund 742 000 barrels per day (bbl/d) of refinery capacity and 56 Mt per year of LNG export terminal capacity.

In the Improved Efficiency Scenario, investment drops by 11% compared with the BAU, leading to USD 226 billion in savings (Figure 16.12). The energy transport sector contributes most of the reduction, dropping by 49% due to lower requirements for energy transport infrastructure with lower production. The downstream sector realises 15% savings due to a 10% decrease in refinery capacity and 16%

decrease in LNG export terminal capacity additions from the BAU levels. Investment savings of 15% in the power sector are due to a decrease in generation capacity additions, coupled with less expansion of transmission and distribution networks. The upstream sector exhibits 5.7% savings from the BAU due to lower demand for fossil fuels.

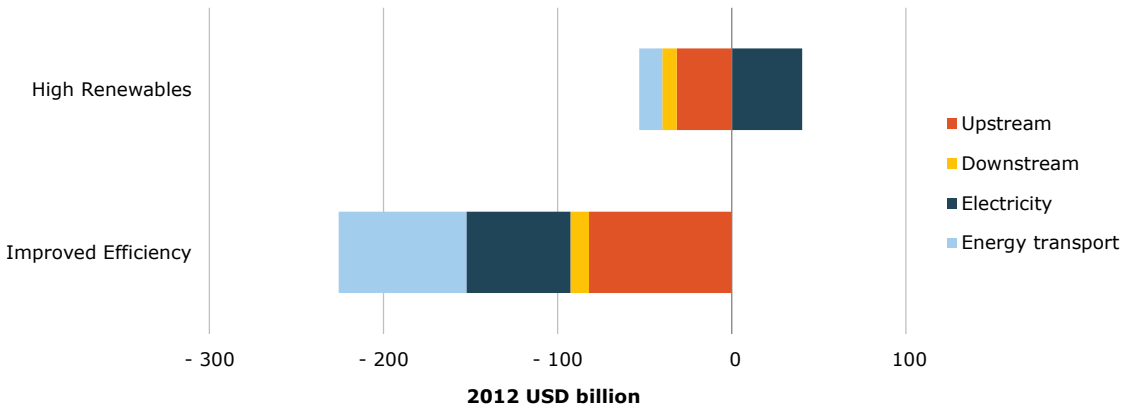
Table 16.4 ● Russia: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	1 046	1 568
	Gas	302	907
	Coal	101	330
	Subtotal	1 449	2 805
Downstream	Refinery	16	104
	LNG export terminals	56	100
	Subtotal	71	204
Electricity	Nuclear	115	137
	Coal	63	130
	Gas	78	96
	Hydro	2.4	7.9
	Wind	0.3	0.7
	Solar	2.9	4.1
	Biomass and others	0.6	0.8
	Geothermal	0.1	0.1
	Transmission lines	29	91
	Distribution lines	113	165
	Subtotal	404	633
Energy transport	Oil	37	73
	Gas	99	276
	Coal	15	18
	Subtotal	151	367
	Total	**2 076**	**4 009**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

Figure 16.12 ● Russia: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.

Source: APERC analysis.

In the High Renewables Scenario, investment is 0.61% lower than in the BAU. A major reduction of 8.7% in energy transport is due to a decline in investment for gas and oil pipelines. Investment in the downstream sector falls by 12% as bioethanol blends displace oil, lowering the need for oil refinery additions, and reduced gas production leads to a decrease in LNG export terminals. Upstream investment is down 2.2% compared with the BAU as renewables displace coal, and gas power plants that reduce fossil fuel demand. However, power sector investment is up by 10% due to an 11-fold increase in renewable capacity additions from the BAU. Solar makes up 7.5% of the capacity additions and wind 21%, supported by declining capital costs from 2015 to 2040.

SUSTAINABLE ENERGY FUTURE

Since 2000, Russia's energy policy has been oriented towards integration into the world's energy markets, strengthening Russia's position in those markets and maximising the benefits of energy resources to the economy. During the Outlook period, Russia implements a number of measures to improve the security of domestic energy consumption and energy export obligations, and makes efficiency improvements along the entire energy supply chain. Russia needs to rehabilitate, modernise and develop its energy infrastructure, including building additional trunk oil and gas pipelines to increase energy export capacity, especially to Asia. To better integrate Russia into the world energy markets, export delivery markets need to be diversified.

Enhancing energy security: Self-sufficiency is at maximum levels

Russia's energy self-sufficiency rate continues to be 100% over the projection period. Among the Alternative Scenarios, the High Renewables Scenario is expected to show the best TPES diversity (HHI 0.33) and electricity generation input fuel diversity (HHI 0.35), compared with the BAU at HHI 0.38 and HHI 0.42, where a lower number indicates greater diversity (Table 16.5). The High Nuclear Case follows at HHI 0.34 for primary energy supply diversity and HHI 0.36 for electricity generation input fuel diversity in 2040. Under the High Gas 100% Case, fuel diversity is HHI 0.42 by 2040 and electricity generation input fuel diversity is HHI 0.51, which does not affect energy security as domestic natural gas is abundant.

Table 16.5 • Russia: Energy security indicators, 2013 and 2040

	2013	2040						
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%	High Nuclear
Primary energy supply diversity (HHI)	0.37	0.38	0.37	0.33	0.38	0.40	0.42	0.34
Primary energy supply self-sufficiency (%)	100	100	100	100	100	100	100	100
Coal self-sufficiency (%)	100	100	100	100	100	100	100	100
Oil self-sufficiency (%)	100	100	100	100	100	100	100	100
Gas self-sufficiency (%)	100	100	100	100	100	100	100	100
Electricity generation input fuel diversity (HHI)	0.41	0.42	0.39	0.35	0.43	0.45	0.51	0.36

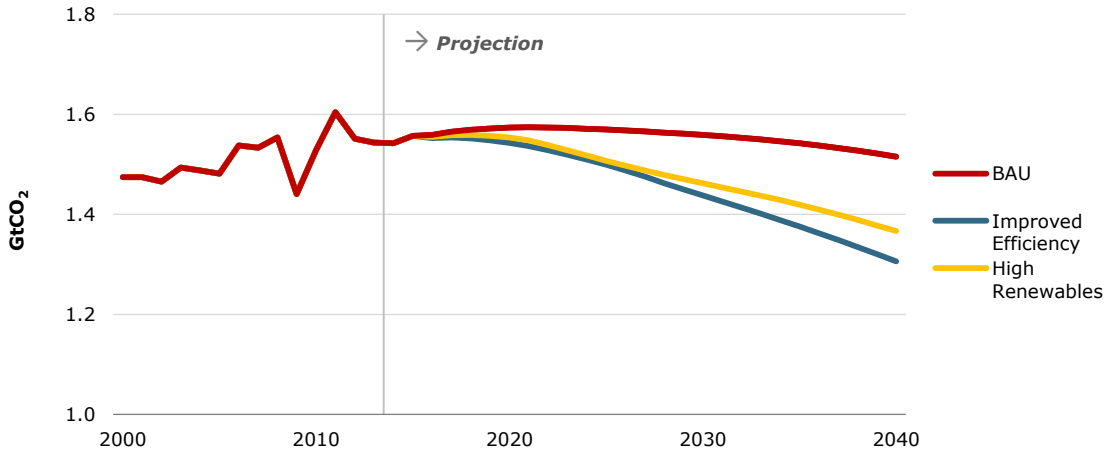
Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

Climate change impacts and risks: Policy not enough to meet the INDC target

According to its Climate Doctrine and Energy Strategy, Russia will adopt legislation and regulations to achieve its stated INDC target by 2030. In its economy-wide INDC, Russia proposes to reduce net GHG emissions by 25% to 30% below the 1990 level by 2030. After accounting for forestry, this is a reduction of only 6% to 11% below the 1990 level of industrial GHG emissions, and an increase of 30% to 38% compared with the 2012 level.

Under the BAU Scenario, the reduction in energy-related CO_2 emissions reaches 28% by 2030 (compared with the 1990 level), contributing to the economy-wide total GHG emissions INDC target (Figure 16.13). The Improved Efficiency and High Renewables Scenarios show larger reductions than the BAU, with the largest reductions estimated at 7.8% by 2030 in the Improved Efficiency Scenario, followed by 6.2% in the High Renewables Scenario.

Figure 16.13 ● Russia: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

RECOMMENDATIONS FOR POLICY ACTION

The Russian government has initiated policies to improve energy efficiency, especially in the buildings sector, and to further promote natural gas and nuclear energy for power generation. However, the BAU Scenario analysis shows that these efforts are insufficient.

To strengthen Russia's energy sector, it is necessary to further deepen international cooperation, expanding into Asia-Pacific energy markets and diversifying energy export products, routes and destinations. Enhanced integration with international business can provide access to capital and technologies. Liberalising domestic energy markets would stimulate competition in the sector, which would in turn bring investments to upgrade ageing infrastructure for district heating, thermal power generation, gas and oil pipelines, and railways. Government should accelerate modernisation of the domestic heating market, further developing its 'alternative boiler' strategy to address the sector's inefficiencies and introduce fair market pricing. Liberalisation benefited the domestic electricity market, which attracted investment for its most recent capacity additions.

Recent electricity blackouts and extreme weather events in Russia have highlighted some of its vulnerabilities, which require Russia to develop integrated approaches to energy security policies. Encouraging renewables requires economy-wide support and improved market entry conditions. For example, the government should consider improving regulations on biofuels taxation, especially bioethanol, to make biofuels more cost-competitive. Another long-term policy option for Russia is to invest in human resource capital in the energy sector, as establishing a strong base of skilled engineers, project managers and energy experts is vital.

These recommendations are in line with the innovative energy development scenario described in the draft Energy Strategy 2035 (of early 2016), in which advances in both energy demand and supply are achieved through accelerated equipment upgrades.

17. SINGAPORE

KEY FINDINGS

- **Singapore's power mix is dominated by gas (95.5% in the first quarter of 2015),** with an insignificant and declining share for oil (0.5%, first quarter of 2015), and a small share of renewables (3.9%, first quarter of 2015). Under the BAU Scenario, gas totally replaces oil by 2040 while renewables' share changes little.

- **Singapore's geographical and geological limitations–particularly scarcity of land–confine its options for renewables** to a small amount of solar energy and waste-to-energy, which accounts for the majority of renewables over the Outlook period.

- **The inauguration of Singapore's LNG terminal in May 2013 has helped it to expand the share of gas in its power mix and improve its energy security** by diversifying its gas supplies and supply routes, formerly fully dominated by piped gas from Malaysia and Indonesia. This dependence is set to completely end by 2030.

- **The Improved Efficiency Scenario offers the largest reduction in energy-related CO_2 emissions in the energy sector** at nearly 7.3% compared with the BAU Scenario in 2040.

ECONOMY AND ENERGY OVERVIEW

Singapore has a vibrant and robust economy. Gross domestic product (GDP), which has grown steadily since the economy's independence in 1965, is expected to increase by 1.5 times between 2013 and 2040, from USD 346 billion to USD 505 billion. Such expansion and population growth of about 15% are projected to increase total final energy demand by 15%, from 20 million tonnes of oil equivalent (Mtoe) in 2013 to 23 Mtoe in 2040.

Singapore is 100% dependent on imports of oil and gas for domestic consumption, including power generation and supplying oil refineries. Refined products are mainly exported to the Asia-Pacific Economic Cooperation (APEC) region (Box 17.1). Land scarcity and absence of suitable geological conditions exclude renewables[1] as a major option to diversify Singapore's energy supplies, including for the power mix. Apart from a limited expansion of grid-connected rooftop solar photovoltaic (PV) installations (636 solar PV installations with a combined capacity of 26 megawatts alternating current (MW_{ac}) in 2014), waste-to-energy is the main renewable energy source in use, accounting for 3.7% of Singapore's power mix in 2014 (EMA, 2015a). Singapore has currently excluded nuclear energy as a way of decreasing its heavy reliance on fossil energy because of concerns over the safety of existing nuclear energy technologies.

Table 17.1 ● Singapore: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	87	169	306	346	405	469	505
Population (million)	3.0	3.9	5.1	5.4	5.7	6.0	6.2
GDP per capita (2012 USD PPP)	28 703	43 212	60 269	63 979	71 743	78 175	82 053
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	12	19	25	26	30	31	32
TPES per capita (toe)	3.8	4.8	5.0	4.8	5.2	5.2	5.2
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	5.0	8.3	15	20	21	23	23
Final energy intensity per GDP (toe per 2012 USD million PPP)	58	49	50	57	53	48	46
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	29	42	44	47	48	51	53
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	100	100	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

The driving forces behind Singapore's energy use are industry (particularly chemicals and petrochemicals), oil refineries, transport (land, sea and air) and buildings (residential and commercial). There is no commercial-scale agriculture.

Singapore's domestic energy consumption, as evident in total final energy demand (TFED) (20 Mtoe, 2013), is significantly smaller than total primary energy supply (TPES) (26 Mtoe) thanks to the large oil refining sector. This sector, a major source of revenue for the economy, exports the bulk of its products (51 Mtoe in 2013) to the Asia-Pacific market (EMA, 2015a). Singapore's status as a hub of global shipping and aviation demands a large amount of bunker and jet fuels, which represent two major

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

products of the three refineries and an important source of income. Hence, energy plays a major role in Singapore's economy, not only as a necessity for fuelling the growing economy, meeting population demand and supporting Singapore's transport role, but also as a major export item in the form of refined products.

ENERGY POLICY CONTEXT

Singapore's 2007 National Energy Report sets out strategies[2] to balance the objectives of energy security, economic competitiveness and environmental sustainability (MTI, 2007). As stressed by the then-Minister of State for Trade and Industry, Mr Teo Ser Luck, in 2015 (MTI, 2015), Singapore has since sought to secure this balance through a range of measures. To end total dependence on piped imports from Malaysia and Indonesia for gas requirements–which accounted for 96% of its power mix in 2015 (EMA, 2015a)–Singapore began operating its first liquefied natural gas (LNG) terminal in May 2013 (SLNG, 2014). This has enabled it to diversify gas suppliers by importing LNG from Australia, Equatorial Guinea, and Trinidad and Tobago (MTI, 2015) while securing additional gas for growing gas demand and adding LNG to the energy mix. The Phase 3 Engineering, Procurement and Construction contract awarded to Samsung C&T Corporation in 2014 will expand Singapore's send-out LNG capacity from 6 million tonnes per annum (Mtpa) to around 11 Mtpa by 2017. A fourth storage tank of 260 000 cubic metres will be added by 2018 (MTI, 2014a).

Singapore is exploring further ways of diversifying the energy mix by scaling up deployment of solar PV panels, regarded as the 'most economically and technically viable renewable energy option' (MTI, 2015). It has launched the SolarNova Programme to aggregate demand for solar energy 'across government buildings and spaces, to yield savings from economies of scale' while seeking to 'demonstrate solar energy's viability in Singapore [to] catalyse further adoption by the private sector' (MTI, 2015).

Singapore is also intensifying efforts to promote more efficient energy use and decrease carbon dioxide (CO_2) emissions. As part of its contribution to the post-2020 climate change agreement, Singapore intends to 'reduce its emissions intensity by 36% from 2005 levels by 2030 and to stabilise [GHG] emissions with the aim of peaking around 2030' (UNFCCC, 2015). This is a remarkable objective as Singapore is already one of the least carbon-intensive economies in the world, ranking 123th out of 142 countries (NCCS, 2015). One key strategy is to improve energy efficiency to reduce the carbon footprint and help 'businesses and households save costs' (MTI, 2015).

Singapore continues to invest in research, development and demonstration (RD&D) of innovative energy technologies to help achieve its energy objectives (MTI, 2015). The Energy National Innovation Challenge (ENIC) seeks to 'find and deploy cost-competitive energy solutions that improve energy efficiency, reduce carbon emissions and broaden energy options'. It is complemented by the Energy Strategic Research Programme (ESRP), aimed at developing 'the clean energy industry by building a vibrant clean energy ecosystem with a critical mass of companies, skilled manpower and R&D capabilities' (MTI, 2015).

BUSINESS-AS-USUAL SCENARIO

This section illustrates energy demand and supply in the Business-as-Usual (BAU) Scenario and summarises the key assumptions and existing government policies included in the BAU analysis (Table 17.2). The definition of the BAU Scenario and the modelling assumptions used in this Outlook are different from those used by the government for its projections, targets and analysis.

[2] Diversify Energy Supplies; Enhance Infrastructure and Systems; Improve Energy Efficiency; Strengthen the Green Economy; Pricing Energy Right.

Table 17.2 • Singapore: Key assumptions and policy drivers under the BAU Scenario

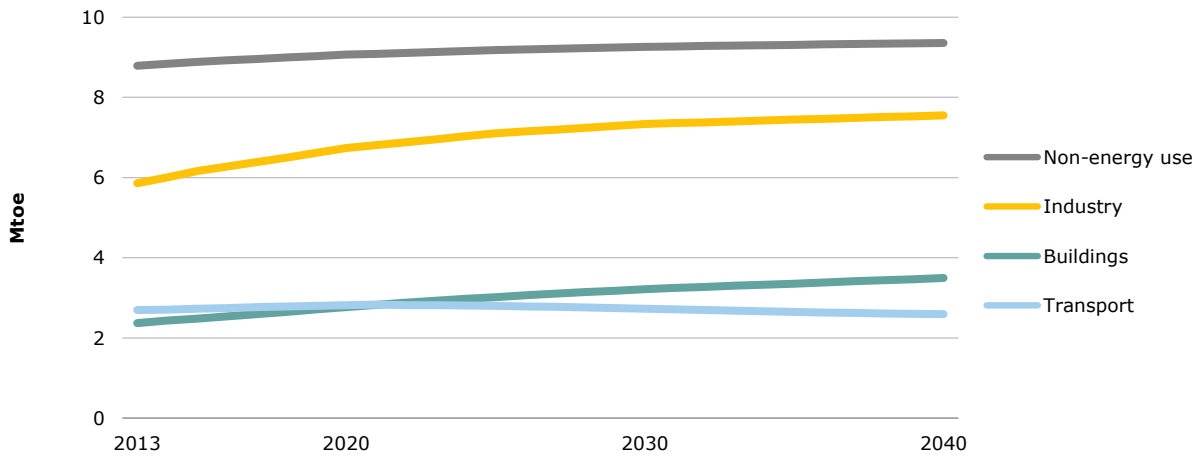
Buildings and industry	• Continued improvement due to various programs targeting these sectors.
Domestic transport	• Extensive expansion of the Mass Rapid Transit (MRT) system to discourage rapid growth of vehicles.
Energy supply mix	• Oil and gas imports continue to increase. • LNG ends 100% dependence on imported piped gas.
Power mix	• No coal or nuclear power plants. • Very limited solar contribution. • Waste-to-energy as the bulk of renewables.
Renewable energy	• Waste-to-energy remains the main fuel. • Rooftop solar PV penetration increases to 600 megawatts peak demand (MW_P).
Energy security	• Singapore relies on 60 days of fuel reserves held by generation companies (gencos) as alternative fuel sources for the gencos during contingencies.
Climate change	• Limited decrease in CO_2 emissions due to heavy dependence on fossil energy because of geographical/geological limitations.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Singapore's TFED under the BAU increases by 15%, from 20 Mtoe in 2013 to 23 Mtoe in 2040, reflecting an average annual increase of 0.55%. The major contributing factor is the growth in demand from the non-energy sector, which accounts for the highest share of the economy's TFED. From 2013 to 2040, this sector's share decreases from over 45% to 41% while preserving its largest share of the economy's TFED. Industry's share increases from almost 30% to 33% and buildings' share from over 12% to more than 15% in the same period, while domestic transport's share drops from 14% to 11%.[3]

Figure 17.1 • Singapore: Final energy demand by sector, 2013-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

With the exception of the transport sector, energy demand increases steadily: the non-energy sector from 8.8 Mtoe to 9.4 Mtoe, as oil refineries expand their operations; industry from 5.9 Mtoe to 7.6 Mtoe, driven by Singapore's vibrant chemical and petrochemical industries; and buildings (residential and commercial combined) from 2.4 Mtoe to 3.5 Mtoe, as the sector grows. Transport energy demand gradually decreases from 2.7 Mtoe in 2013 to 2.6 Mtoe in 2040. Singapore's efforts to decrease CO_2

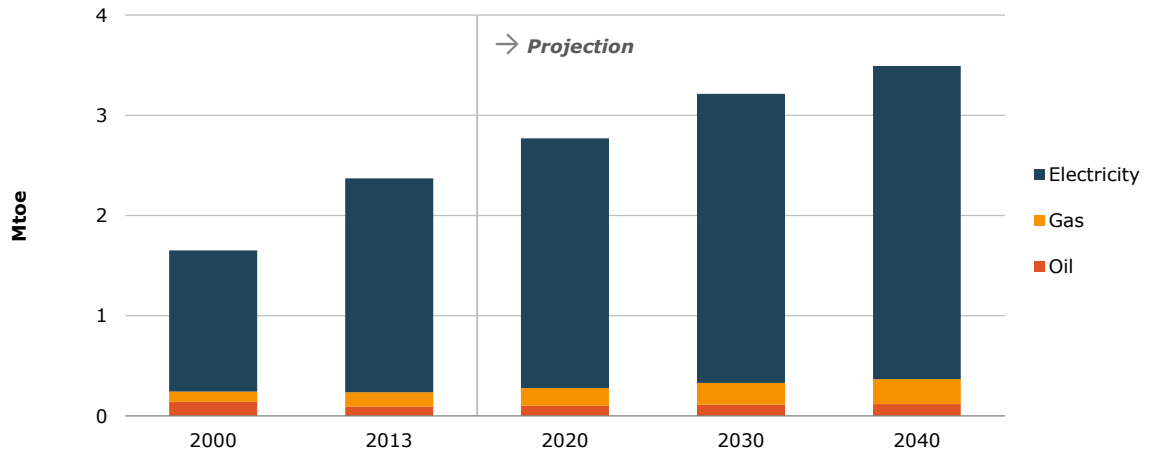
[3] Shares do not include international transport final energy demand.

emissions by discouraging private ownership of vehicles in favour of the efficient and expanding public transit system is the main contributing factor (LTA, 2015).

Buildings energy use: Increasing energy demand and improving efficiency

Under the BAU, energy demand in the buildings sector consisting of commercial and residential grows significantly, from 2.4 Mtoe (2013) to 3.5 Mtoe (2040), an increase of about 46%. The contributing factors include population growth, greater demand for electronics and appliances because of rising living standards, and growth in GDP of almost 46%.

Figure 17.2 ● Singapore: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Commercial buildings account for the bulk of the sector's energy demand (74%), an increase of nearly 3.5% over the 2013 share, which is matched by an equal decrease in residential buildings' share. Singapore's growing importance as an Asia-Pacific hub–especially for energy, trade, tourism, shipping, aviation and high-value-added manufacturing products–ensures that commercial buildings retain a dominant and growing share of the sector's energy demand.

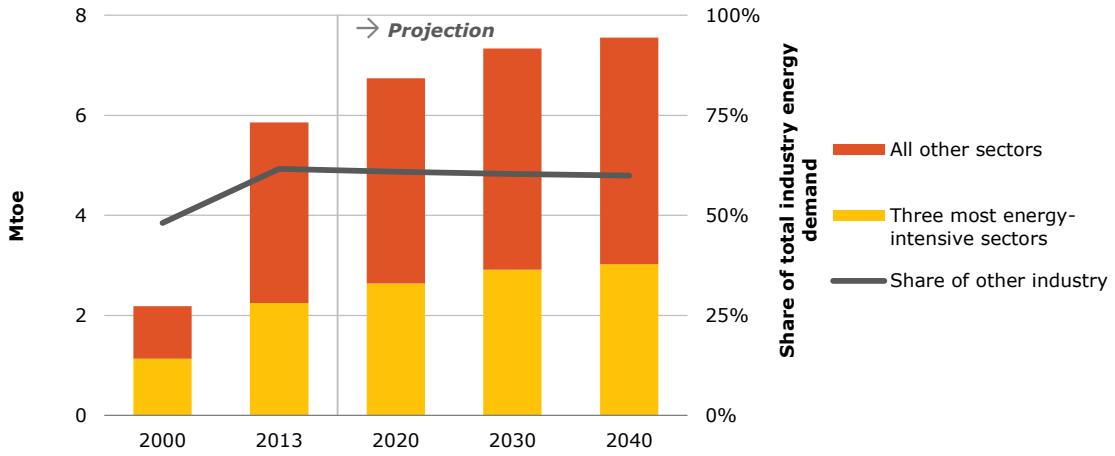
In terms of energy sources, electricity decreases its share of sectoral demand by over 1% to 89% in 2040, leaving small shares for gas (7.2%) and oil (3.4%). In 2013, the shares of oil and gas were 4.1% each. These developments reflect Singapore's efforts to decrease its carbon footprint by encouraging the consumption of cleaner energy rather than oil and by increasing fuel efficiency, with gas now accounting for over 95% of the power mix (EMA, 2015a).

As part of a policy of decreasing CO_2 emissions through improving energy efficiency, in 2012 Singapore introduced legislation aimed at achieving a sustainable building environment and ensuring the continuity of efficient operation of existing buildings throughout their life cycle (EES, 2015a). Part IIIB of the Building Control Act 2012 and the Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations 2013 require building owners to comply with the minimum environmental sustainability standard (Green Mark Standard) for existing buildings when replacing/installing building cooling systems and to submit periodic energy efficiency audits of building cooling systems. This is in addition to the Building Control (Environmental Sustainability) Regulations of 2008 requiring large buildings to meet a basic Green Mark standard covering five key criteria (energy efficiency, water efficiency, environmental protection, indoor environmental quality and other green features) to help reduce total energy used in Green Mark certified buildings (EES, 2015a).

Industry energy use: Expansion with growing energy efficiency

Singapore has a robust and vibrant industrial sector, which grew by more than 168% between 2000 and 2013. Construction is mainly domestic, while manufacturing is primarily export-oriented. The major manufacturing industries are chemical, petrochemical, biomedical, electronics and shipbuilding (MTI, 2014b). Singapore's industrial sector energy demand is projected to increase by about 29% from 5.9 Mtoe in 2013 to 7.6 Mtoe in 2040. This represents a projected annual growth rate of 0.95%.

Figure 17.3 • Singapore: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors across the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.
Sources: APERC analysis and IEA (2015a).

Factors contributing to this growth include an improvement in the sector's energy intensity from roughly 17 tonnes of oil equivalent (toe) per USD million in 2013 to 15 toe per USD million in 2040, as a result of energy efficiency advances. The sector's energy efficiency capability has been built up by government initiatives introduced since 2010, including the Energy Efficiency National Partnership (EENP) program, the Energy Efficiency Improvement Assistance Scheme (EASe), the Grant for Energy Efficient Technologies (GREET) incentive scheme and incentive schemes for small and medium-sized enterprises (SMEs) (EES, 2015b). Singapore intensified such efforts in 2013 when it required energy-intensive industrial companies consuming 54 terajoules (TJ) of energy or more a year to comply with the Mandatory Energy Management Requirements (EES, 2015b).

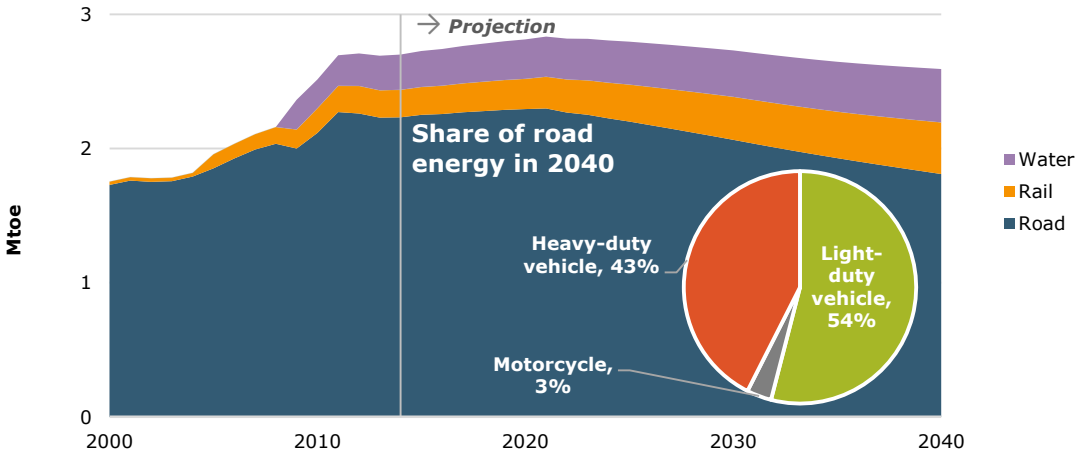
EENP, a voluntary partnership program, is designed to help companies wishing to be more energy efficient to improve their long-term business competitiveness and reduce their carbon footprint (EES, 2015b). As of April 2013, Singapore's energy-intensive industries are required under the Energy Conservation Act to register with the National Environment Agency within six months of qualifying as a registrable corporation and to implement mandatory energy management practices: appointing an energy manager; monitoring and reporting energy use and GHG emissions annually; and submitting energy efficiency improvement plans annually (EES, 2015b).

The chemicals and petrochemicals sub-sector is the single largest industrial energy consumer; its energy demand increases by 1.1% a year, from 2.2 Mtoe in 2013 to 3 Mtoe in 2040. The sub-sector's share of industrial energy demand marginally increases from over 38% to 40%, while that of all other industry decreases slightly, from 62% to 60%, reflecting continuity in the structure of Singapore's industry. Energy demand from all other industry grows from 3.6 Mtoe to 4.5 Mtoe. In descending order, the major contributing industries are pharmaceutical and biotech, electronics, and environment and water.

Transport energy use: Favouring light rail

The domestic transport sector's energy demand is projected to decline by more than 3.7% from 2013 to reach 2.6 Mtoe in 2040. Road transport, which accounts for the bulk of sectoral demand, is projected to reduce its share of this demand from over 83% in 2013 (2.2 Mtoe) to 70% in 2040 (1.8 Mtoe). This is the result of Singapore's efforts to decrease the role of private vehicles in favour of more fuel-efficient light rail (MRT) as part of its commitment to curbing global warming. This objective is reflected in MRT's increasing energy demand from 0.2 Mtoe in 2013 to 0.38 Mtoe in 2040, as its share of domestic transport grows from 7.6% to 15%. It is also reflected in a significant drop in light-duty vehicles (LDVs) energy demand, from 1.3 Mtoe to 0.98 Mtoe. Singapore is currently constructing new MRT lines (Downtown Line, Downtown Line 3 Extension, Thomson-East Coast Line and Tuas West Extension) while adding new stations to existing lines (LTA, 2015). In terms of energy sources, oil continues to account for the bulk of Singapore's domestic transport demand, dropping slightly from 2.5 Mtoe to 2.1 Mtoe, followed by electricity, for which demand increases from 0.2 Mtoe to 0.42 Mtoe as the MRT expands. Gas is projected to claim a small share from 2022 (0.051 Mtoe) as Singapore seeks to switch to less polluting fuels for LDVs.

Figure 17.4 • Singapore: Domestic transport sector final energy demand, 2000-40



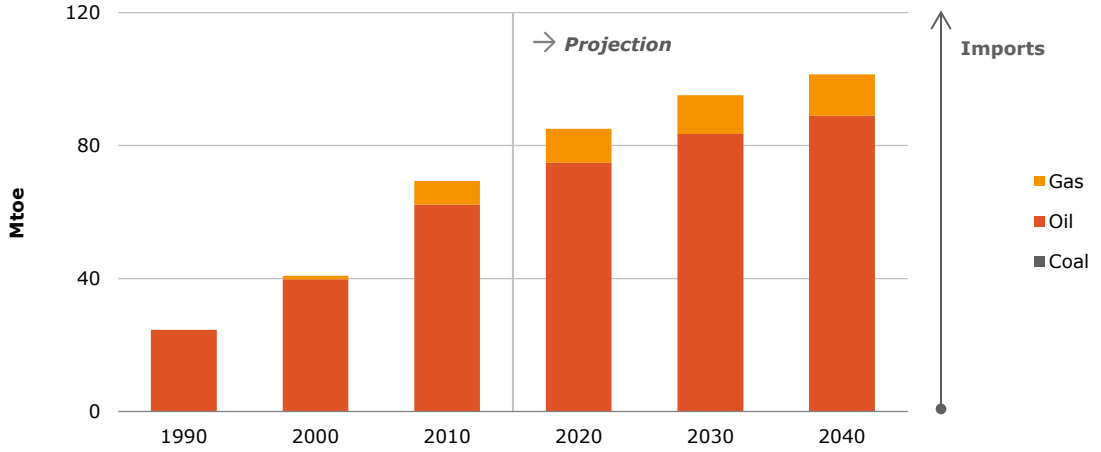
Sources: APERC analysis and IEA (2015a).

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Lacking domestic fossil energy resources, Singapore imports 100% of its demand for oil and gas. Total energy imports are expected to rise by 38% from 73 Mtoe in 2013 to 101 Mtoe in 2040. Oil's share of total imports, which was 88% in 2013 (64 Mtoe), is expected to remain at this level through to 2040 (89 Mtoe). Gas imports are projected to rise by nearly 39% from 8.9 Mtoe to 12 Mtoe. This huge increase is due to Singapore's efforts to diversify energy demand for a host of reasons, including improving energy security by ending reliance on oil, and curbing global warming by decreasing CO_2 emissions.

The bulk of Singapore's oil imports feeds the vibrant refining sector, with refined products mainly exported. Singapore has greatly diversified its oil suppliers, importing oil from around 40 economies and countries to ensure supply security under worst-case scenarios by avoiding over-reliance on any single region and supplier. It now imports from the Middle East, particularly the Persian Gulf (e.g. Saudi Arabia), North Africa (e.g. Algeria) and the Asia-Pacific region (e.g. Malaysia). Given that Singapore has no piped oil imports, it depends on tankers for all oil imports, so the security of importing sea routes remains a major concern.

Figure 17.5 • Singapore: Net energy imports, 1990-2040



Sources: APERC analysis and IEA (2015a).

Unlike oil imports, gas imports are only for domestic consumption. Significant gas imports started in 2000 (1.1 Mtoe), rose to 8.9 Mtoe in 2013, and are projected to further rise to 12 Mtoe in 2040. Singapore ended an exclusive dependence on imported piped gas from neighbouring Malaysia and Indonesia in May 2013 when an LNG regasification plant went on line. As well as improving energy security, this has helped the economy to increase gas consumption, particularly for power generation: gas accounts for 95.5% of the power mix (1Q 2015) (EMA, 2015a). Major LNG suppliers are Australia, Equatorial Guinea, and Trinidad and Tobago (MTI, 2015a). Singapore is expanding the LNG terminal's storage capacity from 6 Mtpa to around 11 Mtpa to enable it to meet domestic demand while leaving a substantial amount for potential re-exports (MTI, 2015a).

Box 17.1 • Singapore's oil refineries

Singapore is completely dependent on imports of oil for domestic consumption and for oil refineries. The bulk of the significant oil imports (64 Mtoe in 2013 and 89 Mtoe in 2040) feed the three refineries, which belong to ExxonMobil, Shell and Singapore Refining Corporation. Their products are mainly exported to the APEC economies, with more than half going to Malaysia, Indonesia and Australia (EIA, 2015). Singapore's oil refining industry has experienced a steady growth of 7.7%, from 1.4 million barrels per day (Mbbl/d) in 2004 to 1.5 Mbbl/d in 2014 (BP, 2015) to place it in the top 10 exporters of refined oil products in Asia in 2014 (EIA, 2015).

Singapore is a major global shipping and aviation hub, which has a significant impact on the refineries. In contrast with other APEC economies (except Hong Kong, China), energy demand for international transport dwarfs that for domestic transport: it was 48 Mtoe in 2013–almost 18 times demand for domestic transport–and is expected to be 70 Mtoe in 2040, close to 27 times that for domestic transport. The result has been a phenomenal demand for bunker and jet fuels, as is apparent in the large share of medium fuels (46%, over 23 Mtoe) and heavy fuels (28%, more than 14 Mtoe) in the refineries' total output of about 51 Mtoe in 2013 (EMA, 2015). Singapore is the world's largest consumer of bunker fuel oil, accounting for nearly one-fifth of worldwide consumption (EIA, 2015).

Primary energy supply: Changing oil and gas shares

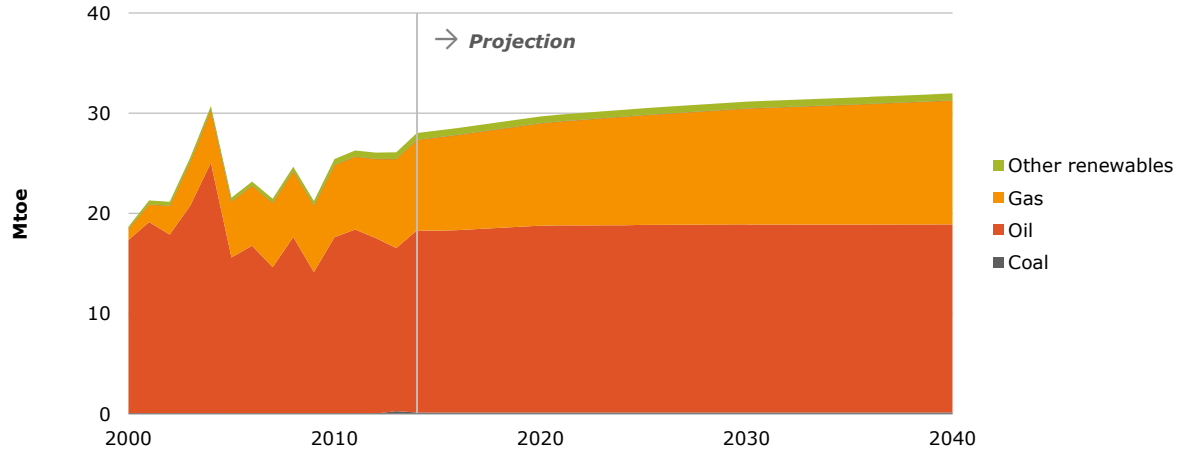
Singapore's TPES is projected to increase by nearly 22% from 26 Mtoe in 2013 to 32 Mtoe in 2040. Fossil energy, which dominates the supply mix, is mainly confined to oil and gas with a very small consumption of coal. There is a small contribution from renewables, primarily waste-to-energy. Oil and gas preserve

their overall dominant role in Singapore's TPES, increasing slightly from a combined share of over 96% in 2013 to 97% in 2040, while coal's share of 1% falls to 0.4% by 2040. However, oil's share declines from 62% (16 Mtoe) in 2013 to 59% in 2040 (nearly 19 Mtoe). On the contrary, gas's share steadily increases from 34% in 2013 (8.9 Mtoe) to almost 39% in 2040 (over 12 Mtoe). Renewables retain their small share of over 2% (0.7 Mtoe) throughout the Outlook period.

The changing shares of oil and gas reflect Singapore's decision to switch to gas as a cleaner fossil energy; geological and geographical limitations, including land scarcity, restrict the options for using renewables to reduce economy-wide CO_2 emissions. Renewables consist of solar energy at a very small scale (EMA, 2015b) and waste-to-energy. In 2015, installed solar capacity was 33.1 MW_p (EMA, 2015a) and Singapore's Energy Market Authority (EMA) has provided for its expansion by increasing the Intermittent Generation Threshold from 350 MW_{ac} to 600 MW_{ac} (EMA, 2015b). This threshold covers power generation from renewables, which varies for natural reasons (sunshine in the case of solar) and requires fossil fuel-fired generators as backup. Waste-to-energy is an established renewables sector in Singapore where wastes are burnt in incinerators to generate electricity, accounting for 3.7% of the power mix in 2014 (EMA, 2015a).

Singapore considers the existing nuclear technologies not safe enough for its densely populated small land area (MTI, 2012). Non-fossil energy's share of TPES is limited to renewables as long as this policy continues.

Figure 17.6 ● Singapore: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

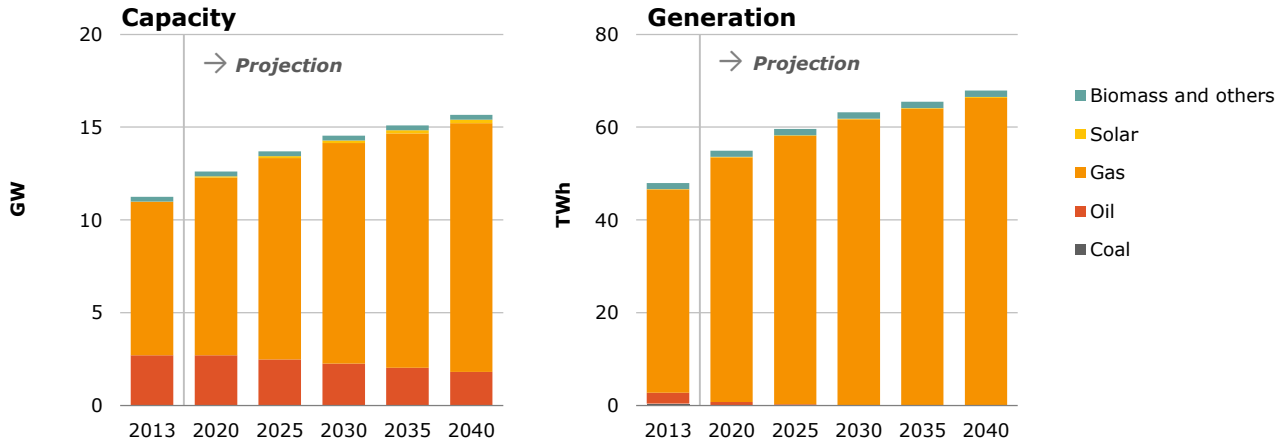
Power sector trends: Gas is replacing oil

Singapore has a robust and expanding power sector mainly consisting of oil- and gas-powered generators. To meet the economy's growing demand for electricity, capacity is projected to rise from more than 11 gigawatts (GW) in 2013 to about 16 GW by 2040. Gas' share of this capacity is projected to increase from 73% to 86% and renewables' share from 2.4% to about 2.9%, at the expense of the oil share, which falls from 24% to 12%. Singapore is now expanding waste-to-energy capacity as the environmental technology company Keppel Seghers is increasing the incineration capacity of the Senoko Waste-to-Energy Plant (2 100 tonnes per day) by 10% by 2016 (Keppel, 2014). Singapore increased the grid-connected solar PV system from 1.9 MW_p in 2009 to 33.1 MW_p in 2014 (EMA, 2015a).

Under the BAU, Singapore's power generation is projected to increase by 42% from 48 terawatt-hours (TWh) in 2013 to nearly 68 TWh in 2040. While some oil generating capacity remains, as indicated above, oil's share of actual generation falls from 4.9% in 2013 to 0% in 2040. Meant to help Singapore decrease CO_2 emissions, this remarkable development increases the share of gas generation from 91% in 2013 to 98%. The decline in coal generation's share from 0.82% in 2013 to 0% in 2040 further contributes to this

objective. Renewables' 2013 share (2.9%) experiences a gradual increase in volume while slightly decreasing its share in 2040 (2.3%) (EMA, 2015a).

Figure 17.7 ● Singapore: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

Only the Improved Efficiency and the High Renewables Scenarios apply to Singapore, because none of the assumptions in the Alternative Power Mix Scenario are applicable.[4] The Improved Efficiency Scenario leads to a 4.4% (1 Mtoe) reduction in final energy demand by 2040 and to the greatest reduction in energy-related CO_2 emissions at 7.3% (3.9 $MtCO_2$) compared with the BAU Scenario. The High Renewables Scenario leads to a 0.74% (0.39 $MtCO_2$) reduction in energy-related CO_2 emissions compared with the BAU Scenario.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

To meet APEC's region-wide goal of reducing energy intensity by 45% by 2035 from 2005 levels[5], Singapore has implemented policies aimed at decreasing energy consumption and improving energy efficiency. The Energy Conservation Act 2013 (ECA) aims to improve energy conservation, efficiency and intensity while reducing CO_2 emissions. The ECA's major objective is to help Singapore achieve its energy intensity reduction target by improving companies' energy performance (EMA, 2012). Additionally, the Mandatory Energy Labelling Scheme helps consumers identify energy-efficient products and make informed purchasing decisions. Minimum energy performance standards have also been implemented to raise the average energy efficiency of household appliances in the market.

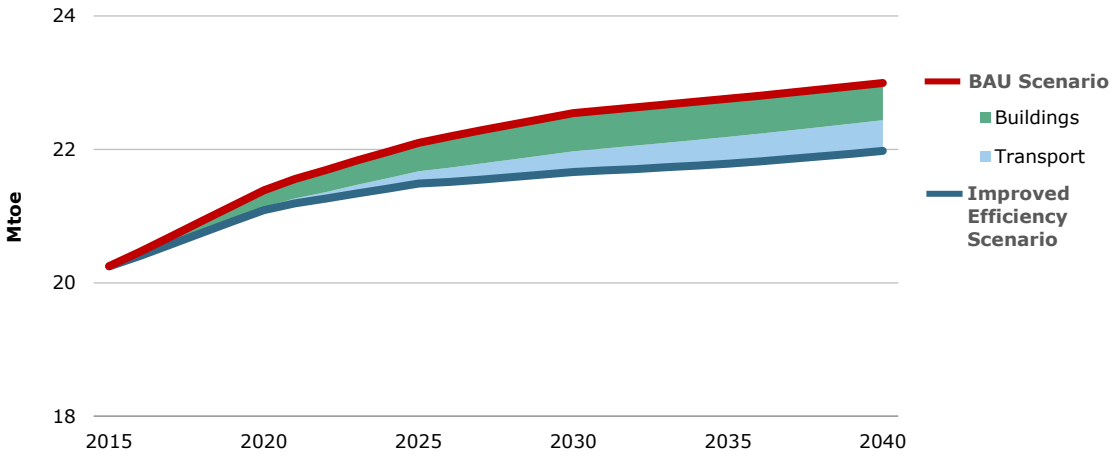
Under the BAU, Singapore reduces energy intensity by about 19% by the APEC target date of 2035 from 2005 levels. This is an impressive reduction as it is more difficult to reduce energy intensity in mainly service-based economies such as Singapore's than in heavy industry-oriented economies. The APEC target is especially difficult for Singapore as it is already highly energy-efficient and one of the world's least carbon-intensive economies, ranking 123th out of 142 economies and countries (NCCS, 2015). Its energy intensity falls by 18% from almost 57 toe per USD million in 2013 to 47 toe per USD million in 2035.

Under the Improved Efficiency Scenario, however, Singapore could achieve a 23% reduction by the APEC target date of 2035, decreasing energy intensity by over 11% from about 57 toe per USD million to almost 45 toe per USD million. The major contributing sectors by 2040 are domestic transport, where

[4] For more details about the Alternative Scenario assumptions, see Chapter 5 to 7 in Volume I.
[5] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

energy intensity reduction saves 0.46 Mtoe compared with the BAU, and buildings (0.56 Mtoe). The Improved Efficiency Scenario underestimates the potential energy intensity reduction as it excludes the industry sector.

Figure 17.8 ● Singapore: Potential energy savings in the Improved Efficiency Scenario, 2015-40



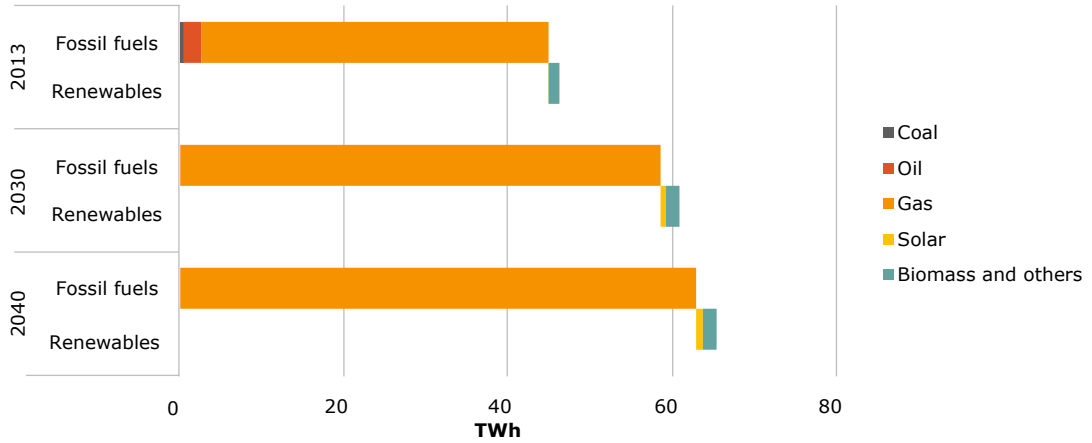
Note: An estimate for savings potential in industry was not calculated due to lack of data and hence the Improved Efficiency Scenario underestimates the potential savings from enhanced energy efficiency.
Source: APERC analysis.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

APEC's doubling renewable goal envisages doubling the APEC region's renewable energy by 2030 from 2010 levels.[6] Singapore's renewable power generation in 2013 was 1.4 TWh. Under the High Renewables Scenario, this is projected to grow to 2.4 TWh in 2030 to increase to 2.6 TWh in 2040. Waste-to-energy accounts for the bulk of Singapore's renewables potential, with a small contribution from solar.

Although land scarcity has limited solar expansion, Singapore has encouraged it by promoting rooftop panels and supporting research and development. The number of grid-connected solar PV installations almost doubled between 2013 and 2014, from 388 to 636, and has increased almost 11 times since 2009, when there were just 59 installations (EMA, 2015a). Installed capacity rose from 1.9 MW_p in 2009 to 15 MW_p in 2013 and then leapt to 33 MW_p in 2014 (EMA, 2015a).

Figure 17.9 ● Singapore: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

[6] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Singapore's energy demand continuously increases under the BAU. The economy is investing in the highly developed energy sector to meet this demand while diversifying the energy mix, decreasing CO_2 emissions, improving energy security and further improving domestic transport. As projected by APERC, the required investment ranges from USD 15 billion under the low-cost investment estimate to USD 53 billion under the high-cost estimate over 2015 to 2040. Singapore has no domestic fossil energy reserves, which eliminates any investment requirements in the upstream energy sector. Downstream accounts for the bulk of projected energy investment: 53% in the low-cost estimate and nearly 74% in the high-cost estimate. This is mainly due to the capital-intensive nature of expanding and upgrading refineries.

Electricity has the second highest investment requirements after downstream with a share of above 44% in the low-cost estimate and over 22% in the high-cost estimate. Repair, maintenance, modernisation and expansion of gas-fired power generators accounting for the bulk of the economy's power generation are the main contributors. The shares of the energy transport sector are small in both low-cost (2.4%) and high-cost (3.6%) projections as the required investment is to be used specifically for additional gas pipelines.

Table 17.3 ● Singapore: Projected investments in the energy sector in the BAU Scenario, 2015-40

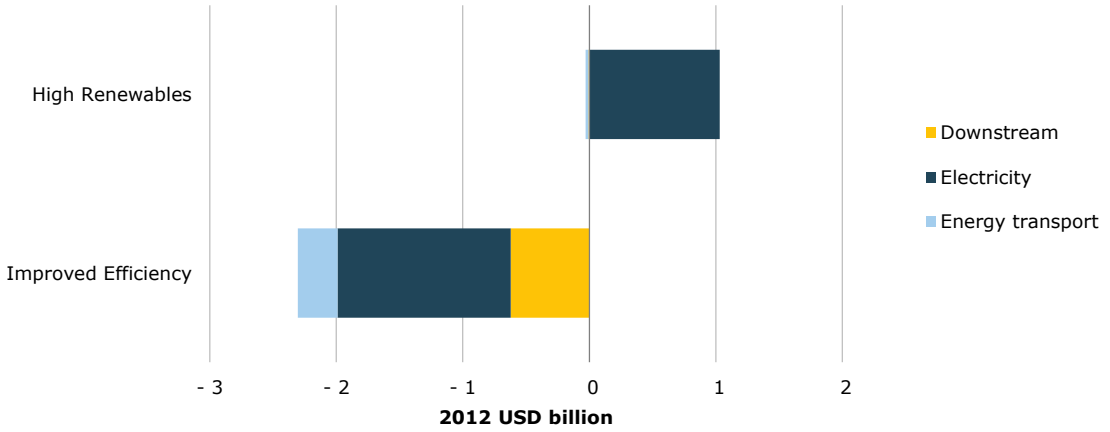
2012 USD billion PPP		Low-cost estimate	High-cost estimate
Downstream	Refinery	7.8	39
	LNG import terminals	0.1	0.3
	Subtotal	7.9	39
Electricity	Gas	4.9	8.1
	Solar	0.5	0.7
	Biomass and others	0.2	0.2
	Transmission lines	0.9	2.2
	Distribution lines	0.1	0.4
	Subtotal	6.7	12
Energy transport	Gas	0.4	1.9
	Subtotal	0.4	1.9
	Total	**15**	**53**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

The Improved Efficiency Scenario leads to investment savings of 15% from the BAU as lower energy demand leads to savings from refineries, new power plants and additional gas pipeline infrastructure. The High Renewables Scenario results in an increase in investment of 6.7% due to a higher demand for investment in renewable power.

Figure 17.10 ● Singapore: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

Energy sustainability is a major concern and priority for Singapore. This is reflected in policies promoting gas, a cleaner fuel than oil and coal, by adding LNG to the power mix in 2013 with the aim of completely replacing oil. Given Singapore's small area, gas is the only practical large-scale way of decreasing the carbon footprint; an additional small contribution by solar was encouraged by the raising of the Intermittent Generation Threshold in 2015 (EMA, 2015b). Using LNG improves the economy's energy security as it enables by 2025 the end of Singapore's dependence on piped gas imports from Malaysia and Indonesia, which met the entire gas demand before 2013 (SLNG, 2015).

Singapore has intensified efforts to reduce its CO_2 emissions since it released the National Climate Change Strategy 2012 (EES, 2015c). The strategy outlines plans to address climate change through an economy-wide approach. Key elements of the strategy include 'reducing emissions across sectors, building capabilities to adapt to the impact of climate change, harnessing green growth opportunities as well as forging partnerships on climate change action' (EES, 2015c). Specific policies aim at reducing emissions in the buildings, industry and transport sectors, as well as those of households, by improving energy efficiency. Recent examples include: for buildings, Part IIIB of the Building Control Act 2012 and the Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations 2013 (EES, 2015a); for industry, the 2013 Mandatory Energy Management Requirements (EES, 2015b); and for households, the Mandatory Energy Labelling Scheme and Minimum Energy Performance Standards for different household appliances (EES, 2015e). Expanding the MRT system has been the major emissions-reduction policy for the transport sector (EES, 2015d).

Enhancing energy security: The role of gas

Under the BAU, Singapore is projected to improve primary energy supply diversity slightly according to the Herfindahl-Hirschman Index (HHI), from 0.51 in 2013 to 0.50 by 2040, where a lower number indicates improved fuel diversity. The main contributing factor is success in increasing the share of gas in primary energy supply and decreasing that of oil. Such supply diversity slightly improves under the High Renewable Scenario (0.49). The economy's electricity fuel diversity declines from 2013 (HHI 0.72) to 2040 (HHI 0.88), as heavy dependence on one fuel (gas) becomes even heavier. However, it improves slightly under the Improved Efficiency Scenario (HHI 0.87) and a little bit more under the High Renewable Scenario (HHI 0.85). Singapore's primary energy supply self-sufficiency declines under the BAU from 2.6% in 2013 to 2.2% in 2040, but improves under the Improved Efficiency Scenario (2.3%) and especially under the High Renewables Scenario (3%).

Table 17.4 • Singapore: Energy security indicators under the different Scenarios, 2013 and 2040

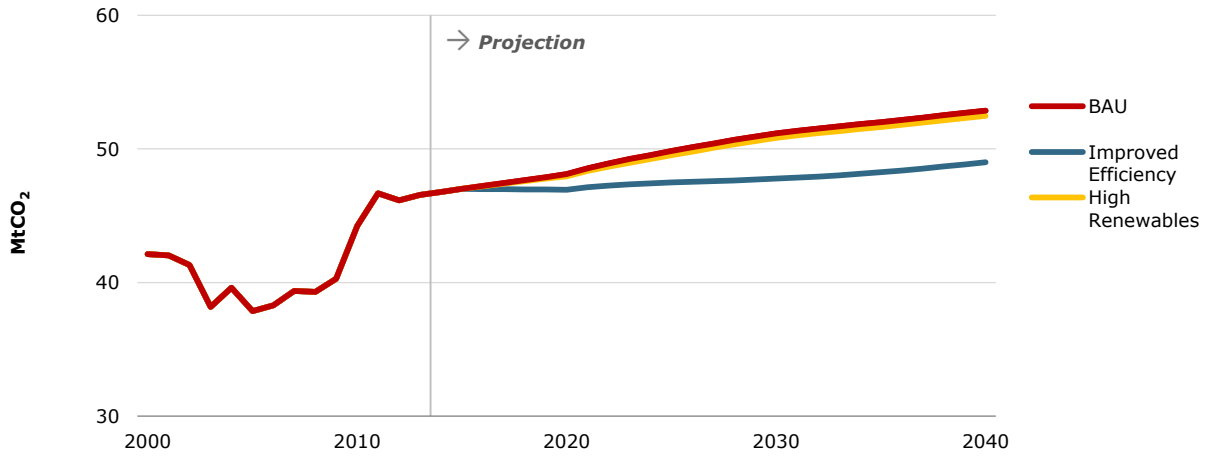
	2013	2040		
	Actual	BAU	Improved Efficiency	High Renewables
Primary energy supply diversity (HHI)	0.51	0.50	0.50	0.49
Primary energy supply self-sufficiency (%)	2.6	2.2	2.3	3.0
Electricity generation input fuel diversity (HHI)	0.72	0.87	0.88	0.85

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

Climate change impacts and risks: Emissions set to grow

Singapore accounts for around 0.11% of global emissions (UNFCCC, 2015). Very limited options in terms of increasing renewables, and the unsuitability of existing nuclear technologies for the small land area (716 square kilometres), make it almost totally dependent on fossil energy. Singapore's mitigation contributions must be viewed in this context. Total energy-related CO_2 emissions under the BAU grow by about 14% from 45 $MtCO_2$ in 2013 to almost 53 $MtCO_2$ in 2040. The power sector accounts for the bulk of such emissions; the sector's 2013 share of 20 $MtCO_2$ increases to 25 $MtCO_2$. The Improved Efficiency Scenario offers the largest reduction potential, with emissions 7.3% below the BAU in 2040, at 49 $MtCO_2$.

Figure 17.11 • Singapore: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions only includes domestic emissions from fuel combustion and does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

RECOMMENDATIONS FOR POLICY ACTION

Singapore's energy demand increases in the Outlook period while its geological and geographical conditions limit its options for fuels to fossil energy apart from a small contribution of renewables. This is a major challenge for the economy, which is mindful of global warming and the necessity of curbing its greenhouse gases. Switching to gas for power generation has been the single major option available to the economy, which totally replaces more polluting oil for power generation during the Outlook period. The remaining options, apart from the ongoing process of maximising the share of renewables, are mainly confined to decreasing energy consumption by improving energy efficiency and intensity. Yet there is a limit to what these measures can achieve in terms of reducing greenhouse gases given that Singapore is already an energy-efficient economy and its service-based economy makes further reduction in energy intensity difficult.

18. CHINESE TAIPEI

KEY FINDINGS

- **Final energy demand from 2013 to 2040 is projected to remain steady** at an AAGR of only 0.042% owing to industry and energy sector optimisation.

- **Diversifying the power mix is challenging due to steadily increasing electricity needs.** Having a fourth nuclear power project on hold increases the risk of power shortages and higher electricity costs.

- **Chinese Taipei will remain dependent on imports for energy supply** with nearly all fossil fuels imported from other economies over the projection period.

- **Power output from non-hydro renewables is projected to increase significantly by 2040,** from 5.2 TWh in 2013 to 19 TWh under the BAU Scenario or 44 TWh in the High Renewables Scenario, led mainly by wind power.

- **CO_2 emissions gradually decouple from economic and social development over the projection period.** Energy-related CO_2 emissions are projected to peak at 284 $MtCO_2$ in 2024, decrease slightly to 264 $MtCO_2$ by 2040 under the BAU; it drops further to 229 $MtCO_2$ by 2040 under the Improved Efficiency Scenario.

ECONOMY AND ENERGY OVERVIEW

Chinese Taipei, located off the southeastern coast of China, consists of the island groups of Formosa, Penghu, Kinmen and Matsu. The total area of Chinese Taipei is 36 193 square kilometres (km^2), being 394 km long and 144 km at its widest point.

Following a period of rapid economic growth, Chinese Taipei has become a developed economy with a gross domestic product (GDP) per capita of USD 40 368 in 2013, approximately twice the Asia-Pacific Economic Cooperation (APEC) average. Chinese Taipei's economic structure changed substantially over the past decade, shifting from industrial production to the services sector. In 2013, services accounted for 65% of GDP, followed by industry (33%) and agriculture (1.7%) (BOE, 2015a). Despite steady growth since 1990, a declining birth rate is expected to lead to population decrease between 2030 and 2040.

Table 18.1 ● Chinese Taipei: Macroeconomic drivers and projections, 1990-2040

		2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	320	585	853	942	1 054	1 172	1 201
Population (million)	20	22	23	23	24	24	23
GDP per capita (2012 USD PPP)	15 680	26 244	36 811	40 368	44 625	49 741	52 878
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	48	85	111	109	112	110	107
TPES per capita (toe)	2.3	3.8	4.8	4.7	4.7	4.7	4.7
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	29	49	68	68	70	70	68
Final energy intensity per GDP (toe per 2012 USD million PPP)	92	83	80	72	67	60	57
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	111	214	256	249	269	278	264
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	100	100	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

In 2011, President Ma Ying-Jeou announced an economy-wide vision of environmental sustainability under the long-term Chinese Taipei development plan Golden Decade National Vision, which states three main policy goals of low-carbon and green energy promotion, creation of an 'eco-homeland', and disaster prevention and protection. The first goal, which aims to develop low-carbon and renewable[1] energy to reduce nuclear dependence, comprises three key targets: 1) Cut carbon dioxide (CO_2) emissions to the 2005 level (250 million tonnes [Mt]) by 2020; 2) increase energy efficiency by 2% each year and reduce energy intensity by 12% of the 2010 level by 2016, and by 18% by 2020; and 3) increase installed capacity of renewable energy to 4 580 megawatts (MW) by 2016 and 6 040 MW by 2020 with corresponding power generation of 12.2 terawatt-hours (TWh) and 16.1 TWh.

In July 2015, the government released the Greenhouse Gases Reduction and Management Act, which set the economy's long-term greenhouse gas (GHG) emissions reduction target at 50% of the 2005 level by 2050. Furthermore, Chinese Taipei announced its Intended Nationally Determined Contribution (INDC) to reduce GHG emissions by 50% of the Business-as-Usual (BAU) level by 2030 (EPA, 2015b).

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

Government plans to enhance energy efficiency will help drive down Chinese Taipei's energy intensity per unit of GDP by 26%, from 72 tonnes of oil equivalent (toe) per million USD in 2013 to 57 toe per million USD by 2040, making it consistently below the APEC average over the projection period (Table 18.1). Total primary energy supply (TPES) per capita is expected to remain flat at 4.7 toe, which is little higher than the current APEC average of 3.5 toe.

ENERGY RESOURCES

Chinese Taipei has very limited domestic energy resources; it imports nearly 99.7% of its fossil fuel supply. In 2013, domestic natural gas accounted for only 0.25% of TPES, while hydro provided 0.43% and geothermal, biomass, solar and wind power combined provided just 1.8%. Improving energy self-sufficiency is vital to energy security.

Policies are being implemented to increase domestic renewable energy production, as well as to enhance natural gas production. In 2013, the Chinese Petroleum Corporation (CPC) completed a geological survey of 48 km^2 and a three-dimensional seismic survey covering 157 km^2 in western Chinese Taipei; it also repaired one well and drilled a new one. At present, 41 producing oil and gas wells (in the Tiezhenshan, Qingcaohu, Jinshui, Chuhuangkeng and Guantian fields) annually yield 0.5 billion cubic metres (bcm) of natural gas (1.9% of natural gas supply) and 10 000 kilolitres of condensate (0.02% of crude oil supply) (CPC, 2014).

ENERGY POLICY CONTEXT

Chinese Taipei's Bureau of Energy formulates and implements energy policy and is responsible for creating a better energy business environment. It recently introduced a suite of energy-related policies that define market rules for renewable energy, petroleum products, natural gas and electricity. The overarching aim is to improve energy security by developing domestic energy resources, especially renewables, supported by secure oil, natural gas and coal imports. Several renewable projects have already been initiated, including the Penghu Low Carbon Island Development Project, the Million Rooftop PVs Promotion Project and the Thousand Wind Turbines Promotion Project (BOE, 2012b, 2014b).

To secure energy supply and meet future demand, in October 2012 Chinese Taipei released its Guideline on Energy Development (BOE, 2012d), which readdresses energy security, energy efficiency and clean energy policy. In addition to diversifying sources and methods of acquiring energy imports, and enhancing the rate of domestic production, the guideline promotes energy development and proliferation via new technologies. High costs and instability of supply are identified hurdles to developing accessible and affordable clean energy domestically, which new energy technologies may be able to resolve.

In response to the 2011 Fukushima nuclear accident, Chinese Taipei released a New Energy Policy on 3 November 2011 to 'ensure nuclear security, steadily reduce nuclear dependence, create a low-carbon green energy environment and gradually move towards a nuclear-free homeland.' This policy aims to steadily reduce nuclear dependence by lowering electricity demand and peak loads, and by promoting alternative energy sources to ensure a stable power supply (BOE, 2011). At the end of 2013, nuclear energy accounted for 10% of TPES and 17% of electricity generation.

The new policy grants no lifespan extensions for existing nuclear plants and outlines decommissioning as follows: Units 1 and 2 of the first plant in 2018 and 2019; Units 1 and 2 of the second plant in 2021 and 2023; and Units 1 and 2 of the third plant in 2024 and 2025. Construction of a fourth plant was halted as a result of public concern over the safety of building in an earthquake-prone region. The government has stated that this suspension does not necessarily mean shutdown; the future of the fourth plant remains undecided (China Post, 2014).

Chinese Taipei's Renewable Energy Development Act (2009) established the incentive for private investment in renewable energy. A feed-in tariff under which the Taiwan Power Company (TPC) purchases power from renewable generators at preferential rates and with guaranteed grid connections helps to secure the market for renewables.

BUSINESS-AS-USUAL SCENARIO

The Business-as-Usual (BAU) Scenario assumes that no new policies are implemented during the Outlook period, other than the existing policies related to energy demand and supply. The main policies assumed within the BAU Scenario are summarised in Table 18.2.

Table 18.2 • Chinese Taipei: Key assumptions and policy drivers under the BAU Scenario

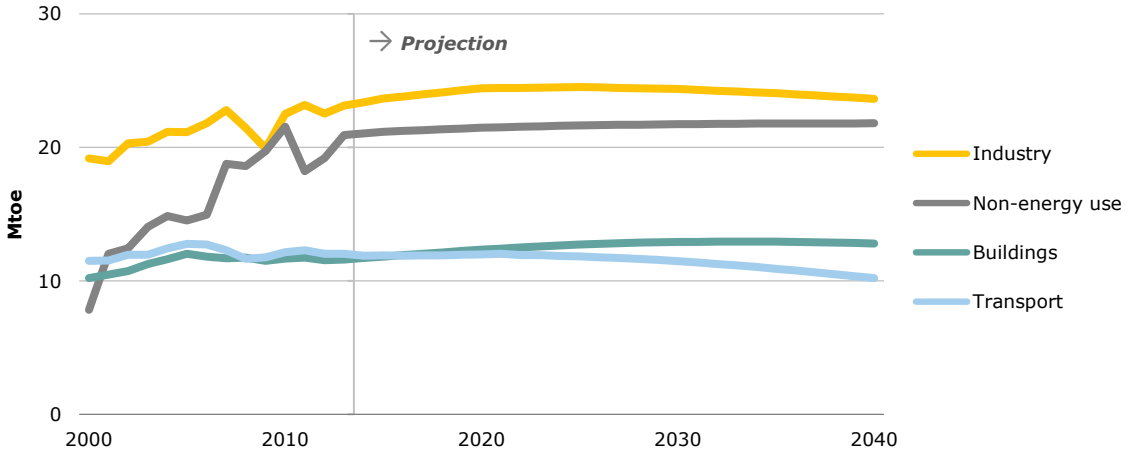
Buildings	• Multi-level energy efficiency labelling scheme for appliances.
Industry	• Industrial structure aimed toward high value-added and low energy-intensive. • Increased value-added products.
Transport	• Increased biofuels based on historical trends. • Vehicle fuel efficiency standards.
Energy supply mix	• Increased use of clean energy such as natural gas in electricity supply.
Power mix	• Consecutive decommissioning of three nuclear power plants before 2025. • Increased shares of coal and gas with more utility plants.
Renewables	• Committed projects are considered. • B2 diesel promotion policy halted in 2014.
Energy security	• Continued energy self-sufficiency improvements.
Climate change	• CO_2 emissions gradually decrease.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Final energy demand is forecast to peak around 2025 at 71 million tonnes of oil equivalent (Mtoe), then decline to 68 Mtoe by 2040. This corresponds with the target of enhancing energy efficiency at least 2% each year by reducing energy intensity by 50% of the 2005 level in 2025. In 2040, the industry sector is expected to consume 35% of total final energy, followed by the non-energy sector (32%), buildings (19%) and domestic transport (15%) (Figure 18.1).

Figure 18.1 • Chinese Taipei: Final energy demand by sector, 2000-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

Over the projection period approximately half of all energy comes from petroleum products used in chemicals and petrochemicals. Other major fuel sources are electricity (32%), coal (9.9%) and gas (5.2%). Coal consumption is projected to decrease from 8 Mtoe to 6.8 Mtoe, while electricity increases from 19 Mtoe to 22 Mtoe if the energy structure is optimised. The projected decline in coal consumption

is due to the GHG emissions reduction policy that promotes the use of natural gas as coal-fired plants are decommissioned.

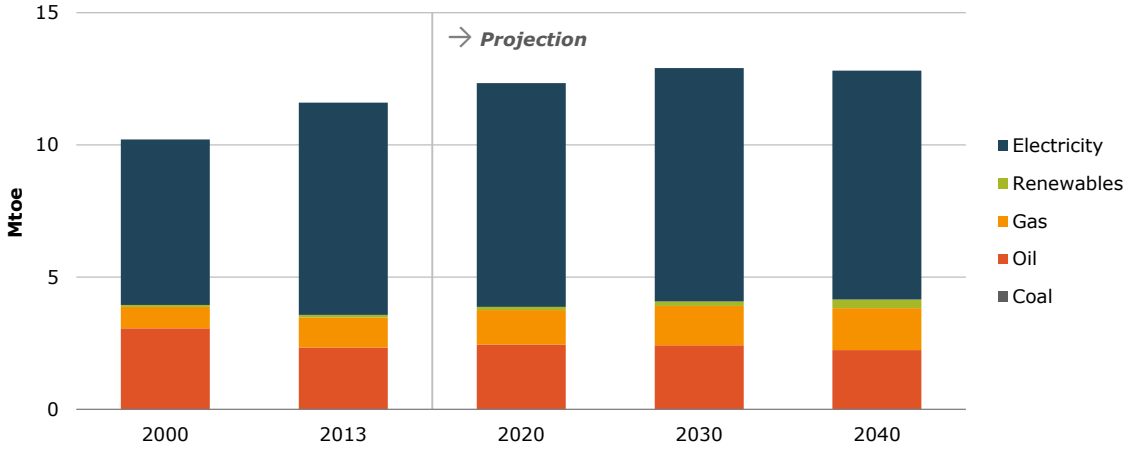
Buildings and agriculture energy use: Improved energy efficiency slows growth

Electricity, the main source of energy in the buildings and agriculture sector, accounts for about 68% of total energy consumption. Chinese Taipei's urbanisation rate of around 75% means electricity is the main energy source for most homes. The government supports electricity savings in buildings through energy efficiency policies, the promotion of green buildings, and technology development and information campaigns. In 2011 the replacement of incandescent lighting with light-emitting diode (LED) traffic lights saved an estimated 247 gigawatt-hours (GWh), equivalent to nearly 0.26% of total electricity consumption in the sector. In 2013 nearly 300 000 mercury vapour streetlights had been replaced by LEDs, saving an estimated 120 GWh of electricity.

A mandatory multi-level energy efficiency labelling scheme has been in force since 2010; it now applies to air conditioning units, refrigerators, vehicles, motorcycles, humidifiers and other equipment. In 2012, mandatory energy label applications included 6 727 air conditioner models, 1 019 refrigerator models and 209 dehumidifier models.

Electricity is projected to dominate energy consumption, with demand reaching 8.7 Mtoe by 2040 (Figure 18.2). Energy efficiency improvements, however, are expected to reduce demand growth from an average annual growth rate (AAGR) of 1% (2000-13) to 0.4% from 2013 to 2040. Although the suspension of the fourth nuclear plant has required higher electricity energy efficiency and conservation measures, low tariffs—much lower than in other energy-importing economies like Japan—are a disincentive to household energy efficiency.

Figure 18.2 ● Chinese Taipei: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

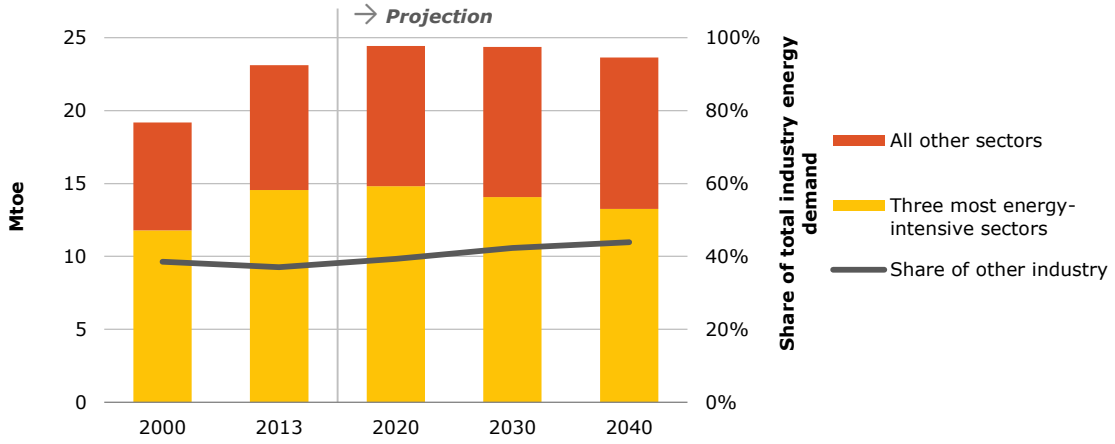
Energy demand in the residential and commercial sub-sectors is expected to evolve differently. While residential demand remains flat at the 2013 level of 5.6 Mtoe, commercial demand rises more than 36% from 3.8 Mtoe in 2013 to 5.1 Mtoe by 2040 as a result of space cooling and electrical equipment and other appliance usage. Flat growth in the residential sub-sector indicates implementation of Minimum Energy Performance Standards (MEPS). MEPS for 18 products (refrigerators, dehumidifiers, LED bulbs, etc.) have been released and 16 more are being drafted (BOE, 2014a).

Industry energy use: Room for energy efficiency improvements

Industry is the largest energy consumer in Chinese Taipei. Demand is projected to increase rapidly to 2020, then flatten and negligible decline after 2030 (Figure 18.3). The chemicals and petrochemicals sub-sector used the most energy in 2013 (8.4 Mtoe), one-third of total industrial energy use; consumption is

projected to peak to 2020 and decline slowly thereafter. Chemicals and petrochemicals accounted for 8.5% of total GDP (USD 82.6 billion) in 2013 and, including non-energy use for feedstocks, represented over 43% of total final energy consumption. Improved energy efficiency in this sector is vital to reduce the overall energy intensity of the economy.

Figure 18.3 ● Chinese Taipei: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors across the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.
Sources: APERC analysis and IEA (2015a).

A 2014 study shows the difference in energy intensity reductions with and without application of best-practice technology to the production of the three most important chemicals in Chinese Taipei: styrene monomer, 10%; purified terephthalic acid, 30%; and low-density polyethylene, 30%. The application of advanced technology clearly improves energy efficiency.

The machinery industry is the second-largest energy consumer at 4.6 Mtoe, nearly 20% of total industry consumption in 2013, mainly for the production of semi-conductors and flat panel displays. Because industry is the overall largest energy user, policy measures to improve efficiency include adjusting the industrial structure and increasing value-added products. The government has been increasing the share of higher-value-added chemicals and petrochemical products, as well as improving manufacturing efficiency and implementing energy efficiency management on specific equipment. In addition, CPC's fifth naphtha cracking plant will be closed at the end of 2015 to reduce final energy consumption in the chemical industry.

Transport energy use: Declining road transport consumption

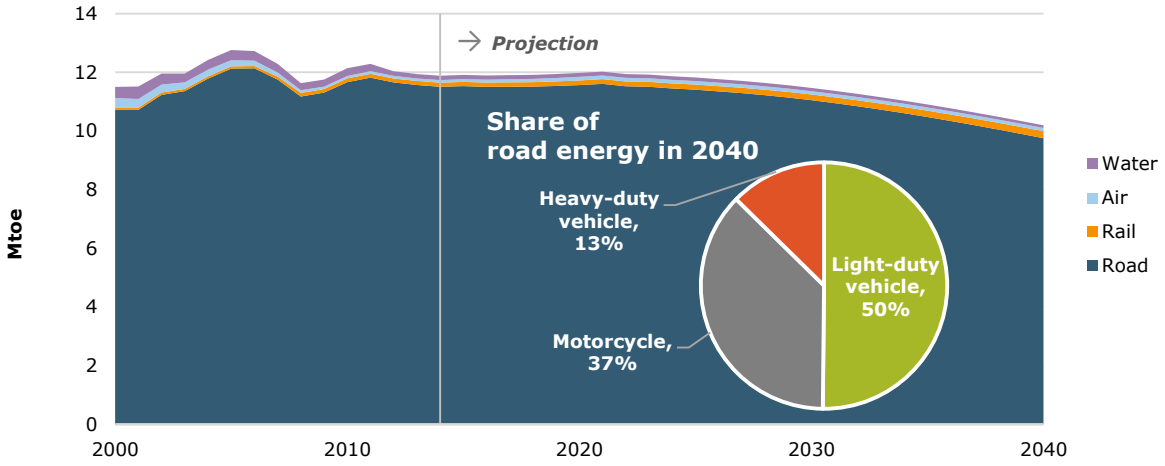
Final energy demand in domestic transport declined sharply between 2006 and 2009 thanks to the introduction of a high-speed rail (HSR) line connecting the two largest cities of Taipei and Kaohsiung in 2007. Oil consumption in road transport decreased as a result of the new rail line, and also decreased in freight transport due to the 2008 financial crisis.

Chinese Taipei's mature public transport system consists of an HSR line, local trains linking towns and cities, mass rapid transit (MRT) in Taipei City, New Taipei City and Kaohsiung City, and buses in all other major cities. Several projects are underway to enlarge public transport coverage: New HSR stations in Miaoli, Changhua and Yunlin counties, and more MRT stations in the Taipei Metropolitan Area including the Taoyuan International Airport Access MRT System running from Taipei to Taoyuan.

Motorcycles are the key driver of energy consumption in the road transport sector and by 2040 will reach 37% of total road transport consumption (Figure 18.4). There are three main reasons Chinese Taipei has the highest motorcycle density in the world: They are significantly less costly than automobiles; they are much easier to park; and public transport networks are currently limited to only the three largest cities.

In 2013, there were approximately 15 million motorcycles (67 for every one hundred people), and about 98% of them used fossil fuels for a consumption of 4.2 Mtoe. Although the number of motorcycles is expected to grow slowly over the projection period, the share of electric motorcycles rises from 3% in 2013 to 30% in 2040 under the BAU, reducing oil consumption. The Environmental Protection Administration (EPA) and local governments have been promoting electric motorcycles by offering a subsidy of USD 700 to USD 1 130 (depending on the make) for e-scooter purchases, resulting in a final price of USD 1 100 to USD 1 800, similar to that of a gasoline motorcycle.

Figure 18.4 • Chinese Taipei: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Energy consumption in transport decreases from 12 Mtoe in 2013 to 10 Mtoe in 2040 due to declining energy consumption in the road transport sub-sector. Reasons for this decline include a larger number of electric motorcycles, a near-saturation of light-duty vehicles (97% in 2012 and 99% in 2040) and fuel efficiency improvements for light- and heavy-duty vehicles. Vehicle fuel economy standards are set according to GHG emissions levels, and vehicles not meeting the standards are not allowed to be imported or sold. Light-duty vehicle fuel economy standards are based on US and EU standards (Table 18.3), and motorcycle fuel economy standards are set by the government (Table 18.4).

Table 18.3 • Chinese Taipei: Light-duty vehicle fuel economy standards, 2014

Cubic centimetres	Fuel economy standards of passenger cars (kilometres/litre)		Fuel economy standards of light-duty trucks, commercial vehicles and passenger cars (kilometres/litre)	
	US standard	EU standard	US standard	EU standard
Below 1 200	16.2	14.1	10.9	9.5
1 200 to 1 800	13.0	11.3	9.9	8.6
1 800 to 2 400	11.4	9.9	8.9	7.7
2 400 to 3 000	10.0	8.7	8.6	7.5
3 000 to 3 600	9.2	8.0	7.6	6.6
3 600 to 4 200	8.5	7.4	7.0	6.1
4 200 to 5 400	7.2	6.3	6.7	5.8
Over 5 400	6.5	5.7	6.1	5.3

Source: LRD (2014).

Table 18.4 • Chinese Taipei: Motorcycle fuel economy standards, 2014

Cubic centimetres	Fuel economy standards (kilometre/litre)
Below 50	48.2
50 to 100	40.6
100 to 150	38.0
150 to 250	28.0
250 to 500	21.1
500 to 750	16.6
750 to 1 000	15.8
1 000 to 1 250	14.7
1 250 to 1 500	13.1
Over 1 500	12.8

Source: LRD (2014).

In road transport, only light-duty vehicle energy demand remains steady at 5.1 Mtoe in 2013 and 4.9 Mtoe in 2040, while heavy-duty vehicle demand decreases from 2.3 Mtoe in 2013 to 1.2 Mtoe in 2040 (a 45% drop), and motorcycle energy demand decreases from 4.2 Mtoe to 3.6 Mtoe (a 14% drop).

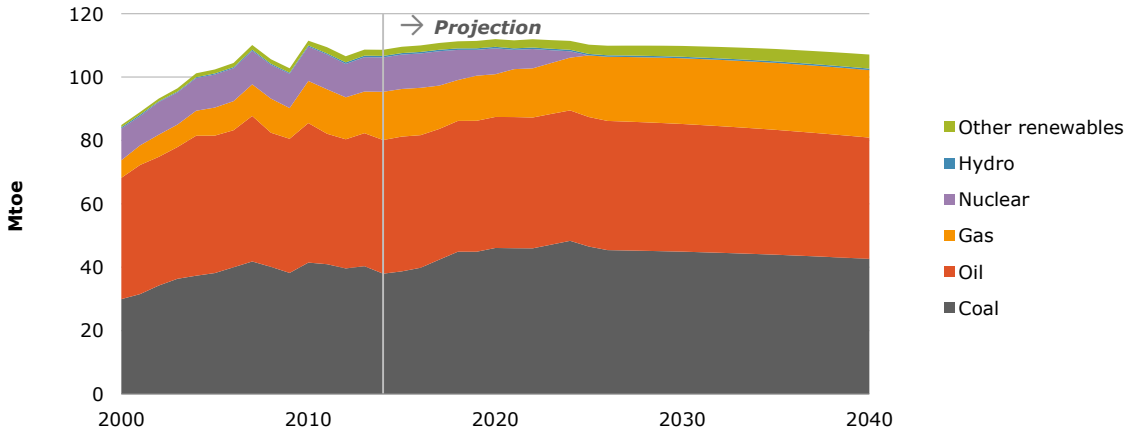
Energy demand for international aviation is forecast to grow at an AAGR of 1.5% over the projection period, from 2.3 Mtoe in 2013 to 3.5 Mtoe in 2040 due to increasing exports of high-value-added products and increasing air traffic between Chinese Taipei and China—especially since the government granted permission for cross-strait charter flights from Taoyuan, Songshan, Kaohsiung, Taichung, Makung, Hualien, Kinmen and Taitung in 2008.

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Limited growth

TPES is projected to peak in 2020 at 112 Mtoe and decline to 107 Mtoe (2013 level) by 2040 (Figure 18.5). The fuel mix changes over the projection period as nuclear power plants are gradually decommissioned by 2025. Fossil fuels continue to dominate the energy supply and the share is increasing as nuclear is phased out. In spite of this, fossil fuel growth peaks around 2025 and decreases slightly to 2040. Wind, solar and biomass shares increase, but only from 1.8% in 2013 to 4.1% in 2040. Hydro develops very slowly, with its contribution to TPES remaining the same.

Figure 18.5 • Chinese Taipei: Total primary energy supply by fuel, 2000-40



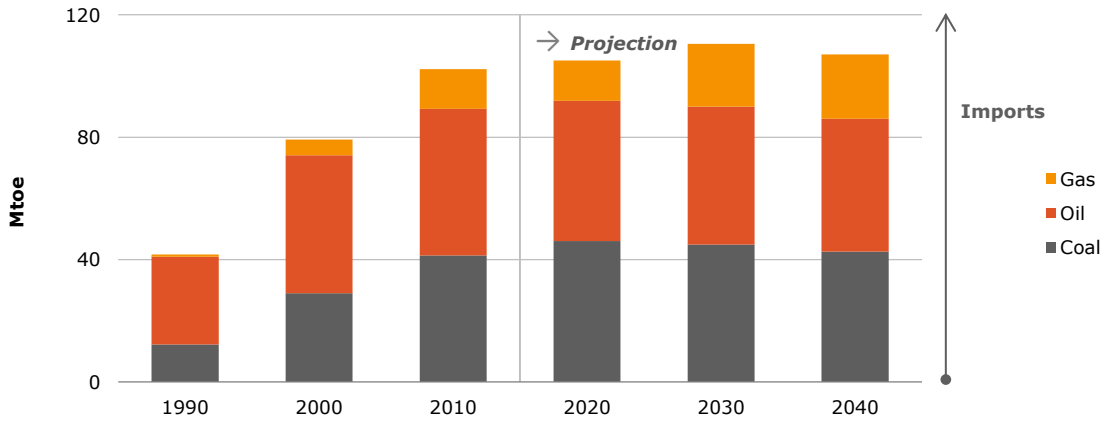
Sources: APERC analysis and IEA (2015a).

Energy trade: More gas imports to meet demand

The lack of domestic energy and mineral resources means that Chinese Taipei imported 43.6 Mtoe of crude oil in 2013, almost its entire crude oil requirement, from the Middle East (Saudi Arabia and Kuwait). Nearly all of its coal requirement was imported from Australia and Indonesia, and the natural gas supply was almost entirely imported as liquefied natural gas (LNG) from Qatar, Indonesia and Malaysia (13.6 Mtoe) (BOE, 2015a).

Energy imports are forecast to grow to 107 Mtoe by 2040, in comparison with 98 Mtoe in 2013 (Figure 18.6). Gas imports grow the most quickly, to 21 Mtoe by 2040—55% higher than 14 Mtoe in 2013. With the second LNG terminal starting operations in 2010, total capacity reached 12 Mt; one more terminal will be constructed to meet projected demand, with initial capacity of 3 Mt and another 3 Mt to be added later (China Times, 2014).

Figure 18.6 • Chinese Taipei: Net energy imports, 1990-2040



Sources: APERC analysis and IEA (2015a).

Power sector trends: Rising share of renewables

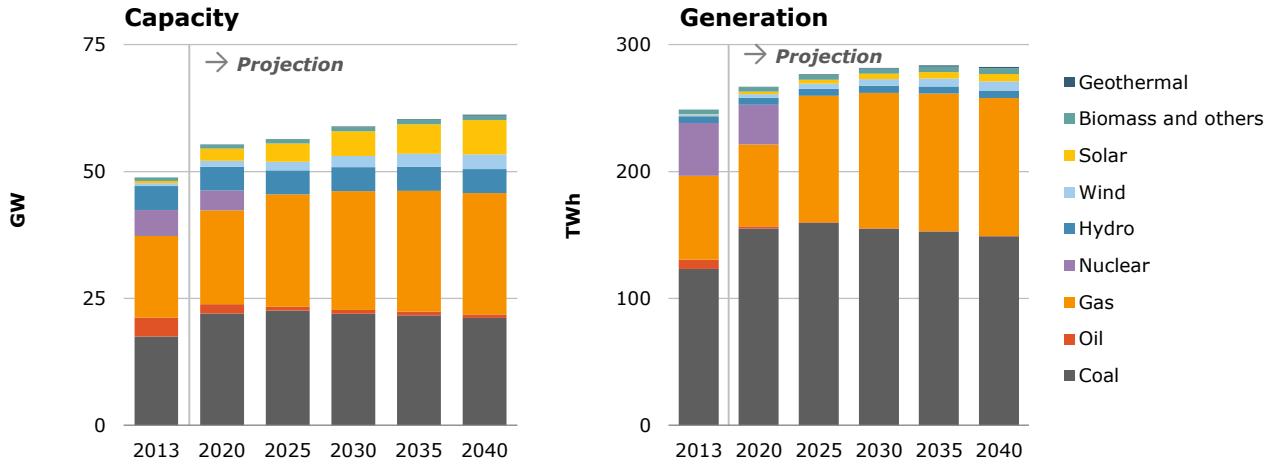
TPC and independent power producers (IPPs) produce electricity in Chinese Taipei. IPPs must sign power purchase agreements with TPC, which distributes the power to consumers. In 2013, TPC produced about two-thirds of electricity (BOE, 2014b).

In parallel with increasing electricity demand, installed capacity reaches 61 GW by 2040 (up 24% from 49 GW in 2013) and generation rises to 282 TWh, 13% above 249 TWh in 2013 (Figure 18.7). Over the projection period, the share of oil declines by 81% for installed capacity and 96% for generation output. All other fuels show increases by 2040, other renewables (516%) for installed capacity.

Developing renewable energy from mature technologies at low generation costs is a priority. The Renewable Energy Development Act (2009) therefore promotes feed-in tariffs and other incentives to attract more private-sector investment to increase renewable installed capacity by 6.5 GW (to 10 GW) over 20 years. Following the Fukushima nuclear accident in 2011, however, the government revised the target to 10 GW of installed renewable capacity by 2025, and 12.5 GW by 2030.

To reach this aggressive target, the Million Solar Rooftop PVs and the Thousand Wind Turbines Promotion projects aim to install 3.1 GW of solar photovoltaic (PV) and 4.2 GW of wind turbines by 2030. These are ambitious goals, as installed PV capacity was only 201 MW in 2012, and wind only 621 MW. These targets are above the projected capacity of 7.1 GW wind and solar combined in 2030, and 2.9 GW wind and 6.7 GW solar in 2040 under the BAU Scenario.

Figure 18.7 • Chinese Taipei: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

To address energy security, economic development and environmental challenges posed by the BAU Scenario outcomes, the Improved Efficiency, High Renewables and Alternative Power Mix Scenarios were developed.[2] The Improved Efficiency Scenario exhibits the lowest energy-related CO_2 emissions by 2040 (229 million tonnes of carbon dioxide [$MtCO_2$]) as well as the lowest final energy demand (61 Mtoe).

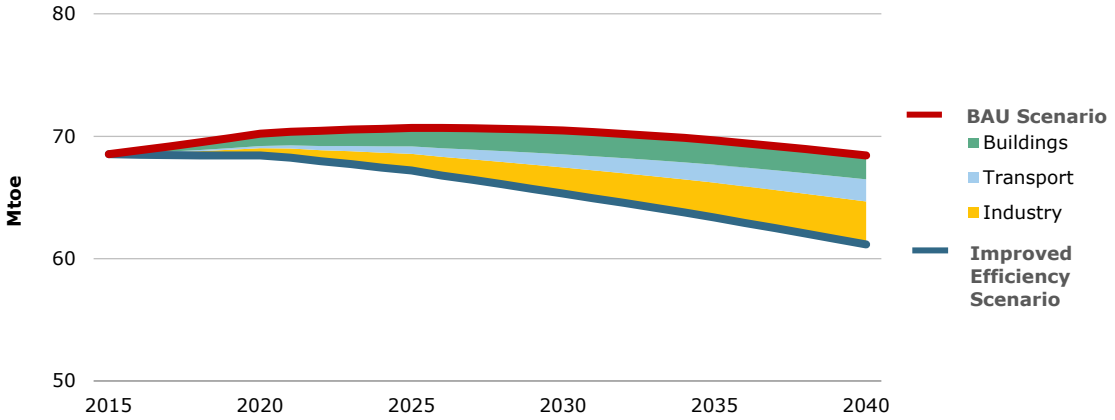
IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

In 2011, APEC Leaders agreed to reduce aggregate energy intensity in the APEC region 45% (from the 2005 level) by 2035.[3] To contribute to this goal, Chinese Taipei implemented its own energy intensity target to reduce energy intensity by 50% by 2025 (from the 2005 level), which is a 2% per year energy efficiency improvement. Additionally the economy is converting traditional manufacturing into higher-value-added industry by expanding information and communication technologies and services. These actions reduce energy intensity by 33% from 2005 to 2035 under the BAU.

Under the Improved Efficiency Scenario, 7.3 Mtoe in energy is saved by 2040, nearly half from industry and the remainder split between buildings and transport (Figure 18.8). The chemicals and petrochemicals sub-sector contributes 0.77 Mtoe, the largest savings in industry. Lower electricity use for appliances, space cooling and lighting would result in 1.8 Mtoe savings in buildings, hence the importance of MEPS. Road transport contributes about 1.9 Mtoe energy savings by 2040, thanks mainly to fuel efficiency improvements in light- and heavy-duty vehicles and motorcycles. These efficiency improvements result from implementation of vehicle fuel economy standards with different levels of engine displacement, and non-sale of vehicles not meeting the standards.

[2] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.
[3] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

Figure 18.8 ● Chinese Taipei: Potential energy savings in the Improved Efficiency Scenario, 2015-40



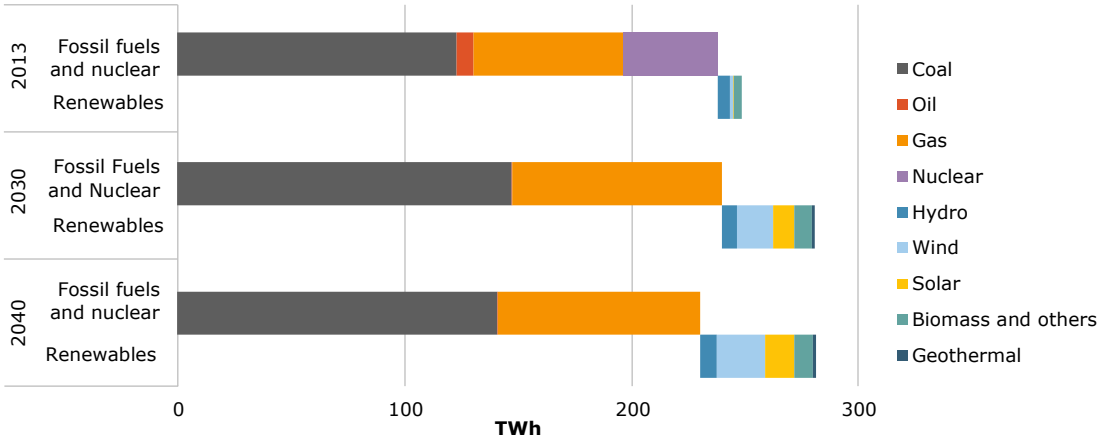
Source: APERC analysis.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

In 2014, APEC Leaders agreed to double the share of renewables in the APEC energy mix by 2030 (from the 2010 level).[4] The High Renewables Scenario models this target for the transport and power sectors.

Under the High Renewables Scenario, the output of wind and solar power reaches 34 TWh by 2040—21 TWh higher than under the BAU (Figure 18.9). By 2040, other renewable energy accounts for 16% of total electricity generation; wind increases by 20 TWh, solar by 13 TWh, biomass by 4.7 TWh, and geothermal by 1.3 TWh between 2013 and 2040. Since some of Chinese Taipei's wind resources are located on islands, transmission and distribution lines need to be expanded.

Figure 18.9 ● Chinese Taipei: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

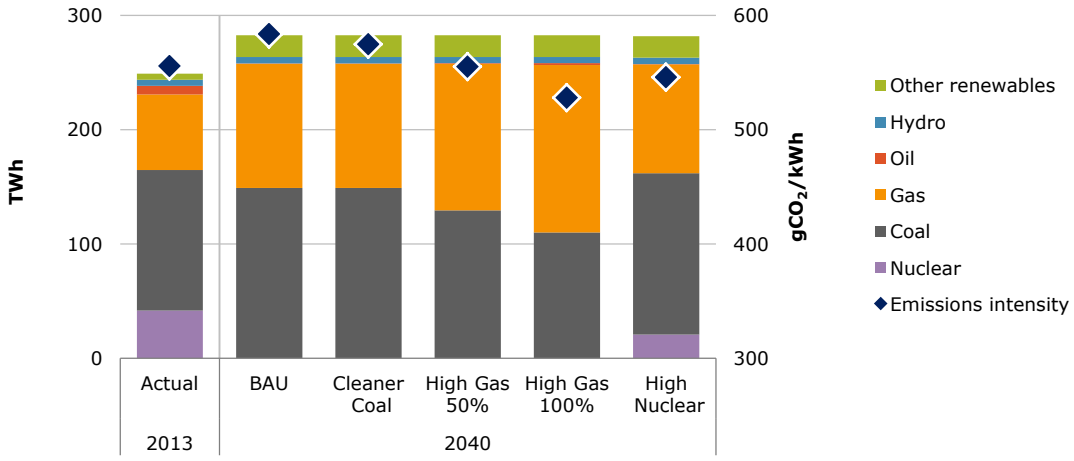
ALTERNATIVE POWER MIX SCENARIO

All four Alternative Power Mix cases apply to Chinese Taipei: The Cleaner Coal Case, the High Gas 50% Case, the High Gas 100% Case and the High Nuclear Case. Under the High Nuclear Case, the two 1 350-MW advanced boiling water reactor (ABWR) units used in the fourth nuclear project (suspended mid-2014) would be put into operation and the other nuclear reactors would be decommissioned by 2025 (WNA, 2016). Nuclear generators are projected to produce 21 TWh annually by 2040 under the High

[4] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

Nuclear Case, whereas production is suspended under the BAU (Figure 18.10). Power sector CO_2 emissions intensity declines to about 546 grammes of CO_2 per kWh (gCO_2/kWh) under the High Nuclear Case and holds at this level, the second lowest of all Alternative Power Mix Scenario cases (the lowest is the High Gas 100% Case). Under the High Nuclear Case, the share of coal declines to 50% (from 53% under the BAU) and the share of gas declines to 34% from 38%, boosting energy self-sufficiency. The main obstacle at present is strong public opposition to nuclear power.

Figure 18.10 ● Chinese Taipei: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

Under the Cleaner Coal Case, all coal-based plants built after 2020 are assumed to be equipped with advanced ultra-supercritical (A-USC) or integrated gasification combined cycle (IGCC) technology. Emissions from power generation rise from 138 $MtCO_2$ in 2013 to 162 $MtCO_2$ in 2040.

Under the High Gas 100% Case, 100% of coal-based capacity additions are replaced with natural gas, whereas it is only half under the High Gas 50% Case. In 2040, the High Gas 50% Case provides 128 TWh of gas-generated electricity, and the High Gas 100% Case produces 147 TWh (compared with 109 TWh under the BAU Scenario). Under the High Gas 50% Case, power sector CO_2 emissions intensity falls to 555 gCO_2/kWh and under the High Gas 100% Case to 528 gCO_2/kWh. Under both cases, total energy-related CO_2 emissions rise by 2040: 246 $MtCO_2$ under the High Gas 100% Case and 255 $MtCO_2$ under the High Gas 50% Case.

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

A total investment of between USD 63 billion and USD 129 billion is needed in energy infrastructure to meet growing energy demands (Table 18.5). The bulk of investment is for power generation, 87% in the low-cost estimate and 79% in the high-cost estimate. An additional generation 12 GW of capacity is required, as well as expanded and refurbished transmission and distribution networks. The downstream segment claims around 11% (low-cost estimate) to 19% (high-cost estimate) of total investment for additional refinery capacity of 189 000 barrels per day (bbl/d), and for LNG import capacity additions of 12 billion cubic metres (bcm) per year. Upstream and domestic energy transport for coal and gas (from source to ports or end-use facility) accounts for about 2.7% of total investment.

Table 18.5 ● Chinese Taipei: Projected investments in the energy sector in the BAU Scenario, 2015-40

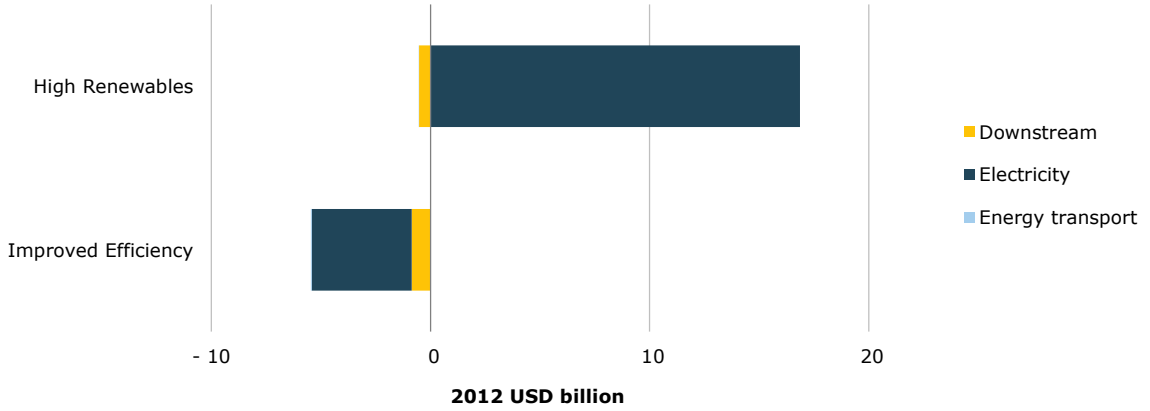
2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	0.02	0.03
	Gas	0.14	0.41
	Subtotal	0.16	0.44
Downstream	Refinery	5.7	23
	LNG import terminals	1.1	1.3
	Subtotal	6.8	24
Electricity	Coal	17	21
	Gas	6.0	9.8
	Hydro	0.1	0.3
	Wind	5.8	15
	Solar	17	25
	Biomass and others	0.4	0.5
	Geothermal	1.2	1.5
	Transmission lines	4.7	5.4
	Distribution lines	2.0	24
	Subtotal	55	102
Energy transport	Gas	0.04	0.20
	Coal	1.5	1.5
	Subtotal	1.6	1.7
	Total	**63**	**129**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

Total investment under the Improved Efficiency Scenario is 8.6% lower than under the BAU, at only USD 58 billion over the Outlook period (Figure 18.11). The downstream sector shows the largest reduction in investment needs (13% below the BAU) because lower gas demand (in both power and industry) displaces about 2.9 Mt per year of LNG import terminal capacity, and a cut in oil demand reduces refinery capacity by 11 000 bbl/d. Investment in the power sector is 8.3% lower under the Improved Efficiency Scenario, as 3 932 MW less power capacity is needed as a result of greater energy efficiency.

Figure 18.11 ● Chinese Taipei: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.

Source: APERC analysis.

The investment requirement under the High Renewables Scenario is 26% higher than under the BAU. Investment in renewable power triggers this increase, as capacity increases by 90% from the BAU Scenario, with wind increasing 9% a year and solar 13% a year. Additional storage requirements for solar generation also augment this investment.

SUSTAINABLE ENERGY FUTURE

Chinese Taipei's 2008 sustainable energy policy outlines a solution beneficial not only for energy production but for the environment and the economy as well: A high-efficiency, high-value-added, low-emission and low-dependence energy consumption and supply system.

The government aims to reduce energy demand by improving energy efficiency, to secure energy supply by diversifying energy sources and increasing upstream acquisitions, and to balance supply and demand. Recent upstream acquisition agreements have given CPC a 5% stake in the Prelude LNG Project (2013) and a 2.6% equity stake in the Ichthys LNG offshore project in northwestern Australia (2014) (CPC, 2014).

Progress in meeting the targets of reducing CO_2 emissions to the 2008 level of 250 $MtCO_2$ between 2016 and 2020, and to the 2000 level of 214 $MtCO_2$ by 2025 will be reviewed through monitoring and follow-up mechanisms.

Enhancing energy security: Stockpiling at home and investing abroad

Securing the energy supply is a priority. The Petroleum Administration Act (2001) requires that refiners and importers maintain 60 days of sales volumes (calculated from the average domestic sales and private consumption over the preceding 12 months); a petroleum fund finances this oil storage. The government also stockpiles 30 days of oil demand under this Act and at least 25 days' demand of LPG (BOE, 2013).

The CPC has engaged in cooperative exploration with foreign governments and large international oil companies throughout the Americas, the Asia–Pacific region and Africa under the name Overseas Petroleum and Investment Corporation for many years. It is now expanding its presence in overseas exploration and production, and at the end of 2013 it was involved in the cooperative exploration of 25 fields in the APEC region. It is optimising the value of its existing overseas oil and gas assets, establishing core areas with high growth rates, bidding for open blocks, seeking field takeovers from major oil companies, and pursuing new oil and gas field mergers and acquisitions to increase reserves (CPC, 2014a).

Although almost all energy will be imported over the projection period and Chinese Taipei's fossil fuel self-sufficiency rate is close to 0 (Table 18.6), oil and LNG stockpiling, together with oil and gas shares in overseas fields, improves energy security to some extent.

Table 18.6 ● Chinese Taipei: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040						
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%	High Nuclear
Primary energy supply diversity (HHI)	0.31	0.33	0.34	0.31	0.33	0.32	0.31	0.30
Primary energy supply self-sufficiency (%)	12	5	5	8	5	5	5	10
Oil self-sufficiency (%)	0	0	0	0	0	0	0	0
Gas self-sufficiency (%)	2	1	2	1	1	1	1	1
Electricity generation input fuel diversity (HHI)	0.35	0.46	0.49	0.42	0.46	0.43	0.42	0.39

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

Energy diversity under the Herfindahl-Hirschman Index (HHI) for both TPES and the electricity fuel mix increases gradually. TPES becomes less diversified with nuclear power phase-out and more fossil fuels, including coal, generating electricity. Renewable energy development could contribute to a more diversified energy supply, but it remains small over the projection period and cannot reverse the overall trend toward less diversification. The economy's lack of large energy reserves and its undiversified TPES may pose some risk in meeting future energy demands.

Climate change impacts and risks: Temperature rise nearly twice the global average

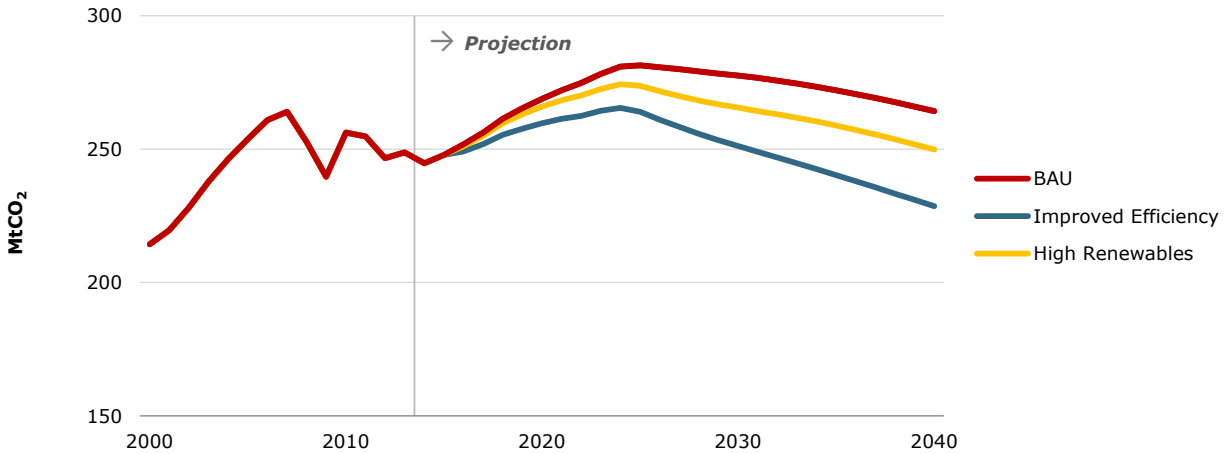
Being a subtropical island makes Chinese Taipei especially vulnerable to the impacts of climate change. Average annual temperature rise is 1.3°C, nearly twice the global average, resulting in increased frequency and intensity of typhoons and floods, a sea level rise that may cause flooding of coastal lands, coastal erosion and the retreat of coastal front, and more frequent and extensive droughts and water shortages (EPA, 2015a).

In 2011, an Energy Conservation and Carbon Reduction Service Team was established, comprising a technology service group, an advocacy group and a volunteer group, to provide technology consulting services to all energy users and the public (BOE, 2014a). In September 2015, Chinese Taipei pledged to reduce its carbon emissions by 50% in 2030 compared with the BAU (using the government's BAU projections) under the INDC, this is equivalent to an emissions target of 214 $MtCO_2$ in 2030 (Taiwan Today, 2015).

Under the BAU, the economy's energy-related CO_2 intensity is expected to decline steadily over the projection period, from 72 toe per 2012 USD million PPP to 57 toe per 2012 USD million PPP, thanks to energy conservation and clean energy development efforts. Final energy-related CO_2 emissions are projected to peak in 2024 at 284 $MtCO_2$ and decline to 264 $MtCO_2$ by 2040 (Figure 18.12). Rising electricity demand and the phase-out of nuclear power cause energy-related CO_2 emissions to rise sharply over the next decade, then plateau briefly and decline slightly thanks to energy efficiency improvements and structural transformation towards a high value-added and low energy-intensive economic structure.

The Improved Efficiency Scenario shows the largest reduction in energy-related CO_2 emissions, at approximately 36 $MtCO_2$ in 2040 or 13% less than the energy-related CO_2 emissions under the BAU Scenario. Meanwhile, the High Renewables Scenario would save about 14 $MtCO_2$, or 5.4% of energy-related CO_2 emissions.

Figure 18.12 • Chinese Taipei: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

RECOMMENDATIONS FOR POLICY ACTION

The greatest challenge is the relatively undiversified power mix. The government's decision to halt construction of a fourth nuclear power plant in April 2014 following public protests may significantly destabilise Chinese Taipei's energy supply and lead to rising electricity costs.

Without nuclear contributing to the power mix, more actions will be required to counteract rising energy-related CO_2 emissions. On the supply side, importing more gas is recommended as gas is cleaner than coal and is also the second-largest power generation fuel. On the demand side, MEPS should be expanded to appliances which are not currently covered, and more advanced technologies should be introduced to reduce energy intensity in the industrial sector, especially in chemicals and petrochemicals.

Furthermore, as Chinese Taipei is endeavouring to develop carbon capture and storage (CCS) technology to further reduce energy-related CO_2 emissions, a stable and long-term policy environment should be established to stimulate CCS development if new coal-fired power plants are built. Policies would need to cover financial incentives as well as regulatory schemes such as a CCS mandate for new coal plants and/or a GHG emissions performance standard.

Should the government decide in favour of nuclear energy, however, more communication between the government and academics, scientists, non-governmental organisations (NGOs) and environmentalists should be undertaken since the public often finds information provided by the government unconvincing. Stricter nuclear safety protocols should also be introduced to build public trust and overcome scepticism.

19. THAILAND

KEY FINDINGS

- **In the BAU Scenario, total final energy demand in Thailand will increase 86% by 2040, growing at an AAGR of 2.3%.** This increase is driven by high growth rates in commercial buildings (2.8%) and industry (2.6%), as the economy aims to move into services (that is, away from manufacturing) and to produce higher value-added products.

- **Existing policies that promote fuel economy and high-efficiency vehicles will help Thailand curb energy demand in transport over the Outlook period.** A more comprehensive policy package would deliver higher savings, particularly if backed up with effective monitoring and evaluation of impacts.

- **Existing plans to switch from gas to coal power generation and to increase renewables can improve the diversity of Thailand's fuel mix and its energy security.** Cleaner coal technologies need to be adopted to curb a corresponding increase in CO_2 emissions.

- **A trade-off exists among potential power mix policies in Thailand.** The High Nuclear Case, and the High Renewables and Improved Efficiency Scenarios, deliver improved energy security by 2040 as they reduce the share of gas in generation to 45% and 48% respectively, compared with 50% in the BAU. The High Gas 100% Case, by contrast, minimises CO_2 emissions intensity but has a negative effect on the energy security index.

ECONOMY AND ENERGY OVERVIEW

Thailand is one of the central states of South-East Asia and is known as the 'the window to South-East Asia.' It is surrounded by developing economies and countries, such as Myanmar, Lao People's Democratic Republic (Lao PDR) and Cambodia, and borders Malaysia in the south. Thailand has a land area of 513 115 square kilometres (km^2) and in 2013 had a population of 67 million. From 2013 to 2040, Thailand's gross domestic product (GDP) is projected to grow about 152%, reflecting an annual average growth rate (AAGR) of 3.5%, while population rises only 8% (0.28% AAGR). Despite being an agriculture-based economy, this sector contributes only 7.2% to GDP, while other sectors play much stronger roles including manufacturing (29%), trade (15%, accounting for both wholesale and retail), and logistics and communication (10%). Other service sectors (comprising the financial, education, hotel and restaurants sub-sectors) account for 26% (National Accounts of Thailand 2013; NESDB, 2015).

Seeking to optimise the advantage of its location, Thailand aims to be the centre of investment and trade in the region. Through the Board of Investment of Thailand (BOI), the current government established ten special economic zones in border cities. Infrastructure investments are prioritised, particularly transport networks such as a new dual-track railway and high-speed train. Recently, economic growth has slowed, largely due to several factors such as the global economy downturn, an ongoing drought situation, and internal conflicts and populist policies that have distorted market mechanisms. Thailand has also been in a period of economic reform as it prepared to join the Association of Southeast Asian Nations (ASEAN) Economic Community (AEC) in 2015, which is expected to be a key driver of rising energy demand in the future. Under the Business-as-Usual (BAU) Scenario, total primary energy supply (TPES) per capita will increase 72% from 2 tonnes of oil equivalent (toe) in 2013 to 3.4 toe in 2040, almost reaching the Asia-Pacific Economic Cooperation (APEC) average (Table 19.1). As the economy becomes more services-oriented, energy demand will increase while the population stabilises.

Table 19.1 ● Thailand: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	256	398	608	668	854	1 221	1 686
Population (million)	57	63	67	67	71	73	73
GDP per capita (2012 USD PPP)	4 529	6 356	9 117	9 906	12 099	16 767	23 152
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	42	72	118	134	167	211	248
TPES per capita (toe)	0.7	1.2	1.8	2.0	2.4	2.9	3.4
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	29	51	85	96	122	154	178
Final energy intensity per GDP (toe per 2012 USD million PPP)	113	127	140	143	142	126	106
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	81	152	223	247	313	412	500
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	80	83	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

ENERGY RESOURCES AND PRODUCTION

Thailand has limited energy resources; its domestic oil resources will deplete by 2019 and natural gas by 2022 (Table 19.2). To maintain a degree of energy security, the economy needs to urgently explore new

energy sources. In late 2014, the Department of Mineral Fuels invited bids for exploration and production rights for various exploration blocks, onshore and in the Gulf of Thailand. The initiative was halted before it could advance further as some sections of the Petroleum Act required amendment to align with the government's energy reform movement (described in the next section) (DMF, 2015). At the same time, current policy calls for a move to clean coal technology in power generation and for diversification of the fuel mix. Public opposition and concerns about the environmental impacts of coal are the main barriers to policy implementation, especially given that the majority of coal produced is lignite, which is particularly 'dirty', leading to higher greenhouse gas (GHG) emissions.

Table 19.2 • Thailand: Energy reserves and production, 2014

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Coal (Mt)	1 239	69	0.14	22nd	7th
Oil (billion bbl)	0.46	2.8	0.03	52nd	12th
Gas (tcm)	0.24	5.7	0.13	44th	12th

Note: Total proven coal/oil/gas reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions.
Source: BP (2015).

In 2013, based on energy data from the International Energy Agency (IEA), Thailand's total primary energy production was 78 million tonnes of oil equivalent (Mtoe). Natural gas accounted for the largest share (36%), followed by renewables[1] (32%), oil (25%), coal (6.5%) and hydro (0.63%).

ENERGY POLICY CONTEXT

Recent energy policy, made under the government of General Prayuth Chan-Ocha and presented to the National Assembly on 12 September 2014, comprises four main pillars: 1) energy price restructuring to better reflect actual costs and encourage more efficient use of energy; 2) exploration and production for oil and gas, both onshore and offshore; 3) construction of new power plants using both renewable energy and fossil fuels; and 4) international cooperation to develop new energy sources (The Royal Thai Government, 2014). These four pillars show that Thailand has prioritised energy security, and recognises the need to boost domestic energy supply by promoting both development of renewables and fossil fuel exploration. Cost-effective energy efficiency measures also need to be pursued, including through energy price market reform and the phase-out of energy subsidies.

The recent decline in oil prices created an opportunity for Thailand to restructure fuel pricing and reduce energy cross-subsidies. Public participation, however, is needed to address the difficulty of policy implementation, particularly for fossil fuel exploration and construction of new fossil fuel-based power plants. International cooperation on energy source development, particularly with the neighbouring countries of Myanmar, Lao PDR, Cambodia and Malaysia, is also crucial for ensuring energy supply in the future.

Thailand achieved an important milestone in 2015 by integrating all energy policy plans into a comprehensive plan called the Thailand Integrated Energy Blueprint (TIEB), which comprises five interelated plans (EPPO, 2015a): 1) the Power Development Plan (PDP 2015) (EPPO, 2015b); 2) the Energy Efficiency Plan (EEP 2015) (EPPO, 2015c); 3) the Alternative Energy Development Plan (AEDP 2015) (DEDE, 2015); 4) the Oil Plan 2015; and 5) the Gas Plan 2015. All plans were updated and consolidated to cover the same time period, from 2015 to 2036. The PDP includes an energy efficiency target to reduce energy intensity by 30% compared with 2010, and also contains energy saving and renewables targets. The AEDP 2015 aims to increase the share of renewables to 20% of power generation and also diversify the fuel mix by increasing the coal share to 23%, of which 17% will be advanced and clean coal technologies, such as the ultra-supercritical (USC) technology (Sutabutr, 2015).

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

BUSINESS-AS-USUAL SCENARIO

This section illustrates energy demand and supply in the BAU Scenario. Table 19.3 summarises the key assumptions. Please note that the definition and time frame of the BAU Scenario in this Outlook is different from the 2015 government's plans (DEDE, 2015; EPPO, 2015a, 2015b and 2015c). The BAU Scenario in this Outlook is based on existing policies, while the government's plans include new policies and ambitious assumptions.

Table 19.3 ● Thailand: Key assumptions and policy drivers under the BAU Scenario

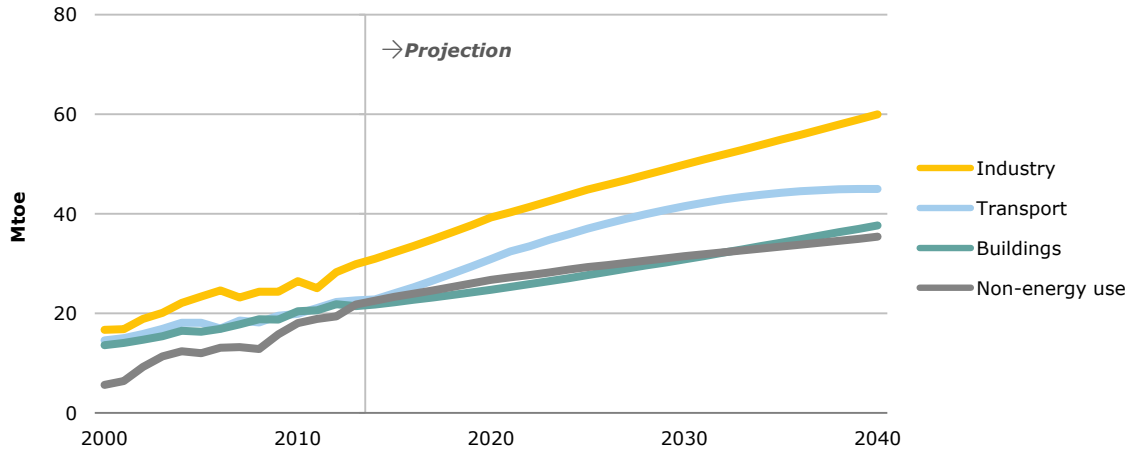
Buildings	• Implement a building energy code. • Implement energy management in designated buildings.
Industry	• Implement energy management in designated factories. • Identify persons responsible for energy. • Train and appoint energy management auditors.
Transport	• Continue to strengthen GHG emissions standards. • Implement an eco-label program. • Apply taxation according to CO_2 emissions. • Tax incentive for eco-cars.
Energy supply mix	• Promote fuel mix diversification.
Power sector	• Reduce dependence on gas in power mix.
Renewables	• Increase share of renewables to 30% by 2036, as outlined in AEDP.
Energy security	• Expand exploration for oil and gas. • Develop renewable energy regarding to AEDP. • Implement energy efficiency policies and measures in EEP.
Climate change	• Work towards Thailand's Intended Nationally Determined Contribution (INDC) to reduce GHGs 20% from the government's BAU projections by 2030.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Energy demand under the BAU Scenario grows 86%, equivalent to an AAGR of 2.3%, over the Outlook period, reaching 178 Mtoe by 2040 (from 96 Mtoe in 2013). Industry shows the highest growth at 2.6% AAGR, followed by domestic transport (2.6% AAGR), and the buildings and agricultural sector (2.1% AAGR). With the expectation of rapidly increasing international trade and travel, international transport (which includes navigation and aviation) has the highest growth rate (2.7% AAGR) of all sectors. Yet overall, transport is the only sector in which energy demand is expected to stabilise by 2040, owing to vehicle fuel economy policies (including vehicle emissions standards and tax incentives for energy-efficient vehicles) that help to curb long-term transport energy demand. Although energy demand growth for buildings and agriculture has the second-lowest growth rate (after non-energy use), its growth reflects increasing penetration of energy-consuming appliances and equipment in buildings associated with higher personal income. Non-energy use will remain a significant share (20%) of energy demand in 2040, having a 1.8% AAGR over the Outlook period.

Figure 19.1 • Thailand: Final energy demand by sector, 2000-40



Notes: Transport only refers to domestic transport; Buildings refers to commercial, residential and agricultural sectors.
Sources: APERC analysis and IEA (2015a).

Buildings energy use: Rising living standards, shift to services sector drive up demand

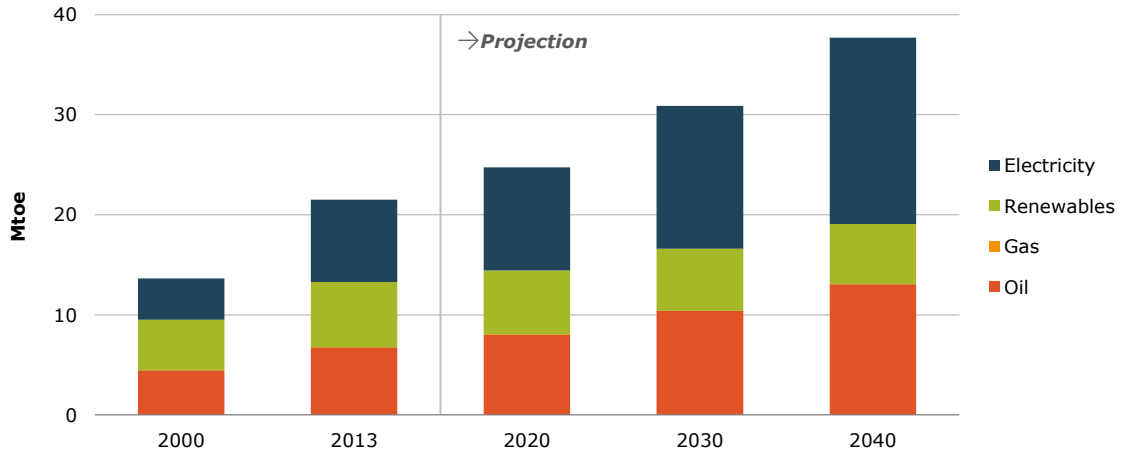
Energy demand in the buildings (including both commercial and residential buildings) and agriculture sector is expected to increase 75% over the Outlook period, from 21 Mtoe in 2013 to 38 Mtoe in 2040, spurred by continuous growth due to rising living standards and an economic shift towards the services sector. Electricity will remain the major source of energy for buildings, and will have the highest growth rate (3.1% AAGR) as penetration of electric appliances increases. Oil demand in the sector will grow at 2.5% AAGR, mostly in agricultural and residential. Demand for traditional biomass in the residential sub-sector will gradually fall as increasing wealth leads households to switch to modern energy sources such as liquefied petroleum gas (LPG) and electricity for cooking and cooling.

According to the Thai government, among large commercial buildings, office buildings consume about 37% of electricity; department stores, hotels, and retail and wholesale business facilities each account for about 12%. Such large commercial buildings are subject to ministerial regulations under the Energy Conservation Promotion Act 1992. A building energy code developed in 2009 has been implemented on new and existing large buildings (defined as all floors in the same building having a total area of more than 2 000 m2). The code comprises mainly performance-based requirements on the systems for the building envelope, lighting and air conditioning. Projections show that if the building energy code were fully implemented and its standards raised gradually to the long-term target of near-zero energy building, electricity consumption for large commercial buildings in Thailand would drop by more than 50% by 2030 compared with the government's BAU projections (Ministry of Energy, 2011).

Thailand also has minimum energy performance standards (MEPS) for appliances and equipment through the Thai Industrial Standards Institute, Ministry of Industry. Air conditioners, refrigerators, self-ballasted compact fluorescent lamps and double-capped fluorescent lamps are subject to mandatory MEPS, while 14 other appliances and kinds of equipment have voluntary standards. The Ministry of Energy has ministerial regulations on high energy performance standards (HEPS) for 28 appliances and types of equipment, which serve as the basis on which the Electricity Generating Authority of Thailand (EGAT) will issue 'No. 5' high efficient labels for electric appliances and the Department of Alternative Energy Development and Efficiency (DEDE) will issue high-efficient labels for energy-required equipment and engines.

With the combination of the building energy code, and MEPS and HEPS for appliances and equipment, Thailand is well established to effectively tackle energy demand in the buildings. The agricultural sector, under the BAU, sees a doubling of energy demand over the Outlook period, as agricultural production increases but improved yields also reflect adoption of more machines and equipment. This rapid increase is tempered by uptake of energy-efficient machines and equipment.

Figure 19.2 • Thailand: Buildings and agriculture sector final energy demand, 2000-40



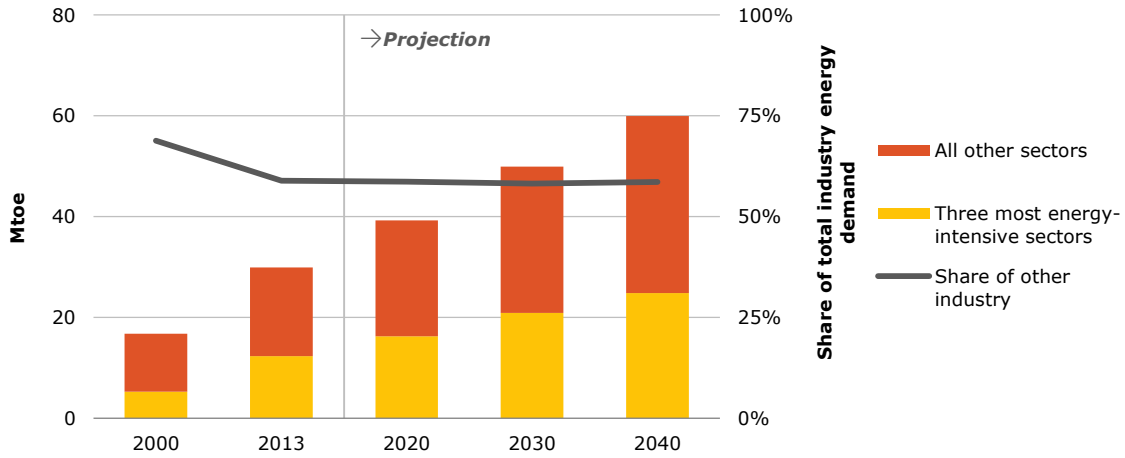
Sources: APERC analysis and IEA (2015a).

Industry energy use: Manufacturing processes for value-added products spur growth

Energy demand in industry will double over the Outlook period, from 30 Mtoe in 2013 to 60 Mtoe in 2040. This is driven largely by the manufacturing sub-sectors, particularly in food and beverages, non-metallic minerals, chemicals and petrochemicals, and machinery. Coal, oil and electricity are expected to be the main energy sources for industry, with demand growing most quickly for oil, which is expected to increase by 215% by 2040. Natural gas and LPG show rapid demand growth for heating in many sub-sectors, particularly food and beverage.

Thailand has energy efficiency policies specific to industry sub-sectors. The Energy Conservation and Promotion Act obliges designated factories to submit energy reports to the DEDE, which provides a feedback report ranking and benchmarking the energy efficiency of all factories in the sub-sector. Regulations also require the designated factories to identify the person(s) responsible for energy and oblige the energy management auditors to monitor energy use and propose energy efficiency programs for the factories. This policy is expected to stabilise share of energy demand for the three most energy-intensive sectors at 40% throughout the Outlook period.

Figure 19.3 • Thailand: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.

Sources: APERC analysis and IEA (2015a).

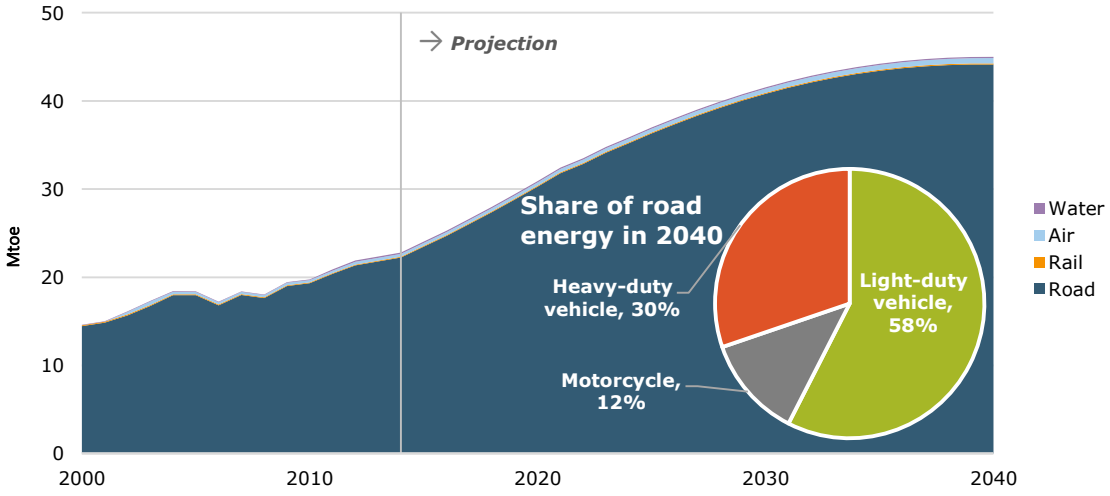
Transport energy use: Road transport continues to dominate

Energy consumption in domestic transport, which will increase from 23 Mtoe in 2013 to 45 Mtoe in 2040 (almost double), continues to be dominated by road transport, which doubles from current levels over the Outlook period. The government could stimulate energy efficiency in transport through policies targeting fuel economy improvement of new vehicles, such as an eco-car program and tax incentives. Improved fuel economy and saturation of vehicle ownership will curb energy demand growth, which is expected to peak towards the end of Outlook period. Thailand is developing MEPS for vehicles, which are expected to be voluntary for the initial stage and then become mandatory, with the standards being raised gradually.

Light-duty vehicles (LDVs) account for 58% of road energy consumption in 2040, followed by heavy-duty vehicles (HDVs) at 30% and motorcycles at 12%. Freight in Thailand still relies heavily on road transport, but developing rail transport has become a high priority. Several double-track railways will be constructed within the next eight years (OTP, 2015). Vehicle ownership (of both LDVs and HDVs) is expected to increase from 198 vehicles per 1 000 people in 2013 to 492 in 2040, reaching a 91% saturation level. The absolute number of vehicles will increase from 13 million in 2013 to 36 million 2040. Compared with only 0.22% of the current stock being hybrid vehicles, a range of high-efficiency vehicles will emerge to have increasingly important shares in 2040, including hybrid vehicles (16%), plug-in hybrid electric vehicles (PHEVs) (6.5%) and battery electric vehicles (BEVs) (2.2%).

Energy demand growth will be higher in international transport (2.7% AAGR) than in domestic transport (2.6% AAGR). Yet in 2040 in absolute volumes, international aviation and navigation will be 9.5 Mtoe, about 20% of the domestic transport energy demand.

Figure 19.4 • Thailand: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

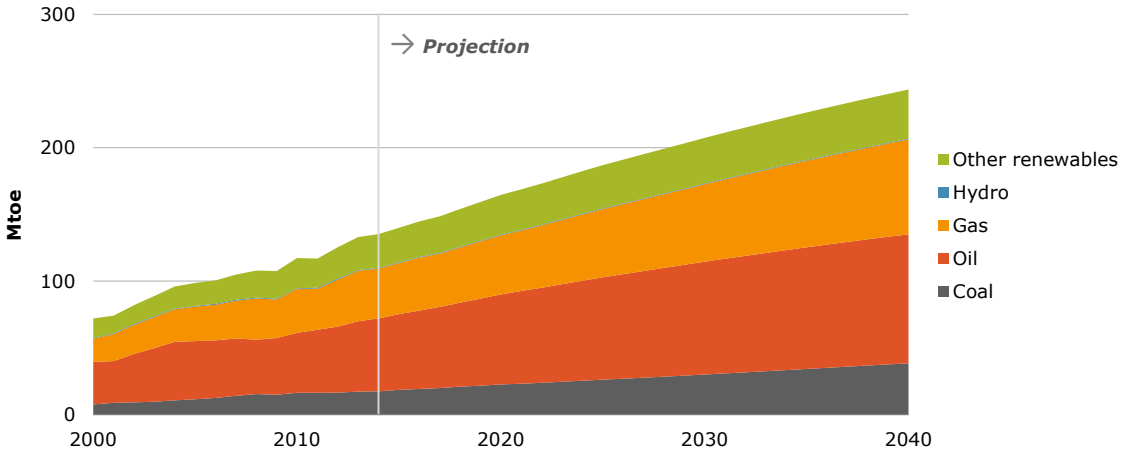
RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Oil and gas still dominate, but coal increases

From 2013 to 2040 under the BAU, Thailand's TPES increases by 85% from 134 Mtoe to 248 Mtoe (Figure 19.5). Oil and natural gas supply increase by 83% and 88% respectively, but their shares in TPES remain almost unchanged, ending the Outlook period at 39% and 29%, respectively. Coal consumption rises 123%, its share increasing from 13% in 2013 to 16% by 2040, reflecting the addition of 7.4 gigawatts (GW) of new coal-fired generation in the Power Development Plan (PDP 2015). As rising incomes prompt a switch away from the use of traditional biomass, the share of renewable energy declines from 19% in 2013 to 15% in 2040.

The primary energy mix in 2040 aligns with Thai government policy that aims to secure energy supply, in part by reducing oil and gas dependency. The rise of coal as a major fuel, however, will drive up environmental impacts such as local pollution. Overall, energy production in Thailand between 2013 and 2040 will drop 17%. By energy type, production for coal, hydro and renewable energy will increase, while oil and gas will decrease as resources are depleted.

Figure 19.5 • Thailand: Total primary energy supply by fuel, 2000-40

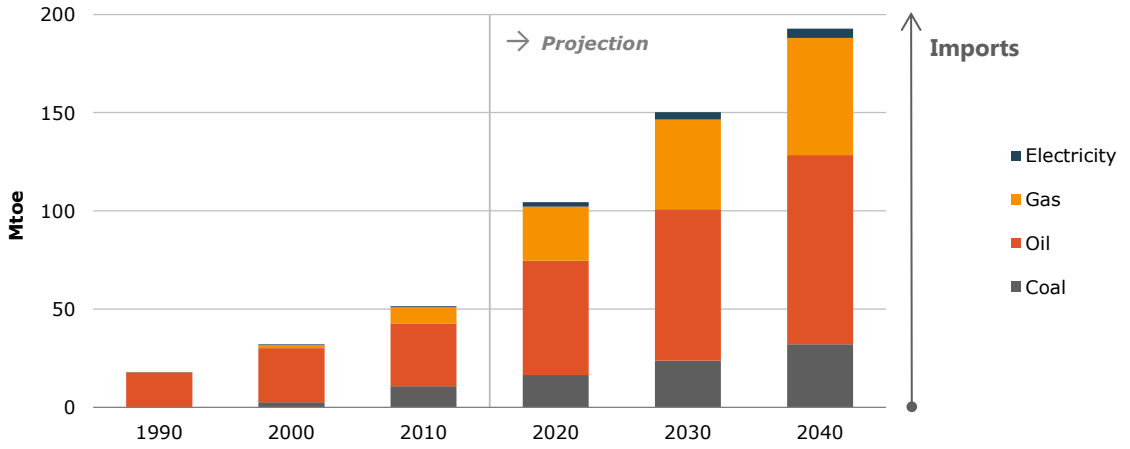


Sources: APERC analysis and IEA (2015a).

Energy trade: Heavy reliance on imports remains dominant feature

Thailand is highly dependent on energy imports, which accounted for 42% of TPES in 2013; the figure rises to 78% by 2040. Oil currently represents 61% of total energy imports, followed by coal (21%), natural gas (17%) and electricity (1.7%). In 2040, the shares become more balanced and gas overtakes coal to hold second place in the ranking, which falls out as oil (50%), natural gas (31%), coal (17%) and electricity (2.5%). The share of natural gas, in fact, almost doubles, with the lead import sources being Myanmar (by pipeline) and the Middle East (in the form of liquefied natural gas [LNG]). Electricity imports increase nearly fivefold by 2040, with neighbouring economies and countries being the main source (particularly Lao PDR, which exports mainly from surplus hydropower).

Figure 19.6 • Thailand: Net energy imports, 1990-2040



Sources: APERC analysis and IEA (2015a).

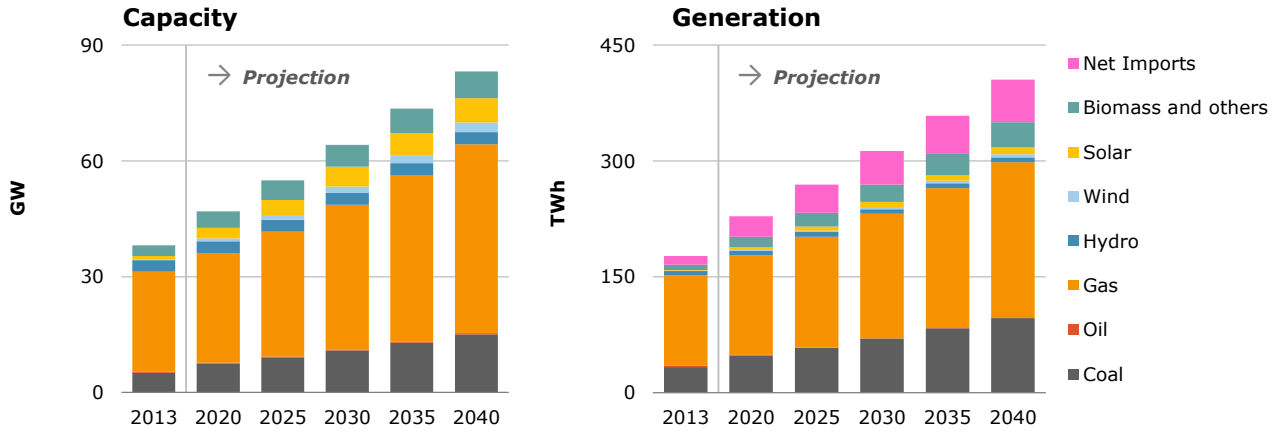
Power sector trends: Fossil fuel dependency dominates, despite rising share of renewables

Electricity capacity (excluding import electricity) in Thailand under the BAU grows by an AAGR of 2.9% from 2013 to 2040, requiring 119% of installed generation capacity—from 38 GW in 2013 to 83 GW by 2040. Despite dropping from its current share of 68%, natural gas will remain the main fuel at 59% of capacity in 2040, followed by coal (which increases its share from 14% to 18%), other renewables (increasing from 10% to 19%) and hydro (a decline from 7.9% to 3.8%).

Clear policy direction to move from gas to clean coal is what drives the rapid growth in coal use for power. Oil's share of generation decreases from just below 0.95% of generation in 2013 to 0.065% in 2040, serving mainly as the substitute fuel when natural gas supply is in maintenance (particularly for the south of Thailand and remote areas/islands). As part of its bid to increase the share of renewables, Thailand will increase its share of imported electricity from Lao PDR from 6.4% in 2013 to 14% by 2040.

The BAU Scenario incorporates Thailand's PDP 2015 (EPPO, 2015b), which aims to diversify the fuel mix in power generation to help alleviate energy security concerns. However, power generation will remain heavily reliant on fossil fuels. Thailand could consider adopting low-carbon emission technologies, such as integrated gasification combined cycle (IGCC) and carbon capture and storage (CCS), which will be demonstrated below in the section on the Alternative Power Mix Scenario. To optimise the use of renewable energy sources, Thailand needs to develop more transmission lines and adopt smart-grid technologies.

Figure 19.7 • Thailand: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

This Outlook discusses three independent Alternative Scenarios—the Improved Efficiency, the High Renewables and the Alternative Power Mix Scenarios. The Improved Efficiency and the High Renewables Scenarios include the Thai government's targets for higher penetration of energy-efficient equipment and renewable energies, respectively.[2] These scenarios discuss Thailand's potential contribution to the APEC energy intensity goal and renewable energy goal. The Alternative Power Mix Scenario focuses on the electricity sector, and discusses the opportunities and challenges of alternative electricity supply options in Thailand. Among these Alternative Scenarios, the Improved Efficiency Scenario contributes the biggest reduction in energy-related CO_2 emissions (22%) while improving the energy self-sufficiency by 2040 when compared with the BAU 2040. The High Renewables Scenario and the High Nuclear Case in the Alternative Power Mix Scenario largely improve the fuel mix diversity and energy self-sufficiency rate with some reductions in emissions compared with the BAU scenario.

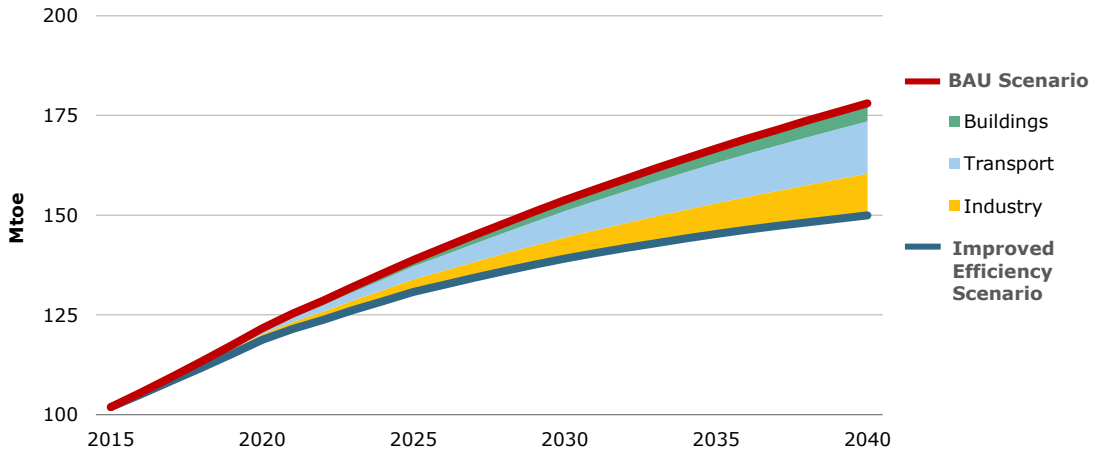
[2] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC'S ENERGY INTENSITY GOAL

The Improved Efficiency Scenario models the collective APEC energy intensity goal.[3] Thailand has set its own target of a 30% energy intensity reduction by 2036 (from the 2010 level), accompanied by an action plan on energy efficiency and targets allocated at sub-sector and measure levels. Under the updated Energy Efficiency Plan 2015 (EEP 2015), some 89 672 gigawatt hours (GWh) of electricity and 44 059 kilotonnes of oil equivalent (ktoe) of fuel and heating demand should be saved by 2036, equal to 30% of total energy demand at that time.

Under the Improved Efficiency Scenario, Thailand could reduce final energy demand 28 Mtoe by 2040, or 16% lower compared with the BAU. It achieves a 26% reduction in energy intensity by 2035 from 2005 levels, compared with a 15% reduction under the BAU. Transport contributes 47% of energy savings, followed by industry at 37% and buildings at 16%. To realise these additional savings, Thailand will need to implement fuel economy standards and labelling for transport, and also review regularly the energy efficiency policy, making it more stringent as needed. Similar approaches are needed for appliances and equipment in industry and buildings. The EEP 2015 states that Thailand will implement energy efficiency resource standards (EERS) to encourage utilities to work with their customers to carry out energy saving measures (EPPO, 2015c). Thailand will also implement a standard offer program (SOP) for energy efficiency activities that are already proven to deliver positive results.

Figure 19.8 • Thailand: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Source: APERC analysis.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

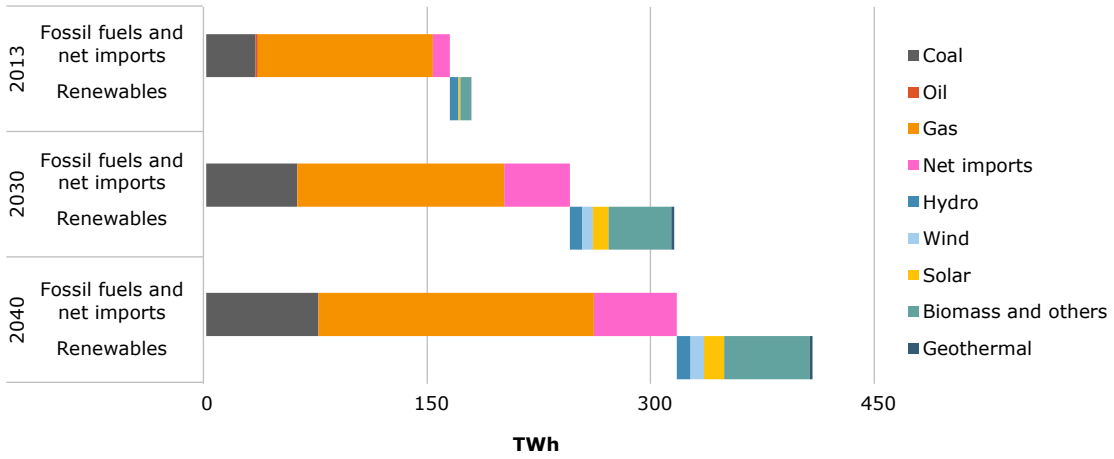
In 2014, APEC Leaders set a goal to double the share of renewable energy in all economies, and across all sectors, by 2030 (from 2010 levels).[4] Thailand's recently published Alternative Energy Development Plan (AEDP 2015) sets a target to boost renewables in final energy consumption from 12% to 30% by 2036 (DEDE, 2015). This target will be consolidated with the new PDP 2015 to increase renewable energy in the fuel mix for power generation from 9.4% in 2014 to 20% by 2036. This target also aims to aggressively increase renewable energy for heating, from 17.3% to 36.7%, and to achieve a threefold growth for biofuels, from 6.7% to 25%.

Under the High Renewables Scenario, the power capacity for each type of renewables will be met as the AEDP 2015 targets. By 2040, biomass has the largest share of capacity at 13% (11 GW), followed by solar at 9.2% (8 GW), wind at 5.8% (5.1 GW), hydro at 4.6% (4 GW) and geothermal at 0.35% (0.3 GW).

[3] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.
[4] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

In the AEDP 2015, Thailand set targets to substantially develop all renewable energy sources by 2036 including: 5.57 GW (2.3 GW in 2013) from biomass, 6 GW (0.82 GW in 2013) from solar, and 3 GW (0.22 GW in 2013) from wind (DEDE, 2015). To achieve this goal, the government will need to introduce feed-in tariffs (FiTs) (to replace the Adder system[5]) and competitive bidding, particularly for very small power plants (VSPPs).

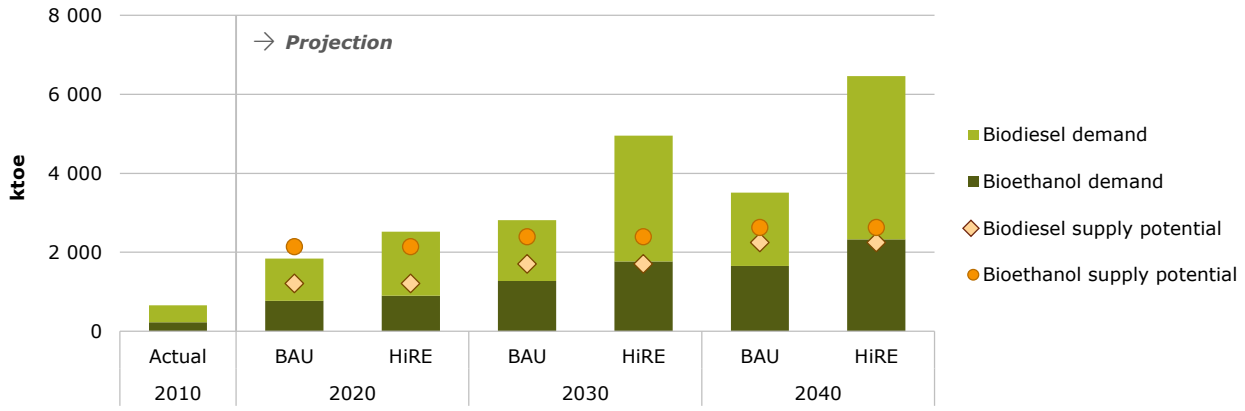
Figure 19.9 ● Thailand: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

Under the High Renewables Scenario biofuels (that is, bioethanol and biodiesel) demand is estimated to rise almost 10 times from 654 ktoe in 2010 to 6 458 ktoe in 2040. Biodiesel, which held a 65% (427 ktoe) share of biofuels demand in 2010, will decline slightly to 64% (4 134 ktoe) in 2040. This is more than double the BAU's biodiesel demand in 2040. These projections indicate that under the High Renewables Scenario, Thailand's supply potential is sufficient to meet bioethanol demand but not to meet biodiesel demand, as the supply potential for biodiesel falls short of demand from 2020 onwards.

Figure 19.10 ● Thailand: Biofuels demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is for the Outlook period only; HiRE = High Renewables Scenario.

Sources: APERC analysis, DEDE (2015), FAO (2014) and IEA (2015a).

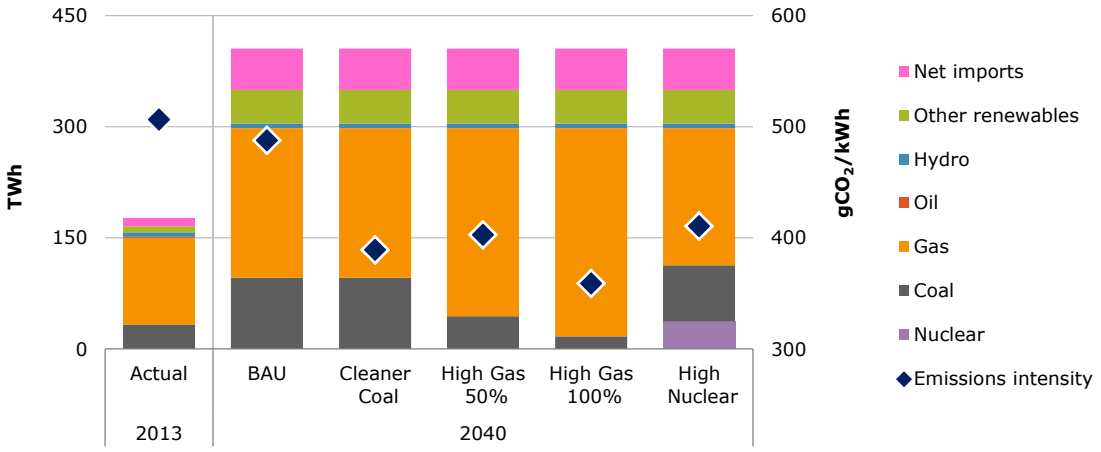
[5] The adder or feed-in premium program was introduced in 2007. Under the program, renewable energy investors are eligible for an additional price on top of the market price for electricity when selling to Thailand's power utilities, that is, the EGAT, the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA).

ALTERNATIVE POWER MIX SCENARIO

All four Alternative Power Mix Scenario Cases apply to Thailand and can be assessed against Thailand's PDP 2015. They are the Cleaner Coal, the High Gas 50%, the High Gas 100% and the High Nuclear Cases.

The Cleaner Coal Case assumes that, from 2020 onwards, all new coal-based electricity capacity is advanced ultra-supercritical (A-USC) or IGCC, with minimum efficiency of 45% to 50%. From 2030, all new plants will be A-USC or IGCC, and will be equipped with CCS. The High Gas 50% Case assumes that 50% of new electricity generation capacity will be gas instead of coal up to 2040; the High Gas 100% Case assumes that it is 100%. To see the impact of nuclear power in fuel mix, the High Nuclear Case assumes that Thailand will add nuclear power to the grid after 2030, that is to say, it will have 4 GW of nuclear power by 2035 and 5 GW by 2040. This nuclear power capacity is higher than the PDP 2015's target and was included in the previous Power Development Plan, which was in effect before the Fukushima incident however, post-Fukushima it was removed and is no longer in effect.

Figure 19.11 • Thailand: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

In terms of power sector CO_2 emissions, the High Gas 100% Case delivers the biggest reduction at 26% below the BAU in 2040. It is, however, the most costly alternative, reflecting higher gas prices in the modelling. Although natural gas provides the environmental benefit of lower emissions, this fuel switch could weaken fuel diversification in Thailand (see Table 19.5). The Cleaner Coal Case delivers the second-lowest power sector CO_2 emissions, a 20% of reduction compared with the BAU. As it projects only 5 GW of capacity at the end of the Outlook period, the High Nuclear Case has a lower impact on emissions with a 16% reduction but scores best in terms of energy security as it diversifies the fuel mix to a greater extent (see Table 19.5).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Thailand's total energy investment requirement from 2015 to 2040 ranges from USD 206 billion (low-cost estimate) to USD 410 billion (high-cost estimate) under the BAU. The power and upstream subsectors account for 80% of the total investment under the low-cost estimate and 74% under the high-cost estimate. Power investment, to support 45 GW of additional capacity and related expansion and refurbishment of the transmission and distribution (T&D) network, accounts for 50% of the total in the low-cost estimate and 46% in the high-cost estimate. Upstream requires 31% of the total investment in the low-cost estimate (29% high-cost estimate), the bulk of it going towards oil production.

The downstream subsector requires 7.3% (low-cost estimate) to 15% (high-cost estimate) of the total investment, for additional refinery capacity (of 528 000 barrels per day [bbl/d]) to maintain the current share of refinery production to total oil demand. This investment also covers total LNG import terminal capacity of 23 763 tonnes per year (t/yr) over the Outlook period. Domestic energy transport for oil, gas and coal (from source to ports or end-use facility) accounts for around 11-13% of the total investment.

Table 19.4 • Thailand: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	48	71
	Gas	13	40
	Coal	2.2	7.3
	Subtotal	63	118
Downstream	Refinery	11	53
	LNG import terminals	2.7	6.1
	Biofuels Refinery	1.9	2.7
	Subtotal	15	62
Electricity	Coal	30	57
	Gas	21	32
	Hydro	0.2	0.6
	Wind	4.5	6.2
	Solar	24	33
	Biomass and others	5.6	7.3
	Transmission lines	6.9	16
	Distribution lines	10	34
	Subtotal	102	187
Energy transport	Oil	22	26
	Gas	2.6	13
	Coal	1.7	4.1
	Subtotal	26	44
	Total	**206**	**410**

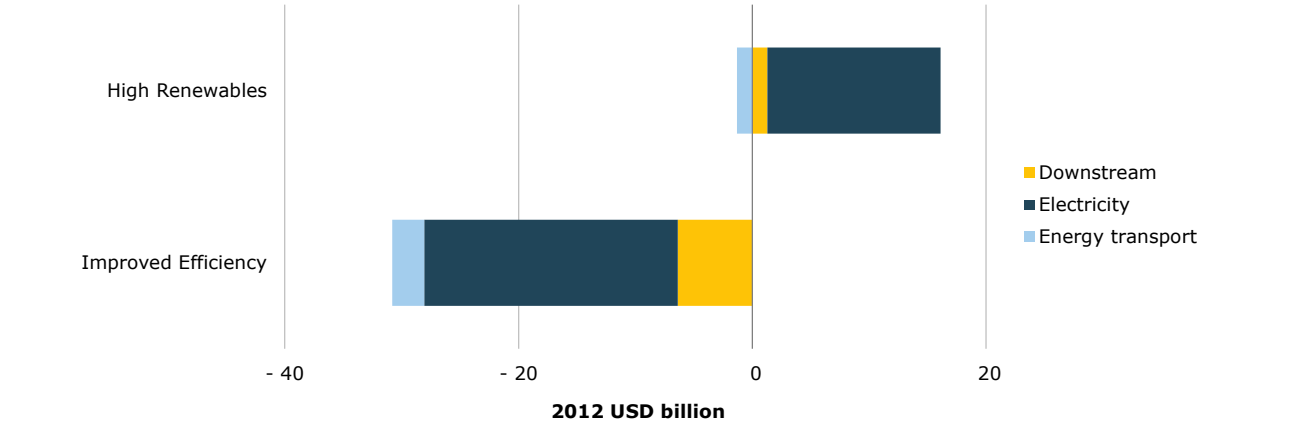
Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

The Improved Efficiency Scenario reduces the investment requirement by USD 31 billion (15% below the BAU), largely because the capacity addition requirement decreases by 16 GW (19% savings). This scenario saves USD 22 billion worth of investment within the power sector (21% lower than the BAU). Reduced oil demand and lower refinery capacity additions (only 355 000 bbl/d or 33% savings) reduce the downstream investment needs by USD 6.4 billion (42% compared with the BAU). This also reflects a 38% reduction in LNG import terminal capacity expansion as a result of lower gas demand.

The High Renewables Scenario, by contrast, increases investment requirements by 7.2% compared with the BAU, as capacity additions for renewables almost double to 22 GW (from only 12 GW in the BAU). The huge increase in renewables capacity for a relatively small incremental rise in investment reflects the assumption that the capital costs for wind and solar are on a declining trend over the Outlook period. Downstream investment shows a 8.5% increase as higher biofuel blends necessitate the installation of more biofuel refinery capacity.

Figure 19.12 • Thailand: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

Enhancing energy security: Reducing gas dependency a key policy goal

In terms of primary energy supply diversity, Thailand's situation is expected to remain unchanged to 2040 under the BAU. Existing energy policy seeks to maintain the current level of energy security by diversifying the energy mix, primarily by reducing dependency on natural gas by switching to coal and increasing shares of renewable energy. Thailand's generation input fuel diversity improves in the BAU as the Herfindahl-Hirschman Index (HHI) reduces from HHI 0.46 to HHI 0.39. Among the Alternative Power Mix Scenarios, the High Nuclear Case provides the best generation diversity index, based on the addition of 5 GW of nuclear capacity by 2040 at HHI 0.31. The High Renewables Scenario provides the second-best primary energy supply diversity, followed by the Improved Efficiency Scenario.

Primary energy sufficiency under the BAU drops by more than half, from 59% in 2012 to 27% by 2040, and so Thailand will need to import 73% of its energy supply to meet demand in 2040.

Table 19.5 • Thailand: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040						
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%	High Nuclear
Primary energy supply diversity (HHI)	0.29	0.29	0.29	0.28	0.29	0.31	0.32	0.28
Primary energy supply self-sufficiency (%)	59	27	30	33	27	27	27	31
Coal self-sufficiency (%)	30	16	20	19	16	24	31	19
Oil self-sufficiency (%)	37	10	12	11	10	10	10	10
Gas self-sufficiency (%)	75	16	21	17	16	14	13	17
Electricity generation input fuel diversity (HHI)	0.46	0.39	0.37	0.35	0.39	0.49	0.60	0.31

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a)

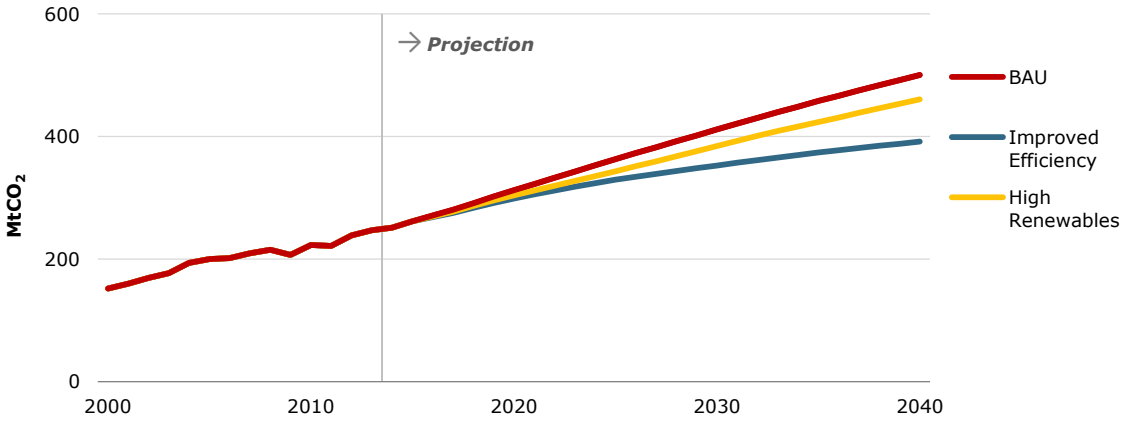
Energy security has been a major policy priority in Thailand. By reducing gas dependency, the PDP 2015 aims to diversify the fuel mix of the power sector. Thailand aims to rebalance the power mix in part by using

clean coal technology in half of all new thermal plants. Under the PDP 2015, coal's share in the fuel mix reaches 25% by 2036 compared with 20% in 2013. The AEDP 2015 aims to increase the share of renewables to 20% in the fuel mix by 2036, from about 8% in 2013.

Climate change impacts and risks: Extreme weather could harm agriculture

As an agriculture-based economy with important coastal areas, Thailand is threatened by climate change impacts such as higher surface temperatures, floods, droughts, severe storms and sea-level rise. At present, the energy sector accounts for about two-third of Thailand's GHG emissions, with electricity generation being the highest (31%) contributor to energy-related CO_2 emissions. Total energy-related CO_2 emissions under the BAU double over the Outlook period, from 247 million tonnes of CO_2 ($MtCO_2$) in 2013 to 500 $MtCO_2$ in 2040. This highlights the importance of decarbonising the power sector to achieve Thailand's climate change objectives.

Figure 9.13 ● Thailand: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Sources: APERC analysis and IEA (2015b).

In its INDC submission to the UN Framework Convention on Climate Change (UNFCCC), Thailand set an economy-wide target to reduce GHG emissions by 20% from the government's projected BAU by 2030 with 2005 as a base year (ONEP, 2015). The government aims to achieve this through various 'soft' initiatives (including public awareness campaigns) and by implementing more 'high-impact' measures (such as promoting waste management, modal shift from road to rail transport, eco-cars and electric vehicles, and tree-planting) (ONEP, 2015). The Improved Efficiency Scenario offers the largest emissions reduction in the energy sector with its total of 392 $MtCO_2$ in 2040 being 22% below the BAU. A more modest 7.9% decrease is seen in the High Renewables Scenario, largely because the BAU already accounts for a doubling of the renewables shares in power and transport. Given the current low share of renewables at 8% in the overall fuel mix, Thailand could consider a higher renewables target to both increase domestic energy supply (hence improving energy security) and reduce emissions.

RECOMMENDATIONS FOR POLICY ACTION

Thailand's recent initiative to reform energy policy has already set targets for energy savings by fuel type and by economic sector. This important step forward needs to be accompanied by the development of sector-level indicators to measure how effectively proposed measures are implemented, and, indeed, to monitor and evaluate the impacts of policies and measures. In transport, for example, the key parameters of fuel economy and vehicle-kilometre travelled (VKT) should be surveyed and collected regularly. Additionally, energy-related data should be consolidated as a single database and opened to public access.

The integration of major energy plans into the so-called TIEB is another important milestone for Thailand. To further strengthen the linkages among the EEP 2015, the AEDP 2015, the PDP 2015, and the 2015 oil and gas plans, Thailand would do well to establish regulatory measures such as EERS and renewable portfolio standards (RPS).

Considering that the Improved Efficiency Scenario demonstrates an opportunity to reduce Thailand's energy intensity by up to 35% by 2040 (compared with the 2005 level), policy should be implemented to promote energy efficiency across all sectors. This can be pursued through tightening energy performance standards, financing energy efficiency activities through standard offer programs (SOPs), strengthening the role of energy service companies (ESCOs) and raising public awareness.

As transport shows the largest potential for energy savings, a comprehensive policy is needed to capture the opportunity. Fuel economy improvement is key to energy efficiency in transport, being able to deliver a crucial reduction in energy consumption per unit of transport and to curb actual energy demand. Vital elements of an effective policy package for fuel economy improvement include: vehicle fuel economy standards and labelling; rebates for the purchase of high-efficiency vehicles; and fee-bates for low-efficiency vehicles, as well vehicle scrappage schemes, and so on. Fuel economy standards should be reviewed and made more stringent every few years to ensure higher energy saving. Additionally, the government should prioritise land-use planning and the development of public transport systems.

In the power sector, switching from gas to coal could help Thailand maintain fuel diversity. However, cleaner coal technologies (such as USC/A-USC or IGCC, together with CCS) need to be adopted to control the increase of energy-related CO_2 emissions. Considering rising public opposition to fossil fuels, a comprehensive study of social and environmental impacts must be carefully conducted to gain public and local stakeholder acceptance of these projects during the transition to a low-carbon economy.

20. UNITED STATES

KEY FINDINGS

- **Despite steady economic growth, TFED is projected to grow at a slower rate over the projection period** thanks to energy efficiency improvements in all sectors, especially transport and buildings. Under the BAU Scenario, energy intensity of TFED improves 32% from 2013 to 2040.

- **Commitments to tackle climate change and meet the INDC will shape the future energy mix.** Government-funded incentive policies and R&D will be needed to achieve these goals.

- **The United States is projected to become a net gas exporter by 2020, and decrease by 80% by 2030.** Oil and gas developments lead to increased gas exports (mainly LNG), and oil imports decrease as coal and gas exports rise.

- **Under the BAU Scenario renewables account for the majority of new capacity additions,** with solar generation increasing fivefold and wind twofold; under the High Renewables Scenario solar generation increases 32 times and wind nearly six times.

- **Energy-related CO_2 emissions under the BAU decrease 3.2% from the 2013 level to 4.9 $GtCO_2$ by 2040.** However, the High Renewables Scenario demonstrates the greatest reduction at 15% compared with the BAU in 2013, followed by the Improved Efficiency Scenario at 14%.

ECONOMY AND ENERGY OVERVIEW

The land area of the United States is 9.8 million square kilometres (km^2) and its population in 2013 was almost 318 million. Gross domestic product (GDP) reached USD 15.9 trillion in 2013, the highest in the world (Table 20.1). As it is an energy-intensive economy, heavy industry contributed approximately 12% of GDP. Major industries are chemicals and petrochemicals, pulp and paper, mining and construction (BEA, 2015). GDP is projected to grow at an average annual growth rate (AAGR) of 1.6%, while population rises at a lower rate of 0.7% from 2013 to 2040.

At 6.9 tonnes of oil equivalent (toe) per capita, the United States has one of the highest levels of energy intensity based on final energy demand per capita within the Asia-Pacific Economic Cooperation (APEC) region, compared to the APEC-wide average of 2.8 toe per capita. High energy demand in the transport and buildings sectors—due to high vehicle ownership, urban sprawl and large average dwelling size—is the main reason for high per capita energy use.

With domestic oil production meeting only 61% of US oil demand in 2013, it is one of the largest oil importers in the world. To diversify the fuel mix, the government implemented the Energy Independence and Security Act of 2007 (EISA) to promote energy efficiency in all sectors as well as reliance on domestic energy production. Development of unconventional oil and gas has reduced energy import dependence from the historical maximum of 32% of total primary energy supply (TPES) in 2006 to 14% in 2013 (pre-1973 level) (IEA, 2015a).

Table 20.1 ● US: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	9 130	12 686	14 921	15 878	17 672	20 800	24 601
Population (million)	253	283	310	317	337	362	383
GDP per capita (2012 USD PPP)	36 107	44 845	48 150	50 066	52 423	57 511	64 155
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	1 915	2 273	2 215	2 188	2 253	2 259	2 231
TPES per capita (toe)	7.6	8.0	7.1	6.9	6.7	6.2	5.8
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	1 294	1 546	1 501	1 495	1 564	1 572	1 577
Final energy intensity per GDP (toe per 2012 USD million PPP)	142	122	101	94	89	76	64
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	4 802	5 643	5 355	5 120	5 059	4 910	4 930
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	100	100	100	100	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

The global economic crisis and oil prices peaking at over USD 140 per barrel of Brent have reversed the trend of importing the majority of TPES and emphasised the importance of energy supply security. The combination of energy conservation and energy efficiency measures, such as those in the EISA, has led to a decoupling of TPES from GDP, with the former remaining almost flat post-2008. Energy security concerns and overall capital cost reductions have led to stronger support for renewable[1] generation, with its share increasing from 8.4% in 2007 to 13% in 2013 (IEA, 2015a).

[1] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

ENERGY RESOURCES

The United States is endowed with abundant natural resources; it is the second-largest coal and the largest oil and gas producer in the world. Oil, natural gas, coal and uranium are the primary non-renewable resources (Table 20.2). Renewable resources include on- and off-shore wind, solar, hydro, diverse biomass and tidal power.

Table 20.2 ● US: Energy reserves and production, 2014

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Coal (Mt)[a]	237 295	262	27	1st	1st
Oil (billion bbl)[a]	48	11	2.9	9th	3rd
Gas (tcm)[a]	9.8	13	5.2	5th	2nd
Uranium (kt U)[b]	207	113	5.6	7th	4th

Notes: [a]Total proven coal, oil and gas reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions. [b]Uranium reserves are 'reasonably assured resources' (RAR); reference year for uranium reserves and production is 2013.

Sources: For coal, oil and gas, BP (2015); for uranium, NEA (2014).

In hydrocarbon fuels, oil is located in Texas, North Dakota and the Gulf of Mexico (EIA, 2015a), and gas is found in Texas, Pennsylvania and Wyoming (EIA, 2015b). Advances in mining technologies have made the extraction of shale oil and gas economically viable and accessible. Coal, the primary fuel for electricity generation, is mined throughout the economy; major recoverable reserves are located in Wyoming, Illinois and West Virginia, where two-thirds of coal is mined using surface methods.

Wind, both on- and off-shore, and solar resources, including a substantial amount suitable for concentrated solar power generation, are abundant. Solid biomass resources in the West and East North Central regions are significant, as is methane potential. Geological studies show significant enhanced geothermal resources are available, but commercially successful technology is still being developed. Large-scale development of traditional and pumped-storage hydroelectricity is slow due to environmental concerns and water restrictions, and is expected to be limited to medium-scale installations.

Of the variety of renewable and non-renewable energy resources available, the most important are solar, wind, coal and natural gas. Availability of relatively inexpensive energy resources has supported recent growth of the economy.

Strong energy interconnections with Canada and Mexico (through pipeline exports and imports of oil and gas), coupled with high domestic oil and gas production, provide affordable energy for domestic consumers and drive energy use and economic development. Domestic natural gas development has reduced net imports from Canada and increased exports to Mexico.

ENERGY POLICY CONTEXT

The United States has a strong state and federal energy policy portfolio to address energy security, transport efficiency and the development of renewables, and to set high environmental standards (Table 20.3). No single policy outlines the economy's energy strategy, but the overall policy aim is to balance energy security, reliability and safety while preserving economic efficiency and competitiveness. In response to the 2008 global economic downturn, the United States announced the American Recovery and Reinvestment Act of 2009 (ARRA) which guaranteed significant investments in power generation and in buildings and transport efficiency. Tracking policy progress supports timely adjustments that reflect changes in macroeconomic indicators and address problematic areas.

Table 20.3 • US: Main energy-related policies, 2015

Energy Independence and Security Act of 2007 (EISA)	**Energy security**: increasing biofuels production, improving vehicle fuel economy, and implementing residential buildings energy efficiency; high-performance commercial and federal buildings. **Targets**: greater energy independence and security; increased renewable fuel production; higher energy efficiency of products, buildings and vehicles; greenhouse gas (GHG) capture and storage options.
American Recovery and Reinvestment Act of 2009 (ARRA)	**Power**: transmission system upgrades; USD 21.5 billion investment in energy infrastructure; USD 27.2 billion for energy efficiency and renewable energy research and investment. **Transport**: USD 48.1 billion for economy-wide infrastructure upgrades. **Buildings**: USD 4.25 billion for repairs and energy-efficient modernisation. **Energy efficiency and renewable energy research and development (R&D)**: grants, loan guarantees, research funding.
Corporate Average Fuel Economy (CAFE)	**Transport**: improve fuel economy of new cars and light-duty trucks. For example, fuel consumption of newly manufactured passenger cars with footprint of 3.8 square metres (m^2) and smaller to improve from 36 miles per gallon (MPG) to 60 MPG (6.53 litres per 100 km [l/100 km] to 3.92 l/100 km) from 2012 to 2025.
Renewable Standards	**Renewable Portfolio Standards (RPS)**: in 31 states as of 2015; also known as Renewable Electricity Standards (RES).
Production Tax Credit	**Renewables**: financial incentive to boost development of wind generation.

BUSINESS-AS-USUAL SCENARIO

This section illustrates energy demand and supply in the Business-as-Usual (BAU) Scenario and summarises the key assumptions from existing government policies (Table 20.4). The definition of the BAU Scenario and the modelling assumptions used in this Outlook are different from those used by the government for its projections.

Table 20.4 • US: Key assumptions and policy drivers under the BAU Scenario

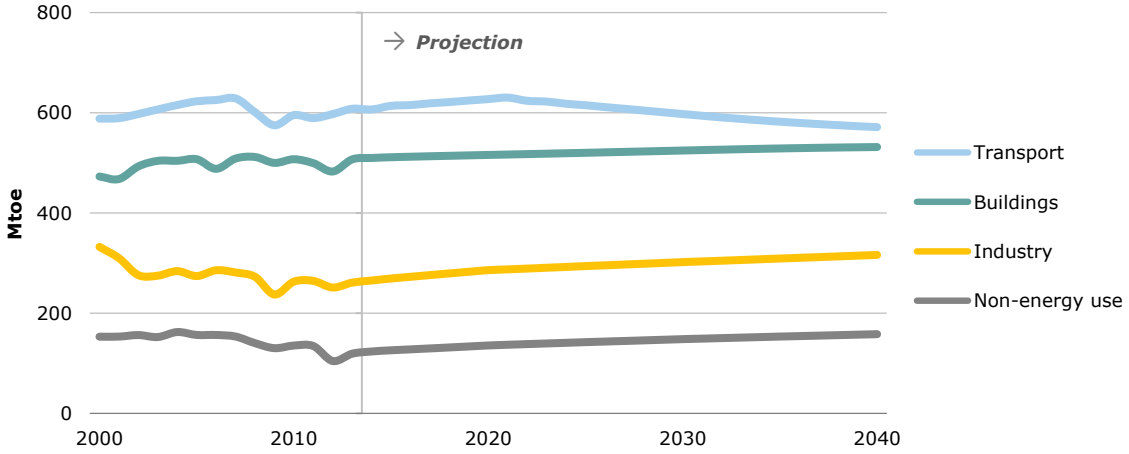
Buildings	• All federal buildings to use energy-efficient lighting and become carbon-neutral by 2030. • Initiatives to promote energy conservation. • Energy efficiency programs for new appliances.
Industry	• Government-funded R&D to improve the energy efficiency of equipment and processes, as part of ARRA. • Waste energy recovery programs.
Transport	• Improved passenger and heavy-duty vehicle fuel economy through new CAFE standards, advances in vehicle technology and federal vehicle fleet efficiency. • Progress towards the Environmental Protection Agency (EPA) economy-wide program regulating GHG emissions of heavy-duty vehicles.
Power mix	• Traditional coal-fired generation to be gradually replaced by gas. • Gradual retirement of nuclear facilities. • Growth in renewable generation through taxpayer-funded R&D.
Energy security	• The EISA to be main energy security policy, promoting self-sufficiency in oil, gas and renewable energy and fuels. • Higher self-sufficiency in oil, gas, coal and renewables.
Climate change	• Work towards Intended Nationally Determined Contribution (INDC) target of reducing GHG emissions by 26% to 28% (including land use, land use change and forestry [LULUCF]), equivalent to 24% to 31% below 2005 level (excluding LULUCF) by 2025.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

In the BAU Scenario, final energy demand grows slowly—a mere 5.5% (0.20% AAGR) between 2013 and 2040—to 1 577 Mtoe. In 2013, domestic transport had the highest (41%) share of final energy demand, followed by buildings (34%) and industry (17%) with non-energy use accounting for the remainder (Figure 20.1). During the post-2008 recession recovery, GDP has grown at an AAGR of 2.2% and, in combination with inexpensive natural gas, has re-ignited the industry sector, now expected to outpace other sectors. Transport remains the largest energy consumer, although improved energy efficiency from CAFE standards for cars and trucks reduces transport's share of final energy demand to 36% by 2040. Energy use in buildings stays relatively flat at 34%, while industry and non-energy use (mainly in industry) show the largest increases with a combined share of 30% in 2040 (from 25% in 2013).

Figure 20.1 • US: Final energy demand by sector, 2000-40



Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

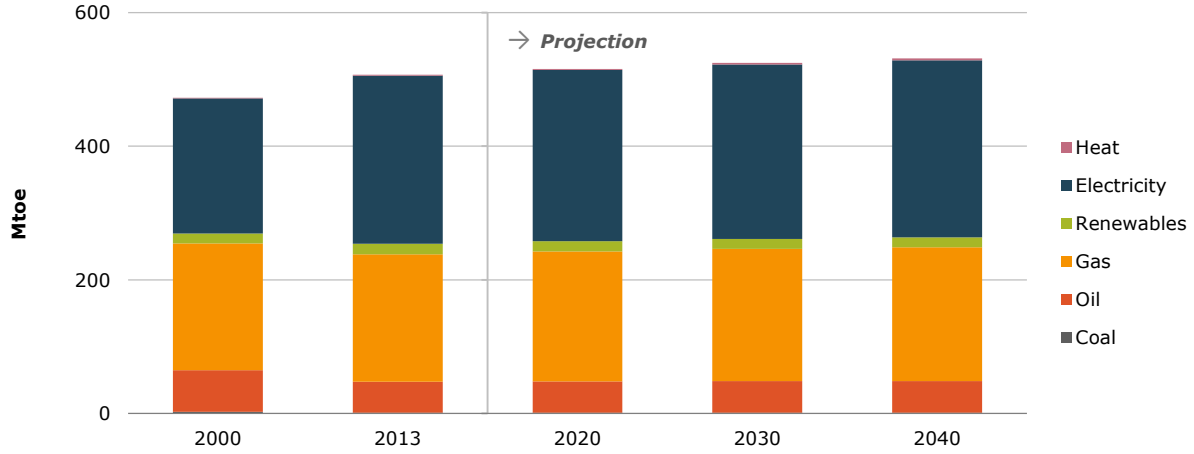
To improve energy efficiency and security, and reduce emissions, the federal government and individual states have introduced policies and R&D programs for energy efficiency and GHG emissions regulation. This includes CAFE standards in transport, state renewable portfolio standards and energy efficiency financing programs.

Buildings energy use: Aim for energy-efficient and net-zero energy buildings

Energy consumption in buildings declines by 0.18% per year, but grows in absolute value from 507 Mtoe in 2013 to 532 Mtoe in 2040 in the BAU Scenario (Figure 20.2). The decline in fuel-oil use is offset by higher gas and electricity demand for space conditioning, and more appliances and equipment in the residential sub-sector drive overall energy growth. Due to the size of the economy, population and average dwellings—as well as abundant appliances and other energy-consuming devices—energy use for buildings is among the highest in APEC at 1.4 toe per capita in 2040.

Net-zero energy buildings can reduce energy consumption, especially in the commercial sub-sector. This strategy supports renewable generation in buildings and two-way energy meters, funded by the Smart Grid Investment Grant program under ARRA (DOE, 2015a). Other measures are tightened appliance and equipment standards, updated building codes reflecting new climatic zoning, and 'green' mortgages. Interactive web-based tools and anonymous public databases (Building Performance Database) using Energy Star methodology drive market demand for more energy-efficient buildings in the residential and commercial sub-sectors.

Figure 20.2 ● US: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

The Building Technologies Office has implemented appliance and equipment standards for more than 60 categories of appliances and equipment under the EISA since 2009 (DOE, 2015b). The Department of Energy (DOE) and Department of Housing and Urban Development (HUD) are arranging efficiency upgrades in millions of homes, and the President's Better Buildings Challenge enlisted more than 250 partners in cities, states, utilities, manufacturers, school districts and businesses to improve energy efficiency (HUD, 2015). In late 2013, the Department of Agriculture announced funding to help businesses and residential customers in rural areas cut their energy bills through energy efficiency and renewable energy.

Federal government buildings must comply with the Climate Action Plan (White House, 2013), and expanded energy performance contracts from USD 2 billion to USD 4 billion provide energy efficiency upgrades for federal buildings at no net cost to the taxpayer. In addition, the federal government must buy at least 20% of its electricity from renewable sources by 2020 and an executive order requires federal government emissions to be reduced by 40% below 2008 levels by 2025.

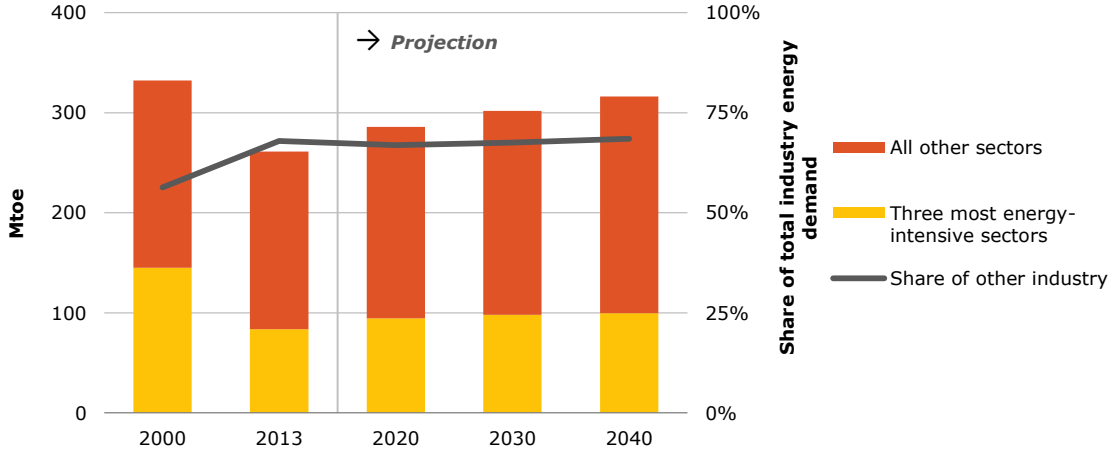
Industry energy use: Demand growth led by chemicals and petrochemicals industry

Energy demand in industry shows the fastest growth at 21% between 2013 and 2040, from 261 Mtoe to 316 Mtoe (Figure 20.3). Industries are recovering from the 2008 economic downturn, and production of fossil fuels in the BAU Scenario rises 23% over the Outlook period. Recovering production rates foster growth in other industrial sub-sectors and drive up industrial energy demand in mining of metals and quarrying (19%), in machinery (38%) and in chemicals and petrochemicals (28%). More affordable oil and gas is responsible for this energy demand growth.

The EISA mandated DOE to support research on the energy efficiency of equipment and processes used in industry, and the EPA to create a waste energy recovery program. Policies initiated by the Building Technologies Office of DOE cover up to 29% of equipment used in industry (DOE, 2015c). Aiming for a 50% reduction in energy use by 2035, most R&D efforts were concentrated on energy conversion and utilisation, and waste minimisation. Tax credits to energy-efficient appliance manufacturers also reduce demand in other sectors.

Energy demand in the three most energy-intensive sectors in the APEC region—iron and steel, chemicals and petrochemicals and non-metallic minerals including cement—is expected to grow from 84 Mtoe to 100 Mtoe over the Outlook period, while all other sectors grow from 177 Mtoe to 217 Mtoe, averaging 68% of total industry energy demand over the Outlook period.

Figure 20.3 • US: Industry sector final energy demand, 2000-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemicals and petrochemicals, and non-metallic minerals.

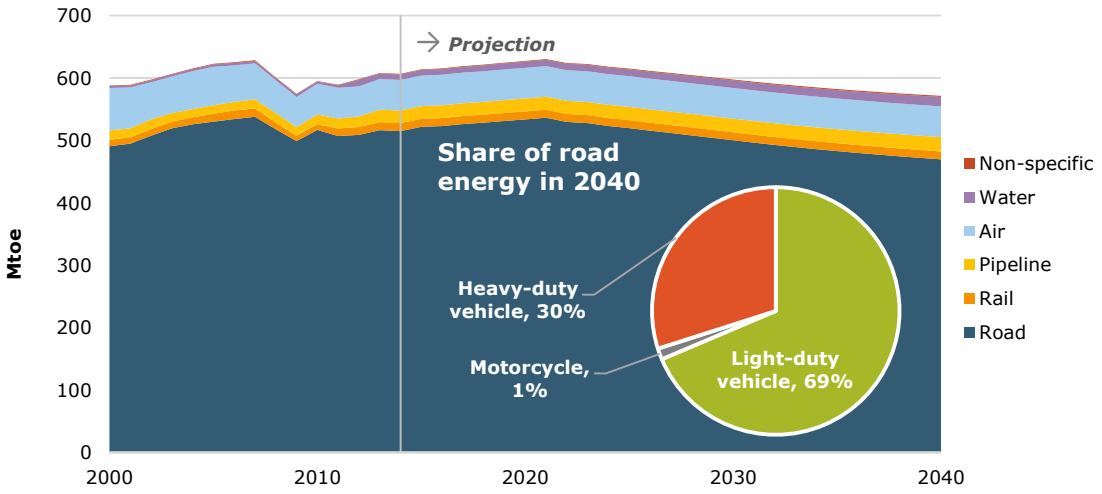
Sources: APERC analysis and IEA (2015a).

Transport energy use: Demand declines with more efficient vehicles

Domestic transport energy demand is projected to decline 0.23% annually between 2013 and 2040, compared to growth of 0.25% per year from 2000 to 2013 (Figure 20.4). The vast land area, large distances between urban centres and lack of significant public transportation infrastructure ensure that road demand will dominate transport energy consumption over the Outlook period. While overall transport energy demand rises slightly between 2013 and 2020, tougher CAFE standards and incentives such as tax credits for hybrid, electric and diesel vehicles lead to energy demand peaking in 2021 at 630 Mtoe and declining steadily thereafter. By 2040, total transport energy demand reaches 571 Mtoe, 6% below the 2013 level.

Programs promoting energy-efficient electric vehicles, the development of charging stations and tax rebates for electric and plug-in hybrids dramatically increase the share of efficient vehicles and reduce final energy demand. In 2040, low-emission vehicles, including electric, hybrid and plug-in hybrid, account for 28% of total car sales, up from just 1.7% in 2013. Total stock share increases from 0.03% to 20%, compared with 13% in Canada and 25% in Japan in 2040.

Figure 20.4 • US: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

In 2011 the EPA and the National Highway Traffic Safety Administration (NHTSA) established GHG emission standards for heavy-duty vehicles and fuel consumption standards for on-road, heavy-duty trucks. Reliance on truck transportation will remain strong and, despite efficiency improvements, fuel demand for heavy-duty vehicles increases from 126 Mtoe in 2013 to 141 Mtoe in 2040 at an AAGR of 0.39%.

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

In 2014 the United States overtook Russia to become the largest gas and oil producer in APEC and the world, whereas until recently the United States relied heavily on imported energy products, mainly oil. As the second-largest coal producer in the world, 91% of coal is used domestically and the rest is exported. Having a high share of relatively inexpensive domestic energy is one of the key drivers of economic growth. The latest advances in mining technology, tax regimes friendly to hydraulic fracturing businesses, and access to the latest horizontal drilling technologies and infrastructure that move significant amounts of water, sand and chemicals quickly, have made domestic oil and gas extraction from tight formations more profitable and have made the United States the global leader in shale oil and gas development. The key challenges to natural gas development are environmental concerns and crude oil price volatility which slows production from tight formations, as happened in 2015.

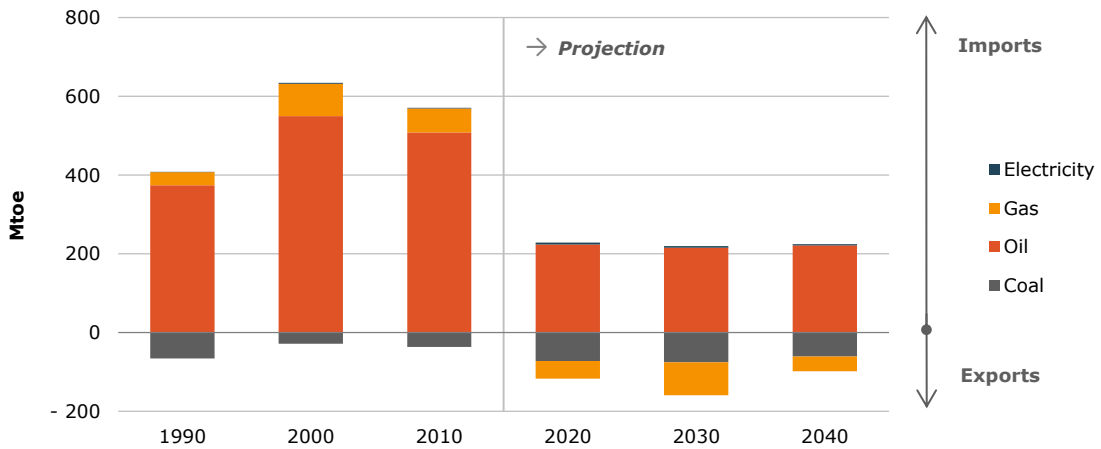
Over the Outlook period, flourishing shale oil and gas production affects the domestic energy mix and boosts the chemical industry as well as mining and construction. Total primary energy production grows at an AAGR of 0.52%, from 1 881 Mtoe to 2 162 Mtoe, with a major increase in gas from 567 Mtoe to 998 Mtoe and oil from 476 Mtoe to 563 Mtoe. Tighter environmental regulations lower the demand for coal from 477 Mtoe to 308 Mtoe in 2040.

Energy trade: Net energy imports fall from 32% of TPES in 2005 to 5.6% in 2040

The United States is a major energy trader on global markets, trading mostly oil and coal and smaller amounts of pipeline gas with Canada and Mexico. Liquefied natural gas (LNG) becomes the third-largest traded energy commodity with the commissioning of export terminals, Europe and Asia being the two main destinations.

In 2013, 4.5 Mtoe of coal was imported (Figure 20.5), 89% as steam coal mainly from Colombia (EIA, 2015c); 73 Mtoe was exported, 44% as steam coal mainly to the United Kingdom, and the rest as metallurgical coal mainly to Brazil (EIA, 2015d). Net coal exports are expected to peak at 89 Mtoe in 2021 and then decline to 62 Mtoe by the end of the Outlook period.

Figure 20.5 • US: Net energy imports and exports, 1990-2040



Sources: APERC analysis and IEA (2015a).

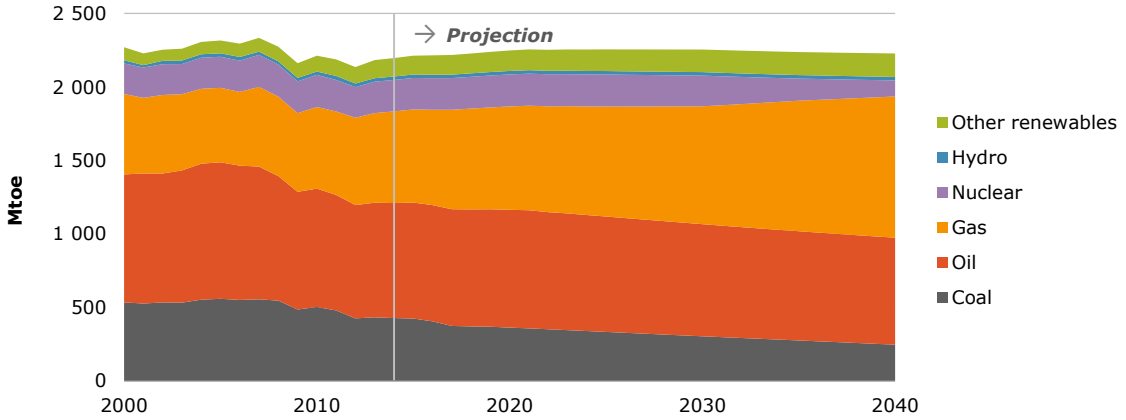
In 2013, 428 Mtoe of crude oil was imported, mainly from Canada, Saudi Arabia and Mexico (EIA, 2015e), and 19 Mtoe was exported, mainly to Canada (EIA, 2015f). Under the BAU Scenario, net oil imports decline sharply by 2020 and then level out at around 225 Mtoe. Lifting or relaxing the current restrictions on crude oil exports may intensify trade and further increase both imports and exports of oil.

In 2013, 80 Mtoe of pipeline gas and LNG were imported, 94% as pipeline gas mainly from Canada (EIA, 2015g), and 41 Mtoe were exported, 98% as pipeline gas mainly to Canada and Mexico (EIA, 2015h). Because pipeline gas exports are limited, LNG export terminals are being built, primarily in Texas and Louisiana, to facilitate exports to Europe and Asia. Due to the sharp increase in gas production, the United States became net gas exporter in 2014; by 2030 exports are expected to reach 84 Mtoe then decline sharply to 37 Mtoe by 2040 due to well depletion. As of 2015, small volumes of LNG were contracted to north-east and South-East Asia as well as to Europe, where the majority is expected to be delivered. As international LNG markets grow, competition between Canada, the Middle East, Australia and smaller players from Africa is expected to intensify.

Primary energy supply: Continued shift to natural gas

TPES dropped significantly in the 2008 economic recession, from a high of 2 334 Mtoe in 2007 to 2 188 Mtoe in 2013 (Figure 20.6). Fossil fuels accounted for 83% of TPES in 2013, nuclear 9.8%, hydro 1.1% and other renewables 5.6%. TPES increases by 2% to 2 231 Mtoe in 2040; as in other developed economies, energy demand tends to flatten or even decline. TPES and economic growth decouple with increased energy efficiency and security.

Figure 20.6 • US: Total primary energy supply by fuel, 2000-40



Sources: APERC analysis and IEA (2015a).

As shares of coal, oil and nuclear in TPES decline, those of gas and renewables increase. The share of coal in TPES declines from 20% in 2013 to 11% in 2040, but the share of gas rises from 28% to 43% due to increased gas-fired power generation. Demand reduction in transport cuts oil's share by 3% and reduces oil imports. Although hydro remains at 1.1%, the share of other renewables increases from 5.6% to 7.2% with the promotion of renewable energy.

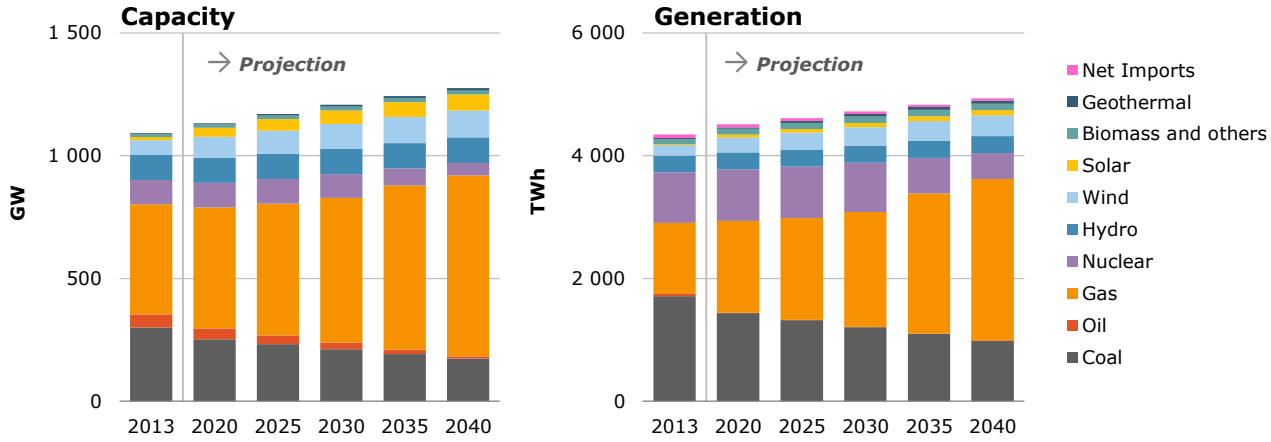
Power sector trends: Switching from coal and nuclear to gas and renewables

In the installed capacity mix, coal has declined and gas and other renewables, especially wind, have increased since 2000. The generation mix followed the same trend, although the share of coal generation declined more quickly under stricter federal and state environmental policies. Over the projection period, installed capacity grows 17% from 1 092 gigawatts (GW) to 1 275 GW and generation increases 14% from 4 346 terawatt-hours (TWh) to 4 936 TWh (Figure 20.7).

Of the total 1 092 GW capacity in 2013, gas accounted for 41%, coal 28% and nuclear 9%. Under the BAU Scenario, total installed capacity increases by 17%, with gas (rising from 41% to 58% of total capacity) remaining the dominant resource. Gas overtakes coal as the largest generation output fuel, growing from 27% in 2013 to 53% in 2040, while coal's share declines from 39% in 2013 to 20% in 2040. 60-year life extensions for nuclear plants mean that 49 GW of current capacity will be retired and fossil fuel's share in generation will increase from 67% to 73%. Peaking and mobile oil capacity, at 4.9% of the capacity mix and 0.85% of total generation in 2013, is gradually phased out and replaced by gas turbines. Hydro generation decreases slightly from 6.2% to 5.6% due to stricter environmental consent and compliance procedures.

Clean energy technology policies, state RPS and tightened emission standards for new power plants are expected to nearly double wind capacity and multiply solar by five, increasing demand for energy storage. Renewable energy policies include RPS adopted in 31 states, feed-in tariffs in 7 states, including California and Hawaii, and PTCs supported by the US Senate. Federal government R&D funding for clean energy will stimulate the switch away from coal, resulting in higher growth in renewables.

Figure 20.7 • US: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

All three Alternative Scenarios (High Renewables, Improved Efficiency and Alternative Power Mix) apply to the United States.[2] The Improved Efficiency Scenario demonstrates the most significant energy demand reduction, 191 Mtoe lower than under the BAU and also results in the second-largest reduction in CO_2 emissions, at 14% below the BAU in 2040. The High Renewables Scenario applies to the power and transport sectors only and results in the greatest energy-related emissions reductions at 15% below the BAU by 2040. The Alternative Power Mix Scenario results in a 5% reduction in energy-related emissions in the High Nuclear Case, and 1% in the Cleaner Coal Case by 2040 compared with the BAU.

IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

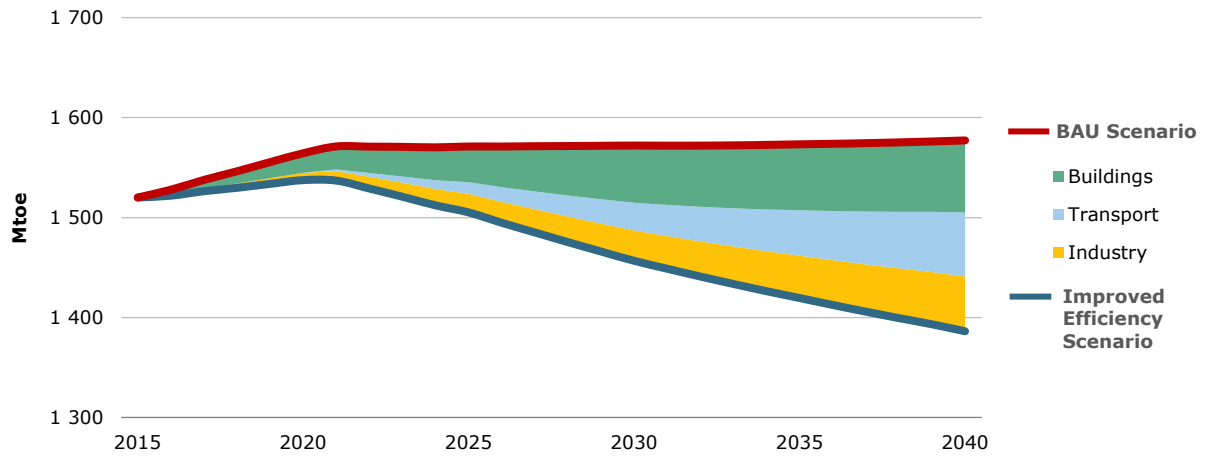
The Improved Efficiency Scenario models the APEC energy intensity goal.[3] The United States can contribute to this goal with an energy intensity reduction of 42% by 2035 under the Improved Efficiency Scenario, versus 36% under the BAU. In the BAU Scenario, energy intensity per GDP decreases substantially from 109 toe per 2012 USD million in 2005 to 69 toe per 2012 USD million in 2035 and

[2] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.
[3] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

64 toe per 2012 USD million in 2040. In the Improved Efficiency Scenario, energy intensity per GDP reduces even further to 63 toe per USD million in 2035 and 56 toe per 2012 USD million in 2040.

Under the Improved Efficiency Scenario, total final energy demand (TFED) decreases by 12% (191 Mtoe) than under the BAU in 2040 (Figure 20.8). The industry sector achieves a 17% (55 Mtoe) reduction in energy demand above the BAU, transport 11% (64 Mtoe) and buildings 14% (72 Mtoe) with comprehensive energy efficiency and conservation measures.

Figure 20.8 ● US: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Source: APERC analysis.

Fuel efficiency improvements 20% above those of the BAU result in transport sector demand savings of 64 Mtoe. The number of vehicles is projected to decline by 5% with the average annual mileage of light-duty vehicles rising by 0.34% and that of heavy-duty vehicles declining by 1.5%. In addition, the share of gasoline- and diesel-powered vehicles drops from 66% in 2013 to 53% in 2040 and that of compressed natural gas (CNG), hybrid, plug-in hybrid, battery and fuel-cell vehicles increases thanks to policies on advanced vehicles and reduced sales taxes. Buildings consume less energy as a result of increased light-emitting diode (LED) lighting, advanced heat-pump water heating, more efficient appliances and space heating and cooling, and reduced standby energy consumption. Industry energy savings are achieved through higher efficiency standards on equipment, especially in the machinery sub-sector (7 Mtoe reduction compared with the BAU), food and tobacco (6.9 Mtoe), and waste energy utilisation, especially paper and pulp, which registers a 10 Mtoe reduction.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

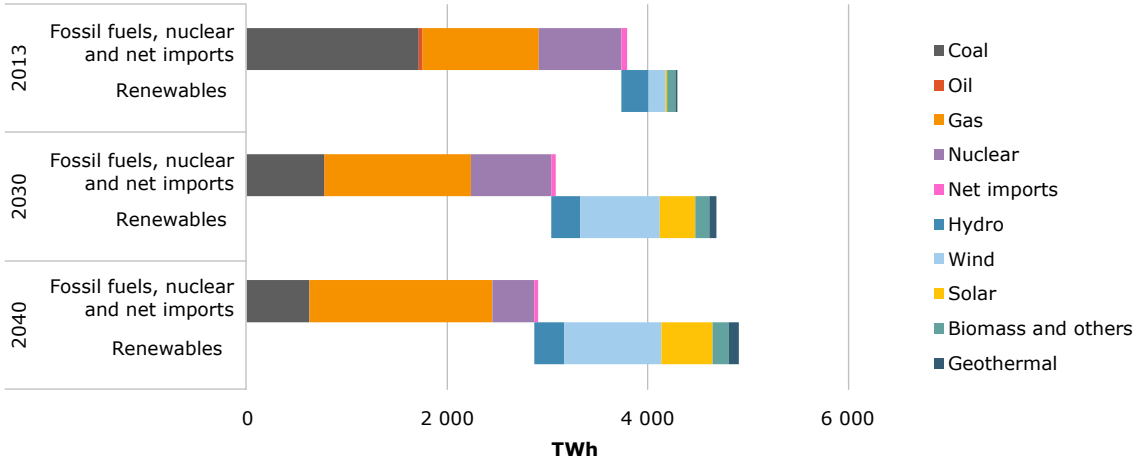
The High Renewables Scenario models the APEC doubling renewables goal within the power and transport sectors.[4] Under this Scenario renewable potential in power is high, at 631 GW or 24% of total APEC potential. This estimate comprises 84 GW of hydro, 250 GW of wind, 263 GW of solar, 20 GW of biomass and 13 GW of geothermal (IRENA, 2015; NREL, 2015; REN21, 2015).

Renewable generation increases at an AAGR of 4.9% under the High Renewables Scenario, compared to 1.6% in the BAU, from 557 TWh in 2013 to 2 036 TWh in 2040 (Figure 20.9). From 13% in 2010, the share of renewables in the generation mix increases to 38% in 2035 and 42% in 2040. Wind accounts for 17% in 2030 and 20% in 2040, followed by hydro at 6.2% and 6.1%, and solar at 7.6% and 10%. The US contribution to the goal of doubling the share of renewables in APEC power generation is significant, as the economy's share of total renewable generation in the region rises from 21% in 2013 to 35% in 2040. With the share of variable renewable generation (wind and solar PV) increasing to 25% in 2040,

[4] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

the technical difficulty of integrating renewables will require measures such as grid storage and improved grid operations, as well as a higher share of flexible generation in spinning reserve. The adoption of RPSs by all remaining states, carbon emissions cap-and-trade, and policies on grid-scale storage development will also be needed.

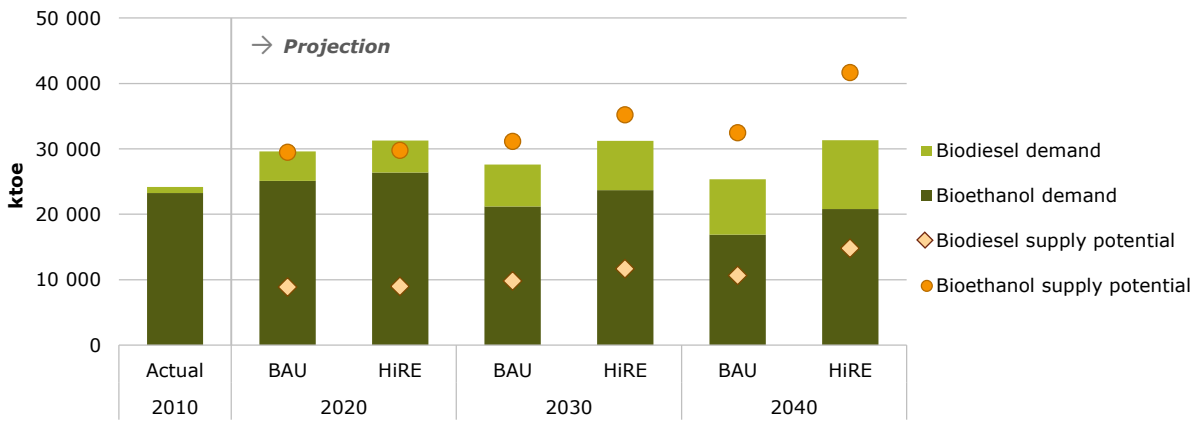
Figure 20.9 ● US: Power sector under the High Renewables Scenario, 2013-40



Sources: APERC analysis and IEA (2015a).

In bioethanol production, 4.8 Mtoe of the EPA-mandated 65 Mtoe of renewable fuels by 2022 is to be cellulosic biofuel to avoid food–fuel competition (EPA, 2015). The EIA projects a compliance level of 36 Mtoe for biofuels and 0.9 Mtoe for cellulosic fuels by 2022 due to US Congress reductions under waiver provisions (EIA, 2015i). Fiscal incentives and interest-rate subsidies were provided to biofuel feedstock producers to make biofuels competitive with traditional fuels. In 2014 an ethanol blend of 10% (E10) had been achieved with production of 26 Mtoe of ethanol fuel and 4 Mtoe of renewable diesel (EIA, 2015j). Under the High Renewables Scenario, bioethanol demand reaches 24 Mtoe in 2030 and 21 Mtoe in 2040, 42% of total APEC bioethanol demand in 2030 and 36% in 2040 (Figure 20.10). Biodiesel demand reaches 7.6 Mtoe in 2030 and 11 Mtoe in 2040, 25% of total APEC biodiesel demand in 2030 and 28% in 2040. Total bioethanol and biodiesel demand can be satisfied by domestic supply potential over the Outlook period, with nearly 21 Mtoe of bioethanol and 4.2 Mtoe of biodiesel available for export in 2040. In 2013, the United States was the largest consumer and producer of biodiesel in APEC, with 53% of total production.

Figure 20.10 ● US: Biofuels demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



Notes: Supply potential refers to biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is shown for the Outlook period only; HiRE = High Renewables Scenario.

Sources: APERC analysis, IRENA (2015), FAO (2014) and IEA (2015a).

ALTERNATIVE POWER MIX SCENARIO

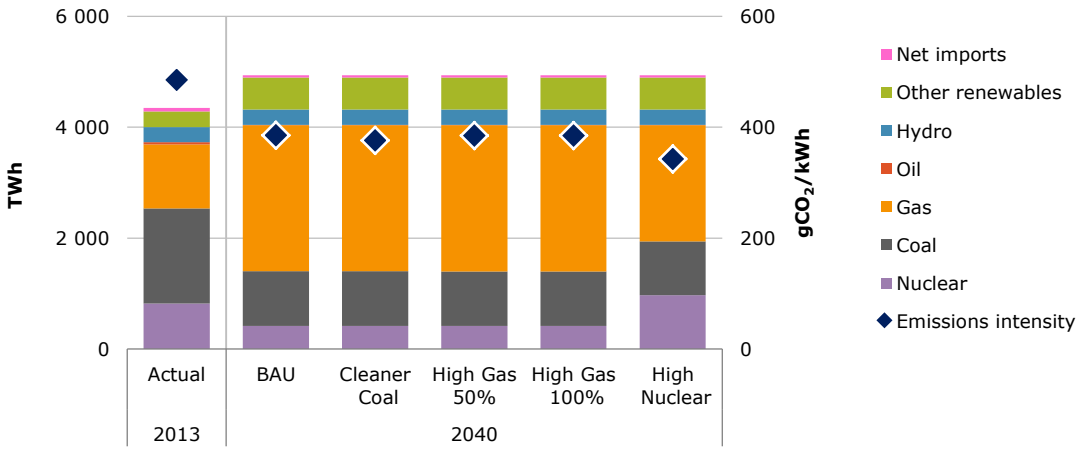
All four Alternative Power Mix Scenario cases—the Cleaner Coal Case, the High Gas 50% Case, the High Gas 100% Case and the High Nuclear Case—apply to the United States. They evaluate the potential for cleaner coal generation, higher shares of natural gas and expanded nuclear power.

The Cleaner Coal Case assumes that more efficient advanced ultra-supercritical (A-USC) and integrated gasification combined cycle (IGCC) technologies replace the BAU coal capacity additions from 2020, and are equipped with carbon capture and storage (CCS) from 2030. This case shows electricity prices and an energy fuel mix similar to the BAU, and energy-related CO_2 emissions decline by a mere 1% above the BAU (Figure 20.11). The implementation of CCS reduces emissions from power generation only slightly, due to the declining share of coal. Costs associated with CCS, as well as strong domestic natural gas production, are the key barriers to implementation of this scenario; gas generation is likely to be preferred.

Under the High Gas 50% Case, 50% of the BAU coal-fired capacity additions are replaced by natural gas combined cycle gas turbine (CCGT) plants and under the High Gas 100% Case replacement is 100%. Both The High Gas 50% and the High Gas 100% Cases show results very close to the BAU, with only 1.3 GW of additional gas capacity by 2040. Both also result in increased gas generation, which halves the share of coal. Coal-fired generation, however, is not phased out, as coal will still be more economically efficient than gas in the coal mining regions and areas with limited gas availability. Neither the High Gas 50% Case nor the High Gas 100% Case demonstrates changes in energy-related CO_2 emissions compared with the BAU.

Nuclear plant lifespans are extended beyond 60 years (except for 4.8 GW of announced retirement) under the High Nuclear Case. Upgrades and new plants, including those under construction and that have Nuclear Regulatory Commission (NRC) or Atomic Safety and Licensing Board hearings, total 6 GW. In the High Nuclear Case, the power mix is well-balanced in '3E' terms (energy, economics and environment) and highly self-sufficient due to reliable domestic uranium production and the lowest emissions and power generation costs. The share of nuclear generation increases to 20% in 2040, compared to 8.5% under the BAU. Installed nuclear capacity in the High Nuclear Case rises to 117 GW in 2040, 67 GW higher than under the BAU. The share of fossil fuel generation declines for a better power mix balance. Power-related CO_2 emissions decline by 11% compared with the BAU level in 2040; however, the government would need to obtain public acceptance of nuclear energy to implement the High Nuclear Case.

Figure 20.11 ● US: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Total energy investment requirements from 2015 to 2040 range from USD 4.2 trillion in the low-cost estimate to USD 7.7 trillion in the high-cost estimate (Table 20.5). As upstream development intensifies to offset the depletion of conventional oil fields, this segment claims the largest investment share (49% to 53%) for oil and gas exploration and production. The power sector follows at 30% in the low-cost estimate and 24% in the high-cost estimate, to fund 183 GW of new capacity additions and to expand and refurbish transmission and distribution grids. The downstream segment requires 6% to 6.7% of total investments for additional refinery capacity of 883 000 barrels per day (bbl/d) to accommodate total oil demand, as well as additions of 39 million tonnes per year (Mt/yr) of LNG import capacity and 214 Mt/yr export capacity. Domestic energy transport of oil, gas and coal (source to port or end-use facilities) claims 15% of investment in the low-cost estimate and 16% in the high-cost estimate.

Table 20.5 ● US: Projected investments in the energy sector in the BAU Scenario, 2015-40

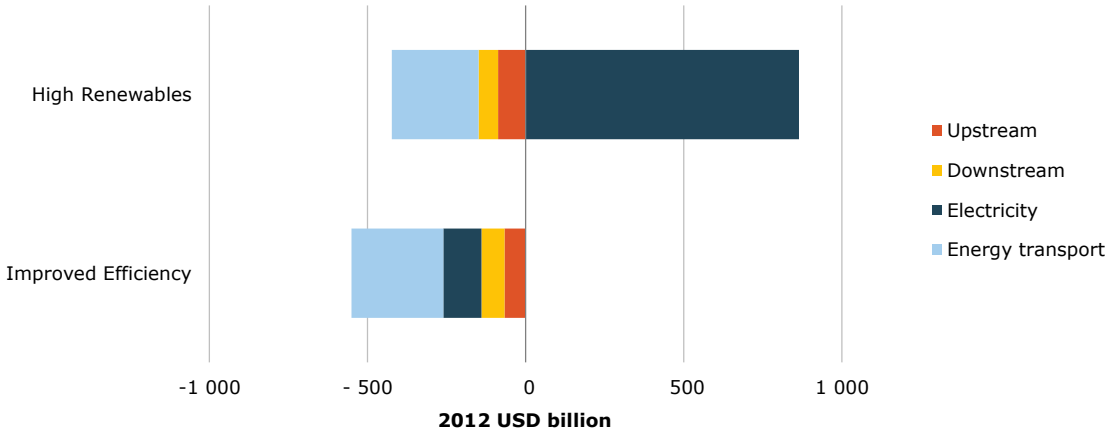
2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	1 352	2 029
	Gas	479	1 436
	Coal	187	608
	Subtotal	2 018	4 072
Downstream	Refinery	24	109
	LNG import terminals	4	10
	LNG export terminals	214	385
	Biofuels refinery	6	9
	Subtotal	248	512
Electricity	Nuclear	6	13
	Coal	43	53
	Gas	290	488
	Hydro	4	12
	Wind	148	250
	Solar	174	209
	Biomass and others	34	44
	Geothermal	32	41
	Transmission lines	212	249
	Distribution lines	318	466
	Subtotal	1 262	1 825
Energy transport	Oil	271	320
	Gas	328	878
	Coal	24	62
	Subtotal	623	1 260
	Total	**4 151**	**7 670**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

Investment savings of 13% of the low-cost estimate (USD 551 billion) can be achieved in the Improved Efficiency Scenario (Figure 20.12). Power sector savings of 10% are achieved through a 151 GW reduction in new capacity additions (82% less new capacity than under the BAU). The resulting reduction in fossil fuel production saves 3% in upstream investment (specifically in gas production). Investment savings of 30% compared with the BAU can also be obtained in the downstream segment, as 79% less additional LNG import capacity and 29% less LNG export terminal capacity are required. Energy transport investment declines 47% due to lower energy and fuel transportation needs.

Figure 20.12 ● US: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC analysis.

In the High Renewables Scenario, total investment increases 11% from the BAU low-cost estimate to USD 4.6 trillion. Investment in electricity rises 69% with 250 GW more capacity additions than under the BAU and major transmission and distribution line extensions. Investment needs increase despite reduced capital expenditures in solar and wind over the Outlook period with strong R&D funding; more than 68% of all new capacity additions are solar and wind, and 27% is gas. Energy transport shows the most notable savings (44%) due to reduced transportation infrastructure. Downstream investment savings of 25% result from a 29% decrease in LNG export terminal capacity with renewables replacing gas generation. Lower fossil fuel demand reduces upstream investment 4.3%.

SUSTAINABLE ENERGY FUTURE

The key aims of US energy development are affordability, accessibility, reliability and sustainability. The latter is indirectly addressed in the EISA, with R&D funding allocated under the ARRA of 2009, tighter vehicle emissions regulations, CAFE standards and active renewable energy development (Table 20.3).

Since 2008, federal agencies have reduced GHG emissions by more than 17%—equivalent to taking 1.8 million cars off the road—and set an aggressive goal of reducing federal emissions 40% by 2025. The government has partnered with farmers to cut emissions and increase carbon sequestration in the agriculture and forestry sectors through voluntary and incentive-based measures. In September 2014, the United States announced new private sector commitments and executive actions to decrease hydrofluorocarbon (HFC) emissions by the equivalent of 0.7 gigatonnes of CO_2 ($GtCO_2$) through 2025.

Box 20.1 • US: Clean Power Plan

In June 2014, the EPA proposed the Clean Power Plan (CPP) to regulate power plant CO_2 emissions from existing fossil fuel-fired generators, including steam generation, IGCC and stationary combustion turbines operating or under construction as of 8 January 2014. In August 2015, after public and expert comments were incorporated into the ruling, the CPP was officially announced by the White House. The 2012 emission levels affected under the CPP, individually defined for each state, range from 400 grams of CO_2 per kilowatt-hour (gCO_2/kWh) to 999 gCO_2/kWh; the range which applies beyond 2030 is 251 gCO_2/kWh to 687 gCO_2/kWh. However, the US Congress repealed the CPP in late 2015.

The CPP was expected to reduce CO_2 emissions 25% in 2020 and 32% in 2030, in line with the US INDC of 26% below the 2005 level in 2025. Outlook preliminary analysis showed that full CPP implementation on schedule would have mostly affected coal-fired and renewable generation. Renewable generation would have risen from 16% to 26% of the power mix, and an additional 198 GW of renewable capacities above BAU projections for 2030 would have been developed, mainly in wind (74%) and solar (24%). However, under the High Renewables Scenario the share of renewable energy grows to 35% of the total power mix in 2030 and CO_2 emissions from power generation are reduced by 45% from the 2005 level.

Enhancing energy security: Self-sufficiency by 2020

Under the BAU, Herfindahl-Hirschman Index (HHI) primary energy supply diversity rises from HHI 0.26 in 2013 to HHI 0.31 in 2040, where a higher number indicates deteriorating diversity, as gas substitutes for coal and oil (Table 20.6). Electricity fuel mix diversity improves by 2030 with a higher share of renewables in the energy mix, but declines again by 2040 due to nuclear capacity retirement and power generation switching away from coal to gas, making the economy gas-dependent. Net energy imports decline to only 2.7% of TPES by 2030, but rise by the end of the Outlook period to 5.6%. The Unites States does not achieve energy self-sufficiency, but becomes a net gas exporter with maximum exports of 84 Mtoe in 2030. Energy exports do not, however, represent a significant portion of total energy production, protecting the economy from global fuel price volatility. Primary energy supply diversity improves in 2040 under the Improved Efficiency and High Renewables scenarios (HHI 0.29), and under the High Nuclear Case (HHI 0.28) compared with the BAU (HHI 0.31). Primary energy supply self-sufficiency improves only under the Improved Efficiency Scenario.

Table 20.6 • US: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040						
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%	High Nuclear
Primary energy supply diversity (HHI)	0.26	0.31	0.29	0.29	0.31	0.31	0.31	0.28
Primary energy supply self-sufficiency (%)	84	93	96	93	93	93	93	93
Coal self-sufficiency (%)	100	100	100	100	100	100	100	100
Oil self-sufficiency (%)	61	77	87	78	77	77	77	77
Gas self-sufficiency (%)	93	100	100	100	100	100	100	100
Electricity generation input fuel diversity (HHI)	0.31	0.33	0.30	0.27	0.33	0.33	0.33	0.28

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

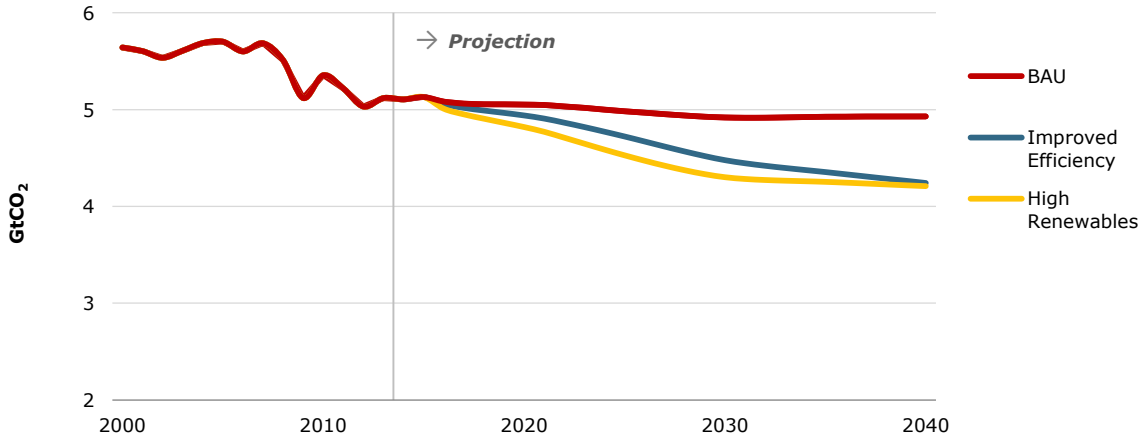
The EISA's main objectives are to improve energy independence and security through improved vehicle fuel efficiency, increased domestic biofuel production, improved lighting and appliance standards and energy savings in buildings and industry. Until 2010 the United States relied heavily on oil imports, but the share of imported crude oil changed from 71% in 2005 to 39% in 2013, and declines further to 23% by the end of the Outlook period under the BAU Scenario.

Climate change impacts and risks: Priority on improved efficiency

In 2013, the United States was the second-greatest CO_2 emissions producer after China. Immediate action is needed to reduce CO_2 emissions and climate-proof infrastructure and facilities (DOE, 2015d). Oil and LNG facilities on the Gulf coast are in high-risk areas, and a response to rising sea levels is required in the next three to five years. Extreme weather events, such as combinations of strong winds, rain and frost are the main causes of increased transmission line faults and major electricity supply interruptions. To address these climate change threats, the government submitted its INDC to reduce net GHG emissions 26% to 28% below the 2005 level by 2025 (14% to 17% below the 1990 level) (UNFCCC, 2015). This supports the long-term goal of reducing emissions to 83% below the 2005 level by 2050 (US Congress, 2009).

Under the BAU Scenario, energy-related CO_2 emissions decline by 3.2% over the projection period from 5.1 $GtCO_2$ in 2013 to 4.9 $GtCO_2$ in 2040. Both the Improved Efficiency and High Renewables Scenarios provide energy-related CO_2 emissions reductions superior to those of the BAU Scenario by 2040. The Improved Efficiency Scenario reduces emissions 14% (0.69 $GtCO_2$) and the High Renewables Scenario 15% (0.72 $GtCO_2$) (Figure 20.13). Further analysis of the High Renewables Scenario shows that 90% of CO_2 emissions reductions come from power generation and the remainder from transport. Strong support for renewable energy becomes moderate in 2030 and emissions levels flatten. In the Improved Efficiency Scenario, however, policies are implemented throughout the Outlook period and sectors contribute to emissions reductions as follows: 46% from buildings, 28% from industry and 26% from transport.

Figure 20.13 • US: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and LULUCF.

Sources: APERC analysis and IEA (2015b).

RECOMMENDATIONS FOR POLICY ACTION

The United States has already initiated policy actions for many sectors—from efficiency standards for appliances and equipment and support for energy-efficient buildings to RPSs—but there are still opportunities for improvement. The preceding section shows that accelerated renewable energy developmentand efficiency measures, which provides significant CO_2 emissions reductions, should be made a priority. For energy efficiency the focus should be on buildings and transport.

To meet the US Congress target of reducing emissions by 83% of the 2005 level by 2050, the economy should further restrict emissions from existing power plants by extending emissions reductions post 2025. This would lead to reduced energy demand, decommissioning of many coal and gas plants, and more extensive development of advanced technologies in renewable energy and carbon sequestration. These actions would result in the reduced CO_2 emissions and advances in renewable technologies observed in the High Renewables Scenario.

In addition to the policies already in place, the United States should more extensively introduce policies aimed at energy use in buildings, such as support for co- and tri-generation in district heating and cooling. Wider installation of solar heating and ground source heat pumps would drive down energy demand for space and water heating. The implementation of demand-response and load-shifting policies in buildings would reduce peak generation requirements. This, combined with lower demand in general, would lead to lower peak demand for air conditioning, requiring less spinning reserve and avoiding unnecessary power plant idling. The above measures would lead to a further 13% reduction in building energy demand under the Improved Efficiency Scenario in 2040, compared with the BAU, as well as lower capacity addition requirements for peak generation.

In addition to CAFE standards and EPA-mandated biofuel production, policies on more efficient urban planning and road network improvements should be introduced. Further improvements of energy transportation infrastructure will be required with advances in shale mining, and rail network upgrades would make goods transport more energy-efficient. In the Improved Efficiency Scenario, such measures reduce the transport sector final energy demand by over 12% compared with the BAU in 2040, leading to lower oil import dependency and more investment opportunities.

21. VIET NAM

KEY FINDINGS

- **Viet Nam shows the second-highest final energy demand growth out of all APEC economies**, at an AAGR of 4.4% between 2013 and 2040 under the BAU Scenario as industrialisation, modernisation and international economic integration accelerate.

- **Strong energy efficiency and savings efforts in all sectors over the next decade are crucial** to avoid investing in power system expansions that may lock in CO_2-intensive power sources and threaten energy security and emissions reductions beyond 2025.

- **An efficient energy sector and clean energy sources are integral to the economy's green growth strategy.** Under the BAU, substantive nuclear and renewables are developed only beyond 2025, as costly or intermittent energy sources jeopardise competitiveness and supply sufficiency. Fossil fuels therefore account for 86% of TPES in 2040.

- **High energy import dependency and deteriorating fuel diversification by 2040 are inevitable.** Under the BAU Scenario, coal and oil self-sufficiency decline from 100% in 2013 to 31% in 2040 for coal and to 0.25% for oil. The timely development of energy import–export companies and infrastructure are the main challenges.

- **The Cleaner Coal Case demonstrates the greatest energy-related CO_2 emissions reductions in 2040, at 150 $MtCO_2$ lower than the BAU.** However, it leads to higher investment, coal consumption and average generation costs compared with some of the other scenarios.

ECONOMY AND ENERGY OVERVIEW

Viet Nam, in the centre of South-East Asia, has a geographically diverse land area of 330 967 square kilometres (km^2) and an exclusive economic zone stretching 200 nautical miles from its 3 260-km coastline (excluding islands). Being in a tropical monsoon zone and profoundly impacted by the East Sea, Viet Nam has warm weather, abundant solar radiation, high humidity and generous seasonal rainfall.

The dynamic emerging economy had a population of 91 million and a gross domestic product (GDP) of USD 332 billion in 2013 (Table 21.1).[1] In per capita income, Viet Nam ranks second-lowest in the Asia-Pacific Economic Cooperation (APEC) region and attained World Bank lower-middle-income classification only in 2010. With transformation from a centrally planned economy in 1986 to an open, socialist oriented market and active international integration (especially after removal of US embargos in 1994), Viet Nam's GDP has grown continuously at an average annual growth rate (AAGR) of 7% during 1990-2010. The economic structure has changed gradually, with the contribution of industry and services expanding to 80% in 2013. Major exports have diversified into manufactured products such as electronics, machinery and vehicles (28% of total value in 2014) and textiles, garments and footwear (21%) from traditional fishery products, coffee and rice (10%) and crude oil (5%).

Table 21.1 • Viet Nam: Macroeconomic drivers and projections, 1990-2040

	1990	2000	2010	2013	2020	2030	2040
GDP (2012 USD billion PPP)	72	151	281	332	495	838	1399
Population (million)	68	80	88	91	96	101	104
GDP per capita (2012 USD PPP)	1 063	1 876	3 176	3 628	5 137	8 258	13 442
APEC GDP per capita (2012 USD PPP)	**9 169**	**11 482**	**15 459**	**17 047**	**21 298**	**28 216**	**35 913**
TPES (Mtoe)	18	29	59	60	94	147	228
TPES per capita (toe)	0.3	0.4	0.7	0.7	1.0	1.5	2.2
APEC TPES per capita (toe)	**2.1**	**2.3**	**2.7**	**2.8**	**3.2**	**3.4**	**3.5**
Total final energy demand (Mtoe)	16	25	48	51	75	112	163
Final energy intensity per GDP (toe per 2012 USD million PPP)	222	167	172	154	152	134	116
APEC final energy intensity per GDP (toe per 2012 USD million PPP)	**164**	**135**	**113**	**110**	**100**	**80**	**64**
Energy-related CO_2 emissions ($MtCO_2$)	17	44	126	130	214	363	631
APEC emissions ($MtCO_2$)	**11 937**	**14 204**	**18 463**	**20 436**	**23 047**	**24 686**	**25 255**
Electrification rate (%)	88	89	96	99	100	100	100

Notes: GDP is measured in USD billion at the 2012 currency exchange rate, using purchasing power parity (PPP) to facilitate comparison across economies. Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP; TPES = total primary energy supply.

Sources: IEA (2015a, 2015b) and World Bank (2015) for historical data; APERC analysis for projections.

Significant foreign investment in the energy sector has been boosting industry growth, export earnings, and science and technology development. Fossil and renewable[2] energy production, based mainly on easily exploited resources, has grown rapidly with industrialisation and modernisation. Between 2000 and 2013, final energy demand doubled from 25 million tonnes of oil equivalent (Mtoe) to 51 Mtoe. Despite this fast growth, per capita primary energy consumption remains among the lowest in APEC at 0.66 tonnes of oil equivalent (toe).

Although still a net energy exporter, Viet Nam's crude oil and coal exports have fallen significantly, shrinking the economy's energy trade surplus. This is the result of policy changes in 2007 focusing on conservation of indigenous natural resources for long-term domestic use, as well as progressive

[1] APERC analysis based on World Bank database. However, according to intercensal population and housing surveys conducted by the General Statistics Office (GSO), Viet Nam population surpassed 90 million only in 2014 and reached 91 million at the end of 2014.
[2] 'Renewables' includes hydro, solar, wind, geothermal, biomass and marine; when 'other renewables' is used, hydro is not included.

developments in large-scale oil refining and coal-fired power capacity. As energy demand rises with GDP, population and income growth, Viet Nam is expected to become a net energy importer.

ENERGY RESOURCES

Fossil energy potential is estimated to be moderate, although thorough resource assessments have yet to be carried out. As of end 2014, Viet Nam's proven fossil energy reserves were 4.4 billion barrels of oil, 620 billion cubic metres (bcm) of gas and 150 million tonnes (Mt) of coal (Table 21.2). Coal basins are mainly in northern regions, while oil and gas have been found offshore and in the south. Renewables suitable for electricity are hydro, solar, biomass, wind and geothermal. The economic and technical potential of hydro is estimated at 25 gigawatts (GW), excluding about 4 GW to 7 GW of small hydropower (less than 30 megawatts [MW]). Potential capacity within the next 20 years for wind is 8 GW, biomass 2 GW and municipal solid waste (MSW) 300 MW to 400 MW (MOIT, 2015b). At the end of 2015, only preliminary data on geothermal potential was available, not yet reliable for establishing a long-term development plan.

Table 21.2 ● Viet Nam: Energy reserves and production, 2014

	Proven reserves	Years of production	Percentage of world reserves	Global ranking reserves	APEC ranking reserves
Coal (Mt)	150	3.6	0.02	36th	11th
Oil (billion bbl)	4.4	33	0.26	24th	6th
Gas (tcm)	0.62	60	0.33	29th	8th

Note: Total proven coal/oil/gas reserves are generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions.

Source: BP (2015).

ENERGY POLICY CONTEXT

All energy activities fall under the Ministry of Industry and Trade (MOIT), within which are two key advisory and executive units: The General Directorate of Energy (GDE) and the Energy Regulatory Authority of Vietnam (ERAV).

The National Energy Development Strategy to 2020 with a Vision to 2050 (PMVN, 2007a) addresses key energy sector development objectives, major policies and measures to be realised up to 2020. It focuses on: 1) energy infrastructure development and enhancement of long-term supply in close association with the socio-economic development strategy; 2) environmental considerations; 3) energy efficiency; and 4) international cooperation.

The National Green Growth Strategy for the Period 2011-2020 with a Vision to 2050 (VGGS) recognises that green growth—long-term developmental and environmental sustainability—is essential for long-term economic development. The aims of the VGGS are investment in the preservation, development and efficient use of natural resources, and the reduction of greenhouse gas (GHG) emissions and environmental improvement, deploying advanced technologies on a sound scientific basis and considering Viet Nam-specific conditions (PMVN, 2012a). The National Action Plan for Green Growth (GGAP), approved in March 2014 to implement the VGGS, categorises activities in four main areas: awareness-raising; institutional improvement; economic restructuring in sectors, localities and enterprises; and technology innovation (PMVN, 2014b). Priority activities for 2013-15 included organising the Inter-ministerial Coordinating Board for the VGGS, completing an institutional framework for economic restructuring in accord with the VGGS, and formulating a green growth financial policy framework.

Table 21.3 summarises the government's major energy demand- and GHG emissions-related targets.

Table 21.3 ● Viet Nam: Government energy-related targets

Energy intensity of GDP	Reduce at an average annual rate of 1% to 1.5% (PMVN, 2012a).
GHG emissions intensity	Reduce by 8% to 10% relative to 2010 by 2020; after 2020, to reduce GHG emissions intensity 1.5% to 2% per year on average (or 20% by 2030). These targets are Viet Nam's voluntary reduction. Additional international support is required for higher targets of 20% by 2020 and 30% by 2030 (PMVN, 2012a; GOV, 2015).
GDP elasticity of industrial energy demand	Reduce to 1 by 2020 and less than 1 thereafter, and to keep industry emissions growth at 4% to 4.5% per year in the 2012-30 period (PMVN, 2014c).
Rural household electrification	Increase from 97.6% in 2013 to 100% by 2020 (IE, 2014; PMVN, 2007a).

Sources: Cited in this table.

Up to 2020, policy focuses on deploying indigenous low-cost energy resources to support economic competitiveness. Clean energies such as new and renewable and nuclear will be promoted in the green growth strategy.

In November 2015, the government issued a renewable energy strategy to 2030 and with a vision to 2050 (PMVN, 2015). The targets are ambitious and include: commercial renewable energy to reach 37 Mtoe (31% of TPES) by 2020 and 62 Mtoe (over 32%) by 2030; renewable power (including large hydropower) to account for 38% of total generation by 2020 and 32% by 2030; and biofuels to increase to 5% of total transport fuel demand in 2020 (800 kilotonnes of oil equivalent [ktoe]) and 13% (3.7 Mtoe) in 2030. These targets reduce fossil fuel imports for energy purposes by about 40 Mt of coal and 3.7 Mt of oil products by 2030.

Demand and supply energy efficiency regulations were initiated in the early 2000s. Significant progress was made in 2013-15 in improving energy measurement, reporting and verification by major consumers, statistics collection, the application of market-based pricing for all fuels and electricity, restructuring and equitising state-owned energy companies and strengthening business regulations of many energy-related activities. Many detailed regulations for implementing new renewable development targets are under review (mainly feed-in tariffs [FiT] rates) or need to be newly established.

BUSINESS-AS-USUAL SCENARIO

This section illustrates energy demand and supply in the Business-as-Usual (BAU) Scenario and summarises the key assumptions from existing government policies (Table 21.4). The definition of the BAU Scenario and the modelling assumptions used in this Outlook are different from those used by the government for its projections, targets and analysis.

Table 21.4 • Viet Nam: Key assumptions and policy drivers under the BAU scenario

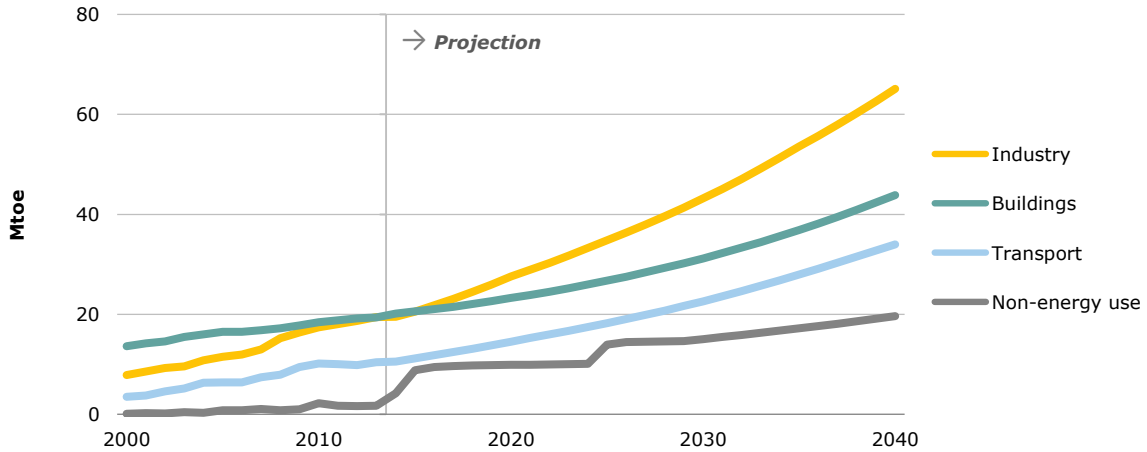
Buildings	• Building code requirements, minimum energy performance standards (MEPS) and labelling programs maintained at current levels. • High-performance cookers used in 30% of rural households by 2020, 60% by 2025 and almost all by 2030.
Industry	• Continued government support for energy efficiency improvements in energy-intensive industries, focusing on steel, cement, chemicals, textiles, food processing and major facilities.
Transport	• Implementation of E5 and E10 biofuel mandates from 2015. • Slow deployment of hybrid cars and electric vehicles (EVs); marginal contribution at end of Outlook period. • Application of Euro 4 emissions standard from 2016 and Euro 5 from 2021 for all imported cars; Euro 4 from 2017 and Euro 5 from 2022 for domestic new cars (PMVN, 2011b); continued application of Euro 3 for motorcycles (MOT, 2014).
Energy supply mix	• Declining share of non-commercial biomass. • Nuclear energy introduced after 2025, accounting for 1% to 2% of TPES by 2030.
Power mix	• Application of large-scale advanced technologies in all new power plants. • Renewable power (excluding large hydropower) share increased to 6% by 2030 (PMVN, 2011a). • Accelerated expansion of gas-fired power capacity based on domestic sources and liquefied natural gas (LNG) imports after 2020. • Nuclear energy after 2025.
Energy security	• Domestic refinery capacity increased to 25 Mt by 2020 and to 45 Mt to 58 Mt by 2025. • Expansion of power and gas grids integrated with Association of Southeast Asian Nations (ASEAN) economies.
Climate change	• Continue to work towards Intended Nationally Determined Contribution (INDC) targets.

Note: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies.

RECENT TRENDS AND OUTLOOK FOR ENERGY DEMAND

Total final energy demand in 2013 was 51 Mtoe, double that of 2000, and is projected to triple to 163 Mtoe by 2040 at an AAGR of 4.4%. Energy efficiency and savings measures, combined with lower population growth after 2025, slow projected final energy demand growth compared with the 2000-13 rate of 5.6%—but it is the second-highest rate in APEC. Industry is the highest-consuming sector throughout the forecast period, with a 41% share increase in 2040 (Figure 21.1). Domestic transport demand continues to grow quickly and surpasses residential demand with a share of 21% in 2040. Residential demand declines significantly to 20% in 2040. Contributions from the commercial and agriculture sectors rise slightly from 4.9% in 2013 to 6.6% in 2040.

Figure 21.1 • Viet Nam: Final energy demand by sector, 2000-40



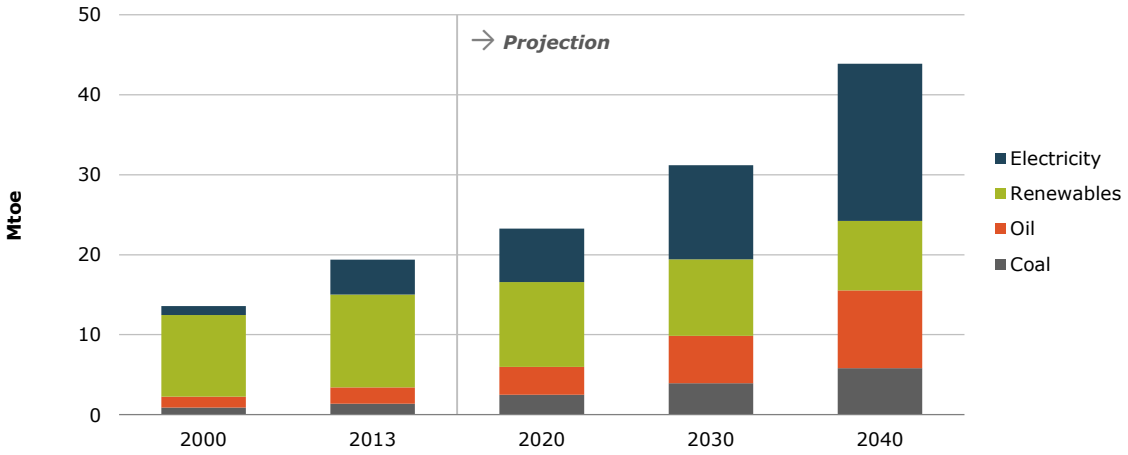
Note: Transport refers only to domestic transport.
Sources: APERC analysis and IEA (2015a).

Energy intensity of GDP is relatively stable to 2020, then decreases at 1.3% per year on average during 2020-40 for an average annual reduction rate of 1% over the entire forecast period.

Buildings and agriculture energy use: Electricity replaces traditional biomass

Combined residential, commercial and agriculture (RCA) energy demand is 44 Mtoe in 2040 under the BAU (Figure 21.2), an AAGR of 3.1%—below that of industry and transport.

Figure 21.2 ● Viet Nam: Buildings sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

Over the last decade, government policies and regulations have promoted consumer energy efficiency, developed efficiency standards for residential and commercial buildings, and set specific energy efficiency targets (PMVN, 2006, 2012b; NAVN, 2010). However, low electricity tariffs, a lack of effective financial incentives and supports, a high number of low-income consumers, and inefficient institutions are barriers to energy-efficient building development. There were only about 40 green building projects completed in 2013 (Solidiance, 2013), but more promotion programs have been organised in cities since 2014—especially in Ho Chi Minh City, the largest, with 7.9 million inhabitants.

Strong development is expected in the green building market in both urban and rural areas thanks to rigorous MEPS, energy efficiency labelling and economic measures. In 2013, the National Technical Regulation on Energy Efficiency Buildings was revised in line with updated international trends of minimum standards for energy-efficient building exteriors and interior equipment. These standards apply from November 2013 to all new or renovated offices, hotels, hospitals, schools, department stores and residences of 2 500 square metres (m^2) or more (MOC, 2013). In addition, MEPS were instituted January 2014 for basic household appliances, and January 2015 for a wider range of office appliances and electronics for business users (PMVN, 2011d). Market-based pricing for all types of energy, including electricity, have been implemented since 2015 and energy efficiency institutions are being strengthened. The promotion of green industry and construction of residential dwellings with higher comfort standards, the advent of multinational corporations and global corporate guidelines, the increasing number of international skilled green buildings architects in the construction market, and rising awareness of energy efficiency and savings among middle-income energy users will contribute to green buildings growth.

Residential energy demand is therefore projected to grow at an AAGR of 2.5% through 2040, slightly lower than in 2000-13 (AAGR 2.6%). The residential energy mix changes significantly as traditional biomass for cooking and heating—mostly fuel wood, rice husks, rice straw and bagasse—decreases 1.1% annually, from 69% in 2013 to 26% in 2040. Traditional biomass is replaced by electricity, liquefied petroleum gas (LPG), coal and modern renewables like biogas and solar energy (for water heating). Electricity grows quickly from 20% in 2013 to become the dominant share (45%) in 2040 as a result of income growth, urbanisation and policies promoting rural electrification.

Commercial sector energy demand grows at an AAGR of 6.1% during 2013-40, driven by GDP growth. Electricity and petroleum products (mainly LPG) continue to account for the largest shares, and both increase almost two percentage points over the Outlook period. Electricity contributes 50% of commercial energy demand in 2040, reflecting increased demand for cooling, heating and lighting; petroleum products (mainly LPG), increase to 39%, and coal falls to 11% (from 15% in 2013).

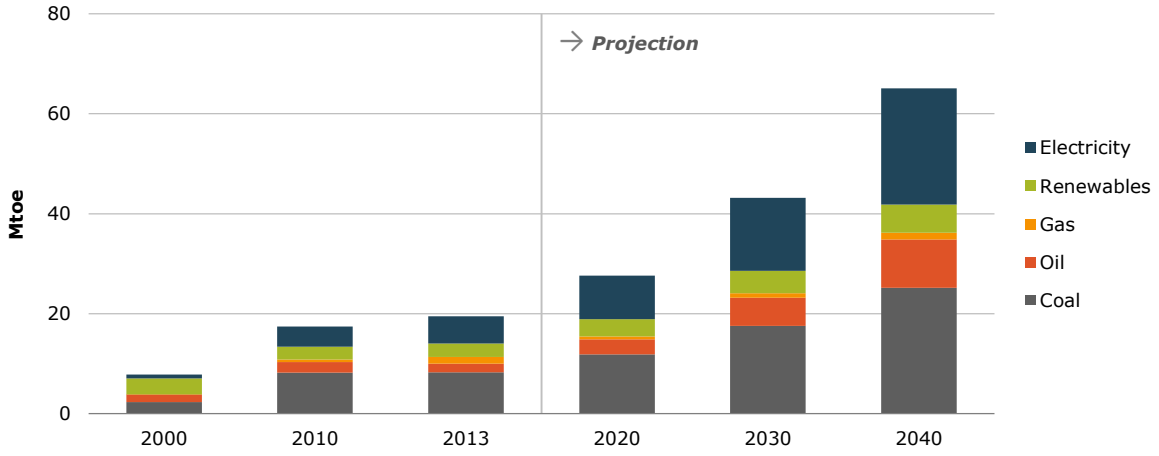
Energy for agricultural activities currently accounts for only 1% of total final energy demand. Demand growth in this sector remains at the same level as for the past ten years, rising at an AAGR of 3.2% during 2013-40. Oil (at 80%) and electricity (at 17%) continue to be the most-consumed fuels as a result of accelerating mechanisation and automation in large-scale agriculture (MARD, 2013).

Industry energy use: Greatest energy consumer despite GDP elasticity less than one

Industry is anticipated to be a key driver of economic growth over the Outlook period. Being a lower-middle-income economy at an early stage of industrialisation, Viet Nam plans to develop all sectors essential for the supply of basic goods for economic development by 2020, as well as key export products such as processed foods, textiles, electronics and higher value-added products (PMVN, 2014c). The construction sector develops rapidly to expand industrial bases and infrastructure in rural and recently urbanised areas, and to connect with the larger ASEAN Economic Community (AEC). Energy efficiency and savings programs were initiated in the early 2000s and intensified in 2007, and pilot projects on energy efficiency and savings in energy-intensive sectors demonstrate that energy savings can reach 20% or higher if heat produced, especially in steel and cement production, is comprehensively re-utilised. More technical and energy regulations in industry tailored to general productive unit design and specific technological procedures were therefore introduced in 2013-14 (PMVN, 2013; MOIT, 2014a). Industrial energy demand thus grows at an AAGR of 4.6% through 2040 under the BAU—below the 7.2% recorded during 2000-13. GDP elasticity falls gradually to 0.87 by 2020 and to 0.80 by 2040.

By energy source, electricity continues to grow quickly as newly built industries introduce more efficient electrical equipment and automated systems. Electricity's share expands from 28% in 2013 to 36% in 2040, almost matching that of coal (Figure 21.3). Coal's share remains the largest at 39% in 2040, but is down from 43% in 2013. Biomass loses third position to oil as its share declines from 14% in 2013 to 9% in 2040 while oil rises to 15% in 2040. The share of gas is stable at 2% (8% if feedstock for fertiliser and petrochemical plants is included) as a result of challenges to large-distribution pipeline developments.

Figure 21.3 • Viet Nam: Industry sector final energy demand, 2000-40



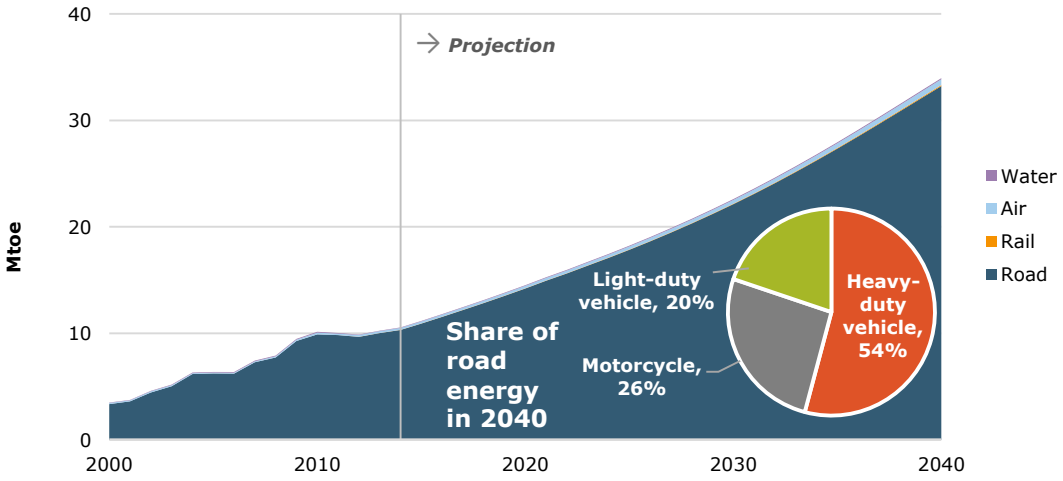
Sources: APERC analysis and IEA (2015a).

Transport energy use: Road transport drives petroleum consumption

Total domestic transport energy demand triples from 11 Mtoe in 2013 to 34 Mtoe in 2040 at an AAGR of 4.5%. Road transport continues to account for a dominant and stable share of 98% by 2040 although rail transport grows fastest (AAGR of 8%) as a result of the government policy to promote modernisation and expansion of rail transport services (PMVN, 2014a) (Figure 21.4).

From a low base of 2 million in 2013, the number of cars increases at an AAGR of 8.1% during 2013-40 (the highest rate in APEC) due to rising income, improved urban planning and better road infrastructure. Of the 11 million new cars introduced 2014-40, light-duty vehicles account for 74%. In energy demand, however, this translates to an increase of only 6 percentage points to reach 19% in 2040. Heavy-duty vehicle consumption remains the highest, rising from 41% to 53%. The share of motorcycles gradually drops to 87% of total vehicle stock and 26% of total road energy demand in 2040 (from 43% in 2013). Motorcycles are the main means of transport in families, so per capita transport energy demand remains low at 0.33 toe in 2040, roughly 58% of the APEC average, despite overall transport energy demand's rapid growth. Additionally enforcing measurement, reporting and verification systems, stricter regulations on vehicle lifespan, MEPS for motorcycles and cars, and the expansion of public transport help maintain low per capita consumption.

Figure 21.4 • Viet Nam: Domestic transport sector final energy demand, 2000-40



Sources: APERC analysis and IEA (2015a).

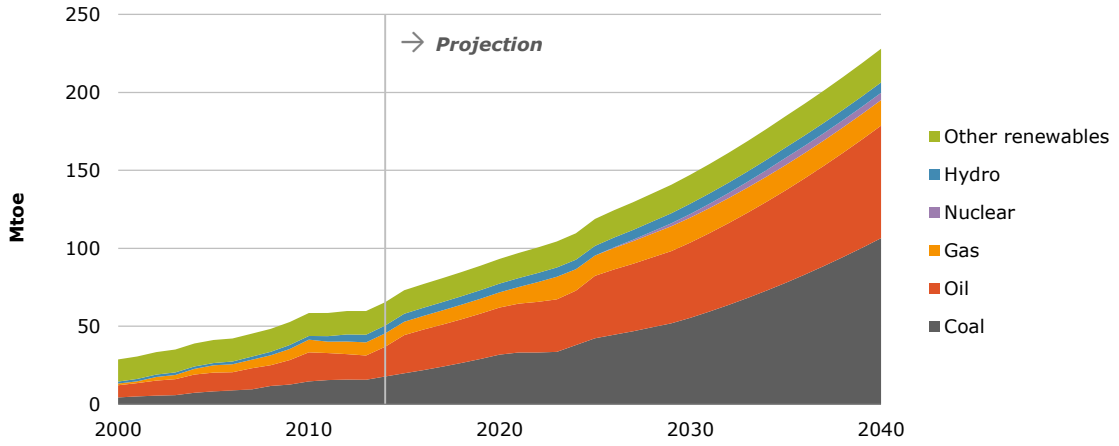
Petroleum products continue to dominate with a 96% share of total energy for domestic transport by 2040, down from 99% in 2013, with increasing shares of bioethanol (2.8%) and electricity (0.89%). The development of electric bicycles and passenger vehicles raises electricity demand at an AAGR of 6.5%, from a low basis to maintain its 2013 share of 0.53%.

RECENT TRENDS AND OUTLOOK FOR ENERGY SUPPLY

Primary energy supply: Coal dominates despite diverse fuel options

The energy system has grown and diversified rapidly over the past two decades with robust domestic gas, coal and hydropower developments which supported a surge in low-cost power generation. TPES therefore doubled during 2000-13 at an AAGR of 5.8%; it is projected to increase at an AAGR of 5.1% over the Outlook period to reach 228 Mtoe in 2040, 3.8 times more than in 2013 (Figure 21.5). Per capita primary energy demand triples to 2.2 toe in 2040, roughly 63% of the APEC average. Higher efficiency requirements and higher incomes stimulate further commercial energy demand growth.

Figure 21.5 • Viet Nam: Total primary energy supply by fuel, 2000-40



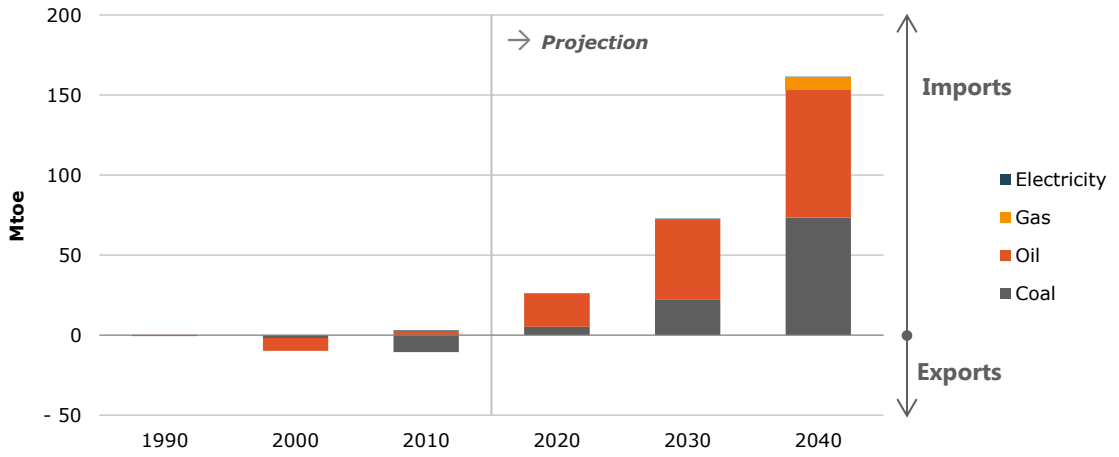
Sources: APERC analysis and IEA (2015a).

Due to policies promoting coal for power generation (to keep electricity prices in check), coal accounts for the largest share in TPES (47%) in 2040. Oil follows with slower growth driven by demand from final sectors, especially transport, to 32%. Reductions in non-commercial biomass accelerate such that it accounts for only 9.5% in 2040. Renewables diversify into biofuels, mini-hydro, wind, solar and MSW landfill power. Domestic hydropower and natural gas also continue to meet increasing energy demand, but these cleaner sources only satisfy about 10% of total demand in 2040. Nuclear power is introduced, but its contribution increases only after 2025 and its share is marginal at 2% of TPES by 2040.

Energy trade: High coal and crude oil import dependency

Viet Nam became a net energy importer in 2015 with constrained crude oil and coal production and continually rising demand in all final consuming and transformation sectors. Although the economy has proven reserves and fossil fuel potential, developing the capacity and infrastructure to supply energy efficiently and reliably is a long process requiring substantial investment and inter-sectoral cooperation. Growth in crude oil and coal production is not anticipated to keep pace with input fuel demands for new refineries and supercritical coal-fired power plants, especially after 2018. Shortages reach unprecedented levels by 2040, with net coal imports rising to over 74 Mtoe and net oil imports to 80 Mtoe (Figure 21.6).

Figure 21.6 • Viet Nam: Net energy imports and exports, 1990-2040



Sources: APERC analysis and IEA (2015a).

Natural gas imports are also needed, especially after 2022, due to the regional demand–supply imbalance and for optimising supply costs. At the end of 2014, several potential sites for large-scale LNG import terminals had been identified and approved by the government (PMVN, 2014d; MOIT, 2015a). The first

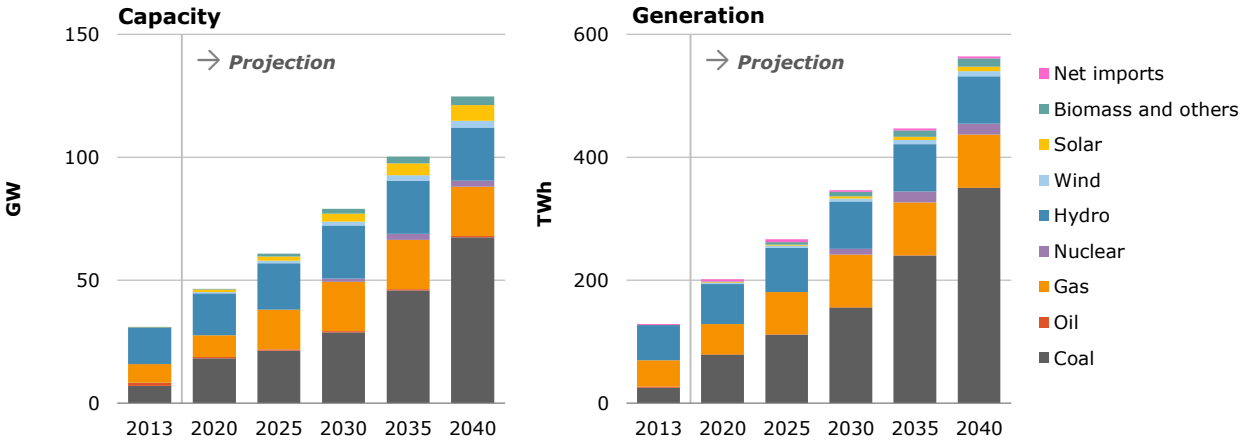
LNG terminal in Binh Thuan province, with a combined capacity of up to 10 million tonnes per year (Mt/y), will be developed during 2020-30. Viet Nam will be subject to increasing pressure over the Outlook period as a result of fuel import dependency and significant investment needed to develop import infrastructure.

Power sector trends: Fast-growing coal power drives fuel demand to almost half of TPES by 2040

Electricity generation quadruples between 2013 and 2040, from 127 terawatt-hours (TWh) to 561 TWh (AAGR of 5.7%) (Figure 21.7). By 2040, nearly 94 GW of new power capacity will need to be added for a total 125 GW.

The share of hydro capacity declines between 2013 and 2040 (48% to 17%) as does that of gas (25% to 16%), while coal dominates over almost the entire period (23% in 2013 and 54% in 2040). Hydro, the priority development source, is deployed at full potential by 2025-30 and maintains 22 GW capacity to the end of the forecast period. Based on domestic and imported gas, combined-cycle gas turbines (CCGTs) almost triple capacity to 20 GW by 2040. As hydro and gas can satisfy only 29% of power generation needs (33% of capacity requirement) in 2040, coal is progressively developed as it is the most economical fuel. The dominance of coal in the power mix will raise local air pollution as well as the economy's energy-related carbon dioxide (CO_2) emissions. The government is planning to introduce nuclear power in 2025-30 and promote new renewable sources such as mini-hydro, biomass, MSW landfill power, wind and solar. Expanding power exchanges with neighbouring economies such as China, Laos and Cambodia are also a possibility. However, these sources account for less than 12% of total installed capacity and only 8.4% of total generation by 2040.

Figure 21.7 • Viet Nam: Power capacity and generation by fuel, 2013-40



Sources: APERC analysis and IEA (2015a).

ALTERNATIVE SCENARIOS

All three alternative scenarios—Improved Efficiency, High Renewables and Alternative Power Mix—apply to Viet Nam.[3] The Improved Efficiency Scenario demonstrates various benefits: a final energy demand savings of 10 Mtoe, an import reduction of over 13 Mtoe, reduction in power sector investment, and also emissions reductions at 46 $MtCO_2$ compared with the BAU in 2040. Energy-related CO_2 emissions reductions are highest in the Cleaner Coal Case—150 $MtCO_2$ lower than BAU in 2040—followed by the High Gas 100% Case at 145 $MtCO_2$ reductions compared with the BAU. However, there are trade-offs with emissions reductions, as it increases investment, coal demand and energy costs. New and creative combinations of energy efficiency initiatives with higher deployment of cleaner fuels and cleaner coal, as

[3] For more details about the Alternative Scenario assumptions, see Chapters 5 to 7 in Volume I.

well as international support, are needed for the most economical efficiency, supply security and environmental effectiveness.

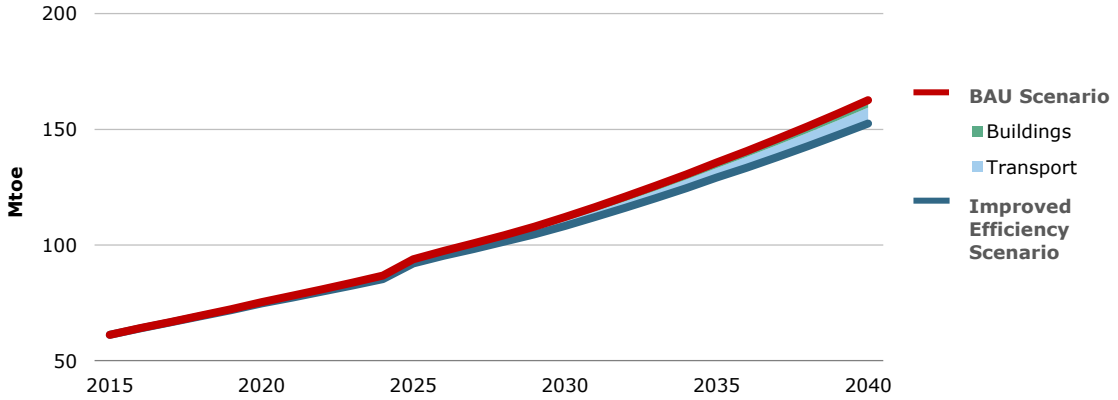
IMPROVED EFFICIENCY SCENARIO TO SUPPORT APEC ENERGY INTENSITY GOAL

The Improved Efficiency Scenario explores energy efficiency opportunities to help meet the APEC energy intensity target.[4] Under the BAU, energy intensity per GDP is forecast to decline 26% by 2035 compared with 2005, whereas energy efficiency programs under the Improved Efficiency Scenario effect a decline of 30%.

The Improved Efficiency Scenario reduces final energy demand by 10 Mtoe compared with the BAU in 2040 (Figure 21.8). Over two-thirds of this savings (68%) comes from transport and one-third (32%) from buildings. The 20% demand savings in transport are the result of: better urban and regional planning; improved public transport from 2020 to reduce private motor vehicles 20% (2.6 million fewer cars in 2040 than under the BAU); and better vehicle fuel economy (improvement of 2% to 2.7% per year from 2013 compared with 1% to 2% under the BAU). As MEPS for residential and commercial buildings, electrical equipment and appliances are already close to being in line with the latest energy-efficient technologies, energy savings in the residential and commercial sectors under the Improved Efficiency Scenario are only 7.2% below the BAU in 2040.

These savings slow annual energy demand growth in buildings and agriculture to 2.8%, and in transport to 3.6% between 2013 and 2040. Major improvements are anticipated after 2025 with a more developed economy, a GDP almost double that of 2013 and an average per capita yearly income of USD 6 500. In addition, lower final energy demand reduces additional power capacity by 7 GW in 2040, an investment savings of USD 14.5 billion. Reduced electricity generation also means 7.3% less power sector CO_2 emissions (25 $MtCO_2$) in 2040 than under the BAU Scenario.

Figure 21.8 • Viet Nam: Potential energy savings in the Improved Efficiency Scenario, 2015-40



Note: No savings were calculated for industry due to data limitations; the Improved Efficiency Scenario therefore underestimates potential savings from enhanced energy efficiency.

Source: APERC analysis.

HIGH RENEWABLES SCENARIO TO SUPPORT APEC DOUBLING RENEWABLES GOAL

The High Renewables Scenario models the APEC doubling renewables goal within the power and transport sectors.[5] Shares of renewable energy in the power and residential sectors are already considerable, and additional policies in 2014-15 confirmed the government's determination to promote renewable options, including renewable power and biofuels, and to develop energy supply sources and control emissions.

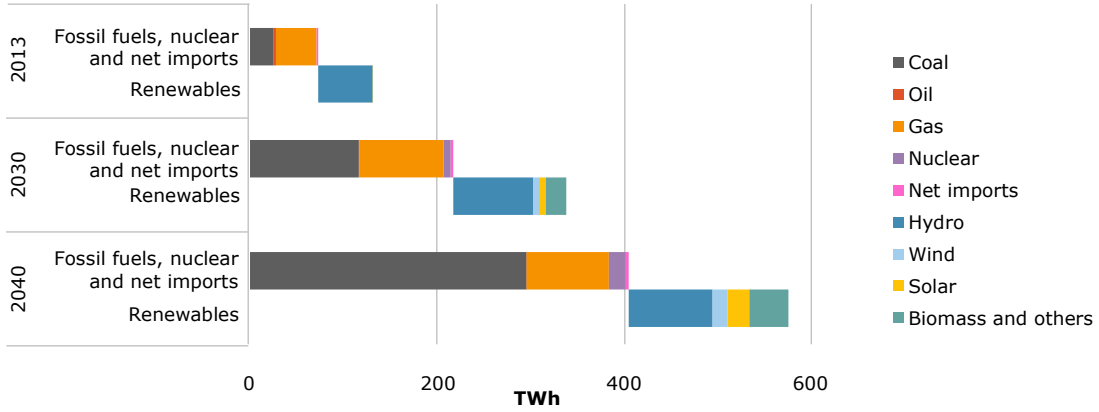
[4] The APEC energy intensity goal aims to reduce energy intensity across APEC by 45% by 2035 (from 2005 levels). It is an APEC-wide, collective target, not a target for each economy. As the denominator of energy intensity remains to be specified, this Outlook uses final energy demand for analysis.

[5] The APEC renewable energy goal aims to double renewables by 2030 from 2010 levels. It is an APEC-wide collective target, and does not specify a target for each economy. For the High Renewables Scenario the target is based on final energy in the power and transport sectors. APERC analysis excludes traditional use of biomass from renewable energy, but includes other types such as biomass for power generation and large-scale hydro.

From 15 GW in 2013, renewables expand to over 34 GW in 2040 under the BAU. The High Renewables Scenario adds a further 2.8 GW of small hydro and 18.6 GW of other renewable power sources to the BAU capacity. As a result, the share of renewables in the power mix increases considerably from 2013 levels: 45% in 2030 and 41% in 2040 for capacity, and 35% in 2030 and 30% in 2040 for generation (Figure 21.9).

A higher penetration of renewables increases the total power installed capacity requirement to 136 GW in 2040, 9.3% more than under the BAU. However, renewable growth under the High Renewables Scenario happens gradually, in step with policy reforms and with international technical and financial support. The High Renewables Scenario demonstrates power sector CO_2 emissions benefits, with reductions of 6% to 14% per year during 2025-40. This scenario also leads to significantly reduced thermal coal imports, at 12 Mtoe or 16% less than under the BAU.

Figure 21.9 ● Viet Nam: Power sector under the High Renewables Scenario, 2013-40

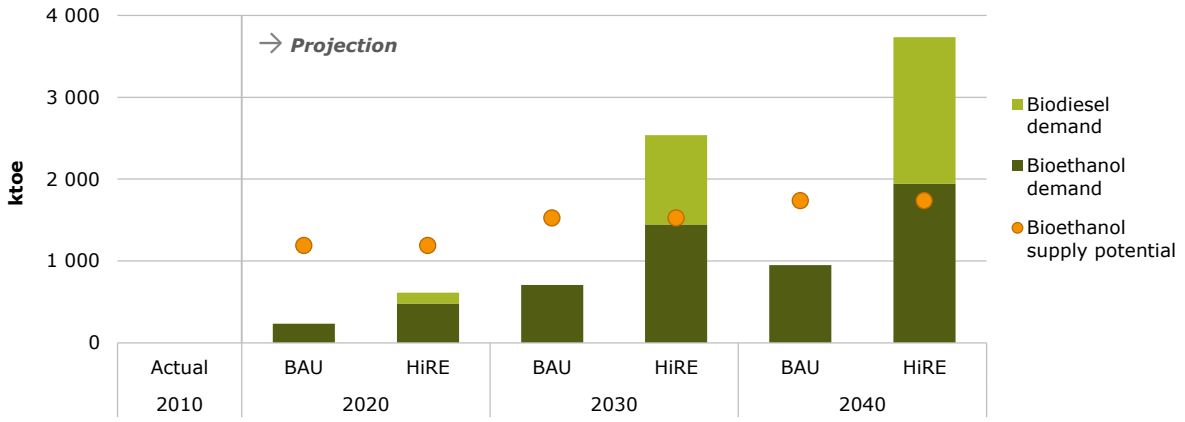


Sources: APERC analysis and IEA (2015a).

The government announced policies in 2007 to promote investment in biofuel research and production, including E5, E10, B5 and B10 as alternatives to conventional fossil fuels (PMVN, 2007b). To boost the domestic bioethanol market, the government stipulated mandatory use of E5 for road vehicles from December 2014 in seven cities and provinces, and from December 2015 for the whole economy. The mandate for E10 applies from December 2016 to seven cities and provinces, and for the whole economy from December 2017 (PMVN, 2012c). In 2014, there were five ethanol plants built with a combined installed capacity of 500 million litres per year, enough for mixing 10 billion litres of E5.

Under the BAU, the bioethanol supply potential gradually increases from 23 kilotonnes of oil equivalent (ktoe) in 2014 to 948 ktoe in 2040, contributing a stable 3% to 3.2% share of total fuel supply from 2025, to meet road transport demand. The High Renewables Scenario demonstrates bioethanol potential of over 1 500 ktoe in 2030 and 1 700 ktoe in 2040 by assuming expansions of biofuel-providing crops such as cassava, maize, rice and sugar cane, and adoption of the most advanced technology and high crop productivity. This is deemed sufficient for Viet Nam to apply increasing blend rates of 15% from 2025 and 20% by 2040 for bioethanol under the High Renewables Scenario, higher than the 6.8% blend rate under the BAU. Also, a biodiesel blend rate of 2% by 2020 and 10% by 2030-40 increases the amount of biofuels in road fuel markets to 8% by 2025 and over 11% by 2030-40—over 2 530 ktoe in 2030 and 3 730 ktoe in 2040. This reduces oil product imports by 2.8 Mtoe (4% lower than under the BAU) (Figure 21.10).

Figure 21.10 ● Viet Nam: Biofuels demand and supply potential in the BAU and High Renewables Scenarios, 2010-40



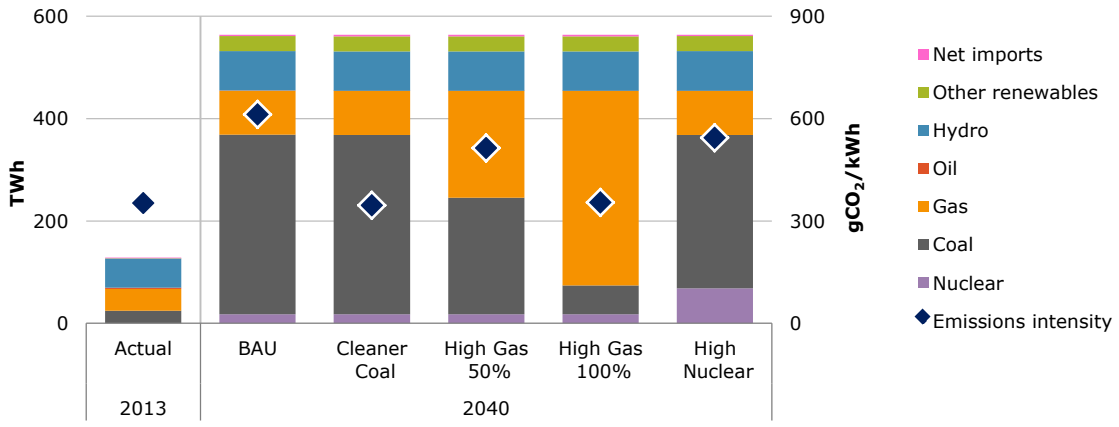
Notes: Supply potential refers to the potential biofuels production if energy feedstock availability was maximised without impacting agricultural production. Supply potential is for the Outlook period only; HiRE = High Renewables Scenario.
Sources: APERC analysis, PMVN (2012c), FAO (2014) and IEA (2015a).

ALTERNATIVE POWER MIX SCENARIO

All four Alternative Power Mix Scenarios apply to Viet Nam: the Cleaner Coal, High Gas 50%, High Gas 100% and High Nuclear Cases.

Under the Cleaner Coal Case, carbon capture and storage (CCS) for all new plants from 2030 results in the highest CO_2 emissions reductions, nearly 150 $MtCO_2$, or 44% less than power sector CO_2 emissions under the BAU (Figure 21.11). However, additional investment is considerable (over USD 19 billion during 2030-40) due to the high cost of CCS, and the average electricity generation cost increases slightly to USD 0.11 per kilowatt-hour (kWh) in 2040, compared with USD 0.10/kWh under the BAU. The application of CCS leads to an additional 10 Mt of coal consumption and hence coal self-sufficiency declines.

Figure 21.11 ● Viet Nam: The BAU and Alternative Power Mix Scenarios by Case, 2013 and 2040



Sources: APERC analysis and IEA (2015a, 2015b).

Natural gas power capacity is 20 GW under the BAU Scenario in 2040, while under the High Gas 50% Case the capacity increases to 48 GW (sixfold from 2013) and under the High Gas 100% Case to 76 GW (10-fold). Thus, power sector CO_2 emissions also decline considerably under the High Gas 100% Case, 42% below that of the BAU Scenario. However, the additional primary gas supply is significant, nearly 48 Mtoe higher in 2040 compared with BAU. The High Gas 100% Case also demonstrates the highest generation cost per unit (averaging USD 0.14/kWh by 2040).

In the High Nuclear Case, nuclear power is introduced from 2026 as in the BAU Scenario, but development is accelerated to replace coal and reach 9.2 GW in 2040, more than triple the capacity under the BAU. In the High Nuclear Case, generation costs drop slightly over those of the BAU, but power sector CO_2 emissions decrease only 11%, the smallest reduction of all alternative power mix scenarios. A higher share of nuclear would be required to reach the emissions reductions of the Cleaner Coal and the High Gas 100% Cases.

SCENARIO IMPLICATIONS

ENERGY INVESTMENTS

Total investments in energy infrastructure from 2015 to 2040 are projected to reach USD 253 billion (low-cost estimate) to USD 510 billion (high-estimate) (Table 21.5). Of this investment, more than half (72% in the low-cost estimate and 59% in the high-cost estimate) is required in the power sector, about a quarter (22% to 28%) for upstream oil, gas and coal activities, and the remaining 4% to 9.1% for downstream oil and gas facilities. As a percentage of GDP, annual energy infrastructure investment requirements are 1.6% to 3.5%.

Table 21.5 ● Viet Nam: Projected investments in the energy sector in the BAU Scenario, 2015-40

2012 USD billion PPP		Low-cost estimate	High-cost estimate
Upstream	Oil	21	31
	Gas	13	40
	Coal	22	71
	Subtotal	56	142
Downstream	Refinery	8.8	44
	LNG import terminals	0.5	1.0
	Biofuels refinery	0.8	1.1
	Subtotal	10	46
Electricity	Nuclear	5.2	8.3
	Coal	99	101
	Gas	8.0	13
	Hydro	8.1	26
	Wind	3.7	8.8
	Solar	13	18
	Biomass and others	4.4	5.8
	Transmission lines	13	31
	Distribution lines	28	90
	Subtotal	182	303
Energy transport	Gas	2.3	12
	Coal	2.9	7.7
	Subtotal	5.2	20
	Total	**253**	**510**

Notes: Investment is estimated based upon a range of figures classified into the lowest and highest costs per unit of energy facility/infrastructure capacity. This is to capture the variability in unit cost of similar energy facility/infrastructure depending on certain conditions and peculiarities; Energy transport includes only pipeline (oil and gas), railroad (oil and coal) and coal import facilities; 'Biomass and others' in electricity includes biomass, geothermal and marine.

Source: APERC analysis.

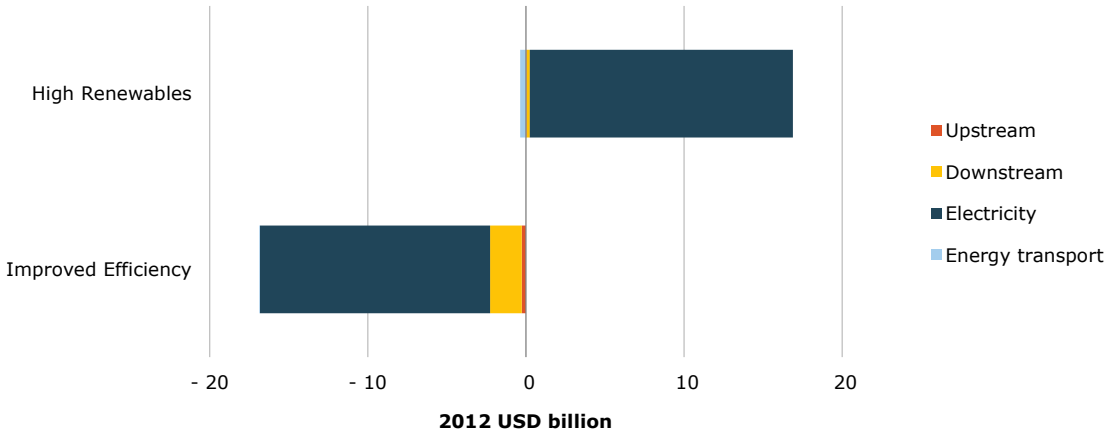
Investment in the downstream sub-sector covers refinery capacity and LNG terminal additions. To maintain the share of domestic refinery production in total primary oil demand (40%) requires 441 000 barrels per day (bbl/d) of new refinery capacity by 2040. Additional LNG import terminal capacity may also be required after 2030 to receive supplementary gas supplies to cover shortages of approximately

6.2 Mt of LNG per year by 2040. Domestic energy transport of oil, gas and coal (from source to ports or end-use facilities) contributes to 2.1% to 3.8% of total investments.

The Improved Efficiency Scenario shows 6.7% investment savings compared with the BAU low-cost estimate (Figure 21.12). The highest savings are in power, at USD 15 billion (8% below the BAU low-cost estimate), as lower demand reduces power generation capacity additions by 7 GW (7.5% below the BAU total capacity) as well as transmission and distribution line requirements. There are also opportunities to reduce investments in other energy activities, by USD 0.3 billion in upstream and USD 2 billion in downstream investments.

Investment under the High Renewables Scenario is 6.5% above the BAU low-cost estimate. Major increases come from the power sector, with USD 15.1 billion for higher shares of renewable capacity and over USD 1.5 billion for additional transmission and distribution systems.

Figure 21.12 ● Viet Nam: Changes in investment requirements in the different Scenarios compared with the BAU, 2015-40



Note: The changes in investment requirements compare the Improved Efficiency and High Renewables Scenarios with the BAU low-cost estimate only.
Source: APERC analysis.

SUSTAINABLE ENERGY FUTURE

Enhancing energy security: High import dependence and deteriorating fuel diversification

Under the BAU Scenario, fuel diversity for power generation deteriorates considerably from a Herfindahl-Hirschman Index (HHI) of HHI 0.31 in 2013 to HHI 0.53 in 2040, where a lower number indicates greater diversity (Table 21.6). Up to 71% of total input fuel in 2040 is coal, while in 2013 shares were relatively even among hydro (26%), gas (38%) and coal (32%). This is also the main reason for deterioration in primary energy supply diversity; over three-quarters of supply depends on only coal and oil in 2040, coal's share being up to 47%. Supply interruptions of either of these fuels would therefore place the economy at risk. Coal and oil self-sufficiency levels change negatively, with domestic supplies able to cover only 31% of coal demand and almost no oil demand by the end of the Outlook period. With higher dependence on international trade, Viet Nam's economy will be more vulnerable to geopolitical issues, international trade route security and price volatility in global energy markets.

Table 21.6 • Viet Nam: Energy security indicators under the different Scenarios, 2013 and 2040

	2013	2040						
	Actual	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Gas 50%	High Gas 100%	High Nuclear
Primary energy supply diversity (HHI)	0.23	0.33	0.32	0.30	0.35	0.28	0.26	0.29
Primary energy supply self-sufficiency (%)	100	33	35	39	31	33	35	38
Coal self-sufficiency (%)	100	31	33	35	28	40	75	34
Oil self-sufficiency (%)	100	0	0	0	0	0	0	0
Gas self-sufficiency (%)	100	51	51	51	51	23	13	51
Electricity generation input fuel diversity (HHI)	0.31	0.53	0.51	0.42	0.57	0.37	0.49	0.41

Note: The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity.
Sources: APERC analysis and IEA (2015a).

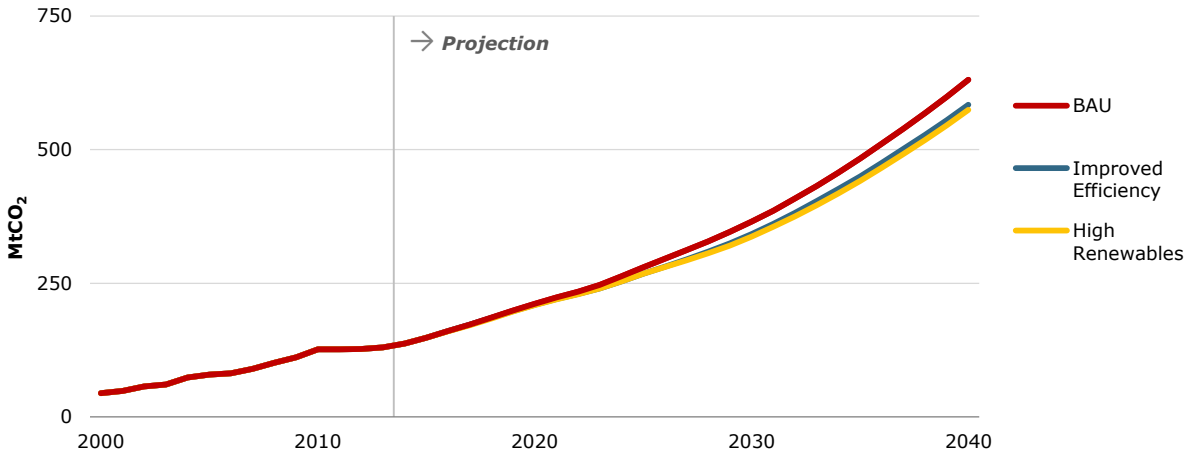
Though all scenarios show an inevitable heavier reliance on energy imports, the alternative scenarios demonstrate that all energy security indicators, especially in self-sufficiency and fuel diversity, could improve with strong efforts towards efficiency in general energy use and supply, as well as deployment of higher shares of cleaner power sources (renewables, gas and nuclear). Applying a combination of the Improved Efficiency and High Renewables scenarios would also reduce energy costs.

Climate change impacts and risks: A small emitter exposed to high risk of rising sea levels

Being in an early stage of industrialisation, and only recently recognised as a lower-middle-income developing economy, Viet Nam contributes less than 1% (0.64% in 2013) of total energy-related APEC CO_2 emissions and only 0.4% globally (IEA 2015b). In the past 50 years, however, extreme climate events such as storms, floods and droughts have increased in frequency and intensity. Viet Nam's INDC is to reduce GHG emissions by 8% by 2030 compared with the government's BAU GHG emissions projections of 787 million tonnes of CO_2 equivalent ($MtCO_2e$) (UNFCCC, 2015), and by up to 25% with international support. The INDC also includes a GHG emissions intensity target to reduce the GHG emissions intensity of GDP by 20% relative to 2010 (or by 30% with international support).

Although both GDP and per capita CO_2 emissions intensity follow the decelerating trend of the last two decades, Viet Nam's energy-related CO_2 emissions rise by almost five times between 2013 and 2040 under the BAU Scenario, to 631 $MtCO_2$, equivalent to 2.5% of total APEC emissions in 2040 (Figure 21.13). The power sector, as the greatest energy-related CO_2 emitting sector at about one-third of the economy's total emissions in 2013, contributes up to 54% of total emissions in 2040 as increased generation outpaces positive efficiency gains from advanced technologies. Industry and transport shares in total direct emissions drop significantly due to increased use of oil and gas in preference to coal and biomass in industry, and stricter vehicle emissions regulations.

Figure 21.13 ● Viet Nam: Final energy-related CO_2 emissions under the different Scenarios, 2000-40



Note: Energy-related CO_2 emissions include only domestic emissions from fuel combustion. It does not include emissions from: non-energy use of fuel; industrial processes; and land use, land-use change and forestry (LULUCF).
Source: APERC analysis and IEA (2015b).

The Alternative Scenario analysis shows that even in cases of high energy efficiency improvements and renewable development, emissions continue to increase through 2040. CO_2 emissions reductions in 2040 are 7.4% below the BAU under the Improved Efficiency Scenario, and 8.9% lower under the High Renewables Scenario. The different power mix scenarios show that deploying fuels other than coal (the most economical option in the short term) can reduce CO_2 emissions by 6.1% (the High Nuclear Case) to 24% (the Cleaner Coal Case) less than the BAU Scenario. As power generation accounts for more than half of total emissions by the end of the projection period, changes in the power sector will significantly affect the whole economy's emissions.

RECOMMENDATIONS FOR POLICY ACTION

Demand- and supply-side measures are needed to enhance energy security. It is desirable for Viet Nam to continue to strengthen energy efficiency and savings regulations as a first priority. Targets for energy efficiency improvements are recommended, specifically for the agriculture, transport and buildings sectors, including financial, regulatory and fiscal incentives. Right pricing should be a key measure. Access to information on potential technologies and best technology practices must be fully transparent. For energy efficiency as well as for renewable energy developments, the government has the opportunity to focus especially on financial mechanisms and policies. A mix of policy instruments—legislative (laws, standards, codes of practice, fiscal systems), economic (subsidies, tradable rights, bonds and deposit refunds, liability systems) and voluntary (agreements, information and promotion programs, research and development)—is required for the most environmental effectiveness, economic efficiency, budget security, enforceability and stakeholder goodwill.

On the supply side, it is recommended that Viet Nam: 1) promote investment in traditional and unconventional energy resources within and outside Viet Nam; 2) exploit domestic energy resources as well as import/export opportunities; 3) prioritise investment in domestic energy transformation, distribution and storage infrastructure, as well as regional supply system integration; and 4) diversify energy import sources.

Investment in assessment of geothermal potential and improving the quality of data for other renewable sources is another priority recommendation for the economy. In addition, targets are needed for increasing electrification of public transport and deployment of electric vehicles, as well as for biodiesel use. Timely progress on the current review of FiT rates and other detailed regulations is also important for implementing successful new high renewable development targets.

Options to improve management and governance, appropriately staffing central and local government institutions, closer coordination among ministers and government agencies, and closer collaboration between government institutions and key energy stakeholders, are necessary. A one-stop shop (website) that details progress on planned activities, including promoted investment programs (especially for renewables), with timeframes and ongoing assessment, would create greater transparency and effectiveness for sectoral information exchanges. This would in turn facilitate timely coordination and enhance societal trust and consensus on the need and opportunity for greater investment in new energy types. Improvements in sub-sector energy statistics would make the formulation of policy more precise. Investment in training and research and development should be increased. Innovative, cost-effective technology and proven management techniques are crucial for inclusive and sustainable growth.

ANNEX I: MODELLING ASSUMPTIONS & METHODOLOGIES

The APEC Energy Demand and Supply Outlook, 6th Edition projections stem from a series of economic models, which are applied to all 21 APEC economies. There are seven sub-models in total: macroeconomic, industry, transport, buildings (including residential, commercial and agriculture), renewables, electricity, and investment.

The Annex I contents are as follows:

1. Introduction
2. Key macroeconomic assumptions
   - GDP and population
   - Energy price
3. Key methodologies
   - Macroeconomic model
   - Buildings model
   - Industry model
   - Transport model
   - Electricity model
   - Renewables model
   - Supply assumptions and energy security
   - Investment model

To find out more about the modelling assumptions, please go to APERC's website (http://aperc.ieej.or.jp).

ANNEX II: DATA PROJECTION TABLES

The APEC Energy Demand and Supply Outlook, 6th Edition data tables show projections for primary energy supply, final energy demand, electricity generation and capacity, and carbon-dioxide (CO_2) emissions from fossil-fuel combustion under the Business-as-Usual (BAU), Improved Efficiency, High Renewables and Alternative Power Mix Scenarios by each individual economy and the APEC total.

To access the tables, please either go to APERC's website (http://aperc.ieej.or.jp) or the Annex II file on the USB version of the Outlook.

REGIONAL GROUPINGS

China	China
Oceania	Australia; New Zealand; Papua New Guinea
Other Americas	Canada; Chile; Mexico; Peru
Other north-east Asia	Hong Kong, China; Japan; Korea
Russia	Russia
South-East Asia	Brunei Darussalam; Indonesia; Malaysia; The Philippines; Thailand; Viet Nam
United States	United States

COMMONLY USED ABBREVIATIONS AND TERMS

2012 USD PPP	2012 USD purchasing power parity
AAGR*	average annual growth rate
ADB	Asian Development Bank
APEC	Asia Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of South-East Asian Nations
BATs	best available technologies
BAU	business-as-usual
bbl	barrels
bbl/d	barrels per day
bcm	billion cubic metre
billion bbl	billion barrels
BRT	bus rapid transit
CBM	coal bed methane
CCGT	combined cycle gas turbine
CCS	carbon capture and sequestration
CFL	compact fluorescent light
CNG	compressed natural gas
CO_2	carbon dioxide
COP	Conference of the Parties
CSP	concentrated solar power
DSM	demand-side management
EGEDA	APEC Expert Group on Energy and Data Analysis
EIA	U. S. Energy Information Administration
EPA	Environmental Protection Authority (US)
ESCOs	energy service companies
EU	European Union
EV	electric vehicle
FCEV	fuel cell electric vehicle
FED	final energy demand
EWG	APEC Energy Working Group
FDI	foreign direct investment
FiT	feed-in tariff
GDP	gross domestic product
GHG	greenhouse gases
gCO_2/kWh	grammes of carbon dioxide per kilowatt-hour, emissions intensity unit
$GtCO_2$	gigatonnes of carbon dioxide
GW	gigawatt
GWh	gigawatt-hour
HDV	heavy-duty vehicle
HHI	Herfindahl-Hirschman Index

HVAC	heating, ventilation and air conditioning
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IGCC	integrated coal gasification combined cycle
INDC	Intended Nationally Determined Contribution
kt U	kilotonnes of uranium
ktoe	kilotonnes of oil equivalent
kWh	kilowatt-hour
LDV	light-duty vehicle
LEAP	Long-range Energy Alternatives Planning System
LED	light-emitting diode
LNG	liquefied natural gas
LPG	liquefied petroleum gas
Mbbl	million barrels
Mbbl/d	million barrels per day
mcm	million cubic metres
MEPS	minimum energy performance standard
MRT	mass rapid transit
MSW	municipal solid waste
Mt	million tonnes
$MtCO_2$	million tonnes of carbon dioxide
Mtoe	million tonnes of oil equivalent
MVE	monitoring verification and enforcement
MW	megawatt
MWh	megawatt-hour
NEA	Nuclear Energy Agency
NRE	new and renewable energy
OECD	Organisation for Economic Cooperation and Development
PHEV	plug-in hybrid electric vehicle
PJ	petajoule
PPP	purchasing power parity
PV	photovoltaic
R&D	research and development
T&D	transmission and distribution
Tcm	trillion cubic metres
toe	tonnes of oil equivalent
toe per unit of GDP	tonnes of oil equivalent per unit of GDP, energy intensity unit
TPES	total primary energy supply
TFED	total final energy demand
TW	terawatt
TWh	terawatt-hour
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USC	ultra-supercritical (coal-fired power generation)
USD	US dollar
WB	World Bank

*The average annual growth rate, *r*, is calculated as a percentage using the formula:

$$r = \left[\left(\frac{Pn}{Po}\right)^{\frac{1}{n}} = 1\right] \times 100$$

where Po is the number at the start of the period, Pn is the number at the end of the period and ***n*** is the length of the period between Pn and Po in years.

TABLES OF APPROXIMATE CONVERSION FACTORS

CRUDE OIL*

From	To				
	tonnes (metric)	kilolitres	barrels	US gallons	tonnes per year
	Multiply by				
Tonnes (metric)	1	1.165	7.33	307.86	-
Kilolitres	0.8581	1	6.2898	264.17	-
Barrels	0.1364	0.159	1	42	-
US Gallons	0.00325	0.0038	0.0238	1	-
Barrels per day	-	-	-	-	49.8

* Based on worldwide average gravity

PRODUCTS

	To convert			
	barrels to tonnes	tonnes to barrels	kilolitres to tonnes	tonnes to kilolitres
	Multiply by			
Liquefied natural gas (LPG)	0.086	11.6	0.542	1.844
Gasoline	0.118	8.5	0.740	1.351
Kerosene	0.128	7.8	0.806	1.240
Gas oil/diesel	0.133	7.5	0.839	1.192
Fuel oil	0.149	6.7	0.939	1.065

NATURAL GAS (NG) AND LIQUEFIED NATURAL GAS (LNG)

	To					
	billion cubic metres NG	billion cubic feet NG	million tonnes oil equivalent	million tonnes LNG	trillion British thermal units	million barrels oil equivalent
	Multiply by					
1 billion cubic metres NG	1	35.3	0.90	0.74	35.7	6.60
1 billion cubic feet NG	0.028	1	0.025	0.021	1.01	0.19
1 million tonnes oil equivalent	1.11	39.2	1	0.82	39.7	7.33
1 million tonnes LNG	1.36	48.0	1.22	1	48.6	8.97
1 trillion British thermal units	0.028	0.99	0.025	0.021	1	0.18
1 million barrels oil equivalent	0.15	5.35	0.14	0.11	5.41	1

UNITS

1 metric tonne	= 2204.62 lb = 1.1023 short tons
1 kilolitre	= 6.2898 barrels = 1 cubic metre
1 kilocalorie (kcal)	= 4.187 kJ = 3.968 Btu
1 kilojoule (kJ)	= 0.239 kcal = 0.948 Btu
1 British thermal	= 0.252 kcal unit (Btu) = 1.055 kJ
1 kilowatt-hour (kWh)	= 860 kcal = 3 600 kJ = 3 412 Btu

CALORIFIC EQUIVALENTS

One tonne of oil equivalent equals approximately:

Heat units	10 million kilocalories 42 gigajoules 40 million British thermal units
Solid fuels	1.5 tonnes of hard coal 3 tonnes of lignite
Gaseous fuels	See Natural Gas (NG) and Liquefied Natural Gas (LNG) table
Electricity	12 megawatt-hours

One million tonnes of oil or oil equivalent produces about 4400 gigawatt-hours (= 4.4 terawatt-hours) of electricity in a modern power station.

1 barrel of ethanol = 0.57 barrel of oil

1 barrel of biodiesel = 0.88 barrel of oil

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Asia Pacific Energy Research Centre (APERC)
Institute of Energy Economics, Japan
Tokyo, Japan
E-mail: master@aperc.ieej.or.jp
Website: http://aperc.ieej.or.jp

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35 Heng Mui Keng Terrace, Singapore 119616
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