Asia-Pacific
Economic Cooperation

Volume I

APEC
Energy Demand and Supply Outlook
6th Edition

2016

APERC
Asia Pacific Energy Research Centre

Asia-Pacific
Economic Cooperation

APEC ENERGY DEMAND AND SUPPLY OUTLOOK

6th Edition

Volume I

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ASIA PACIFIC ENERGY RESEARCH CENTRE

This report, along with detailed tables of the model results,
is published at http://aperc.ieej.or.jp/

May 2016

Published by:

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

Published for:

Published for APEC Secretariat
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APEC#216-RE-01.8 ISBN 978-981-09-8921-7

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)

ACKNOWLEDGEMENTS

The development of the APEC Energy Demand and Supply Outlook, 6th Edition could not have been accomplished without the contributions of many individuals and organisations. We would like to thank all those whose efforts made this Outlook possible, in particular those named below.

We are very grateful to our sponsors The Ministry of Economy, Trade and Industry, Japan, who provided the primary funding for this project.

We wish to express our appreciation to the APERC Annual Conference and Workshop participants who met with us and provided invaluable insights into the issues raised in the draft report.

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.

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EXECUTIVE SUMMARY

With 21 economies individually and collectively facing the energy challenges of the early 21st century, the Asia-Pacific Economic Cooperation (APEC) has an opportunity to influence global trends. Three overriding challenges stand out: i) the need to affordably meet growing energy demand associated with population growth and rising incomes; ii) the need to reduce energy-related carbon dioxide (CO_2) emissions in an effort to reduce the environmental impacts of energy production and consumption; and iii) the need to develop and deploy new technologies for energy production and use them to support the first two challenges.

In this sixth edition of the APEC Energy Demand and Supply Outlook, the Asia Pacific Energy Research Centre (APERC) first assesses a Business-as-Usual (BAU) Scenario, examining the potential to meet these challenges if current energy-related trends continue unchanged to the year 2040 (the Outlook period). The results fall far short of the above objectives as well as APEC's energy goals. To address this gap, APERC modelled three alternative pathways: the Improved Efficiency Scenario to support APEC's energy intensity reduction goal of 45% between 2005 and 2035; the High Renewables Scenario to outline a pathway to double the share of renewables in APEC between 2010 and 2030; and the Alternative Power Mix Scenario which evaluates trade-offs among the use of cleaner coal, gas and nuclear energy in the electricity sector.

Having identified five key trends that either make it more difficult to achieve the stated goals or even undermine their attainment, APERC offers a series of messages on how policy makers can take the lead in steering policy, technology and finance onto a more sustainable pathway. Elements of the following synopsis are explored in depth in the Outlook, with Volume I examining the various scenarios from an APEC-wide perspective and Volume II concentrating on individual economies. Ultimately, strong coordination and cooperation at both levels will be needed to achieve the common objectives. Unless otherwise stated, the Key Trends identified in the synopsis refer to findings from the BAU Scenario, while the Key Messages highlight ways to seize opportunities and meet challenges as APEC energy systems evolve.

KEY TREND #1: CHINA AND SOUTH-EAST ASIA DRIVE APEC ENERGY DEMAND

Total final energy demand (TFED) in APEC reaches 7 000 million tonnes of oil equivalent (Mtoe) in 2040, rising 32% compared with 2013 levels, with China and South-East Asia being the main drivers of growth. China accounts for more than half of the demand growth, due to its sheer size and continued economic growth. Aggressive, strategic efforts to control energy demand growth over the next decade, however, prove effective and demand flattens after 2030. Energy demand in South-East Asia more than doubles owing to rapid economic development, with aggregate gross domestic product (GDP) expanding at 4.3% annually on the average, as well as low current rates of per-capita energy consumption.

Industry remains the largest energy consumer in APEC, with demand reaching 2 291 Mtoe or 33% of TFED in 2040. A notable change from the recent past is that the majority of demand growth is from less energy-intensive sectors such as food processing and mining. Industrial energy demand slows after 2020, when demand for cement and steel in China is expected to peak. In the buildings sector, the residential sub-sector is the primary driver of growing energy demand (particularly of electricity), as rising living standards boost demand for space conditioning and for appliances and devices. Rapid growth in transport energy demand continues to 2020 as the number of vehicles in APEC nearly doubles to 1.27 billion by

2040 with increased vehicle ownership. Again, the effect is particularly strong in developing economies such as China and South-East Asia.

Over the Outlook period, energy demand decouples from economic growth as a result of efforts to reduce energy intensity by strengthening energy efficiency policies, implementing conservation measures and shifting economic development. Overall energy demand growth in APEC consequently slows considerably during the Outlook period, with the annual average growth rate (AAGR) falling to 1%—i.e. nearly half the 1990-2013 rate of 1.8%. While promising efforts are made to improve energy efficiency under the BAU Scenario, energy efficiency policies currently in place are insufficient to meet the goal of reducing energy intensity by 45% by 2035; this target is achieved in 2037.

KEY MESSAGE: ENERGY EFFICIENCY OFFERS THE MOST ATTRACTIVE OPTION TO IMPROVE ENERGY SECURITY AND ADDRESS CLIMATE CHANGE

The Improved Efficiency Scenario shows that additional measures to implement cost-effective energy efficiency strategies can cause APEC energy demand to peak by 2029 and fall 13% by 2040 (compared with the BAU). These savings reduce overall demand by 921 Mtoe, equal to the combined 2013 consumption of Russia, Japan and Korea.

This scenario also demonstrates that the energy intensity target can be achieved earlier—in 2032—suggesting that opportunity exists to push for further reductions. Early actions and concerted efforts on the part of both governments and industry in APEC are vital to this process. To identify opportunities and implement effective strategies and policies, APEC economies should prioritise the development of energy efficiency indicators and collection of relevant end-use data. Efforts to enhance collaboration, such as the APEC Peer Reviews on Energy Efficiency, can support the realisation of energy efficiency potentials and goals.

While most APEC economies have introduced policies to advance energy efficiency, the strength of these policies varies greatly, as does the capacity to develop comprehensive programs, enforce regulations and monitor impacts. As a result, the energy efficiency gains achieved through policy intervention also vary greatly across economies.

Governments should act to increase public awareness of the potential value and benefits of energy efficiency. This may be needed at various levels, starting with governments that have not yet made energy efficiency a priority. Efforts should then expand to business owners that do not understand the value of energy efficiency to their operations and profit margins. Government funding for research and development (R&D) focusing on energy efficiency is of particular importance in all sectors, and close cooperation between governments and industry is necessary to develop a portfolio of promising technologies. Finally, governments should take steps to communicate to consumers, including children, who are largely unaware of the benefits of energy efficiency.

In industry, in which a relatively small number of large consumers represents the majority of energy demand, APEC policy makers should prioritise the adoption of best available technologies (BATs) and best practices in new industrial developments, and establish mechanisms to support upgrades or retrofits of existing facilities. Fuel economy policies for new vehicles are vital to energy efficency in transport; fuel efficiency standards must be implemented in APEC economies in which they are currently lacking, and strengthened where they do exist. In addition, governments should introduce—at the earliest stage possible to realise long-term impacts sooner—new concepts of urban design and transport planning. Continuous implementation, maintenance and updating of mandatory building codes and minimum energy performance standards (MEPS) are the most effective way to improve and maintain energy efficiency in buildings.

KEY TREND #2: RENEWABLES IS THE FASTEST GROWING ENERGY SOURCE

All APEC economies have made commitments to promote renewable power generation and have implemented a variety of policies to support wider adoption of renewable technologies, including master plans and supporting regulation for renewables development.

Renewables represent the fastest-growing energy source over the Outlook period, rising at an AAGR of 2.5%. Their absolute contribution to TFED nearly doubles from 251 Mtoe in 2010 to 457 Mtoe in 2030, but the share only increases from 5.2% in 2010 to 6.7% in 2030, falling short of the doubling target under the BAU. APEC economies will need to intensify the development and deployment of renewables, with governments providing additional incentives and measures to achieve the doubling goal.

In the power sector, some economies have set medium- or long-term targets, either for the share or for the volume of renewables in the power generation mix, or for new capacity additions or total generation capacity. The forecast expansion of renewable capacity, which rises 2.7 times from 620 gigawatts (GW) in 2010 to 1 702 GW in 2030, also falls short of the doubling goal, as the share of renewables increases only modestly, from 16% in 2010 to 22% in 2030.

In transport, APEC economies have applied a variety of approaches and strategies to increase the supply and demand for biofuels. These include mandating a percentage of biofuels in gasoline or diesel (blend rate mandate) or setting a target volume of biofuels supply. Demand for biofuels in the transport sector nearly doubles, rising from 29 Mtoe in 2010 to 56 Mtoe in 2030, but again misses the doubling goal as the share of biofuels rises from 2.3% in 2010 to just 3.1% in 2030.

KEY MESSAGE: HIGH RENEWABLES SCENARIO OUTLINES AN ECONOMIC PATHWAY TO ACHIEVE THE APEC DOUBLING RENEWABLES GOAL

The High Renewables Scenario sets out a least-cost pathway to achieve the APEC goal of doubling the share of renewables by 2030, and even surpass these levels by 2040. For successful renewables development in APEC, policy makers will need to provide strong policy direction within a supportive framework. This includes clear near- and long-term targets and strategies, R&D support for promising renewable technologies and strategic public-private co-funding of pilot projects. Liberalisation of electricity markets and policies aimed at limiting the growth of fossil-fired generation are also needed, and APEC members should encourage information and data exchange across technical, policy and academic areas to help stimulate local capacity for renewables and enhance international technology collaboration. Efforts to enhance collaboration, such as the APEC Review on Low-Carbon Energy Policies can help to accelerate renewables deployment. Educational programs could help to improve public acceptance and raise adoption levels.

Installation of an estimated 1 692 GW of additional renewable generation capacity (i.e. an average of 100 GW per year) is needed to achieve the doubling goal in renewable electricity generation by 2030. While a formidable task, compared with APEC 2015 renewable capacity additions of just over 100 GW, this interim target is in line with current rates of renewable investment in the region. Wind and solar photovoltaic (PV) increase the most, with average annual capacity additions of 62 GW to 2040 providing over 75% of all new renewable capacity. While this leads the share of variable renewable generation to reach 16% by 2040, it also increases the requirements for flexibility measures in APEC energy systems for smooth renewables integration in the power generation mix, including flexible gas generation, grid expansion, demand-side management and energy storage.

In transport, improved cultivation practices and use of unutilised agricultural land would lead to an APEC biofuels supply potential of 144 Mtoe by 2040, while biofuels demand rises from 29 Mtoe in 2010 to 87 Mtoe in 2030 and 95 Mtoe by 2040. This achieves the doubling goal, but a mismatch between biofuels supply potential and demand in individual economies becomes evident; thus, APEC policy makers should encourage biofuels trade among APEC economies. Economies should implement the biodiesel standards developed by APEC in 2007 to enhance intraregional biodiesel trade, and APEC should establish a similar standard for bioethanol. Further, the economies should also consider the development of second- and third-generation biofuels through regional and domestic R&D initiatives, as well as share best practices in a cooperative manner.

Investment requirements to achieve the doubling renewables target increase by only 6% compared with the BAU, demonstrating that the target can be affordably achieved. Such modest increase is partially offset by savings from lower capital investments for coal, gas and oil infrastructure, as well as fuel savings. Other benefits include a 10% reduction in CO_2 emissions compared with the BAU, and a more diversified electricity mix.

KEY TREND #3: FOSSIL FUELS REMAIN DOMINANT IN THE ENERGY MIX

Despite the rising uptake of renewables, APEC remains reliant on fossil fuels to meet growing energy demand: fossil fuels account for 82% of the energy supply mix in 2040, down only slightly from 86% in 2013. Coal remains the leading source of power (41% in 2040) due to rapid growth in electricity demand, particularly in China and South-East Asia. This leads to a net addition of 670 GW of new coal-fired power generation capacity, which pushes up APEC demand for coal by 13% between 2013 and 2040. Natural gas shows the highest growth rate (AAGR of 2.1%) among fossil sources, with its share of the energy mix rising from 20% in 2013 to 27% by 2040. The abundance of low-priced gas in certain economies offers an attractive option to reduce energy-related emissions in the short-term. In certain economies, such as the United States, Canada, Mexico and Peru, rising shares of gas drive the energy mix, particularly in power generation.

To reconcile the energy needed for economic growth with environmental sustainability, APEC economies need to meet growing energy demand while reducing CO_2 emissions. The continued predominance of fossil fuels in the region’s electricity mix calls for generation portfolios with lower carbon intensities. Despite rising shares of renewable electricity, including considerable shares of hydropower in some APEC economies, over the Outlook period coal, natural gas and nuclear energy account for most of the region’s electricity generation.

KEY MESSAGE: CLEANER COAL TECHNOLOGIES, HIGHER SHARES OF NATURAL GAS AND EXPANDED NUCLEAR ENERGY NEEDED TO DECARBONISE POWER MIX

The Alternative Power Mix Scenario evaluates trade-offs among the use of clean coal technologies, higher shares of natural gas and expansion of nuclear energy in APEC’s electricity generation mix. Across all alternative premises, and across APEC as a whole, electricity generation in 2040 still relies predominantly on coal.

This continued coal use can only be sustained through the uptake of cleaner coal technologies coupled with widespread adoption of carbon capture and storage (CCS), the latter being particularly critical. CCS deployment on all new coal facilities from 2030 could reduce CO_2 emissions by 12% compared with the BAU by 2040, while the use of more efficient coal generation technologies reduces emissions by barely 3%. Economies should focus on improving the economics of CCS projects by coordinating and aligning policies that provide more economic incentives, and by promoting private investment in CCS projects to strengthen their commercial viability. Such measures would increase the likelihood of CCS projects becoming commercially viable at the scale needed to substantially reduce CO_2 emissions while meeting rising electricity demand.

Substituting all new coal-fired capacity with natural gas (as modelled in the High Gas Cases) would lead to the lowest power sector emissions in 2040 (14% below the BAU). For many APEC economies, however, this would lead to the highest generation costs and result in rising dependence on gas imports. This could also lead to economic competiveness and security of supply concerns. While gas offers an attractive option to support decarbonisation, it should be viewed strictly as a transitional fuel; over the longer term, the CO_2 emissions intensity of gas generation means its emissions would exceed those of cleaner coal with CCS and nuclear.

The challenge of securing sufficient natural gas supply might prompt more vigorous intraregional trade of liquefied natural gas (LNG) and pipeline gas imports, and increase development of domestic unconventional gas resources. To accelerate gas trade, governments could consider reducing tariffs and provide economic incentives to private developers across the value chain of the natural gas industry. Boosting pipeline gas and LNG projects could bring major benefits to economies that lack domestic gas resources and to those that have potential resources but lack the commercial signals to stimulate their development. Obviously, it would also benefit those with excess gas to export. APEC offers a unique forum to explore cooperative mechanisms that favour more extensive LNG trade, foster closer dialogue between producers and buyers, and promote more flexible contracting and investment schemes.

Expanded use of nuclear energy in APEC results in the lowest generation costs, a decrease of 4% compared with the BAU, while also reducing CO_2 emissions by 10%. The main challenges are in building the additional nuclear capacity required by 2040 and in using this source of energy with sufficiently high safety standards to support economic growth while mitigating the physical hazards to society. APEC economies should strengthen information exchange and experience-sharing among regulators and help nuclear newcomers develop local expertise. Improving the outreach and communication of the benefits and risks of nuclear power will help overcome public acceptance barriers.

KEY TREND #4: APEC ENERGY SUPPLY GAP WIDENS

Energy supply production grows across all fuel types (except nuclear) in APEC over the Outlook period. High energy-demand projections, however, result in a regional supply gap of more than 10%, meaning dependence on imports will increase. The continued dependency on fossils fuels in the region poses energy security concerns and raises the question about if and when APEC economies will establish more ambitious policy interventions to pursue a sharp reduction in fossil fuel dependency.

While the diversity of primary energy supply in APEC improves as the share of renewables rises, rapid energy demand growth results in rising imports that slightly reduce the level of primary energy self-sufficiency, from 93% in 2013 to 92% in 2040. While APEC continues to be self-sufficient in coal, oil self-sufficiency drops from 86% to 75% and gas self-sufficiency falls from 100% to 92%.

By 2040, more than half of all APEC economies experience a reduction in primary energy self-sufficiency and face growing dependence on imports to meet energy demand. The most dramatic changes occur in South-East Asia, where energy demand rises the most quickly. Brunei Darussalam, Canada and Russia are the only APEC economies that remain self-sufficient across all fuels. Malaysia and Viet Nam become net energy importers, while net imports decrease significantly in Mexico and the United States thanks to the development of domestic oil and gas resources.

KEY MESSAGE: INVESTMENT IN ENERGY SUPPLY NEEDED TO ADDRESS ENERGY SECURITY CONCERNS

As energy demand in APEC continues to increase, concern grows regarding the need to balance energy supply security and the environmental effects of the chosen energy mix. Even if APEC member economies trade all surplus energy production among themselves, APEC would still need to import 1 140 Mtoe (over 10% of total supply) from outside the region. Thus, in addition to enhancing trade, APEC should pursue further collaboration to expand existing production and transport infrastructure, and to accelerate deployment of renewable and other low-carbon energy technologies.

APERC analysis shows substantial potential for economies to optimise fossil fuel trading as a means of managing diverse levels of development and resource endowment, while also pursuing technology transfer and overall development of energy services. Investing in energy supply to meet future demand should also be prioritised across APEC. Natural gas use, for example, requires substantial up-front investments covering power generation, regasification terminals, LNG storage and pipeline networks to the demand centres. Governments need to implement robust policies and targets that will facilitate energy sector investments, particularly for economies that need to import these resources.

A total investment of USD 17 trillion to USD 35 trillion is needed for the additional energy system capacity requirements to meet the region’s growing demand. Bridging the gap between the investment required and funding available is a huge challenge for most economies, especially developing economies with limited access to affordable capital. Regional cooperation may be necessary to create a business or investment framework that helps economies attract private sector investment within a suitable long-term financing structure. Such a framework could even promote joint investment ventures between and among private energy companies in the region.

KEY TREND #5: CO_2 EMISSIONS CONTINUE RISING AS COAL REMAINS THE LARGEST POWER SOURCE

Energy-related CO_2 emissions under the BAU reach 25.3 gigatonnes of CO_2 ($GtCO_2$) in 2040, an increase of 24% over 2013 levels, the result of high energy demand and growing reliance on coal-fired power in many APEC economies. The power sector contributes the largest share (50%) of the increase in APEC emissions as 670 GW of additional coal-fired and 800 GW of new gas-fired capacity are added over the Outlook period. Urgent action is needed to support decarbonisation of the APEC power sector, particularly in Asia where abundant low-cost coal makes it the preferred source. Early transition away from coal will have long-lasting benefits, particularly in avoiding the 'lock-in' associated with the long (40+ years) lifespan of coal-fired plants.

Technology development continues to play a major role in shaping the energy sector. Dramatically declining costs are making wind and solar PV increasingly competitive with fossil fuels in power generation, while more efficient end-use technologies are helping to lower energy demand. The development and growth of unconventional gas and oil resources have helped to lower coal consumption in the United States and could reduce future demand in China.

Transport is the second-fastest growing emitter in APEC. As vehicle ownership rises in line with higher income levels, rapid growth in transport energy demand pushes related emissions up by 1 $GtCO_2$ in 2040. China and South-East Asia show the largest increases in transport emissions as 453 million new vehicles are added by 2040. But the trend is not universal: while APEC transport emissions rise overall, the introduction or ongoing tightening of fuel economy improvements and the deployment of advanced vehicles help reduce emissions in many regions (including the United States, other north-east Asia and Russia).

KEY MESSAGE: APEC ENERGY TARGETS NEED TO BE INTENSIFIED TO MEET GLOBAL CLIMATE OBJECTIVES, REQUIRING ENHANCED COLLABORATION

The APEC targets to reduce energy intensity and double renewables can help curb the growth of energy-related emissions. Neither the Improved Efficiency nor the High Renewables Scenario, however, leads to an overall reduction from current levels. This highlights the need to pursue a combined strategy of energy efficiency improvements and measures to decarbonise the energy supply. Combining both scenarios delivers a 27% reduction in emissions in 2040 (compared with the BAU), at which time total emissions of 18.5 $GtCO_2$ are actually 9% lower than in 2013. While encouraging, this level of emissions remains more than double the estimated 8 $GtCO_2$ to 9 $GtCO_2$ needed in 2050 to achieve the global 2°C goal.

APEC should consider increasing the level of ambition of its existing energy targets and potentially introducing additional targets that could support a more dramatic transformation of the energy sector. Individual APEC economies should monitor and re-evaluate their INDCs, strengthening when possible commitments that will lead to faster decarbonisation of the energy sector.

Implementing policies to decarbonise the power sector and accelerate energy efficiency are two of the most important priorities for APEC economies. While doubling the share of renewables helps to reduce growth of power sector emissions, it is insufficient to achieve long-term decarbonisation of the power sector. In the long term, even higher shares of renewables would be needed. The heavy reliance on coal shown in APERC analysis brings to the forefront the need to limit the addition of new coal capacity and ensure that any coal plants built will apply the most efficient technologies and include CCS. Nuclear power can also provide stable, zero-carbon baseload power generation and should be considered by economies where it is a viable option.

Accelerating energy technology development and deployment is central to establishing more secure and environmentally sustainable energy systems. APEC economies should continue working together to share best practices and lessons learnt, and enhance collaboration on a range of low-carbon technologies including renewables, energy efficiency, nuclear, clean fossil fuel technologies and CCS. They should also support capacity-building across member economies to accelerate the transition.

1. INTRODUCTION

KEY FINDINGS

- **The role of the APEC region in shaping the global energy sector will grow** as the region assumes a more prominent position as the centre of world energy demand.

- **Developments in energy demand in China and South-East Asia over the Outlook period continue to dominate APEC trends.** Between 2013 and 2040, total primary energy demand in APEC in the BAU Scenario rises by 35%. Before 2030, China accounts for the majority of this increase; after 2030, energy demand growth in South-East Asia overtakes, being double that of China.

- **Since the 1990s, coal has fuelled much of the growth in APEC economic activity; in 2006, coal consumption surpassed that of oil.** This unabated use of coal is clearly unsustainable; APEC economies need to step up efforts to develop and deploy cleaner energy sources, including cleaner coal, natural gas, renewables and nuclear.

- **APEC governments have implemented and announced major changes to energy policy, which will shape the region's energy future.** Most APEC economies now have either firm or aspirational energy efficiency and renewable energy targets; the stated goals are encouraging but still insufficient.

- **In addition to the reference BAU Scenario, this edition of the Outlook examines three alternative scenarios to address energy challenges in APEC economies: the Improved Efficiency, High Renewables and Alternative Power Mix Scenarios.**

OVERVIEW

The APEC Energy Demand and Supply Outlook, 6th Edition, (Outlook) presents the latest energy trends and evaluates major energy challenges and opportunities to 2040 for the Asia-Pacific Economic Cooperation (APEC) region. Targeting policy makers, the report aims to foster understanding among APEC economies of the key drivers of both domestic and regional energy demand and supply, the need for energy infrastructure development and related policy issues. In addition to the standard updates of economic and price assumptions, this edition of the Outlook incorporates several new developments, including enhanced modelling of the Business-as-Usual (BAU) Scenario and comparison with three alternative scenarios (Box 1.1).

Box 1.1 • New developments incorporated in the Outlook, 6th Edition

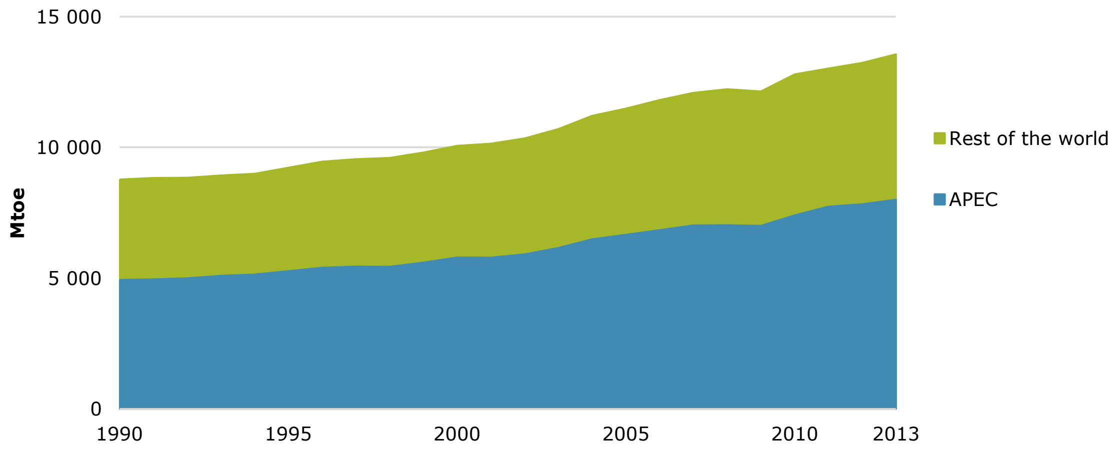
To provide a more refined analysis of the APEC energy outlook, the Asia Pacific Energy Research Centre (APERC) made several modifications to the modelling and approach.

- A new macroeconomic model was developed to project gross domestic product (GDP) for each of the 21 APEC economies.
- The power model was restructured to take into account long-term cost dynamics, increase the number of technologies from 14 to 19, and improve modelling of load curves (to consider daily and seasonal characteristics).
- An improved renewables model incorporates estimates of economic renewable potential and economy-specific levelised cost of electricity (LCOE) assumptions within the power generation model. Biofuels feedstock potential is modelled to evaluate higher biofuels targets and minimum blend rates.
- The investment model has been enhanced to include updated cost data from recent and committed energy projects, as well as forecasts for capital cost reductions for technologies such as wind and solar. In addition, the analysis was expanded to include investment needs for biofuels production and rail infrastructure for coal transport.
- Three new alternative scenarios have been developed. 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.
- Crude oil price assumptions in 2020 and 2030 have been lowered to USD 75 and US 100 per barrel and a price of USD 125 has been assumed for 2040 (IEEJ, 2015).

The APEC region represents nearly 60% of the world's primary energy demand and more than half of real GDP; thus, actions taken in the region play a strong role in determining the future of the global energy sector (Figure 1.1). As the region includes four of the world's five largest energy users (China, Japan, Russia and the United States), it is vital to world energy demand.

In 2013, APEC's total primary energy demand reached 8 000 million tonnes of oil equivalent (Mtoe), an increase of 62% over the 1990 level. In comparison, global energy demand rose by just 55% over the same period, reaching 13 500 Mtoe in 2013. Since 1990, rapid economic development in China has been the main driving force behind growth in both APEC and global energy demand. APEC energy demand has been rising at an average annual growth rate (AAGR) of 2.1%, slightly above the global rate of 1.9%.

Figure 1.1 • Total primary energy demand, 1990-2013



Sources: EGEDA (2015) and IEA (2015).

The region's diverse grouping of economies includes some of the world's most energy-intensive (Brunei Darussalam, Canada and Russia) and also the least energy-intensive (Papua New Guinea, Peru and the Philippines). Economies in Asia—particularly China and South-East Asian economies—showed the fastest growth energy use, both in APEC and globally.

Table 1.1 • Energy statistics by regional grouping, 2013

	Energy production (Mtoe)	Total primary energy supply (Mtoe)	Electricity consumption (TWh)	Energy intensity (toe/unit GDP)	Primary energy supply per capita (toe)
China	2 566	3 010	4 500	147	2.2
United States	1 881	2 183	3 783	94	6.9
Russia	1 340	732	744	173	5.1
Other north-east Asia	85	840	1 707	73	4.1
Other Americas	688	509	830	92	2.5
Oceania	361	151	248	86	4.3
South-East Asia	744	569	705	114	1.1
APEC	**7 666**	**7 995**	**12 517**	**110**	**2.8**
World	13 541	13 541	21 538	108	1.9

Notes: TWh = terrawatt hours; toe = tonnes of oil equivalent.
Sources: IEA (2015) and World Bank (2015).

The 21 APEC economies include major energy consumers and producers. Some economies are major energy exporters (Australia, Brunei Darussalam, Canada and Russia); others import nearly all of their energy supply (Chile, Japan, Korea and Singapore). The drivers of energy use differ significantly, reflecting the wide range of climates, geographical conditions, population densities and economic structures. Despite these differences, APEC economies share many energy goals, including a strong focus on enhancing energy security and environmental sustainability while supporting economic growth.

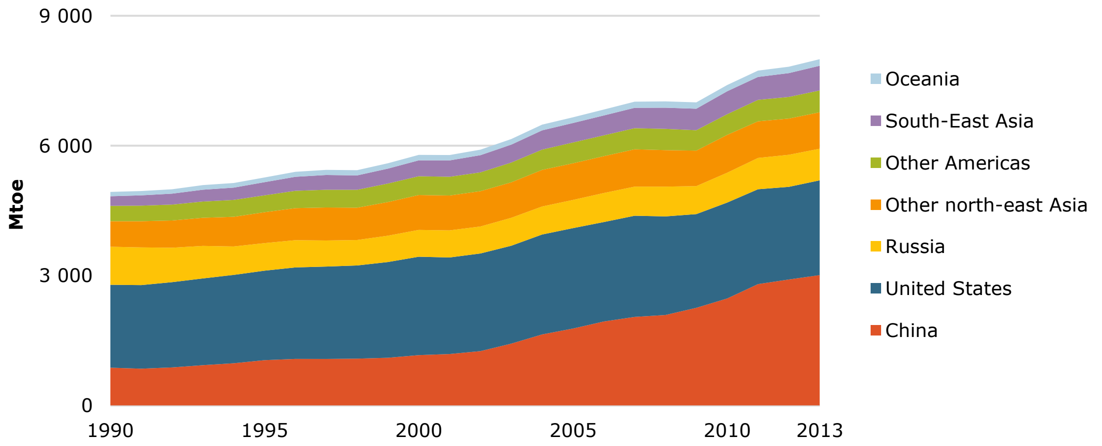
Developments in APEC have far-reaching implications for the global energy outlook. In addition to being at the centre of global energy demand, APEC economies have led major energy technology developments that influence regional and global trends, including shale gas and oil exploration, nuclear energy, energy efficiency, electric vehicles (EVs), and innovation in solar photovoltaic (PV) energy that have led to dramatic cost reductions.

RECENT TRENDS IN THE APEC ENERGY SECTOR

CHINA LEADS RAPID GROWTH IN ENERGY DEMAND

The significant role of China in shaping the energy outlook of APEC is undeniable. Since 1990, China's energy demand has more than tripled, and the economy has accounted for 70% of the additional energy supply in the region. In 2013, China's consumption of 3 010 Mtoe made up 38% of APEC total primary energy demand (Figure 1.2). Only Malaysia showed higher growth, with energy demand rising fourfold between 1990 and 2013. In 2009, China overtook the United States as the world's largest energy user. These two economies combined represent two-thirds of APEC energy use, highlighting their critical roles in determining the energy future of both APEC and the world.

Figure 1.2 • Total primary energy demand by APEC regional grouping, 1990-2013



Sources: EGEDA (2015) and IEA (2015).

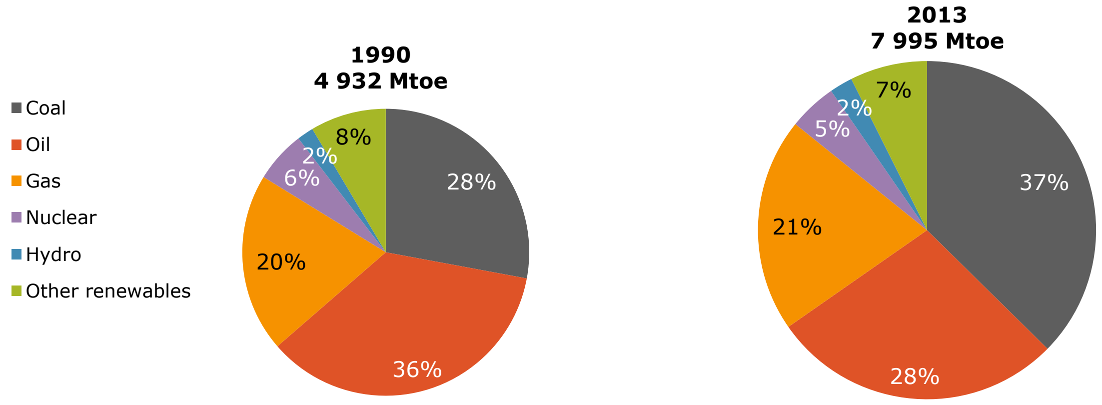
In 11 of the 21 APEC economies, energy demand has more than doubled since 1990. Five of these economies are in South-East Asia, the second-fastest growing region after China. Yet, as South-East Asia has some of the lowest levels of energy consumption per capita and several economies that are developing rapidly, its energy demand is expected to show the highest growth rates in the future. In absolute terms, demand in South-East Asia remains well below that of China, Russia and the United States.

Among developed APEC economies, Korea's energy demand rose the fastest, nearly tripling between 1990 and 2013, fuelled by rapid economic development and reflecting initially low domestic energy consumption compared with other mature APEC economies. Over that period, Korea rose from being the eighth-largest energy user to being the fifth-largest, overtaking Canada in 2011. With the breakup of the Soviet Union and the economic restructuring that followed, Russia's energy demand declined by 17% (it is the only APEC economy to show a reduction in energy use).

COAL OVERTAKES OIL AS LEADING FUEL SOURCE IN APEC

Fossil fuels dominate the APEC energy mix. In 2013, 86% of total primary energy supply (TPES) came from fossil fuels, up from 84% in 1990. A large increase in the share of coal, from 28% in 1990 to 37% in 2013, is the most significant change in the energy supply mix (Figure 1.3). Rapid demand growth for electricity prompted the addition of more than 880 gigawatts (GW) of coal-fired power plants in APEC (mainly in China and South-East Asia), pushing coal past oil to become the largest energy source in the region. China's rapid industrialisation over the last two decades, which included the economy becoming the world's leading producer of energy-intensive materials such as steel, cement and aluminium, has been fuelled primarily by coal. Coal demand in APEC over this period more than doubled, reaching 3 000 Mtoe in 2013 (from 1 400 Mtoe in 1990).

Figure 1.3 • APEC total primary energy supply by fuel, 1990 and 2013



Sources: EGEDA (2015) and IEA (2015).

Demand for oil rose 27% between 1990 and 2013, reaching over 2 200 Mtoe; this was driven by higher transport energy demand, primarily for road vehicles. This more modest growth in oil demand compared with coal resulted in oil's share of TPES falling from 36% in 1990 to 28% in 2013. Two factors significantly contributing to the growth in road transport energy are higher freight transport demand (linked to rapid industrialisation in China) and the addition of 334 million new vehicles in APEC (reflecting rising income levels). The latter trend is expected to continue over the coming decades, as vehicle ownership levels in 10 APEC economies (particularly in China and South-East Asia) remain below (11 to 215 vehicles per 1 000 inhabitants) the APEC average (228 vehicles per 1 000 inhabitants). Among APEC economies that are members of the Organisation for Economic Cooperation and Development (OECD), the average is 620 vehicles per 1 000 inhabitants.

Higher consumption of natural gas, which rose 65% between 1990 and 2013, was driven (as with coal) by growing electricity demand, prompting the addition of 550 GW of new gas-fired capacity in the region. The United States showed the largest increase in gas demand (in contrast to China leading the rise of coal consumption), as development of shale gas triggered switching from coal- to gas-fired electricity generation. South-East Asia and the other Americas region, both of which are major natural gas producers, also showed large increases in gas-fired generation.

Over this period, the share of non-fossil energy showed a small decrease (reflecting coal consumption growth outpacing that of all other fuels). Consumption of other renewables, primarily traditional biomass and geothermal, rose more moderately demonstrating that efforts to switch away from traditional biomass to modern fuels helped to reduce overall growth. Nuclear energy consumption rose 29% between 1990 and 2013, but was dampened by the closure of Japan's nuclear fleet following the Fukushima accident in March 2011, which caused nuclear energy supply to drop by 16% between 2010 and 2013. Hydro was the only non-fossil source to maintain its share (2%) of the energy mix. More than 330 GW of new hydro power (including pumped hydro) was added to meet rising electricity demand.

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 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 1.2).

Table 1.2 • 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 developed by APERC 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 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 energy excluding non-energy use as the basis to evaluate 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. It is applied based on final energy.

The High Renewables Scenario assumes that all announced government targets for 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% of 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 (GHG) 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 to 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 the 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.

DRIVERS OF ENERGY USE IN APEC

A variety of factors influence the outlook for energy demand and supply in APEC, including changes in energy policy, economic development, demographics and technological progress. Assumptions about economic and population changes are particularly important in determining projections for energy demand, while energy policy and technology developments are central to determining the region's energy supply mix.

[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.

ENERGY POLICY DEVELOPMENTS AND OUTLOOK FOR ENERGY TECHNOLOGY

Since the release of the 5th Edition (2013) of the APEC Energy Demand and Supply Outlook, APEC governments have implemented and announced major changes to energy policy that will shape the region's energy future (Table 1.3). Most APEC economies now have either firm targets or aspirational goals for energy efficiency and renewable energy. The number of APEC economies with energy efficiency standards—currently 18—is growing and the benefits of such policies are already evident in lower energy consumption growth rates. Many economies have committed to limiting the use of inefficient coal-fired plants, while others plan to phase out coal plants that are not equipped with CCS.

Table 1.3 • Summary of major energy policy drivers by APEC economy

Australia	Increase energy productivity by 40% between 2015 and 2030; renewables target of 33 TWh by 2020.
Brunei Darussalam	Targets by 2035 (2005 base) of 10% renewable electricity and energy intensity reduction of 45%; increase gas and oil production to 650 000 bbl/d.
Canada	Strict regulations on coal-fired electricity and phase out of nuclear; diversify oil and gas exports.
Chile	20% of electricity from non-hydro renewables by 2025; 20% energy savings goal by 2020; and 70% of electricity generation from renewables by 2050.
China	Rapid expansion of public transport systems, tightening of fuel economy standards and target of 5 million EVs and FCEVs in 2020; 60% to 65% reduction in CO_2 intensity by 2030 (2005 base), with CO_2 emissions peaking around 2030; non-fossil primary energy reaching 20% by 2030.
Hong Kong	40% reduction in energy intensity by 2025 (2005 base); limit coal to no more than 10% of power mix, with gas reaching around 40%, renewables 3% to 4%, and remainder being imported nuclear.
Indonesia	2025 energy mix of at least 23% renewables, oil less than 25%, coal minimum 30% and gas minimum 22%; target 1% annual reduction in energy intensity to 2025; fossil fuel subsidy reform and gradual decline in coal and gas exports.
Japan	Liberalise electricity and gas markets, strengthen energy efficiency measures, pursue power mix target of 20% to 22% nuclear, 22% to 24% renewables, 27% LNG, 26% coal and 3% oil; energy-related CO_2 reductions of 25% by 2030 from FY 2013.
Korea	Maintain nuclear share at 29% of capacity; renewables target of 11% of TPES by 2035.
Malaysia	Renewables capacity target of 2.1 GW by 2020; continued implementation of market-based energy pricing and of enhanced efforts to improve energy efficiency.
Mexico	Energy sector reforms opening oil and gas industry to private sector investors; in power generation, maximum fossil fuel targets of 65% by 2024, 60% by 2035 and 50% by 2050.
New Zealand	90% renewable electricity by 2025; enhanced building codes and minimum energy performance standards (MEPS).
Papua New Guinea	Develop gas reserves for LNG exports and increase gas use for electricity.
Peru	Continue development of major gas finds; blend rate of 5% for bioethanol and 2% for biodiesel; expand use of natural gas in power sector; increase electrification rate to 99% by 2025.
The Philippines	Maintain renewables share of power generation at 30%; increase electrification rate to 90% by 2017; expand exploration and development of oil, gas and coal; 10% bioethanol and 2% biodiesel blend rate.
Russia	Diversify energy exports towards Asia-Pacific; renewables target of 2.5% by 2020; 25% to 30% GHG reduction by 2030 (1990 base); 44% energy intensity reduction target by 2030 (2005 base).
Singapore	Reduce emissions intensity by 36% in 2030 (2005 base); PV target of 350 MW by 2020.
Chinese Taipei	Consecutive decommissioning of nuclear power plants between 2018 and 2025; accelerate deployment of renewables with capacity target of 12.5 GW by 2030.
Thailand	Fuel price reform; 30% energy intensity reduction by 2036 (2005 base); energy mix with coal up to 23% and renewables at 20% by 2036.
United States	New corporate average fuel economy (CAFE) standards for cars and light trucks; renewable fuel standards with mandated levels of biofuels production. Renewable Portfolio Standards in 33 states varying from 2% of aggregate generation capacity by 2021 in South Carolina to 50% retail sales in California by 2030.
Viet Nam	Reduce energy intensity by 1% to 1.5% annually; 100% rural electrification by 2020; non-hydro renewables to reach 6% by 2030; and nuclear energy introduced after 2025.

Notes: bbl/d = billion barrels (of oil) per day; L = litre; km = kilometre; LNG = liquefied natural gas; MW = megawatts; FCEV = fuel cell electric vehicles.

Sources: Refer to Volume II for economy-specific references.

Malaysia and Indonesia have already implemented fossil fuel subsidy reform; other economies are considering taking advantage of the sharp decline in oil prices to phase out fossil fuel subsidies. All APEC economies[2] that are part of the United Nations Framework Convention on Climate Change (UNFCCC) process have submitted Intended Nationally Determined Contributions (INDCs), which detail their commitments to take action on climate change under a new global climate agreement. Many INDCs include energy-related targets that are expected to accelerate implementation of energy efficiency measures and adoption of clean energy (including renewables, nuclear and cleaner fossil-fuel technologies).

Technology development continues to play a major role in shaping the APEC energy sector. Dramatic cost declines are making wind and solar PV increasingly competitive with fossil fuels in power generation. The development and growth of unconventional gas and oil resources have helped to reduce coal consumption, and are expected to help lower oil and gas imports to the region.

MACROECONOMIC ASSUMPTIONS

Economic development

This edition of the APEC Energy Demand and Supply Outlook is based on a new macroeconomic model that projects GDP for each of the 21 APEC economies using a Cobb-Douglass production function, which comprises the three major factors of capital, labour and total productivity (a detailed description can be found in Annex I).

Table 1.4 • GDP assumptions for APEC economies, 1990-2040

	Average annual growth rates (%)				GDP USD billion (PPP)	
	1990-2000	2000-13	2013-25	2025-40	2013	2040
Australia	3.3	3.1	3.0	2.6	953	2 008
Brunei Darussalam	2.2	1.2	1.1	1.4	21	29
Canada	2.9	2.0	1.8	1.6	1 467	2 300
Chile	6.3	4.3	3.5	2.0	327	663
China	10.3	9.9	6.6	3.6	13 246	48 184
Hong Kong	4.0	3.7	2.4	2.0	375	672
Indonesia	4.2	5.4	4.6	4.2	1 281	4 070
Japan	1.1	0.9	1.2	1.0	4 633	6 246
Korea	6.3	4.2	2.8	1.7	1 660	2 999
Malaysia	7.1	4.7	4.8	3.7	514	1 550
Mexico	3.5	2.2	3.4	2.7	1 803	4 038
New Zealand	2.9	2.5	2.4	2.2	136	249
Peru	3.8	5.7	4.2	3.7	336	944
The Philippines	2.9	4.9	6.1	5.9	446	2 143
Papua New Guinea	4.1	4.6	7.0	6.0	22	115
Russia	-3.8	4.4	1.6	1.3	2 516	3 696
Singapore	6.9	5.6	2.1	0.9	346	505
Chinese Taipei	6.2	3.7	1.5	0.4	942	1 201
Thailand	4.5	4.1	3.6	3.4	668	1 686
United States	3.3	1.7	1.6	1.7	15 878	24 601
Viet Nam	7.6	6.3	5.7	5.3	332	1 399
APEC	**3.3**	**3.8**	**3.6**	**2.7**	**47 901**	**109 299**

Sources: APERC analysis and World Bank (2015).

[2] Hong Kong, China, falls under the China INDC while Chinese Taipei is not included within the UNFCCC process.

Over the Outlook period, GDP (based on purchasing power parity, or PPP) in APEC is projected to more than double, from USD 48 trillion in 2013 to nearly USD 110 trillion by 2040. The GDP of China surpasses that of the United States around 2016 and by 2040 is nearly quadruple the 2013 level. As time passes, China's AAGR slows: from historical levels of about 10%, it drops to 6.5% over the next decade, then to 3.6% between 2026 and 2040.

Asia, particularly China and South-East Asia, continues to experience the fastest economic growth (Table 1.4). Projections for mature OECD economies are more modest; as a result, their share of APEC GDP declines from 55% in 2013 to just 39% by 2040. Papua New Guinea, APEC's smallest and least-developed economy, shows the most rapid GDP growth, thanks to the development of its vast natural gas reserves and a new LNG terminal (which has begun exporting LNG to Japan, Chinese Taipei and China).

Population

This analysis draws population assumptions from two sources, the United Nations Department of Economic and Social Affairs (UNDESA) and Centre d'Etudes Prospectives et d'Informations Internationales (CEPII), which assume an AAGR of 0.5% between 2013 and 2025, followed by a lower 0.2% between 2025 and 2040. By 2040, APEC's population reaches more than 3 billion people, of whom over two-thirds live in Asia, but its share of the global population falls to 33% (from 39% in 2013). While the populations of most APEC economies rise (with the exception of Japan and Chinese Taipei), growth rates vary considerably. In China and Korea, population continues to grow between 2025 and 2040, but the rate of growth declines.

Table 1.5 • Population assumptions in APEC economies, 2013-40

	Average annual growth rates (%)		Population (millions)		Urbanisation rates (%)	
	2013-25	2025-40	2013	2040	2013	2040
Australia	1.6	1.3	23	34	89	92
Brunei Darussalam	1.6	0.9	0.41	0.57	77	82
Canada	0.8	0.5	35	42	81	86
Chile	0.7	0.3	18	20	89	92
China	0.2	-0.2	1 363	1 361	53	70
Hong Kong	1.1	0.6	7.2	8.9	100	100
Indonesia	0.7	0.4	251	290	52	66
Japan	-0.3	-0.5	127	114	92	97
Korea	0.1	-0.2	50	49	82	87
Malaysia	1.5	1.0	29	41	79	84
Mexico	0.9	0.6	118	145	73	83
New Zealand	1.1	0.6	4.4	5.5	86	89
Peru	0.9	0.7	31	38	78	84
The Philippines	1.6	1.2	98	142	45	53
Papua New Guinea	2.0	1.7	7.3	12	13	20
Russia	0.3	0.1	143	151	74	79
Singapore	0.6	0.4	5.4	6.2	100	100
Thailand	0.5	0.1	67	73	48	66
Chinese Taipei	0.1	-0.3	23	23	75	n/a
United States	0.8	0.6	317	383	81	86
Viet Nam	0.7	0.3	91	104	32	49
APEC	**0.5**	**0.2**	**2 810**	**3 043**	-	-

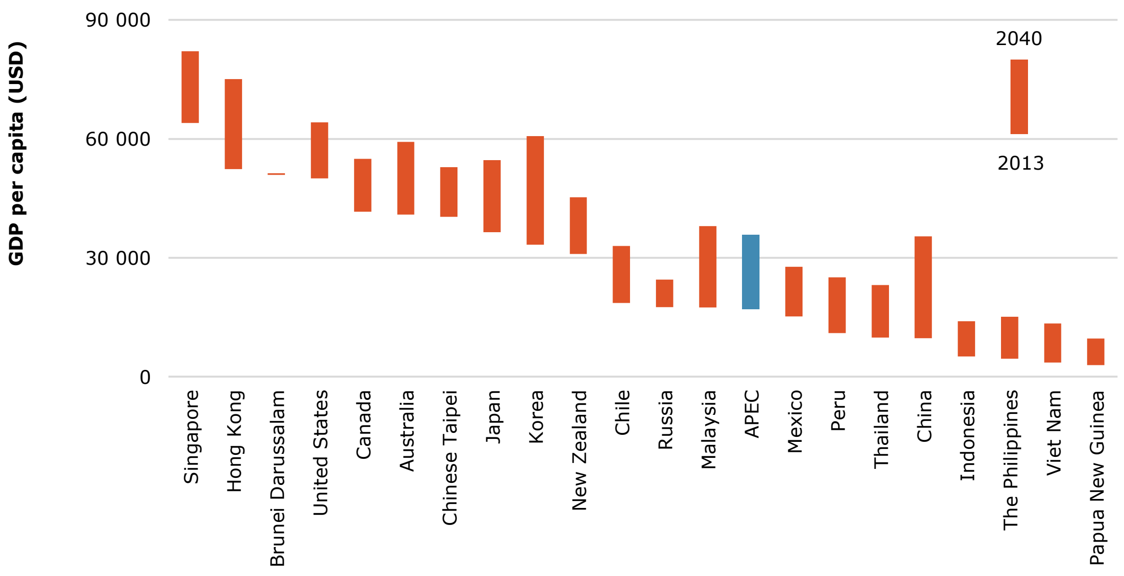
Sources: APERC analysis, CEPII (2012), MI (2015) and UNDESA (2014, 2015).

In most APEC economies, rising urbanisation drives up energy use. People in urban areas, particularly in developing Asia, consume significantly higher levels of energy than those in rural areas because of differences in lifestyles and demand for higher comfort levels. In APEC, urbanisation rates range from as low as 13% in Papua New Guinea to 100% in Hong Kong and Singapore, with most economies having urbanisation rates well above 70%. Exceptions include China, Indonesia, the Philippines, Papua New Guinea, Thailand and Viet Nam, where urbanisation rates range from 13% to 53%. UNDESA estimates that urbanisation levels will rise in all economies, with China, Thailand and Viet Nam reporting the largest percentage changes. By 2040 all economies except Papua New Guinea, the Philippines and Viet Nam reach urbanisation rates above 65%.

With significantly higher levels of energy consumption in urban versus rural areas, this trend towards increasing urbanisation puts pressure on energy demand in many developing APEC economies, highlighting the need to implement more energy-efficient urban design strategies. Urban planners should encourage the development of more compact cities with good public transport networks and highly energy efficient buildings, rather than sprawling cities in which private vehicle use tends to be high.

Forecasts of energy demand in the buildings and transport sectors are particularly sensitive to assumptions about GDP per capita. As average income levels increase, individual demand for energy services also rises as people buy and use more personal vehicles, appliances and electronic gadgets. Per-capita GDP over the Outlook period rises in all APEC economies. Singapore remains the wealthiest economy based on this indicator, while China shows the largest growth, more than tripling GDP per capita thanks to rapid economic development and low population growth rates.

Figure 1.4 • GDP per capita by APEC economy, 2013-40



Sources: APERC analysis, IEA (2015) and World Bank (2015).

APEC ENERGY OUTLOOK IN THE BAU SCENARIO

REGIONAL ENERGY TRENDS TO 2040

Asia continues to determine APEC energy trends

Under the BAU Scenario, developments in Asia continue to determine APEC energy demand over the Outlook period. Between 2013 and 2040, TPES rises 35%, with most of the increase from China, which adds 1 685 Mtoe (almost equivalent to the combined 2013 energy consumption of Russia, Japan, Canada and Korea–the third; fourth; fifth; and sixth largest energy consumers in APEC) (Table 1.6). South-East

Asia also shows a sharp increase in energy demand: with TPES more than doubling, this region accounts for 27% of the additional energy consumed in APEC (Figure 1.5).

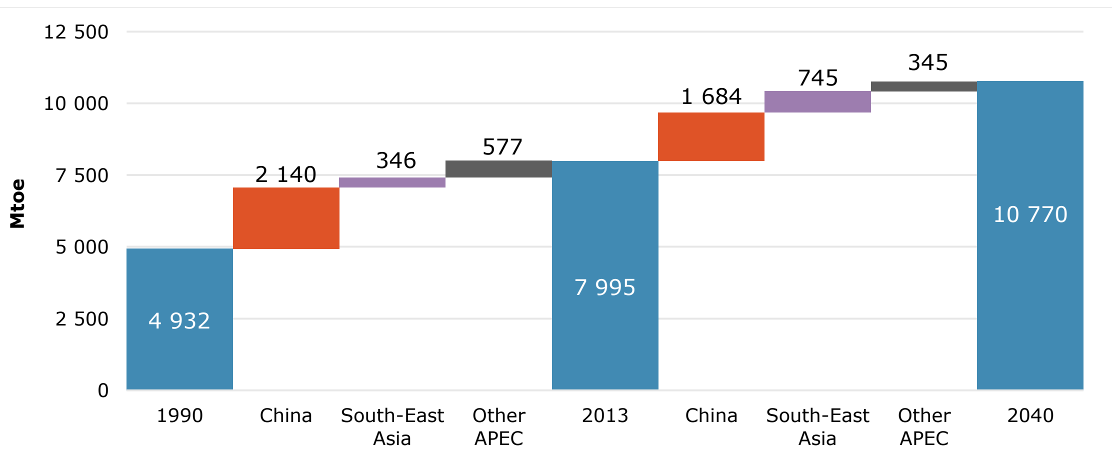
Table 1.6 • Total primary energy supply by APEC economy, 1990-2040 (Mtoe)

	1990	2013	2020	2030	2040	AAGR 2013-40 (%)
Australia	86	129	134	140	144	0.39
Brunei Darussalam	1.7	3.0	4.0	4.4	5.0	1.84
Canada	209	257	295	307	318	0.79
Chile	14	39	49	59	65	1.95
China	871	3 010	3 976	4 555	4 695	1.66
Hong Kong	8.8	13.2	12.8	13.2	12.2	-0.28
Indonesia	99	213	315	430	554	3.60
Japan	439	455	454	439	410	-0.38
Korea	93	264	282	292	291	0.37
Malaysia	22	89	103	127	149	1.93
Mexico	123	191	234	274	302	1.70
New Zealand	13	20	20	22	24	0.71
Peru	10	22	33	48	60	3.82
The Philippines	29	45	57	79	102	3.13
Papua New Guinea	0.9	2.6	4.7	7.7	12.1	5.93
Russia	880	732	779	789	788	0.27
Singapore	12	26	30	31	32	0.75
Thailand	42	133	165	207	244	2.26
Chinese Taipei	48	109	112	110	107	-0.05
United States	1 915	2 183	2 249	2 255	2 228	0.08
Viet Nam	18	60	93	147	228	5.08
APEC	**4 932**	**7 995**	**9 401**	**10 337**	**10 770**	**1.11**

Sources: APERC analysis, EGEDA (2015) and IEA (2015).

Over the Outlook period, APEC achieves a decoupling of energy consumption from economic growth, as efforts to reduce energy intensity by strengthening energy efficiency policies and conservation measures take effect. As a result, overall energy demand growth in APEC slows considerably between 2013 and 2040, with AAGR falling to 1.1% (about half the rate of 2.1% between 1990 and 2013).

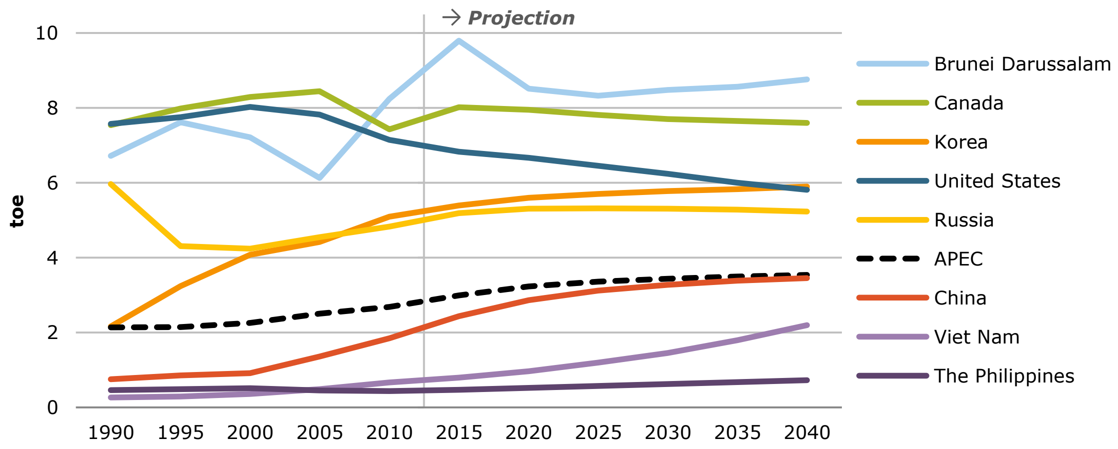
Figure 1.5 • Total primary energy supply developments by regional grouping, 1990-2040



Sources: APERC analysis and IEA (2015).

While energy intensity (energy consumption per unit of GDP) falls in all APEC economies, trends in energy per capita are mixed. Average energy consumption per capita continues to rise, from 2.8 tonnes of oil equivalent (toe) in 2013 to 3.5 toe in 2040, but actual consumption varies dramatically across APEC, from just 0.7 toe in the Philippines to 8.8 toe in Brunei Darussalam (Figure 1.6). Viet Nam, which had the second-lowest energy use per capita in 1990, shows the fastest growth rates: energy use per capita triples over the Outlook period to 2.2 toe (still well below the APEC average). Energy consumption per capita also rises significantly in China and South-East Asia, as higher income levels boost energy demand.

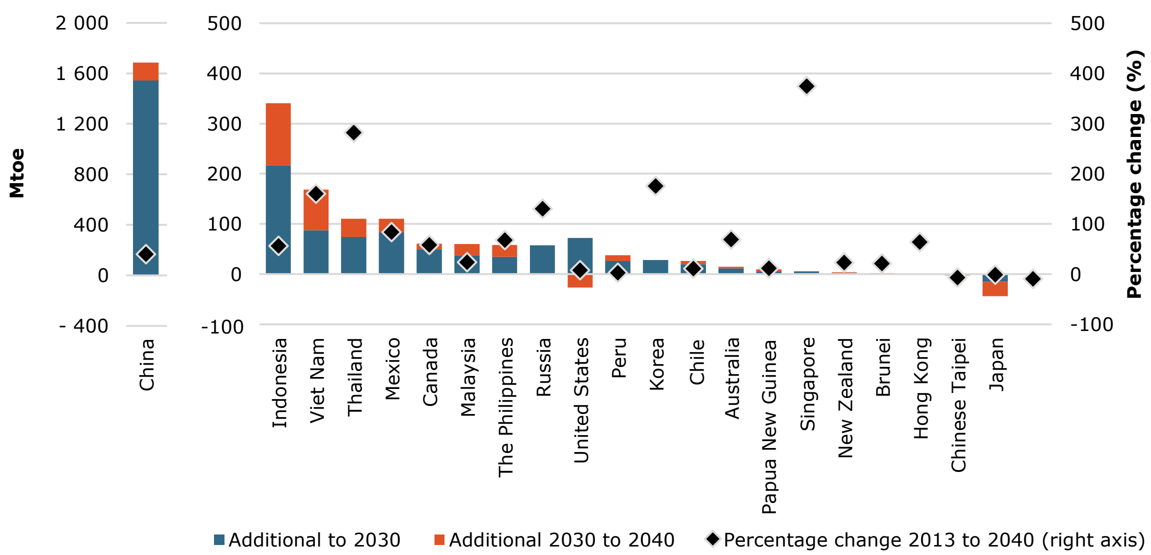
Figure 1.6 • Total primary energy supply per capita in selected APEC economies, 1990-2040



Sources: APERC analysis, IEA (2015) and UNDESA (2015).

In most mature APEC economies, energy consumption per capita declines as economies shift towards the service sector and improve energy efficiency. One notable exception is Korea, where energy per capita continues to rise as industrial energy use increases and population declines. After 2035, Korea overtakes the United States in terms of energy use per capita in APEC, behind only Brunei Darussalam and Canada. The United States shows the largest reduction (i.e. improvement) in energy consumption per capita, with the volume of 5.8 toe by 2040 being a substantial decline from a high of 8 toe in 2000. Efforts to improve energy efficiency (particularly in transport) and a continued increase in the service sector's share of the economy lead TPES in the United States to peak around 2025 and decline thereafter.

Figure 1.7 • Total primary energy supply additions by APEC economy, 2013-40



Sources: APERC analysis.

South-East Asia drives APEC energy demand after 2030

As China's economy matures, energy demand growth slows after 2030, with primary energy supply rising only 140 Mtoe between 2030 and 2040, compared with 1 540 Mtoe between 2013 and 2030 (Figure 1.7). After 2030, South-East Asia leads growth in APEC energy consumption, with primary energy demand rising by 288 Mtoe (i.e. double the growth in China). In the United States and Chinese Taipei, primary energy demand peaks around 2025 and declines towards 2040. Japan is the only economy in which energy use falls significantly over the Outlook period, as the population declines and energy efficiency improves.

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.

2. ENERGY DEMAND OUTLOOK

KEY FINDINGS

- **Total final energy demand is expected to reach 7 000 Mtoe in 2040 in the APEC region under the BAU Scenario.** This represents a 32% increase from the 2013 level of 5 293 Mtoe.

- **Growing demand in China and South-East Asia drive the increase in APEC final energy demand over the Outlook period.** China, which shows demand increase from 1 943 Mtoe in 2013 to 2 875 Mtoe in 2040, comprises the bulk of APEC total final energy demand growth. South-East Asian economies' energy demand increases more than twofold, owing to its fast-growing economies.

- **Industry remains the largest energy-consuming sector over the Outlook period;** with annual growth of 1%, it comes to account for one-third of total final energy demand.

- **The increasing number of vehicles in China and South-East Asia drives rapid growth in transport energy demand, particularly to 2025.** Of more than 1.27 billion vehicles operating in 2040 in APEC, more than 400 million are in China and more than 200 million are in South-East Asia.

- **Under the BAU, the APEC 45% energy intensity target is not reached until 2037;** this highlights the need to implement additional energy efficiency measures.

INTRODUCTION

Asia-Pacific Economic Cooperation (APEC) is a dynamic region in which diverse economies have agreed to work together to support sustainable economic growth and prosperity in the region (APEC, 2014). Over the past decade, most APEC economies have experienced rapid economic growth alongside rising population, which drives up individual and collective energy demand requirements.

This chapter presents the outlook for energy demand in the APEC region under a Business-as-Usual (BAU) Scenario.

Final energy demand in APEC under the BAU reaches 7 000 million tonnes of oil equivalent (Mtoe) in 2040, with the People's Republic of China and South-East Asia being the main drivers of the increase. A more comprehensive analysis of final energy demand in APEC, based on both past trends and future projections, forms the bulk of this chapter. It also includes analysis of the aspirational goal set by APEC Leaders in 2011 to reduce energy intensity by 45% by 2035, against the 2005 level (APEC, 2011), starting with an assessment of gains made from 1990 to 2013, in part through energy efficiency measures. (Part 2 of the Outlook includes a chapter that explores an Improved Efficiency Scenario under which strategic action is taken to enhance energy efficiency).

In examining how current policies and energy demand patterns play out in APEC under the BAU, this analysis serves as a reference by which leaders can assess whether current policies are effective or need to be adapted, and how to improve targets or accelerate pending legislation (if any exist) to achieve the APEC aspirational goal on energy intensity reduction.

The 2011 Honolulu Declaration: Towards a seamless regional economy

APEC Leaders and members agreed in 2011 to work together for greater economic cohesion and security under a green growth strategy, as follows:

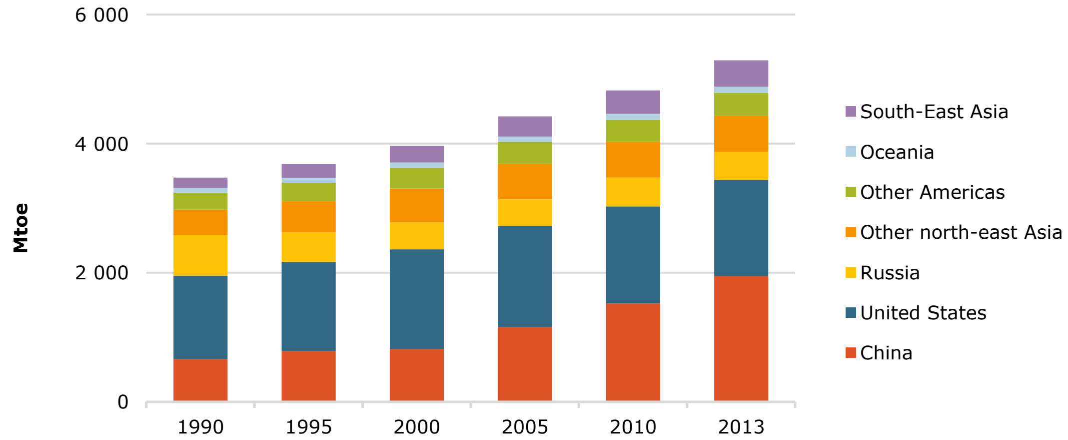
'We will also take the following steps to promote our green growth goals:

- Rationalise and phase out inefficient fossil-fuel subsidies that encourage wasteful consumption, while recognising the importance of providing those in need with essential energy services, and set up a voluntary reporting mechanism on progress, which we will review annually;
- Aspire to reduce APEC's aggregate energy intensity by 45% percent by 2035.'

CHINA OVERTAKES UNITED STATES AS MAIN SOURCE OF ENERGY DEMAND GROWTH IN APEC

Energy demand growth in APEC has seen a break from historic trends in the past five years: after the United States consistently showed the highest demand in absolute terms since 1990, China moved from second to first place in 2010. Russia has steadily remained the third-largest consuming economy. While APEC total final energy demand (TFED) showed an annual average growth rate (AAGR) of 1.8% over the period 1990 to 2013, this masks the much higher energy demand growth seen in China (4.8% AAGR) and the group of economies that make up South-East Asia (4.1% AAGR). Despite this demand growth, which reflects strong overall economic development, energy demand per capita in both China and South-East Asia remain well below the APEC average. For example, China's final energy demand per capita in 2013 was 1.4 tonnes of oil equivalent (toe) and that of South-East Asia was 1.6 toe on average, as compared with the United States (4.7 toe) and Russia (3 toe). Russia's energy consumption, by contrast, declined from 1990 levels of 625 Mtoe to 435 Mtoe in 2013, mainly due to the economic crises that followed the break-up of the Soviet Union (Figure 2.1) (World Bank, 1992).

Figure 2.1 • Final energy demand by regional grouping, 1990-2013



Sources: APERC analysis and IEA (2015).

OUTLOOK FOR APEC ENERGY DEMAND

The BAU Scenario shows how current growth trends, if sustained, will affect energy demand over the Outlook period. Given the diverse natures of the industry, transport, and buildings and agriculture sectors, the Asia Pacific Energy Research Centre (APERC) applied different tools to project their respective energy demand over the period 2014 to 2040. To facilitate comparison, APERC used gross domestic product (GDP) in 2012 USD PPP (purchasing power parity) as the common measure. Historical economic data were drawn from the World Bank (World Bank, 2015a), with the exception of Chinese Taipei (which APERC also estimates). Detailed descriptions of the sectoral and macroeconomic models are available in Annex I: Key assumptions and methodologies.

ASIA CONTINUES TO DETERMINE OUTLOOK FOR ENERGY DEMAND IN APEC

Under the BAU, TFED in APEC reaches 7 000 Mtoe in 2040, a 32% increase from the 2013 level of 5 293 Mtoe that represents an AAGR of 1%. But a closer look shows the growth rate tapering off; robust growth of 2.4% annually to 2020 subsequently slows to 0.7% annually to 2035, then to just 0.2% annually to 2040. Throughout the Outlook period, energy demand growth slows in China, the United States and other north-east Asia, which together account for the bulk of energy demand.

China shows the most significant drop-off in projected demand growth: from a robust 4.1% AAGR to 2020, the rate slows down to 0.8% from 2020 to 2035. Post-2035, China's energy demand contracts by 0.2%. This translates to TFED levels of 2 571 Mtoe in 2020, 2 897 Mtoe in 2035 and 2 875 Mtoe in 2040. Decreasing energy demand aligns with government policy to move towards a more sustainable pattern of growth (IMF, 2015).

Although marginal in terms of actual share, South-East Asia's AAGR of 2.8% between 2013 and 2040 (an increase from 410 Mtoe to 871 Mtoe) also plays a role in driving APEC TFED (Figure 2.1). Among South-East Asian economies, Viet Nam has the fastest final energy consumption growth (4.4% AAGR), as a relatively young population transitions from an agricultural economy to being more urban and industrialised (World Bank, 2015b).

Final energy demand in other north-east Asia declines over the Outlook period, at an annual average rate of 0.1%, largely due to a foreseen contraction in Japan's energy demand (at 0.4% annually on average). This should not be viewed negatively, however; Japan's declining energy consumption reflects continually improving technological changes and energy efficiency improvements.

ENERGY EFFICIENCY EFFORTS IN APEC INCREASING

In the Sydney Declaration of September 2007, APEC set targets for improving energy efficiency across the region but stopped short of prescribing action plans or targets for individual economies, instead leaving each member to design its own targets and initiatives. Some members adopted the APEC goal of improving energy intensity by 45% by 2035 (such as Brunei Darussalam, Hong Kong, China and Thailand). Others, especially in other north-east Asia (such as Japan, the Republic of Korea and Chinese Taipei), committed to energy efficiency goals well beyond the 45% target. By using different target years or base years, or by measuring their energy savings in petajoules (PJ), several economies (e.g. Canada, Chile, New Zealand and Peru) have framed their goals in ways that are not directly comparable to the APEC goal (APERC, 2010).

Table 2.1 • Energy efficiency policies in APEC

	Overall targets		Sectoral goals	Buildings			Transport	Industry
	Energy savings	Energy intensity reduction		Envelope	Appliances	Labelling	Standards/ Economic incentive	Energy audits
Australia	40% by 2030	-	✗	✔	✔	✔	✗	✔
Brunei Darussalam	-	45% by 2035	✗	✗	✗	✗	✗	✔
Canada	20% by 2020	-	✗	✔	✔	✔	✔	✔
Chile	-	-	✗	✔	✔	✔	✔	✔
China	-	16% by 2015	✔	✔	✔	✔	✔	✔
Hong Kong	-	40% by 2025	✗	✔	✔	✗	✗	✗
Indonesia	-	1%/yr up to 2025	✔	✔	✗	✗	✗	✔
Japan	30% by 2030	-	✔	✔	✔	✗	✔	✔
Korea	-	46% by 2030	✔	✔	✔	✔	✔	✔
Malaysia	-	-	✔	✗	✔	✗	✗	✗
Mexico	15% by 2026	-	✔	✔	✔	✔	✗	✔
New Zealand	0.72 Mtoe by 2025	-	✗	✔	✔	✔	✗	✗
Papua New Guinea	-	-	✗	✗	✗	✗	✗	✗
Peru	15% by 2018	-	✔	✗	✗	✗	✗	✗
The Philippines	10% by 2030	-	✔	✔	✔	✗	✗	✔
Russia	-	50% by 2030	✗	✔	✔	✔	✗	✔
Singapore	-	35% by 2030	✗	✔	✔	✔	✔	✔
Chinese Taipei	-	20% by 2015	✔	✔	✔	✔	✔	✔
Thailand	-	30% by 2036	✔	✔	✔	✗	✗	✔
United States	-	-	✔	✔	✔	✔	✔	✔
Viet Nam	5% to 8% by 2015	-	✔	✔	✔	✗	✗	✔

Note: For the United States, the overarching energy efficiency goal and policy is to double energy productivity by 2030 relative to 2010.

Sources: APERC analysis and economy reports.

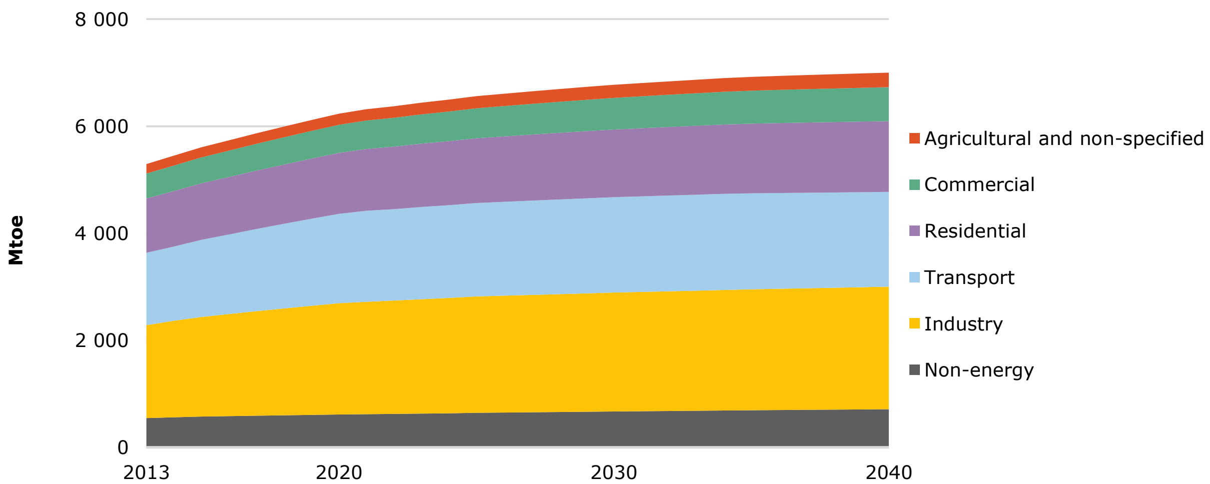
A recent survey conducted by World Energy Council (WEC) and France's Agency for Environment and Energy Efficiency (ADEME) shows that most economies in Asia, Oceania (both members and non-members of the Organisation for Economic Co-operation and Development [OECD]) and Latin America (including Mexico) have set quantitative sectoral targets for energy savings; some have also set targets for energy intensity reduction. In many cases, the targets become more stringent over time. Canada and Mexico, for instance, target an overall savings of 15% by 2015, pushing on to 20% by 2020. China aims for an overall energy intensity reduction of 16% by the end of its 12th Five-Year Plan (2011-15). China has already achieved a 6% energy intensity reduction in 2013 compared with 2010. In other north-east Asia, Japan pledged (during the 5th East Asia Summit [EAS] Energy Ministers Meeting) to an overall energy savings of 40% by 2025, while Korea targets an energy intensity reduction of 46% by 2030. In South-East Asia, Indonesia included in its National Energy Conservation Master Plan (RIKEN) an aim of reducing energy intensity by 1% annually to 2025 (starting in 2005), and Singapore's Energy Conservation Act sets an overall energy intensity reduction of 35% by 2030 (Table 2.1).

Economies in APEC may also apply various measures and programs designed with flexibility (including voluntary measures) to improve energy efficiency without restraining competiveness in international markets. Options include subsidies for energy audits, as well as soft loans and grants to reduce the payback time of investments in new equipment, in equipment upgrades or in processes—all of which aim to make energy efficiency investments more attractive to consumers. The benefits of such measures, including spillover effects, to achieve overall energy savings and energy intensity reductions are highlighted in the following examination of sector-specific energy demand trends.

INDUSTRY ENERGY DEMAND

From 2013, industry took over as the lead energy-consuming sector in APEC, following a period (1990-2013) in which its AAGR of 2.4% outpaced that of both transport (2%) and buildings and agriculture (1%). The BAU shows industry continuing to drive growth of APEC TFED with an AAGR of 1% over the Outlook period, pushing volumes from 1 737 Mtoe in 2013 to 2 291 Mtoe in 2040. The sector also remains the major energy consumer in APEC, accounting for one-third of TFED. When non-energy use is included, industry demand reaches 3 001 Mtoe, or more than 40% of the total APEC energy demand (Figure 2.2).

Figure 2.2 • Final energy demand in the BAU by sector, 2013-40



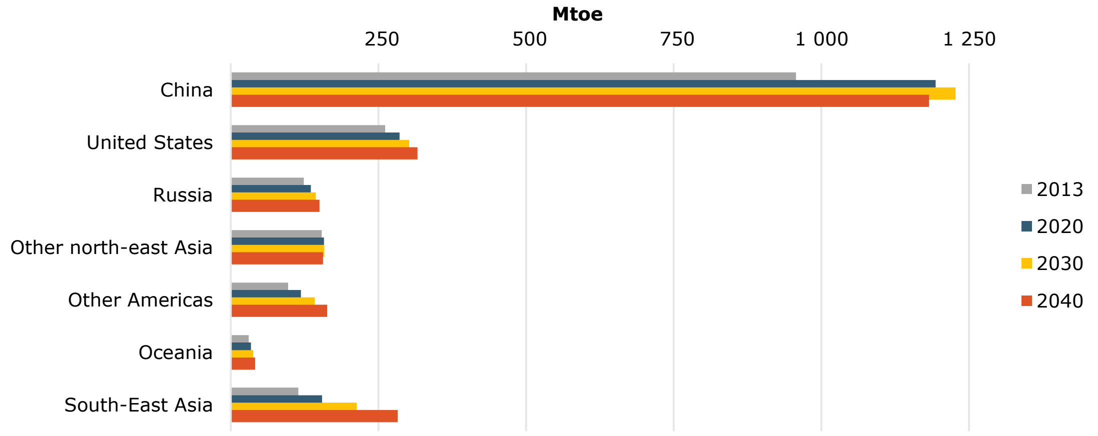
Sources: APERC analysis and IEA (2015).

LESS ENERGY-INTENSIVE INDUSTRY TO DRIVE FUTURE GROWTH

A shift in APEC's industrial energy demand structure is projected in the BAU Scenario, due largely to broad economic growth in 13 emerging and developing economies in Asia and Latin America that is underpinned by international trade. Rapid growth in annual average GDP is projected in South-East Asia which drives the growth in industry, especially in the Philippines (4.9%), Viet Nam (4.6%) and Indonesia (3.7%). The expected increase in GDP will have a matching increase in the production of medium-tech industries (coke, refined petroleum products and nuclear fuel, rubber and plastic, non-metallic mineral products, basic metals, and fabricated metal products) and high-tech industries (e.g. chemicals and chemical products to manufacture motor vehicles and transport equipment). Food and beverage is the only low-tech industry sector that sustains any growth in both developing and industrialised economies, much like what is happening now in Viet Nam, Indonesia, Thailand and the Philippines where food and beverage remains relatively stable, while growth is seen in iron and steel, and in chemicals and petrochemicals (UNIDO, 2013).

Although China's share of energy demand is decreasing, from 55% in 2013 to 52% in 2040, it maintains a majority share of APEC industry demand under the BAU. The next largest energy-consuming economies in APEC in 2040 are the United States (14%) and Russia (7%). The total share of APEC's industrial energy demand by these three economies decreases from 74% in 2013 to 70% in 2040 (Figure 2.3). China shows a declining trend especially after 2020 when its top energy-intensive sub-sectors (including steel and cement [non-metallic minerals]) are assumed to peak. China's recent emphasis towards a 'new normal' for the economy could potentially result in an earlier peaking; some experts suggest that the peak already occurred in 2014. In fact, considerable uncertainty remains as to how quickly this economic transition will occur in China. This trend, however, is consistent with declining demand seen in other mature industrialised economies (the United States, Japan, Russia, Korea, Canada, Chinese Taipei and Australia).

Figure 2.3 • Industry sector final energy demand by regional grouping, 2013-40



Sources: APERC analysis and IEA (2015).

Slumps in industry energy demand in Russia reflect the effects of low oil prices and geopolitical tensions, which continue to harm the economy. A continued decline in investments may further curtail the Russian manufacturing sector during the Outlook period (UNIDO, 2015).

China's dramatic growth in industrial activity over the last decade resulted in its emergence as the 'factory' of the world; demand for steel, cement and other manufactured products grew rapidly along with overall economic development and rising urban population. In 2012, China produced 50% of manufactured goods imported by industrialised countries (UNIDO, 2013). The iron and steel industry became the main pillar of China's economic development, growing rapidly since the 1990s when crude steel production exceeded more than 100 million metric tonnes. China has been the world's largest crude steel producer for 16 consecutive years.

A growing middle class that is demanding more consumer products will help to support manufacturing activity as China shifts to less energy-intensive industries. In addition, as skills and technical capacity have developed in emerging economies (such as China), other economies have moved more complex activities to these locations. On the condition of technology sharing, for example, automotive multinationals have set up design and engineering centres in China, which enables them to better meet local customer requirements (in line with different preferences and purchasing conditions) (UNIDO, 2011).

Box 2.1 ● The newly industrialised economies

High levels of private domestic financial investment combined with rapidly growing human capital were the principal engines of rapid growth in Korea and Chinese Taipei during the period 1995-2010, earning them a place among the so-called newly industrialised economies (NIEs) (World Bank, 1993). Growth in the export of manufactured goods facilitated adoption of foreign technology.

Though not reflected in the BAU projection, analysis shows that economic growth correlates with manufacturing value-added (MVA) growth (UNIDO, 2013), which has a share of about 20% of global GDP. A rapid increase in MVA is especially evident in APEC's poorer economies during the early part of the Outlook period. As income rises in such economies, so does demand for manufactured products.

Korea, for instance, has completely transformed its manufacturing structure from low-tech (such as food and beverages and furniture making) to high-tech industries (e.g. chemical and chemical products, as well as motor vehicles, trailers, semi-trailers and other transport equipment). This strategy boosted Korea’s GDP per capita at a faster rate than previously seen in other industrialised economies (UNIDO, 2013).

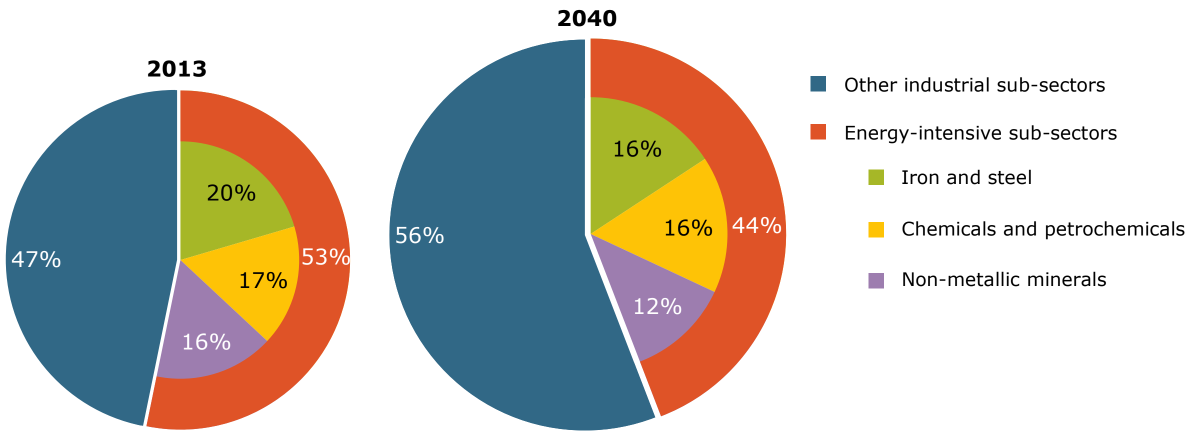
Other developing economies such as China, Chinese Taipei and Malaysia have ventured into manufacturing of medium-low technology products for global markets, particularly in labour-intensive sectors such as textiles, wearing apparel, and leather products and footwear. These economies have also engaged in more production activities—from design and manufacturing to distribution and marketing—and have invested heavily in education, research and development (R&D), and industry infrastructure to catch up with developed economies in APEC (UNIDO, 2013).

Chemicals and petrochemicals drive the growth in industry

In the BAU Scenario, the chemicals and petrochemicals sub-sector shows the largest growth of 32% to 371 Mtoe in 2040 (from 287 Mtoe in 2013), showing potential to sustain its share (16%) in total industrial energy demand (Figure 2.4). More than 95% of manufactured goods involve plastics and other chemicals; for example, plastics make up 50% of the volume of new cars (ExxonMobil, 2015). The sub-sector itself tends to expand as economies grow; as living standards rise, so does demand for plastics and other chemical products.

Energy demand in a group of APEC’s less energy-intensive sub-sectors also grows rapidly under the BAU, including food and tobacco at an AAGR of 1.6%, and pulp and paper at 1.1%. The overall consumption share of the less energy-intensive sub-sectors increases sharply, from 47% in 2013 to 56% in 2040, reflecting strong effects from structural change and production growth in economies with large populations experiencing steady increases in income. Post-2025, the less energy-intensive or other industrial sub-sectors will rebound to take the major share in total industry energy demand, as experienced in the period leading up to 2010.

Figure 2.4 • Industry sector final energy demand by sub-sector, 2013 and 2040



Sources: APERC analysis and IEA (2015).

Switch from coal to electricity for industry energy demand

Coal use in industry grew rapidly between 1990 and 2013, at an AAGR of 3.6% (the same rate as electricity). Having long been the main supply of energy for industry, coal grew to a 38% share in 2013—an increase of nine percentage points from 1990. China was significantly dependent on coal during this period, with figures ranging from 50% to 80% of energy demand in the sub-sectors of chemicals and petrochemicals, iron and steel, and non-metallic minerals.

A major switch from coal to electricity in final energy demand by industry marks the Outlook period from 2013 to 2040. An absolute reduction in coal use is seen in the two most coal-intensive industry sub-sectors in China (iron and steel, and non-metallic minerals) while projected structural changes lead to a rebound in the more electricity-intensive sub-sectors of machinery and non-ferrous metals. By 2030, electricity (28% in 2013) and coal (38% in 2013) account for equal shares (31%) of industry demand, after which electricity demand (33% in 2040) surpasses coal (26% in 2040). This shift reflects both accelerated modernisation of industry sub-sectors and structural changes in emerging and developing economies, especially during the period 2013 to 2020.

Through the Outlook period, APEC will continue to rely heavily on oil and gas to satisfy energy demand in industry, with their joint share actually rising from 24% in 2013 to 31% in 2040. Gas use grows most rapidly (AAGR 2.2%) of all industry feedstocks, while oil's AAGR is just 1.6%. This can be attributed to gas becoming more available and more efficient for industry use, especially in chemicals and petrochemicals. By 2040, industrial gas demand grows most notably in the United States (39% of incremental growth to reach a share of 33%) and China (219% of incremental growth to a share of 25%).

Non-energy use driven by demand for feedstocks in chemicals and petrochemicals

Non-energy use in industry should not be overlooked, having increased faster (AAGR 3%) than the other major energy sectors from 1990 to 2013. Among the fossil resources, petroleum products were overwhelmingly used particularly for petrochemical feedstocks, asphalt and road oil, petroleum coke, and liquefied petroleum gas (LPG). In fact, petrochemical products accounted for almost 80% (on average) of total non-energy use from 1990 to 2013.

China’s non-energy demand expanded by an AAGR of 6.3%, from 42.9 Mtoe in 1990 to 165 Mtoe in 2013, driving an overall increase in the sector and accounting for about one-quarter of total APEC non-energy demand.

In the BAU Scenario, non-energy demand grows at 1% annually, reflecting growing demand for various petrochemical products as feedstock to a wide range of products (such as plastic, paints, adhesives, artificial fibres and detergents). Total non-energy demand reaches 711 Mtoe in 2040, an increase of 165 Mtoe from 2013.

Gas use grows continuously, particularly as a source of methane and natural gas liquids (NGLs) as feedstocks to produce methanol, ammonia and plastics, which are increasingly in demand. At an AAGR of 1.9%, demand for natural gas in non-energy increases more robustly than oil, although demand can change as petrochemical processes shift easily from one feedstock to the other, depending on affordability and availability. Gas for non-energy use continues to compete with other energy demand sectors (specifically in the industry sector where gas demand grows rapidly) in terms of volume and price over the Outlook period. Russia is projected to have the major share of APEC's total gas demand for non-energy use (greater than 30%).

Energy efficiency opportunities in industry are diverse and widespread

Industry consumes a large volume of energy, with different sub-sectors having different consumption requirements and a wide range of processes requiring diverse sources, from liquid fuels to electricity. For each APEC economy, the mix of industries and processes, along with their share of APEC's total industry energy consumption, is different—often reflecting availability of energy resources. For example in 2040, Canada has large shares of pulp, paper and printing (25%) and of mining and quarrying (12%) industries, as does Chile (20% and 44%, respectively). Singapore and Chinese Taipei have strong shares of chemical and petrochemical industries (40% and 33%, respectively). Iron and steel, which is one of the most energy-intensive industries, is surprisingly strong in Peru (30%).

Energy efficiency in industry has improved significantly in the last decade across the APEC region. While substantial additional gains can be made through implementation of best available technologies (BATs) and design guidelines for existing assets, the application of effective energy management in industry—irrespective of size, technology or process—has been shown to boost efficiency by an additional 5% (WEC, 2013a).

Guided by the Energy Policy Act of 2005, the US Department of Energy (US DOE) is working to reduce industrial energy intensity by 25% by 2017, and has set up the Advanced Manufacturing Office to provide support to industry (EIA, 2013). Japan, which is widely known for efficient use of energy, established the Energy Conservation Law and set up energy audit programs, a voluntary improvement program for factories that have been in place since the oil crises of the 1970s. Both have contributed to reinforcing energy management in firms, thus improving energy efficiency (Kimura, 2007).

BUILDINGS AND AGRICULTURE ENERGY DEMAND

The buildings (residential and commercial sub-sectors combined) and agriculture sector accounted for 1 307 Mtoe in 1990 and grew to 1 658 Mtoe in 2013, accounting for more than one-third of total APEC energy consumption. The size and high consumption levels of this sector in the United States and China put their combined share at more than 50% of the total APEC buildings and agriculture energy demand during the period. A notable increase in US energy consumption during that period reflects a rapid increase in the number of dwellings, which rose 21% (EIA, 2015a).

In the BAU projections, the buildings and agriculture sector has a total energy demand of 2 227 Mtoe in 2040, up from 1 658 Mtoe in 2013 and reflecting an AAGR of 1.1%. The aggregated sectors account for just one percentage point less than industry's share of TFED, making it the second-largest energy-consuming sector during the Outlook period.

The largest volume growth is expected in the residential sub-sector as increasing populations, urbanisation and rising living standards push up the number of households in APEC and the energy demand per household. Urbanisation tends to result in fewer people per household and therefore fewer shared energy services. Asia's urbanisation rate, for example, will likely rise from almost 45% in 2014 to 60% by 2040

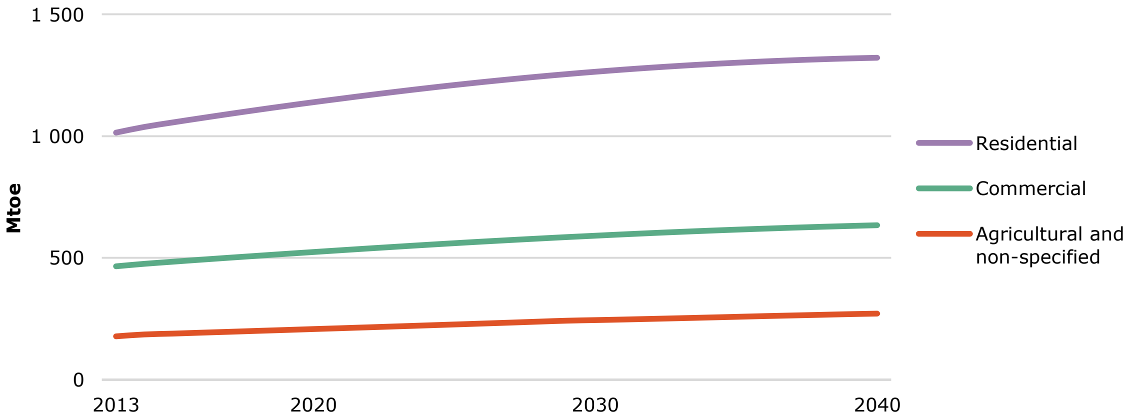
(ExxonMobil, 2015). Growth of China's economy over the past decade shows a strong correlation between rapid urbanisation and increases in residential energy consumption (World Bank, 2014).

RESIDENTIAL SUB-SECTOR DOMINATES ENERGY USE IN BUILDINGS

Residential energy consumption reaches 1 322 Mtoe in 2040 and accounts for 59% of the total buildings and agriculture energy demand in the BAU Scenario (Figure 2.5). As in the other major energy-consuming sectors, stronger growth in China (AAGR 1.7%) and South-East Asia (AAGR 1.2%) influences overall residential energy demand growth across APEC. Energy consumption in the residential sub-sector alone tends to be sluggish, starting with an AAGR of 1.7% from 2013 to 2020 which declines to 1% between 2020 and 2030, then to only 0.4% from 2030 to 2040. Much of the change is due to declining energy demand in major regions.

In terms of share, China, the United States and Russia take the top three spots; together, they account for 75% of the total residential energy demand over the Outlook period. Residential energy demand growth is sluggish in Russia (by 0.8%, from 103.2 Mtoe in 2013 to 117.6 Mtoe in 2030, then by 0.4% to reach 122.4 Mtoe in 2040). In other north-east Asia, demand declines (by 0.1%, from 73.1 Mtoe in 2013 to 70.6 Mtoe in 2040). The weakening of demand reflects lower population and the impacts of residential energy efficiency improvements through Russia's Energy Efficiency Law and Japan's Top Runner Program[1] in the residential sector (EIA, 2013).

Figure 2.5 • Buildings and agriculture sector final energy demand, 2013-40



Sources: APERC analysis and IEA (2015).

Electricity becomes the major fuel source in residential sub-sector

Electricity is projected to be the major energy source contributing to demand growth of the residential sub-sector over the Outlook period (Figure 2.6). With an AAGR of 5% for electricity as urbanisation rates and incomes rise rapidly, China will likely drive the surge in electricity consumption in APEC's residential sector.

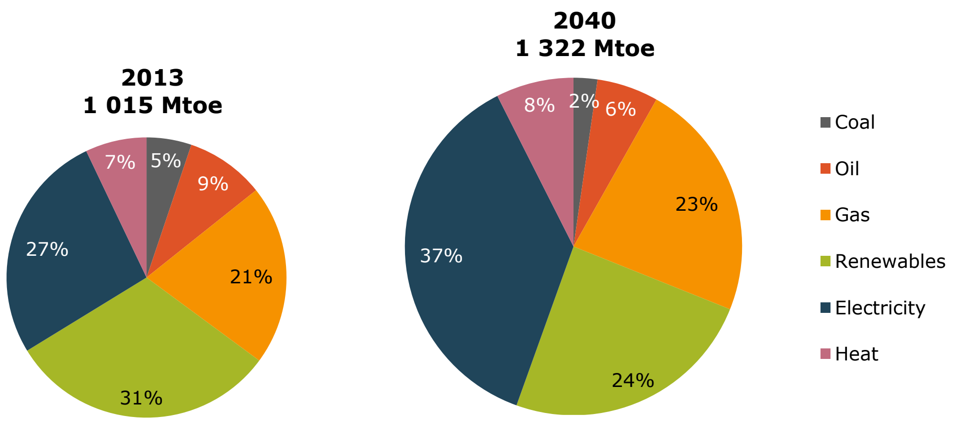
Rising penetration of electric products (such as air conditioners, water heaters, appliances, computers and smart devices) during the Outlook period reflects the rising living standards of individuals, especially in developing economies (ExxonMobil, 2015). In China, for example, the rate of air-conditioner ownership was less than 1% of the urban population in 1992; by 2003, it had skyrocketed to 62%. By 2030, over 80% of Mexican households are projected to own an air conditioner, 20% more than in 2005. A similar trend is also expected in South-East Asia economies such as Malaysia, Thailand and Chinese Taipei (McNeil and Letschert, 2008). Indonesia's electrification rate is expected to reach almost 100% by 2020, which will likely boost ownership of electric appliances.

[1] Introduced in 1999 as a countermeasure to reduce energy consumption in the civil and transport sectors in Japan. The program sets energy efficiency standards for 31 products across machinery, equipment and vehicles under the Energy Conservation Law (http://www.asiaeec-col.eccj.or.jp/top_runner/index.html).

Renewable energy sources, which have been a popular fuel used in early decades of this century, will retain a significant share (28% on average) of the total residential demand over the period from 2013 to 2040. This increase in renewables, especially biomass and other traditional fuels for residential use, is due to the lack of access to modern fuels in some economies. China makes up the bulk (>60%) of renewables consumption under the BAU Scenario in APEC from 2013 to 2040, followed by Indonesia (>10%). Some growth in demand for solar water heating in the residential sector is projected, but it will not be as large as biomass demand. The net result is a more or less stable demand for renewable energy in the residential sub-sector over the Outlook period.

The projected demand for oil products in the residential sub-sector shows a declining trend, from 92 Mtoe in 2013 to 78 Mtoe in 2040, as more economies move away from oil due to price volatility and the loss of oil markets to natural gas (as gas distribution networks expand).

Figure 2.6 • Residential sub-sector final energy demand by fuel, 2013 and 2040



Sources: APERC analysis and IEA (2015).

COMMERCIAL ENERGY DEMAND IN ASIA DRIVES GROWTH

As their economies continue to grow, increased urbanisation and wealth push up energy demand in the commercial sectors in China (AAGR 3.1%) and South-East Asia (AAGR 3.7%) (PWC, 2014). The United States accounts for the largest share (35% or 220 Mtoe) of total commercial demand in 2040; and together with China (26%) and other north-east Asia (16%) these regions are APEC's major commercial energy consumers in the BAU.

Electricity use in the commercial sector will grow at an AAGR of 1.8%, resulting in an increase from 236 Mtoe in 2013 to 384 Mtoe in 2040 to account for the bulk of the total APEC commercial energy demand (Figure 2.7). The United States, China and Japan are the top three electricity consumers in the sector, with a combined demand of 169 Mtoe (36% of total commercial demand) in 2013 and 268 Mtoe (42%) in 2040.

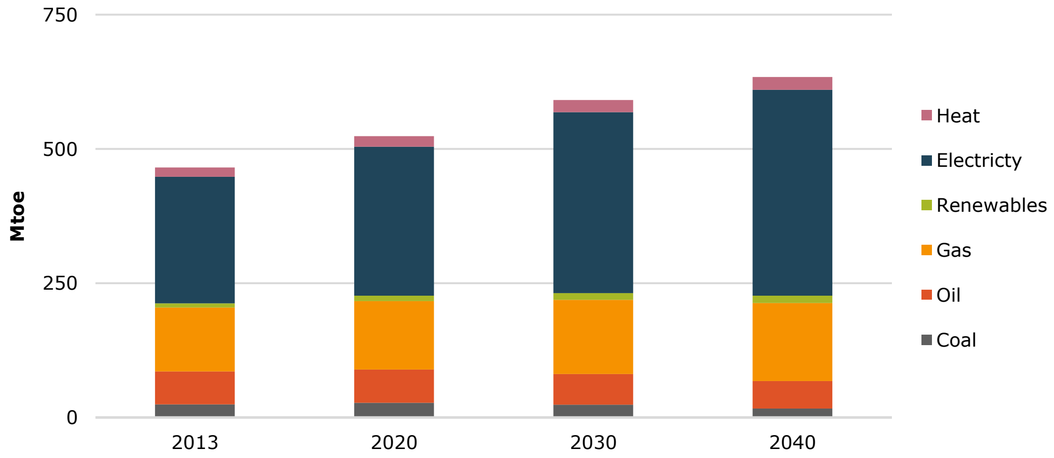
Growth in electricity demand in the commercial sector is mostly associated with increasing urbanisation and rising standards of living in APEC. Out of 28 mega-cities[2] in the world, seven are located in Asia: Tokyo and Yokohama in Japan; Jakarta in Indonesia; Seoul and Incheon in Korea; Shanghai in China; and Manila in the Philippines (UN, 2014). Escalating commercial activities associated with these growth factors will spur the need for more infrastructure, including offices, schools, health facilities and leisure/entertainment facilities (malls, theatres, hotels, etc.), all of which require energy for space heating, air conditioning, lighting, and equipment or appliances (PWC, 2013).

[2] Mega-cities are defined as areas of continuous urban development with more than 10 million people.

In China, the government's new economic policy calls for and is initiating a move from manufacturing to services. Between 2000 and 2010, a concentration of finance, insurance and real estate services emerged in China's large cities, spurring a related increase in electricity demand (World Bank, 2014). Electricity demand in Tokyo, the world's largest city, is projected to remain constant to 2030, in part due to an ageing population that will place higher demand on health services and facilities, and thus on associated energy demand (UN, 2014).

In the Philippines, which is notable as the world's business process outsourcing (BPO) capital owing to its large English-speaking labour force, the service sector is a main economic driver (ASEAN Briefing, 2015). Servicing other parts of the world, many BPO companies (such as call centres) operate 24 hours per day, using a lot of space cooling and lighting.

Figure 2.7 • Commercial sub-sector final energy demand by fuel, 2013-40



Sources: APERC analysis and IEA (2015).

Gas penetration in the commercial sector, used mainly for space heating, becomes significant over the Outlook period (23% share) as economies switch away from dirtier coal and diesel to address local pollution issues. The United States, China and Japan, where cool climatic conditions generally push up energy consumption, will be the prominent users of gas in the commercial sub-sector. The United States alone will account for almost 55% of APEC commercial gas consumption in 2040; adding China and Japan boosts the total share to 81%. Oil, which is used mainly for cooking, water and space heating, declines from a share of 13% in 2013 to 8% in 2040 as a result of fuel switching to gas and electricity.

Though minimal in terms of absolute volumes (8 Mtoe in 2013 and 14 Mtoe in 2040), renewables will have an AAGR of 2%, making them the fastest-growing fuel source in the commercial sub-sector. China, the United States and other north-east Asia will continue to lead renewable energy consumption during the Outlook period, accounting for 80% of total renewables in the commercial sub-sector.

AGRICULTURE SECTOR LEADS ENERGY DEMAND GROWTH

While traditionally accounting for a minimal share of energy demand in the APEC region, agriculture is undergoing a considerable change. With a shift from animal and human power to energy-fuelled machines and equipment, agriculture's energy demand AAGR of 1.6% will outstrip that of the residential and commercial sub-sectors. Over the Outlook period, this represents a 40% increase or an additional 40 Mtoe of energy demand, from 101 Mtoe in 2013 to 141 Mtoe in 2040. As most of its economies are agricultural in nature, an AAGR of 2% between 2013 and 2040 in South-East Asia drives the overall energy demand growth in APEC. China, however, continues to account for the bulk of total energy demand in agriculture.

Oil will continue to dominate total fuel demand in agriculture, increasing in absolute volume (but with a slight drop in share) from 62 Mtoe (61%) in 2013 to 83 Mtoe (59%) in 2040. Rapid penetration of modern agriculture equipment during the Outlook period increases use of electricity by an additional 9 Mtoe, boosting the 2013 level of 17 Mtoe to 26 Mtoe in 2040 (GRACE, 2015).

APEC BUILDINGS BECOMING MORE ENERGY-EFFICIENT

Energy efficiency in the buildings sector is increasing as many economies are already establishing programs with that aim. At present, lack of detailed end-use data makes it impossible to carry out in-depth analysis of buildings energy demand in the BAU Scenario. However, several studies show that lighting, which accounts for a relatively small portion (4% to 16%) of end-use consumption has one of the highest relative savings potential in buildings (Retroficiency, 2013). Compact fluorescent lights (CFLs), for example, use two-thirds less energy and may last 6 to 10 times longer than incandescent light bulbs (WEC, 2013b).

In other north-east Asia, Japan's Top Runner Program, which promotes the manufacture and use of energy-efficient appliances and equipment, has dramatically improved energy efficiency to date and is expected to continue contributing to efficiency gains in the future. In 2013, Japan revised the Energy Conservation Law, broadening its scope to include large energy-consuming equipment, such as refrigerators for commercial use, printers and light-emitting diode (LED) lamps. Since its inception in April 1998 with 9 items, the program has expanded to 31 items (as of March 2015).

Russia has a federal program called the Energy Conservation and Improvement of Energy Efficiency for the Period until 2020, which calls for the implementation of measures to reduce energy consumption in buildings, including a ban on old lighting units and the introduction of LED lighting, promotion of new technology platforms that encourage use of smart energy systems, and initiatives to improve heating use (among others).

Several other economies are implementing programs to achieve energy savings in the buildings sector. In South-East Asia, Indonesia has the Presidential Instruction No. 13 (implemented in 2011), which has an energy savings target of 20% by 2025 in buildings. In Oceania, New Zealand completed in 2014 an extensive insulation retrofit program upgrading around 15% of the residential building stock while Australia implemented in 2011 the Energy Efficiency in Government Operations (EEGO) program (WEC, 2013b).

TRANSPORT ENERGY DEMAND

Between 1990 and 2013, energy demand in APEC's transport sector surged, with particularly rapid growth (AAGR of 2.7%) from 1995 to 2000 due largely to robust demand growth in China (13.7%) and South-East Asia (3.8%). From 2000 to 2013, continued rapid growth was seen in South-East Asia (4.7%) and China (8.6%) while other north-east Asia showed a negative trend (-0.6%). As vehicle ownership is highly correlated with income, rapidly rising per capita income in China and South-East Asia (especially Viet Nam and Malaysia) boosted the purchase of more private vehicles.

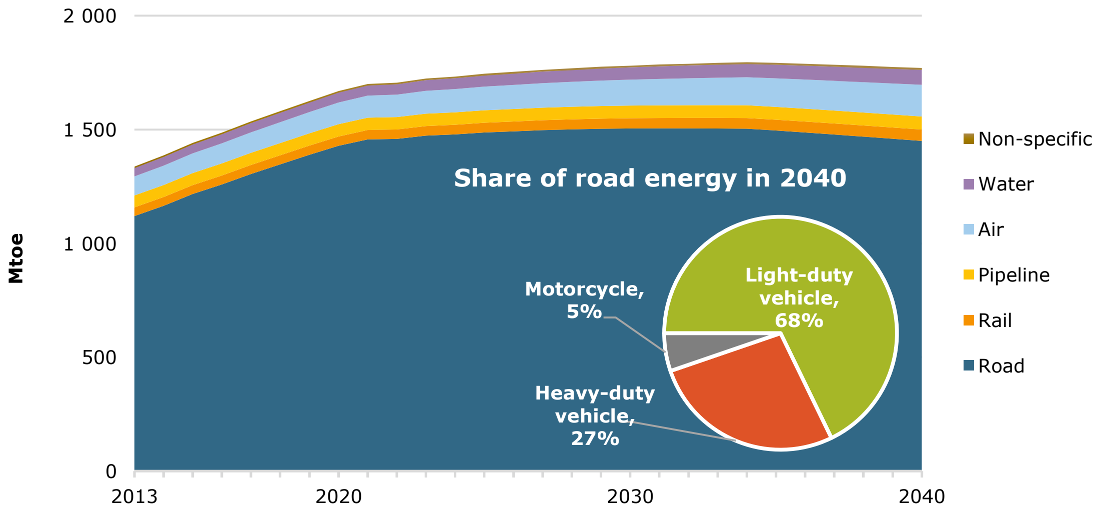
Rapidly increasing urbanisation also contributed to growth of transport demand. Expansion of major cities in APEC, such as Beijing, Shanghai, Mexico City and Kuala Lumpur, led to considerable increases in personal and commercial mobility. In some cases in some economies, insufficient mass transit drives up the rate of vehicle ownership and need for expanding road networks.

ROAD TRANSPORT REMAINS DOMINANT FORCE IN TRANSPORT ENERGY DEMAND

Energy demand in the APEC transport sector under the BAU Scenario grows 32%, from 1 353 Mtoe in 2013 to 1 772 Mtoe in 2040 (an AAGR of 1%). This upsurge is linked to high AAGRs in China (2.6%) and South-East Asia (3.4%). Transport energy demand in these two regions will increase by 424 Mtoe, from 369 Mtoe in 2013 to 792 Mtoe in 2040; the rest of APEC decreases by 5 Mtoe. To 2025, total APEC transport energy demand will grow sharply (AAGR of 2.2%), due to rapidly growing demand in developing APEC economies (especially China at 6.3%) and South-East Asia (4.7%). Post-2025, transport demand will stabilise as vehicle ownership stabilises and stronger fuel economy standards are implemented in developed APEC economies and in China (EIA, 2013). Declining energy demand in transport in the United States, and other north-east Asia offsets rising demand in other Americas, Oceania and Russia. Transport energy demand in South-East Asia continues to rise over the entire Outlook period, due to high demand for road transport in Indonesia, Viet Nam and the Philippines.

Road transport remains the dominant transport mode with a share of more than 80% of total energy demand in the transport sector. This demand will, however, peak in 2034 and then decrease as fuel economy of new vehicles improves. Light-duty vehicles (LDVs) continue to hold the largest share of road energy demand, about 68% in 2040, while shares are much lower for heavy-duty vehicles (HDVs; 27%) and motorcycles (5%). Overall, shares of road energy demand by vehicle type stay almost unchanged over the Outlook period (Figure 2.8).

Figure 2.8 • Domestic transport sector final energy demand by mode of transportation, 2013-40



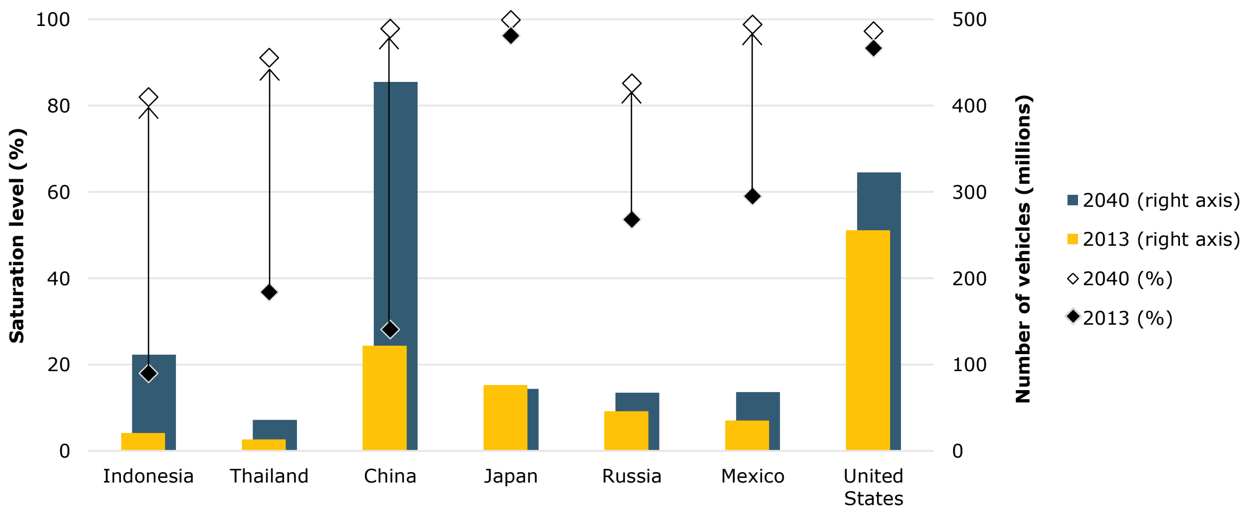
Sources: APERC analysis and IEA (2015).

Domestic air transport within APEC economies shows the fastest energy demand growth, nearly doubling by 2040 compared with the 2013 level. As in other sub-sectors, rapid growth in China and South-East Asia is the major driver. Again, the increase reflects rising prosperity, which results in higher purchasing power of middle-income earners.

Vehicle stock in China expands to 1.3 times that in the United States in 2040

In terms of vehicle stock, the increase of vehicles in China from 2013 to 2040 will bring China close to being on par with the total number of vehicles in United States in 2040. This reflects that vehicle ownership in 2013 is close to saturation (that is, almost 100%) in developed economies (such as Japan and the United States) but is quite low in emerging economies, and thus has room for rapid expansion. (Figure 2.9)

Figure 2.9 • Vehicle stock with saturation level, selected APEC economies, 2013 and 2040



Sources: APERC analysis and economy reports.

Vehicle ownership, measured as vehicles per 1 000 people (and saturation level), in the APEC region as a whole will increase from 228 (49%) in 2013 to 421 (90%) by 2040 (maximum saturation would be 466) (Table 2.2). In 2040, vehicle ownership will reach more than 80% in all but three APEC economies; saturation remains below 40% in Papua New Guinea, the Philippines and Viet Nam. The environmental impacts of reaching vehicle ownership saturation will level off and then decline in some regions, as higher fuel efficiency will help to curb actual energy demand growth.

Table 2.2 • Vehicle ownership with saturation level by APEC economy, 2013-40

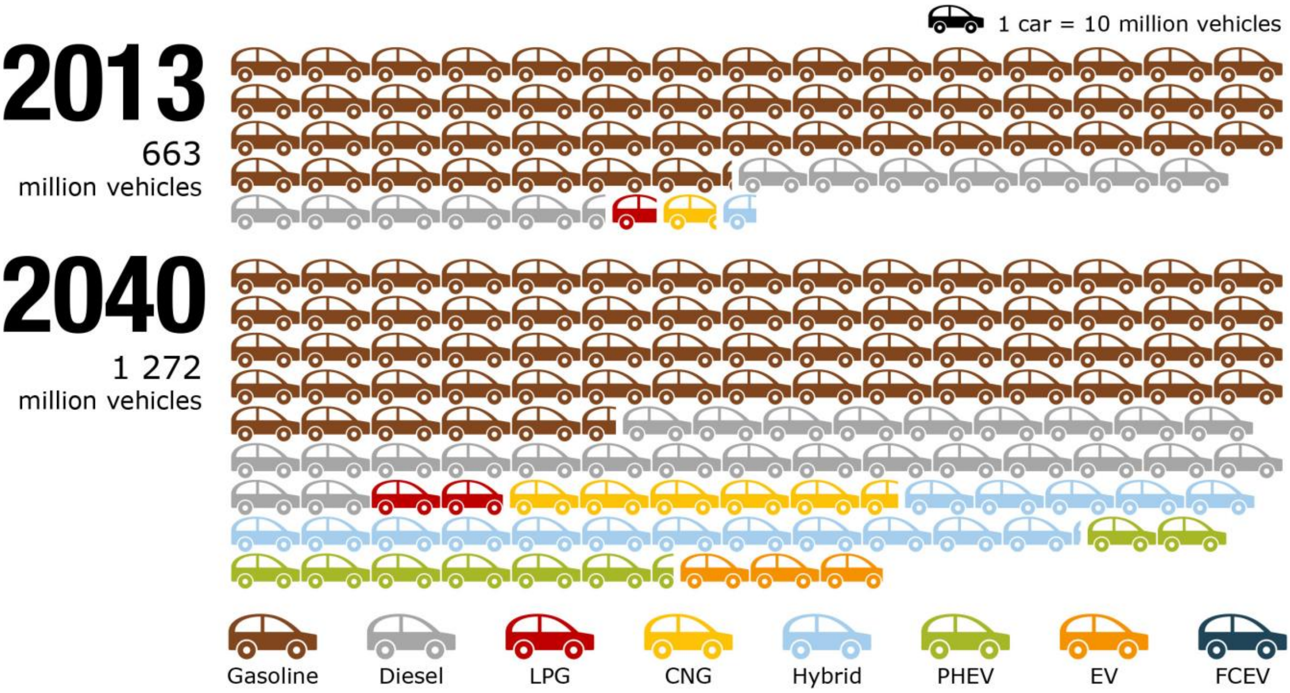
	Vehicles/1 000 people				Vehicle saturation	Saturation level (%)			
	2013	2020	2030	2040		2013	2020	2030	2040
Australia	706	731	753	767	780	90	94	97	98
Brunei Darussalam	419	418	418	419	420	100	100	100	100
Canada	646	679	709	737	780	83	87	91	94
Chile	226	306	382	425	503	45	61	76	84
China	90	195	271	313	320	28	61	85	98
Hong Kong	86	87	86	86	92	93	94	94	94
Indonesia	84	146	266	385	470	18	31	57	82
Japan	603	613	623	626	627	96	98	99	100
Korea	395	436	459	467	472	84	92	97	99
Malaysia	427	516	584	608	617	69	84	95	99
Mexico	288	394	462	482	488	59	81	95	99
New Zealand	726	740	759	772	780	93	95	97	99
Papua New Guinea	12	15	23	37	320	4	5	7	12
Peru	76	153	269	352	420	18	36	64	84
The Philippines	38	45	65	100	410	9	11	16	24
Russia	321	385	456	511	600	54	64	76	85
Singapore	163	165	167	168	170	96	97	98	99
Chinese Taipei	308	313	316	317	320	96	98	99	99
Thailand	198	275	403	492	540	37	51	75	91
United States	812	820	834	846	870	93	94	96	97
Viet Nam	18	27	59	124	320	5	9	18	39
APEC	**228**	**308**	**374**	**421**	**466**	**49**	**66**	**80**	**90**

Sources: APERC analysis and economy reports.

The total vehicle stock in APEC will increase from 663 million in 2013 to 1.27 billion by 2040, with China's share accounting for 34% by the end of the Outlook period. To offset the rising emissions associated with the steep increase in the number of vehicles, more economies will likely put in place policies to support vehicles with higher fuel economy. The share of high efficient vehicles increases from 1% in 2013 to 22% of the total vehicle stock in 2040, with a mix of hybrid vehicles (13%), plug-in hybrid vehicles (PHEVs; 7%) and electric vehicles (EVs; 2%) (Figure 2.10). The increase in the number of hybrid vehicles is significant as this market segment will provide a 30% fuel economy benefit compared with conventional gasoline vehicles (ExxonMobil, 2015).

In terms of fuel, oil still holds the majority share of energy demand in transport during the Outlook period with a 90% share in 2013 and 85% in 2040, while the share of electricity shows the most rapid growth (AAGR 4.8%) due to higher deployment of PHEVs and EVs. Many APEC economies, including China, Japan and the United States, have ambitious EV targets. The share of natural gas (either compressed natural gas [CNG] or liquefied natural gas [LNG]) used in transport is also expected to rise sharply as economies look to reduce emissions and imports of oil.

Figure 2.10 • Vehicle stock by technology, 2013-40



Note: FCEV = fuel cell electric vehicle; FCEV = 0.3 million vehicles in 2040.
Source: APERC analysis.

Biofuels blends become increasingly important

To curb the use of crude oil, especially for oil-importing economies, mandated blending of biofuels in diesel or gasoline is in place for the transport sector in some APEC economies. During the Outlook period, biofuels demand in transport increases significantly at 2.2% AAGR. This represents a total biofuel consumption of 65 Mtoe in 2040, twice the 2013 level of 36 Mtoe. The BAU Scenario assumes bioethanol blends of 4% to 6% and biodiesel blends of 2% to 4% in APEC.

The United States, which has mandated biofuel blends, accounts for 39% of APEC total biofuels consumption in 2040. When the Renewable Fuel Standard (RFS)—a mandatory minimum volume of biofuels to be used in the transportation fuel supply—was enacted in 2005, the Environmental Protection Agency (EPA) mandated a target of 36 billion gallons (approximately 65 Mtoe) of renewable fuels by 2022, 16 billion gallons (28 Mtoe) of which must derive from cellulose products (US Congress, 2007). The Energy Information Agency (EIA) projects a compliance level of 36 Mtoe for biofuels, and 0.9 Mtoe of cellulosic fuels by 2022 due to US Congress reductions under waiver provisions (EIA, 2015b).

China, with the highest (8.5%) AAGR for biofuels over the next two decades, shows volumes growing from 1.7 Mtoe in 2013 to 15 Mtoe in 2040, making it second place in terms of total APEC shares. Currently, nine provinces in China have requirements of 10% bioethanol blends. Biofuels consumption in South-East Asia will also increase significantly, growing at 7.2% annually between 2013 and 2040. Other APEC economies have also mandated biofuel blends. Canada has a RFS, introduced in 2011, featuring E5 ethanol and B2 biodiesel. Peru has E7.8 ethanol and B5 biodiesel mandates. Chile has E5 ethanol and B5 biodiesel targets in place, but no mandates (Biofuels Digest, 2013).

In South-East Asia, Indonesia has an 'on-and-off' 2% to 2.5% biodiesel mandate and an E3 ethanol mandate. Malaysia launched a B5 blending mandate in 2011, while the Philippines has an E10 ethanol and B2 biodiesel mandate. In Thailand, a B5 biodiesel mandate was initiated but has become 'on and off' based on palm oil supplies. With an AAGR of 15% resulting from a recently implemented 5% biofuel blend mandate, Viet Nam is the frontrunner in the BAU Scenario in terms of biofuels growth during the Outlook period. Some economies in other north-east Asia have biodiesel mandates in place, including Korea (B2) and Chinese Taipei (B1) (Biofuels Digest, 2013). The Japanese government has set a maximum 3% for ethanol blend into petrol.

The state of New South Wales in Australia has in place an E4 ethanol blending mandate and a B2 biodiesel mandate. The Queensland E5 ethanol mandate, expected to take effect in 2011, was shelved due to opposition from the Against Ethanol Mandates Alliance (Biofuels Digest, 2013). In New Zealand where biofuels were dairy industry by-products, implements B5 and E10.

Fuel-efficient vehicles gain popularity in APEC

The transport sector is also challenging for improving energy efficiency, especially as transport energy demand grows. Transport energy consumption is correlated with increases in per capita income. Higher incomes increase the ability of consumers to buy vehicles and also increase the movement of goods or passengers. To improve energy efficiency in transport, policymakers rely on a range of tools, such as (but not limited to): implementing fuel economy standards; shifting to more sustainable transport modes (e.g. from private vehicles to public transport, and from trucks to rail and water transport); and reducing overall transport demand (e.g. through spatial planning and other multi-sectoral policies) (WEC, 2013a).

In the BAU projections, two regions in APEC show a clear decline in the AAGR of transport demand, namely, the United States (-0.2%) and other north-east Asia (-1.2%), due to energy efficiency improvements and declining population, especially for the latter region. Japan, for example, in addition to its Top Runner Program on fuel economy which delivers improvements of both passenger and freight vehicles, has an ageing population reflecting lesser driving activity.

China currently has in place several programs promoting fuel-efficient cars. To spur the sales of hybrids and EVs, and thus reduce fuel consumption, the government extended a tax exemption initially offered to consumers who buy the most fuel-efficient cars to companies that purchase ‘green’ vehicles for business purposes. China's State Council announced that EVs, PHEVs and fuel-cell electric vehicles (FCEVs) will be exempt from the so-called vehicle and vessel tax, which is traditionally applied to new cars, trucks and commercial vehicles at the time of purchase. In addition, several start-ups sprouted in China in 2015, backed by investors and internet companies that see opportunities in government policies to promote EVs and upgrade traditional vehicle manufacturing industries (Walsh, 2015).

In the United States, the average fuel economy of vehicles sold in 2013 reached a high of 24 miles per gallon (mpg), nearly 2% higher than in 2012. The US National Highway Traffic Safety Administration (NHTSA), which regulates fuel economy, and the EPA, which regulates greenhouse gas (GHG) emissions, implement the new unified standards for fuel economy and GHG emissions over the years 2017 to 2025. The Corporate Average Fuel Economy (CAFE) standard requires that vehicles offered for sale in the United States attain an average fuel economy of 40.3 mpg to 41 mpg by 2021, rising to 48.7 mpg to

49.7 mpg by 2025. These standards will prompt the fuel economy of the US new vehicle fleet to double between 2012 and 2025 (NHTSA, 2014).

A survey carried out by WEC-ADEME found that several APEC economies now impose car labelling and fuel efficiency or carbon dioxide (CO_2) emissions standards. Both car labels and fuel/CO_2 efficiency standards exist in the United States, Canada, Japan, Korea, China and Australia. Efficiency labels for new cars are mandatory in economies such as Australia, Canada, Chile, Japan, Mexico, New Zealand, Korea, Singapore, Chinese Taipei and the United States. Labels remain voluntary in other economies, such as the Philippines (WEC, 2013a).

PROGRESS ON ENERGY INTENSITY TARGET

Energy intensity is most commonly defined as the amount of energy consumption per unit of GDP, as GDP data are readily available and easy to obtain. It is often used as a proxy to analyse energy efficiency improvements in an economy; however, many factors that alter energy intensity (for better or worse) may make energy consumption per unit of GDP a poor indicator to track improvements in energy efficiency. Changes in economic structure, for example, often have a dramatic effect on energy intensity, but do not necessarily reflect improved efficiency.

Subsequent to APEC Leaders setting the target to reduce energy intensity by 45% by 2035 (against the 2005 level), APERC has been endeavouring to help the APEC Energy Working Group develop their response to the APEC Energy Minister's instruction, in part by analysing evidence of energy intensity reduction. As the Leaders did not give a precise definition of energy intensity in their declaration, one challenge is that intensity can potentially be monitored based on primary energy, final energy or final energy excluding non-energy use. Given differences in fuel mixes within APEC economies and different conversion factors from primary to final energy, the analysis presented here is based on final energy (Table 2.3) and final energy excluding non-energy use (Table 2.4).

The APEC-wide goal of energy intensity reduction does not set specific economy or sectoral targets. Past trends show progress over the period from 1990 to 2013 continuing into the future, such that energy intensity under the BAU Scenario improves by 43% in 2035 against the base year of 2005.

Table 2.3 • Final energy demand and energy intensity including non-energy demand, 1990-2035

	1990	1995	2000	2005	2010	2013	2035
Total final energy demand BAU (Mtoe)	3 474	3 684	3 967	4 425	4 827	5 293	6 921
Energy intensity (toe/per 2012 USD million PPP)	164	152	135	124	113	110	71
Reduction in final energy intensity (%)	-	-	-	-	-9	-11	-43

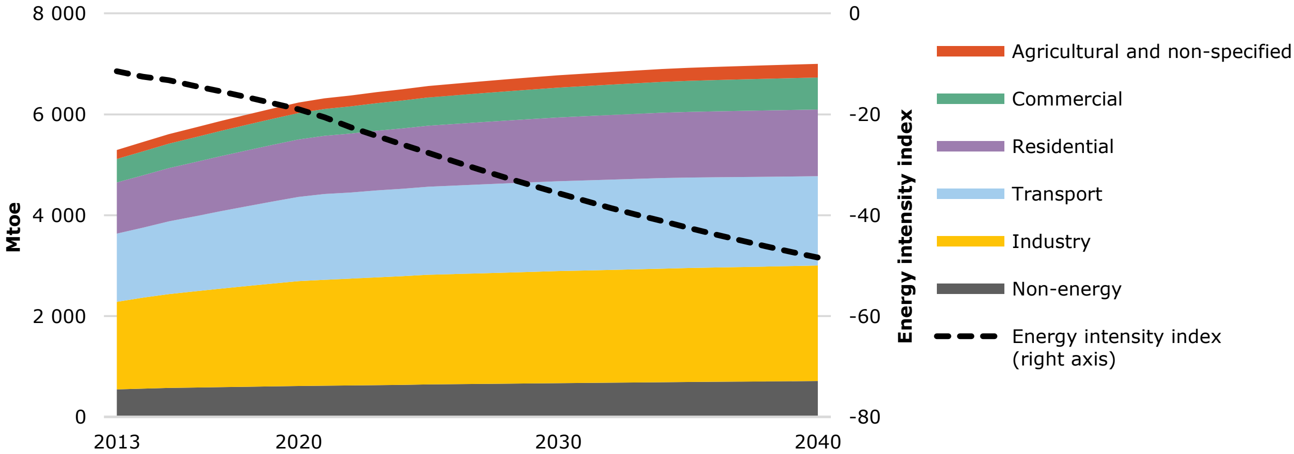
Note: Reductions in final energy intensity values are in relation to 2005.
Sources: APERC analysis and IEA (2015).

BAU FALLS SLIGHTLY SHORT OF APEC-WIDE 45% ENERGY INTENSITY REDUCTION GOAL

In the BAU Scenario, final energy intensity continually improves throughout the Outlook period, as a general trend of progressive reduction is assumed for all industry sectors and all economies (based on positive achievements attained regionally and globally since 2005). But it takes two years longer—to 2037—to reach the APEC-wide goal of 45% reduction from the 2005 level (Table 2.3). In 2035, energy intensity will be reduced to 71 toe per 2012 USD million PPP, which represents a 43% improvement (Figure 2.12). Energy intensity reduction in industry can be achieved through four main measures: deploying existing BATs; increasing levels of process integration in new industrial production facilities; improving production techniques; and developing and installing new technologies with higher efficiency.

Enabling fuel and feedstock switching can also improve energy efficiency, as can promoting more recycling (especially in iron and steel, paper and pulp, and chemicals and petrochemicals sectors).

Figure 2.11 • Final energy demand by sector and energy intensity reduction target, 2013-40



Sources: APERC analysis and IEA (2015).

Measuring the energy intensity reduction in buildings is more challenging: getting a more realistic picture would require additional data collection within APEC economies to better understand the current energy intensity of space conditioning (cooling and heating). In general, a shift from the use of solid fuels (such as charcoal and fuelwood) for cooking and heating, which is still significant in APEC in the BAU, to modern fuels (such as electricity, natural gas and LPG) would significantly improve energy intensity. Most electricity-based activity in buildings (such as lighting, heating and cooling) is now managed to some degree through various energy efficiency and conservation programs.

Reducing energy intensity in transport will also be a significant factor in meeting the APEC goal of a 45% reduction by 2035. To offset the steep rise in the number of vehicles, more APEC economies will need to adopt higher fuel economy standards; recent declines show that tougher fuel economy policies being implemented in some economies are having the desired impact. Increasing alternative fuels and deploying non-petroleum-fuelled vehicles (EVs, PHEVs, etc.) will influence the rate and degree of energy intensity improvement in transport.

Table 2.4 • Final energy demand and energy intensity excluding non-energy demand, 1990-2035

	1990	1995	2000	2005	2010	2013	2035
FED excluding non-energy demand in BAU (Mtoe)	3 186	3 350	3 582	3 974	4 329	4 747	6 229
Energy intensity (toe/per 2012 USD million PPP)	150	139	122	112	102	99	64
Reduction in final energy intensity (%)	-	-	-	-	-9	-11	-42

Notes: Reductions in final energy intensity values are in relation to 2005. FED = final energy demand.
Sources: APERC analysis and IEA (2015).

From a theoretical perspective, the preferred indicator for monitoring energy intensity is final energy demand excluding non-energy demand (the latter comprises feedstock use in chemicals and petrochemicals, and coke ovens in iron and steel, which are fixed). However, as data quality of non-energy use varies significantly—with a number of APEC economies reporting incomplete statistics—care should be taken when evaluating results based on this indicator. TFED excluding non-energy demand is projected to reach 6 229 Mtoe in 2035 (Table 2.4).

RECOMMENDATIONS FOR POLICY ACTION

Early actions and concerted efforts for energy efficiency on the part of both government and industry in APEC are vital to ongoing energy intensity reduction in the coming decades. Recent declines across all sectors are a clear indication that policies and measures already being implemented are effective, and suggest that additional policies to be duly implemented in the future will deliver additional progress. A proper regulatory framework and wider information dissemination will improve the potential to sustain this activity over the next two decades to achieve the desired goal.

Designing near-term plans for economy development is crucial for long-term sustainable development of each industrial sector, as well as for individual economies and APEC as a whole. To achieve the 45% energy intensity goal, APEC economies will need to ensure that appropriate policies are in place to deploy BATs in both energy-intensive and less energy-intensive industrial sectors. This may involve one or more of a range of policy measures such as standards, best practices, financial and non-financial incentives, and regulatory reforms to create transparent and fair competitive markets, and support removal of price subsidies.

Government funding for R&D projects is of particular importance in all sectors. Specifically, close cooperation between governments and industry will be needed to develop a portfolio of promising technologies as well as to ensure design and implementation of final product standards and promote the use of best practices for industrial production processes.

Fuel economy policy for new vehicles must be implemented in those APEC economies that do not yet have fuel efficiency standards, and strengthened where they do exist. Both vehicle ownership and fuel economy improvement of new vehicles should be monitored. In addition, new concepts of urban land use and transport planning should be introduced at the earliest possible stage so that their long-term effects are realised eariler.

An important role for APEC leaders is to encourage international cooperation, including applying mechanisms to facilitate the transfer and deployment of advanced and new technologies. These mechanisms need to deliver win-win solutions for economies that have abundant energy resources and are also high energy consumers.

3. ENERGY SUPPLY OUTLOOK

KEY FINDINGS

- **TPES will continue to rise in APEC, by 2 780 Mtoe in 2040 compared with 2013 levels.** This increase is equivalent to 127% of the United States demand in 2013. Rapid economic growth in China and South-East Asia accounts for nearly 90% of this growth.

- **Fossil fuels will continue to play the major role—above 80% of TPES—in the APEC region.** Oil and coal dominate supply while natural gas shows robust growth throughout the Outlook period.

- **Tremendous growth in TPES is seen in China (56%) and the South-East Asia region (131%),** reflecting increasing population and rising incomes. These economies thus hold potential to optimise their energy supply and reduce demand.

- **In the transition to cleaner fuel options, the highest AAGRs (2.1%) are in natural gas (adding 1 220 Mtoe by 2040) and renewables (590 Mtoe, starting from a lower base).** Some 60% of the combined renewables and gas increase occurs in China and South-East Asia.

- **Energy production grows across all fuel types.** Due to high energy demand projections, however, APEC as a region will have a supply gap of more than 10%, meaning dependence on imports will increase.

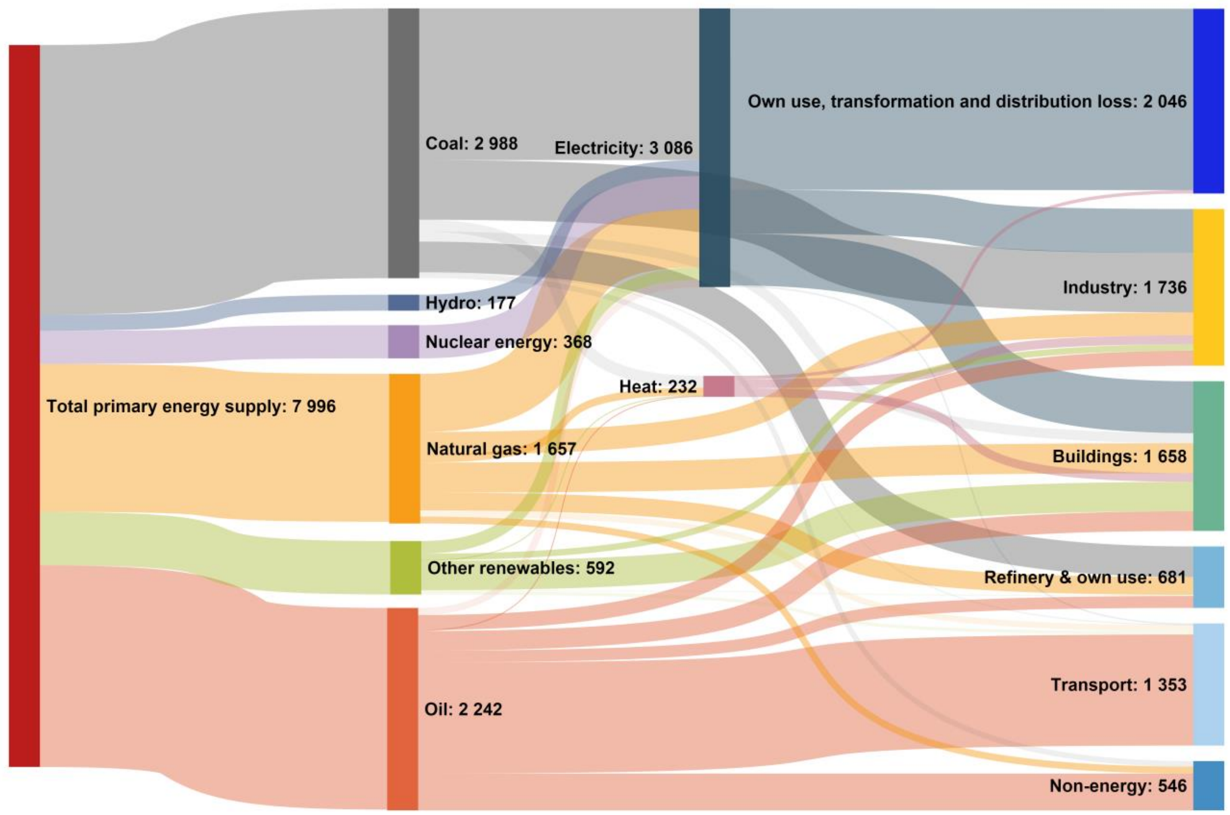
INTRODUCTION

Fossil fuels dominate primary energy demand in the Asia-Pacific Economic Cooperation (APEC) region, with a share of 86% in 2013 (Figure 3.1). From 1990 to 2013, the share of fossil fuels increased by two percentage points while the share of non-fossil fuels shrank from 16% in 1990 to 14% in 2013, despite an increase in real volumes. Various factors drove the increase of the fossil fuels share, including fuel switching from traditional biomass to modern energy sources and expansion of electricity demand in developing economies.

This chapter presents the primary energy supply projections to 2040 in the APEC region according to the Business-as-Usual (BAU) Scenario, which includes existing policies. The scenario also includes policies that are highly likely to be implemented in the foreseeable future; however, it does not necessarily incorporate 'targets', 'goals' or policy proposals for which implementation is uncertain. In exploring a BAU Scenario, this chapter will examine APEC's energy supply gap. The projected supply of each fuel will be explained further, along with some of the challenges relating to each fuel. Towards the end, the chapter will briefly explore energy security issues (in-depth examination in Chapter 9) and opportunities for APEC members to expand regional cooperation in energy trading.

The Asia Pacific Energy Research Centre (APERC) acknowledges that future energy policies in APEC are unlikely to follow those used to develop the BAU Scenario. The value of the BAU projections is that they show where current policies would likely lead over the next 25 years, and thus open the question of what a more desirable future would look like and how governments—individually and collectively—can act to ensure that future. What is clear from the BAU projections is that energy supply in APEC needs to expand substantially, whether based on fossil fuels or on a transition to clean energy sources. The overriding challenge, which needs to be addressed by all APEC members, is how to achieve a mutually beneficial energy scenario for 2040.

Figure 3.1 • Total primary energy supply and demand by fuel and by sector, 2013 (Mtoe)

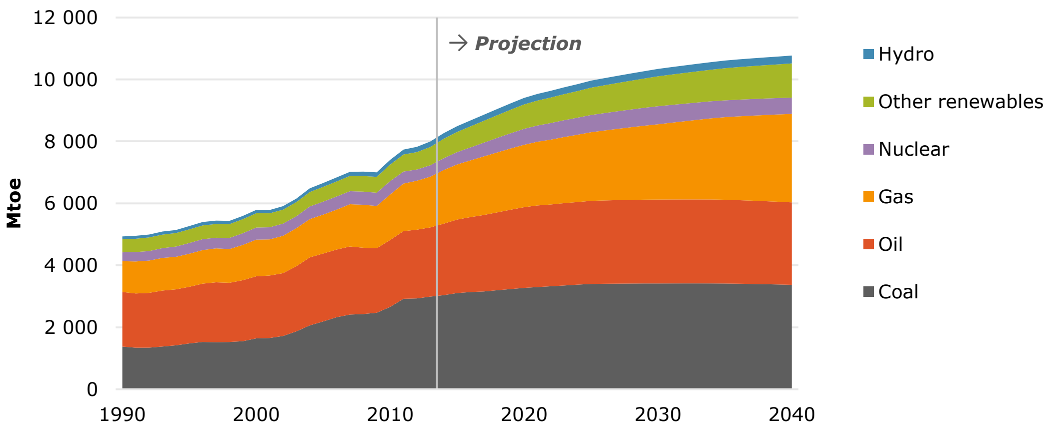


Sources: APERC analysis and IEA (2015) and SankeyMATIC (2016).

OUTLOOK FOR APEC ENERGY SUPPLY

On average, APEC total primary energy supply (TPES) increases more than 102 million tonnes of oil equivalent (Mtoe) per year from 2013 to 2040. This is equivalent to an average annual growth rate (AAGR) of 1.1% under the BAU Scenario, with primary energy supply reaching 10 770 Mtoe by 2040 (Figure 3.2). This forecast trend is below the AAGR of 2.1% (134 Mtoe annually) seen between 1990 and 2013. Fossil fuels continue to dominate with a projected increase of 2 000 Mtoe over the Outlook period, accounting for 73% of TPES growth across APEC. The share of fossil fuels declines slightly, from 86% in 2013 to below 83% in 2040. Energy demand grows significantly in the emerging economies but only modestly in developed economies.

Figure 3.2 • Total primary energy supply by fuel, 1990-2040



Sources: APERC analysis and IEA (2015).

Natural gas shows the highest growth among fossil fuels, increasing by 74% from 1 638 Mtoe in 2013 to 2 854 Mtoe in 2040. Oil demand has a more modest increase of 19% (428 Mtoe), from 2 234 Mtoe to 2 641 Mtoe. Coal increases by only 13% (381 Mtoe), from 2 988 Mtoe to 3 370 Mtoe, the slowest growth rate among all primary energy fuels.

Despite efforts to deploy renewable energy to help mitigate carbon dioxide (CO_2) emissions, in 2013 fossil fuels still dominated more than 80% of APEC primary energy supply. Under the BAU, this heavy reliance on fossil fuels continues for several decades.

In nearly half of APEC economies, fossil fuel shares increase over the Outlook period. Shares in few economies decrease significantly; China is most notable, as the decline from 88% in 2013 to 80% by 2040 is in line with the policy to reduce fossil fuel dependency (UNFCCC, 2015). In contrast, the fossil fuel share in South-East Asia increases from 75% in 2013 to 81% in 2040, while other Americas rises from 78% to 82%. These increases reflect how economic development will alter fossil fuel use in both regions.

Renewable energy demand in APEC nearly doubles under the BAU, from 768 Mtoe in 2013 to 1 360 Mtoe in 2040. Renewables and gas have the highest growth rate (AAGR 2.1%) among primary energy supply in APEC.[1] China and South-East Asia will lead the region's renewables deployment, with 80% of all renewables development occurring in these economies.

Based on BAU analysis of APEC members' official plans, nuclear energy demand increases from 368 Mtoe in 2013, to peak at 583 Mtoe in 2030 then subsequently decline to 530 Mtoe by 2040. Nearly 80% of new nuclear deployment occurs in China, where electricity demand increases substantially. In the United

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

States, the abundance of low-cost gas makes nuclear less competitive (particularly older-generation fleets), translating into a decline of almost 50% from 215 Mtoe in 2013 to 110 Mtoe by 2040.

From 1990 to 2013, for every 1 Mtoe of renewable energy added to TPES, APEC as a whole added 11 Mtoe of fossil fuels, which cancelled out any significant shift to cleaner energy. APERC projections show that by 2040, this ratio will fall dramatically with just 3 Mtoe of fossil fuels added for each 1 Mtoe of renewables. This improvement highlights response to the 2014 decision by APEC leaders to set a goal to double the share of renewable energy in all economies, and across all sectors, by 2030 (from 2010 levels). The decision reflects a desire to support sustainable energy development and mitigate climate change.

The outlook for APEC's energy mix shows significant changes for the coming decades, with shares of coal and oil falling while those of gas and renewables rise (Table 3.1). Coal's share, the largest since having overtaken oil in 2006, peaked in 2013. Oil's share continues a downward trend with the application of more stringent fuel economy policies. The share of gas shows the largest increase, rising from 20% in 2013 to 26% by 2040. The renewable energy share rises from 10% in 2013 to 13% in 2040. At just 5% in 2040 (down from 7% in 2000), nuclear represents the lowest share.

Table 3.1 • Share of total primary energy supply by fuel, 1990-2040 (%)

	1990	2000	2013	2020	2030	2040
Coal	28	28	37	35	33	31
Oil	36	35	28	28	26	25
Gas	20	20	20	21	23	27
Fossil fuel	84	83	86	84	83	83
Renewables	10	10	10	11	12	13
Nuclear	6	7	5	5	6	5
Non-fossil	16	17	14	16	17	17

Sources: APERC analysis and IEA (2015).

NET ENERGY SUPPLY GAP CONTINUES TO WIDEN IN THE FUTURE

Over the next two decades, APEC's primary energy supply trend changes significantly. Total fossil fuel production under the BAU Scenario increases by 23% from 6 530 Mtoe in 2013 to 8 050 Mtoe in 2040. Net fossil fuel production increases from 1 000 Mtoe in 2013 to 1 400 Mtoe in 2040, while net energy imports increase from 1 500 Mtoe to 2 300 Mtoe.[2] As a region, APEC continues to be a net energy importer, with total imports doubling from 512 Mtoe in 2013 to 1 100 Mtoe by 2040.

Based on APERC BAU analysis, derived from various sources such as official energy production forecasts, gas production grows at 1.7% annually from 2013 to 2040 while coal production remains almost flat (0.3%). Oil production shows a small annual increase (0.6%) (Table 3.2).

Table 3.2 • Fossil fuel production by fuel, 2013-40 (Mtoe)

	2013	2020	2030	2040
Coal	3 183	3 293	3 458	3 427
Oil	1 701	1 926	2 011	2 003
Gas	1 645	2 016	2 393	2 621

Sources: APERC analysis and IEA (2015).

[2] Net energy supply is calculated by subtracting domestic fossil fuel production from fossil fuel demand. A positive value shows domestic production falls short of meeting demand, with the value indicating the amount of imported energy needed to satisfy the demand 'gap'. Economies in this situation are considered net energy importers. A negative value indicates a surplus in energy production, which can be sold or exported to other users. Economies in this situation are considered net energy exporters.

APEC continues to be a net exporter of coal over the Outlook period while becoming a net natural gas importer post-2020 (Table 3.3). Net coal exports drop from 195 Mtoe in 2013 to 57 Mtoe by 2040, partly due to lower global demand as governments introduce policies in support of a shift to less CO_2-intensive energy supplies. Natural gas production increases from 1 645 Mtoe in 2013 to 2 621 Mtoe in 2040. This 60% increase in gas supply over the Outlook period is outpaced by a demand increase of 74%. Over the Outlook period, APEC dependence on net oil imports grows significantly—from 693 Mtoe in 2013 to 952 Mtoe by 2040.

APERC projections reflect many uncertainties regarding fossil fuel production, particularly for large producers and users. Even though China holds the largest unconventional gas reserve in APEC, extracting the resources can be challenging: current low energy prices on the global markets may make the extraction cost uneconomic. In some circumstances, it will be more economic for APEC economies to import natural gas and liquefied natural gas (LNG) rather than produce it domestically.

Table 3.3 • Net energy imports and exports by fuel, 2013-40 (Mtoe)

	2013	2020	2030	2040
Coal	-195	-24	-45	-57
Oil	693	871	937	952
Gas	-7	-2	36	234

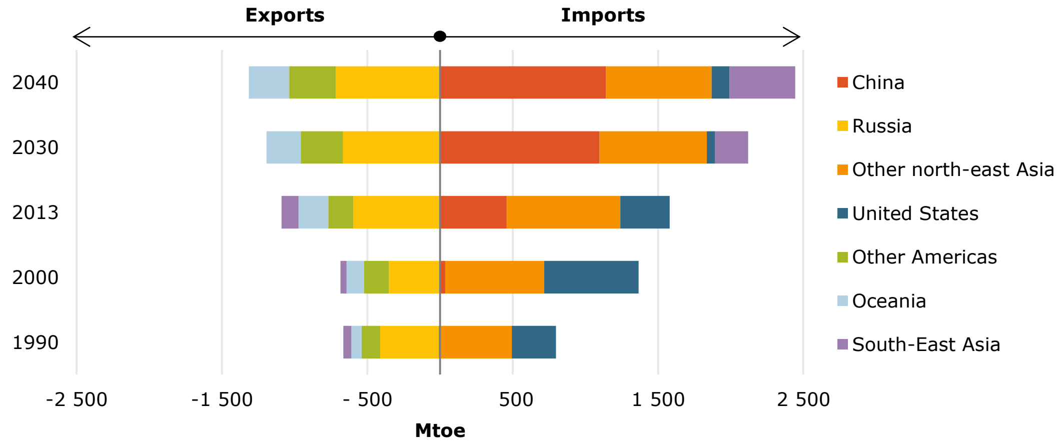
Note: Negative indicates net export; positive indicates net import.
Sources: APERC analysis and IEA (2015).

Seven APEC members will be net energy exporters by 2040, but this is a drop from nine economies in 2013. A corresponding closing of the supply gap reflects new production from conventional and unconventional resources, especially in economies with huge fossil fuel reserves (e.g. Russia, the United States, China, Canada and Australia) (Figure 3.3). Development and deployment of renewables and nuclear also help to reduce the energy supply gap, as both are considered indigenous sources.

The energy supply gap for APEC members widens over the Outlook period. China continues to be a net energy importer, but faces a twofold gap increase, as its shortfall of 505 Mtoe in 2013 rises to over 1 140 Mtoe by 2040. As China's primary energy demand increases to 4 695 Mtoe in 2040, around 24% will need to be met through imports, compared with 17% in 2013.

The biggest shifts in the energy supply gap will occur in the United States and South-East Asia. As the shale gas revolution boosts production to record surpluses of 40 Mtoe in 2040, US dependency on fossil fuel imports plummets 60%, from 303 Mtoe in 2013 to 122 Mtoe in 2040. With total US oil imports decreasing to 221 Mtoe by 2040 from 660 Mtoe in 2005, competition among APEC members to procure energy resources should weaken somewhat.

Figure 3.3 • Energy supply gap by regional grouping, 1990-2040



Sources: APERC analysis and IEA (2015).

The opposite situation is emerging for South-East Asia, which traditionally has been a major energy exporter in APEC; almost all economies will become net energy importers or experience higher dependency on imports. Under the BAU, for example, Malaysia and Viet Nam become net energy importers post-2016. Two exceptions are worth noting. Indonesia continues to be net energy producer as its coal production rises, although import demand for oil and natural gas also rises. With its current oil and gas reserves, Brunei Darussalam should also be able to remain an energy exporter over the Outlook period.

Intensifying energy trade among members could fill some of the APEC energy gap. As the bulk of current energy imports originate in Middle East and North Africa economies, most tankers transit through straits and canals that are almost at peak capacity for handling ships (e.g. the Straits of Malacca and the Suez Canal). Trade among some APEC members has the advantage of bypassing routes considered hot spots, which helps boost energy security.

ENERGY SUBSIDIES REFORM NEEDS TO BE PURSUED MORE AGGRESSIVELY

Reforming energy subsidies is a high priority for APEC. In 2011, APEC leaders encouraged member economies to rationalise and phase out inefficient fossil fuel subsidies that encourage wasteful consumption while ensuring vulnerable groups have access to essential energy services.

Worldwide fossil fuel subsidies in 2013 were estimated at USD 548 billion. Some 22% of these subsidies are applied in APEC economies; together, their value exceeded the gross domestic product (GDP) of Viet Nam for the same year. As the price of oil declined from above USD 100 per barrel (bbl) in 2013 to below USD 30/bbl in January 2016, total subsidies are expected to shrink in the future due to lower oil prices as well as reform initiatives taken by APEC members (IEA, 2016).

Table 3.4 • Energy subsidies by APEC economy and by fuel, 2014

	Fossil Fuel	Electricity	Renewable Energy
Australia	Subsidies (including in production)	No subsidies	No subsidies
Brunei Darussalam	Subsidies (including in production)	Subsidies (including in production)	No subsidies
Canada	No subsidies	No subsidies	Subsidies (including in production)
Chile	No subsidies	No subsidies	Subsidies (including in production)
China	Subsidy reform initiatives post-2014	Subsidies (including in production)	Subsidies (including in production)
Hong Kong	No subsidies	No subsidies	
Indonesia	Subsidy reform initiatives post-2014	Subsidy reform initiatives post-2014	Subsidies (including in production)
Japan	No subsidies	No subsidies	Subsidies (including in production)
Korea	Subsidies (including in production)	No subsidies	No subsidies
Malaysia	Subsidy reform initiatives post-2014	Subsidy reform initiatives post-2014	Subsidies (including in production)
Mexico	Subsidy reform initiatives post-2014	Subsidies (including in production)	No subsidies
New Zealand	No subsidies	No subsidies	No subsidies
Papua New Guinea	No subsidies	No subsidies	No subsidies
Peru	No subsidies	No subsidies	No subsidies
The Philippines	No subsidies	No subsidies	Subsidies (including in production)
Russia	Subsidies (including in production)	Subsidies (including in production)	Subsidies (including in production)
Singapore	No subsidies	No subsidies	No subsidies
Chinese Taipei	Subsidies (including in production)	Subsidies (including in production)	Subsidies (including in production)
Thailand	Subsidy reform initiatives post-2014	Subsidies (including in production)	Subsidies (including in production)
United States	No subsidies	No subsidies	Subsidies (including in production)
Viet Nam	Subsidies (including in production)	Subsidies (including in production)	Subsidies (including in production)

Legend: No subsidies | Subsidy reform initiatives post-2014 | Subsidies (including in production)

Notes: Fossil fuel subsidies include subsidies for fossil fuel production and consumption; electricity consumption subsidies exclude subsidies for renewables. For Outlook purposes, APERC considers FiTs as subsidies. Some large economies, such as Canada and the United States, apply FiTs in only some (not all) territories and states. Chile has a small subsidy for thermal solar panels for sanitary water.

Sources: APERC analysis and IEA (2016).

Nearly half of APEC economies implement some form of fossil fuel subsidies. With current low oil prices, many are trying to initiate reform by focusing on targeted subsidies. To encourage development of renewable energy, for example, more than half of APEC members have introduced some form of subsidy, often feed-in tariffs (FiT) (Table 3.4).

OIL SUPPLY

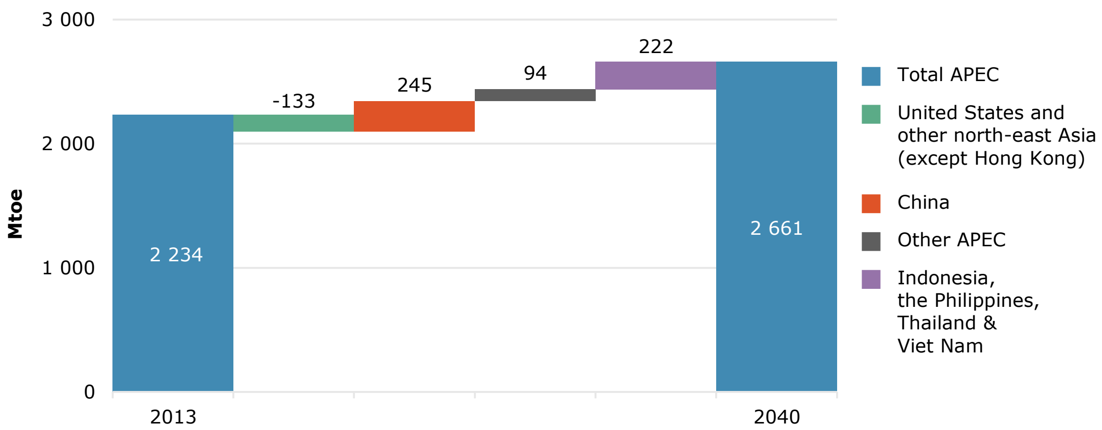
Oil will continue to play a major role in fuelling APEC economic growth in the BAU Scenario, driven largely by increased mobility as a growing population advancing to middle-class status adopts a new lifestyle. Yet many uncertainties influence APERC projections for oil demand in the APEC region, such as volatile crude oil prices, unstable world economic growth and policies for fuel switching towards cleaner options. These factors affect long-term oil supply projections.

Producing oil is dependent on the economics of production costs and the market oil price. Under the BAU, production flattens in some APEC economies in the next three to five years due to the sharp decline in oil prices.[3] As long-term oil prices are forecasted to bounce back to around USD 100/bbl post-2030, long-term production forecasts also rise. In addition, lower oil prices have forced unconventional oil producers to become more efficient in managing oil production, which has allowed them to become more competitive with conventional oil producers.

OIL'S SHARE IN ENERGY MIX FALLS FROM 28% IN 2013 TO 25% BY 2040

From 1990 to 2013, APEC oil demand increased by 27% from 1 760 Mtoe to 2 234 Mtoe. China recorded the highest growth at 370 Mtoe, followed by Korea and Indonesia at around 45 Mtoe each. By contrast, demand fell by 103 Mtoe in Russia (from 263 Mtoe in 1990 to 160 Mtoe in 2013) and by 48 Mtoe in Japan (from 250 Mtoe to 202 Mtoe).

Figure 3.4 • Oil demand growth by regional grouping, 2013-40



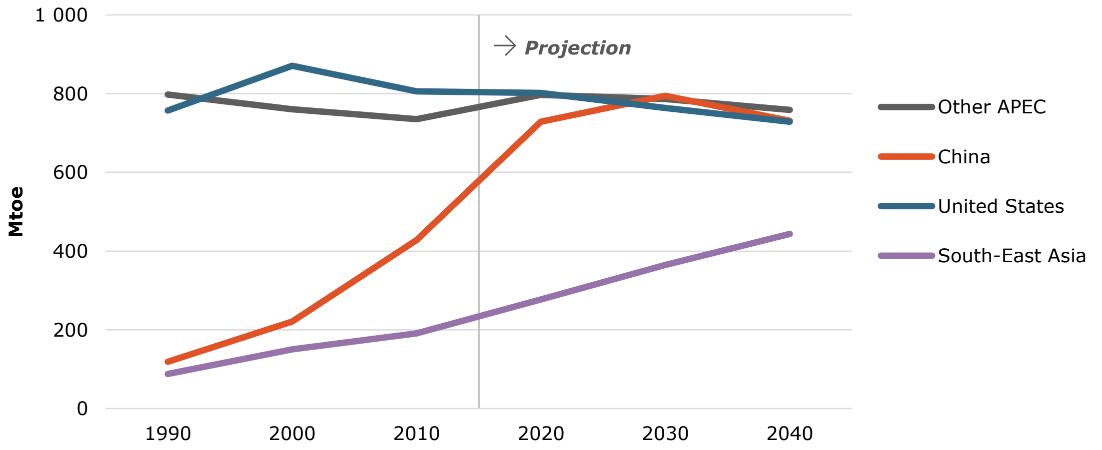
Sources: APERC analysis and IEA (2015)

Oil demand in APEC over the Outlook period grows modestly (AAGR 0.7%), from 2 234 Mtoe in 2013 to 2 661 Mtoe in 2040 (Figure 3.4). Most of the growth is in Asian economies such China (50%) and South-East Asia (doubling from the 2013 level). The share of oil in APEC total primary energy demand declines, however, from 28% in 2013 to 25% in 2040, largely as governments implement policies to curb consumption (e.g. vehicle fuel efficiency for transport).

[3] APERC does not have a comprehensive global supply model. As a result, most projections on fossil fuel production rely on official economy projections, with certain assumptions made for economies that do not produce projections. Therefore, APERC analysis relies on available reserves, with limited assumptions on the economics of production and trade, and limited consideration on price sensitivity.

China's oil demand increases at an AAGR of 1.5%, from 486 Mtoe in 2013 to a peak of 795 Mtoe by 2030; it declines subsequently to 730 Mtoe by 2040 (Figure 3.5). By 2030, China becomes the highest oil user in APEC, a position it maintains over the Outlook period. By 2040, 70% of oil supply in China comes from import sources, up from 60% in 2013. Oil demand declines in four economies (the United States, Japan, Korea and Chinese Taipei), with the largest reductions in Japan (64 Mtoe) and the United States (52 Mtoe).

Figure 3.5 • Oil supply by regional grouping, 1990-2040

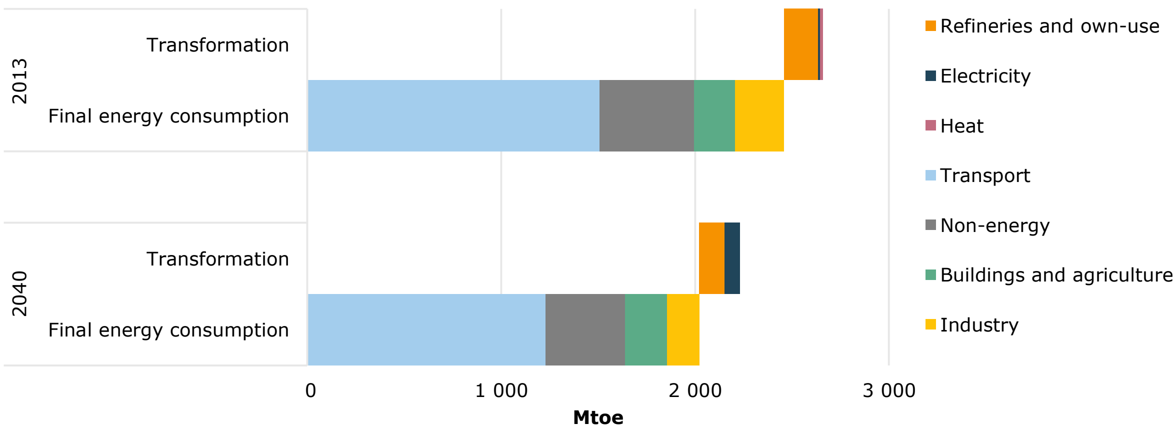


Sources: APERC analysis and IEA (2015).

Post-2030 under the BAU, oil demand peaks and then declines in most APEC economies. China oil demand decreases by 70 Mtoe, while the Oceania and other Americas regions show almost flat growth (less than 1%) between 2030 and 2040. South-East Asia economies, however, show continued strong growth (2% AAGR) from 2030 to 2040. This sub-region's share of total APEC oil demand rises to 17% in 2040 (from 9% in 2013). The aggregated economies of Indonesia, the Philippines, Thailand and Viet Nam show an oil demand increase of 2.5 times from 159 Mtoe in 2013 to 380 Mtoe in 2040, due to rapid rise in vehicle ownership.

Transport has been the main driver in oil demand for decades. In 2013, transport accounted for 60% of total APEC oil demand and this share remains the same in 2040 (Figure 3.6). But a geographical shift is underway: in 1990, 75% of APEC total vehicle stock was in the United States and Japan; by 2013, the share of these two economies had dropped to slightly above 50% at the same time as vehicle stocks were growing rapidly in emerging economies such as China, South-East Asia and other Americas, which collectively account for 84% of APEC's new vehicle sales.

Figure 3.6 • Oil demand by end-use and by sector, 2013 and 2040



Sources: APERC analysis and IEA (2015).

By 2040, oil demand for domestic transport increases by 270 Mtoe (from 1 230 Mtoe in 2013 to 1 500 Mtoe in 2040), thus remaining the largest consuming sector with a 61% share in 2040. Together, industrial and non-energy use increase by 29%, from 574 Mtoe in 2013 to 740 Mtoe in 2040. Though coal and natural gas are now the main fuels for producing electricity, oil still plays a small role in APEC. In 2013, 90 Mtoe of oil was used to generate electricity, nearly 35% in Japan to compensate for the temporary shutdown of nuclear plants for inspection following the Fukushima incident (EIA, 2015a).

APEC oil production remains flat, though demand increases

APEC oil production remains almost flat over the Outlook period; exceptions to this trend include Canada, China, Mexico, Russia and the United States (which together register a total increase of 342 Mtoe by 2040). Some APEC members that traditionally have been net oil exporters, particularly in South-East Asia, will become net importers post-2015 as demand increases and reserves decline.

In 2013, Russia was APEC's largest oil producer, followed by the United States, China, Canada and Mexico. Together, these economies produced more than 90% of total APEC oil in 2013; by 2040, they account for 95% of production. As production increases, US import dependency declines by more than one-third (from 340 Mtoe in 2013 to 220 Mtoe in 2040). South-East Asia oil production decreases by more than 30% over the Outlook period, as most oil wells pass peak production and are depleted. Even some economies applying enhanced oil recovery techniques to boost domestic production may peak, as this technique is only feasible at higher oil prices and most fields are considered marginal.

Oil production in Canada increases due to its huge oil sands reserves, while substantial tight oil supply helps the United States reduce oil import dependency. In both cases, though, the volume of oil extracted is subject to market conditions, environmental regulations and world crude oil prices.

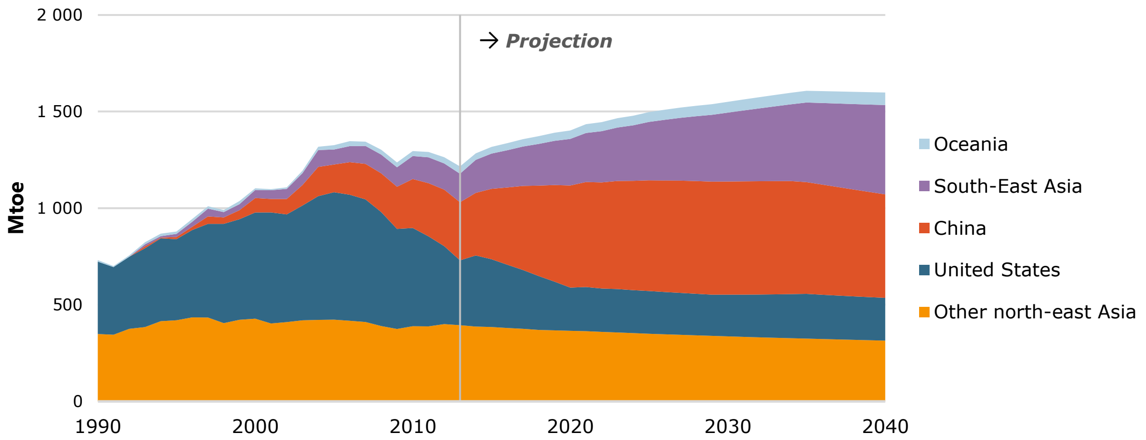
Intra-APEC oil trade is not yet fully exploited

APERC projections show APEC net oil imports increasing from 693 Mtoe in 2013 to 952 Mtoe in 2040. The BP Statistical Review of World Energy 2015 indicates that the United States imported most of its crude oil from Mexico and Canada, the Middle East and West Africa, while North-East Asia economies import oil from the Middle East and South-East Asia via the South China Sea (BP, 2015). This leaves a large gap in crude oil trade among APEC members, which offers advantages such as fewer choke points (particularly from unstable regions such as Middle East) and shorter transport routes.

Of more than 3 300 billion barrels of unproved, technically recoverable tight oil that is available in 42 economies around the world, roughly 56% of the resources are located in APEC economies (EIA, 2013). With huge reserves available in certain economies, significant opportunity exists to increase trade volumes across the Pacific. The United States, for example, is expected to reduce net oil imports from a high of 660 Mtoe in 2005 to 220 Mtoe by 2040 (Figure 3.7). This will release some of the crude oil typically imported to North America for possible diversion to the Asian region, particularly China and South-East Asia.

China's net oil import under the BAU increases from 301 Mtoe in 2013 to 535 Mtoe by 2040, while import volumes to South-East Asia increase by 210% (from 147 Mtoe to 462 Mtoe). Malaysia and Viet Nam became net oil importers in 2013 and 2014 respectively, due to declining production and rising demand.

Figure 3.7 • Net oil imports by regional grouping, 1990-2040



Sources: APERC analysis and IEA (2015).

COAL SUPPLY

The APEC region continues to be a major player in the global coal industry throughout the Outlook period in the BAU Scenario. Driven by factors such as economic growth, urbanisation, market development and technology breakthroughs, coal demand increases steadily. As it is abundant and low-cost, coal is the fuel of choice for meeting energy demand in many APEC economies, even though the costs in terms of environmental impacts are well documented.

Development of clean coal technology, as well as more efficient coal production and use, are gaining momentum in APEC, propelled by the shared aims of reducing emissions and maximising the value of coal. Industry players are pursuing various technology improvement initiatives such as advanced coal combustion technologies, carbon capture and storage (CCS), and integrated gasification combined cycle (IGCC). These efforts should be expedited to help mitigate negative impacts on the environment and human health, and to some extent, negative social impacts.

Indonesia domestic market obligation

In 2009, Indonesia's Ministry of Energy and Mineral Resources issued a ministerial regulation on the Preferential Supply of Domestic Mineral and Coal Demands, otherwise known as the domestic market obligation (DMO) regulation. Generally, the DMO is designed to curb coal exports to ensure local demand is met first.

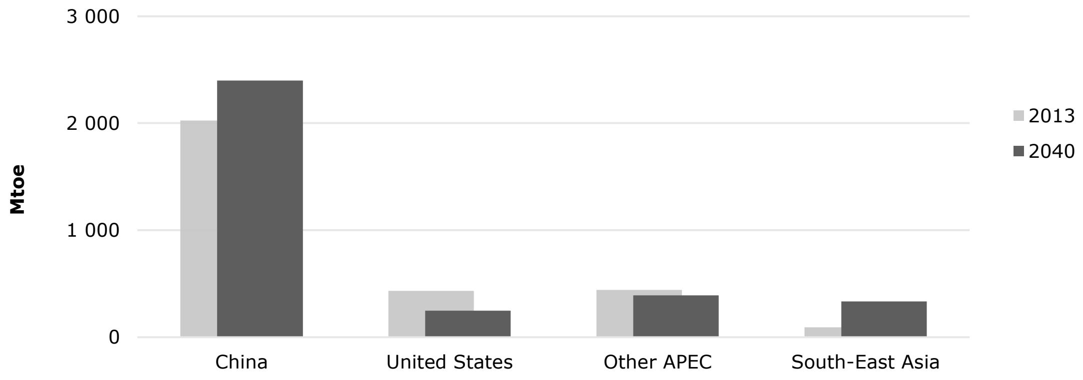
Under the Indonesia Medium Term Development Plan 2015-2019, coal production reaches 440 Mtoe, of which 32% has been allocated for local consumption (an increase from 24% in 2014). The DMO is a way for the government to expand domestic coal demand while ensuring energy security (BPKP, 2015).

COAL REMAINS THE LARGEST FUEL SOURCE IN APEC DESPITE DECLINING SHARE

From 1990 to 2013, coal demand in APEC economies increased by 120%, from 1 377 Mtoe to 2 988 Mtoe. In 2013, China accounted for two-thirds of total APEC coal demand, reflecting an increase of more than 3.5 times the 1990 levels.

Over the Outlook period, growth in coal demand in APEC slows, averaging only 0.4% annually to reach slightly over 3 370 Mtoe (about 13% higher than the 2013 level) (Figure 3.8). China will continue to contribute a 70% share of coal demand in the region, but is also expected to pursue cleaner fuel options, causing coal demand to peak at 2 475 Mtoe in 2029 before declining to 2 400 Mtoe in 2040.

Figure 3.8 • Coal demand by regional grouping, 2013 and 2040

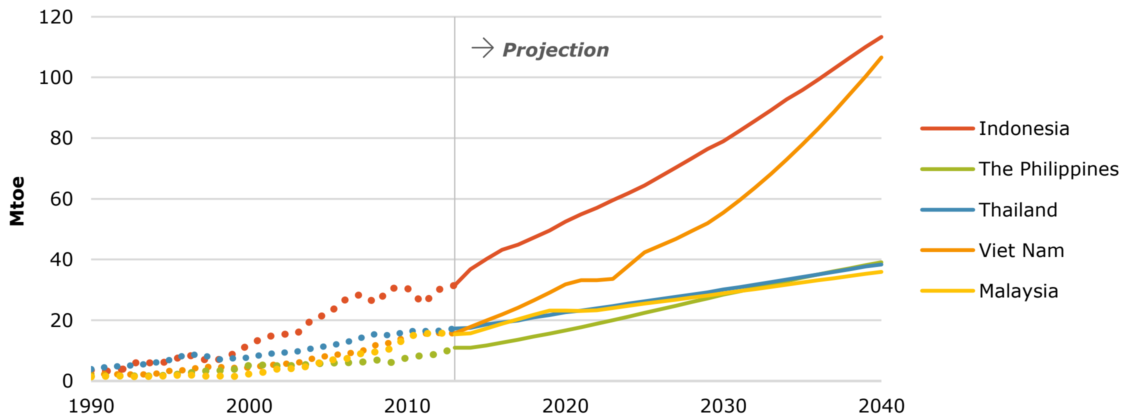


Sources: APERC analysis and IEA (2015).

With unconventional gas production in the United States expected to increase rapidly, particularly in the current context of competitive gas prices and more stringent environmental policies, coal demand is expected to decrease by more than 40% to 246 Mtoe in 2040 (down from 432 Mtoe in 2013). By contrast, some other north-east Asia economies expect to see demand grow for coal to 2040, including Korea (by 4.4 Mtoe) and Chinese Taipei (by 2.3 Mtoe).

South-East Asia economies, especially Indonesia, Malaysia, the Philippines, Thailand and Viet Nam, warrant special attention as coal demand is projected to increase nearly fourfold from 91 Mtoe in 2013 to 333 Mtoe in 2040 (Figure 3.9). Indonesia, one of the biggest coal producers in the world, will use more domestically produced coal, increasing from 32 Mtoe in 2013 to 113 Mtoe by 2040. Viet Nam, which has been a coal exporter over the past two decades, is expected to rely on imports for about two-thirds of its coal supply in 2040, as demand increases sevenfold, from 16 Mtoe in 2013 to 107 Mtoe in 2040.

Figure 3.9 • Coal demand in selected economies, 1990-2040



Sources: APERC analysis and IEA (2015).

Most of the new coal demand in South-East Asia is from power generation needed to keep pace with growing economies and populations. As economies grow, the middle-income population is expected to increase with a resulting increase in demand for electricity. In parallel, some economies will undergo fuel switching from traditional biomass to electricity, particularly in Indonesia and the Philippines where electricity grids are extended into rural areas. Within this rapid regional demand growth for coal, only Indonesia will have sufficient domestic supply; the other economies will continue or start to import coal. In light of this rapid increase in coal demand, APERC developed a modelling exercise to evaluate how it will affect the power sector. The Cleaner Coal Case asseses the potential to mitigate emissions from coal power plants (see in-depth analysis in Chapter 7).

Coal production remains flat, reflecting weak demand growth

The BP Statistical Review of World Energy 2015 indicates that nearly 70% of the world's proven coal reserves are located in APEC, with the United States, Russia and China having the largest reserves (BP, 2015).[4] The United States and Russia are expected to have a positive reserves-to-production ratio for more than 50 years. In China, the coal reserve is expected to last 30 years.[5]

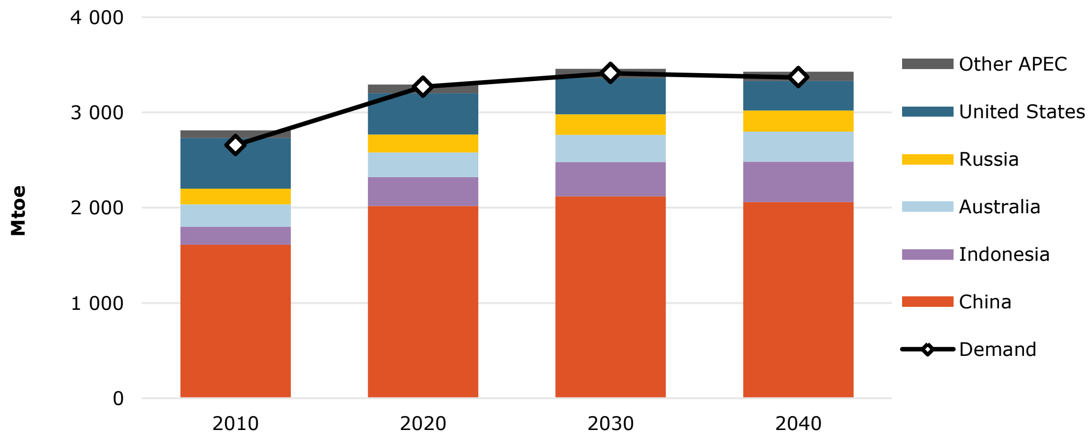
Under the BAU Scenario, coal production in APEC remains flat from 2020, largely due to weaker demand. By 2040, APEC produces 3 427 Mtoe of coal, an increase of only 7.7% from 3 183 Mtoe in 2013. Five major coal-producing economies (China, Australia, the United States, Indonesia and Russia) are projected to maintain their 97% share of APEC's coal production throughout the Outlook period.

Coal production in China, under the BAU, peaks at 2 120 Mtoe in 2030 (up from 1 895 Mtoe in 2013), then decreases slightly to 2 057 Mtoe by 2040 (Figure 3.10). Contributing factors include uncertainty in policies pertaining to production and emission mitigation targets set by the government, and the fact that sizeable coal reserves are located inland while the economy's demand centres are in densely populated coastal areas, which makes the large transportation investment needed an important consideration.

As coal demand in the United States decreases by more than 40%, from 430 Mtoe in 2013 to 246 Mtoe in 2040, production declines in parallel. Historical data shows that the United States usually maintains an excess production margin 10% to 15% above domestic demand for export. Thus, APERC projects that US coal production will decrease by more than one-third, from 477 Mtoe in 2013 to 308 Mtoe in 2040.

Indonesia increases coal production by 50%, from 281 Mtoe in 2013 to 427 Mtoe by 2040. Since domestic coal demand reaches only 113 Mtoe by 2040, the economy will have in excess of 314 Mtoe for export, enough to meet the coal import requirement in other South-East Asia economies, Korea and Chinese Taipei.

Figure 3.10 • Coal production by regional grouping and total APEC demand, 2010-40



Sources: APERC analysis and IEA (2015).

Coal production in Russia increases slightly from 184 Mtoe in 2013 to 224 Mtoe in 2040 under the BAU. As domestic demand decreases from 108 Mtoe in 2013 to 83 Mtoe in 2040, the economy will have an excess of 141 Mtoe to export to other APEC members, particularly China and other north-east Asia economies.

[4] There are two internationally recognised methods for assessing world coal reserves. The first is produced by the German Federal Institute for Geosciences and Natural Resources (BGR) and is used by the IEA as the main source of information about coal reserves. The second method was developed by the World Energy Council (WEC) and is used by the *BP Statistical Review of World Energy*. For consistency, APERC used the BP Statistical Review of World Energy across the Outlook.

[5] A ratio indicating the remaining lifespan of a natural resource. This ratio is expressed in terms of years, and is used in forecasting the future availability of a resource to determine project life, income, employment etc. While applicable to all natural resources, it is commonly applied for fossil fuels.

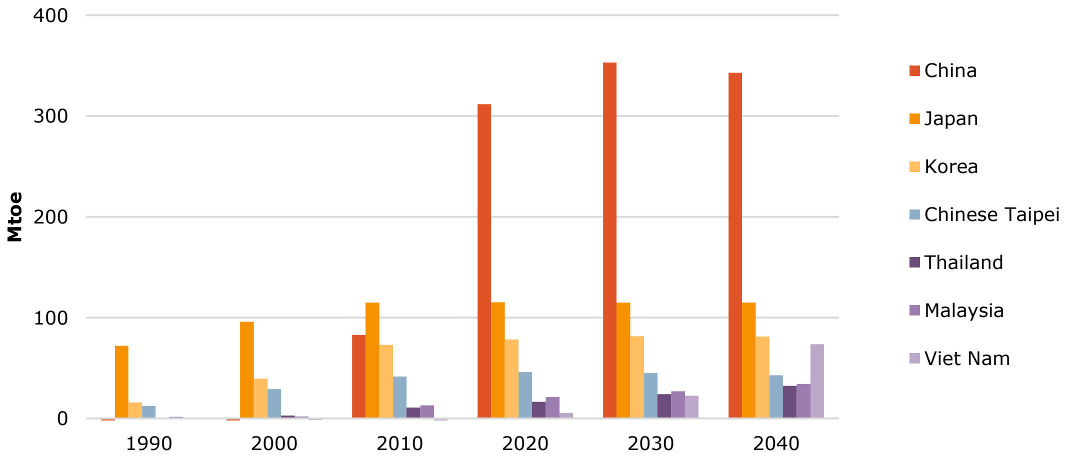
Filling the import gap among members to realise potential intra-APEC coal trade

According to Key World Energy Statistics 2014, the APEC region is home to five of the world's ten biggest coal exporters: Indonesia, Australia, Russia, the United States and Canada. Similarly, five of the top ten coal importers are APEC members: China, Japan, Korea, Chinese Taipei and Malaysia (IEA, 2015). By improving energy trade within the region, APEC members can help each other ensure security of coal supply.

Japan, China, Korea and Chinese Taipei continue to import large volumes of coal in 2040, while emerging economies (such as Viet Nam, Thailand and Malaysia) join the ranks of main coal importers in the region. China's coal production remains almost flat although demand increases, forcing the economy to import 14% of total supply in 2030 (when peak coal demand is expected). Coal imports to Chinese Taipei are projected to increase as nuclear energy is phased out and replaced by coal for electricity generation.

By 2040, Australia, Canada, Indonesia, Russia and the United States have excess coal production totalling 830 Mtoe, while total coal imports across APEC are expected to reach 774 Mtoe. APEC could explore the possibility of increasing coal trade among its members to help secure coal supplies. More than 95% of APEC's coal import requirements will be located in Asia (Figure 3.11). Assuming that coal-exporting APEC members were to give priority to APEC coal importers, a net volume of 57 Mtoe remains available for export to economies beyond APEC.

Figure 3.11 • Projected net coal imports for selected APEC economies, 1990-2040



Sources: APERC analysis and IEA (2015).

NATURAL GAS SUPPLY

Natural gas is increasingly important to the APEC energy mix under the BAU Scenario, partly because it is the fossil fuel with the lowest CO_2 intensity. As technological developments help to expand recoverable reserves, natural gas is becoming the fuel of choice to meet rapidly growing energy demand in many economies.

In transition to cleaner energy options, gas has been identified as one of the fuels that can be used to mitigate environmental impacts in the short term. Use of gas is also seen as a means of diversifying the fuel mix to secure supply, particularly in power generation.

Unconventional gas resources, particularly shale gas, have recently caught global attention; the sheer vastness of these resources has the potential to shift the energy balance for many economies. As more than half of the global demand and production of natural gas is located in APEC, development of shale gas resources could help member economies improve their energy balances and potentially enhance intra-regional trade of natural gas and LNG.

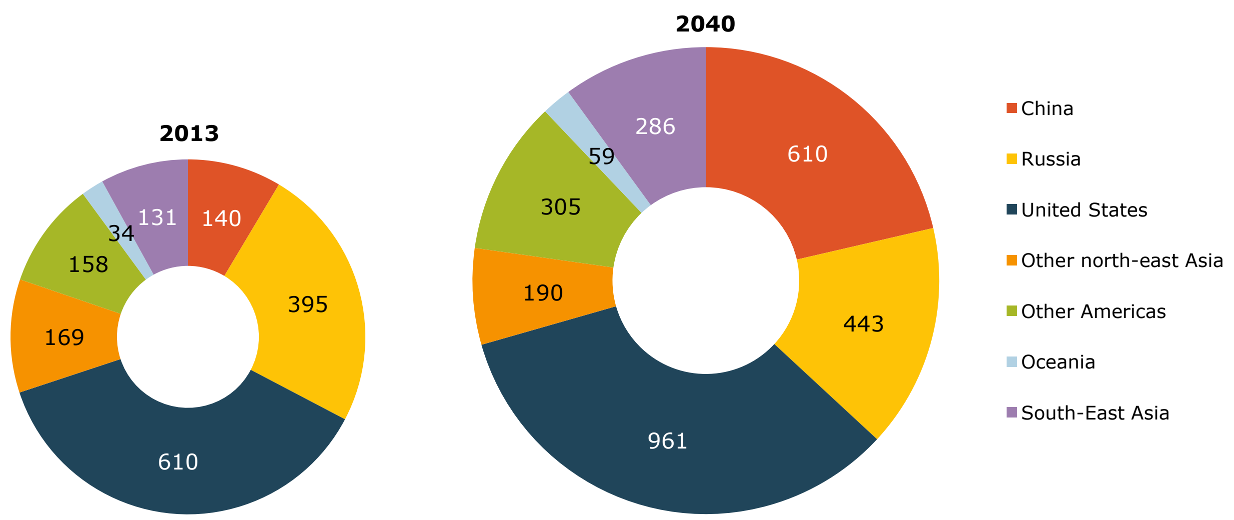
ENVIRONMENTAL CONCERNS MAKE NATURAL GAS THE FOSSIL FUEL OF CHOICE

Unconventional gas, an abundantly available resource, is often considered as a 'cleaner' alternative to coal—and is thus attracting the attention of APEC Leaders. In fact, industry players in APEC members (particularly Canada and Australia) are actively investing in unconventional gas. The message to optimise natural gas use has been echoed in many ministerial meetings and has prompted many APEC studies on the potential of unconventional gas.

In September 2012 (in Vladivostok, Russia), APEC leaders ratified their commitments and agreed to review the current state and prospects of energy markets of the APEC region. A key element was to increase the share of natural gas in the energy mix to facilitate the transition to a lower-carbon economy without prejudice of other energy sources, while also evaluating the production, trade potential and environmental impact of shale and other unconventional natural gas resources (APEC, 2012). In September 2014, APEC Energy Ministers went a step further in promoting cleaner energy options by showing support for development of unconventional oil and gas in their economies, with emphasis on the pursuit of scientific solutions that minimise the associated environmental impacts (APEC, 2014).

Between 1990 and 2013, APEC natural gas demand increased by 65% (an AAGR of 2.2%), from 994 Mtoe to 1 638 Mtoe. All APEC economies recorded some increase in natural gas demand, with the highest growth recorded by the United States (172 Mtoe), followed by China (128 Mtoe) and Japan (62 Mtoe). Following the Fukushima incident and the temporary shutdown of its nuclear fleet, natural gas demand surged 23% in Japan, from 86 Mtoe in 2010 to 106 Mtoe in 2013. Strong growth in natural gas demand was also seen in Malaysia (an increase of 31 Mtoe) and Thailand (an increase of 33 Mtoe) from 1990 to 2013, largely due to rapid expansion of electricity generation from indigenous gas production.

Figure 3.12 • Natural gas demand by regional grouping, 2013 and 2040 (Mtoe)

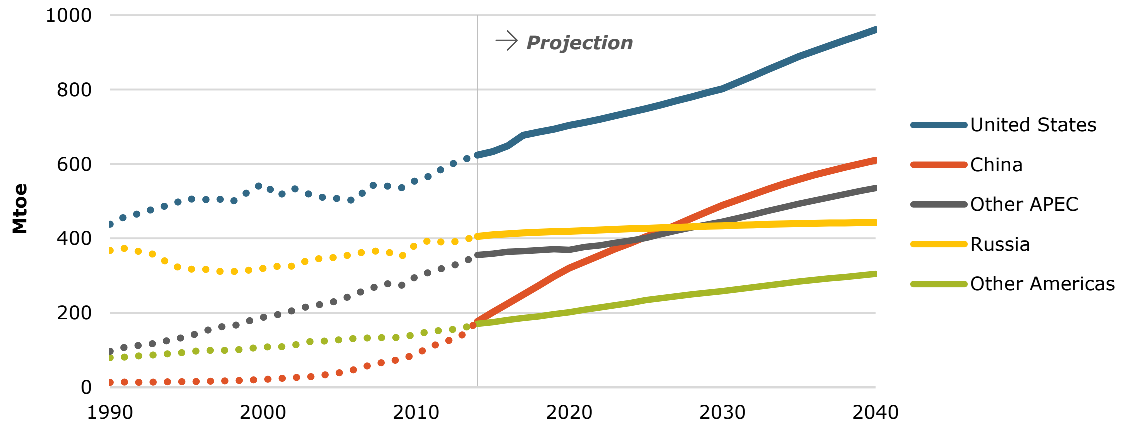


Sources: APERC analysis and IEA (2015).

Under the BAU, APEC natural gas demand increases by 75%, from 1 638 Mtoe in 2013 to 2 854 Mtoe in 2040 (Figure 3.12). Most of the demand increase occurs in economies endowed with large gas reserves. Six economies (Canada, China, Indonesia, Mexico, Russia and the United States) account for 84% of APEC total natural gas demand through the Outlook period.

In the United States, which has large unconventional gas resources, demand reaches 961 Mtoe in 2040, while China (with the second-highest natural gas demand in APEC) consumes 610 Mtoe—i.e. nearly two-thirds that of the United States (Figure 3.13). The highest AAGRs are in China (5.6%), Indonesia (4.9%) and Peru (4.6%).

Figure 3.13 • Natural gas demand by regional grouping, 1990-2040



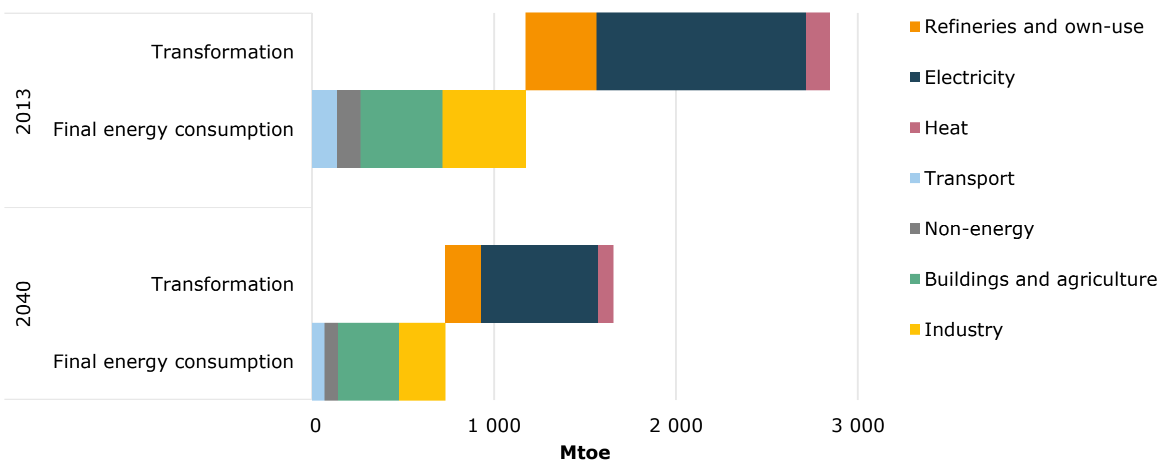
Sources: APERC analysis and IEA (2015).

Natural gas slowly replacing coal in electricity generation

In 2013, 39% of total natural gas demand in APEC was used to generate electricity. By 2040, the share of gas demand for power generation stays the same, but in absolute volume gas demand for generating electricity grows by 80%, rising from 644 Mtoe (2013) to 1 160 Mtoe (Figure 3.14). In China alone, gas consumption in the electricity sector increases more than sevenfold, from 20 Mtoe in 2013 to 173 Mtoe in 2040. Natural gas consumption in US electricity generation doubles, from 207 Mtoe in 2013 to 423 Mtoe in 2040.

Gas consumption in industry also shows strong growth—nearly 80% over the Outlook period—from 254 Mtoe in 2013 to 457 Mtoe in 2040. The highest absolute increases are in China (79 Mtoe) and the United States (42 Mtoe).

Figure 3.14 • Natural gas demand by end-use and by sector, 2013 and 2040



Sources: APERC analysis and IEA (2015).

Natural gas production increasing, but falls short of rising demand

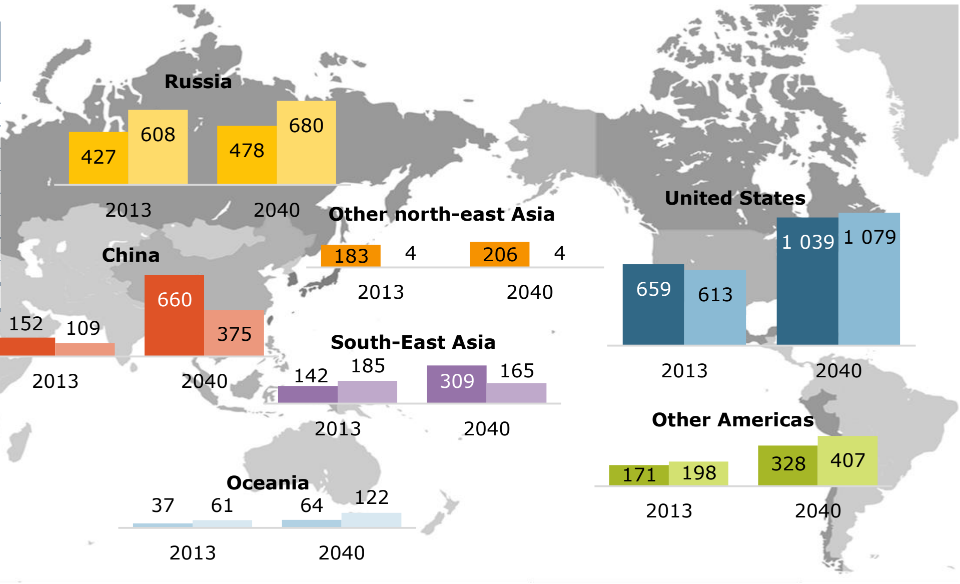
APERC projections under the BAU show production of natural gas in the APEC region increasing 1.7% annually from 2013 to 2040. The United States, with its vast shale gas resources, increases production from 567 Mtoe in 2013 to nearly 1 000 Mtoe in 2040 to become the region's largest producer. Production in Russia increases from 563 Mtoe to 629 Mtoe, while China, the second-largest natural gas consumer, is expected to increase production from 101 Mtoe to 347 Mtoe. Combined production of these three economies accounts for three-quarters of total gas production in APEC.

Although China expects a threefold increase in gas production, domestic supply will not be sufficient to meet rising demand. The economy therefore becomes more reliant on natural gas imports: in 2040, imports account for nearly 40% of supply (up from 28% in 2013). Of note, South-East Asia as a whole becomes a net importer of natural gas by 2030, while individual economies begin importing sooner: Indonesia in 2026, Malaysia in 2035 and Viet Nam in 2032. Brunei Darussalam is the only APEC economy that remains a net gas exporter in South-East Asia over the Outlook period.

In its recently released Energy Plan, Peru projects that gas production will increase fivefold by 2040 (from the 2013 level) (MINEM, 2015). Having been a small natural gas exporter, Peru will join the ranks of gas exporting economies and come to play a larger role. By 2040, Peru will have an excess of 39 Mtoe of natural gas, more than enough to meet the import demands of Chinese Taipei and Malaysia at that time.

Figure 3.15 • Major technically recoverable unconventional gas resources by regional grouping

Economies	Shale gas resources (bcm)
Australia	12 149
Canada	16 227
Chile	1 387
China	31 576
Indonesia	1 302
Mexico	15 434
Russia	8 127
Thailand	142
United States	17 643
APEC	103 991



Note: This map is for illustrative purposes and is without prejudice to the status of or sovereignty over any territory.
Sources: APERC analysis, IEA (2015), EIA (2013).

Based on the APEC Unconventional Gas Census produced by the APEC Energy Working Group in 2013, unconventional gas already provided over 30% of annual natural gas production in 2011 in the 21 APEC economies. The Census also shows that the volume of technically recoverable unconventional gas in APEC is enough to support over 200 years of production at current production rates. Further exploration is needed to collect more accurate data, but industry players expect the APEC resource will likely increase (APEC EWG, 2013).

Endowed with huge natural gas reserves and resources, APEC will continue to be a net gas producer for the next two decades, indicating significant potential for enhanced intra-regional trade up to 2030, at which time APEC will become a net gas importer. Dozens of LNG liquefaction projects have been proposed in Australia, Canada, the United States, Malaysia, Indonesia and Russia; at present, 25 of 26 liquefaction terminals under construction globally are located in APEC economies (IGU, 2015).

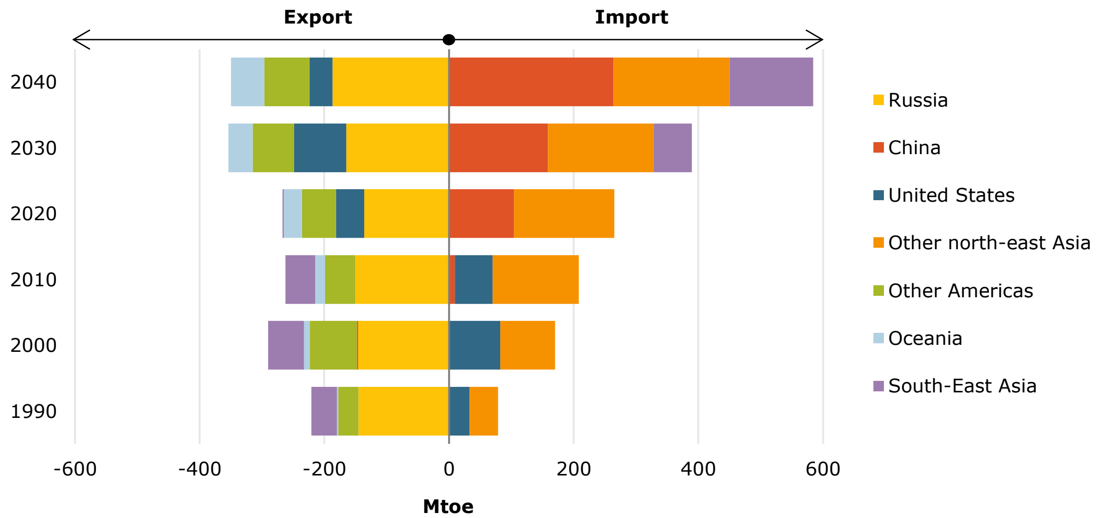
With effective market signals, APEC can take advantage of the full potential of natural gas

In 2013, technically recoverable unconventional gas resources in APEC were estimated at 103 991 billion cubic metres (bcm). Shale gas accounts for more than half (65 840 bcm), followed by coal-bed methane (28 700 bcm) and tight gas (20 160 bcm) (APEC EWG, 2013). Given the magnitude of this resource potential, APERC analysed the impacts of switching from coal- to gas-fired generation for new coal plants assumed in the BAU Scenario and in the Alternative Power Mix Scenario (Chapter 7). Several economies show potential for even higher production; based on the official forecast for higher gas production made by Canada and the United States, both economies may be able to produce an additional 390 Mtoe, on top of BAU production projections (NEB, 2015; EIA, 2015b). With the potential of additional gas, supply should be able to meet the demand requirement of the High Gas Case (both High Gas 50% and High Gas 100% Cases) in the Alternative Power Mix Scenario (see Chapter 7). However, adequate market signals—such as a high gas price, construction of infrastructure to ensure all gas produced gets onto the market, and policies that stimulate high demand for natural gas—will be needed.

Huge opportunity for APEC members to boost natural gas trade

By 2040, a group of 14 APEC members will need to import 605 Mtoe of natural gas, while seven others will have a combined surplus of more than 370 Mtoe. Thus, APEC will become a net gas importer; by 2040, additional imports of 235 Mtoe are needed from outside the region (Figure 3.16). In this situation, where APEC as a whole will have small gas supply shortages, a second issue emerges: the mismatch between producing and importing economies. Economies in other north-east Asia will continue to be natural gas importers while Russia, Oceania and other Americas economies continue to produce excess gas for export. With nearly 80% of global LNG trade in 2014 happening in the Pacific region, business and governments may want to consider building additional LNG terminals on the Pacific side in order to meet increasing demand within the APEC region (IGU, 2015).

Figure 3.16 • Natural gas supply gap by regional grouping, 1990-2040



Sources: APERC analysis and IEA (2015).

Box 3.1 ● Liquified natural gas as a transport fuel

With the aim of promoting active discussion on how to secure a stable, competitive and flexible global market for liquefied natural gas (LNG) and investigating the latest market trends, the Ministry of Economy, Trade and Industry (METI) of Japan and APERC have jointly hosted the annual LNG Producer-Consumer Conference. One new frontier discussed during the conference is the use of LNG as transport fuel.

About 180 000 trucks and buses powered by LNG are currently in operation globally (nearly 95% have been deployed in China) and about 150 ships (Shell Eastern Petroleum Pte Ltd, 2015). As LNG is considered cleaner than oil, and LNG engine technology is proven, reliable and available, LNG has the potential to dramatically change the future of transport fuel. Significant growth and value in the market for natural gas and LNG as transport fuels could displace more than 1.5 million barrels per day (MMbbl/d) of oil demand by 2030. Use of natural gas as a transport fuel will be spurred by three main drivers—environmental, technological and commercial (IHS, 2015).

Three major challenges must be addressed to develop LNG as a fuel option for transport: infrastructure, a regulatory framework that facilitates infrastructure and market development, and engine and fuel system costs.

Infrastructure must be developed in parallel with demand. At present, 10 projects of LNG bunkering infrastructure are being undertaken globally by lead gas operators, usually in partnership with ship builders and ports operators (GDF SUEZ LNG, 2012).

Regulatory bodies play a major role in proactively advocating for legislation that reflects the impending shift in energy use while also establishing market frameworks that allow LNG to compete on a level playing field with other fuels. Decision makers should collaborate closely with industries to develop regulation that reduces the complexity of the supply chain. For example, the anti-pollution rules set by International Maritime Organization, a UN agency, has set limits on nitrogen oxide (NOx) and sulphuric oxide (SOx) emissions from ship exhaust, which will stimulate LNG use in the maritime sector, and subsequently lead to development of additional LNG bunkering infrastructure.

Engine and fuel system costs will change with fuel switching. Gas demand in trucks will reach 81 billion cubic metres (bcm) by 2030, split between LNG and compressed natural gas (CNG). An additional 17 bcm in LNG demand is expected to come from ships by the same year while demand in the trucking and marine sectors is expected to account for 10% of all globally traded LNG (IHS, 2015). This transition creates a huge need to improve the engine and fuel usage efficiency in order to reduce running system costs.

NUCLEAR ENERGY SUPPLY

Nuclear energy has remained one of the main primary energy sources in the APEC region since 1990, when 286 Mtoe supplied 5.8% of TPES (equivalent to 1 100 TWh). In 2010, nuclear reached a peak of 433 Mtoe (1 660 TWh), with the subsequent drop (to 368 Mtoe or 1 400 TWh) linked to the temporary shutdown of nuclear plants in Japan following the Fukushima incident. The United States dominates at present, having nearly 60% of the total share of nuclear demand in APEC. Several changes are expected under the BAU Scenario.

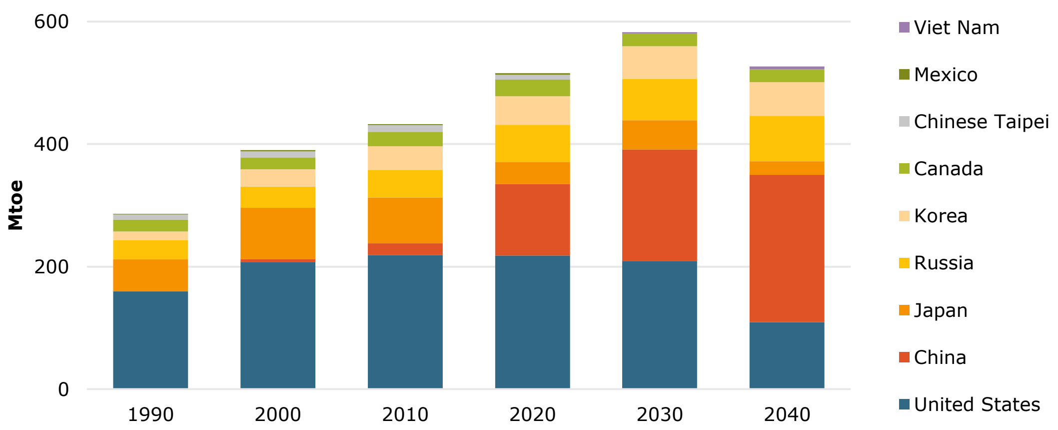
APEC NUCLEAR ENERGY DEMAND SHIFTS FROM WEST TO EAST

APEC nuclear energy demand under the BAU Scenario increases nearly 200 Mtoe over the Outlook period, from 368 Mtoe in 2013 to peak at 580 Mtoe (2 240 TWh) in 2030 and subsequently declines to 526 Mtoe (2 020 TWh) by 2040 (Figure 3.17). China overtakes the United States as the leader in nuclear energy production, in part because US demand declines under BAU projections, from 215 Mtoe in 2013 to 209 Mtoe in 2030, and plummets in the following decade to only 110 Mtoe as a large numbers of plants are retired (even after a 20-year extension is considered).

The exception is China, where nuclear demand expands by nearly eightfold, from 29 Mtoe (112 TWh) in 2013 to 241 Mtoe (924 TWh) in 2040. Two-thirds of new nuclear plants in China begin operations by 2025, the rest by 2040. Japan retained nuclear energy as part of its future fuel mix and began to restart its nuclear reactors in August 2015. As of 31 January 2016, three reactors were in operation and others are expected to be restarted after receiving regulatory approval.

Most APEC economies with nuclear energy programs are assumed to carry them forward, albeit at a smaller scale. Chinese Taipei and Mexico are exceptions, as they plan to phase out nuclear for various reasons such as public concerns and retirement of aging nuclear plants. At the time of publication, there is no strong evidence that governments from these economies will continue with nuclear energy programs. Viet Nam will be the only new entrant in nuclear energy, with its first plant expected to begin operating in 2030.

Figure 3.17 • Nuclear energy demand, 1990-2040



Sources: APERC analysis and IEA (2015).

Fuelling nuclear: Uranium demand in APEC is set to increase

Uranium is the fuel stock for nuclear power plants, and APEC economies with nuclear programs need to maintain sufficient supply. The World Nuclear Association database shows that APEC economies hold more than 54% of global uranium reserves, with Australia having nearly 30% while another 24% is spread among reserves in Canada, China, Russia and the United States. Production of uranium, however, is not always carried out in the same places: Kazakhstan (which is not an APEC economy) produces the largest share of uranium from mines (41% of world supply from mines in 2013), followed by Canada (16%) and Australia (9%) (NEA, 2014).

Table 3.5 • Uranium production by APEC economy, 2015-40

tonnes of uranium	2015	2020	2025	2030	2035	2040
Australia	8 000	16 700	18 000	19 000	16 600	17 100
Canada	15 800	17 300	19 300	19 400	17 900	15 400
China	2 400	2 300	2 300	2 900	3 200	3 400
Russia	3 400	2 900	2 900	3 100	3 400	3 600
United States	2 400	2 100	2 100	2 200	2 400	2 600
APEC	**32 000**	**41 300**	**44 600**	**46 600**	**43 500**	**42 100**

Sources: APERC analysis and NEA (2014).

APERC projections derived from NEA Uranium 2014: Resources, Production and Demand show that uranium production in APEC is able to meet at least 90% of regional demand (NEA, 2014). With the largest uranium reserves in the world, Australia is expected to overtake Canada by 2040 as the lead producer of uranium among APEC economies.

Uranium demand increases tremendously in APEC, from 35 600 tonnes in 2015 to 47 000 tonnes in 2040. The region remains a net uranium importer, becoming increasingly dependent as imported volumes rise from more than 3 500 tonnes in 2015 to 5 000 tonnes in 2040.

Table 3.6 • Annual reactor-related uranium requirements by APEC economy, 2015-40

tonnes of uranium	2015	2020	2025	2030	2035	2040
Canada	2 400	2 400	1 900	1 900	1 900	1 900
China	4 900	10 400	13 500	16 200	18 900	21 500
Japan	100	3 200	4 700	4 200	2 600	2 000
Korea	3 400	4 200	4 400	4 700	4 800	4 900
Mexico	300	200	0	0	0	0
Russia	4 400	5 400	5 700	6 000	6 300	6 600
Chinese Taipei	1 000	700	0	0	0	0
United States	19 100	19 400	19 400	18 600	13 400	9 700
Viet Nam	0	0	0	200	400	400
APEC	**35 600**	**45 900**	**49 600**	**51 800**	**48 300**	**47 000**

Source: APERC analysis.

RENEWABLE ENERGY SUPPLY

Renewable energy is high on the APEC development agenda, pursued by APEC Leaders as a path towards sustainable development.[6] During the 2012 APEC Energy Ministerial Meeting, members agreed on a declaration to develop renewable energy sources as one element of efforts to increase energy security and reduce emissions while also contributing to economic development by creating jobs and providing basic access to energy (APEC, 2012).

In September 2014, the APEC Energy Ministers reiterated the commitment to develop renewable energy by setting a target to double the share of renewables in the APEC energy mix (including in power generation) by 2030 (from the 2010 level). The target is particularly ambitious, as it is set over a period in which APEC economic development is expected to be strong, with associated increases in energy

[6] In primary energy supply, renewable energy is defined as including traditional biomass and large hydro.

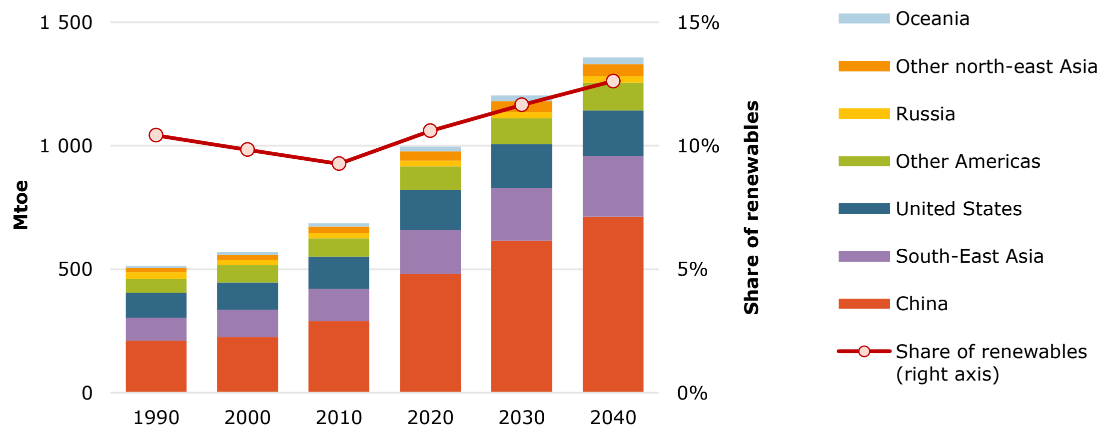
demand (APEC, 2014). This section examines the degree to which the BAU Scenario is aligned with this target.

RENEWABLE ENERGY, THE FASTEST-GROWING ENERGY SOURCE IN APEC

In 1990, renewable energy accounted for roughly 10% of TPES in the APEC region. Though renewable energy has increased in absolute terms, its share in the mix dropped below 10% in 2000. This reflects economic progress, particularly in developing economies, in which an increase in the electrification rate normally corresponds to the reduced use of traditional biomass.

China, the largest energy user in APEC, is also the largest renewable energy contributor, accounting for over 43% of total APEC demand in 2013, followed by the United States at 19% and South-East Asia economies with 18% (a mix of traditional biomass and modern energy use) (Figure 3.18).

Figure 3.18 • Renewable energy production by regional grouping, 1990-2040



Sources: APERC analysis and IEA (2015).

Renewable energy demand under the BAU almost doubles, reaching 1 360 Mtoe in 2040 (from 770 Mtoe in 2013). While all APEC economies expect to expand renewable energy, more than two-thirds of the increase occurs in China, pushing its share in APEC total renewable supply from 43% in 2013 to 52% in 2040. South-East Asia is expected to add more than 105 Mtoe by 2040, while the United States adds 37 Mtoe; other APEC members (Russia, other north-east Asia, other Americas and Oceania) together add 68 Mtoe. Further investigation of renewable energy can be found in Chapter 4 on the electricity sector and in Chapter 6 on the High Renewables Scenario.

Biofuels demand increases, with further additions possible

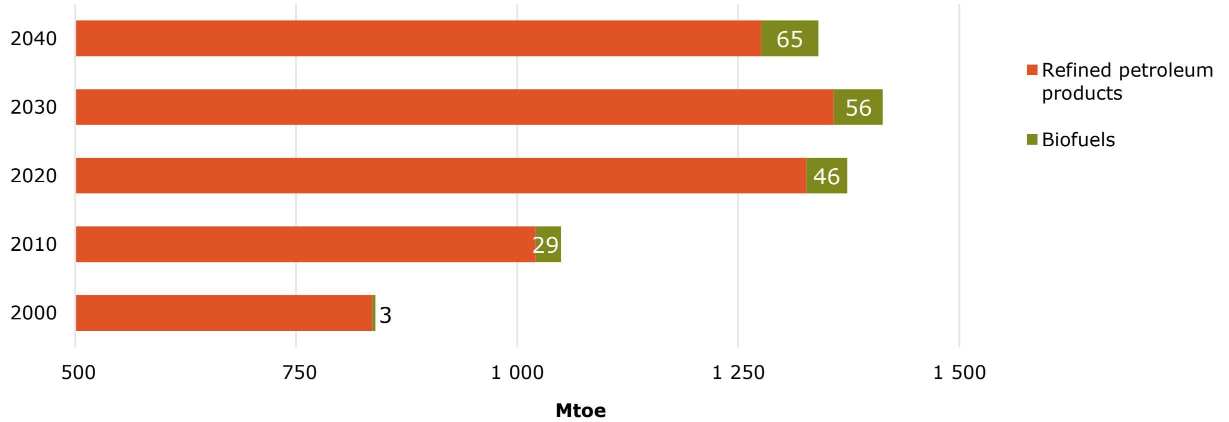
Biofuels demand in APEC increases rapidly, from 36 Mtoe in 2013 to 65 Mtoe in 2040 (Figure 3.19). Of 21 APEC members, 15 economies plan to pursue use of biofuels, creating huge potential for expansion. When biofuels have an AAGR above 2.2%, they outpace (by a factor of three) petroleum products, which grow at 0.7% annually. China, the United States and South-East Asia will drive biofuels demand in APEC, together accounting for 88% of total APEC biofuels demand by 2040.

Biofuels are divided into two types: bioethanol and biodiesel. The targets for each have been set differently across APEC economies. Bioethanol has attracted the highest attention, with targets mostly set at E5 or above in the short term, while China, Indonesia, Japan, Thailand, the Philippines and Viet Nam have set an ambitious target of implementing E10 or above post-2020.[7] As for biodiesel, Indonesia, the Philippines and Thailand have set targets of implementing B20 and higher in the future.

[7] Both bioethanol and biodiesel are labelled according to their characteristics, with E for bioethanol and B for biodiesel, while the number following each letter is the blend rate. For example, E10 is the blend of 10% ethanol and 90% gasoline.

At present, six APEC economies (Brunei Darussalam, Chile, New Zealand, Papua New Guinea, Russia and Singapore) have not set any official target for developing biofuels; closer cooperation among APEC members may be needed to develop biofuel markets in these economies. Overall, the projected growth in biofuels will be a huge boost for the goal of doubling the share of renewables in the APEC energy mix.

Figure 3.19 • Growth of biofuels and refined petroleum product demand, 2000-40



Sources: APERC analysis and IEA (2015).

RECOMMENDATIONS FOR POLICY ACTION

Fossil fuels continue to dominate the APEC energy mix in coming decades under the BAU Scenario, which raises questions about the implications of such dependency, and about if and when APEC economies will establish more ambitious policy interventions to pursue a sharp reduction in fossil fuel dependency. As energy is a time- and capital-intensive industry, it is also important to ask what collective efforts could be undertaken to reduce the cost of an energy system transformation and stimulate a better-managed industry. Ultimately, the overriding question is whether APEC has done enough to ensure sustainability for future generations based on the projections made by APERC in this Outlook.

As energy demand in APEC will continue to increase, there is great concern for the need to balance energy supply security and the environmental impacts of the chosen energy mix. Even if APEC member economies trade all surplus energy production among themselves, APEC would still need to import more than 1 000 Mtoe from outside the region. Thus, in addition to enhancing trade, APEC should pursue further collaboration to expand existing production and transport infrastructure, and to accelerate deployment of renewable and other low-carbon energy technologies.

Investing in energy supply, particularly in less CO_2-intensive energy supply, to meet future demand should be prioritised across APEC. Natural gas use, for example, requires substantial upfront investments, especially for economies that need to import these resources. The investment needs are diverse, covering power generation, regasification terminals, LNG storage and pipeline networks to the demand centres. Governments need to establish robust policies and targets that will help investors make decisions on cleaner energy without jeopardising energy security; for some APEC economies, this has already led to diversification away from coal and oil with a corresponding increase in the use of natural gas.

To boost investor confidence, governments can demonstrate their commitment to expand sustainable energy sources and intensify research and development (R&D) on clean energy technologies. The expectation for economic growth in developing and emerging economies is likely to translate into higher energy demand, requiring increased supply. Such economies should seize the opportunity to deploy more advanced technologies, which can attract new investment. Developed APEC economies can engage by transferring technology and know-how, which will benefit APEC as a whole. As demonstrated in the Alternative Power Mix Scenario, strategic deployment of the best-suited technologies for a given economy context can deliver a wide range of additional benefits (see Chapter 7).

APEC was established with the aim of building a dynamic and harmonious Asia-Pacific community by championing free and open trade and investment, promoting and accelerating regional economic integration, encouraging economic and technical cooperation, enhancing human security, and facilitating a favourable and sustainable business environment. APEC pursues these goals through policy action and agreements that deliver tangible benefits and results (APEC, 2015).

To advance this mission, APEC needs to foster closer relationships among its members to build understanding and create trade opportunities. APERC analysis shows substantial potential for APEC members to optimise very diverse levels of development and resource endowment by engaging in energy trading that involves fossil fuel import and export, while also pursuing technology transfer and overall development of energy services.

In facilitating trade, an integrated energy market in APEC would also reduce the region's dependence on energy imports from other economies. As demonstrated by the LNG Consumer-Producer Conference hosted by Japan’s METI and APERC, opportunities to engage in dialogue, and participate in forums and conferences, will help buyers and producers to better understand current situations and future trends.

Coordinated communication among APEC members is critical, based on openness and transparency that engages stakeholders at every level. For economies that still have fossil fuel subsidies, educational campaigns to inform people about the burden such subsidies pose for governments should be a high priority, along with explanations of how funds used to support such subsidies could be redirected towards more productive development.

Access to data is very important in enabling APERC (and other analysts) to project scenarios of future energy demand and supply within APEC. The availability and quality of existing datasets vary considerably across APEC, which affects the robustness and utility of scenario modelling. Economies therefore need to prioritise the collection of up-to-date energy consumption and production data in order to better understand how current energy trends influence the future of the energy sector.

4. ELECTRICITY OUTLOOK

KEY FINDINGS

- **Electricity demand in the APEC region has more than doubled since 1990, and continues to grow by 70% over the Outlook period.** China and South-East Asia are projected to double their electricity demand by 2040, raising their shares to about half and one-tenth of APEC demand.

- **Further policy actions, including promotion of energy efficiency and low-carbon technologies, are necessary to ensure that electricity systems in the APEC region are environmentally sustainable.** Renewables and nuclear generation grow under the BAU Scenario, but not by enough to rein in fossil fuel consumption, so annual CO_2 emissions from the electricity sector rise more than 30% by 2040.

- **APEC economies need to enhance policies promoting renewable energy to double renewables in power generation from 2010 to 2030, the year of the APEC renewables goal.** Although renewables show the largest growth rate among the technologies, their share rises from 16% in 2010 to only 22% in 2030 under the BAU Scenario.

- **Economies need to secure huge investments for stable electricity supply, ranging from USD 6.8 trillion to USD 10.9 trillion**. These investments in generation and transmission are required not only in developing economies to meet rising demand, but also in mature economies to deploy renewables and replace ageing plants and networks.

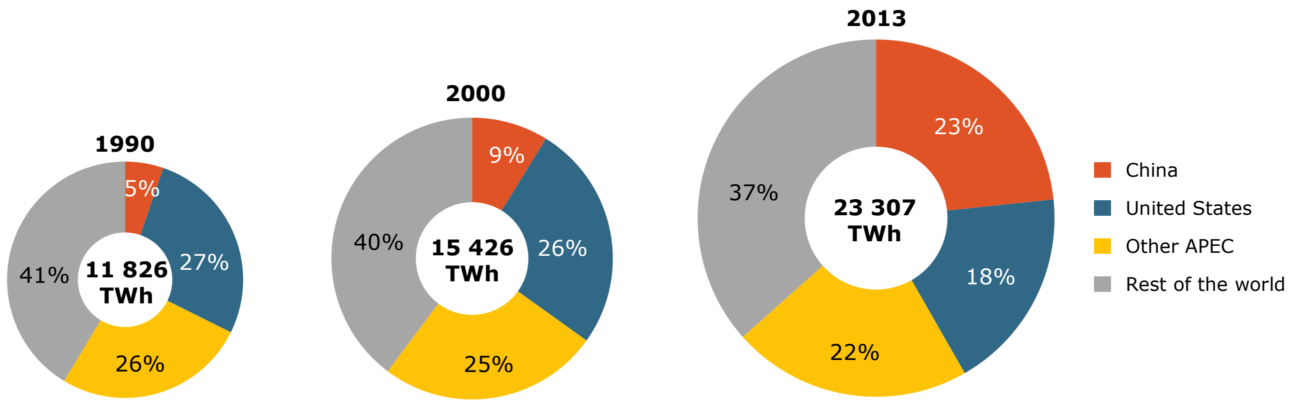
- **Lower energy prices lead to falling average generation costs in the short term, but the effect differs across the APEC region.** Energy-importing economies largely benefit from energy deflation, whereas the power generation costs in energy-producing economies are less sensitive to developments in the energy market.

INTRODUCTION

Asia-Pacific Economic Cooperation (APEC) economies include the world's major electricity markets, together accounting for about 60% of global generation over the last two decades (Figure 4.1). Each APEC economy has tended to maximise the stability and minimise the costs of its electricity supply to support economic growth. In addition, decarbonisation has become an important focus, as the electricity sector is one of the sectors emitting the most carbon dioxide (CO_2), accounting for about 40%[1] of total energy-related CO_2 emissions in APEC in 2013 (IEA, 2015a). Electricity demand in the APEC region is expected to grow, driven by developing economies; therefore, in order to promote decarbonisation as well as to enhance energy security, APEC energy ministers agreed in 2014 on a goal of 'doubling the share of renewables in the APEC energy mix, including in power generation, from 2010 levels by 2030'[2] (APEC, 2014).

The People's Republic of China and the United States are the two largest economies in terms of generation, accounting for 23% and 18% in the world in 2013, respectively. China significantly increased its share after 2000, and exceeded the US level in 2011. Total generation has grown since 1990 in all economies except Russia.[3] Higher growth in developing economies has lowered matured economies' share of generation. For example, although the United States increased its total generation by 34% from 1990 to 2013 in absolute terms, its global share decreased from 27% to 18%.

Figure 4.1 • Share of world electricity generation by regional grouping, 1990-2013



Note: TWh = terawatt-hours
Sources: IEA (2015a) and EGEDA (2015) for Papua New Guinea.

Power generation in APEC as a whole is not environmentally sustainable. Approximately 70% of generation has been from fossil fuels over the last two decades (Figure 4.8). Non-fossil generation has grown, but fossil fuel-fired generation more than doubled in absolute terms. In 2010—the base year of the APEC doubling renewables goal—renewables accounted for 16% of total APEC generation, fossil fuels for 72% and nuclear for 12%. Two-thirds of the APEC economies relied on fossil fuel sources for more than 70% of their electricity supply. Renewables held a majority share in just three economies: New Zealand (73%), Canada (63%) and Peru (53%), thanks to abundant hydro resources. APEC includes nuclear-free economies as well as four of the world's five economies[4] with the largest nuclear capacity, as of February 2016: the United States (99 GW), Japan (40 GW), China (27 GW) and Russia (25 GW) (IAEA, 2016).

This chapter presents electricity sector projections to 2040 in the APEC region according to the Business-as-Usual (BAU) Scenario, which includes existing policies (Table 4.1). The scenario also includes policies that are highly likely to be implemented but does not necessarily incorporate targets, goals or policy

[1] Before allocating the electricity sector's emissions to consuming sectors.
[2] This chapter focuses on renewable generation in the power generation. Asia Pacific Energy Research Centre (APERC) analysis excludes traditional use of biomass from renewable energy, but considers other types, including biomass for power generation and large-scale hydro.
[3] Mainly because of the drop in industrial consumption in the 1990s, during the economic recession after the breakup of the Soviet Union. See Figure 4.3.
[4] The other country is France, with the second-largest capacity in the world (63 gigawatts [GW]) as of February 2016 (IAEA, 2016).

proposals whose implementation is uncertain. Electricity sector projections in the High Renewables and Alternative Power Mix Scenarios are discussed in Chapters 6 and 7.

METHODOLOGIES AND KEY ASSUMPTIONS

APERC projects electricity demand by economy from 2013 to 2040 using three energy demand models—the industry, transport, and buildings and agriculture sectors (see Chapter 2)—which rely on macroeconomic indicators, sector-specific information and econometrics approaches.

This Outlook projects electricity supply using a bottom-up, least-cost model. The model determines capacity expansion and operation of each technology under technical and political constraints. Electricity demand is modelled as representative yearly or daily load duration curves, depending on data availability of each economy (see also Annex I), and the model dispatches generation and storage technologies to balance demand and supply based on cost optimisation. The cost of each technology includes capital costs (such as annual payments to recover initial investments and decommissioning costs), operation and maintenance (O&M) costs, fuel costs, and carbon penalties. APERC's cost assumptions rely primarily on each economy's official assessments[5] and analysis by the International Energy Agency (IEA) (IEA, 2014a). The following generation technologies are considered in the BAU Scenario: nuclear, coal subcritical, coal supercritical/ultra-supercritical, advanced coal technologies, gas turbine, combined-cycle gas turbine (CCGT), oil-fired, hydro (large and small scale), onshore wind, offshore wind, solar photovoltaic (PV), concentrating solar power (CSP), geothermal and biomass/others. The model also takes into account pumped hydro storage and battery storage technologies. Assumptions for lifetimes are: 30-60 years for nuclear, 40-60 years for fossil fuel-fired plants and 25 years for solar and wind, based on economy-specific regulations and historical information.

APERC uses the optimisation model for the long-term projections; however, it is important to note that APERC's approach is not a simple optimisation. The model considers existing policies, including each economy's or utility's power development plan as well as project information, as a set of constraints. Table 4.1 summarises key assumptions for BAU electricity supply by regional grouping,[6] except for Japan which is currently the fourth-largest market and shows drastic policy changes after the Great East Japan Earthquake in 2011.

Table 4.1 • Key assumptions for electricity supply in the BAU

	Key assumptions
China	**Fossil fuels**: Gas-fired supply accelerates, but coal-fired supply still dominates new fossil fuel capacity additions, based on the trend in the 12th Five-Year Plan[a] (State Council, 2013) and Action Plan on Energy Strategies for 2014-20. **Nuclear**: The economy reaches its target of 58 GW by 2020 (State Council, 2014) and then adds three to four reactors a year on average. **Renewables**: The trends of past deployment continue, driven by the government's strong initiative to curb air pollution. Capacity factors of variable renewables[b] in remote areas improve because of transmission network enhancements.
United States	**Fossil fuels**: Gas-fired generation grows, driven by low-cost domestic gas production, and existing coal-fired plants are retired after about 50 years of operation. **Nuclear**: Five reactors under construction as of mid-2015 begin operating, and each existing reactor is retired after 60 years of operation. **Renewables**: The BAU Scenario includes renewable promotion policies, including renewable portfolio standards (RPSs), feed-in tariffs (FiTs) and tax exemptions.
Russia	**Fossil fuels**: Gas remains the dominant fuel type, as with past trends. **Nuclear**: The economy continues nuclear developments, and existing reactors are retired after 45 years of operation. **Renewables**: Capacity auction schemes are included. The economy continues to limit new renewable additions under the scheme in order to control the impacts on electricity costs and prices (MOE of Russia, 2013).

[5] For example, APERC refers to METI (2015) for Japan and EIA (2013) for the United States.
[6] This Outlook has seven regional groupings: China, the United States, Russia, Oceania (Australia, New Zealand and Papua New Guinea), other Americas (Canada, Chile, Mexico and Peru), other north-east Asia (Hong Kong, Japan, Korea and Chinese Taipei) and South-East Asia (Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore, Thailand and Viet Nam).

Table 4.1 (cont.) • Key assumptions for electricity supply in the BAU

Japan	**Fossil fuels:** Power producers pursue their current development plans. As of 2015, gas-fired plants dominate their long-term plans of new fossil fuel capacity additions (OCCTO, 2015). **Nuclear:** Three reactors[c] that were under construction before the Fukushima accident of March 2011 begin operating. Existing reactors retire after 40 years of operation, except for reactors whose retirements have been announced or whose lifetime extensions are being examined by the Nuclear Regulation Authority as of 2015. **Renewables:** The FiT system continues. The purchase price of renewable energy is reduced in a phased manner, taking into account cost reductions of renewable technologies. As for variable renewables, this Outlook assumes that part of authorised capacity[d] is installed, based on recent differences between authorised capacity under the FiT system and actual installations.
Oceania	**Australia:** Gas-fired capacity makes up the majority of new fossil fuel additions, based on information about projects that have been approved, are in advanced planning or are under construction (ESAA, 2015). Small-scale renewables, such as rooftop PV, continue to drive renewables development despite 2020 targets on large-scale renewables. **New Zealand:** The largest coal plant, Huntly Power Station, shuts down by the end of 2018 (GNE, 2015). Gas remains the dominant fossil fuel. Cost-competitive renewables, such as wind power, grow. **Papua New Guinea:** The domestic grid connects major cities, and the main fossil fuel sources shift from diesel to gas. The economy also develops its hydropower potential (DNPM, 2010; PNG Power Ltd, 2014).
Other Americas	**Canada**: Gas becomes the main fossil fuel source due to the Emission Performance Standard. The regulation limits emissions from new coal-fired plants to 420 grams of CO_2 per kilowatt-hour (gCO_2/kWh). There are no additions of nuclear reactors. Existing nuclear reactors' lifetimes are 36-60 years. **Chile**: Coal remains the main fossil fuel source. Renewable generation, especially solar PV and CSP, grow thanks to good solar resources and supports from the government (MOE of Chile, 2015). **Mexico and Peru**: Gas-fired capacity increases, based on each economy's current development plan (SENER, 2014 for Mexico; MINEM, 2012 for Peru). In Mexico, there are no new nuclear reactor additions, and existing reactors' licences expire after 30 years of operation.
Other north-east Asia (except Japan)	**Hong Kong**: No new coal-fired plants (EPD, 2015), and the economy shifts from coal-fired to gas-fired generation. **Korea**: The economy pursues the government plan (MOTIE, 2015). Coal-fired capacity dominates new fossil fuel additions in Korea. Nuclear additions follow the plan. Existing reactors' lifetimes are 40 years (30 years designed lifetime plus 10 years' extension), except for the reactor whose retirement has already been announced (KORI-I in 2017). **Chinese Taipei**: The economy pursues its utilities' power plant development plan (Taipower, 2014). As for fossil fuels, balanced development of coal and gas is assumed. As for nuclear, there are no new additions, and reactors currently under construction are not included. Retirements of existing reactors follow the utility's plan. FiT for renewables continues.
South-East Asia	**Brunei Darussalam and Singapore**: Both continue to rely on gas generation, mainly by installing gas combined-cycle plants with higher efficiency. Brunei installs a 10 megawatt (MW) waste-to-energy plant by 2020, while Singapore gradually increases solar PV. **Indonesia**, **the Philippines and Viet Nam**: Each economy increases its reliance on coal-fired generation because of low fuel costs and local coal resource availability (PLN, 2015; DOE of the Philippines, 2015; MOIT, 2015). In Viet Nam, two planned Russian reactors are commissioned after 2025. Indonesia develops geothermal resources. **Malaysia and Thailand**: As for fossil fuels, both continue to develop coal and gas for fuel diversification reasons as well as to manage generation costs (Energy Commission of Malaysia, 2014; MOE of Thailand, 2015). Renewable promotion policies, such as FiT in Malaysia, continue. Thailand increases electricity imports from neighbouring economies.

Notes: This table summarises the main policies assumed within the BAU Scenario; it is not intended as a comprehensive list of all energy policies. See also each economy chapter in Volume 2. [a]The 12th Five-Year Plan directs the economy's development from 2011 to 2015. As the 13th plan has not yet been released as of end-2015, this Outlook assumes that the policy direction in the 12th plan continues after 2015. [b]Wind and solar PV. [c]Oma, Shimane-III, Higashidori-I. [d]This Outlook assumes that 60% of authorised utility-scale PV capacity (as of September 2015) and 90% of residential PV and wind capacity are installed over the projection period.

Sources: Cited in this table.

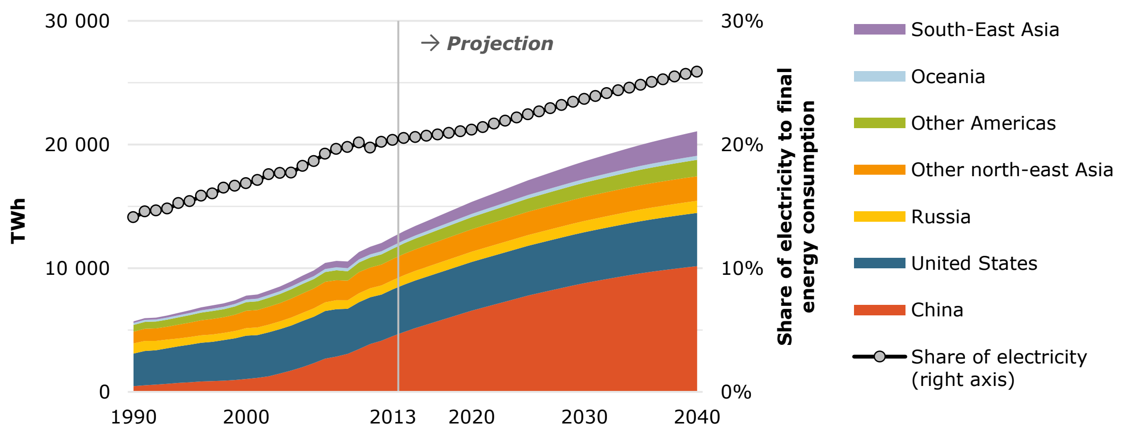
The BAU Scenario assumes that existing policy trends continue over the Outlook period. APERC analysis also takes into account carbon tax and emissions policies implemented during the Outlook period—such as carbon taxes in Japan from 2012 (MOE of Japan, 2012) and New Zealand's Emissions Trading Scheme from 2008 (MfE, 2008). In this Outlook, nuclear and renewables capacity are subject to government policies and recent development trends; therefore, the supply model determines fossil fuel-fired capacity, and operation of power generation and storage technologies.

ELECTRICITY DEMAND

The three energy demand models project electricity demand in the industry and transport sectors, and in buildings and agriculture (see Chapter 2). Prospective economic growth is a key driver of the models: electricity demand is expected to grow significantly in developing economies but only modestly in mature economies. Electricity consumption is projected to rise from 20% of total final energy consumption in 2013 to 26% in 2040, mainly because rising per capita income allows people to purchase a wider array of appliances and other electrical equipment, such as air conditioners and washing machines.

Electricity demand in the APEC region more than doubled from 1990 to 2013, and continues to grow by 70% over the Outlook period, with an annual average growth rate (AAGR) of 1.9% (Figure 4.2)[7]. Growth is mainly driven by China and South-East Asia, each of which more than doubles its electricity demand, at AAGRs of 3.1% for China and 3.9% for South-East Asia.[8] Incremental demand in China is larger than its current scale in the United States, and that in South-East Asian economies is 1.4 times more than its current scale in Japan. Despite a slowdown in China's economic growth, it remains the main driver of APEC electricity demand. China remains the largest electricity consumer, expanding its share in APEC from 36% in 2013 to 48% by 2040. South-East Asia increases its share from 6% to 10%; by 2040, the market size of South-East Asia exceeds that of other north-east Asian economies (Hong Kong, Japan, Korea and Chinese Taipei).

Figure 4.2 • Electricity demand in the BAU by regional grouping, 1990-2040

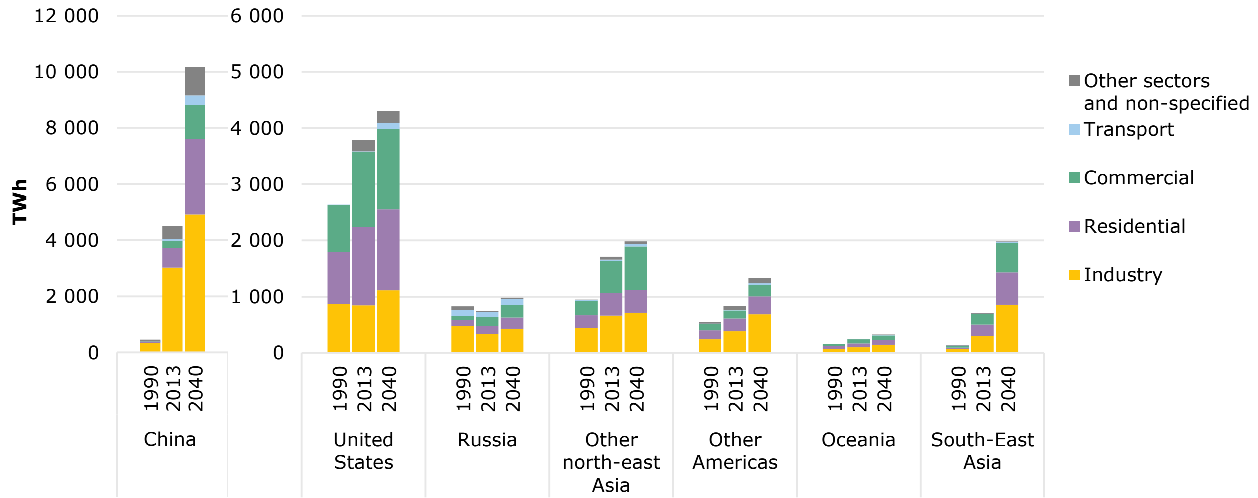


Sources: APERC analysis, IEA (2015a) and EGEDA (2015).

Other Americas are also expected to grow at a high AAGR of 1.7%, driven by Mexico, Chile and Peru. Incremental demand in the United States, Russia and other north-east Asian economies is lower, with a growth rate of 0.5% to 1.0%, mainly because economic and population growth are more modest than in other regions. The three regions' collective share of regional demand falls from half in 2013 to just over one-third in 2040.

[7] This BAU electricity demand is assumed for alternative scenarios, too, except for the Improved Efficiency Scenario.
[8] The growth of China's demand is based on APERC's macroeconomic assumptions, especially gross domestic product (GDP). We assume slowdown of China's GDP growth from currently about 7% per year to 3% by 2040; however, it is important to note that large uncertainties exist in the macroeconomic assumptions, and there is ongoing debate about when and at what level energy demand in China will peak.

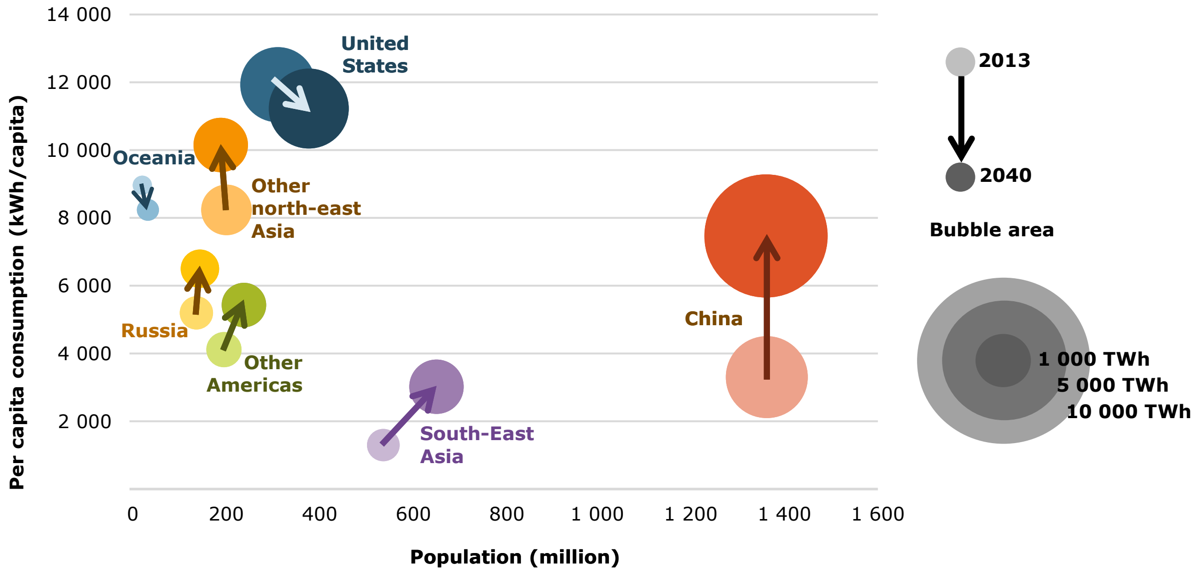
Figure 4.3 • Electricity consumption by regional grouping and by sector, 1990-2040



Note: Data of 'other sectors and non-specified' in the United States in 1990 are not covered in IEA (2015a).
Sources: APERC analysis, IEA (2015a) and EGEDA (2015).

The sector that consumes the most electricity varies across the APEC region (Figure 4.3). In China, the surge of consumption has been driven mainly by industry, reflecting the relocation of industrial facilities to China from mature economies. Over the Outlook period, by contrast, the residential sector shows the largest growth, as increasing urbanisation and rising per capita income allow households and individuals to purchase more electrical appliances. The residential sector's share of demand in China jumps from 15% in 2013 to 25% by 2040. In other regions which include developing economies, such as South-East Asia and other Americas, consumption also grows in the residential sector as well as in the industrial and commercial sectors. In mature economies, such as United States and other north-east Asia, consumption grows mainly in the commercial sector. One reason for the growth in the commercial sector is fuel shifting; for example, energy demand for space and water heating shifts from oil products (such as kerosene for oil heaters) and gas (such as gas for water heaters) to electricity for heat pump facilities. Further penetration of office equipment also pushes up electricity demand in the commercial sector.

Figure 4.4 • Annual electricity consumption per capita by regional grouping, 2013 and 2040



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

In Russia, electricity consumption in industry declined[9] between 1990 and 2013, but is projected to rise by 30% between 2013 and 2040. The sector's consumption decreased by 39% in the 1990s, on average -5.3% per year, because of the economic recession after the breakup of the Soviet Union. Industrial consumption then gradually recovered, rising by 0.6% per year from 2000 to 2013. APERC expects the gradual increase to continue over the Outlook period in most sub-sectors.

Differences in electricity consumption per capita narrows over the Outlook period, but large differences still remain in 2040 because of varying per capita income and economic structure (Figure 4.4). Per capita consumption in China and South-East Asia more than doubles by 2040 as increasing per capita income boosts ownership of electrical appliances. China's consumption grows from 3 300 kilowatt hours per capita (kWh/capita) in 2013 to 7 460 kWh/capita in 2040, exceeding that of Russia (6 500 kWh/capita in 2040). South-East Asia's consumption grows from 1 300 kWh/capita to 3 020 kWh/capita; however, this is still the lowest in the APEC region, implying a large potential for further demand growth even after 2040. Consumption in other north-east Asia reaches 10 000 kWh/capita mainly due to higher penetration of office equipment in the commercial sector, as well as fuel shifts for space and water heating in buildings, as mentioned above in Figure 4.4.

Per capita consumption declines in two APEC economies, Australia and the United States. In the United States, it falls from 11 930 kWh/capita today to 11 220 kWh/capita in 2040, thanks to energy efficiency policies, such as minimum energy performance standards for appliances and equipment in place since 2009, as well as efficiency upgrades in millions of homes arranged by the Department of Energy and the Department of Housing and Urban Development. Australia's consumption is projected to decrease from 8 860 kWh/capita today to 7 590 kWh/capita in 2040, pushing down the Oceania level. Despite economic and population growth over the last few years, electricity demand in Australia has been curbed by energy efficiency measures and surging retail electricity prices.[10] Total demand gradually increases over the projection period, but its growth (0.8%) is lower than population growth (1.4%), resulting in a per capita reduction.

ELECTRICITY SUPPLY

OVERVIEW

The fuel mix for power varies widely across APEC, reflecting the different energy situation in each economy, such as indigenous energy production, economic structure and environmental concerns. APEC economies also differ significantly in the size of their electricity markets; APEC trends are markedly driven by the larger economies. Fossil fuels continue to dominate the power generation mix (Table 4.2). Although fossil fuels' share of total generation decreases by three percentage points between 2010 and 2040, in absolute terms fossil fuel generation increases by more than 70% (+7 000 TWh) to meet rising demand. The incremental fossil fuel generation is split almost evenly between coal and gas. Renewables' share of generation increases from 16% in 2010 to 22% in 2030 and 24% in 2040, thanks to existing decarbonisation policies.

[9] The United States also shows a slight decline in industrial consumption from 1990 to 2013. This is mainly because of a change in the methodology in IEA statistics in 2014. Electricity and natural gas data in the chemicals and petrochemicals industry present a break between 2001 and 2002, resulting in electricity consumption data showing a decline in 2002.

[10] Retail electricity price more than doubled for households in Australia from 2008 to 2014, and increased by 82% for business. Investment in transmission and distribution due to ageing assets pushed up prices (BREE, 2014).

Table 4.2 • Electricity generation by fuel, 2010-40

	Generation (TWh)			Share (%)		
	2010	2030	2040	2010	2030	2040
Fossil fuels	**9 582**	**14 643**	**16 614**	**72**	**67**	**68**
Coal	6 575	9 422	9 963	49	43	41
Gas	2 687	5 154	6 597	20	24	27
Oil	319	67	53	2	0.3	0.2
Nuclear	**1 658**	**2 236**	**2 020**	**12**	**10**	**8**
Renewables	**2 135**	**4 848**	**5 740**	**16**	**22**	**24**
Hydro	1 765	2 778	2 949	13	13	12
Wind	163	1 075	1 444	1	5	6
Solar	10	420	614	0.1	2	3
Geothermal	53	109	131	0.4	0.5	0.5
Biomass and others	145	467	602	1	2	2
Total	**13 375**	**21 727**	**24 374**	**100**	**100**	**100**

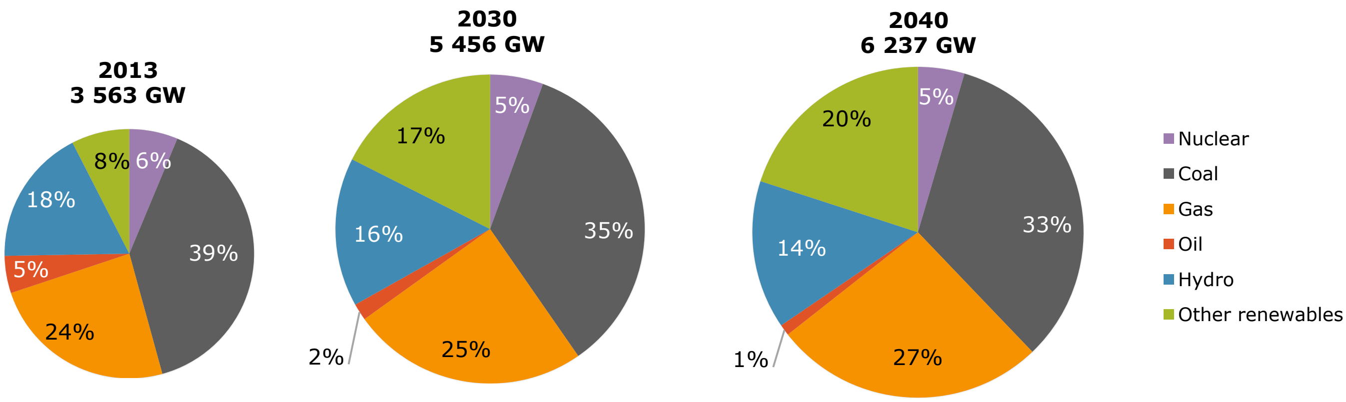
Note: Totals may not be exact due to rounding.
Sources: APERC analysis and IEA (2015a).

POWER GENERATION CAPACITY

APEC installed capacity nearly doubles

To meet rising electricity demand, power-generating capacity in the APEC region increases by 75% (Figure 4.5). APEC installed capacity reaches 6 237 GW in 2040, of which 35% (2 153 GW) is renewable energy, including 1 115 GW of variable renewables (VREs)—wind and solar PV. The renewables capacity expansion in APEC is led by the larger economies, such as China, United States and Japan, due to abundant potential, improved economics and strong policies to promote low-carbon energy. Growth of total installed capacity (+75% from 2013) is larger than that of projected electricity demand (+70%) because of the deployment of VREs, which have lower capacity factors than conventional plants, and because backup capacity is required to balance their variability.

Figure 4.5 • Power generation capacity by fuel, 2013-40



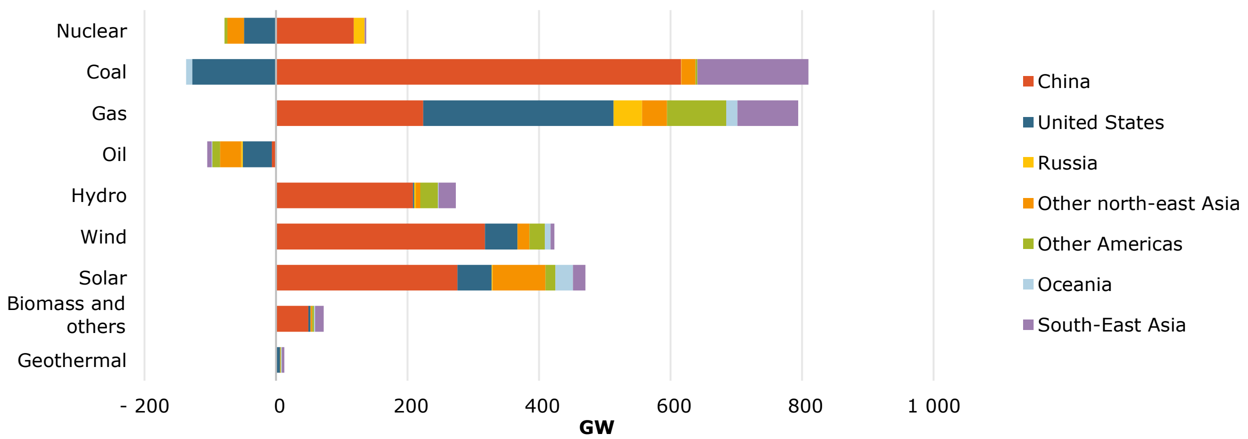
Sources: APERC analysis, Platts (2015), IRENA (2015) and individual economy references (refer to Volume II).

China and the United States together account for about 90% of wind additions, and these two economies together with Japan for 85% of solar in APEC over the Outlook period (Figure 4.6), with China taking the lead. Grid access in China creates challenges for VREs, resulting in a lower capacity factor. China plans to enhance the high-voltage transmission network to resolve geographical demand-supply imbalances and to utilise abundant renewables effectively (State Council, 2013). Such grid enhancements in China help continuous development of VREs, adding 320 GW of wind and 280 GW of solar power, and improve their capacity factor.

VREs in the United States show the second-largest growth. Renewable promotion policies, such as RPSs, FiTs and tax exemptions, support the continuous deployments of wind and solar (each about 50 GW). Solar power also increases rapidly in other north-east Asia, driven mainly by Japan, where the FiT system put in place in 2012 significantly improves investment opportunities for solar PV. Its capacity is projected to increase by more than 70 GW by 2040, accounting for about 90% of new solar additions in other north-east Asia.

While renewables expansion is significant, the reality is that coal- and gas-fired plants still make up the majority of APEC capacity over the Outlook period. Net additions of coal (673 GW) and gas (794 GW) exceed those of wind (420 GW) and solar (470 GW). Capacity is expected to increase for both gas-fired and coal-fired generation; gas-fired plants because of lower emissions and easier siting, coal-fired plants because of their cheap and relatively stable fuel supply. Coal-fired plant expansion is projected mainly in China[11] and South-East Asia, while use of gas-fired plants increases in United States and other Americas, where low-price domestic gas is abundant. Gas also grows in China and South-East Asia in order to increase use of cleaner fuels and for fuel diversity. Although coal still dominates China's new fossil fuel capacity additions according to existing policies (State Council, 2013), its heavy air pollution is pushing the economy towards sources with lower emissions, including natural gas, which reaches 220 GW by 2040. Among South-East Asian economies, Indonesia, the Philippines and Viet Nam increase reliance on coal, whereas Malaysia and Thailand develop gas as well.

Figure 4.6 • Electricity generation capacity changes by regional grouping and by fuel, 2013-2040



Source: APERC analysis.

Although nuclear capacity increases in absolute terms from 220 GW in 2013 to 283 GW by 2040, its share of APEC capacity declines from 6% to 5% because its growth rate is lower than other fuel types. Nuclear capacity grows in China, Korea, Russia and Viet Nam by a combined total of 148 GW over the Outlook period. China continuously expands nuclear power, reaching its target of 58 GW by 2020 (State Council, 2014), and is assumed to add three to four reactors a year on average after 2020 under the BAU Scenario. Russia expands nuclear power by 17 GW, Korea by 11 GW and Viet Nam by 2.4 GW by 2040. However, these additions are partly offset by nuclear retirements (with a total capacity of 78 GW) in several economies, including Canada, Japan, Mexico, Chinese Taipei and the United States, due to current licence expirations, reactor lifetime regulations and reactor owners' plans. The BAU Scenario implies that the current lifetime regulations and retirement plans may result in modest nuclear growth in

[11] This Outlook projects continued coal capacity additions in China to meet the rising electricity demand; however, it is important to note that large uncertainties exist in China's demand outlook (footnote 8) as well as continued additions of coal-fired plants.

APEC. Further new additions or lifetime extensions are necessary for nuclear generation to increase its share in total APEC generation.

Variable renewables reach 30% of APEC peak load

Total capacity of VREs increases from about 220 GW in 2013 to 850 GW by 2030 and 1 120 GW by 2040, when it reaches 30% of peak load in APEC. To integrate VREs while maintaining reliability of electricity supply, each economy needs to prepare sufficient measures to manage short-term variability (in general, less than 20 minutes) and longer-term variability (hourly, daily and seasonally), such as ramping up and down of flexible generation, charging and discharging of storage, demand-side management programs, and curtailments.

Various factors, including daily load curve characteristics and interconnections with neighbouring systems, affect the need for the variability management measures. However, the share of VREs in peak demand provides an approximation of the scale of intermittency and hence of backup measures needed to ensure system adequacy (Figure 4.7). For example, solar PV typically produces 70% to 90% of its capacity during sunny daytime, and its output falls to zero at night. Therefore, an electricity system in which solar PV capacity makes up 50% of peak load needs to absorb diurnal output changes in a ratio to 35% to 45%[12] of peak demand. In systems with daytime peaks, where PV production correlates with peak demand time, daily load curves can absorb a part of the PV output surge during the day, reducing the need for backup measures. By contrast, in systems with flat daytime load and night-time peaks, larger-scale backup may be required to absorb the daytime PV surge and to cover the loss of PV output during peak time. As for diurnal wind variability managements, randomness of wind velocity may always require the electricity systems to prepare a certain level of backup, depending on site-specific conditions of wind turbines.

Total installed capacity of VREs over the Outlook period is highest in China (700 GW), followed by the United States (175 GW) and other north-east Asia (120 GW). In terms of the ratio of VREs to the peak load, Oceania shows the highest, followed by China. Wind holds the majority share of VREs in China and the United States in capacity terms, while solar PV leads VRE penetration in other north-east Asia and in Oceania, reflecting each region’s resource potential, access to transmission and subsidies.

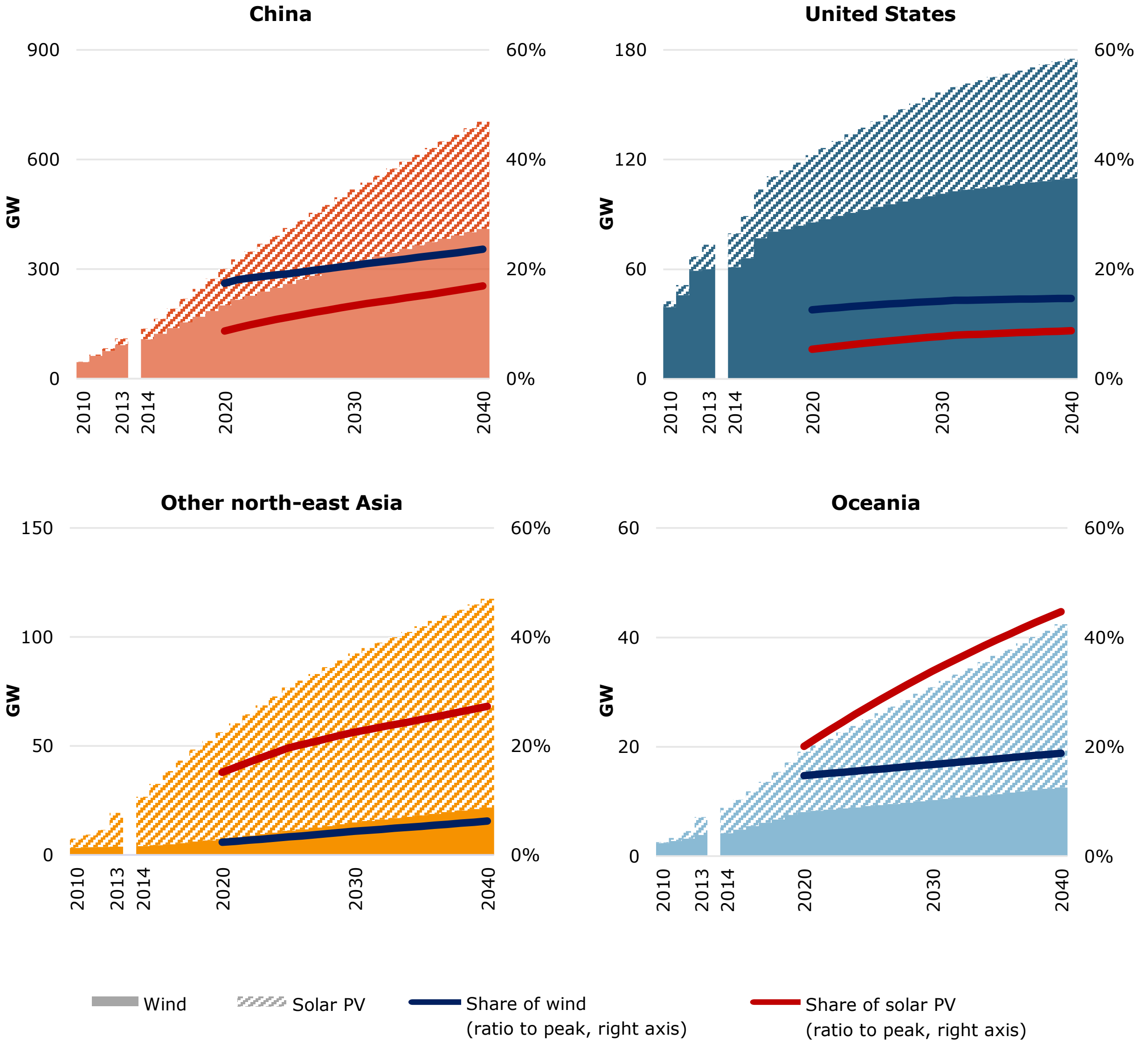
In China, growth of renewables benefits from policy direction, support schemes and infrastructure enhancements, including high-voltage transmission networks. Wind capacity amounts to 410 GW by 2040, or 24% of peak load; solar capacity reaches 290 GW, or 17% of peak load. Both wind and solar power grow in the Unites States, favoured by the cost-competitiveness of wind turbines and residential PV. Tax incentives for wind also push its deployment. Total installation of wind reaches 110 GW, or 15% of peak load; solar capacity reaches 66 GW, or 9% of peak load. The United States is projected to increase the share of gas-fired capacity (see US chapter in Volume II), which provides flexibility to grid operation; however, operation as backup reduces the capacity factor of gas-fired plants. For example, the CCGT capacity factor decreases from about 60% in the 2010s to 40% by 2040. This would reduce profitability of flexible generation, and pose financing challenges to backup generation; in a liberalised market, capacity markets may have a more important role to ensure enough backup capacity for reliable power supply.

Solar PV increases significantly in other north-east Asia to more than one-fourth of peak load, driven by the recent boom in Japan (mainly utility-scale PV due to higher purchase price in the FiT system). It also surges in Oceania, reaching 45% of peak load, led by Australia. The recent trend towards higher deployment of residential PV in Australia is projected to continue as high electricity tariffs make this technology more attractive. As in the United States, existing and newly added flexible generation, such as oil-fired plants in Japan and gas-fired plants in Japan and Australia, help to integrate renewables. In

[12] 50% (solar PV capacity in a ratio to peak) multiplied by 70-90% (diurnal output changes in typical sunny days). Note that location of the PV panel affects the PV output characteristics; for example, many sites contribute to smoothing variability and daytime surge.

Japan, existing pumped hydro storage, which reaches 28 GW by 2030, also plays an important role in balancing demand and supply.

Figure 4.7 • Variable renewables capacity and share in peak load, selected APEC regional groupings, 2010-40



Note: Regional peak load in the figures is calculated as a simple summation of peak load in constituent economies. The figure shows the share of VREs after 2020.
Source: APERC analysis.

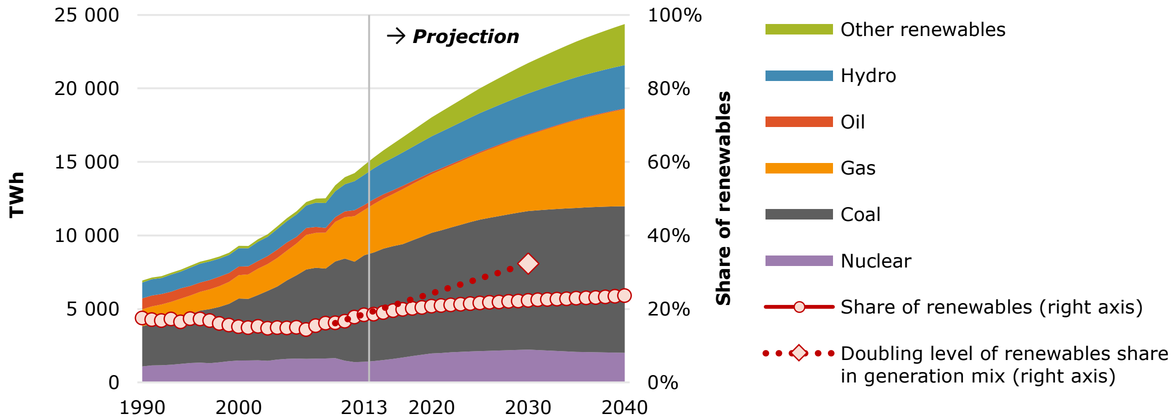
ELECTRICITY GENERATION

Fossil fuels still dominate, but renewables expand significantly

APEC economies are projected to accelerate deployment of low-carbon technologies, but fossil fuels still dominate generation because of the lower capacity factor of renewables and current intentions to add fossil fuel plants (Figure 4.8). Fossil fuels still account for almost 70% of generation in 2040. Although their share of generation declines, coal generation increases in absolute terms by 2 721 TWh (38%) between 2013 and 2040, and gas by 3 510 TWh, more than doubling. Gas generation increases across APEC, while the increase in coal generation is driven mainly by China and South-East Asia. By contrast, oil generation drops from 344 TWh (2% of APEC generation) to 53 TWh in 2040 (0.2%) because of nuclear restarts in Japan, higher fuel costs and ageing of existing facilities.[13] Nuclear's share of APEC generation, around 10% in 2013, slightly declines to 8% by 2040. It peaks around 2030, after which expansion is partly offset by retirements of ageing reactors.

Renewables show the largest growth in generation, rising 2.1 times over the Outlook period, an AAGR of 2.8%. However, APEC economies do not achieve the doubling renewables goal in power generation by 2030 (nor 2040). In order to achieve this goal, economies need to further enhance policies to promote renewable energy. Among renewables, hydro, wind and solar are the major technologies to be deployed under the BAU Scenario. Hydro is expected to remain the largest renewable source, accounting for 12% to 14% of total generation. Wind and solar drive the growth of 'other renewables', reaching 6% (wind) and 3% (solar) of APEC generation by 2040. By contrast, geothermal's share remains modest, about 1%, mainly because its potential scale is smaller than that of wind and solar and because it faces barriers related to environmental regulation.

Figure 4.8 • Electricity generation and share of renewables by fuel, 1990-2040



Sources: IEA (2015a) for historical data; APERC analysis for projections.

Regional generation mix reflects local resource availability and policy direction

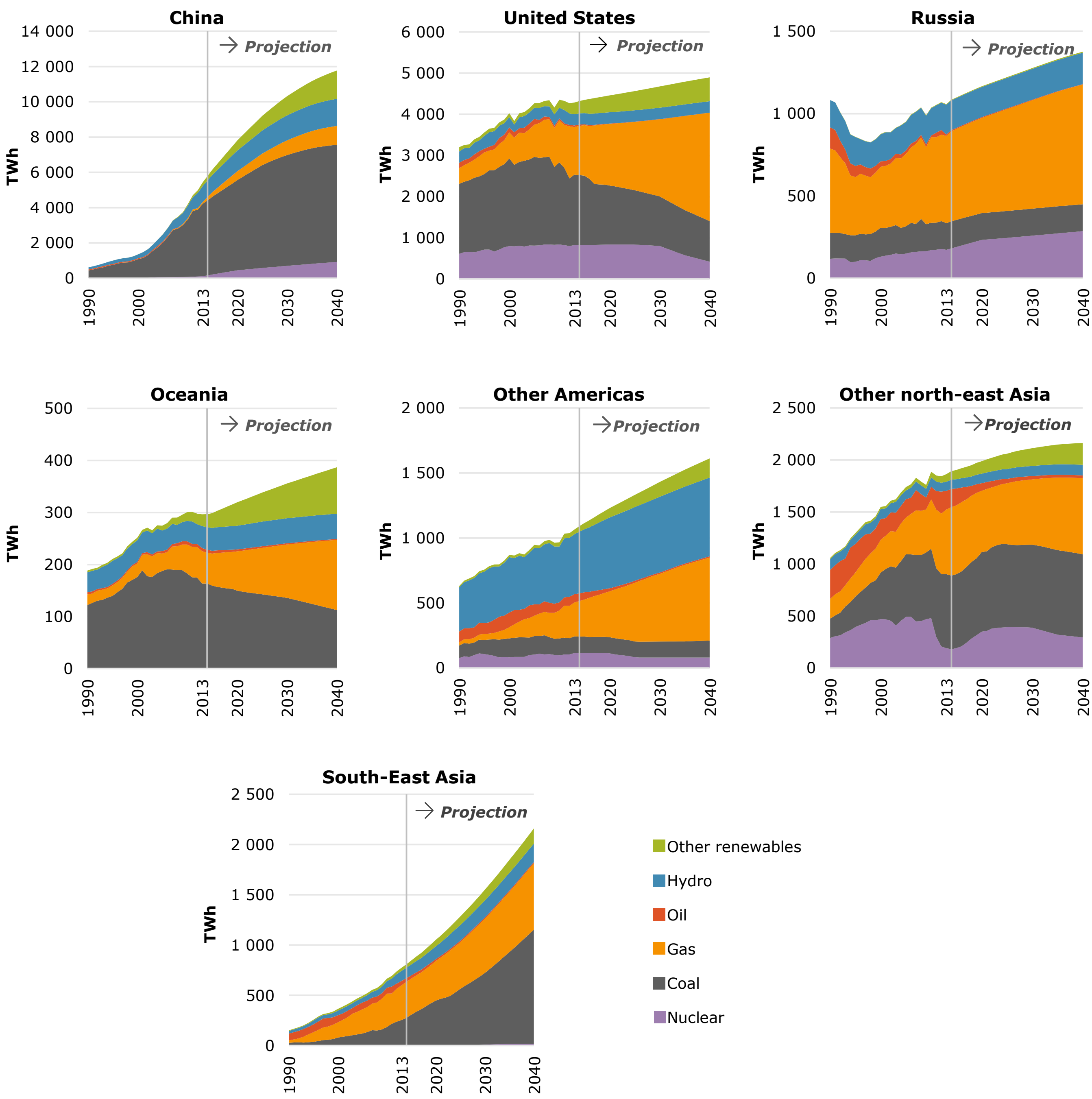
The power generation mix varies significantly across the APEC region, reflecting the direction of energy and environmental policy in different economies, and the availability of local energy resources (Figure 4.9). Coal increases mainly in China and South-East Asia, while gas generation grows in all regions with the exception of Japan because of nuclear restarts. Other north-east Asia, consisting of the economies with limited indigenous energy supply, shows a well-diversified power mix historically and over the Outlook period.

Coal generation still dominates in China, although the economy is pursuing less pollutant fuel, including gas, to mitigate air pollution. Shifting to cleaner generation decreases coal's share from 76% in 2013 to 56% in 2040 and increases non-fossil's share to more than one-third by 2040, but, in absolute terms, coal generation still increases to meet growing demand. This Outlook implies that further policy enhancements are important to curb China's coal generation. In the United States, low-cost domestic gas supply and the improved economics of wind turbines and residential PV help expand gas-fired generation to about 50% and renewables to about 20% of generation by 2040, while coal's share decreases from 40% to 20%. Nuclear generation declines in the 2030s because of retirements of existing reactors after 60 years of operation under the BAU Scenario. In Russia, the generation mix maintains existing trends, relying mainly on gas (50% to 53%) over the projection period. Russia has recently introduced policies promoting renewables; a capacity auction scheme began in 2013 and local content requirements were relaxed in 2015. However, Russia limits new renewable additions in order to control the impacts on

[13] The largest oil-fired generating economy is Japan, accounting for 44% of APEC oil generation in 2013. Oil-based generation largely increased after the earthquake in 2011, from 90 TWh in 2010 to 150 TWh in 2013, to cover the loss of nuclear generation. Electric power companies in Japan (except Okinawa electric power company) operated 33 GW in fiscal year 2013, of which 28 GW is already over 30 years old (METI, 2014).

electricity costs and prices. In addition, there is limited transmission infrastructure linking resources, which are usually in remote areas, far from demand centres, resulting in modest renewables' growth over the Outlook period.

Figure 4.9 • Regional generation mix by fuel, 1990-2040



Sources: APERC analysis and IEA (2015a).

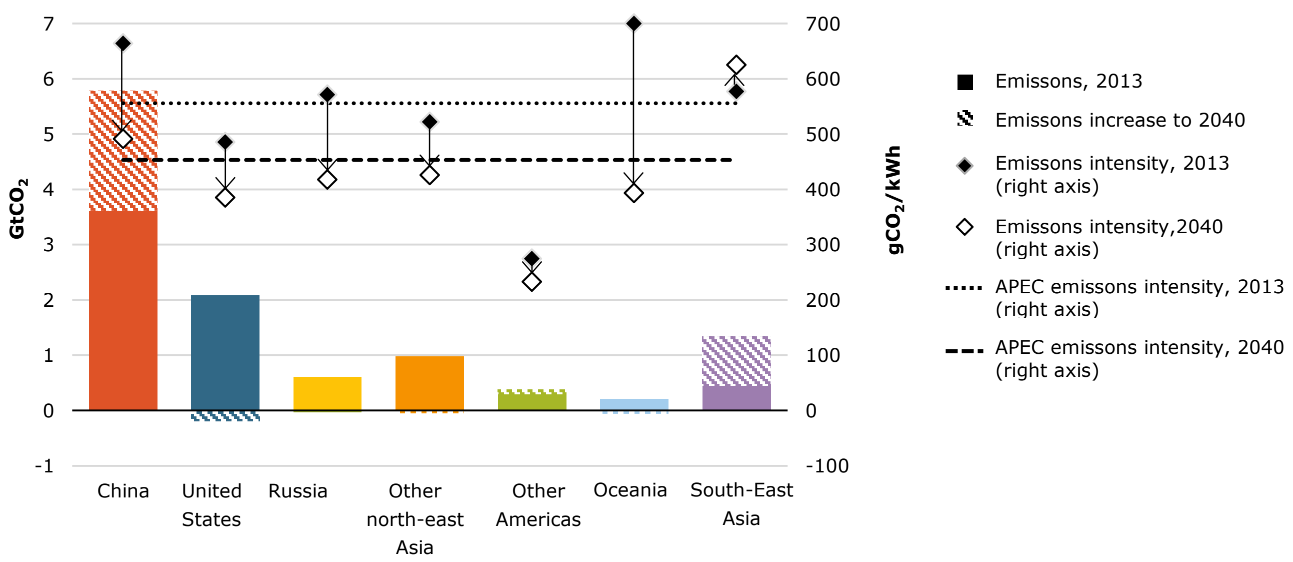
Renewable generation expands in Oceania from 22% in 2013 to 36% in 2040, driven mainly by the surge of residential PV in Australia and by wind power in New Zealand. Fossil fuels in Oceania gradually shift from coal to gas. The largest coal-fired plant in New Zealand is planned to be retired in 2018 (GNE, 2015), and in Australia more gas-fired plants are planned to be added than coal-fired plants (ESAA, 2015). In other Americas, gas-fired generation increases significantly, driven by local resource availability, especially in Canada and Mexico, where gas covers the retirements of nuclear plants. In other north-east Asia, which includes major energy importers such as Japan, Korea and Chinese Taipei, the power mix remains diverse. In 2040, generation is divided among nuclear (14%), coal (37%), gas (34%) and renewables (15%). Expansion of nuclear power in Korea is offset by retirements of plants in Japan and Chinese Taipei, resulting in an overall decline in nuclear generation after 2025. The nuclear retirements in these two economies also result in a larger reliance on fossil fuels, which may pose energy security concerns. South-East Asia also continues to rely on fossil fuels but moves towards coal from gas or oil, mainly because of cheap fuel and remaining local resource availability.

EMISSIONS FROM POWER GENERATION

The BAU Scenario implies that more efforts are needed to build environmentally sustainable energy systems in APEC, especially in China and South-East Asia. APEC emissions intensity improves from 556 gCO_2/kWh in 2013 to 453 gCO_2/kWh by 2040 as renewables and gas increase their share. Nevertheless, annual emissions from generation are projected to increase by 34%, from 8 gigatonnes of CO_2 ($GtCO_2$) in 2013 to 11 $GtCO_2$ in 2040, as coal- and gas-fired generation continues to rise.

Annual emissions surge, mainly in China (by 2.2 $GtCO_2$) and South-East Asia (0.9 $GtCO_2$) (Figure 4.10). The sum of annual emissions in these two regions reaches 60% of APEC emissions in 2040. Although China shows the largest decline in emissions intensity, from 660 gCO_2/kWh to 490 gCO_2/kWh, growing electricity demand results in emissions rising to a level more than double that of the United States in 2040. South-East Asia is the only region in which emissions intensity increases. The region's absolute emissions approximately triple because of surging demand and increasing reliance on coal, whose generation share rises from about 30% in 2013 to 50% by 2040.

Figure 4.10 • Annual CO_2 emissions and emissions intensity by regional grouping, 2013-40



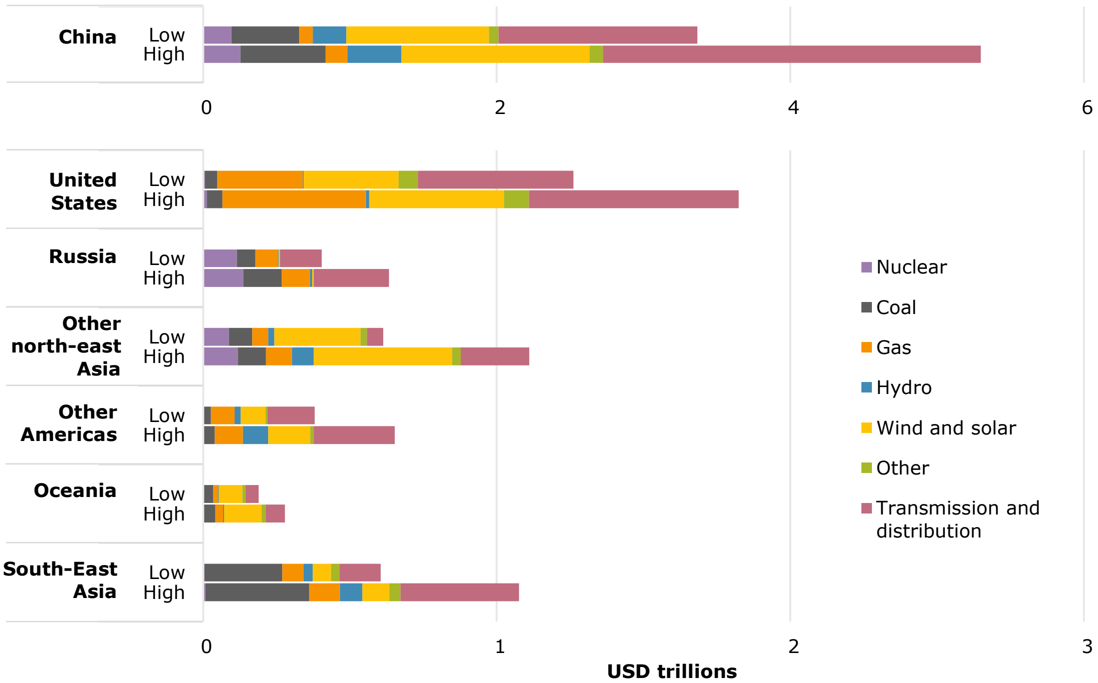
Sources: APERC analysis, IEA (2015a) and EGEDA (2015).

In contrast, annual emissions decline over the Outlook period in four regions, even in the BAU Scenario: the United States (-9%), Russia (-5%), Oceania (-26%) and other north-east Asia (-5%). All are developed economies (except for Papua New Guinea, in Oceania) with modest demand growth (less than 1.0% in AAGR) and policies to deploy lower-carbon technology. In the United States, fuel shifts from coal to gas as well as renewables growth reduce CO_2 emissions from power generation. The United States shows the largest reductions in absolute terms across the region (-0.2 $GtCO_2$ from 2013 level). In Russia, 17 GW of net additions of nuclear power reduce emissions. In Oceania, higher deployment of gas-fired and renewables, such as residential PV in Australia and wind in New Zealand, result in the emissions reductions. In other north-east Asia, renewables development and nuclear restart in Japan as well as nuclear additions in Korea curb emissions. Despite the nuclear retirements in Japan, nuclear generation in 2040 (84 TWh from 14 GW) is still much higher than in 2013 (9 TWh with total 44 GW capacity) because of nuclear shutdowns after the Great East Japan Earthquake.

INVESTMENT

To ensure a stable electricity supply, APEC economies have to secure huge investments over the projection period, ranging from USD 4.4 trillion[14] (low-cost estimate) to USD 6.4 trillion (high-cost estimate) for power generating facilities and from USD 2.4 trillion to USD 4.5 trillion for transmission and distribution (T&D) networks (Figure 4.11). China accounts for about half of APEC total investments both in low- and high-cost estimates (USD 3.4-5.3 trillion), due to its market size and growth. Regions with mature economies, such as the United States and other north-east Asia, also offer large investment opportunities because of their need to replace ageing power plants, acceleration of renewables and the higher investment costs per unit of capacity. The second-largest investments are in the United States (USD 1.3-1.8 trillion), followed by other north-east Asia and South-East Asia (USD 0.6-1.1 trillion in each region).

Figure 4.11 • Cumulative investment in the electricity sector by regional grouping, 2040



Notes: Low = low-cost estimate; High = high-cost estimate; 'Other' includes oil, geothermal, biomass and marine.
Source: APERC analysis.

Renewables attract the majority of investments, reaching USD 2.3-3.5 trillion, or about half of total investments for power plants across APEC. Renewables' share in regional power plant investments exceeds half in all regions, except for Russia and South-East Asia. Investments for fossil fuel-fired plants vary from region to region, reflecting differing energy resources and policy direction. The United States and other Americas invest mainly in gas; China and South-East Asia in coal; and Russia, other north-east Asia and Oceania in both gas and coal. Under the BAU Scenario, the major nuclear market would be China, followed by Russia and other north-east Asia (mainly Korea). Investments for nuclear power are estimated to be USD 0.4-0.5 trillion across the APEC region. The share of T&D tends to be larger in economies with vast land areas and widely distributed demand centres. T&D accounts for less than one-

[14] Unless otherwise indicated, references to costs and investments are expressed in 2012 USD PPP (purchasing power parity).

fourth of total power investments in other north-east Asia and Oceania but about 40% to 50% in China, the United States and other Americas (mainly because of Canada).

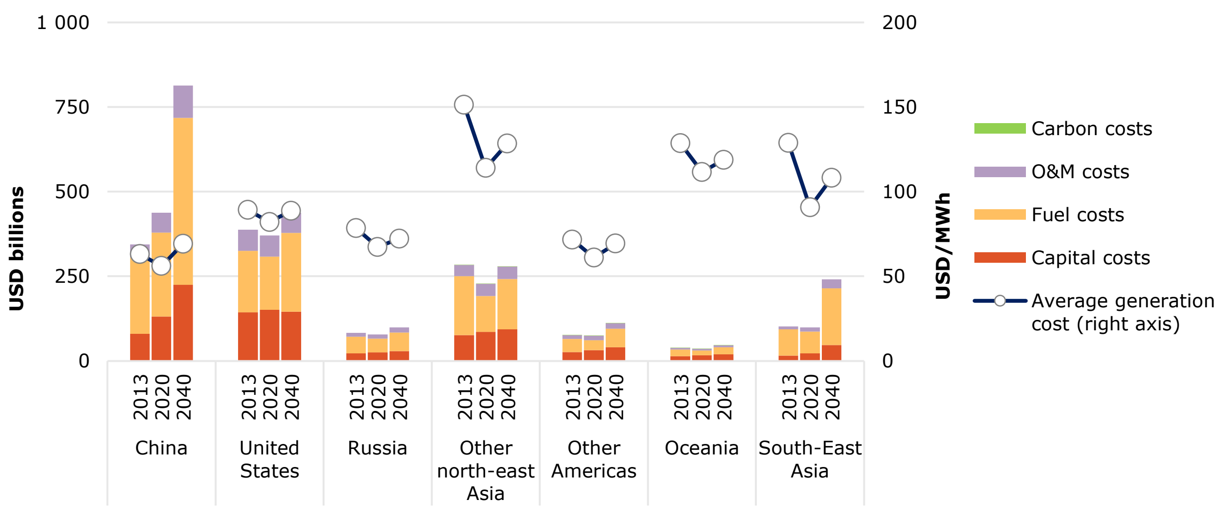
GENERATION COST

Overall generation cost in this Outlook comprises capital costs (defined as annual payments to recover initial investments and decommissioning costs[15]) for both existing and new power plants, fuel costs, and O&M costs (Figure 4.12). Each cost component reflects regional factors such as resource availability, technological developments, and energy and environmental policy direction. Under the BAU Scenario, the carbon penalty for fossil fuel combustion is considered in the economies where carbon penalties have been or will be implemented on the power-generating process during the Outlook period, such as Australia (from 2012 to 2014), Japan and New Zealand (DOE of Australia, 2014; MOE of Japan, 2012; MfE of New Zealand, 2008). Average generation cost, estimated by dividing total annual cost by annual generation, provides the basis for the wholesale electricity price in competitive and price-regulated markets (IEA, 2014b).

Changes in energy prices drive power generation cost trends. The total annual costs of power generation in APEC remain at USD 1.3 trillion from 2013 to 2020, then rise to USD 2 trillion in 2040. The average annual cost declines from the current USD 88 per megawatt-hour (MWh) to USD 73/MWh in 2020, then increases to USD 83/MWh by 2040. The reduction from now to 2020 is mainly due to energy price drops since mid-2014. APERC analysis assumes that crude oil prices continue to decrease until around 2020 and then gradually increase (see Annex I for energy price assumptions). The midterm fall in energy prices reduces fuel costs across APEC, but the impact differs region by region. In the longer term, gradually rising energy prices push up fuel costs, and the deployment of capital-intensive renewables increases capital costs as well.

In China, due to its expanding market, total annual cost more than doubles from USD 340 billion in 2013 to USD 810 billion in 2040. The economy continues to rely on low-cost coal generation for the majority share, and the average cost remains lower than the APEC average, at USD 56/MWh in 2020 and USD 69/MWh in 2040. Due to the predominance of fossil generation, fuel costs hold the majority share of China's generation cost structure over the Outlook period; capital costs account for 20% to 30%, fuel costs for around 60% and O&M costs for about 10%.

Figure 4.12 • Total generation cost and average generation cost by regional grouping, 2013-40



Note: Carbon costs are fractional because only a few economies implement carbon taxes and tax rates are low.
Source: APERC analysis.

[15] We refer to IEA analysis and economies' analysis for decomissioning costs (see IEA [2015b] and METI [2015]).

In other north-east Asia and South-East Asia, average generation costs decline by 25% to 30% from the current level to 2020, mainly because of fuel cost reductions driven by lower energy prices. Major economies in these regions link natural gas pricing to crude oil prices, so crude oil price drops since mid-2014 largely reduce fuel costs for gas-based generation. Increasing cheaper coal or nuclear generation also contributes to curbing average generation costs. The share of generation using higher-cost fuels, such as oil and gas, decreases from 43% to 33% by 2020 in other north-east Asia and from 50% to 39% in South-East Asia. These shifts are due to nuclear restart in Japan, nuclear installation in Korea and an increasing share of coal-fired generation in South-East Asian economies, except for Brunei Darussalam and Singapore. In the longer term, increasing energy prices gradually push up fuel costs in both regions; however, average generation costs in 2040, especially the fuel cost component, are expected to be even lower than current levels. In other north-east Asia, this is mainly because of the elimination of oil-fired generation and lower gas prices compared with 2013. In South-East Asia, the expansion of low-cost coal generation curbs generation costs. The BAU Scenario takes into account Japan's carbon tax, but the low level of this tax means it does not significantly affect the power generation cost structure.[16]

In the United States, Russia and other Americas, by contrast, average generating costs are stable. As these regions consist of large energy-producing economies, average generation costs are less sensitive to the midterm energy market trend than in the major importing regions, such as other north-east Asia. The cost structure of the United States from 2020 to 2040 shows a jump in fuel costs combined with a slight decline in investment costs due to nuclear retirements in 2030s; additional gas consumption to cover these retirements; and increasing gas production costs in these economies.

APEC NEEDS TO FURTHER ACCELERATE RENEWABLES IN POWER GENERATION

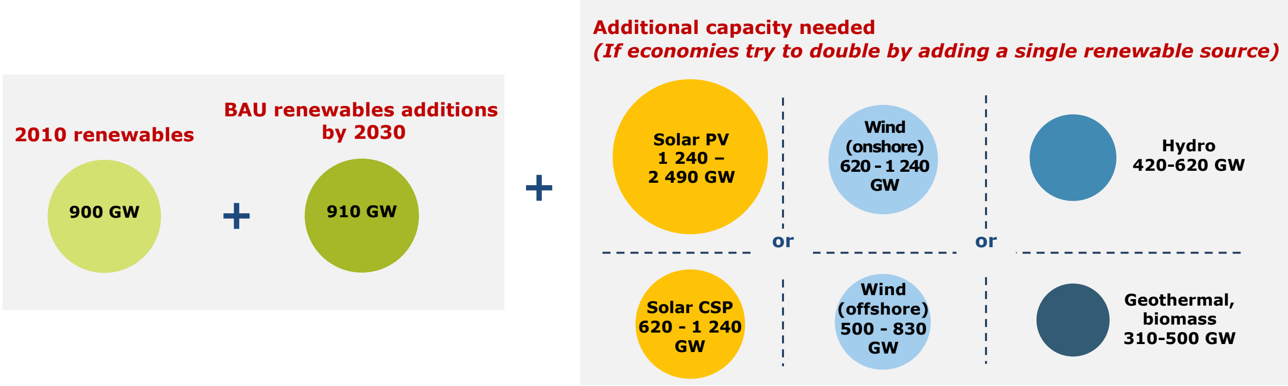
Renewables' share of the power generation rises from 16% in 2010 to 22% by 2030, but this is well below the doubling level of 32%.[17] The goal is not achieved even by 2040, when renewables' share reaches only 24%, so policies promoting renewable energy need to be strengthened in the APEC region.

Substantial amounts of capacity need to be added to double renewables' share in the electricity sector. Under the BAU Scenario, total APEC renewables capacity jumps from 900 GW in 2010 to 1 810 GW by 2030. APERC estimated the additional renewables capacity needs if economies try to double by adding a single renewable source (Figure 4.13). The estimated additional capacity ranges from 310 GW to 2 490 GW, depending on the capacity factor of the renewables added, which is assumed to range from 80% to 10%. This estimation does not take into account losses through storage or through curtailments to stabilise the grid. If such losses are considered, even more installed capacity would be needed to achieve a doubling.

If the additional renewables are mainly solar PV or onshore wind, which are easier to deploy but have lower capacity factors (10% to 20% for solar PV and 20% to 40% for onshore wind), a further 620 GW to 2 490 GW is needed. These additional renewables would require APEC to significantly enhance renewables policies, given the total renewables development by 2030 in the BAU Scenario (total +910 GW, of which 630 GW is VREs). On the other hand, the additional capacity can be reduced to 310 GW to 620 GW if the economies prioritise higher capacity factor renewables, such as hydro, biomass and geothermal. However, in general, these renewables face resource limits (smaller potential compared with solar and wind energy), economic challenges (such as high feedstock costs for biomass) and siting constraints (such as environmental regulations around hydro and geothermal resource location). APEC economies need to consider how to develop renewables in an economically and environmentally sustainable manner, considering these challenges.

[16] For example, JPY 289 per tonne of CO_2 from April 2016 (MOE of Japan, 2012).
[17] This chapter focuses on renewables only in the power generation; comprehensive discussions about the APEC doubling renewables goal are in Chapter 6.

Figure 4.13 • Minimum additional renewables capacity needed to meet doubling target in power generation mix, 2013-30



Note: Assumptions for capacity factor are as follows: 10%-20% for solar PV, 20%-40% for solar CSP and onshore wind, 30%-50% for offshore wind, 40%-60% for hydro, and 50%-80% for geothermal and biomass. This calculation does not take into account each resource potential in APEC.

Source: APERC analysis.

RECOMMENDATIONS FOR POLICY ACTION

APEC economies have implemented various policies and plans aimed at decarbonising their electricity systems and making them more efficient. According to the BAU Scenario, however, these policies are insufficient to achieve environmentally sustainable electricity systems. APEC economies need to strengthen policies aimed at curbing electricity consumption, such as promoting energy efficiency and conservation measures on the demand side, not only within each economy but also through cooperation between developed and developing economies.

The APEC region also needs stronger policies to accelerate deployment of lower-carbon technologies, such as renewables, cleaner coal and nuclear. The BAU Scenario implies that renewables developments are not enough to support the APEC doubling renewables goal. Economies should promote renewables by strengthening support schemes such as FiTs in an economically reasonable manner; by facilitating siting and licensing procedures (e.g., environmental regulation for geothermal developments); and by developing and introducing measures and technologies to support adoption of intermittent renewables (see also Chapter 6). The level of deployment of VREs should be taken into consideration when designing policies aimed at promoting them. As for nuclear, the current lifetime regulations and retirement plans may result in modest growth in APEC. Further new additions or lifetime extensions are necessary for nuclear generation to hold or increase its share in APEC power generation.

Economies need to secure huge investments in order to ensure stable electricity supply. Developing economies have an enormous need for investment to meet growing demand; mature economies are also projected to need large investments to deploy renewables and replace ageing plants and networks. Financing for T&D is also important, especially in economies with large land areas and widely distributed demand centres, such as Canada, China and United States, where T&D account for half of total power investments.

5. IMPROVED EFFICIENCY SCENARIO

KEY FINDINGS

- **Policy measures taken in the Improved Efficiency Scenario cause APEC's energy demand to peak by 2029; by 2040, demand is 13% lower than in the BAU.** This is a saving of 921 Mtoe, equivalent to the combined consumption of Russia, Japan and Korea in 2013.

- **With the largest energy demand growth, China has the largest saving potential:** it delivers 43% of total APEC savings from extending its focus on energy efficiency for large energy consumers to less intensive industries.

- **Industry provides the largest share—40% or 372 Mtoe—of demand reduction compared with the BAU**. Promotion and support mechanisms for the adoption of best available technologies are key to achieve this result.

- **Fuel efficiency standards for light- and heavy-duty vehicles are essential to achieve the savings potential in transport.** Their implementation delivers a 15% reduction in demand compared with the BAU, largely from light-duty vehicles.

- **Buildings save 279 Mtoe (13%) from the BAU with the implementation of minimum energy performance standards and building envelope improvements.** Heating and cooling device standards are particularly important.

- **APEC achieves its energy intensity target by 2032 under this scenario, and is 49% lower than the 2005 level by 2035.** Additional efficiency potential gives APEC an opportunity to aim for a more ambitious target.

INTRODUCTION

Energy efficiency is one of the most cost-effective tools economies in the Asia-Pacific Economic Cooperation (APEC) can apply to reduce energy demand and realise associated benefits such as emissions reductions and improved energy security. The International Energy Agency (IEA) estimates that energy efficiency measures undertaken by 11 of its member countries[1] since the 1970s led to energy savings of 1 337 million tonnes of oil equivalent (Mtoe) (IEA, 2014a).

To acknowledge the importance of energy efficiency and encourage its progress, APEC Leaders agreed in 2007 on an aspirational goal to reduce the energy intensity[2] of the region by 25% by 2035 (compared with 2005). As it became apparent this target would be achieved early, in 2011 APEC Leaders set a more ambitious goal of 45% reduction in energy intensity (over the same time frame) (APEC, 2011).

While Chapter 2 discusses progress towards this target, this chapter explores a more aggressive Improved Efficiency Scenario, in which strategic policy intervention drives the adoption of commercially available options in all sectors. The key areas include the adoption of best available technologies (BATs) and practices in industry; appliance efficiency and building envelope improvements in buildings; and road fleet fuel efficiency and urban planning in the transport sector. It is of note that while energy intensity is not a true measure of energy efficiency (which is more appropriate at an end-use or activity level), it is used as a proxy to help facilitate a regional goal and encourage action on energy efficiency. In the Business-as-Usual (BAU) Scenario, policies implemented across APEC lead to a 42% energy intensity reduction by 2035 (compared with 2005)—even as energy demand increases with population growth, rising incomes and overall economic growth. More action, however, is required to meet the 45% target.

Measures considered in the Improved Efficiency Scenario result in an energy demand reduction of 735 Mtoe (11%) by 2035 and 921 Mtoe (13%) by 2040 compared with the BAU. These savings translate into an energy intensity reduction of 49% by 2035 and 56% by 2040, suggesting that significant cost-effective opportunity exists for APEC to boost its energy intensity target even further.

APEC's total energy demand under the Improved Efficiency Scenario still grows compared with current levels, but unlike the BAU Scenario, demand peaks at 6 256 Mtoe in 2028 as the additional energy efficiency policies enable APEC to decouple economic and population growth from energy demand. This is significant, as in the BAU energy demand continues to grow throughout the period, with its associated costs, emissions and security issues.

Table 5.1 • Final energy demand and intensity reductions in the BAU and Improved Efficiency Scenarios, 2005-40

	2005	2013	2025	2035	2040
Total demand BAU (Mtoe)	4 425	5 292	6 561	6 921	7 000
Total demand Improved Efficiency (Mtoe)	4 425	5 292	6 250	6 186	6 080
Intensity reduction (%)	-	-11	-31	-49	-56

Sources: APERC analysis and IEA (2015a).

IMPROVED EFFICIENCY SCENARIO

The Improved Efficiency Scenario was conceived to explore energy efficiency opportunities in APEC economies to help APEC meet its intensity target. However, as this target will be almost met under the

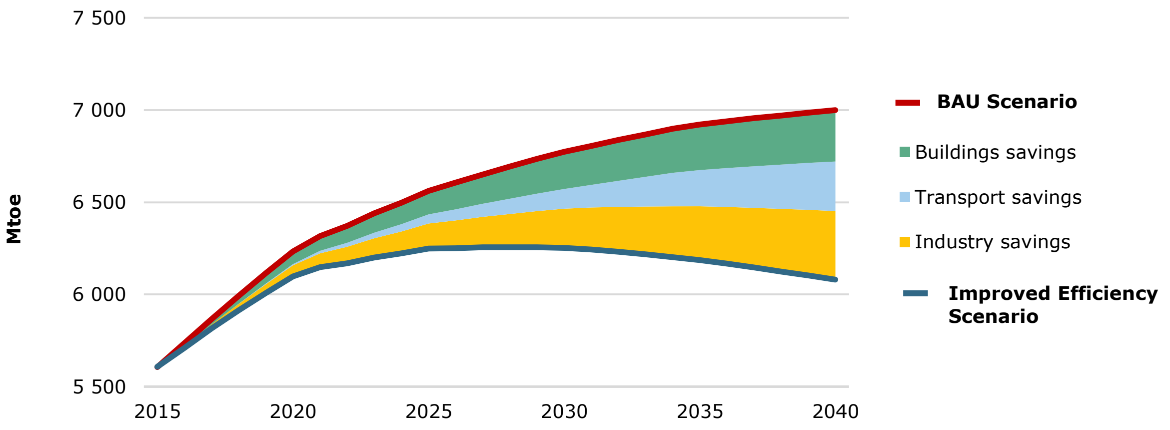
[1] Australia, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Sweden, United Kingdom and the United States.
[2] Energy intensity is calculated as the tonnes of oil equivalent (toe) of final energy demand per gross domestic product (GDP), calculated using 2012 USD million PPP (purchasing power parity).

BAU Scenario (based on existing policies and current trends), the objective changed to assess the potential savings that can be obtained from implementing energy efficiency measures that are cost-effective today in all sectors.

The Asia Pacific Energy Research Centre (APERC) estimates final energy demand in APEC through three separate models, one for each sector: transport, industry, and buildings.[3] The results are then collated to obtain a final overall result.

Measures highlighted in this chapter are already in place, in one way or another, in several APEC economies; many could be applied cost-effectively across more economies or tightened where they are in place to further improve energy savings. The Improved Efficiency Scenario shows the substantial potential to reduce energy demand in APEC through measures such as expanding and updating minimum energy performance standards (MEPS) in buildings (i.e. appliances and equipment), implementing fuel efficiency standards in transport, and regulating energy management practices in industry.

Figure 5.1 • Energy savings in the Improved Efficiency Scenario by sector, 2015-40



Source: APERC analysis.

The Improved Efficiency Scenario estimates energy efficiency gains of 921 Mtoe over the BAU by 2040, an overall decrease in final energy demand of 13%. This is roughly equivalent to the combined energy demand of Russia, Japan, and Korea in 2013. As the modelling does not include all end-uses for buildings (e.g. computers and home entertainment systems are not included) or all sub-sectors (agriculture is excluded and only energy use for road transport was evaluated in the transport sector), the results are conservative: savings would increase if all end-uses were included.

Industry delivers the largest share of energy savings, contributing 40%—over half of which come from China. Transport delivers a 29% share, of which China accounts for 31% and the United States for 24%. Buildings account for the remaining 30%, with China again making the largest contribution (41%).

Total energy demand peaks in 2028 at 6 256 Mtoe in this scenario, thereafter decreasing continuously until the end of the Outlook period. Total energy demand in 2040 is 6 080 Mtoe, a 3% decrease from the 2028 peak. Despite this progress in efficiency, final energy demand increases and is 15% higher than in 2013 at the end of the Outlook period.

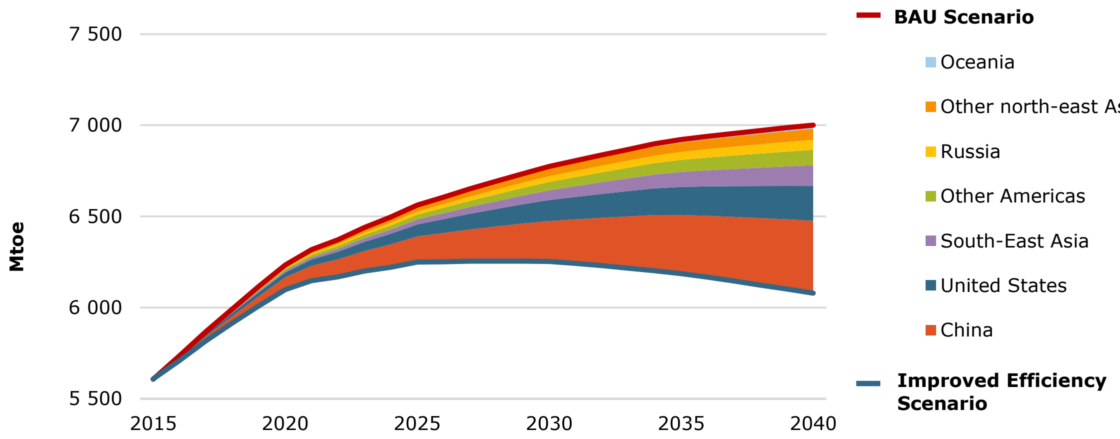
China and the United States dominate energy savings in all sectors due to the size of their economies and their shares—approximately two-thirds—of final energy demand through the Outlook period. By 2040, these two economies combined represent 64% of all savings (i.e. in line with their proportion of demand).

[3] Agriculture is included in the buildings model and non-energy in the industrial model.

The difference is that energy savings in China come primarily from industry (50%) while buildings dominate in the United States (38%).

South-East Asia makes a significant contribution (12%) to total energy savings as it is the fastest-growing region. The savings come largely from transport (47%), followed by industry (31%) and buildings (22%). The remaining regions (Russia, other Americas, Oceania and other north-east Asia) account for 24% of the savings, although different sectors dominate in different regions.

Figure 5.2 • Energy savings in the Improved Efficiency Scenario by regional grouping, 2015-40

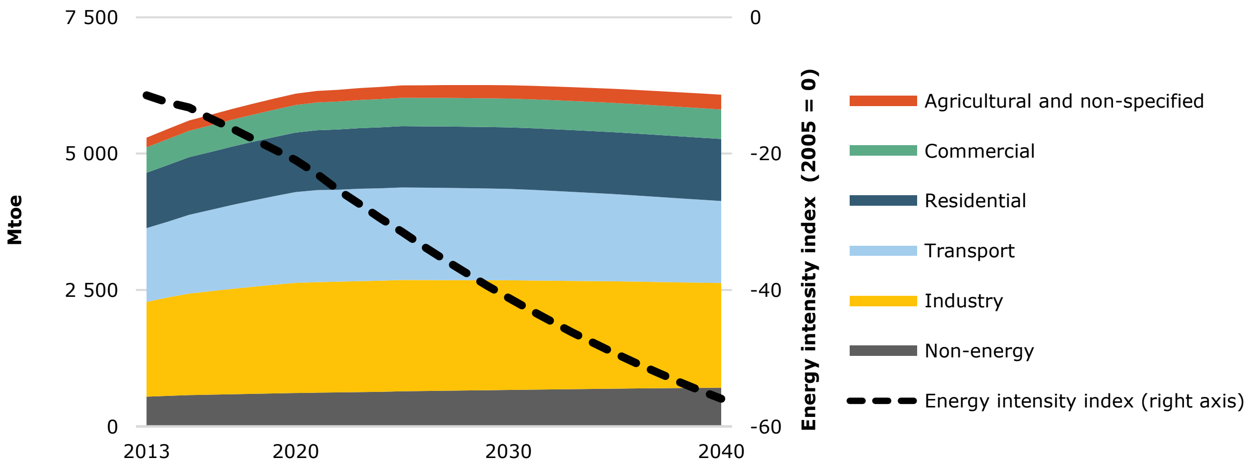


Source: APERC analysis.

Despite these efforts, APEC energy demand rises by 787 Mtoe over the Outlook period (a 15% increase on 2013) as economies continue to grow and develop. The challenge is particularly evident in economies that begin the period with a low consumption level but have high growth rates for the economy and population. In Peru, for example, economic growth pushes per-capita income from USD 11 000 to USD 25 000 over the Outlook period while the population increases by 23%; in combination, this causes energy demand to explode from 17 Mtoe in 2013 to 48 Mtoe in 2040 in the BAU. Similar growth is seen in economies of South-East Asia.

ENERGY INTENSITY TARGET PROGRESS

Figure 5.3 • Final energy demand by sector in the Improved Efficiency Scenario, 2013-40



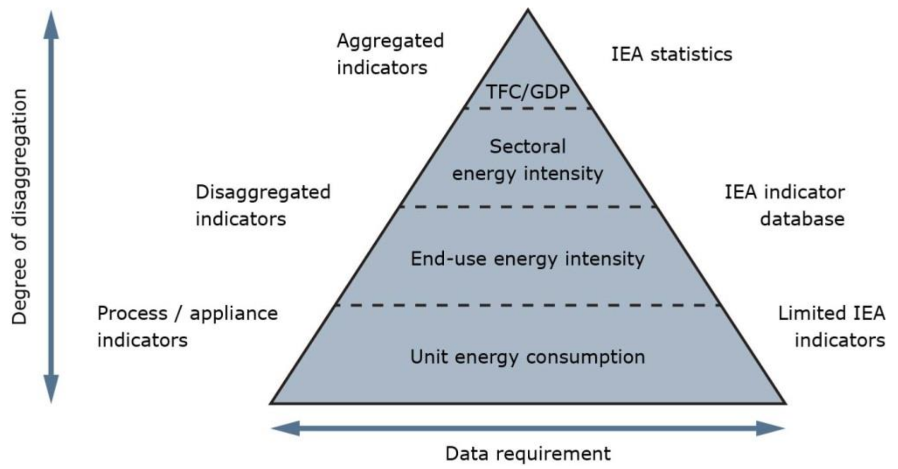
Sources: APERC analysis and IEA (2015a).

The 921 Mtoe of energy demand reduction estimated in the Improved Efficiency Scenario enables APEC to surpass the energy intensity target by a significant margin. In the BAU, APEC achieves a 42% reduction of intensity by 2035 compared with 2005; the cost-effective energy efficiency measures undertaken in the Improved Efficiency Scenario enable APEC to meet its 45% reduction target by 2032 and deliver a reduction of 56% by 2040.

Energy intensity is used for this target instead, as energy efficiency indicators are very data-intensive and better applied at a sector or individual process level. Intensity has several drawbacks, however, including its inability to distinguish between actual efficiency and structural changes that occur 'naturally' as an economy develops, such as activity migrating away from energy-intensive manufacturing towards services industries, which are significantly less energy-intensive.

The IEA describes a hierarchy of energy efficiency indicators, with each level providing a higher level of detail but also having higher data requirements (Figure 5.4).

Figure 5.4 • Pyramid of energy efficiency indicators



Notes: TFC = total final consumption; GDP = gross domestic product
Source: IEA (2014c).

Energy intensity, as discussed in this publication, sits at the top of the pyramid: it has a minimum level of data requirements and is often used as a proxy measure to monitor energy efficiency changes in an economy. While useful as a domestic level indicator, energy intensity has numerous drawbacks. Observation of a change, for example, does not reveal whether the change is due to efficiency measures, fuel switching or, most importantly, structural change in the economy. The latter case is likely for many APEC economies over the Outlook period. Of the numbers provided above, a significant proportion of this change likely occurs naturally as economies evolve and move towards the services sectors, which need much less energy to produce each unit of GDP.

The lower levels of the pyramid show increasingly detailed breakdowns of energy consumption, ending with units of energy consumed by an individual sub-sector, process or appliance. Energy efficiency in the cement industry, for example, could be measured as the energy required to produce a tonne of clinker (a key energy-intensive component in cement), but in agriculture different amounts of energy are needed to produce grain, fruits or vegetables or to bring livestock products to market. While data can be aggregated on a sectoral basis, obtaining the data in the first place is still difficult. Additionally, sectoral composition varies from economy to economy, affecting the overall energy intensity.

This specificity of detail, coupled with the fact that not all indicators are relevant or a high priority for all economies, makes it impossible to produce a suite of energy efficiency indicators for many economies in the APEC region (or to warrant the significant resources, both in time and funds, required to produce an extensive suite of energy efficiency indicators). A more suitable approach may be to have each economy identify areas of high priority and collect relevant data; this would balance the need for information and opportunity for action with the resources required for data collection. A summary of indicators taken from the IEA manual for developing energy efficiency indicators shows the types of data that may be useful domestically or regionally (IEA, 2014b) (Table 5.2).

Table 5.2 • Recommended energy efficiency indicators by sector and end-use

	End-use	Indicator	Key data
Residential	Space heating	Energy use per floor area heated	• Heating energy use • Floor area heated
	Space cooling	Energy use per floor area cooled	• Cooling energy use • Floor area cooled
	Water heating	Energy use per dwelling	• Water heating energy use • Total number of dwellings
	Lighting	Energy use per dwelling	• Lighting energy use • Total number of dwellings
	Cooking	Energy use per dwelling	• Cooking energy use • Total number of dwellings
	Appliances	Energy use per type of appliance	• Appliance energy use • Number of appliances
Services	Space heating	Energy use per floor area heated	• Heating energy use • Floor area heated
	Space cooling	Energy use per floor area cooled	• Cooling energy use • Floor area cooled
	Water heating	Energy use per unit of activity (GDP)	• Water heating energy use • Unit of activity (GDP)
	Lighting	Energy use per unit of activity	• Lighting energy use • Unit of activity
	Other equipment	Energy use by category	• Other equipment energy use • Number of appliances
Industry	N/A	Energy use per unit of output by sector	• Energy use • Total output
	N/A	Energy use per unit of value added by sector	• Energy use • Total value added
Transport	Passenger transport	Energy use per passenger km travelled by mode	• Energy use • Passenger km travelled
	Freight transport	Energy use per tonne km travelled by mode	• Energy use • Tonne km travelled

Source: IEA (2014b).

An economy can use these indicators to better understand energy use in its main sectors or to compare its own performance against other economies and identify energy efficiency opportunities. The indicators can also be used to track changes over time and thus to assess whether policies implemented are proving effective. The above indicators are only a starting point; as economies target specific areas of energy consumption, it will be necessary to delve deeper into these sectors. To evaluate the potential savings and impact of incentives to stimulate deployment of efficient electric motors, for example, governments will need data on the market penetration of electric motors and their energy consumption.

To identify opportunities for energy efficiency improvements and implement more effective strategies and policies, APEC economies should prioritise the development of energy efficiency indicators and collection of relevant end-use data. This will enable economies to address their energy intensity objectives more effectively and achieve better results.

INDUSTRY ENERGY EFFICIENCY POTENTIAL

Industry is the largest energy demand sector in APEC, consuming 33% of energy in 2013 and accounting for 32% of demand growth in the BAU. Energy efficiency policy can be a challenge in industry due to the heterogeneity of activities and, in many cases, the uniqueness or scale of activities. Technologies for cement, steel and food product manufacturing, for example, are markedly different. Some technologies, however, are common to several sub-sectors and use significant amounts of energy, notably industrial boilers and electric motors.

Given these differences, varying policy approaches have been used in the industrial sector, for example: stimulating sub-sectors or companies to adopt BATs and practices through energy audits; launching campaigns that improve levels of information and awareness of potential savings; setting overall savings targets for sub-sectors; and creating incentives schemes that make energy efficiency investment more attractive to companies. Alternatively, some economies are encouraging high-efficiency boilers and electric motors through MEPS or incentives programs.

For the Improved Efficiency Scenario, APERC's industry model treats each economy individually, estimating industrial energy demand by collating the estimated demand of each sub-sector. This top-down energy intensity approach is based on two elements: gross industrial output (monetary production amount) and energy intensity per output amount. The model has a component of energy demand elasticity to account for structural and price changes as an economy develops. The model incorporates energy efficiency by reducing each sector's energy intensity according to the level of development of each sub-sector in each economy (within a pre-set range of potentials).

Assuming the same levels of industrial production as the BAU, the estimated savings show the potential for energy efficiency in all industrial sub-sectors. The model accounts for changes in the structure of an economy as it develops, and incorporates such changes into forecasts of industrial production.

Table 5.3 • Potential industry sector energy efficiency savings in the Improved Efficiency Scenario

	Assumed improvement potential (%)	
	Developed economies	Developing economies
Iron and steel	10 – 15	25 – 35
Chemicals and petrochemicals	10 – 25	15 – 30
Non-metallic mineral	20 – 25	20 – 30
Food and tobacco	25 – 40	25 – 40
Paper, pulp and printing	20 – 30	15 – 30
Non-ferrous metals	5 – 40	5 – 55

Source: Saygin et al. (2010).

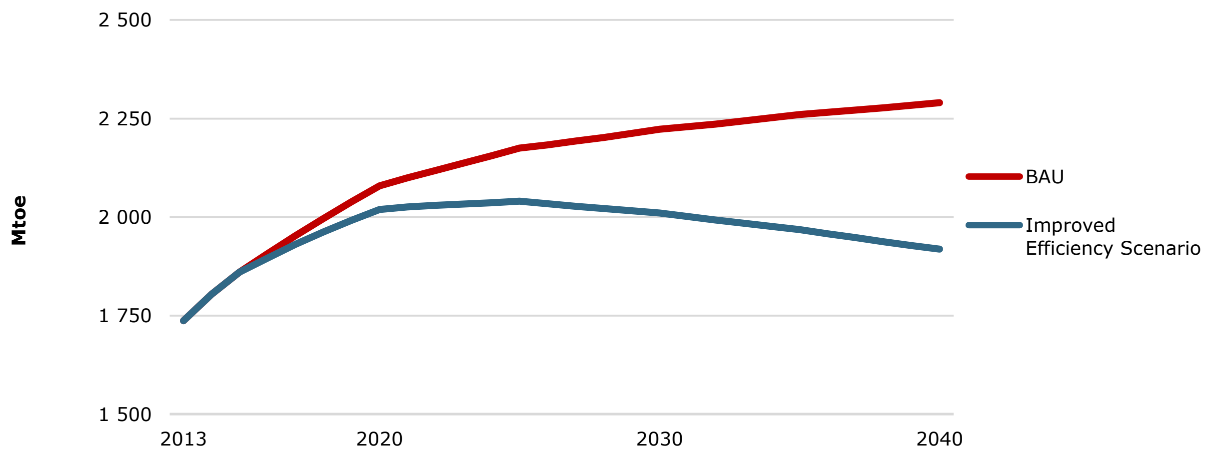
CHINA DOMINATES INDUSTRY ENERGY SAVINGS

APEC energy demand from industry in the Improved Efficiency Scenario is 372 Mtoe lower than in the BAU, with China accounting for over half of the savings. Significantly, this 16% overall reduction cuts industrial energy demand growth from 554 Mtoe to just 182 Mtoe for the period.

Final industrial energy demand peaks in 2025 in this scenario, then slowly declines until the end of the Outlook period; in 2040, final industrial energy demand is 1 918 Mtoe, 6% lower than the 2025 peak of 2 040 Mtoe (Figure 5.5). This implies that a strong drive on energy efficiency enables APEC to decouple industrial output growth from energy demand growth. Output grows by 79% by 2040 and continues to grow, while energy demand growth was only 10% and showed a decreasing trend towards the end of the period.

China, as the world's largest producer of energy-intensive products, accounted for 55% of APEC industry energy demand in 2013. Aware of its huge energy demand, and considering its future economic and environmental well-being, China focused on energy efficiency in its 12th Five-Year Plan (China's key strategic development document). The policy targeted the 10 000 largest energy-demanding enterprises, which account for two-thirds of the economy's demand, to carry out energy efficiency, pollution control action, and meet specific energy intensity reduction targets (KPMG, 2012; IPEEC, 2014).

Figure 5.5 • Industry sector final energy demand in the BAU and Improved Efficiency Scenarios, 2013-40



Note: Excludes non-energy use.
Sources: APERC analysis and IEA (2015a).

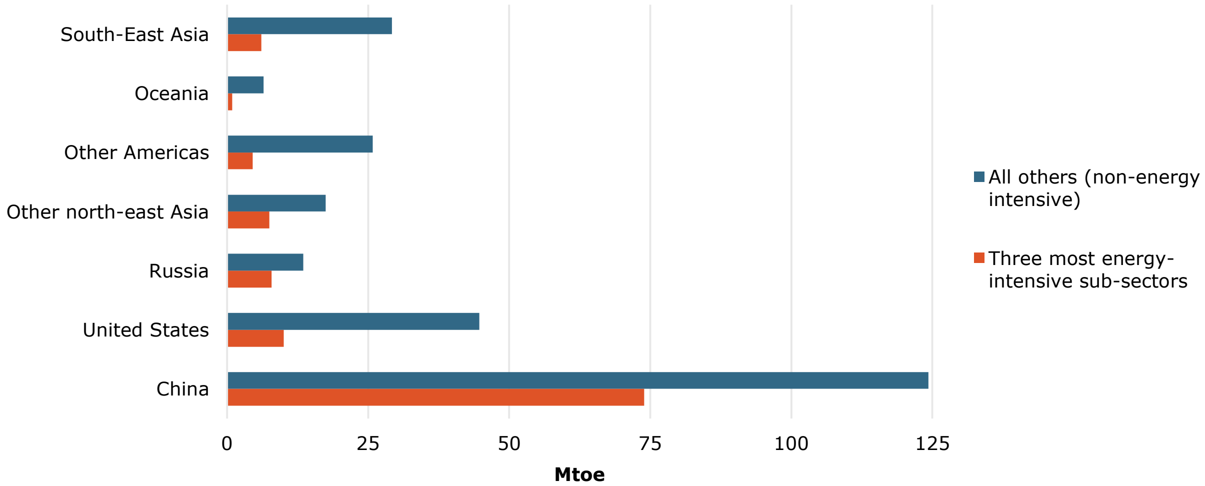
The policy has achieved strong results in reducing energy demand from 2011, which are accounted for in APERC's BAU Scenario for China. In the Improved Efficiency Scenario, APERC assumes that further energy efficiency potential exists for these companies; the rest of the industrial sector can also contribute significantly (Lu et al., 2014; LBNL, 2014). The potential, coupled with the sheer scale of demand, makes China the largest (53%) contributor to industry energy savings in APEC.

The United States is the second-largest contributor (15% saving potential) to APEC industry energy demand savings, due to its large industrial base and continuously advancing efficiency initiatives. The vast majority of these savings (82%) come from the others sub-sector as it also experiences the greatest production growth. The United States has a long and impressive track record in industrial energy efficiency; potential remains, however, to accelerate implementation through government intervention to overcome existing barriers (DOE, 2015).

South-East Asia also provides significant energy saving potential, as it is projected to experience the largest regional growth. Industrial energy demand more than doubles in the Improved Efficiency Scenario, from 114 Mtoe in 2013 to 247 Mtoe in 2040, some 35 Mtoe lower than in the BAU. An estimated 87% of demand growth comes from the others sector. Ultimately, the region accounts for 9% of all APEC industrial savings.

Across APEC, the majority of industrial energy savings (70%) are in the less energy-intensive, which include higher value-added sectors such as construction, electronics manufacturing and food product manufacturing (which is expanding in the region). The less intensive industries (noted as 'others sub-sector') also have the largest energy demand growth over the Outlook period, accounting for 84% of industry demand growth in the BAU. In the Improved Efficiency Scenario, the others sub-sector accounts for most of demand growth in industry; in fact, total industry demand grows despite an overall reduction by the three most energy-intensive sub-sectors. Still, total demand growth in the others sub-sector is only 25% in the Improved Efficiency Scenario, a substantial improvement from the 57% growth in the BAU.

Figure 5.6 • Energy savings in the Improved Efficiency Scenario by sector and by regional grouping, 2013-40



Note: The three most energy-intensive sub-sectors in the APEC region are iron and steel, chemical and petrochemicals, and non-metallic minerals.
Source: APERC analysis.

The three energy-intensive sub-sectors account for the remaining energy savings (30%) in industry, with notable reductions in total demand in iron and steel production (33 Mtoe or 9%) and in cement manufacturing (35 Mtoe or 12%) compared to 2013 as output flattens and energy efficiency reduces energy demand. The chemical and petrochemicals industry energy demand, by contrast, grows by 44 Mtoe (15%) as industrial output increases at an average annual growth rate (AAGR) of 1.7%.

ADOPTION OF BATS IS ESSENTIAL TO ACHIEVE RESULTS

Promoting the adoption of best available technologies (BATs) for each industry is a key measure for energy efficiency in industry. This does not always imply switching to new technologies but rather using available technologies more widely and efficiently. In steel manufacturing, for example, the largest efficiency potential comes from recovering by-product gases (e.g. coke-oven gas and blast furnace gas) for use as an energy source (IEA, 2010). Increased steel recycling also enables greater use of electric arc furnaces instead of blast furnaces, which can deliver efficiency gains of up to 50%. The feasibility of this option needs to be assessed by each economy, as it depends on the availability of scrap metal (IEA, 2010). Replacing small-scale blast furnaces with larger units that are much more efficient per unit of production is another option for the steel industry.

In the cement industry, BAT is a six-stage precalciner/preheater dry-process kiln, which requires around half the energy of wet kilns. Economies with growing cement demand need to ensure BAT is the industry standard when installing new capacity; economies still using outdated wet or vertical shaft kilns should provide incentives or introduce regulation to phase out inefficient equipment (Moya, Pardo & Mercier, 2010).

In other industries, wider application of BATs and best-practices—such as minimising heat losses, heat recovery through exchangers, selecting the most efficient heat plant, and selecting the right size of motors and using them efficiently—can provide significant efficiency gains.

The types and strength of measures vary significantly across APEC due in part to available resources, expertise and institutional support. In China, the government set required targets and provided financial support to help specific industries achieve these targets. It also imposed sanctions and/or penalties for companies that did not meet the targets, such as remedial action plans, cutting access to government awards, or barring access to government-funded programs.

Other economies lag behind in strategic government action, often having less coherent approaches. One economy, for example, was providing economic incentives for energy audits but without any provision (mandatory or financial) to implement recommendations. Essentially, once the audit was carried out the results could be shelved, resulting in a poor implementation rate for energy efficiency recommendations.

Australia used an alternative approach that proved successful. The Energy Efficiency Opportunities program required large energy consumers to carry out energy audits to identify energy efficiency opportunities and to make the results public. This had the effect of using public opinion to encourage companies to implement energy-saving measures as a means of maintaining or developing their reputations. The program was successful in that companies implemented 54% of identified savings opportunities; in fact, it was discontinued in 2014 after achieving its main goals (IEA, 2015b). It is worth noting, however, that not all the potential savings were identified, as the quality of the reporting varied and some companies complied with the bare minimum of legal requirements, leaving gaps in the analysis (Energetics, 2009).

In fast-growing economies, such as South-East Asia, that aim to grow their industrial base or in those that already have large industrial bases, policy makers should prioritise the implementation of BATs. While not all economies have extensive resources, several low-cost options can be implemented quickly, including: mandatory energy efficiency auditing and reporting, employing dedicated energy managers, training programs on energy efficiency, and banning low-efficiency (obsolete) technologies.

BUILDINGS ENERGY EFFICIENCY POTENTIAL

This sector includes the residential, commercial, and agricultural sub-sectors and accounted for 31% of total energy demand in 2013. The key efficiency opportunities explored in the Improved Efficiency Scenario are improving the performance of energy-consuming appliances and of the building envelope in the residential and commercial sub-sectors (the scenario modelling did not cover agriculture). APERC used a bottom-up approach based on the BUENAS model developed by the Lawrence Berkeley National Laboratory (McNeil et al., 2008).

In the residential sub-sector, this approach estimated the penetration rate for a range of residential appliances and used a dynamic stock model to track how appliances change over time. The model set an assumed baseline, then applied improved energy efficiency rates per appliance to estimate savings from the baseline. Once the bottom-up savings were calculated and collated, APERC subtracted them from the figures generated by the BAU top-down model to provide an improved efficiency energy demand result.

The analysis was limited to a number of key end-uses in the residential sub-sector due to limited data availability. Space heating efficiency potentials were estimated, using a similar approach, for five economies (Canada, China, Japan, Russia and the United States) in which heating demand represents a large proportion of residential consumption. APERC plans to examine remaining household energy demand in future publications.

In the case of lighting efficiency, two factors are key: the mix of technologies used and the rate at which incandescent bulbs are phased out in favour of compact fluorescent lamps (CFLs) and light-emitting diode (LED) lighting. Using available data on the current technology mix for each APEC economy, and considering government targets for incandescent bulb phase-out or LED penetration, APERC assumed the BAU and Improved Efficiency Scenarios path for the lighting mix to estimate savings.

Analysis of efficiency potential in commercial buildings focuses on energy demand per unit of floor area. The model estimates commercial sector energy demand per square metre and total floor area using a relationship of GDP to demand per square metre algorithm. This accounts for increased comfort levels as GDP rises and businesses are able to provide greater energy services. The model then breaks this demand down into end-uses such as heating and cooling, lighting, and ventilation.

Energy efficiency was assessed using an index that indicates efficiency gains compared with the BAU. Space heating was estimated for the same five economies above, in which commercial heating demand represents a large proportion of total demand. Not all end-uses were modelled due to data limitations; APERC aims to include them in the next edition of the Outlook.

The BAU and Improved Efficiency Scenario assumptions applied in the model for each appliance varied by economy, reflecting differences in the distribution of standards, brands and economic status. While a change in size of appliances is not explicitly treated in the model, it is assumed that that size will be considered in the MEPS implementation process. Below are the ranges of efficiencies for each end-use, with the highest assumed performance (e.g. LED technology for lighting) in the Improved Efficiency Scenario against the worst efficiency (e.g. incandescent bulbs) under the BAU (Table 5.4).

Table 5.4 • Key efficiency assumptions for the buildings sector in the BAU and Improved Efficiency Scenarios by sub-sector

	Appliances	Measure	Range of efficiency	
			Highest in IES	Lowest in BAU
Residential	Fridges	Yearly consumption	216 kWh/yr	644 kWh/yr
	Air conditioners	Efficiency ratio	5.81	2.55
	Water heaters – fuel	Percentage	91%	76%
	Lighting	Watts	10 W LED	60 W incandescent
	TV	Yearly consumption	102 kWh/yr	261 kWh/yr
	Washing machines	Yearly consumption	6 kWh/yr	194 kWh/yr
	Standby	Watts per device	1 W	5 W
Commercial and residential	Space heating – fuel	Percentage	96%	71%
	Space heating – heat pump	Coefficient of performance	5.81	2.6
Commercial only	Lighting	% Improvement	30%	
	Cooling	% Improvement	40%	
	Ventilation	% Improvement	20%	
	Refrigeration	% Improvement	34%	

Note: IES = Improved Efficiency Scenario
Source: McNeil et al. (2008).

BUILDINGS ENERGY DEMAND CONTINUES TO GROW

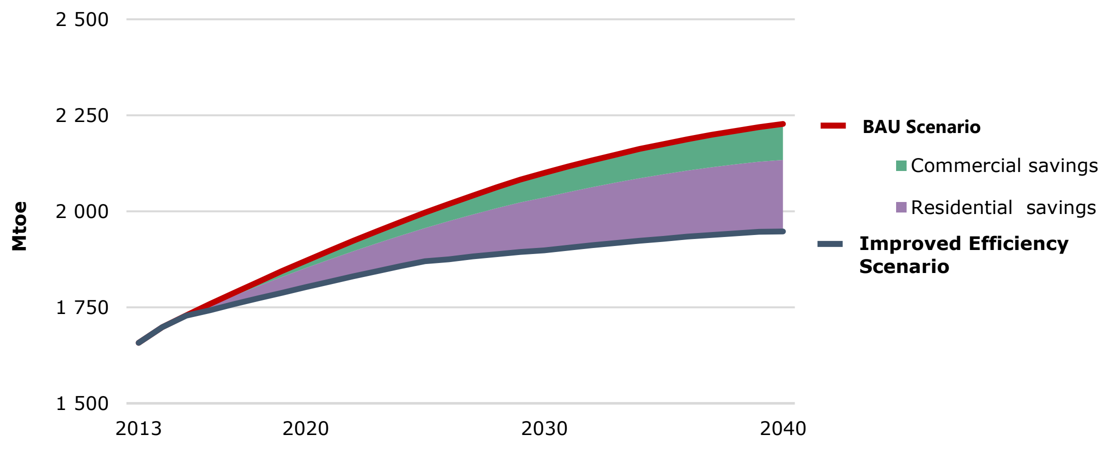
The Improved Efficiency Scenario delivers energy savings of 279 Mtoe from the end-uses above, a reduction of 13% from the BAU. These end-uses account for up to 80% to 90% of buildings energy demand in most APEC economies, with some exceptions. In Chile and Korea, for example, space heating is a significant component of demand, but was not included in the estimations.[4]

[4] Some economies were not included due to data limitations and their relatively small size in APEC energy demand.

Buildings energy use, unlike in industry and transport, continues to grow throughout the Outlook period in both the BAU and Improved Efficiency Scenarios. Growing population, economic growth and a shift of economic activity towards the commercial sectors drive an increase for energy demand, totalling 1 948 Mtoe in 2040 (a 290 Mtoe increase from the 2013 baseline). Towards the end of the Outlook period, the growth rate slows significantly, suggesting a potential peak shortly after.

Residential sub-sector demand is roughly double that of the commercial sector in APEC throughout the Outlook period. Energy demand reduction in the residential sub-sector is estimated at 186 Mtoe by 2040 in the Improved Efficiency Scenario, a 14% reduction compared with the BAU. More efficient space heating (through BAT heating appliances and improved insulation) delivers the largest contribution (37%) of residential savings, followed by lighting (14%) and water heating (13%).

Figure 5.7 • Buildings sector energy savings by sub-sector, 2013-40



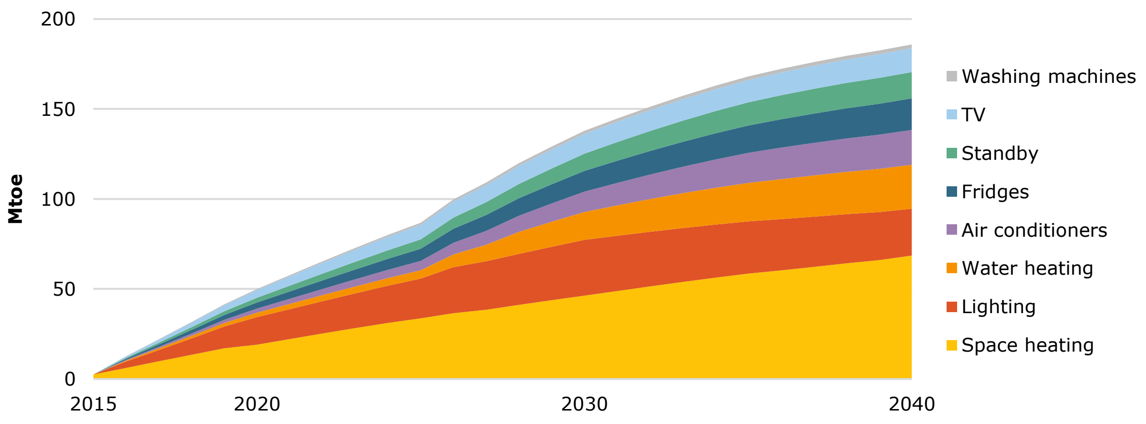
Sources: APERC analysis and IEA (2015a).

Space and water heating represent the majority of total residential demand in many economies (e.g. 80% in Russia and Korea, 60% in the United States and China and 55% in Japan). Adoption of heat pumps, which are three or four times more efficient than other technologies for both water and space heating, shows tremendous potential for energy efficiency in buildings. The Improved Efficiency Scenario assumes widespread uptake of heat-pump water heaters in only Canada and the United States over the Outlook period, yet shows 16 Mtoe of savings. Wider uptake of this technology could be important for the other economies with high demand for space and water heating.

Building insulation is another important factor in significantly reducing energy demand for space conditioning—i.e. both heating and cooling. The combination of improved building insulation and efficient heating and cooling devices (e.g. heat pumps and air conditioners) can reduce energy demand by 50% to 90% (GEA, 2012). Although not modelled in this Outlook, similar savings potential is known to exist for cooling energy demand.

In lighting, adoption of LED or CFL lighting (requiring an average of 10 watts [W] per bulb) provides significant savings over incandescent (60 W per bulb). While LED and CFL are already being deployed in most economies, incandescent bulbs still have a large market share. Using subsidies to accelerate deployment of efficient lighting, or bans to phase out incandescent bulbs, can generate savings up to 31 Mtoe.

Figure 5.8 • Residential energy savings by end-use, 2015-40

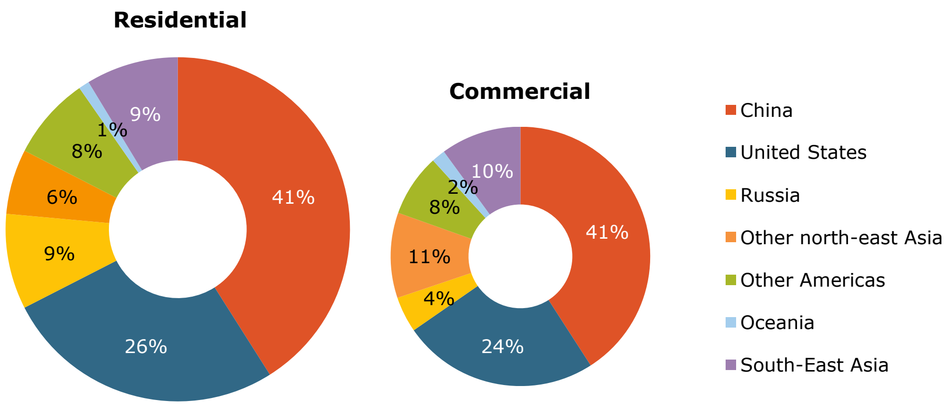


Source: APERC analysis.

Other available technologies to reduce energy demand in buildings—or indeed to self-generate energy rather than create energy market demand—include solar water heaters, solar photovoltaic (PV) or advanced building materials. These align more closely with renewable energy deployment than with energy efficiency, and are thus not included in the Improved Efficiency Scenario. Also, efficiency measures in other end-uses (such as entertainment and electronics) could deliver additional savings in proportion to their actual use and energy consumption, but are not included in this analysis.

Space heating also provides the largest energy savings in the commercial sector. The combination of improved thermal envelopes and increased efficiency of space heating systems delivers 34% of savings in this sub-sector, with substantial contributions coming from cooling (27%) and lighting (23%).

Figure 5.9 • Buildings sector share of energy savings by regional grouping and by sub-sector, 2013-40



Source: APERC analysis.

China, again, is by far the largest contributor to energy savings in buildings in the Improved Efficiency Scenario, delivering 41% of total APEC savings in both residential and commercial sub-sectors. Similarly, the second-largest contribution comes from the mature but very large market of the United States while the rapidly developing economies of South-East Asia are the third-largest contributors.

Given that space conditioning offers the greatest energy demand savings in buildings, it is strategic to concentrate on measures that increase the efficiency of heating, ventilation and air-conditioning (HVAC) systems and building envelope improvements. Moreover, integration of highly efficient HVAC systems and building materials and components (e.g. better insulation, double/multiple window glazing) deliver cumulative savings. Considering a building from a whole-system approach is the most cost-effective and provides the greatest benefits (IEA, 2013).

MEPS PROVIDE THE GREATEST OPPORTUNITY IN BUILDINGS

With energy demand growth a certainty in buildings, APEC policy makers should take steps to ensure that efficiency measures curb such growth. Implementing MEPS and energy efficiency labelling programs are key policy actions being applied across APEC. Appliance MEPS have a long history of success, as shown in global analysis by the Lawrence Berkeley National Laboratory (Table 5.5) (LBNL, 2014). Not all economies have them in place, however, and the number of appliances covered and the minimum level requirements vary across APEC. Significant additional savings potential could be achieved by broadening the array of appliances subject to standards and indeed by standardising the MEPS.

It should also be noted that appliance technologies are changing and improving rapidly; some are becoming economically viable for widespread adoption while others become obsolete. As such, standards require continuous updating and tightening to ensure that they remain relevant and spur further technological efficiency advancements.

A key issue arising with the implementation of MEPS and labelling schemes is the effort required to carry out monitoring, verification and enforcement (MVE) of product compliance with the stated requirements. To make such programs effective, it is necessary to have access and resources to carry out market surveillance and the authority to punish infringements. The cost of testing, which requires specialised equipment and expertise, is currently the biggest barrier to effective MVE programs. Testing is often complicated by different jurisdictions applying different performance testing regimes. As a consequence, test results for a specific appliance model in one economy may be irrelevant for other economies. In some cases, appliances considered highly efficient in some economies may fail to meet more stringent requirements in other economies (APEC, 2014).

Table 5.5 • Number of MEPS implemented by selected economies and by sub-sector

	End-use	Australia	Canada	Chile	EU	Japan	Korea	Mexico	US
Residential	Appliances	-	-	1	6	1	2	2	6
	HVAC	2	3	-	3	1	-	1	5
	Lighting	-	-	1	-	-	-	-	1
	Electronics	1	3	-	2	1	2	-	1
	Water heating	1	1	-	1	1	1	1	1
	Subtotal	4	7	2	12	4	5	4	14
Commercial	HVAC	-	-	-	1	-	-	-	1
	Refrigeration	-	1	-	-	1	1	-	3
	Other	1	-	-	-	-	-	-	2
	Subtotal	1	1	-	1	1	1	-	6
Total		**5**	**8**	**2**	**13**	**5**	**6**	**4**	**20**

Source: LBNL (2014).

APEC policy makers should concentrate on developing standards that facilitate diffusion of efficient appliances across all jurisdictions. The current system often requires manufacturers to go through multiple compliance processes to satisfy different economies. Harmonisation of standards and testing methods would make both the appliances and the approval processes more efficient, and be particularly beneficial to economies with low resources, which could make use of results in other jurisdictions to help with enforcement. APEC has launched a project to encourage information and testing-results sharing across jurisdictions with the aim of helping economies to better allocate their MVE resources (APEC, 2014).

Improving the thermal performance of building envelopes is another priority area as space conditioning (for cooling and heating) is the biggest energy demand end-use in both residential and commercial buildings. The classic approach to building thermal improvement is to decrease energy losses or gains from the environment. This can be achieved by improving design (e.g. orienting building to maximise natural heating or cooling), increasing wall insulation, installing double- or triple-glazed windows, and taking steps to minimise drafts. Efficient building design can substantially change energy demand load: a strategically oriented and well-insulated building, for example, may require a substantially smaller HVAC system.

Different policy approaches have achieved varying degrees of success in this regard, but building codes have proven the most effective. APERC recommends that all APEC economies integrate a strong thermal component in their building codes. It is noted that it takes a long time for new building codes to have a real impact on energy demand, as the rate of new builds each year is only around 2% to 4% of the existing building stock. To reduce energy demand in buildings more quickly, it is necessary to also encourage retrofitting of current building stock. Several mechanisms have proven effective, including: voluntary building rating systems that encourage owners to improve building performance; benchmarking programs to enable comparison; financial incentives to make new buildings efficient or retrofit older ones; and promoting energy service companies (ESCOs).

Singapore is a good example of taking an integrated approach in driving energy efficiency in buildings. A building code, implemented in 1979, requires all new buildings to meet stringent energy standards which were revised considering progress in building technology and energy efficiency of building services. In 2005, the Building Construction Authority (BCA) implemented the Green Mark scheme, which is a green building rating system to promote the adoption of green building design and technologies that improve energy efficiency. Today, the scheme has become the domestic yardstick and qualifying standard for various incentives. It recognizes best performers, and sets a high energy efficiency standard for new and existing building development.

TRANSPORT ENERGY EFFICIENCY POTENTIAL

The transport sector accounted for 26% of APEC total energy demand in 2013. Energy efficiency in this sector focuses on road transport, which is responsible for 84% of all transport energy demand (efficiency gains from other modes of transport are not included in this analysis). APERC uses a dynamic stock module to model the flow of vehicles (both light-duty vehicles [LDVs] and heavy-duty vehicles [HDVs]) through the fleet in each economy, and to assess how policy measures (such as fuel efficiency improvements) affect change over time.

The model uses current ownership statistics and a logistic equation to estimate how the level of vehicle ownership changes over time, based on key socio-economic indicators such as GDP and population density. To track changes in the fleet, the model uses average age and ownership levels to generate annual vehicle retirements and additions.

Two key approaches to energy efficiency are assessed with this model: measures that improve the technical efficiency of vehicles and measures that change urban form (design) to reduce transport demand and emphasise more fuel-efficient modes of transport.

The approaches considered for improving vehicle fuel efficiency are: increasing the fuel efficiency of internal combustion engine (ICE) vehicles; and accelerating the rate at which new vehicle technologies (e.g. electric vehicles [EVs] and plug-in hybrid electric vehicles [PHEVs]) are introduced into the LDV market. Penetration rates of these technologies increase significantly in the Improved Efficiency Scenario, although total penetration remains modest, reflecting the cost premium of such vehicles. These technologies are not yet commercially available for the HDV fleet.

Table 5.6 • Key transport fuel efficiency annual improvement assumptions in the BAU and Improved Efficiency Scenarios, 2013-40

	Labelling scheme	Group of economies	2013-30	2030-40
BAU	No	Brunei Darussalam, Indonesia, Malaysia, Mexico, Papua New Guinea, Peru, The Philippines, Russia, Thailand	1%	1%
	Yes	Australia, Canada, Chile, China, Hong Kong, Japan, Korea, New Zealand, Singapore, United States, Viet Nam, Chinese Taipei	2%	1%
Improved Efficiency	No	Brunei Darussalam, Indonesia, Malaysia, Mexico, Papua New Guinea, Peru, The Philippines, Russia, Thailand	2%	2%
	Yes	Australia, Canada, Chile, China, Hong Kong, Japan, Korea, New Zealand, Singapore, United States, Viet Nam, Chinese Taipei	2.7%	2%

Source: APEC (2015).

The assumed rate of fuel efficiency gains for APEC economies was based on a target set by the Global Fuel Efficiency Initiative (GFEI) (GFEI, 2016). APEC economies were separated into two groups based on whether or not they currently have fuel economy labelling schemes or fuel efficiency standards (APEC, 2015). Economies having such schemes were subject to a higher rate of improvement than those still lacking vehicle efficiency policies (Table 5.6).

Urban form can have a strong influence on energy consumption in transport and on vehicle saturation—i.e. the ratio of vehicles to inhabitants in a city (GEA, 2012). A sprawling city tends to have higher per-capita consumption as more energy is needed to travel or deliver goods over greater distances. Distance and density affect the suitability, effectiveness and availability of public transport as well as the feasibility of walking or cycling.

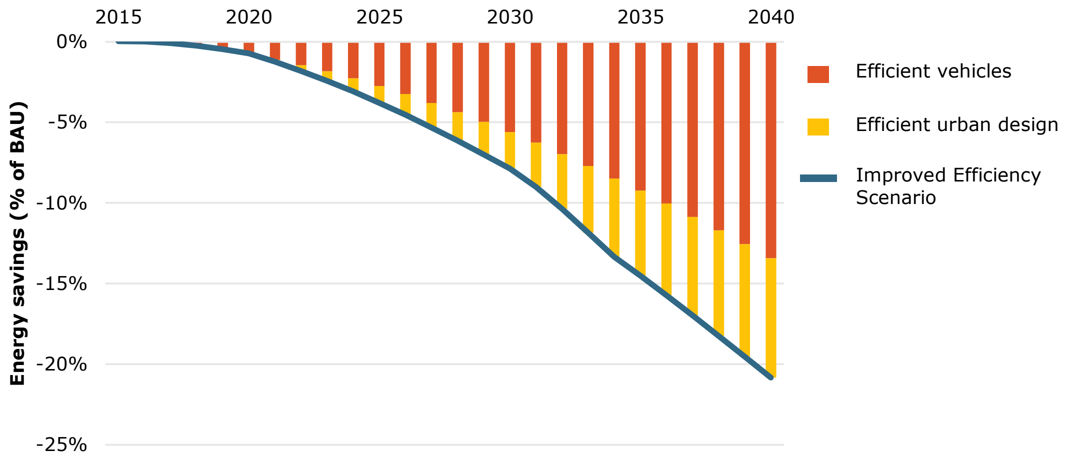
APERC estimated the impacts of efficient urban form by assuming that urban density remains constant or increases if city expansion is controlled through policy and if the city provides efficient choices for public transport systems. Such measures can reduce vehicle ownership by about 10% to 20% compared with the BAU Scenario. Tokyo, Singapore and Hong Kong are good examples of cities with high population density and highly effective mass transport systems that provide low-energy-intensity transportation.

ROAD TRANSPORT HOLDS SIGNIFICANT POTENTIAL FOR EFFICIENCY GAINS

Transport final energy demand in the Improved Energy Scenario grows by 150 Mtoe by 2040, an increase of 11% compared with 2013 and a 15% reduction (269 Mtoe) against the BAU (which shows an increase of 419 Mtoe). In this scenario, transport energy demand peaks in 2025 (nine years earlier than in the BAU) at 1 695 Mtoe, and decreases afterwards at an average rate of almost 1% per year. Final transport demand in 2040 is 1 503 Mtoe, 11% lower than the peak in 2025.

Fuel efficiency improvements deliver most (194 Mtoe) of the savings. An effective approach is the corporate average fuel efficiency (CAFE) standard implemented in the United States, which obliges motor vehicle manufacturers to achieve a minimum average fuel efficiency across all vehicle types manufactured in a given year. In 2011, the Obama administration announced a target of 54.5 miles per gallon (mpg) (4.3 litres per 100 km [L/100km]) by 2025 (NHTSA, 2015). The remaining savings in the Improved Efficiency Scenario are achieved through urban design policies.

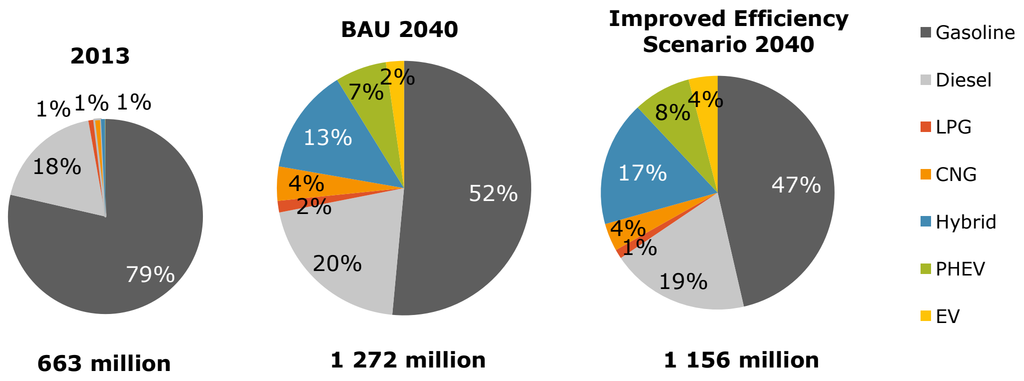
Figure 5.10 • Road transport energy savings in the Improved Efficiency Scenario, 2015-40



Source: APERC analysis.

Increasing deployment of new, highly efficient technologies, such as EVs or PHEVs, is an important avenue to improve fuel efficiency in the entire LDV fleet. Currently, the upfront costs of these technologies are higher than for traditional ICE vehicles, but savings provided over the life of the vehicle make hybrid models more cost-effective than counterparts in the same vehicle classes, particularly in small- and medium-sized cars (Vicentric, 2013). In addition, as technology develops and markets grow, manufacturing and sale costs will decline, making these vehicles more attractive to manufacturers and consumers. Education about the total cost of ownership can help consumers understand how the long-term economic gains repay the larger upfront cost.

Figure 5.11 • Shares of vehicle stock by technology in the BAU and Improved Efficiency Scenarios, 2013 and 2040



Notes: LNG = liquefied natural gas; CNG = compressed natural gas; The size of the circle reflects overall growth of transport energy demand; EV=EV+FCEV. In the BAU EV is 29.1 million and FCEV is 0.3 million, and in the Improved Efficiency Scenario EV is 43.1 million and FCEV is 3.3 million.

Sources: APERC analysis and IEA (2015a).

In the Improved Efficiency Scenario, policies aimed at promoting green vehicles or new vehicle technologies boost deployment of hybrids, PHEVs, EVs to 29% of the fleet, up from 22% in the BAU. This increase of 56 million high-efficiency vehicles on the road by 2040 is a significant improvement; however, massive potential remains as PHEVs and EVs (the most efficient vehicles) represent only 12% of the fleet at that time. As the technology is developing quickly, the market share is expected to rise rapidly.

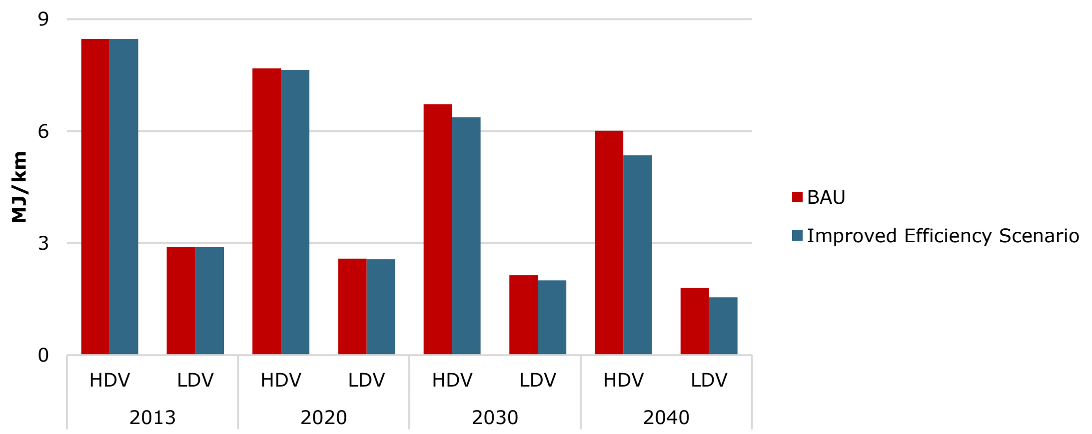
Efficient urban design policies focus on providing alternative modes of transport (such as cycling, buses and trains) to replace transport using LDVs. It reduces overall vehicle demand and the size of the fleet. In the Improved Efficiency Scenario, the total number of vehicles in the fleet across APEC is 1 156 million, which reflects a 9% decrease (i.e. 116 million vehicles) from the BAU due to effective policies.

The final average fuel efficiency of road transport improves significantly (i.e. fuel demand per km travelled decreases) over the Outlook period. In the Improved Efficiency Scenario, the energy required by LDVs decreases from 2.9 megajoules per kilometre (MJ/km)[5] in 2013 to 1.5 MJ/km in 2040 (from 8.3 L/100km to 4.3 L/100km), This is 14% lower than the BAU and represents the bulk of savings in transport. The fuel efficiency of HDVs increases from 8.6 MJ/km to 5.4 MJ/km (24.6 L/100km to 15.5 L/100km), an 11% savings compared with the BAU (Figure 5.12).

Significant potential for further efficiency gains is available through existing LDV technologies, including through widespread adoption of PHEVs and EVs which have energy requirements as low as 0.7 MJ/km. While not yet widespread in HDVs, some manufacturers are starting to offer these technologies in some models, with their application expected to increase over time (Volvo, 2014).

China (31%) and the United States (24%) provide the largest transport energy savings in the Improved Efficiency Scenario, but for different reasons. In China, the fast-developing economy enables ever-increasing levels of vehicle ownership, increasing the fleet size to nearly 390 million vehicles in 2040 (34% of all APEC vehicles). In this case, even modest fuel efficiency gains per vehicle generate significant savings at the APEC level. The United States has a more mature vehicle market with stable (near saturation) ownership rates; the vehicle fleet will increase only as population grows. However, as it currently has the largest vehicle fleet (255 million in 2013), more aggressive targets applied to all new vehicles deliver significant savings.

Figure 5.12 • Fuel efficiency improvement in the LDV and HDV fleet, 2013-40

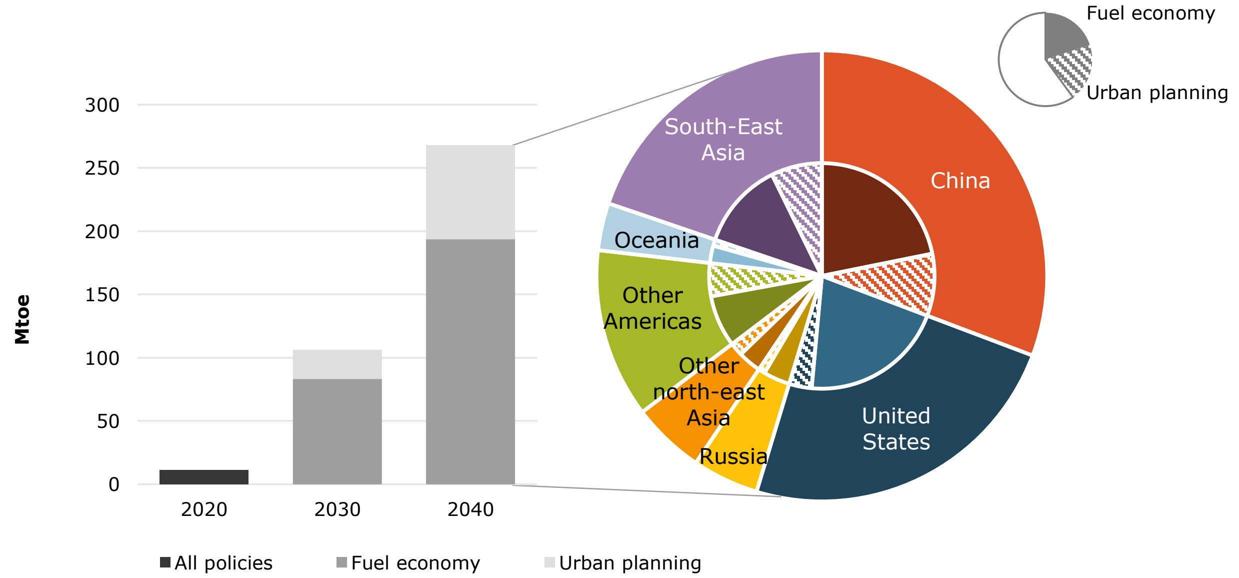


Source: APERC analysis.

South-East Asia includes several fast-developing economies where the fleet will increase dramatically; as in China, stimulating adoption of more efficient vehicles holds a large saving potential. An increase of 122 million units during the Outlook period (causing a tripling of the 2013 fleet) causes a doubling of energy consumption to 223 Mtoe. Still, measures taken in the Improved Efficiency Scenario deliver a 19% reduction (53 Mtoe) compared with the BAU.

[5] Vehicle fuel efficiency is usually expressed in litres of fuel per 100 km (L/100km); this analysis uses MJ per km (MJ/km) to include vehicles using other forms of fuel and technologies.

Figure 5.13 • Transport energy savings by regional grouping and policy, 2020-40



Source: APERC analysis.

Efficient urban design policies lead to lower vehicle saturation levels in APEC economies, with stocks ranging between 5% and 15% lower than in the BAU Scenario. In 2040, a 9% reduction in vehicle stock (compared with the BAU) delivers a 75 Mtoe reduction in road transport energy demand. The savings from urban design are somewhat offset by increased demand for alternative transport modes of transport of 20 Mtoe.

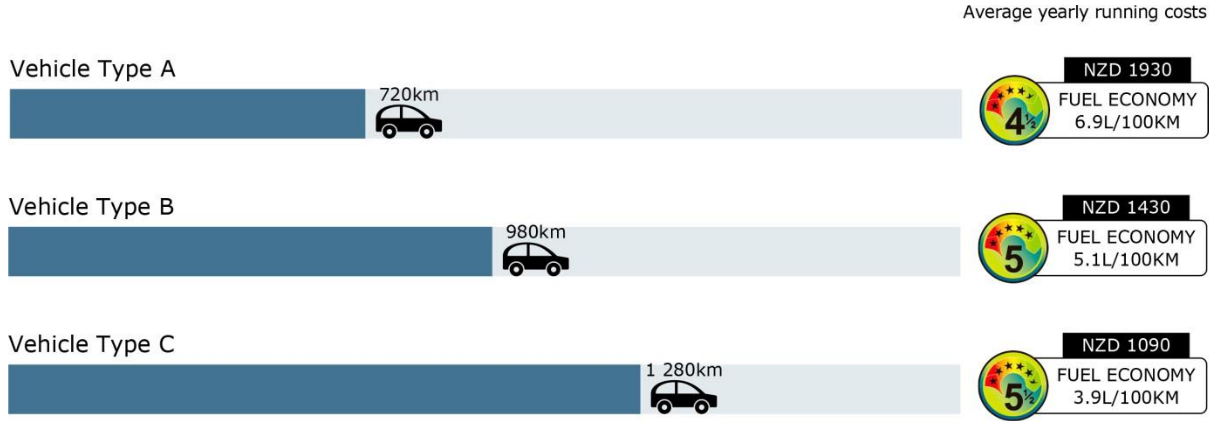
FUEL EFFICIENCY STANDARDS: A KEY OPPORTUNITY FOR APEC

Energy efficiency potential in transport has increased significantly in recent years with the development and deployment of new transport technologies, especially the use of electric batteries to deliver various types of hybrids or EVs. The US Environmental Protection Agency (EPA) recently rated a compact EV as having an energy efficiency equivalent to 126 mpg (53 km/L) compared with 36 mpg (15 km/L) for the leading comparable ICE vehicle (EPA, 2015). Similarly, the ICE has advanced significantly, with new vehicles performing more efficiently than previous models. Mazda claims, for example, that its Skyactiv technology offers a 15% efficiency improvement on previous models, making its performance on par with hybrid vehicles in some vehicle classes (Mazda, 2015).

A large gap still exists between the most and least efficient models within specific vehicle classes, suggesting significant opportunity for improvement with existing technology. A web-based tool designed to inform consumers about fuel efficiency and costs of fuel highlights the huge efficiency gap among models (Figure 5.14). The tool shows the distance a vehicle would travel on NZD 100 (around USD 82[6]) of fuel, comparing vehicle fuel economy of up to three models. The screen capture below compares three vehicles in the compact class—an average performing vehicle, the best performing standard vehicle and a hybrid.

[6] Exchange rates are obtained from the World Bank's Official exchange rate (LCU per USD) publication (World Bank, 2015).

Figure 5.14 • Web-based tool to allow consumers to compare vehicle fuel efficiency



Note: Average yearly running costs are based on a fuel price assumption of NZD 2.00/L and annual distance of 14 000 kms. 2013 World Bank official exchange rate USD 1: NZD 1.22.
Source: EECA (2015).

While PHEVs and EVs are starting to be deployed in APEC, their adoption remains low over the Outlook period in most economies. Policy makers should prioritise these large potential efficiency gains by directing policy action to promote both the research and development (R&D) of new technologies and increased deployment of proven solutions. The available potential makes the near doubling of fuel efficiency achieved in this scenario a conservative result.

Current battery technology has been a particular challenge to the widespread adoption of EVs, with slow charging and limited driving range being a barrier for many vehicle buyers. A step-change in battery innovation is required in order for EVs to compete with the range and durability of current ICE vehicles. Governments can take action to make these new battery technologies more cost-competitive, thereby stimulating the development of healthy markets.

Different approaches can be used for this. In Japan, the government prioritised the development of advanced vehicle technologies as beneficial for the environment and for domestic industries and job creation; thus, it provided substantial subsidies for new technology vehicles (WRI, 2014). As a result, hybrid vehicles have been the highest selling car in Japan for several years; in 2015, two of the top three selling cars were hybrid (JADA, 2016). If resources for vehicle subsidies are not available, fuel efficiency standards (such as the CAFE standards mentioned earlier) can provide significant results; fuel consumption by the LDV fleet in the United States is estimated to be 14% lower in 2001 due to the implementation CAFE standards (NAS, 2002).

Another option to make electric transportation more desirable is to increase the relative price of oil against other fuels. This does not imply senselessly raising oil prices, but rather ensuring that consumers face the full cost of choosing fossil fuels, including environmental impacts. Eliminating subsidies or putting an environmental tax on oil equivalent to estimated environmental remediation costs would make consumers fully accountable for the consequences of their consumption. In parallel, when consumers choose a cleaner transportation option, the opportunity to benefit from higher savings offers a better incentive. To make new, highly efficient technologies more economically attractive, the US State of California has applied a combination of a green vehicle subsidy with a so called 'guzzler' tax on high-consumption vehicles. Governments can also directly support R&D in electric transportation.

Reducing transport demand by optimising urban planning is also an effective way to reduce energy demand, although more time is needed to realise the impact. It is particularly relevant in many APEC economies such as China and the South-East Asia where urbanisation is expanding rapidly and personal vehicle ownership is currently low (UNDESA, 2014). Without effective public transport, severe traffic and pollution problems in such areas will only worsen as vehicle ownership increases.

Limiting urban sprawl by using zoning laws or implementing green belts, while also providing efficient and convenient public transport options (such as metro systems or dedicated bus lanes) can reduce overall demand (Leaver et al., 2011). The potential effects are more limited in developed economies, where well-established infrastructure and vehicle ownership make it more difficult to transform the systems in place. Land-use changes and increased public transport can begin to stimulate a transition.

OPPORTUNITIES AND CHALLENGES

Results of the Improved Efficiency Scenario demonstrate the sizeable opportunity available to APEC economies to curb growing energy demand by implementing policies that have been proven both effective and cost-effective. Achieving an overall peak in energy demand while sustaining economic growth, surpassing the APEC energy intensity target, and realising the associated benefits of energy efficiency (such as emissions reduction, enhanced energy security and improved productivity) will deliver substantial value to individual economies and to APEC as a whole.

To capture this opportunity, APEC economies need to develop both energy efficiency strategies and enabling policies. While most APEC economies have introduced policies to advance energy efficiency, the strength of these policies varies greatly among economies, as does the capacity to develop comprehensive programs, enforce regulations and monitor impacts. As a result, the energy efficiency gains achieved through policy intervention also vary greatly across economies.

The availability of funds or capital for energy efficiency is often raised as a key challenge, whether for purchasing new efficient vehicles, equipment and appliances, retrofitting the building stock, or at a higher level finding the resources to fund government programs. The barrier of upfront capital costs (sometimes significant) often affects less-developed economies more strongly; even 'low-cost' initiatives such as changing incandescent light bulbs for more efficient and long-lasting LED or CFL technologies can present a challenge. New Zealand, for example, required strong policy intervention coupled with a subsidy program and awareness campaigns to convince consumers that investing in CFL lighting would deliver savings that warranted the initial expense.

Capacity is another key challenge: the level of policy, technical, and enforcement capacity available within APEC economies vary significantly and influence roll-out of programs and their results. Enforcement capacity is essential to ensure, for example, that all new buildings are properly assessed or that all new appliances entering a specific market meet energy efficiency specifications or MEPS.

Increasing awareness of the potential value and benefits of energy efficiency is also important. This may be needed at various levels, starting with governments that have not yet made energy efficiency a priority and expanding to business owners that do not understand how energy efficiency can benefit their operations and profit margins. Public awareness campaigns are needed to inform general consumers who are unaware of energy efficiency, or are sceptical of whether its benefits are worth the investment.

To overcome such challenges, APEC economies need to identify suitable mechanisms to increase capacity, such as leveraging international experience and adopting cost-effective BATs (and also learning from the growing body of knowledge about BATs). Developed economies should demonstrate leadership by pushing for best practice in all sectors, which would stimulate developing economies to follow suit, adapting actions to suit their own contexts. Aggressive action at both levels can improve productivity and bolster economic growth while also reducing energy demand, curbing emissions and improving energy security.

Box 5.1 • Peer Review on Energy Efficiency

In keeping with its mission of advocating rational policy making, APERC carries out various cooperative and capacity building projects on energy efficiency (APERC, 2015). These efforts focus on policies that effectively target benefits, have government support, and include mechanisms to evaluate results. The aim of these projects is to either support policy directly through expert peer review or to build capacity by organising and hosting workshops. The key cooperative project on efficiency is the Peer Review on Energy Efficiency (PREE).

The primary PREE activity involves setting up a panel of experts (led by APERC) to visit a host economy for a week of intensive policy discussion and document assessment. This helps build understanding of the current situation of the host economy and of key policy developments and their impact on energy efficiency. The panel examines the institutional context, energy efficiency goals and targets, energy data collection and monitoring, policy measures, R&D for energy efficiency, and education. After the review, the expert panel provides recommendations to improve the current situation. All PREE results are available online at http://aperc.ieej.or.jp/publications/reports/pree.php.

As part of PREE, APERC also produces the Energy Efficiency Policy Compendium, which collates all active energy efficiency policies in APEC economies. The aim is to have a single resource to facilitate policy consultation and research. As energy efficiency policy is a very dynamic field, APERC updates the Compendium annually. The most recent Compendium is available online at http://aperc.ieej.or.jp/publications/reports/compendium.php.

Finally, APERC annually hosts the Energy Efficiency Policy Workshop, which focuses on building capacity on diverse topics. The overarching aim is to provide an opportunity for developing economies to improve their knowledge and experience in energy efficiency policy.

RECOMMENDATIONS FOR POLICY ACTION

Clearly, opportunity exists for APEC to realise additional energy savings by pursuing policy actions outlined in the Improved Efficiency Scenario, which would deliver the additional benefits of lower costs, fewer emissions and improved security. In order to identify these opportunities and implement effective strategies and policies, APEC economies should prioritise the development of energy efficiency indicators and collection of relevant end-use data.

Most APEC economies already have some form of energy efficiency policies in place for each sector. At present, policies for labelling appliances are the most common approach, but often these are information-based and voluntary rather than mandatory, which limits their effectiveness and potential benefits. Other economies have implemented mandatory policies but enforcement is weak due to lack of resources or expertise. Some APEC economies, for example, have energy efficiency measures in a robust building code, but lack sufficient qualified inspectors; thus, only a small proportion of buildings can be properly inspected.

As technologies and policy measures advance, the significant potential for energy efficiency in all sectors can be expected to increase. This is most evident in transport, where electrification can boost efficiency to three or four times the level of current ICE vehicles. To realise the benefits of this step-change in technology, however, action must be taken to make electricity systems more energy efficient and boost the contribution of renewable energy sources. Otherwise, the efficiency gains and CO_2 emissions reduction afforded by the electric drivetrain are lost in the electricity generation process. Stimulating R&D in battery technology can synergistically help on both sides, as longer-lasting, more energy-dense and less-costly batteries address the major end-consumer barrier to EV purchases, while broader deployment of storage options enables higher shares of renewables in energy systems.

In industry, where a relatively small range of large consumers represent the majority of energy demand, APEC policy makers should prioritise the adoption of BATs and best practices in new industrial developments and establish mechanisms to support upgrades or retrofits. This is particularly important in fast-developing economies where industrial energy demand growth will rise most rapidly.

Policies such as the requirement to employ dedicated energy managers and mandatory energy auditing are proving effective. In cases in which company chief executives generally have a short-term view, and are thus unlikely to support any investment that does not show a return on the balance sheet within one year, or when companies simply cannot afford such investments, policy makers may need to provide economic support and incentives to enable implementation of energy audit recommendations. In some cases, mandatory requirements may be needed, such as the forced implementation of upgrades with payback under two years.

Continuous implementation, maintenance and updating of mandatory building codes and MEPS are the best way to improve and sustain energy efficiency in buildings. This is particularly true in developing economies where limited resources may make it impossible to target all areas of growth. Extensive experience on building codes is available in APEC and globally, including through international bodies that support policy development, such as the Collaborative Labelling and Standards Program (CLASP). As technologies advance regularly, standards should be updated to maintain the momentum for further improvement.

China's engagement in energy efficiency is vital due to the size of its population and economy. Recent policies are already delivering significant savings; applied more broadly as the economy continues to show the largest expansion in APEC, China offers the largest savings potential. China is aware of the importance of managing its fast-growing economy by pursuing responsible growth, particularly in areas such as energy efficiency and mitigating the effects of climate change.

The Improved Efficiency Scenario clearly shows that implementing commercially available energy efficiency improvements enables APEC to not only achieve but surpass its stated energy intensity target. It also establishes that higher efficiency gains are possible with current technology, which implies the need for action to remove barriers to broader deployment. Finally, as technology advances, the energy efficiency potential is likely to increase, creating an opportunity for APEC to pursue a more aggressive energy intensity target in the future.

6. HIGH RENEWABLES SCENARIO

KEY FINDINGS

- **The APEC goal of doubling the share of renewable energy by 2030 (from 2010 levels) cannot be achieved within the BAU Scenario.** The High Renewables Scenario outlines a least-cost pathway to meeting this goal, which requires an extra 808 GW of renewable capacity additions and 31 Mtoe of additional biofuels for transport.

- **Tremendous opportunity exists to increase renewables utilisation in APEC.** In 2013 only 31% of the total economic potential was utilised, much of this dominated by hydropower. Large unutilised potential exists particularly for wind and solar.

- **In the High Renewables Scenario, APEC solar and wind capacity expands by 62 GW/yr over the Outlook period–faster than 50 GW of capacity additions in 2013,** providing over 75% of all new renewable capacity additions. By 2040, the share of variable renewables increases to 16% of total generation. More rapid deployment of wind and solar lead average capital costs to fall 17% and 38% respectively by 2040.

- **Total APEC supply potential for biofuels is estimated to reach 144 Mtoe in 2040 in the High Renewables Scenario,** as improved cultivation practices and use of unutilised land helps to boost the potential supply of biofuel feedstocks.

- **Biofuels trade among APEC economies will be needed to meet rising biofuels demand in the High Renewables Scenario,** which is projected to nearly triple from 35 Mtoe to 95 Mtoe as mandatory blend rates are assumed to be implemented across various economies.

INTRODUCTION

On 2 September 2014 at a forum in Beijing, People's Republic of China, Energy Ministers representing Asia-Pacific Economic Cooperation (APEC) made a joint statement in which they agreed to 'aspire to the goal of "doubling the share of renewables in the APEC energy mix, including in power generation, from 2010 levels by 2030".' To attain this target, member economies will need to enhance cooperation and promote innovation in renewable energy technologies, so as to reduce costs and improve the competitiveness and sustainability of renewable energy in the energy market (APEC, 2014).

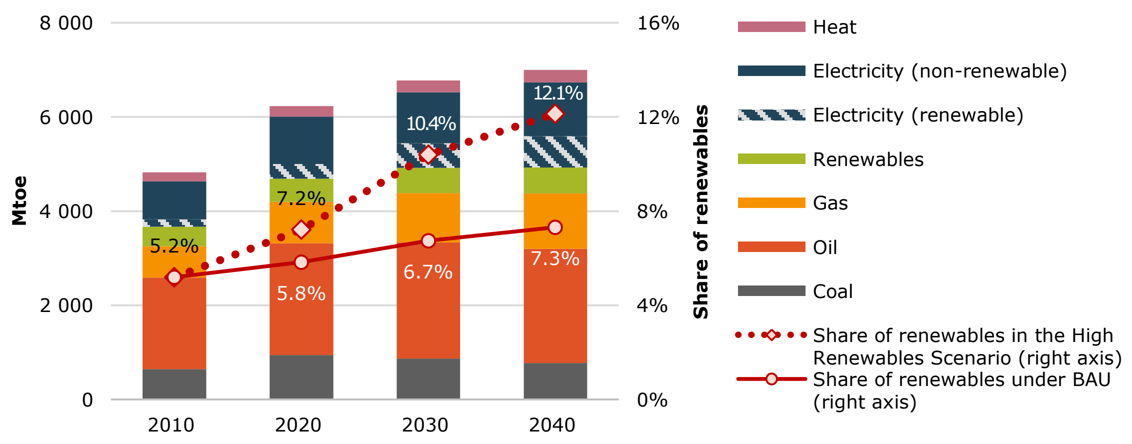
This chapter examines how the High Renewables Scenario can influence renewables projections in the APEC region over the Outlook period, focusing on renewables in power generation and the transport sector. For the purpose of this analysis, total final energy demand (TFED) is used as the denominator in determining the share of renewables in the total mix; large hydropower is included in the modelling while traditional biomass is excluded.

Renewables offer significant benefits for APEC, providing secure, sustainable and environmentally friendly energy. The renewables resource potential in the region is enormous, and recent technology advances make it possible for economies to harness more renewable energy, specifically in power generation.

Under the High Renewables Scenario, increasing the share of renewable power generation and boosting biofuels production and use bring the share of renewables in TFED to 10.4% in 2030, double the 2010 level of 5.2%—ergo, achieving the goal set forth in the Beijing Declaration (Figure 6.1).

To reach this goal, however, on average 100 gigawatts (GW) of renewable generation capacity (excluding pumped hydro) needs to be added each year from 2013 to 2030, nearly twice the renewable capacity additions projected under the Business-as-Usual (BAU) Scenario, although in line with the 2015 renewable capacity additions of over 100 GW (IRENA, 2016). In addition, biofuels demand in the transport sector must reach 87 million tonnes of oil equivalent (Mtoe) in 2030, some 31 Mtoe higher than in the BAU and a tripling of the level of 29 Mtoe in 2010.

Figure 6.1 • Total final energy demand in the High Renewables Scenario, 2010-40



Sources: APERC analysis and IEA (2015a).

RENEWABLE ENERGY POLICIES IN APEC

All APEC economies have made commitments to promote renewables in power generation through a policy framework. Most policies are based on objectives of enhancing energy security, sustaining socioeconomic development and addressing climate change. Ten economies have legislation on renewables development already in place, while others have formulated regulations and master plans (Table 6.1).

Table 6.1 • Renewable energy policy frameworks in the APEC region

	Renewable energy-specific legislation	RE-related policy /plan	Development strategy	Target RE generation share	Feed-in Tariff (FiT)	Renewable portfolio standard (RPS)	Tax incentive
Australia	√	√	√	23.5% in 2020	-	-	√
Brunei Darussalam	-	√	√	10% by 2035	-	-	-
Canada	-	√	√	√*	√*	√*	√
Chile	√	√	√	20%^ in 2025, 70% in 2050	-	-	-
China	√	√	√	20% primary in 2030	√	√	-
Hong Kong	-	√	√	√	-	-	√
Indonesia	-	√	√	232 Mtoe (247.4 GW) in 2050	√	-	√
Japan	√	√	√	22-24% in 2030	√	-	√
Korea	√	√	√	(13.4%) in 2035	-	√	√
Malaysia	√	√	√	3% in 2020	-	√	√
Mexico	√	√	√	(29.1%) in 2028	-	-	√
New Zealand	-	√	√	90% in 2025	-	-	-
Papua New Guinea	-	-	-	100% in 2050	-	-	-
Peru	√	√	√	60% (5%^) in 2020	-	-	-
The Philippines	√	√	√	(+9.9 GW, +200%) in 2030	√	√	√
Russia	-	√	√	4.5%^ (25 GW^) in 2030	√	-	-
Singapore	-	√	√	-	-	-	-
Chinese Taipei	√	√	√	12.6% (27.1%) in 2030	√	-	√
Thailand	-	√	√	20% in 2036	√	-	√
United States	-	√	√	√*	√*	√*	√
Viet Nam	-	√	√	6% in 2030	√	-	-

Note: √= existing; - = not existing currently; * = applied in some local territories or states; ^ = target excludes large-scale hydro; (…) corresponds to installed renewable capacity targets.
Sources: APERC analysis and economy reports.

Each economy has different approaches and mechanisms for implementing renewable energy policy. Some have set medium- or long-term targets, for either the share or the volume of renewables in the power generation mix or for new capacity additions or total generation capacity. Twelve economies have set these types of long-term targets to 2030 and beyond. Other economies have adopted financial incentives such as FiTs[1] and RPSs[2]. FiTs are aimed at specific renewable technologies, and typically applied at a regional or economy-wide level. RPSs set a minimum share or increase in the share of renewable generation. In addition, most APEC economies use government incentives, subsidies and taxation measures, such as renewable funds, research and development (R&D) grants and tax exemptions.

[1] Feed-in tariff is a policy mechanism designed to encourage deployment of energy technologies. A FiT guarantees that electricity generated and supplied to the grid will be purchased at a long-term set price.
[2] Renewable Portfolio Standard is a policy mechanism designed to increase generation of renewable electricity. A RPS specifies a minimum share of customer electricity load to be supplied by designated renewable resources.

Technological advances, government policy commitments and financial support are needed in combination to accelerate the development of renewable power generation to the level required to meet APEC's goal of doubling the share of renewables. Most APEC economies have made commitments, through biofuel policy frameworks, to promote, produce and use biofuels in transport. Most of these policies aim to increase fuel diversity and reduce greenhouse gas (GHG) emissions to mitigate climate change. Fourteen of the 21 economies have established biofuels regulation; others, such as China, the Philippines and Thailand, have even included biofuels policy in their energy development plans (Table 6.2).

Table 6.2 • Biofuels policy frameworks in the APEC region

	Regulation	Blend rate mandate		Blend rate target		Incentives, subsidies and taxation
		Bioethanol	Biodiesel	Bioethanol	Biodiesel	
Australia	√	√*	√*	E4/E5*	B2*	√
Brunei Darussalam	-	-	-	-	-	-
Canada	√	up to E8.5^	up to B4^	E5	B2	√
Chile	-	-	-	-	-	-
China	-	E10^	-	10 Mt (2020)	2 Mt (2020)	√
Hong Kong	√	-	-	-	-	√
Indonesia	√	E3	B10	E20 (2025)	B30 (2025)	√
Japan	√	√	-	0.5 million Loe (2017)		√
Korea	√	-	B2	-	B5 (2020)	√
Malaysia	√	-	B7	-	B10	√
Mexico	√	E2	-	√	-	√
New Zealand	-	-	-	-	-	-
Papua New Guinea	-	-	-	-	-	-
Peru	√	-	-	E7.8	B5	√
The Philippines	√	E10	B2	E20 (2020)	B20 (2025)	√
Russia	√	-	-	-	-	-
Singapore	-	-	-	-	-	-
Chinese Taipei	√	-	-	-	-	√
Thailand	-	-	B7	4 billion L/yr	5 billion L/yr	√
United States	√	up to E15^	up to B10^	136 billion L/yr (2022)^		√
Viet Nam	√	E5	-#	E10 (2017)	-	√

Note: √ = existing; - = not existing currently; * = applied in New South Wales and Queensland for bioethanol and in New South Wales for biodiesel; ^ = applied at federal level and in some local territories or states; # = biofuels traded with no mandated blend rate; Mt = million metric tonnes; Loe = litres of oil equivalent; L/yr = litres per year.

Sources: APERC analysis and IEA (2015a).

APEC economies use various approaches and strategies to increase the supply of and demand for biofuels in transport. These include mandating a volume-based percentage of biofuels in gasoline or diesel (i.e. a blend rate mandate) or setting a target volume of biofuels to be supplied. Nine economies have set mandatory bioethanol blend rates, ranging from E2 (a mix of 2% bioethanol and 98% gasoline) in Mexico to E10 (a 10%:90% ratio) in the Philippines, and in some parts of China and the United States. Eight economies have set mandatory blend rates for biodiesel, ranging from B2 (a mix of 2% biodiesel and 98% diesel) in Canada and in New South Wales of Australia to B10 (a 10%:90% ratio) in Indonesia and the Philippines. Some economies with increasing supply potential, improving technologies and enabling market conditions have set near-term targets to introduce and increase biofuel blend rate mandates for both bioethanol and biodiesel. Indonesia and the Philippines have set targets to increase bioethanol blend to 20%; for biodiesel blend, the Philippines has a 20% target and Indonesia a 30% target. Thailand has a target of 11 million litres per day (L/d) of bioethanol (with equivalent blend rate of 30%) and 14 million L/d of biodiesel (equivalent 20% blend rate). China has a 2020 target of 10 million tonnes (Mt) of bioethanol and 2 Mt of biodiesel. The United States set a target of 15 billion gallons per year of ethanol by 2022.

In addition, to improve the competitiveness of biofuels with gasoline and diesel, most APEC economies have provided as a part of their biofuel policies mechanisms such as incentives either through R&D funding, subsidies and tax incentives. These policies are designed to spur the growth of biofuels supply and demand within APEC, and should be enhanced and deployed broadly to accelerate the uptake of biofuels.

RENEWABLES IN THE BAU SCENARIO

GROWTH IN RENEWABLES IS INSUFFICIENT TO MEET APEC DOUBLING GOAL

Under the BAU Scenario, TFED in APEC increases by 40%, from 4 827 Mtoe in 2010 to 6 774 Mtoe in 2030. Although renewables in TFED nearly double (from 251 Mtoe in 2010 to 457 Mtoe in 2030), their share increase (from 5.2% in 2010 to 6.7% in 2030) falls short of the doubling target (Figure 6.1). Clearly, APEC economies will need to intensify the development and deployment of renewables to achieve the stated goal. Assuming the doubling requirement by 2030 applies for each sector, the share of renewables in power generation must reach 32% (from 16% in 2010) and 4.6% in transport (from 2.3% in 2010).

Under the BAU, power generation shows an annual average growth rate (AAGR) of 2.5%, increasing from 13 375 terawatt hours (TWh) in 2010 to 21 727 TWh in 2030 (Figure 6.4). At this rate, the forecasted expansion of renewable capacity falls short of the doubling goal: renewables' share increases from 16% in 2010 to just 22% in 2030. Hydropower maintains the highest share of renewable generation, decreasing slightly from 13.2% in 2010 to 12.8% in 2030 in total power generation even though it shows an absolute increase from 1 765 TWh to 2 778 TWh. Wind power generation increases by an AAGR of 9.9%, from 163 TWh in 2010 to 1 075 TWh in 2030, with its share of generation more than quadrupling (from 1.2% to 4.9%). Solar power generation grows the fastest (AAGR of 21%), from only 9.8 TWh in 2010 to 420 TWh in 2030, with its share rising from only 0.07% in 2010 to 1.9% in 2030.

Total renewable installed capacity (excluding pumped hydro) rises 2.7 times from 620 GW in 2010 to 1 702 GW in 2030. The largest capacity increase is in wind, which grows fivefold from 95 GW in 2010 to 472 GW in 2030. The second largest increase is in solar, which expands by a remarkable 42 times from 9.2 GW in 2010 to 382 GW in 2030.

Demand for biofuels in transport grows from 29 Mtoe in 2010 to 56 Mtoe in 2030, an AAGR of 3.4%. As a result, the share of renewable fuels in domestic transport demand picks up from 2.3% in 2010 to 3.1% in 2030. A slowing demand for biofuels after 2030 is attributed to a downward trend in transport oil demand, due to improved vehicle efficiency and expanding usage of compressed natural gas (CNG), electric and hybrid vehicles (USDA, 2014), and biofuel blends reaching the limits prescribed by vehicle manufacturers.

Total bioethanol demand in APEC shows only 1.8% AAGR, growing from 26 Mtoe in 2010 to 37 Mtoe in 2030. In 2030, the United States accounts for nearly 57% of APEC bioethanol consumption, and China accounts for 18%. Demand for biodiesel rises more quickly (AAGR of 9.9%), from 2.8 Mtoe in 2010 to 19 Mtoe in 2030. Again, the highest shares are in the United States (35%) and China (20%). Biofuels also expand in other sub-regions; the exception is Russia, which has no biofuels blend rate mandates or targets.

PATHWAY TO DOUBLING RENEWABLES IN ELECTRICITY

The High Renewables Scenario assumes that APEC economies fully meet their own renewable targets in power generation, and also undertake the development of the additional renewable generation needed to meet the APEC doubling goal[3] based on a least-cost approach. Additional renewable generation choices are made by considering the levelised cost of electricity (LCOE) and the economic potential[4] for each renewable technology in each economy. Post-2030, renewables' share in power generation continues to increase, in line with the available economic potential of economies. Anticipated technological advances that will improve the performance and capacity factors of renewable technologies have been taken into consideration in determining the renewables capacity additions.

APEC REGION HAS ABUNDANT RENEWABLE ENERGY POTENTIAL

Modelling carried out by Asia Pacific Energy Research Centre (APERC) determined the economic potential of renewable energy for every considered technology and for each of the 21 economies. The potential estimations for each economy include five elements: economy sources, available energy cost curves (adjusted to 2012 USD PPP [purchasing power parity]), resource maps, estimations from pertinent sources or references, and APERC estimates.

The APEC region is endowed with abundant renewable resource potential. APERC estimates the economic potential of renewables in 2013 at 2 618 GW, consisting of 821 GW of hydro; 831 GW of wind; 794 GW of solar; 138 GW of biomass and other renewables, and 35 GW of geothermal (Table 6.3). Further modelling would be necessary to assess the renewable potential for heating and cooling applications in industry and buildings.

Table 6.3 • Estimated economic potential of renewable electricity in APEC, 2013

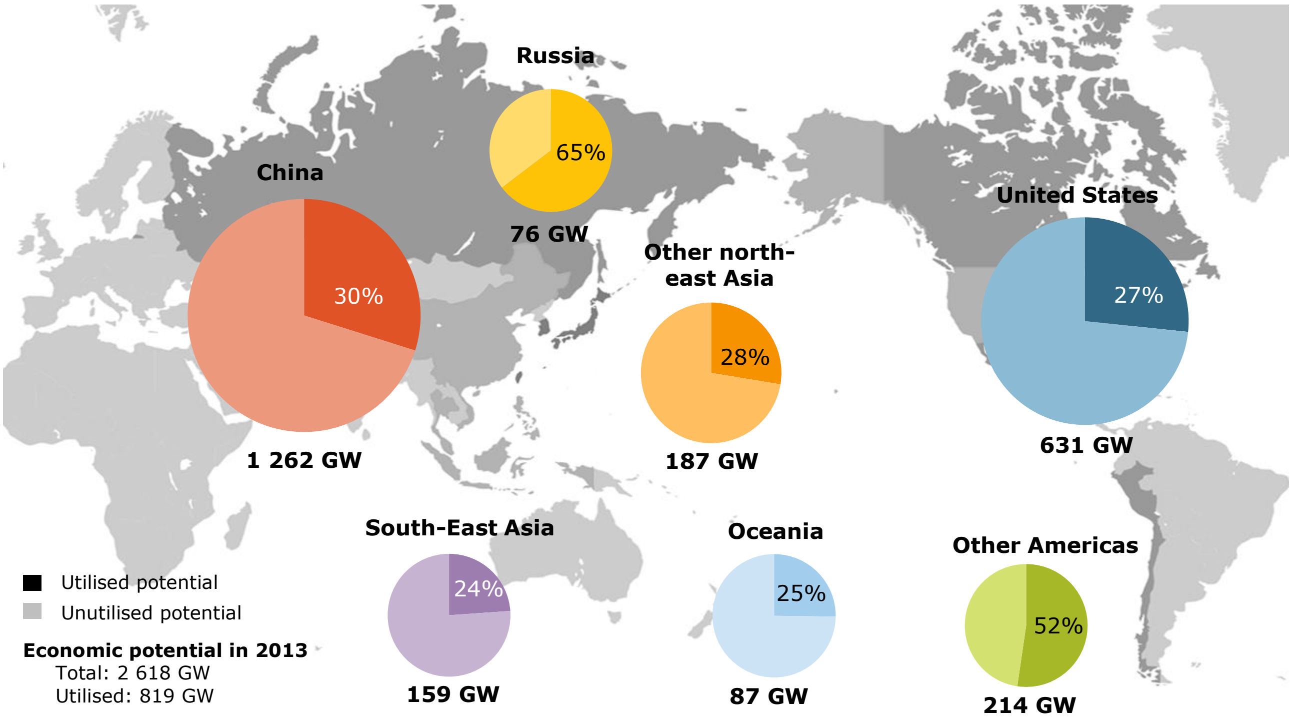
	Hydro		Wind		Solar		Biomass and others		Geothermal		Total	
	GW	Utilised	GW	Utilised	GW	Utilised	GW	Utilised	GW	Utilised	GW	Utilised
China	429	60%	442	21%	337	5%	54	16%	1	5%	1 262	30%
United States	84	94%	250	24%	263	5%	20	61%	13	26%	631	27%
Russia	63	76%	6	0%	3	0%	3	25%	1	16%	76	65%
Other north-east Asia	36	68%	38	10%	97	16%	13	54%	3	17%	187	28%
Other Americas	127	76%	47	21%	24	6%	11	32%	6	14%	214	52%
Oceania	14	93%	37	10%	30	11%	3	30%	3	30%	87	25%
South-East Asia	68	44%	11	3%	39	3%	33	12%	8	40%	159	24%
APEC	**821**	**67%**	**831**	**20%**	**794**	**7%**	**138**	**27%**	**35**	**26%**	**2 618**	**31%**

Source: APERC analysis.

[3] As renewable potential and electricity demand are specific to each APEC economy, doubling the regional renewable share in power generation does not imply doubling renewables in each economy.
[4] Economic potential is the proportion of the technical potential that can be utilised economically, which takes into account costs and other socioeconomic factors (IRENA, 2014a).

As of 2013, the APEC region had utilised only 31% of the estimated economic renewable capacity potential, but with varying rates per available renewable source: hydro (67%), biomass and other renewables (27%), geothermal (26%), wind (20%), and solar (7%). China has 48% of the total APEC economic renewable energy potential, the United States' share is 24%, and the shares of other sub-regions vary from 3% to 8% (Figure 6.2).

Figure 6.2 • Estimated economic potential of renewable electricity in APEC, 2013



Note: This map is for illustrative purposes and is without prejudice to the status of or sovereignty over any territory.
Source: APERC analysis.

The economic potential of hydropower in APEC is estimated at 821 GW or 31% of APEC's total renewable potential, with 67% being utilised. This estimation excludes pumped hydropower, as it is not included in renewable technologies. Nearly 52% of the total hydro economic potential is in China, with 60% utilised.[5] Other Americas follows with 15% (with most of the sub-region's potential located in Canada and Mexico), of which 76% has been utilised. The United States comes third with 10%, but the utilisation rate of 94% is the highest in APEC.

The economic potential of wind in APEC is estimated at 831 GW or 32% of APEC's total renewables potential, with only 20% being utilised. China holds 53% of the region's potential, with 79% still unexploited. The United States has the second-largest potential of 30%, represented by large amounts of offshore potential, 76% of which is undeveloped. Other sub-regions have smaller potentials with utilisation rates varying from 0% to 21%.

APEC's solar capacity potential accounts for 30% of APEC's total, but is the least utilised (7%). The highest utilisation rate is in other north-east Asia at 16% of capacity, followed by Oceania with 11%, other Americas with 6% and China with 5%. The latter holds 42% of the solar potential, followed by the United States (33%) and other north-east Asia (12%). Over 95% of the solar potential in other sub-regions has not been developed; in Russia, only a marginal quantity of the solar potential has been harnessed. High levels of concentrating solar power (CSP) potential exist in the United States and in western China.

[5] The economic potential is based on the government target of 350 GW hydropower generation capacity by 2020 (IRENA, 2014b).

APEC's economic capacity potential for biomass and other renewables is estimated at 5.2% of the total. With only 37 GW utilised, huge remaining untapped potential should be explored. China and South-East Asia combined account for two-thirds of the total biomass potential. Indonesia, Malaysia and Thailand, with government targets to develop biopower, are expected to provide the highest growth in APEC. Development of ocean and tidal energy is currently limited to a small number of commercial projects and many pilot projects around the globe; as such, development of these technologies will be slower than that of biomass generation.

The APEC region aligns closely with the Pacific Ring of Fire, where much of the world's geothermal energy potential is concentrated. All APEC economies, except for Brunei Darussalam and Hong Kong, have economic geothermal potential, but few have developed it. APEC's total is estimated at 35 GW or only 1.3% of the region's total renewable potential. About 26% of the economic potential was utilised in 2013, with shares of total highest in South-East Asia (40%), Oceania (30%) and the United States (26%). Geothermal potential in South-East Asia is primarily found in Indonesia and the Philippines, which have set targets to further develop geothermal power generation. The largest untapped geothermal potential is in the United States and other Americas.

COST OF ELECTRICITY GENERATED FROM RENEWABLES IS DECLINING

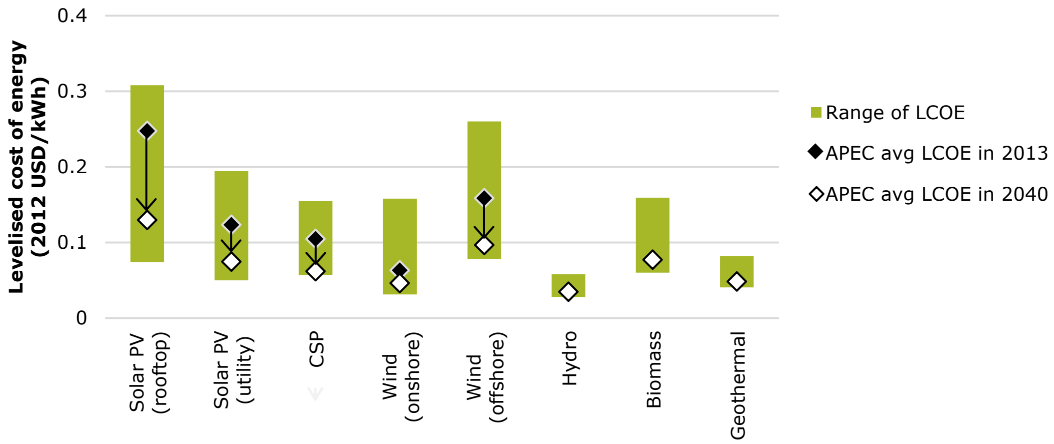
Between 1990 and 2013, renewable generation in APEC increased by 126% to 2 714 TWh, with major annual growth achieved in wind (23%) and solar (21%), the most common forms of variable renewable energy (VRE). This growth was supported by improved policy support and increased R&D spending that enabled technological advancements as well as economy of scale. For solar photovoltaics (PV), this has led to improved efficiency, extended lifetime and significant cost reduction—from nearly USD 7 per watt (W) in 1990 to USD 0.54/W in 2013 for a crystalline silicon (Si) module with over 20% solar cell efficiency. For wind generation, policy and R&D support led to increased turbine height and per unit capacity, from 40 metres (m) and 0.5 megawatts (MW) in 1990 to 150m and 7.5 MW in 2013, which in turn resulted in overall material savings and reduced cost—from nearly USD 2/W in 1990 to USD 0.92/W in 2013 (EWEA, 2009; WEC, 2013; IRENA, 2012; REN21, 2014).

Using LCOE, a common method for comparing the power generation costs of different technologies over their economic lifetimes (IEA, 2010), this report assesses the gross cost of building and operating electricity generation technologies without considering subsidies or incentives provided by an economy. For solar and wind power generation, APERC assumes that when the share of VRE exceeds a certain level (30% for some economies;[6] 20% for others), an additional cost arises from the need to expand and reinforce power grids.

LCOE varies by renewable technology and by economy. In many economies, hydropower and geothermal have among the lowest LCOEs compared with other renewables. The lowest LCOE for hydropower is in Viet Nam at USD 0.027 per kilowatt-hour (kWh) and for geothermal in the United States at USD 0.039/kWh (Figure 6.3). APERC analysis shows that APEC weighted average cost of electricity generated from solar PV and wind power will decline over the Outlook period, with utility-scale solar PV LCOE falling 37% to USD 0.074/kWh, rooftop solar PV dropping 45% to USD 0.113/kWh, onshore wind declining 24% to USD 0.060/kWh, and offshore wind falling by 35% to USD 0.110/kWh. Technological advancements resulting in improved capacity factors, manufacturing economies of scale and 'learning-by-doing' effect will help reduce the LCOE for these technologies. The LCOE for CSP also decreases substantially, with the weighted average cost falling by 40% to USD 0.123/kWh in 2040. Advances in thermal storage technology improve the dispatchability and flexibility of CSP.

[6] These are Australia, Canada, Hong Kong, Japan, Korea, New Zealand, Russia, Singapore, Chinese Taipei and the United States. The factors considered are developed power grids with high level of interconnectivity, high electrification rate and availability of flexible generation.

Figure 6.3 • Estimated LCOE of renewables in the High Renewables Scenario, 2013-40



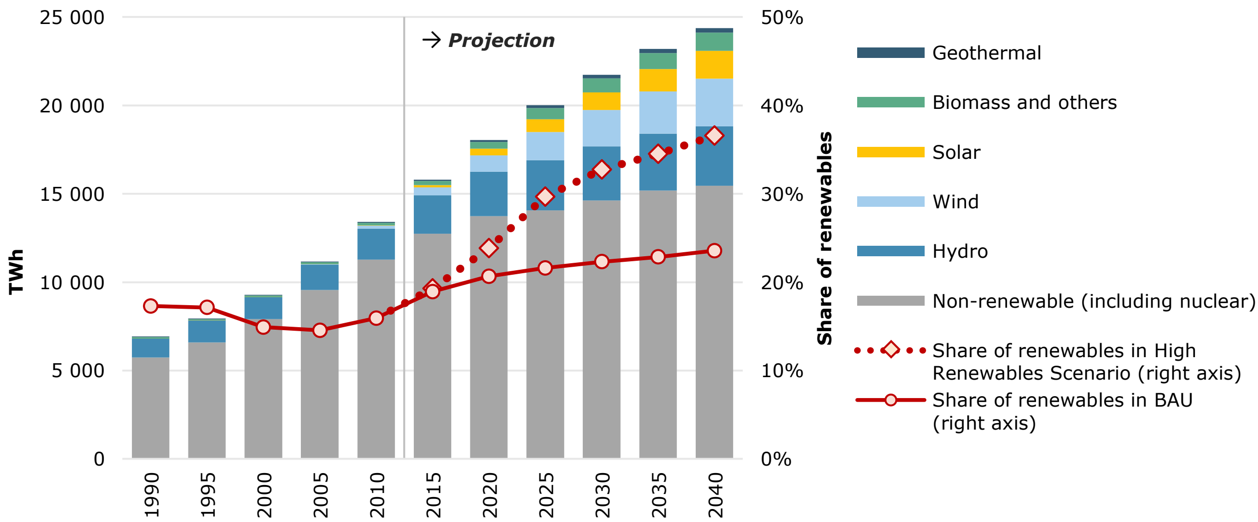
Source: APERC analysis.

While declining LCOE of renewables provides an incentive for investors and can help to increase the share of renewable generation in the power mix, additional support mechanisms are needed to spur future renewable investments. Carefully formulated government policy is essential, and could include the following proven measures: loan guarantees, stimulating renewables development in remote and isolated areas, fossil fuel subsidy reform, and setting clear sectoral and economy-wide renewable targets. Power purchasing agreements (PPAs), RPSs and FiT schemes can also be used as incentives to boost grid-connected renewable energy projects, as can power generation tax credits and tax benefits. Such measures make renewables more competitive with conventional fuels, offering a way to increase energy security while addressing the environmental issues associated with energy production and transformation.

SOLAR AND WIND GROW AT THE FASTEST RATES

Under the High Renewables Scenario, renewable generation in APEC increases at an AAGR of 4.5% (1.7% higher than in the BAU) over the Outlook period, from 2 716 TWh in 2013 to 7 109 TWh in 2030 and 8 911 TWh in 2040 (Figure 6.4). The share of renewables in the power mix reaches 33% in 2030 and 37% in 2040. To meet the goal of doubling, an average of more than 100 GW of new renewable capacity is added each year between 2013 and 2030.

Figure 6.4 • Renewables share of power generation in the BAU and High Renewables Scenarios, 1990-2040



Sources: APERC analysis and IEA (2015a).

In the High Renewables Scenario, total hydropower capacity in APEC increases from 551 GW in 2013 to 827 GW in 2030 and 908 GW in 2040. Correspondingly, hydropower generation grows at an AAGR of 1.8% (0.5% higher than in the BAU), from 2 054 TWh in 2013 to 3 066 TWh in 2030 and 3 350 TWh in 2040. Hydro's share of the power mix remains relatively stable at 14% over the Outlook period.

Solar generation exhibits the highest AAGR (13%) among renewables from a lower starting point; its share of the APEC power mix grows from 0.37% in 2013 to 4.6% in 2030 and 6.5% in 2040. Solar capacity expands enormously (against the BAU levels) to 678 GW (+297 GW) in 2030 and 912 GW (+390 GW) in 2040, with generation increasing to 1 004 TWh in 2030 and 1 580 TWh in 2040.

Wind generation grows at the second-fastest rate (7.9% AAGR), from 2.3% in 2013 to 9.5% (2 055 TWh) in 2030 and 11% (2 707 TWh) in 2040. Wind power capacity escalates (against the BAU) from 170 GW in 2013 to 806 GW (+354 GW) in 2030 and 965 GW (+401 GW) in 2040.

Biomass and other renewable generation grows at 5.8% AAGR, with its share increasing from 1.4% in 2013 to 3.6% (790 TWh) in 2030 and 4.2% (1 029 TWh) in 2040. Installed capacity increases (against the BAU) from 37 GW in 2013 to 146 GW (+61 GW) in 2030 and 187 GW (+77 GW) in 2040.

Geothermal generation shows an AAGR of 5.8% from 54 TWh in 2013 to 194 TWh (share of 0.89%) in 2030 and 246 TWh (1%) in 2040. Geothermal capacity increases (against the BAU level) from 9.2 GW in 2013 to 33 GW (+15 GW) in 2030 and 42 GW (+20 GW) in 2040.

RENEWABLES VARY FROM REGION TO REGION

The development of renewables in each economy under the High Renewables Scenario will depend on the available economic potential, economy targets, energy development plans and economic viability (Figure 6.5). The major contributors to APEC's total renewable generation are China (46% in 2030 and 47% in 2040) and the United States (23% in 2030 and 2040).

By 2040, hydropower will provide 14% of total APEC power generation. Over the Outlook period, the largest development of hydropower will be in China, with 488 GW of installed hydro capacity and generation of 1 713 TWh, or 51% of APEC hydropower generation in 2040. Other Americas, mainly Canada and Mexico which both have large remaining economic potential, follow with a 20% share in 2040. With large existing hydropower capacity, the United States contributes substantially to the region's total hydro-based power generation, even though the economy has little remaining economic hydro potential (IRENA, 2015). South-East Asia adds 43 GW of installed capacity, primarily in Indonesia, Malaysia and Viet Nam. Development in Oceania is moderate and is limited to small- and medium-scale installations (due to high utilisation of available large-scale resources) (ABARE, 2010; Kelly, 2011). Other sub-regions develop hydropower to a smaller extent.

Substantial wind capacity additions are expected in China (447 GW) and the United States (230 GW), which together account for 83% of APEC wind installed capacity and 86% of generation. China's share increases from 41% in 2013 to 50% in 2040. Onshore wind technology accounts for 90% of total wind power capacity in 2040, but some offshore technology is developed mainly in China, Japan, Korea, Chinese Taipei and the United States. Recent expansion of wind power has been driven by the declining cost of wind power technology globally: the cost of onshore wind power has fallen 18% since 2009, and wind turbine costs have dropped nearly 30% since 2008 (IRENA, 2014a). Under the High Renewables Scenario, capital cost reduction for wind energy is assumed to be 0.7% per year (%/yr) over the Outlook period, compared with 0.3%/yr under the BAU.

Figure 6.5 • Renewables installed capacity and generation in the High Renewables Scenario, 2013-40

Note: HR = the High Renewables Scenario
Source: APERC analysis.

The major players in developing solar power (as with wind) will be China (additional capacity of 386 GW) and the United States (220 GW), together accounting for 70% of APEC's total installed capacity and 75% of generation. Around 60% of total solar generation capacity would be utility-scale solar PV, while rooftop solar PV accounts for 29% and CSP for 11%. Chile, China and the United States are expected to be the major developers of CSP in the near future. Development of solar power in APEC expands rapidly, thanks to policy support and declining costs of solar power globally: solar PV module costs have fallen by 80% since 2008 and are expected to keep declining in the near future (IRENA, 2014a) as a result of advances in technology and manufacturing economies of scale. APERC assumes that average capital costs for solar energy will decline at 1.9%/yr over the Outlook period, compared with 1.5%/yr under the BAU.

As for biomass and other renewables, China provides 40% of total biomass installed capacity in 2040, and 43% of generation with feedstock available in the form of crop residue. South-East Asia (mainly Indonesia, Malaysia and Thailand) accounts for 26% of APEC biomass capacity and 25% of generation. The United States accounts for 13% of installed capacity and 16% of generation, doubling its capacity over the Outlook period. Russia has substantial biomass resource potential, but it is uneconomical compared with natural gas generation; development is limited to the agricultural sector and thus accounts for only 4.4% of APEC's installed capacity. Oceania's biomass potential is limited by environmental constraints and a smaller resource base. Other sub-regions show positive developments in biomass, driven by policy support or government targets. Large economic potential, competitive costs and supportive policy drive the expansion of biomass in the power generation mix.

Geothermal energy is mainly developed in the United States (44% of APEC total geothermal), Indonesia (12%) and the Philippines (8.9%). The latter two have large unexploited geothermal potential located close to demand, and have government targets for additional capacity installation within the Outlook period. Other sub-regions provide 14 GW of capacity additions, with participation constrained by limited resource potential, high rates of economic resource utilisation and environmental issues. The United States accounts for 40% of geothermal generation output and South-East Asia provides 25%. Given its huge untapped potential and cost-competitiveness, geothermal energy is expected to play an increasing role in enhancing energy security and reducing emissions from power generation.

DOUBLING THE SHARE OF RENEWABLES IN TRANSPORT

The estimated biofuel supply potential for transport in the BAU Scenario is based on existing cultivation practices and soil structures. In addition, only crops with surplus production after domestic consumption and exports, as defined by the United Nations Food and Agriculture Organisation (FAO), are considered as potential feedstock. The High Renewables Scenario assumes an increase in potential feedstock for biofuels as unutilised agricultural land is brought into production, crop structure is improved by the inclusion of 'energy crops', and productivity is enhanced. Economies with higher productivity levels will serve as benchmarks for increasing productivity of other economies, assuming it proves possible to transfer successful crop production practices and technology.

The analysis divides economies into those that have seasonal climates and those with tropical climates, and assumes the possibility to transfer cultivation technology within climate types from high-productivity economies to those with lower output. The analysis used information and data on agricultural land and crop production from the FAO, and obtained crop prices from economy data or UN statistics. In estimating supply, the modelling assumes that only first-generation biofuel technologies are used. Biofuels demand under the High Renewables Scenario is estimated using the following assumptions:

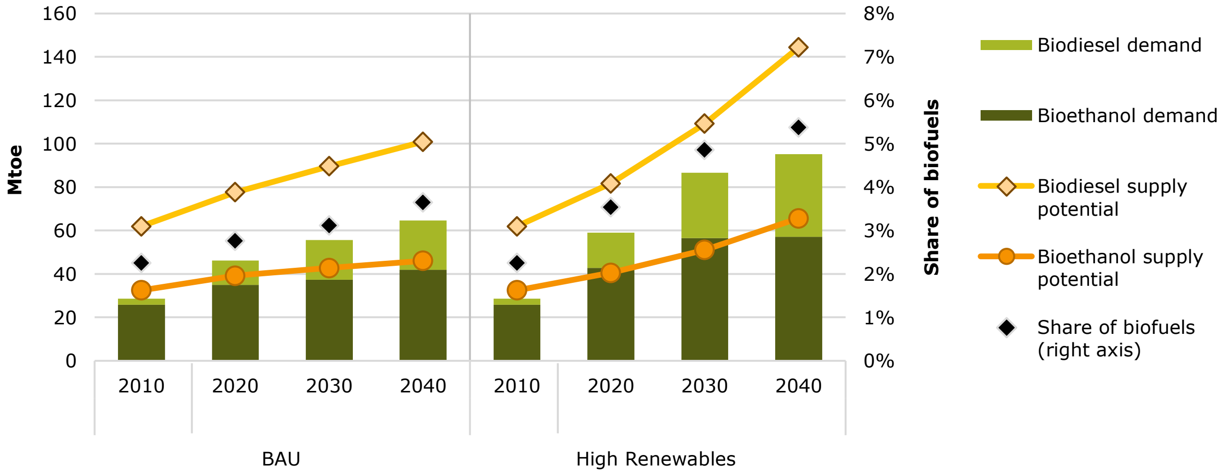
- If the economy has mandated a minimum blend rate and/or target for biofuels, but has no biofuels supply potential, it is assumed that the minimum blend rate and/or target is maintained. If there is sufficient biofuels supply potential, the blend rate (minimum or target) increases to a level that matches potential.
- If the economy has no mandated minimum blend rate and/or target for biofuels and no supply potential, then no biofuels blend rate is considered. If such an economy has sufficient supply potential, a minimum biofuels blend rate that matches potential is assumed to be set.

BIOFUELS SUPPLY POTENTIAL IN THE APEC REGION CAN BE INCREASED

Total biofuel supply potential in the APEC region is projected to increase at an AAGR of 1.4% in the BAU, rising from 70 Mtoe in 2013 to 90 Mtoe in 2030 and 101 Mtoe in 2040. A higher AAGR of 2.7% in the High Renewables Scenario delivers 109 Mtoe in 2030 and 144 Mtoe in 2040 (Figure 6.6). APEC bioethanol supply potential rises at 2.2% a year on average in the High Renewables Scenario, and biodiesel supply at 3.2% a year.

The United States has the largest share in APEC bioethanol supply potential, about 63% in 2040, reflecting a large area of unutilised arable land that offers potential to increase crop productivity. South-East Asia and China contribute about 8% and 9% of APEC potential, respectively. South-East Asia has room to expand land utilisation for energy crop production (particularly in Indonesia and Thailand), while China has higher potential to increase energy crop productivity.

Figure 6.6 • APEC biofuels supply potential in the BAU and High Renewables Scenarios, 2013-40



Source: APERC analysis and IEA (2015a).

For biodiesel, almost 75% of the supply potential in APEC comes from South-East Asia, particularly Indonesia and Malaysia, which still have large areas of unutilised arable land and potential to increase productivity of crops such as palm fruit. The United States also contributes a significant share (20%), as it has a large area of unutilised arable land and potential to increase crop productivity. Other Americas contributes 4.9%, as it can increase productivity of soybean crops. In China, biodiesel production remains low due to a shortage of lipid or vegetable oil as feedstock, an effect of unclear arrangements in agribusiness for producing biodiesel (ADB, 2009).

BIOFUELS DEMAND DRIVEN BY GOVERNMENT SUPPORT

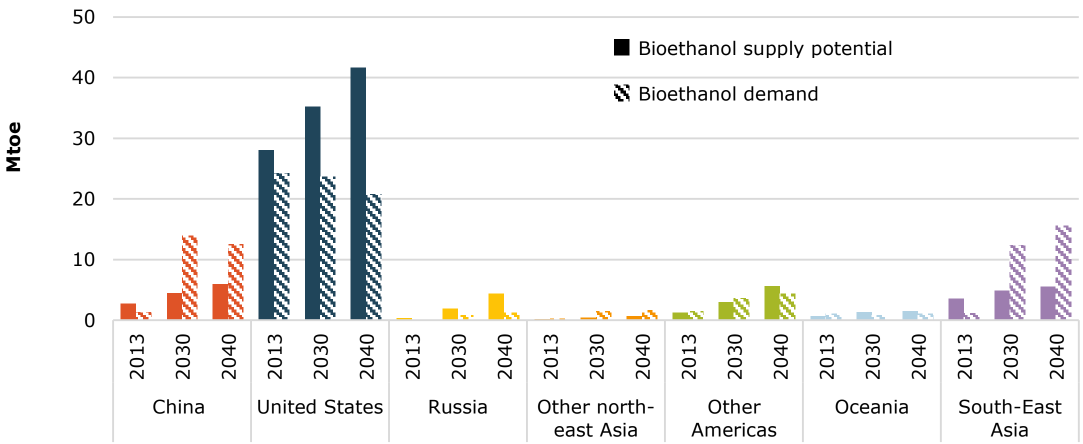
Under the High Renewables Scenario, biofuels demand in APEC grows at an AAGR of 3.7% over the Outlook period (1.5 percentage points higher than in the BAU), rising threefold from 29 Mtoe in 2010 to 87 Mtoe in 2030 and 95 Mtoe in 2040 (Figure 6.6). The growth is attributed to government support through policies on mandated and target blend rates, and incentives for greater use of biofuels. As a result, the share of biofuels in transport rises from 2.3% in 2010 to 4.9% in 2030 and 5.4% in 2040. Biofuels' share of total domestic transport in 2030 more than doubles from 2010 levels.

At an AAGR of 6.6%, biodiesel demand grows faster than bioethanol (AAGR 2.6%); however, about two-thirds of the biofuels demand comes from bioethanol. Biodiesel demand reaches 30 Mtoe in 2030 and 38 Mtoe in 2040, while bioethanol demand reaches around 57 Mtoe in 2030 and onwards. Bioethanol's share is higher because demand for gasoline is much larger than for diesel in APEC, and some economies have a higher blend rate (mandated and/or target) for bioethanol than for biodiesel.

Demand for bioethanol falls slightly (0.14%) between 2035 and 2040 under the High Renewables Scenario because gasoline use decreases as a result of improved vehicle fuel efficiency and greater use of alternative fuels and/or vehicles (such as CNG, electric vehicles and hybrids), mainly in developed economies (USDA, 2014).

Total biofuels supply potential in APEC falls short of projected demand between 2019 and 2034 due to a shortfall in bioethanol feedstock supply.

Figure 6.7 • Bioethanol supply potential and demand in the High Renewables Scenario by region, 2013-40



Source: APERC analysis.

United States leads early bioethanol consumption; South-East Asia catches up by 2040

The United States accounts for 42% of APEC bioethanol demand in 2030 and 36% in 2040 (Figure 6.7). In addition, the US government has set vehicle GHG emissions standards and fuel economy standards of 23.2 kilometres per litre (km/L) (54.5 miles per gallon [mpg]) for passenger cars, light-duty trucks and medium-duty passenger vehicles manufactured in 2025 (MY 2025) (NHTSA, 2015).

In South-East Asia, bioethanol demand grows steadily throughout the Outlook period, as transport energy demand grows rapidly and supply potential remains high. As part of efforts to diversify transport fuels and address climate change, these economies boost bioethanol use by setting mandated minimum blend rates and higher blend rate targets, and by implementing policy to accelerate its development and deployment. South-East Asia accounts for 22% of APEC bioethanol consumption in 2030 and 27% in 2040, with notably high growth in Indonesia, the Philippines, Thailand and Viet Nam.

Bioethanol production does not meet growing bioethanol demand in APEC during the period 2019 to 2034, even in the High Renewables Scenario, in which demand is 37% higher than in the BAU. As a result, some economies may have to secure additional supplies from overseas producers, or develop and deploy advanced or alternative sources of bioethanol feedstock, such as second- and third-generation bioethanol. Additional sources of bioethanol supply are needed in Canada, China, Indonesia, Japan, Mexico, Peru, the Philippines and Chinese Taipei.

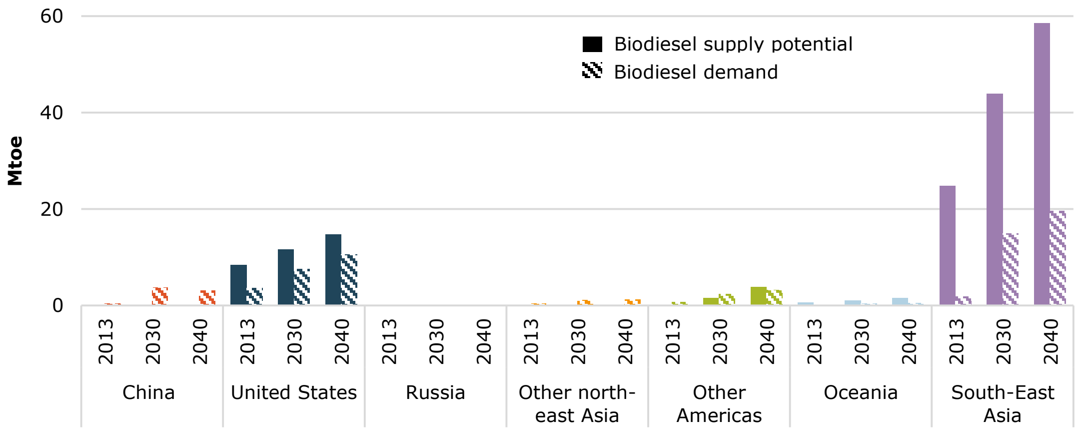
Biodiesel consumption growth is strongest in South-east Asia

South-East Asia accounts for about 50% of total biodiesel demand in 2030 and 2040, as some economies (including Indonesia, Malaysia, the Philippines, Thailand and Viet Nam) implement mandated minimum blends and higher blend rates. In the United States, where vehicle stock using diesel fuels increases (particularly heavy-duty vehicles), the share of APEC biodiesel demand reaches 25% in 2030 and 28% in 2040 as the mandated minimum blended rate is assumed to increase slightly towards the end of the Outlook period. APERC analysis assumes there is no biodiesel use in transport in Russia, which has no mandated or target blend and has a low supply potential (Figure 6.8).

Overall, APEC experiences an excess of biodiesel supply in both the BAU and High Renewables Scenarios. Through cooperation, economies with excess supply may find markets in economies with shortfalls (China and other north-east Asia). Large excess supply potential is found in South-East Asia (Indonesia and Malaysia), other Americas (Mexico), Oceania (Papua New Guinea) and the United States. Development and deployment of advanced biodiesel feedstock will become particularly attractive in economies with low or limited supply potential based only on first-generation technologies.

Increasing biofuels demand and harnessing the available supply potential in some economies will require government support through policies that strengthen existing measures and set higher blend targets. Expanding the share of biofuels will reduce dependency on oil for transport, helping to lower CO_2 emissions. Considering the benefits of using biofuels, economies with no mandated biofuels blend would do well to pursue such policies, while higher blend rates could be implemented in economies with existing biofuels policy.

Figure 6.8 • Biodiesel supply potential and demand in the High Renewables Scenario by region, 2013-40



Source: APERC analysis.

OPPORTUNITIES AND CHALLENGES

APEC economies will face a number of barriers and challenges, as well as opportunities, on their path to doubling the share of renewables. Currently, the most widely recognised barrier for renewable generation is the costs of renewable technologies at all levels, that is, for consumers, developers and investors. The technological challenges of integrating renewables in buildings and power grids, high financing costs, existing subsidies for fossil fuel power generation, and uncertain or insufficient renewable energy policy also create barriers in some economies and some sectors. Additionally, lack of public awareness of benefits of renewables results in low public acceptance. The development of renewable fuels (biofuels) will face distinct challenges such as feedstock availability, lack of policy support, bioethanol taxation, technological challenges with vehicle engine fuel compliance and, especially in the case of first-generation biofuels development, food versus fuel competition.

Setting strong and clear renewable energy targets with supporting policy frameworks is central to success. Several APEC economies have recently announced ambitious renewable targets. The Philippines, for example, issued a policy maintaining the share of renewables at 30% of total power generation capacity (DOE, 2015). In its 4th Basic Plan for New and Renewable Energy, Korea set the goal of an 11% share of renewables (which includes wastes) in total primary energy supply mix by 2035 (MOTIE, 2014). Japan has stipulated a 20% share of renewables in the generation mix by 2030 (METI, 2014). China, as the global leader in renewables and with its vast resource potential, has committed to increase the share of primary non-fossil energy (largely renewables) to 20% by 2030 as indicated in its Intended Nationally Determined Contribution (INDC), submitted to the Paris meeting of the Conference of the Parties (COP 21) of the UN Framework Convention on Climate Change (UNFCCC).

For successful renewables development in APEC, policy makers need to create strong policy frameworks, with clear near- and long-term targets and strategies for research, development, demonstration and deployment (RDD&D) to support promising renewable technologies. They should also seek to collaborate with the private sector to co-fund pilot projects. Liberalisation of electricity markets and policies that limit the growth of fossil-fired generation should be considered carefully. Educational programs could help to improve public acceptance of renewables and raise adoption levels. By encouraging information and data exchange in technical, policy and academic areas, APEC members could stimulate development of local capacity for renewables implementation and enhance international collaboration.

VARIABLE RENEWABLE ENERGY: MANAGING IMPACT WITH EFFECTIVE OPERATION

Solar PV and wind generate electricity and supply power to the system only when the sun shines and wind blows; this dependence on intermittent sources accounts for the term 'variable renewable energy'. This is fundamentally different from other renewables, such as hydro, that provide electricity in a dispatchable manner, and can make it challenging to maintain the necessary balance of electricity supply to meet demand in real time. For systems with large or rapidly growing shares of solar PV and wind generation, the need to integrate VRE sources has become a pressing challenge.

Many experts have presented strategies for integrating large shares of VRE to grids or systems without significant cost increase. The International Energy Agency (IEA) suggests that a VRE share between 5% and 10% of annual generation can be considered as 'Low' (IEA, 2014). This level presents only a small technical challenge for the grid operator, as long as some basic principles are observed: avoiding uncontrolled local concentration of VRE plants ('hot spots'); ensuring sufficient reserves to compensate for the variability of VRE power plant output; and hourly to monthly forecasting of VRE generation. A VRE share of 20% to 45% of annual generation is considered as 'Large'; while it requires system-wide integration efforts to improve the system flexibility, a large share remains manageable (Box 6.1).

Box 6.1 ● The four flexible resources that enable VRE integration

When the share of VRE reaches 20% to 45% of annual generation, that is, the share of VRE becomes 'Large', the power system flexibility should be increased. According to the IEA, one of the basic strategies would be to advance four flexible resources that improve VRE integration (IEA 2014):

- **Grid infrastructure** consists of all assets (high-voltage transmission lines, distribution lines and other devices) that connect power generation plant to demand.
- **Dispatchable generation** can be categorised as dispatchable non-renewable energy technologies (e.g. combustion engine bank combined cycle; steam turbine [gas/oil]) and firm renewable energy technologies (e.g. reservoir hydro; geothermal power).
- **Electricity storage** encompasses all technologies that can absorb electrical energy at a given time and return it as electrical energy at a later stage.
- **Demand-side integration (DSI)** is defined as a combination of two activities: on the one hand, activities to influence or remotely manage load, including energy efficiency and demand-side management (DSM), and on the other hand the active response of consumers (demand-side response [DSR]). DSI holds the promise of providing flexibility cost-effectively.

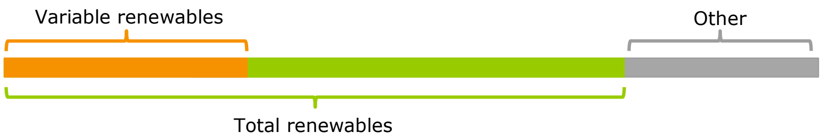
Source: IEA (2015b).

Under the High Renewables Scenario, most APEC economies have Low VRE shares, and power system integration is relatively straightforward for grid operators. Australia, New Zealand and the United States, however, have Large VRE shares and will need to manage integration (Table 6.4). The latter two have substantial installed hydro capacity, which will provide significant spinning reserve and capability to maintain frequency control to reduce stress on their electricity grids.

Table 6.4 • VRE share of power generation in the High Renewables Scenario, 2030 and 2040

	Share of variable renewables in total power generation	
	2030	2040
Australia	42%	49%
Brunei Darussalam	8%	8%
Canada	8%	8%
Chile	21%	18%
China	12%	16%
Hong Kong	2%	2%
Indonesia	3%	12%
Japan	10%	12%
Korea	8%	10%
Malaysia	3%	3%
Mexico	8%	9%
New Zealand	21%	23%
Papua New Guinea	6%	4%
Peru	1%	1%
The Philippines	7%	6%
Russia	2%	3%
Singapore	1%	1%
Chinese Taipei	9%	12%
Thailand	7%	6%
United States	21%	25%
Viet Nam	4%	7%

Source: APERC analysis.



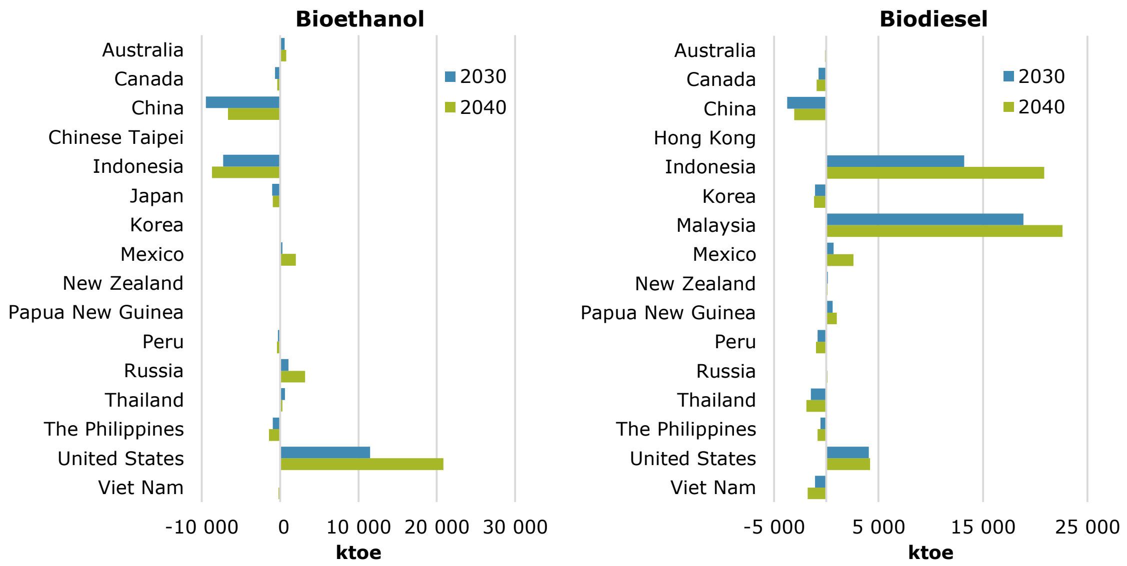
APEC BIOFUELS TRADE IS A MUST FOR THE SHORT AND MEDIUM TERM

To compensate for the imbalances between biofuels demand and supply in some economies, APEC should encourage biofuels trade among members. Mexico, Russia and the United States are among potential bioethanol exporters; Indonesia, Malaysia and the United States are among potential biodiesel exporters (Figure 6.9). The main importers of bioethanol include China, Indonesia, Japan and the Philippines, while China, Korea, Thailand and Viet Nam are among the main importers of biodiesel.

To successfully implement intraregional biofuels trade, APEC members will need to address the following issues in the near term: reduce barriers for export and import to create stable market conditions; establish regional biofuels technical standards and certification; and put in place effective trade agreements (IEA, 2011). APEC has taken steps (in 2007) to address the varying quality and specifications of biodiesel by establishing guidelines for the development of biodiesel standards, which are based on first-generation B100 as the trading fuel to be blended according to local vehicle conditions and fuel standards. The guidelines also suggest that the biodiesel blend should meet the ASTM D6751 (US) standards or the EN 14214 (European) specifications, but with adaptation to local conditions (APEC, 2007).

In the long term, APEC economies should develop and deploy advanced biofuels, as is being done currently in Australia, China and the United States. In China, advanced bioethanol projects use agricultural residue, while the United States is using sugar cane and flue gas. Australia and the United States are pursuing projects based on algae (Solechi et al., 2013).

Figure 6.9 • Net balance of bioethanol and biodiesel in the APEC region, 2030 and 2040



Notes: Net balance is the difference between supply potential and demand; Ktoe = kilotonnes of oil equivalent; Where economies are not included biodiesel and/or bioethanol are not produced and/or consumed.
Source: APERC analysis.

Availability of fiscal and non-fiscal incentives encourages the private sector to develop supply potential, including advanced biofuel feedstocks that are not in competition with commercial crops, and to invest in infrastructure. Given the low oil price at present, many economies find it a challenge to make biofuels competitive with petroleum products. The higher price of biofuels may dissuade future demand, and thus undermine efforts to expand the share of biofuels in total transport energy demand.

RECOMMENDATIONS FOR POLICY ACTION

The High Renewables Scenario demonstrates how APEC can achieve the goal of doubling renewable energy by 2030—and even surpass this aim over the Outlook period. The formulation of a comprehensive, APEC-wide renewable development plan or roadmap, linked to individual economy development plans, is vital. Such a plan should be based on a least-cost approach and reflect the varying resource availability of diverse economies and technology affordability. Both strong government policy and technological progress are needed to accelerate development of renewables in power generation.

The role of government policies in realising the doubling goal should not be underestimated, as they can influence many areas. Support for R&D can help to drive down the costs of renewables and improve performance, leading to greater competitiveness with dominating fossil fuel generation. Government support is essential to establish a growing renewables market and manage its integration into existing power markets. Comprehensive renewable policy covering power generation, transport and buildings, coupled with fiscal and non-fiscal incentives and other support mechanisms, are critical to the promotion and expanded use of renewables in power and non-power applications. Measures such as PPAs, FiTs and RPSs can help improve the bankability of renewable energy projects.

An APEC roadmap on renewable technology development and deployment should include next-generation renewable technologies, building in mechanisms for economies to adopt these technologies based on their applicability to local conditions. The plan must also take into account the infrastructure requirements for integrating large capacity from dispatchable and variable renewables. Coordinated infrastructure development through interconnectivity and grid-scale energy storage, combined with skilled grid operation, will be needed to integrate large shares of VRE.

Technology development and transfer would enable more economies to embrace higher shares of renewables. APEC could play a key role by supporting local training and capacity building in those economies with limited renewables expertise. Similarly, sharing experiences and good practices on renewables deployment policies and measures among APEC economies can help to accelerate renewables deployment across the region.

In parallel, economies should strengthen and improve electricity systems to increase system flexibility to allow integration of higher VRE shares into electricity markets. A joint study on VRE integration among APEC economies could be developed to evaluate the need for greater flexibility or additional interconnections in various economies as greater VRE shares are deployed.

Those APEC economies that lack or have insufficient renewables support policy and incentive mechanisms should consider taking steps to correct these shortcomings in order to encourage renewable development. They may advance quickly by adopting the good practices of economies that have already made significant progress in the development and use of renewables such as China, the United States and the Philippines.

The roadmap should also seek to accelerate development of advanced biofuels (second- and third-generation) and next-generation feedstocks, including the sharing of information among economies. This would help to address the supply shortfall, especially of bioethanol, within the region. The roadmap should also offer options to reduce the cost of advanced biofuels, to make them more price-competitive with petroleum products (gasoline and diesel) and to encourage economies to expand their biofuels programs with higher blend rate targets.

To address the mismatch between biofuels production and demand, APEC should encourage trade among member economies and promote implementation of the biodiesel standards developed in 2007. Similarly, an APEC standard for bioethanol should be established.

Development of vehicle standards that enable operation on various biofuel blend rates could support the wider deployment of flex-fuel vehicles and encourage increased biofuels use. Introduction of more flex-fuel vehicles in the market, particularly those that can accommodate high blend rates (up to 85%), can help to increase the share of biofuels in total transport energy demand. APEC should encourage economies to engage with associations of car manufacturers on these issues.

7. ALTERNATIVE POWER MIX SCENARIO

KEY FINDINGS

- **Under various premises, coal remains the dominant source for electricity generation across APEC through to 2040.** To reduce the CO_2 intensity of the power sector more rapidly, economies will need to accelerate deployment of renewables and clean coal technologies, increase shares of natural gas and expand nuclear energy.

- **Widespread adoption of CCS technologies is the only effective way to sustain coal-based electricity generation through the Outlook period.** By 2040, extensive use of CCS in coal-based generation cuts CO_2 emitted under the BAU Scenario by 12% in the electricity sector; without these technologies, reductions are barely 3%.

- **The High Gas 100% Case, in which natural gas replaces expected coal-based generation additions, delivers the largest power sector emissions reduction—14% lower than in the BAU in 2040.** This case, however, demands 51% more natural gas supply, which has implications for energy security.

- **The High Nuclear Case reduces CO_2 emissions by 10% from BAU by 2040**. As this case calls for nuclear-based installed capacity 2.4 times higher than the 2013 level and 0.9 times above the BAU, public acceptance presents the greatest challenge.

INTRODUCTION

To reconcile economic growth with environmental sustainability, Asia-Pacific Economic Cooperation (APEC) member economies are looking for ways to decouple their energy needs from rising greenhouse gas (GHG) emissions. In particular, they are considering more stringent measures to lower the energy intensity and the predominance of fossil fuels in the electricity sector. This is a complex task, however, because it is not based on any APEC-wide mandate or goal, and the weights given to environmental, economic and energy security criteria tend to differ among member economies.

Is electricity generation at the crossroads between the use of coal, natural gas and nuclear energy? Despite the rising use of renewable energy and the considerable share of hydro power in some APEC economies, thermal-based technologies still account for most of the region's electricity generation. These technologies are expected to remain dominant to 2040, so it is worth exploring alternative energy options that are less carbon-intensive and still technically feasible. To this end, APERC has developed the Alternative Power Mix Scenario to examine such alternative options in the use of coal, natural gas and nuclear energy for thermal power plants.[1]

Coal: Low costs at the expense of increased pollution. Coal is the single largest energy source of electricity generation in APEC, having contributed nearly half of the electricity produced in 2013. In general, coal is reliable and inexpensive because of vast worldwide supplies. At current consumption levels, proven coal reserves are large enough to last at least another century (BP, 2015). This abundance, and the low capital costs of dedicated power plants, favour the use of coal for large-scale electricity generation, for which it is a fuel particularly appropriate to meet base-load demand.

However, coal combustion produces significant quantities of toxic air pollutants, including the highest carbon dioxide (CO_2) emissions of all fossil fuels. In addition, mainstream coal-based electricity generation technologies have low levels of efficiency and coal mining has harmful environmental effects on land, water and air.

Natural gas: The cleanest fossile fuel, yet not widely available. Mainly due to its use for electricity generation, natural gas demand is growing quickly in many member economies. It was the second-largest energy source for electricity generation in APEC in 2013, accounting for nearly 21% of output. Power plants fuelled by natural gas offer major benefits, including affordable capital costs, shorter construction times and higher efficiency levels, especially if combined-cycle technologies are used. Together, these characteristics offer the technical flexibility necessary to meet intermediate and peaking electricity demand.

The most important benefit provided by natural gas is probably environmental, as its combustion yields the lowest CO_2 emissions of all fossil fuels. The use of natural gas in combined-cycle power plants, for example, might emit one-third less CO_2 than coal-fired plants equipped with supercritical (SC) or ultra-supercritical (USC) technologies (EDMC, 2015).

Nevertheless, greater use of natural gas for electricity generation has some major disadvantages. As global gas reserves are concentrated in a small number of economies, supplies—and ultimately trade—depend on the existence of dedicated facilities such as pipelines, liquefied natural gas (LNG) terminals and storage. The deployment of this infrastructure increases fuel costs and industrial requirements for maintenance and safety. In addition, in most economies the price of natural gas is linked to that of crude oil, which makes fuel costs volatile and compromises the reliability of natural gas supplies. From an environmental perspective, the extraction and distribution of natural gas can produce fugitive emissions of methane, a GHG. Moreover, although the production of unconventional gas resources such as shale gas promises a wider supply, it has a larger environmental impact than conventional gas. All these concerns raise questions about increasing the contribution of natural gas to the electricity generation mix.

[1] The potential use of renewable energy was explored in the previous chapter.

Nuclear energy: Zero emissions but social controversy. The use of nuclear energy also has significant benefits and disadvantages. Uranium supply is stable and well distributed worldwide, and its use for electricity is a proven technology that produces zero CO_2 emissions in the generation process at low operating costs. These characteristics make nuclear energy an attractive choice to meet base-load electricity demand.

Nuclear power plants incur high investment and maintenance costs and require long construction timeframes, resulting in less favourable project economics that carry longer payback periods. An even greater obstacle is the generalised negative social attitude to the development of nuclear energy, which has worsened in the aftermath of catastrophic accidents. The most recent major accident, in March 2011 at Fukushima, Japan, led many economies to reassess, and even reduce or cancel their nuclear development targets. The political and social tension surrounding nuclear power is increased by the potential for nuclear fuel to be misused for military purposes and by the safety risks and economic costs involved in disposing of spent fuel and nuclear waste, as well as decommissioning retired power plants.

TRADE-OFFS AMONG COAL, GAS AND NUCLEAR DRIVE THE DESIGN OF ENERGY POLICY

The use of coal, natural gas and nuclear energy for thermal-based electricity generation entails merits and drawbacks that result in several trade-offs (Table 7.1). While environmental, economic and technical considerations are relatively straightforward, those related to energy security are more difficult to assess and define. Energy security has been largely framed within the 'four As' of availability, accessibility, affordability and acceptability (APERC, 2007); nevertheless, this paradigm has fallen short of transcending the physical dimension of energy supply to explain the multiple domains, risks and timespans that are interdependent and contingent on particular contexts and priorities (Cherp and Jewell, 2014; Sovacool, 2011). Owing to this multidimensionality, there is no best single energy source to be adopted universally by APEC economies. Instead, each economy must design an electricity portfolio that is diversified, emits less CO_2 and still supports economic growth. To that end, economies need to examine the main trade-offs and drivers involved in their use of certain fuels.

Table 7.1 • Merits and drawbacks of the fuels examined in the Alternative Power Mix Scenario

	Coal	Natural gas	Nuclear
CO_2 emissions	● (Drawback) High excluding with CCS	● (Neutral effect) Lowest among fossil fuels	● (Benefit) Nil
Fuel costs	● (Benefit) Relatively cheap and stable	● (Drawback) Relatively expensive[a]	● (Benefit) Inexpensive relative to electricity output
Capital investment	● (Neutral effect/Drawback) Low to medium with more advanced technologies	● (Benefit) Increasingly lower	● (Drawback) High
Construction timeframes	● (Neutral effect) Medium to long	● (Benefit) Short	● (Drawback) Long
Operational flexibility	● (Neutral effect) Mainly base-load	● (Neutral effect) Intermediate and peaking loads	● (Neutral effect) Mainly base-load
Operational efficiency	● (Neutral effect) Average	● (Benefit) High	● (Neutral effect/Drawback) Low to average
Energy security	● (Benefit) Supply is abundant and widely distributed	● (Benefit) Supply concentrated in a few economies but LNG increasingly available	● (Benefit) Uranium supply is stable and widely distributed
Other issues	● (Drawback) Pollution impacts	● (Drawback) Fugitive methane emissions	● (Drawback) Acute political and social resistance resulting from past catastrophic accidents

Legend: ● Benefit ● Neutral effect ● Drawback

Notes: [a] Except for gas producing economies as trade and use requires dedicated infrastructure in the form of LNG terminals and transmission pipelines.
Source: APERC analysis.

Guided by these considerations, this chapter examines alternative fuel mixes for the electricity sector based on the use of coal, natural gas and nuclear energy. It provides projected outcomes, along with major opportunities and challenges, for individual member economies and for the APEC region as a whole. The last section of the chapter highlights potential areas for policy action.

SCENARIO OVERVIEW

The Alternative Power Mix Scenario provides a quantitative assessment of the benefits of high-efficiency coal technologies, higher shares of natural gas and the expansion of nuclear energy in APEC's electricity sector between 2013 and 2040. The scenario aims to show the effects on the electricity mix of member economies in terms of installed capacity, fuel use and CO_2 emissions, with the ultimate purpose of illustrating potential trade-offs and implications for policy makers in APEC member economies.

Within the Alternative Power Mix Scenario, four cases have been devised: Cleaner Coal, High Gas 50%, High Gas 100% and High Nuclear. While these cases are based on diverging assumptions, aside from the High Gas Cases, energy price projections used are those of the Business-as-Usual (BAU) Scenario.

Cleaner Coal Case: This case assumes the progressive addition of coal-based electricity capacity equipped with more efficient technologies. In the best scenario, new coal-fired power plants deploy USC and advanced-USC technologies (A-USC) equipped with steam thermal processes like pulverised coal combustion and integrated gasification combined cycle (IGCC), and eventually carbon capture and storage (CCS) systems. As well as being more efficient, these technologies reduce CO_2 emissions by 15% to 25% per unit of electricity generated.

Given the recent progress of some APEC economies in deploying next-generation A-USC and IGCC plants with CCS, it is plausible to presume that these technologies will become commercial after 2030 in economies where coal demand remains large in volumetric terms (Group A). In other economies where coal use is intensive but next-generation technologies have not yet been deployed (Group B), it is reasonable to assume that after 2030, USC plants equipped with CCS will prevail. Advanced coal-based generation technologies are expected to have high thermal efficiency levels, and to enable significant cost efficiencies due to their more simplified system configuration over conventional IGCC plants.

In consequence, the Cleaner Coal Case assumes that in a group of 13 selected APEC economies with significant levels of coal-based electricity generation, all coal-based power plants built after 2020 will be equipped with at least SC technologies. Based on their economic characteristics and maturity in their use of coal for electricity generation, these economies were further divided into two major categories (Table 7.2).

Table 7.2 • Technology assumptions in the Cleaner Coal Case by regional grouping

	Type of technology in new coal plants after 2020	Type of technology in new coal plants after 2030
Group A (Australia, China, Japan, Korea, Chinese Taipei, Russia and the United States)	A-USC or IGCC Efficiency: 45%-50%	A-USC or IGCC with CCS
Group B (Chile, Indonesia, Malaysia, the Philippines, Thailand and Viet Nam)	SC or USC Efficiency: 38%-46%	USC with CCS

Source: APERC analysis.

High Gas 50% Case and High Gas 100% Case: The main assumption in these cases is that natural gas replaces either all new coal-based generation capacity (High Gas 100% Case) or half of it (High Gas 50% Case), building up an electricity supply with lower CO_2 emissions. APEC economies are assumed to gradually shift from coal to gas from 2013, and after 2020 all coal-based capacity additions are replaced with gas.

These cases envisage replacing only planned additional capacity because it would be technically and economically unfeasible to replace at once all coal-based power plants in operation, given that coal is the dominant energy source for electricity generation in many APEC member economies and in the region as a whole. Moreover, many coal-fired power plants that started operating recently need to remain active for some time to pay back their capital costs. In consideration of these criteria, the High Gas Cases were applied to 13 member economies: Australia, Chile, China, Indonesia, Japan, Korea, Malaysia, the Philippines, Russia, Chinese Taipei, Thailand, the United States and Viet Nam.

Five economies were excluded because coal-based capacity makes up less than 5% of electricity generation by 2040, and there is thereby low potential to replace coal-based additions with natural gas (Canada, Hong Kong, Mexico, New Zealand and Peru). In Singapore the use of coal is less than 5%; this economy and Brunei Darussalam were excluded from the High Gas Cases because gas-based generation is already high, making up 85% or more of capacity by 2040. Finally, in Papua New Guinea there is no coal-based generation that could support the premises of the High Gas Case.

Furthermore, the High Gas Cases assume that member economies will not expand domestic natural gas production to 2040 under the BAU, with the aim of demonstrating how much natural gas would need to be traded into the region to meet increased demand. For this reason, it is also assumed that increased demand raises natural gas prices by 10% from 2025, 20% from 2030 and 30% in 2040 compared with the BAU Scenario.

High Nuclear Case: The main premise is that 11 APEC economies expand nuclear-based generation beyond the BAU assumptions to reduce CO_2 emissions reliably and cost-effectively between 2013 and 2040. An additional consideration was the decreasing dependence on imported fossil energy in some economies, including those with little or no domestic coal and gas supplies (Korea and Japan) or still depending on imports (China, Indonesia, Malaysia, Thailand and Viet Nam). This criterion does not apply to Russia and the United States, which are self-sufficient in coal and gas. Projections of additional capacity are based on potential to expand nuclear-based generation in 11 APEC economies.

Nine of the 11 economies either use nuclear-based generation (China, Japan, Korea, Russia and the United States) or have plans to develop it soon (Indonesia, Malaysia, Thailand and Viet Nam). These nine economies are assumed to expand nuclear-based generation because they need to meet rising electricity demand while reducing CO_2 emissions, displacing fossil-fuelled power plants and diversifying their power mixes.

In the other two of the 11 economies, Mexico and Chinese Taipei, it was assumed that there will be no capacity expansion but that current nuclear plants will undergo sufficient maintenance and refurbishments to extend their lifetimes, resulting in more nuclear-based generation than in the BAU Scenario. Although Canada uses nuclear-based generation, it was excluded from the High Nuclear Case because it plans to retire 3.2 GW of nuclear capacity by 2040 and is more likely to use abundant hydro power and fossil energy resources than nuclear power.

The potential of each member economy to expand nuclear-based capacity up to 2040 was estimated by considering existing capacity, planned retirements and lifetime extensions, as well as capacity under construction, planned and/or proposed. Generation projections were calculated using capacity projections and the capacity factors of each economy. Projections were based on the most recent government plans to develop nuclear energy and the relevance of nuclear energy to the electricity sectors of the 11 economies. Official documents and proposals concerning the development of nuclear energy were considered, as well as related corporate announcements from utilities in member economies where the private sector is an active developer of nuclear technology.

POTENTIAL FOR CHANGE IN THE ELECTRICITY MIX OF APEC ECONOMIES

According to the above premises, the use of nuclear energy, coal and natural gas in the Alternative Power Mix Scenario will vary by member economy. There is room to implement substantial changes in the electricity configurations of many APEC member economies, especially in those that account for the largest share of the region's total generation (Table 7.3). In 10 economies, including the four largest electricity-generating economies, there is great potential to change the electricity mix, as the Cleaner Coal, High Gas and High Nuclear cases are all theoretically possible: China, Indonesia, Japan, Korea, Malaysia, Russia, Thailand, Chinese Taipei, the United States and Viet Nam. In three economies there is moderate potential for change: Australia, Chile and the Philippines. In eight economies there is very little potential (Mexico) or no potential for change (Brunei Darussalam, Canada, Hong Kong, New Zealand, Papua New Guinea, Peru and Singapore), due to high reliance on a single fuel, the high contribution of renewable energy, certain environmental policies or the current absence of some of the energy technologies considered in this scenario.

Table 7.3 • Applicability of the assumptions in the Alternative Power Mix Scenario by Case

	Cleaner Coal	High Gas	High Nuclear
Australia	✔	✔	✕
Brunei Darussalam	✕	✕	✕
Canada	✕	✕	✕
Chile	✔	✔	✕
China	✔	✔	✔
Hong Kong	✕	✕	✕
Indonesia	✔	✔	✔
Japan	✔	✔	✔
Korea	✔	✔	✔
Malaysia	✔	✔	✔
Mexico*	✕	✕	✔
New Zealand	✕	✕	✕
Papua New Guinea	✕	✕	✕
Peru	✕	✕	✕
The Philippines	✔	✔	✕
Russia	✔	✔	✔
Singapore	✕	✕	✕
Chinese Taipei*	✔	✔	✔
Thailand	✔	✔	✔
United States	✔	✔	✔
Viet Nam	✔	✔	✔

Note: * In these economies, while no expansion of nuclear-based capacity was assumed, nuclear-based electricity generation surpasses the BAU levels by 2040 as a result of lifetime extensions of existing nuclear power plants.
Source: APERC analysis.

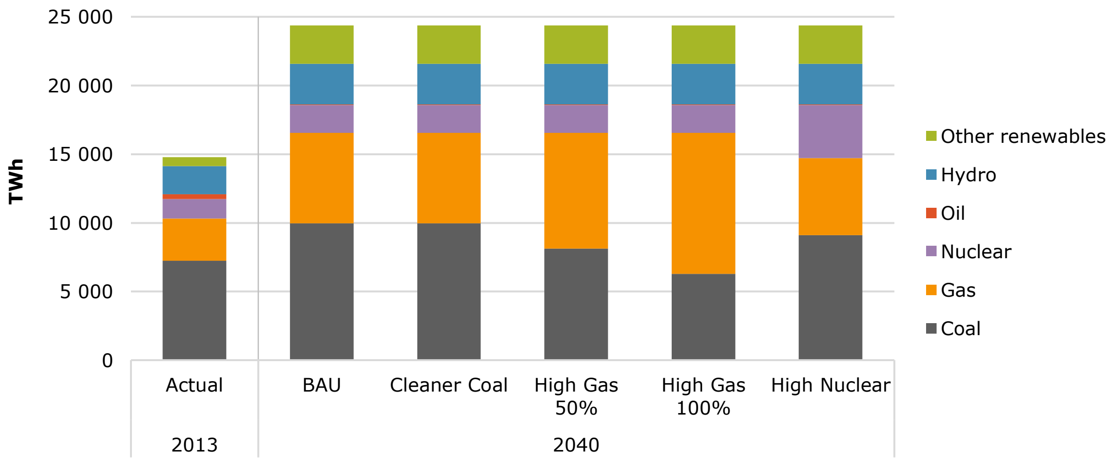
SCENARIO RESULTS

OVERVIEW

The configuration of APEC's electricity generation might change substantially depending on which cases in the Alternative Power Mix Scenario prevail (Figure 7.1). In the Cleaner Coal Case, APEC coal-fired electricity generation is progressively more efficient. Although output by 2040 is roughly the same as in the BAU Scenario, carbon intensity is much lower because of the use of more advanced technologies, including CCS. By 2040, CCS could represent around 15% of the more than 9 974 terawatt-hours (TWh) of coal-fired generation in APEC, equivalent to 6% of the region's total electricity generation.

Gas-based electricity generation by 2040 is 8 431 TWh in the High Gas 50% Case (28% higher than the BAU figure of 6 597 TWh) or 10 276 TWh in the High Gas 100% Case (56% higher than the BAU). As a result, the share of natural gas in APEC total electricity generation expands from 27% in the BAU to as much as 35% in the High Gas 50% Case and 42% in the High Gas 100% Case.

Figure 7.1 • Total electricity generation by fuel and by Case, 2013 and 2040



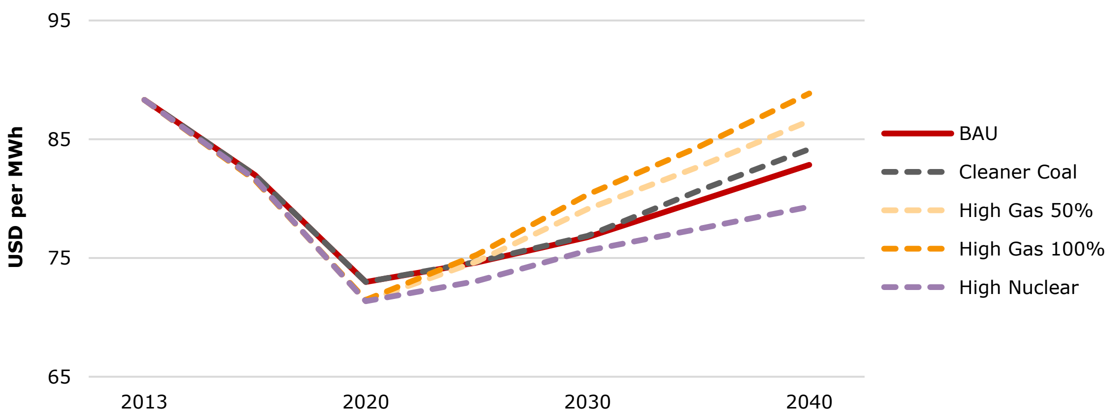
Note: Data excludes imports.
Sources: APERC analysis and IEA (2015).

In the High Nuclear Case, the amount of generation based on nuclear technologies more than doubles over the BAU, passing from 8% of the region's total electricity generation in 2013 to 16% by 2040, involving the addition of 314 gigawatts (GW) of nuclear-based installed capacity.

Electricity generation costs are lower only under the high nuclear case

The capital and operating costs of deploying the technologies considered in this scenario entail different competitiveness implications for the electricity generation mix of APEC economies. The average costs of electricity generation in the APEC region by 2040 are higher by 2% in the Cleaner Coal Case, 5% in the High Gas 50% Case and 8% in the High Gas 100% Case (Figure 7.2). Only in the High Nuclear Case are average costs lower, by 4%. Conversely, capital costs are highest in the High Nuclear Case because of accelerated nuclear power plant development, followed by the Cleaner Coal Case because of the introduction of CCS after 2030. Capital costs in both High Gas Cases are lower than under the BAU.

Figure 7.2 • Average electricity generation cost by Case, 2013-40



Sources: APERC analysis and IEA (2015).

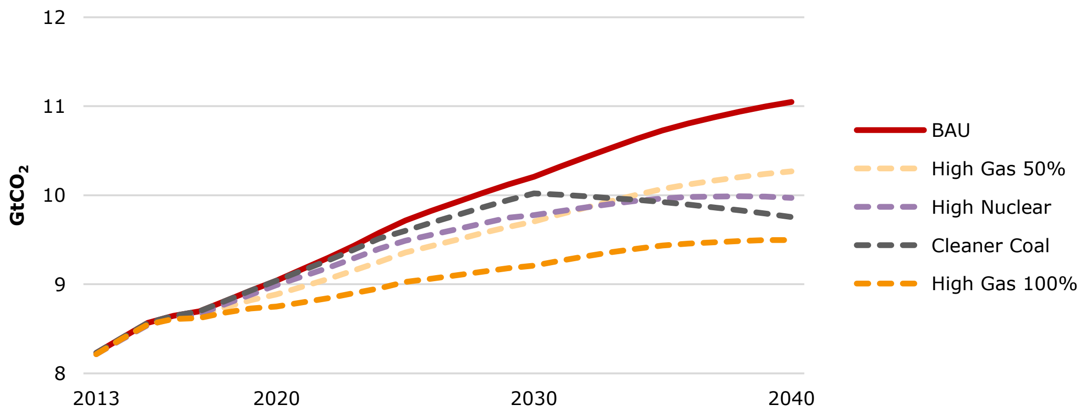
As for average generation costs, trends and levels remain similar across the different cases, as they largely follow the projections in energy prices and electricity demand. In general, APEC-wide electricity generation costs dip in the short term as a result of the projected decline in oil and gas prices up to 2020, but increase thereafter, albeit at a slower rate between 2030 and 2040 due to deceleration in electricity demand. In the long term, the projected rise of natural gas prices increases average generation costs in the High Gas Cases much faster and over a longer period than in the BAU Scenario, in spite of projected lower capital costs by 2040. By contrast, wider adoption of nuclear technology, in combination with more moderate electricity demand, could result in average generation costs close to—and then lower than—the BAU, making this technology the most cost-competitive.

Largest CO_2 emissions reduction comes from highest use of gas

For each alternative case, not only do the volumes of CO_2 emitted differ, but also the long-term trajectories. In both High Gas Cases, CO_2 emissions rise steadily but more slowly than in the BAU (Figure 7.3). In the Cleaner Coal Case, emissions are also expected to increase steadily to 2030, then decline substantially with the massive introduction of more efficient coal generation technologies, including CCS. In the High Nuclear Case, the combined accelerated development of nuclear-based capacity and stagnant coal-based generation lead CO_2 emissions to plateau between 2029 and 2036, then fall as coal-based generation decreases and numerous nuclear power plants begin operating.

Among the alternative cases, the High Gas 100% Case yields the largest CO_2 emissions reduction. Emissions are 7% below the BAU in the High Gas 50% Case, 10% below in the High Nuclear Case, 12% in the Cleaner Coal Case and 14% in the High Gas 100% Case.

Figure 7.3 • Total CO_2 emissions from electricity generation by Case, 2013-40



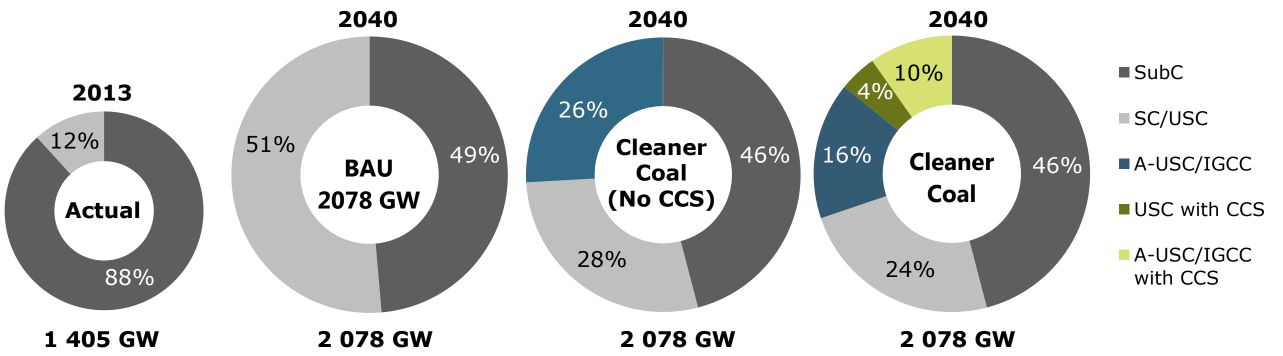
Sources: APERC analysis and IEA (2015).

CLEANER COAL: DEPLOYMENT OF CCS CRITICAL IF EMISSIONS ARE TO DECLINE

As the most abundant and affordable fuel, coal has a role in providing energy for the period to 2040. Despite rising demand for natural gas and renewable energy in the BAU Scenario, coal is still the most consumed fuel in the APEC power mix by 2040, providing nearly 41% of the region's total electricity output. The BAU Scenario projects APEC-wide electricity generation based on coal to grow 38% over the Outlook period, from 7 242 TWh in 2013 to 9 960 TWh in 2040; while its share of the region's generation declines from 49% to 41%, coal is still the fuel most used for electricity generation.

In the Cleaner Coal Case, the amount of coal-based generation is the same as in the BAU, but its technological configuration is increasingly efficient (Figure 7.4). In terms of capacity, the least efficient subcritical (SubC) power plants are a mainstay throughout the Outlook period, amounting to half the total coal-based capacity in APEC by 2040, with little variation across different assumptions. In the Cleaner Coal Case, for example, SubC technologies still account for half the total coal-based generation, but the remainder is comprised of more efficient technologies. In comparison with the BAU, in the Cleaner Coal Case the share of SC and USC technologies is halved and replaced by 2040 with a combination of USC and A-USC or IGCC technologies, with or without CCS.

Figure 7.4 • Coal-based electricity generation capacity by technology in the BAU and the Cleaner Coal Case, 2013 and 2040



Notes: SubC = subcritical; SC/USC = supercritical/ultra-supercritical; USC with CCS = ultra-supercritical equipped with carbon capture and storage; A-USC/IGCC = advanced ultra-supercritical/integrated gasification combined cycle; A-USC/IGCC with CCS = advanced ultra-supercritical or integrated gasification combined cycle with carbon capture and storage.
Sources: APERC analysis and IEA (2015).

Even if no CCS technologies are deployed, coal-based generation is still more efficient in the Cleaner Coal Case, but the share of technologies equipped with CCS could be as much as 15% of APEC-wide coal-based generation by 2040. Nevertheless, this still requires the addition of 331 GW of SC/USC technologies, 333 GW of A-USC or IGCC technologies and 203 GW of CCS equipment in USC and A-USC with IGCC (Table 7.4).

Table 7.4 • Coal-based electricity generation capacity by Scenario, by technology and by Case, 2040

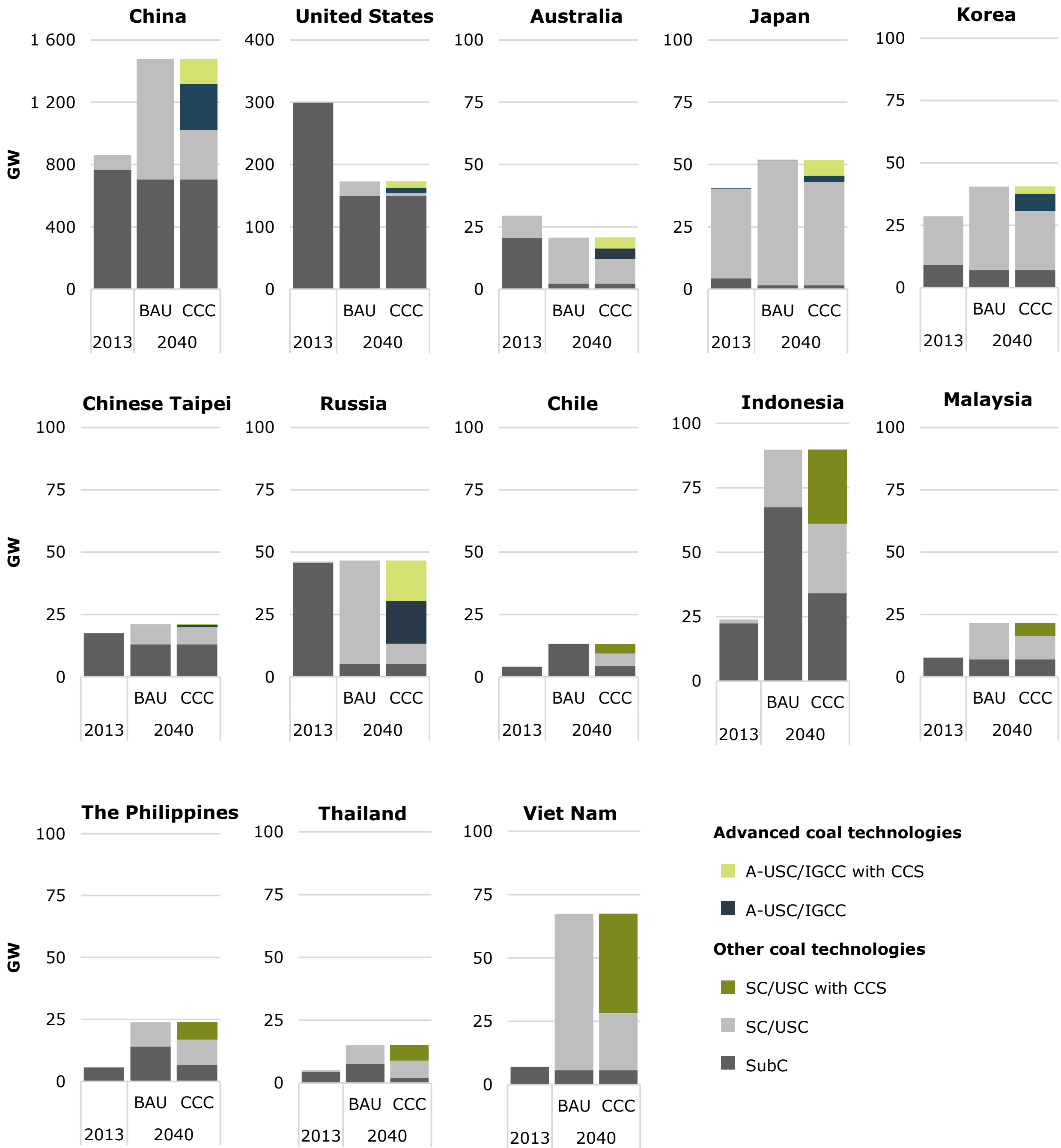
	BAU				Cleaner Coal Case (No CCS)				Cleaner Coal Case				
	SubC	SC/ USC	USC with CCS	A-USC/ IGCC	SubC	SC/ USC	USC with CCS	A-USC/ IGCC	SubC	SC/ USC	USC with CCS	A-USC/ IGCC	A-USC/ IGCC with CCS
Australia*	2	18	-	-	2	10	-	8	2	10	-	4	4
China*	703	775	-	-	703	319	-	456	703	319	-	294	162
Japan*	2	50	-	0.3	2	41	-	9	2	41	-	3	6
Korea*	7	33	-	-	7	24	-	10	7	24	-	7	3
Russia*	5	42	-	-	5	8	-	33	5	8	-	17	16
Chinese Taipei*	13	8	-	-	13	7	-	1	13	7	-	1	0.4
United States*	150	23	-	-	150	5	-	18	150	5	-	8	10
Chile^	13	-	-	-	4	9	-	-	4	5	4	-	-
Indonesia^	67	22	-	-	34	56	-	-	34	27	29	-	-
Malaysia^	7	15	-	-	7	15	-	-	7	9	5	-	-
The Philippines^	14	10	-	-	7	17	-	-	7	10	7	-	-
Thailand^	8	7	-	-	2	13	-	-	2	7	6	-	-
Viet Nam^	6	62	-	-	6	62	-	-	6	23	39	-	-
Subtotal	**998**	**1 065**	**-**	**0.3**	**943**	**584**	**-**	**536**	**943**	**495**	**90**	**333**	**203**
Remaining economies†	12	1	2	-	12	1	2	-	12	1	2	-	-
APEC	**1 010**	**1 066**	**2**	**0.3**	**954**	**586**	**2**	**536**	**954**	**496**	**92**	**333**	**203**

Notes: *Group A; ^Group B; †In remaining APEC economies, CCS capacity is assumed only at Boundary Dam in Saskatchewan, Canada.
Source: APERC analysis.

Given the dominance of coal in China and the magnitude of its total electricity generation, this economy is critical to the premises of the Cleaner Coal Case. About 88% of the additional A-USC or IGCC generation capacity in APEC is installed in China, and its share for these same technologies with the addition of CCS is 80%. The second-largest capacity additions of these advanced technologies occur in Russia, but at a much smaller magnitude.

In Group B, projections of additional USC technology capacity, including CCS, are better balanced. Around 44% of installed capacity additions based on USC technologies equipped with CCS are expected in Viet Nam, followed by Indonesia with 32% and the remainder spread among the other economies in that group (Figure 7.5).

Figure 7.5 • Coal-based electricity generation capacity by technology in the BAU and Cleaner Coal Case, 2013 and 2040



Notes: The scale of magnitude differs among the economies; CCC = Full assumptions of Cleaner Coal Case (with CCS technologies).
Sources: APERC analysis and IEA (2015).

For economic and energy security reasons, many economies have historically opted to meet rising electricity needs with coal-fired power plants. Intensive use of coal largely underpinned the industrialisation of many developed economies, as well as the recent economic growth of several emerging economies. In China, for example, coal was sourced domestically, which made it cost-effective and reduced China's reliance on imported fuels. These advantages avoided the costs of deploying more expensive technologies, expanded energy access for the Chinese population and improved China's economic competitiveness.

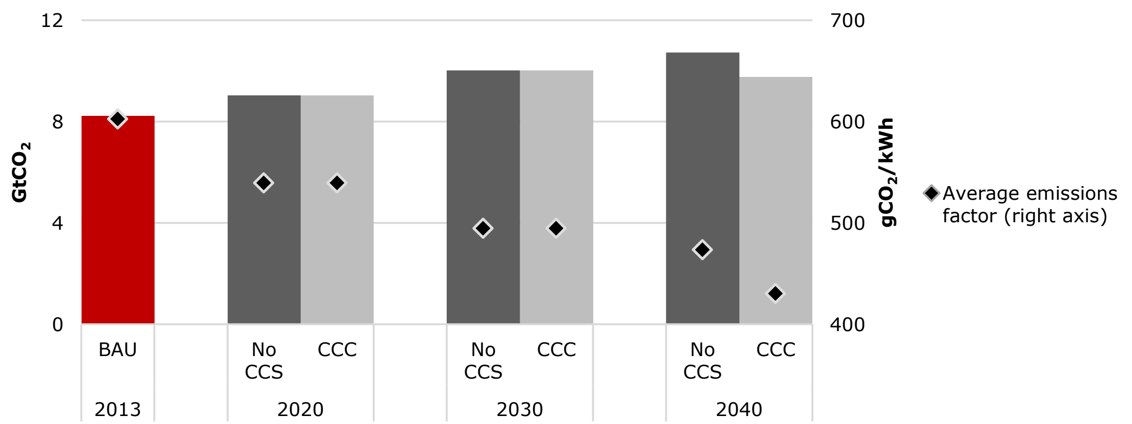
Nevertheless, the expansion of conventional coal-based generation is no longer compatible with the global call for massive decarbonisation of energy systems and the commitments of individual APEC member economies, and the region as a whole to effectively address climate change. In consequence, the viability of coal-based generation rests on the adoption of more advanced technologies with higher efficiency levels and lower CO_2 emissions. By 2040, the Cleaner Coal Case avoids the emission of 1.3 gigatonnes of CO_2 ($GtCO_2$), a reduction of 12% from the BAU, with CCS application being by far the main factor in this decrease. Without CCS, the decrease in CO_2 emissions is barely 3% (Figure 7.6).

From a lifecycle approach, the use of CCS also results in a reduction of sulphur oxide (SO_x). With the introduction of CCS, the SO_x emitted by typical pulverised combustion coal-fired power plants is estimated to fall from between 0.11 grams per kilowatt-hour (g/kWh) and 0.7 g/kWh to between 0.04 g/kWh and 0.15 g/kWh, which is much closer to the range of emissions in a conventional gas-fired plant with combined cycle technologies (between 0.04 g/kWh and 0.2 g/kWh) (Jaramillo, et al., 2007).

Even though more efficient coal-fired generation plants offer economies the same amount of generation with less coal, this is not strictly the case for CCS systems. The main reason for this is the energy penalty, or the decrease in plant efficiency and electricity output resulting from the increased energy requirements of the capture process. In other words, to produce the same amount of heat and electricity, CCS power plants use more coal than conventional coal-based power plants.

The range of energy penalty largely depends on the particular technology used, such as pre-combustion, oxy-fuel combustion or post-combustion (Thorbjörnsson, et al., 2015). In line with these notions, the decline by 2040 in the APEC-wide coal demand for electricity generation in comparison with the BAU is 4% in the Cleaner Coal Case without CCS (equivalent to 80 million tonnes of oil equivalent [Mtoe]), but if CCS technologies are included the demand is only lower by 1% (28 Mtoe). In any case, this issue does not represent a major problem to APEC economies.

Figure 7.6 • CO_2 emissions from electricity generation in the Cleaner Coal Case by technology, 2013-40



Note: No CCS = Cleaner Coal Case without CCS technologies.
Sources: APERC analysis and IEA (2015).

Despite the environmental benefits of more advanced coal technologies, they are less feasible economically as they incur higher costs. By 2040, total annual costs in the Cleaner Coal Case without CCS descend by USD 3 billion, but if CCS technologies are deployed an additional USD 32 billion is required, 2% more than under the BAU. Likewise, in relation to the energy produced, average costs remain nearly as in the BAU by 2040, but if CCS technologies are introduced, average costs increase 2%, passing from USD 82.8 per megawatt-hour (MWh) to USD 84.2/MWh. There is a combination of trade-offs for each of the 13 economies considered, and for the APEC region as a whole, resulting from the Cleaner Coal Case and the introduction of CCS technologies (Table 7.5).

Table 7.5 • Energy indicators in the Cleaner Coal Case, 2040

	Cleaner Coal Case (without CCS)				Cleaner Coal Case			
	Fuel demand (variation from BAU in %)	**CO_2 emissions** (variation from BAU in %)	**Average costs** (USD per MWh)	**TGC** (2012 USD billion)	**Fuel demand** (variation from BAU in %)	**CO_2 emissions** (variation from BAU in %)	**Average costs** (USD per MWh)	**TGC** (2012 USD billion)
Australia*	-4.1	-2.9	128	40	-2.4	-14.3	130	40
China*	-4.0	-3.7	69	815	-2.7	-12.7	71	831
Japan*	0.9	-0.4	145	163	2.6	-7.2	146	164
Korea*	-3.4	-2.7	108	77	-2.6	-7.4	109	78
Russia*	-14.0	-3.3	72	99	-11.0	-8.7	73	101
Chinese Taipei*	-0.6	-0.5	117	33	-0.5	-1.5	117	33
United States*	-1.0	-0.4	89	437	-0.5	-2.4	89	439
Chile^	-3.9	-2.0	109	17	-2.0	-33	113	18
Indonesia^	-7.6	-6.3	97	63	1.4	-24.2	103	68
Malaysia^	-	-	119	39	7.4	-12.9	122	40
The Philippines^	-8.4	-7.6	105	20	1.5	-25.2	110	21
Thailand^	-7.3	-3.9	113	46	2.8	-20.3	114	46
Viet Nam^	-2.4	-2.2	100	57	13.2	-43.7	110	62
APEC (21 economies)	**-3.7**	**-2.8**	**83**	**2 028**	**-1.4**	**-11.6**	**84**	**2 062**

Notes: *Group A; ^Group B; †In remaining APEC economies, CCS capacity is assumed only at Boundary Dam in Saskatchewan, Canada; TGC = Total generation cost.
Source: APERC analysis.

Installing cleaner coal-based electricity generation is particularly relevant for many APEC economies that cannot stop or radically change their use of coal because it is 'locked in', meaning that it makes up a large share of the power mix. At the same time, this lock-in may also represent an opportunity in these economies, as their coal share may be large enough to justify institutional support and investments to introduce more efficient technologies in existing power plants and electricity generation portfolios.

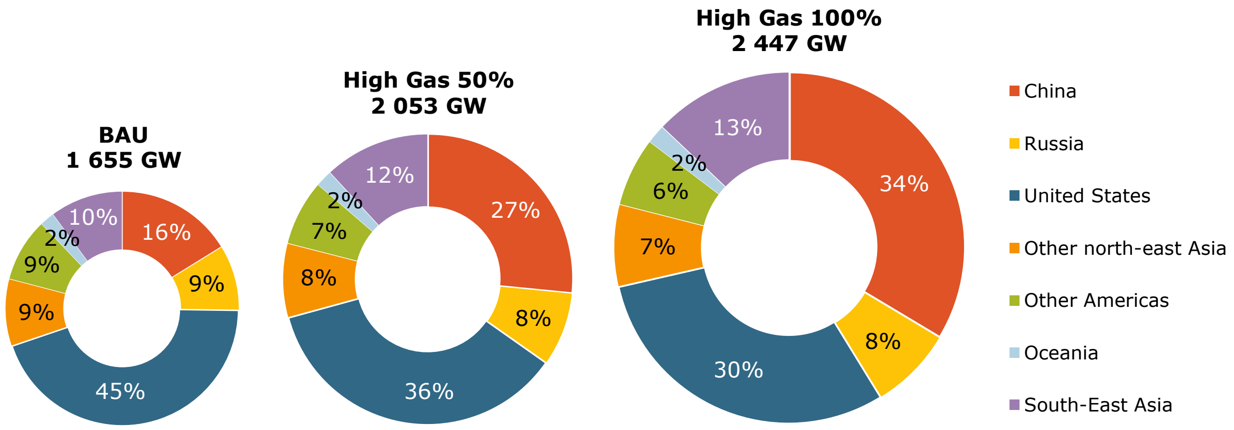
While the massive development of CCS technologies is still at a very early stage, the world's first large-scale coal-fired power plant equipped with CCS began operating in autumn 2014 at SaskPower's Boundary Dam in Canada, an APEC member economy. Irrespective of this milestone and each economy's maturity in use of coal, all will need to surmount serious technical and economic challenges to develop coal-based generation with CCS more rapidly.

HIGH GAS: CLEANEST GENERATION OPTION AT THE EXPENSE OF RISING FUEL IMPORTS

The electricity generated in APEC with technologies fuelled by natural gas is projected to be 28% above the BAU projections in the High Gas 50% Case, and 56% greater in the High Gas 100% Case by 2040. By economy, the highest growth under the High Gas 100% Case is expected in Chile, which expands gas-based electricity output 5.2 times over the BAU. Large growth in gas-based generation is also demonstrated in Viet Nam (4.4 times), the Philippines (3.9 times) and China (3.3 times).

To generate the additional electricity required, installed gas-based generation capacity in APEC needs to be 24% above the BAU by 2040 in the High Gas 50% Case and 48% larger in the High Gas 100% Case. In deploying this capacity within APEC, significant changes are likely to occur on an economy basis. Although the United States holds 45% of APEC gas-based capacity by 2040 in the BAU Scenario, its share diminishes to 36% in the High Gas 50% Case and 30% in the High Gas 100% Case, in step with the rising use of gas in other APEC economies (Figure 7.7). Conversely, China's share of APEC gas-based capacity passes from 16% in the BAU to 27% in the High Gas 50% Case and 34% in the High Gas 100% Case.

Figure 7.7 • Gas-based electricity generation capacity in the BAU Scenario, High Gas 50% and High Gas 100% Cases by regional grouping, 2040



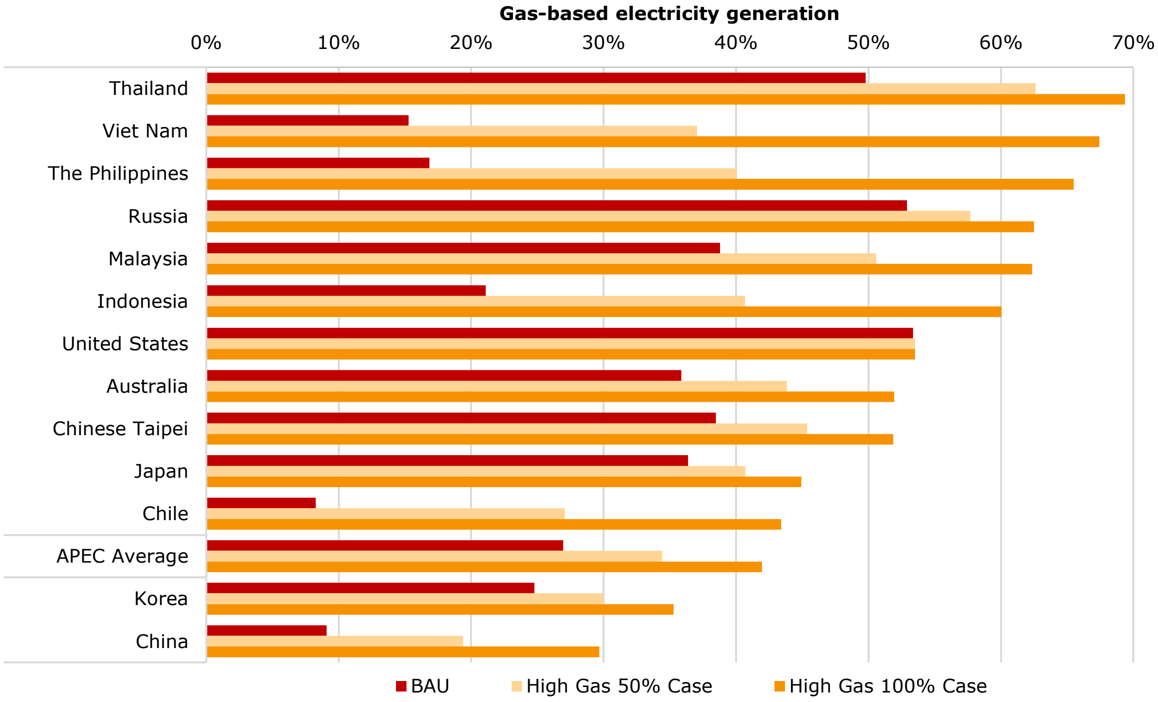
Notes: The sizes of the second and third charts representing the High Gas Cases are proportional to the first chart, in terms of respective generation capacity in comparison with the BAU; data excludes imports.
Sources: APERC analysis and IEA (2015).

The ongoing rising trend in the use of natural gas is intensified under the High Gas Cases. The share of natural gas in APEC total electricity output by 2040 grows from 21% in 2013 to as much as 27% in the BAU, 35% in the High Gas 50% Case and 42% in the High Gas 100% Case. The most remarkable changes in natural gas use are expected in economies with great potential to replace capacity additions based on coal, and in which the scale of electricity generation maximises fuel-change effects.

By economy, gas-based generation could be the highest in Thailand, growing to as much as 70% in the High Gas 100% Case. However, the greatest potential to expand gas-based generation is in Viet Nam, where the share by 2040 could grow from 15% of electricity generation in the BAU to as much as 37% in the High Gas 50% Case and 68% in the High Gas 100% Case. Similar substantial opportunities are estimated for the Philippines, Indonesia and Chile consecutively, followed by other economies mostly in South-East Asia (Figure 7.8).

Given the dominance of coal in the mix and the magnitude of electricity generated, the contribution of natural gas in some economies is more moderate at best. In China, for instance, even under the most optimistic assumptions in the High Gas 100% Case, natural gas fuels less than 30% of electricity generation by 2040. While natural gas does not penetrate the electricity mix as significantly in China as in other economies, the absolute magnitude of China's electricity output means that even small changes substantially affect the electricity configuration of the APEC region as a whole.

Figure 7.8 • Share of gas-based electricity generation in total output in the BAU Scenario, High Gas 50% and High Gas 100% Cases in selected APEC economies, 2040



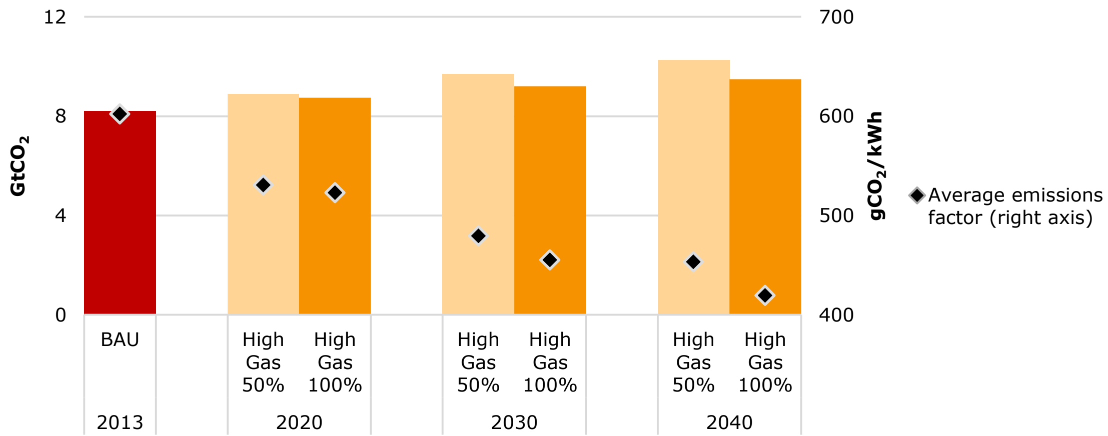
Note: Data excludes imports.
Source: APERC analysis.

In Russia there is moderate potential for a higher share of natural gas, mainly because under the BAU this fuel is already dominant by 2040, and because a larger nuclear power contribution is projected, which cannot be replaced by gas. In other north-east Asian economies, the outlook for a larger share of gas is also modest, largely because the pace of coal-based capacity additions that gas might replace is progressively slower and because the consumption of natural gas is already high. In the United States, the potential for gas-based generation growth in the two High Gas Cases is marginal as there is already a rapid switch to gas-based generation under the BAU. This recent preference for natural gas generation in the United States is largely underpinned by burgeoning domestic gas production, mostly in the form of shale gas.

The major environmental benefit of increased use of natural gas for electricity generation is the reduction of CO_2 emissions, which by 2040 are 7% lower than under the BAU in the High Gas 50% Case and 14% lower in the High Gas 100% Case (Figure 7.9). Of the different cases in the Alternative Power Mix Scenario, the High Gas 100% Case offers the largest potential to reduce CO_2 emissions and carbon intensity.

On an economy basis and compared with the BAU, the largest CO_2 emissions reductions under the High Gas 100% Case take place in Viet Nam (42%), the Philippines (39%) and Chile and Indonesia (34% each). Despite these milestones, China accounts for 59% of total CO_2 emissions avoided in the High Gas Cases.

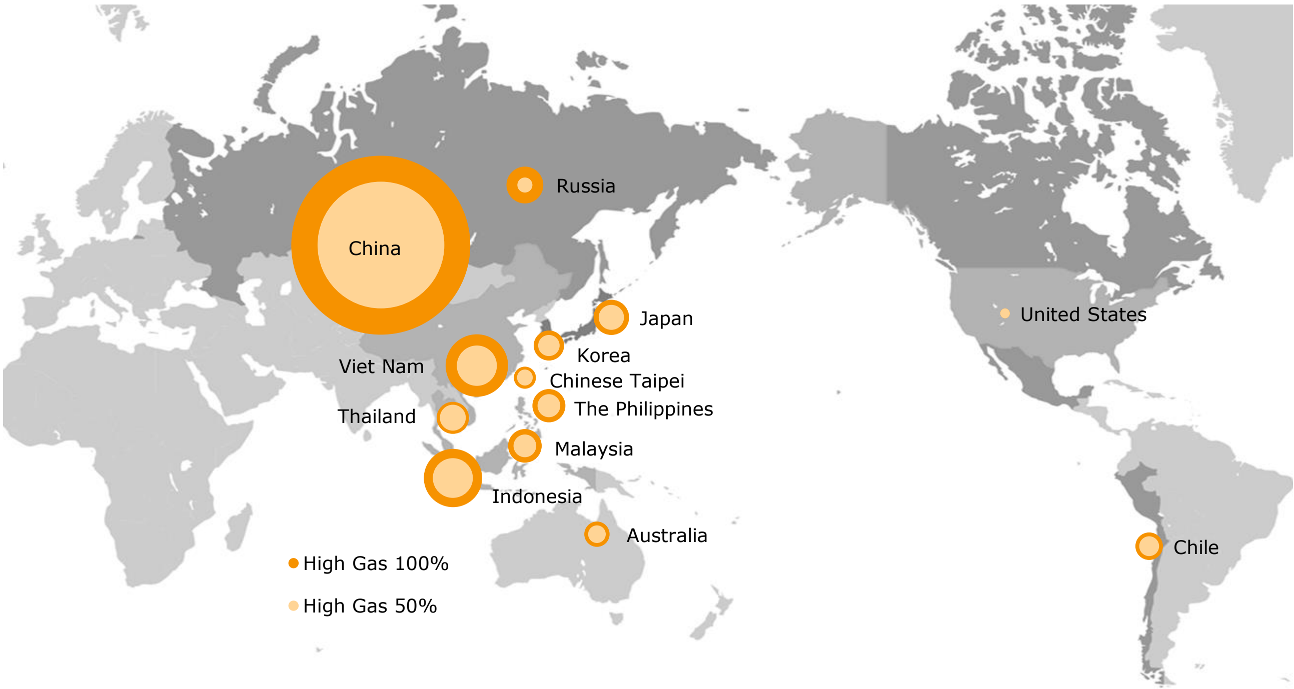
Figure 7.9 • CO_2 emissions from electricity generation in the High Gas 50% and High Gas 100% Cases, 2013-40



Sources: APERC analysis and IEA (2015).

Likewise, in annual fuel demand, the largest increase in natural gas use beyond BAU projections in absolute terms occurs in China, which alone accounts for just above two-thirds of additional gas consumed in both High Gas Cases. The largest increases under the High Gas 100% Case are expected in Chile, where gas consumption increases 4.7 times over the BAU, Viet Nam (4.4 times), the Philippines (3.9 times) and China (3.3 times) (Figure 7.10).

Figure 7.10 • Expansion of natural gas demand for electricity generation in the High Gas 50% and High Gas 100% Cases, 2040

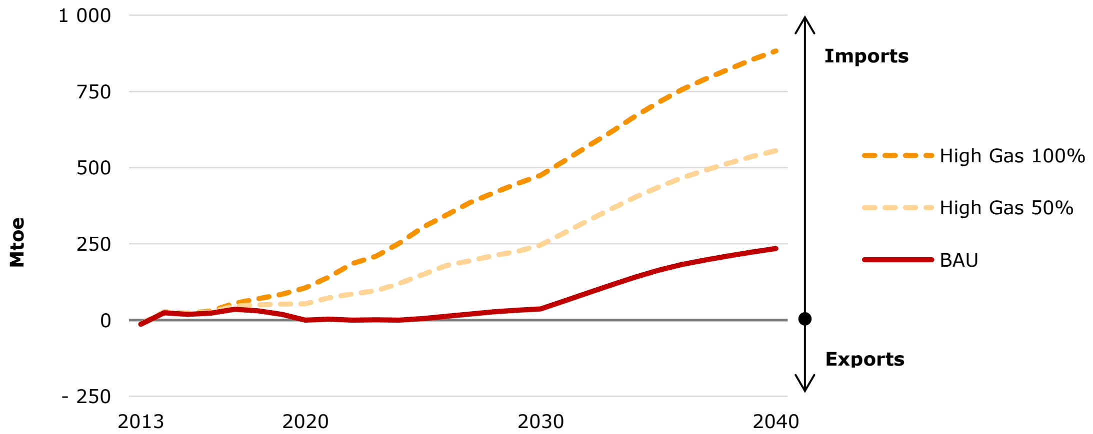


Note: Bubble size is determined by gas demand (in Mtoe); This map is for illustrative purposes and is without prejudice to the status on sovereignty over any territory.
Source: APERC analysis.

For the APEC region as a whole, annual demand for natural gas for electricity generation by 2040 increases by 25% over the BAU in the High Gas 50% Case and by 51% in the High Gas 100% Case. In consequence, flows of imported gas are 2.3 times higher in the High Gas 50% Case and 3.6 times higher in the High Gas 100% Case. By the end of 2040, gas imports could grow from nearly 235 Mtoe in the BAU to 556 Mtoe in the High Gas 50% Case and 883 Mtoe in the High Gas 100% Case (Figure 7.11).

Expanded gas imports create a higher economic burden (Table 7.6). Annual total electricity generation costs in APEC are estimated to be higher by USD 90 billion in the High Gas 50% Case (a 5% rise) and by USD 147 billion in the High Gas 100% Case (a 7% rise), making both High Gas Cases the most expensive in the Alternative Power Mix Scenario. Fuel costs alone represent a higher share of total generation costs in both High Gas Cases (more than 60%) than in the BAU (about 58%).

Figure 7.11 • Net trade of natural gas in the BAU Scenario and in the High Gas 50% and High Gas 100% Cases, 2013-40



Notes: Includes the use of natural gas for heat generation. Positive values indicate net imports; negative values indicate net exports.
Sources: APERC analysis and IEA (2015).

Economies in which significant natural gas growth is expected are among those projected to incur the highest capital costs. In accordance with the premises of the High Gas 100% Case, expanded gas-based electricity generation increases total investments significantly in economies where there is great potential for substitution. For example, associated investments could grow as much as 34% in Viet Nam and 21% in the Philippines.

Table 7.6 • Electricity generation indicators in the BAU Scenario and in the High Gas 50% and High Gas 100% Cases, 2040

	Net trade of natural gas			CO_2 emissions			Total generation costs of electricity*		
	Mtoe			$MtCO_2$			2012 USD billion		
	BAU	HG 50	HG 100	BAU	HG 50	HG 100	BAU	HG 50	HG 100
Australia	-51	-47	-43	137	126	115	38	40	40
Chile	7	11	15	70	56	45	16	16	15
China	264	461	657	5 783	5 327	4 868	814	791	821
Indonesia	56	75	98	479	394	315	67	72	76
Japan	98	106	114	440	424	408	163	175	179
Korea	60	66	72	289	276	262	77	81	84
Malaysia	7	13	21	192	173	156	39	47	51
The Philippines	2	10	17	138	112	83	21	23	25
Russia	-187	-184	-170	575	531	513	99	105	104
Chinese Taipei	21	24	27	165	157	149	33	36	37
Thailand	60	68	72	171	141	126	46	53	54
United States	-37	-36	-36	1 888	1 885	1 885	437	479	479
Viet Nam	8	28	56	343	288	198	57	64	76
APEC	**232**	**521**	**824**	**11 047**	**10 268**	**9 498**	**2 029**	**2 119**	**2 176**

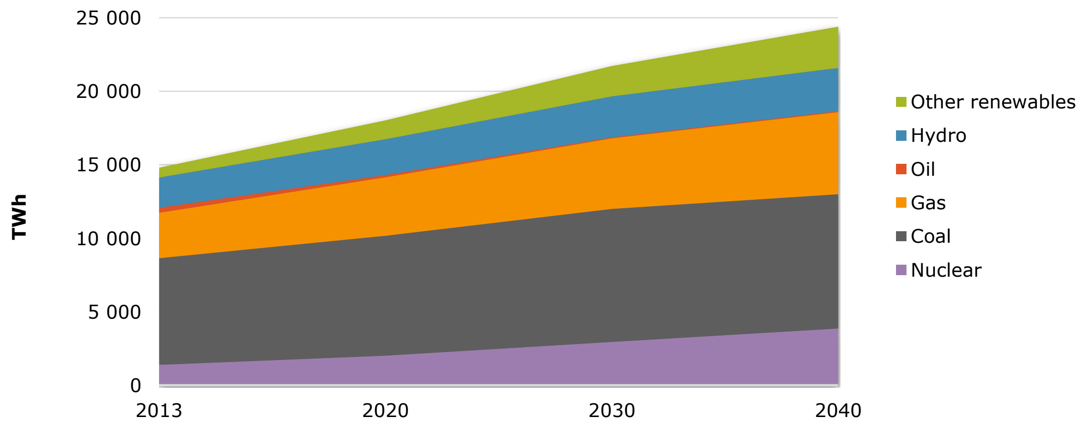
Notes: *Includes capital costs, fuel costs, operation and maintenance costs and carbon costs; HG 50 = High Gas 50% Case; HG 100 = High Gas 100% Case.
Source: APERC analysis.

HIGH NUCLEAR: THE POTENTIAL TO DEVELOP CLEANER ELECTRICITY SYSTEMS

The APEC region has remarkable potential to expand nuclear energy. Under the High Nuclear Case, nuclear-based generation is projected to grow 92% more than under the BAU by 2040, from 2 020 TWh to 3 875 TWh. Such generation output requires nuclear-based installed capacity growth of 90%, from 283 GW to 538 GW (Figure 7.12).

The share of nuclear energy in total APEC electricity generation doubles by 2040 under the High Nuclear Case, from 8% to 16%, pushing down the shares of coal (from 41% to 37%) and natural gas (from 27% to 23%). The expansion of nuclear energy under the High Nuclear Case and the resulting drop in coal and gas demand contributes to APEC's low-carbon economy, in line with the region's commitment to reduce CO_2 emissions to limit its contribution to global warming.

Figure 7.12 • Total electricity generation in the High Nuclear Case by fuel, 2013-40



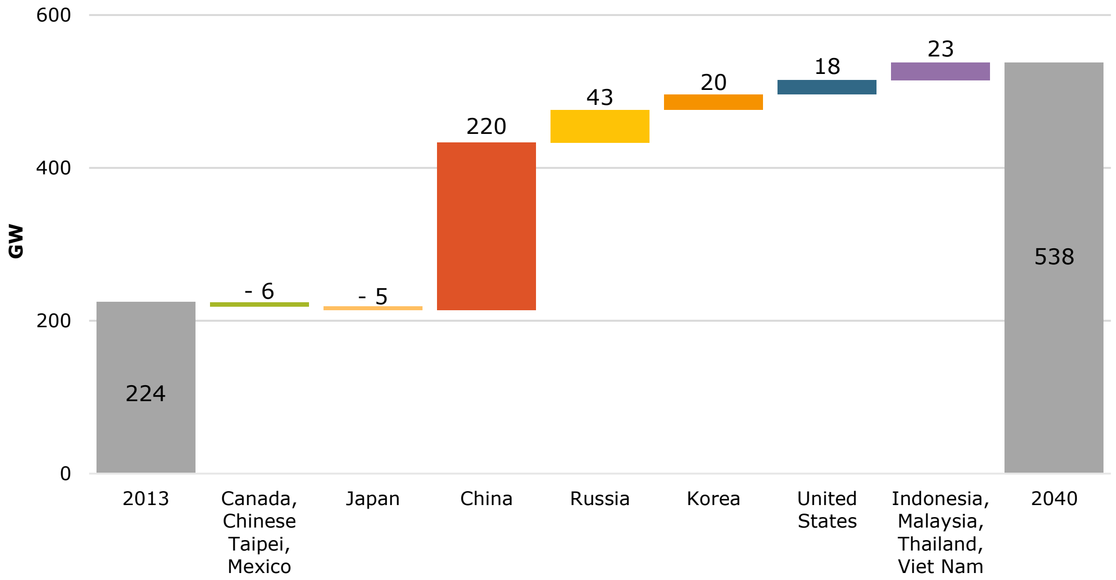
Sources: APERC analysis and IEA (2015).

Eight APEC members currently have nuclear energy power plants and four have plans to develop them. The first group includes China, Chinese Taipei, Japan, Korea, Mexico, Russia and the United States. Canada also uses nuclear-based generation, but has plans to cut nuclear capacity up to 2040, contrary to the premises of the High Nuclear Case. In the second group, economies expected to install nuclear energy plants are Indonesia, Malaysia, Thailand and Viet Nam.

Under the assumptions of the High Nuclear Case, four economies account for the bulk of nuclear growth by 2040. China is the single largest contributor in both capacity (101 GW) and generation (710 TWh), followed by the United States (67 GW and 555 TWh), Russia (27 GW and 180 TWh) and Japan (26 GW and 159 TWh) (Figure 7.13). These four economies account for 87% of installed nuclear capacity and 86% of nuclear generation in the APEC region by 2040 under the High Nuclear Case. From 2013 levels, capacity grows by 17 and generation by 15 in China, and in Russia growth is 2.7 times for both capacity and generation, reflecting lifetime extensions of operating nuclear power reactors and the construction of new ones. US capacity and generation growth rates are relatively smaller (1.2 times for both), indicating lifetime extensions primarily and only a small amount of added capacity (18.3 GW), while many reactors are decommissioned. Abundant and inexpensive coal, and in certain regions gas, is a major disincentive to investing in nuclear energy, which is more capital-intensive.

In other economies with nuclear power sectors, capacity and generation are expected to decline under the High Nuclear Case but still surpass BAU levels by 2040. Chief among them is Japan, which had the second-largest nuclear capacity and generation in APEC before the Fukushima accident. After the accident, most of this capacity was shut down and there has since been strong public opposition to developing nuclear energy in Japan and other economies. For this reason, it was assumed that Japan's nuclear capacity decreases by 10% in comparison with 2013, remaining at 40 GW, although generation increases more than 26 times with the reactivation of its nuclear reactors to reach 243 TWh in 2040. Nuclear capacity halves to 2.5 GW and generation to 21 TWh by 2040 in Chinese Taipei for similar reasons.

Figure 7.13 • Additions of nuclear-based electricity capacity in the High Nuclear Case in selected APEC economies, 2013-40



Sources: APERC analysis and IEA (2015).

Leading in nuclear capacity and generation in 2040 are Viet Nam (capacity 9.2 GW; generation 69 TWh) and Indonesia (7 GW; 52 TWh) among the economies with plans for new nuclear development, followed by Thailand (5 GW; 37 TWh) and Malaysia (2 GW; 15 TWh). These results reflect Viet Nam's and Indonesia's longer experience with nuclear energy and stronger need to reduce fossil energy dependence. All four economies aim to reduce CO_2 emissions.

Table 7.7 • Share of fossil fuel energy in electricity generation mix in the BAU Scenario and the High Nuclear Case, 2040

	BAU				High Nuclear Case				Resulting reduction in the share of fossil energy (percentage points)
	Coal (%)	Gas (%)	Oil (%)	Total fossil share (%)	Coal (%)	Gas (%)	Oil (%)	Total fossil share (%)	
China	56	9	0.0	65	51	8	<1	59	6
Chinese Taipei*	53	38	0.1	91	50	34	<1	84	7
Indonesia	62	21	1.4	84	56	19	1.4	76	8
Japan	33	36	2.2	71	30	25	2.2	57	14
Korea	39	25	NA	64	33	22	NA	55	9
Malaysia	46	39	0.1	85	42	39	<1	80	5
Mexico*	6	73	0.5	80	6	71	<1	77	2
Russia	12	53	0.1	65	10	41	<1	52	13
Thailand	24	50	0.1	74	19	46	<1	64	9
United States	20	53	0.0	73	20	43	<1	62	11
Viet Nam	62	15	0.0	77	53	15	<1	68	9

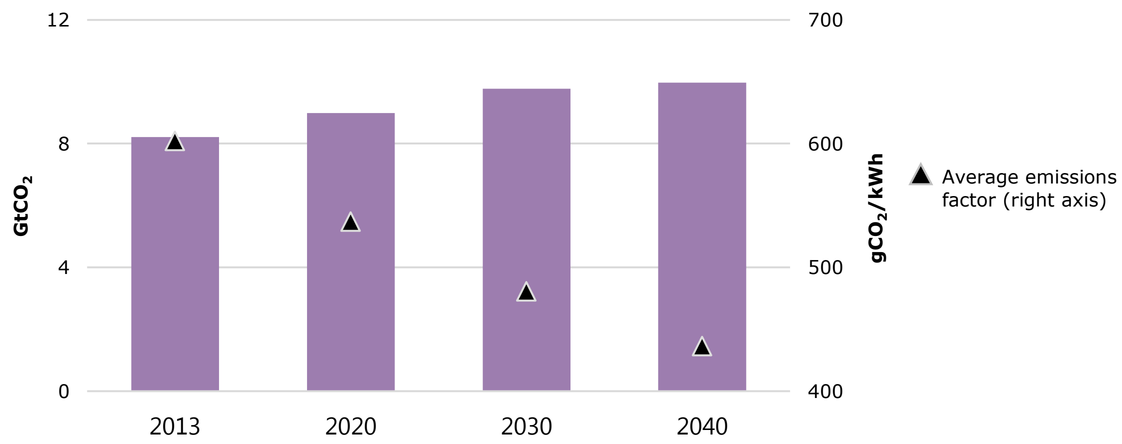
Notes: *In these economies, there is no expansion of nuclear-based capacity in the High Nuclear Case, but as a result of lifetime extensions of current power plants, nuclear-based electricity generation surpasses BAU levels by 2040 and displaces fossil energy to a certain extent; NA = not applicable.
Source: APERC analysis.

Under the High Nuclear Case, the expansion of nuclear-based generation reduces the share of fossil energy—mainly coal and gas, except in Japan and Indonesia where there is a share of oil-based fuels in the power mix. In economies with nuclear energy sectors, Japan registers the largest reduction in fossil energy use (14%), followed by Russia (13%) and the United States (11%) (Table 7.7). The rankings reflect shares of nuclear energy in the power mixes. The reduction in Korea, Thailand and Viet Nam is also significant (9% in each).

In comparison with the BAU Scenario, the High Nuclear Case reduces CO_2 emissions by 10% in 2040 (or 1 076 million tonnes of CO_2 [$MtCO_2$]) through the replacement of 17% of the gas (193 Mtoe) and 8% of the coal (162 Mtoe) used for power generation (Figure 7.14), which is still lower than the emissions avoided under the High Gas 100% and Cleaner Coal Cases. Fuel pricing explains the replacement of a higher proportion of gas than of coal: nuclear-based generation replaces more gas (which emits less CO_2 but is more expensive) than coal (which emits more CO_2 but is much more affordable). However, an installed capacity of nuclear energy 2.4 times above 2013 levels is required.

The expansion of nuclear energy also helps APEC economies meet CO_2 emissions reductions objectives and diversify their power mixes. The share of coal in China's power mix drops from 56% under the BAU Scenario to 51%, and gas falls from 9% to 8%. Russia's coal share decreases from 12% to 10% and gas drops from 53% to 41%. The 20% share of coal in the United States does not change, but gas decreases significantly from 53% to 43%. Korea registers a drop in the share of coal from 39% to 33%, and of gas from 25% to 22%.

Figure 7.14 • CO_2 emissions from electricity generation in the High Nuclear Case, 2013-40



Sources: APERC analysis and IEA (2015).

Reduced dependence on coal and gas also diminishes vulnerability to fluctuations in availability and/or prices of these fuels for the APEC economies concerned. Availability and price are not issues for the coal- and gas-rich economies, especially Russia and the United States, but they are major sources of concern for economies that depend on imports of these fuels for part (China) or the bulk (Korea) of power mix demand.

By 2040, the High Nuclear Case saves the APEC region 4% of the total generation costs estimated under the BAU. Savings in annual total electricity generation cost is USD 86 billion—dropping from USD 2 029 billion under the BAU Scenario to USD 1 943 billion—and encompasses capital costs, fuel costs, operation and maintenance costs, and carbon costs. Some economies with nuclear power sectors achieve savings in total generation costs, namely China (USD 74 billion), Japan (USD 11 billion) and Korea (USD 2 billion), while the United States experiences an increase (USD 11 billion). Total electricity generation costs decrease in three economies new to nuclear energy—Indonesia (USD 8 billion), Thailand (USD 2 billion) and Viet Nam (USD 1 billion)—but increase in Malaysia (by USD 3 billion), the other nuclear-energy newcomer.

In short, the High Nuclear Case makes a remarkable contribution to the energy sectors of the APEC economies concerned, while helping them progress towards APEC's low-carbon objective.

SCENARIO LIMITATIONS

The main shortfall of the Alternative Power Mix Scenario is that its scope is only limited to the trade-offs among coal, natural gas and nuclear energy, omitting other major energy sources for electricity generation, especially renewable energy.

The scenario also assumes that the supply and trade of coal, natural gas and uranium in APEC and worldwide remain reliable, and that there are no breakthroughs in the domestic production of these natural resources in any APEC economy. In addition, coal and uranium costs are projected to remain stable throughout the Outlook period; nevertheless, the prices of these two fuels could fluctuate significantly from the BAU, thus affecting their competitiveness and the advantages in their use for the region's electricity generation, at least up to 2040. The only price assumptions that differ from the BAU are used in the High Gas Cases, to account for the high uncertainty of natural gas prices and their differentiation in several major regional blocs, but even the price trend assumed for natural gas could diverge substantially.

Lastly, the cases in the Alternative Power Mix Scenario assume that the use of certain energy sources for electricity generation is mutually exclusive. In fact, cleaner coal, natural gas and nuclear energy could be developed concurrently in many economies.

Cleaner Coal Case: While the large-scale introduction of more efficient coal-fired technologies produces ample benefits in the use of coal for electricity generation purposes, the dissemination of USC and A-USC power plants faces some difficulties due to technological differences among economies, mainly related to coal quality. There are also many unanswered technological questions about the large-scale deployment of CCS as a major solution in coal fired-generation.

High Gas 50% Case and High Gas 100% Case: Under BAU assumptions, natural gas is already expected to grow faster than coal or nuclear energy as an energy source for both electricity capacity and generation. In recent years, many economies have promoted the expanded use of natural gas to reduce carbon intensity and the emission of other pollutants, so it may not be technically feasible to increase the use of this fuel more substantially. In addition, higher natural gas requirements estimated in the High Gas Cases do not account for changes in the demand for this fuel in end-use sectors, which may accelerate or limit its use in the electricity sector.

High Nuclear Case: Current policies, ongoing projects and announced plans of governments and industry support this case, but often these do not span the entire projection period (2013-40). Therefore, the High Nuclear Case assumes that current policies and plans continue to 2040, and that the respective nuclear energy sectors follow their known patterns of expansion in the absence of any contrary indication. An additional consideration is the volatility and level of the price of uranium compared with the prices of other fuels.

Certain factors affecting the expansion of nuclear energy, such as public acceptance, waste management practices, capital shortage and the lack of skilled personnel and infrastructure are bound to change, so development plans for this technology may be altered during the Outlook period.

Given the experience of the past six decades, it is possible that the current drawbacks of nuclear energy (high costs and long construction timeframes) will improve over the Outlook period. Depending on the magnitude of improvements, nuclear energy could become attractive and affordable enough to be expanded significantly. Finally, if global warming worsens, the need for higher shares of carbon-free energy sources such as nuclear and renewables will become more urgent. In that case, barriers to nuclear energy expansion, in terms of competitiveness with fossil energy, could become minor in comparison with the environmental benefits.

OPPORTUNITIES AND CHALLENGES

The largest potential for reducing APEC CO_2 emissions from the electricity generation sector (to below BAU levels) lies in expanding the use of natural gas, as in the High Gas 100% Case, followed by the Cleaner Coal, High Nuclear and High Gas 50% Cases. Each of these options involves several trade-offs, reflecting the intrinsic features of each energy source and the context of each member economy—implying both opportunities to be seized and challenges to be overcome.

While the applicability of the Alternative Power Mix Scenario assumptions varies by member economy, many have substantial opportunities to modify their electricity configurations up to 2040, including the region's largest electricity generators, especially if they implement major actions well in advance, some of which are detailed below. It must be stressed that no single fuel choice is absolutely better than others, and that carrying out any of these cases would likely create the growing dominance of a single energy source in the power mix, which may be undesirable. The objective of the alternative scenarios, particularly the Alternative Power Mix Scenario, is to explore what outcomes derive from a variety of options, revealing implications and effects that can inform energy policy decisions.

Each of the four cases in the Alternative Power Mix Scenario has different effects and trade-offs for each of the 15 economies analysed. These can be organised into three categories according to how they reduce CO_2 emissions, dilute the concentration of any single energy source in the power mix on the basis of the HHI[2], and reduce generation costs (Table 7.8).

Table 7.8 • Comparative assessment of the cases addressed in the Alternative Power Mix Scenario

	CO_2			DIV			EC		
	CC	HG	HN	CC	HG	HN	CC	HG	HN
Australia			NA			NA			NA
Chile			NA			NA			NA
China									
Indonesia									
Japan									
Korea									
Malaysia									
Mexico^	NA	NA		NA	NA		NA	NA	
The Philippines			NA			NA			NA
Russia									
Chinese Taipei^									
Thailand									
United States									
Viet Nam									

Legend	Largest positive effect	Next best positive effect	Positive effect	Negative effect	Not Applicable

Notes: CO_2 = reduction of CO_2 emissions, DIV = diversity of the electricity generation mix, EC = total generation costs; CC= Cleaner Coal, HG = High Gas 100% Case, HN = High Nuclear; ^In spite of no nuclear expansion assumed in these economies under the High Nuclear Case, nuclear generation still surpasses BAU levels by 2040; The table does not show Brunei Darussalam, Canada, Hong Kong, New Zealand, Papua New Guinea, Peru and Singapore as none of the cases in the Alternative Power Mix Scenario was applicable.

Source: APERC analysis.

CLEANER COAL: MAKING CCS FEASIBLE MUST BE A PUBLIC-PRIVATE PRIORITY

Member economies should work together to expand the use of cleaner coal technologies across APEC. Cooperation in finding technology solutions that can be commercially adopted, as well as in implementing effective legal and regulatory frameworks, is vital to the wider adoption of efficient coal-fired generation

[2] The Herfindahl-Hirschman Index (HHI) is a measure of market concentration and diversity. For further information please go to Chapter 9.

capacity. APEC should particularly give more attention to the deployment of clean coal technologies, including feasible USC, A-USC and IGCC, as a way of mitigating climate change.

IGCC technologies, which are more expensive than USC and not yet widely deployed, also need to be supported by APEC. They would significantly improve efficiencies in generating plants burning low-quality coal, which are common in South-East Asia. The progress some APEC economies are making in developing coal-fired plants with CCS should be prioritised for expansion.

The United Kingdom's decision to shut down all coal-based power plants by 2025, announced just before the COP21 climate change meeting in Paris in December 2015, reflects the complexity underlying the long-term use of coal for electricity generation. It also signals a less optimistic outlook for the global development of CCS. According to the International Energy Agency (IEA, 2013), the deployment of CCS requires at least seven major actions:

- **a)** financial support mechanisms for the demonstration and early development of projects, to attract private financing;
- **b)** policies that encourage projects on all elements of CCS, including storage exploration, site characterisation and development;
- **c)** legal instruments and finance provisions that mandate electricity generation based on CCS technologies, whether from a base-load, fossil fuel or new capacity perspective;
- **d)** new industrial applications of capture systems proven at pilot and commercial stages;
- **e)** expanded efforts to improve knowledge and stress the relevance of CCS to the general public and other stakeholders;
- **f)** mechanisms to reduce the cost of electricity from CCS technologies, e.g. through sustained technology development and the use of high efficiency power generation cycles; and
- **g)** efficient promotion of CO_2 transport infrastructure, anticipating demand centres and demanded volumes.

As the developer of the first CCS project at Boundary Dam in Canada, Shell also suggests that the technological focus to drive CCS costs down dramatically be coupled with engagement with diverse stakeholders, a particularly powerful tool for building the trust and confidence that sustain successful projects. In this case, Shell established formal and informal channels of communication with local residents and collaborated with the Pembina Institute, an environmental research organisation whose objective, trusted voice improved dialogue with community groups and social acceptance of the project (Shell, 2015).

HIGH GAS: SUPPLY, INFRASTRUCTURE AND PRICING REMAIN MAJOR CHALLENGES

Natural gas has become more relevant in the electricity generation portfolio worldwide because it can help to decouple growth in electricity demand from growth of CO_2 emissions. Despite these advantages, the availability and price of the resource, especially relative to coal, pose major hurdles to expanding natural gas-based electricity generation. Ultimately, economies will need to make decisions based on natural gas balance; the following guidelines offer some insight.

Economies with insufficient natural gas supply: In Chile and China, domestic production and imports of natural gas are insufficient to meet demand; thus, they favour other fuels to meet electricity generation requirements, especially less costly and more abundant coal. A diversification of gas supplies, spanning pipeline and LNG gas imports and probably the development of domestic unconventional gas resources (specifically tight gas in Chile and coalbed methane, tight gas and shale gas in China), could promote greater use of gas in the medium and long terms. In other economies where domestic supplies are marginal, such as Chinese Taipei, Korea and Japan, the use of imported gas is already high.

Economies lacking natural gas trade: In Viet Nam and the Philippines, the lack of cross-border pipelines and LNG infrastructure prevents natural gas imports, so gas supply depends completely on domestic production. Improving transmission and trade infrastructure could help these economies generate electricity with a lower CO_2 intensity.

Economies exporting natural gas: As major exporters of natural gas, Australia, Indonesia, Malaysia and Russia may moderate the use of natural gas for electricity generation to maintain export commitments or revenues. They will likely fuel electricity generation plants with more cost-effective options instead, such as coal or even nuclear in the case of Russia. Economies in this situation however, must be aware of the trade-offs involved, and take action to minimise emissions from coal-fired plants and strengthen the safety of nuclear plants.

Economies aiming to diversify the electricity mix: In economies already using gas extensively, a greater share in the electricity mix might be undesirable given the need to expand other energy sources for energy security and environmental reasons.

In many economies, increased use of natural gas will greatly depend on policies aimed at overcoming supply and infrastructure challenges. Economies that wish to increase the use of natural gas in electricity generation will need to expand domestic production (whenever gas resources are available) and broaden their import sources. Expanding natural gas supplies will require strong institutional, economic and technical policy support, and economies with potential domestic resources should assess the extensive development of these supplies to help reduce gas import dependence. In every case, collaboration with the public and private sectors to find mutually beneficial opportunities will be necessary to obtain capital inflows for infrastructure.

Some APEC economies have the world's largest unconventional gas resource bases. Until recently, unconventional gas development was looked upon favourably; the previous edition of this Outlook (APERC, 2013) was optimistic in its assessment of massive unconventional gas extraction beyond the United States. In practice however, several economies that tried to meet rising energy demand needs with domestic unconventional gas resources—shale gas in particular—have encountered multiple difficulties. Unconventional gas is more costly and riskier to extract and produce than conventional gas. To provide net benefits for the diverse stakeholders involved, it must be done cost-effectively and in alignment with environmental sustainability and social responsibility principles. These issues are examined in detail in APERC's Pathways to Shale Gas Development in Asia-Pacific (2015).

HIGH NUCLEAR: SOCIAL ISSUES WILL REMAIN THE MOST CRITICAL DETERRENT

By supplying large-scale, emission-free electricity generation, nuclear energy provides an advantage to several economies, especially to those aiming to reduce dependence on fossil fuel imports. Expanding nuclear in economies where it is already used could bring environmental benefits by cutting CO_2 emissions, improve energy security through diversification of the power mix, and provide financial relief by reducing fossil fuel imports.

These advantages have prompted four APEC economies—Indonesia, Malaysia, Thailand and Viet Nam—to develop nuclear energy to support the energy demand associated with rapidly expanding economic development. While only Viet Nam has implemented formal actions towards this goal, Indonesia, Malaysia and Thailand are likely to follow suit within the Outlook period. Nevertheless, unless an economy achieves a certain level of nuclear capacity, usually between 15% and 20% of its power mix, the benefits of nuclear energy in terms of CO_2 emissions reductions may be limited. Unless the remaining power generation is as clean as possible (i.e. using the most advanced technologies assumed in the Cleaner Coal Case or higher shares of natural gas as in the High Gas Cases), emissions from conventional coal and gas generation would counter any gains made by adding nuclear.

To reach the full potential of nuclear energy, key recommendations across its lifecycle must be heeded. To accelerate deployment of nuclear technology, it will be necessary to enhance current reactor technology, which in turn will require permanent research and development (R&D) efforts and investments. Action will be needed to ensure that nuclear fuels are extracted and disposed of in environmentally sustainable ways. Governments will need to implement effective regulations that provide economic incentives for developers, contingent on the underlying risks, while ensuring enforcement of the highest safety standards. All stakeholders need to recognise the low-carbon nature of nuclear energy and promote investment and economic mechanisms that favour its deployment (NEA, 2015).

Other recommendations include ensuring that an adequate skilled workforce is available and able to follow the steep nuclear energy technology learning curve, and expand the installed capacity as required. This implies disseminating codes and standards that apply to the entire lifecycle, from the construction of power plants to their decommissioning and the disposal of nuclear waste and spent fuel. Finally, ongoing outreach to the public through targeted education and information programmes is needed to improve the fact-based perception and understanding of nuclear energy, including the trade-offs against other energy options.

Box 7.1 ● Small modular reactors

Small nuclear reactors (SNRs) for power generation, typically of capacity under 300 MW, are not novel, as many are already in operation and being built globally. However, small modular reactors (SMRs) are a new, safer and less costly alternative to large power reactors. Versions are being developed in many economies, including APEC economies such as China, Japan, Korea, Russia and the United States.

SMRs may be built as modules (units) in a larger complex with capacity added incrementally as required. They can also be built as independent small units for remote areas and/or areas with low electricity demand, where medium (300 MW to 700 MW) and large (above 700 MW) nuclear reactors or equivalent fossil fuel-fired generators are not appropriate. Small units are a much more manageable investment than larger ones, and thus more affordable for economies with limited financial resources.

Various SMR designs are being developed, partly to offer alternatives to costly large power reactors and partly to feed small electricity grids under 4 GW. Very small, fast reactors (under 50 MW) are being considered for areas away from transmission grids and with small loads, while very small reactors (vSMRs) are proposed for units under 15 MW, especially for remote communities.

At least three main design options are available: light water reactors, fast neutron reactors and graphite-moderated high-temperature reactors. The first has the lowest technological risk, whereas the second can be smaller and simpler, and operate longer before refuelling.

Benefits of SMRs include simpler design, economy of series production largely in factories, short construction times and reduced siting costs. Most are also designed for a high level of passive or inherent safety in the event of malfunction and thus are safer than current nuclear reactors. For added safety, some SMRs are designed to be installed underground. These reactors provide high resistance to potential safety risks and pose no health hazard for people living in the proximity. In the case of an accident, for example, hazardous materials (particularly radiation) would be kept underground by the sealing of the facility’s ground-level access points. Many safety provisions that are necessary, or at least prudent, in large reactors may not be necessary in smaller reactors. In 2009 the International Atomic Energy Agency (IAEA) assessed that, under its Innovative Nuclear Power Reactors and Fuel Cycle program, 96 SMRs could be in operation globally by 2030 in the ‘high’ case and 43 in the ‘low’ case.

The most advanced SMR project is in China, where Chinergy is building a 210-megawatt electrical (MWe) High Temperature Reactor–Pebble-bed Module (HTR–PM) plant consisting of twin 250-megawatt thermal (MWt) high-temperature gas-cooled reactors.

Source: World Nuclear Association (2015).

RECOMMENDATIONS FOR POLICY ACTION

To ensure economic growth that is simultaneously cost-competitive and environmentally sustainable, APEC member economies must explore different electricity generation configurations. Coal is the least expensive option for electricity generation, but more advanced technologies are needed to reduce its CO_2 intensity along with the switch to other fuels that present higher efficiency gains in generation. By 2040, measures described in the Alternative Power Mix Scenario could reduce CO_2 emissions by 7% to 14% in comparison with the BAU.

As APEC's largest electricity producer and a major user of coal for electricity generation, China has a critical role in bringing about substantial changes in the CO_2 intensity of the entire region. The depth and breadth of the energy and climate policies implemented in China will greatly affect sustainability and cost-effectiveness across APEC, and will influence demand for certain fuels and projects associated with their development and trade.

Replacing all the expected coal-based capacity additions in APEC with natural gas, as in the High Gas 100% Case, results in the largest emissions reduction in the electricity sector. Such an energy shift decreases the CO_2 emitted by 14% from BAU levels by 2040, but also requires a natural gas supply 51% larger. From a purely economic perspective, the High Nuclear Case is the only one that might accrue investment savings in comparison with the BAU.

To reduce the carbon intensity of its power mix more rapidly, APEC has several options other than renewable energy, such as deploying more clean coal technologies, using higher shares of natural gas and expanding nuclear energy. Each option entails different technical, economic, environmental, social and energy security considerations, which will further differ in each APEC economy.

Cleaner Coal Case: Projections indicate that unless CCS technologies are implemented in all new coal plants, it will be impossible to substantially reduce CO_2 emissions from coal-based electricity generation. To this end, economies should focus on improving the economics of CCS projects by coordinating and aligning policies that provide more economic incentives, and by promoting private investments to strengthen the commercial viability of these projects, particularly at the early demonstration stage. Such measures increase the likelihood of CCS projects becoming commercially viable at the scale needed.

High Gas 50% and High Gas 100% Cases: The use of natural gas to replace all additional coal-based capacity offers the largest potential to reduce CO_2 emitted by the electricity sector across APEC. Nevertheless, achieving this potential requires expanded natural gas imports, which consequently raises electricity generation costs. The huge challenge in securing this gas supply could be used to promote more vigorously the trade of LNG and pipeline gas imports among member economies, and to explore development of domestic conventional and unconventional gas resources.

Accelerating gas trade by reducing tariffs and providing economic incentives to private developers across the value chain might result in more pipeline gas and LNG projects. This could significantly benefit economies that lack domestic gas resources, as well as those with potential gas resources that currently lack the commercial signals to stimulate development. APEC is an excellent forum to explore cooperative mechanisms that favour more extensive LNG trade, closer dialogue between sellers and producers, more flexible contracting and investment schemes, and integration for sellers and purchasers all along the LNG value chain.

High Nuclear Case: Expanding nuclear power provides a reliable way to increase electricity generation with zero CO_2 emissions and competitive prices. The main challenges remain in building the additional nuclear capacity required by 2040 and in using this energy source with sufficiently high safety standards, to support economic growth and prosperity while mitigating the physical hazards to society.

Economies developing nuclear power for the first time require long-term planning to set up the infrastructure required, including capacity building for developing regulatory oversight. APEC economies should strengthen the sharing of information and experience among regulators, and help nuclear newcomers to develop local expertise. The availability and technical capabilities of personnel who can build and operate reactors, and manage nuclear waste, will determine the pace and extent of nuclear power expansion. Finally, improving communication and public outreach on the benefits and risks of nuclear power will help to overcome public acceptance barriers.

Overall, great potential exists to transform the APEC electricity mix to tackle energy security, economic growth and environmental sustainability challenges. In alignment with their own energy and climate agendas, economies must be aware of the trade-offs involved in defining their electricity plans and the lead times for developing the necessary infrastructure. Collaboration and coordination with the private and public sector will be important in allocating sufficient investments to transform the electricity mix in a timely manner, and to capitalise on economic and environmental opportunities.

8. ENERGY INVESTMENT

KEY FINDINGS

- **APEC requires cumulative energy investments of USD 17 trillion to USD 35 trillion from 2015-40 under the BAU Scenario.** This represents 1.8% of projected GDP on average for individual economies, or 0.89% of projected total APEC GDP.

- **Although its economic growth slows, China requires the largest share (34%) of total energy investments in APEC, more than half allocated to the power sector.** Next is the United States (24%), with almost half allocated to the upstream sub-sector.

- **The upstream sub-sector requires the highest share of total investment**–almost half–as APEC includes several economies that are global leaders in fossil fuel production.

- **Higher penetration of renewable energy (as in the High Renewables Scenario) increases the total investment requirement by only 6.3% from the BAU.** Additional investment requirements in the power sector are partially offset by lower investment needs in the upstream, downstream and energy transport sub-sectors due to displacement of coal and gas in power generation.

- **Among the cases in the Alternative Power Mix Scenario, the High Nuclear and High Gas 100% Cases require the lowest total investment.** In the High Nuclear Case, higher investments in the power sub-sector are more than offset by investment reductions in other sub-sectors. The High Gas 100% has the lowest investment in power generation.

- **Improved cost data is needed to reduce uncertainties regarding investment estimates.** This will support improved analysis of APEC energy investment requirements.

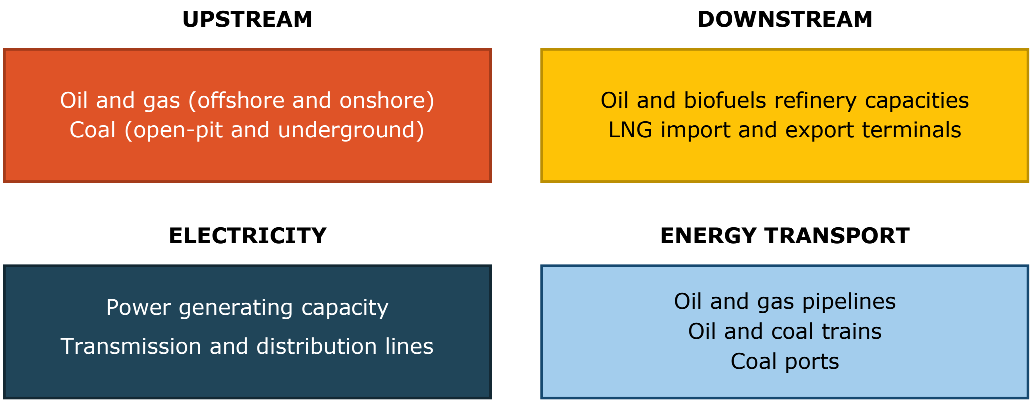
INTRODUCTION

Adequate, sustainable and affordable energy systems are an essential element of economic growth and stability. The Asia-Pacific Economic Cooperation (APEC) region represents about half of global gross domestic product (GDP), and so plays a fundamental role in maintaining and enhancing the flow of energy that is vital to economic growth. Within this context, the Asia Pacific Energy Research Centre (APERC) assesses the investment requirements for total energy infrastructure needed to meet growing energy demand within APEC economies.

Over the Outlook period, a variety of factors could affect investments, such as the real interest rate, inflation, economic performance and government policies. The investment model results set forth a number of challenging investment decisions for energy sector stakeholders. Policy makers are encouraged to create a more favourable investment climate for both the public and private sectors, through incentives, regulations and international cooperation that promote the continued development of the energy sector in all APEC economies. Investment requirements are presented in this chapter for the Business-as-Usual (BAU), Improved Efficiency and High Renewables Scenarios, as well as for the four cases that make up the Alternative Power Mix Scenario: the Cleaner Coal, High Gas 50%, High Gas 100% and High Nuclear Cases.

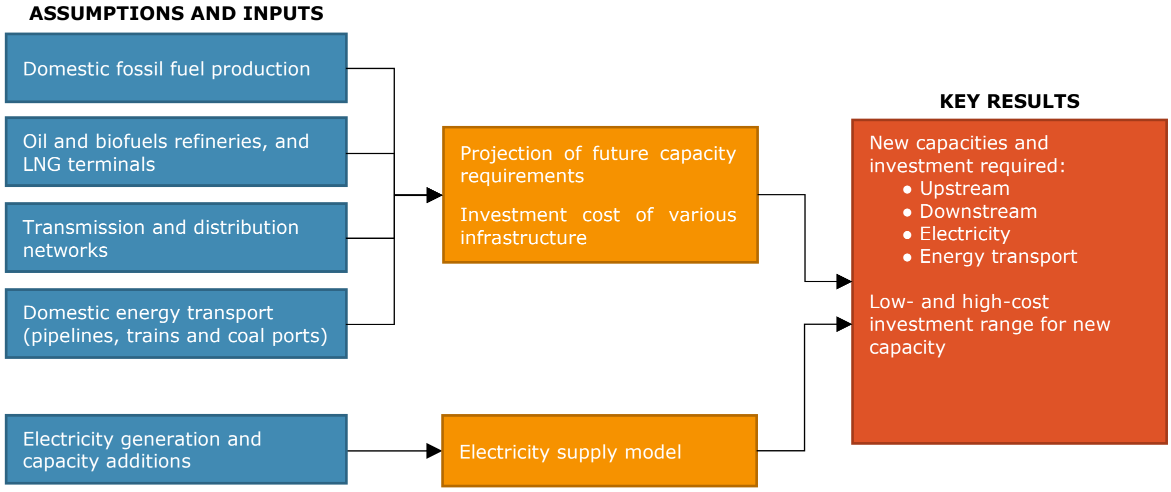
This chapter provides investment estimates based on the additional capacity needed to ensure that energy systems can meet growing energy demand in the region. It classifies a range of figures into lowest and highest cost per unit of energy facility/infrastructure capacity, and presents these as the 'low-cost and high-cost estimates'. These estimates demonstrate the variability in unit cost of similar energy facilities or infrastructure depending on regional conditions and peculiarities. Unless otherwise specified, investments for the 2015-40 period are expressed in 2012 USD PPP values.

Figure 8.1 • Energy sector components



Investments are calculated for capacity expansion of energy facilities in each sub-sector by cost per unit of capacity. The energy system is classified into four sub-sectors: upstream (oil, gas and coal extraction), downstream (refineries and liquefied natural gas [LNG] terminals), power (generation, transmission and distribution [T&D]), and energy transport (oil and gas pipelines, trains for oil and coal, and coal ports). For the sake of simplicity, investment analysis per sub-sector focuses on projections for the low-cost estimate only. The chapter outlines the initial results and goes into detail for each sub-sector, outlining methodologies and key results.

Figure 8.2 • Investment modelling methodology

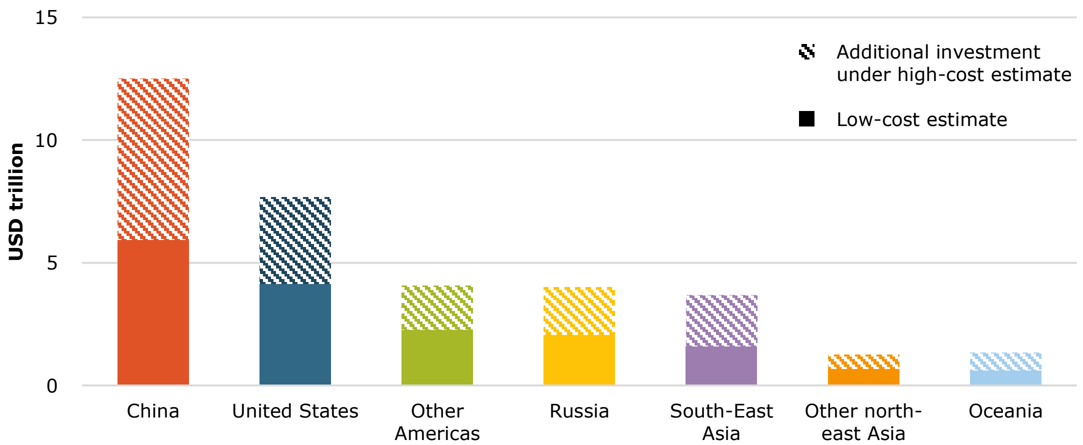


OVERALL INVESTMENT RESULTS

The APEC region includes the world's largest energy consumers—China, the United States, Russia and Japan. Investments are needed to develop the additional infrastructure required for the production and delivery of energy to support projected economic growth and increasing energy demand. Under the BAU Scenario, total GDP of the APEC region shows an annual average growth rate (AAGR) of 3.1%, while the AAGR of energy demand is 1%. These growth trends create a total investment requirement of between USD 17 trillion and USD 35 trillion.

More than half of the APEC investments are required in two regions, China and the United States. Although China's economic AAGR slows to 4.9% (from historical peak of 10%), the economy will require about 35% of the region's energy infrastructure investment to meet its 1.5% AAGR in energy demand. China needs USD 5.9 trillion in the low-cost estimate and USD 12.5 trillion in high-cost estimate. The United States will need the second-largest investment (24% of the region's total), while other Americas and Russia demand around 12% each. South-East Asia, one of the fastest-growing regions in APEC with an aggregate economic growth rate of 4.3% per year, requires 10% of total investment. Other north-east Asia and Oceania require the lowest shares of total investment, at only 4% each. Other north-east Asia is the only region demonstrating negative growth in energy demand at 0.1%; due to its limited fossil fuel resources, it has very low investment needs in the upstream sub-sector.

Figure 8.3 • Energy investment requirements by regional grouping, 2015-40



Source: APERC analysis.

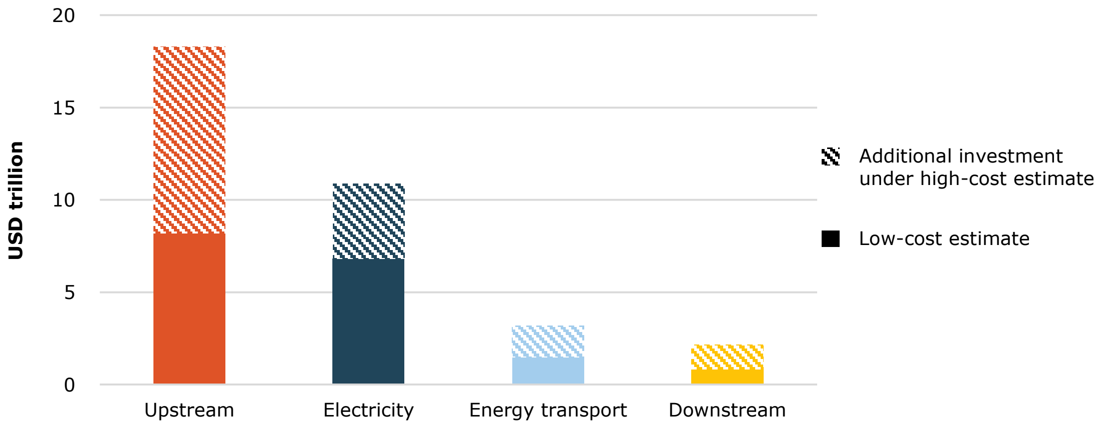
ENERGY SUB-SECTOR INVESTMENT REQUIREMENTS

Across APEC, the majority of investments are allocated to upstream development. At USD 8.2 trillion in the low-cost estimate, this sub-sector accounts for almost half of projected investment requirements during the Outlook period. In the high-cost estimate, the upstream sub-sector share expands to 53%, reaching USD 18.3 trillion, mainly because of the high variability of upstream investment costs. Such investment is needed for the foreseen increase of 1% per year in fossil fuel production in APEC. Much of the growth in fossil fuel production will be for natural gas, which shows an AAGR of 1.7%.

The second-largest proportion of investment is in the electricity sub-sector, at 39% of the total (USD 6.8 trillion) in the low-cost estimate and 31% (USD 10.9 trillion) in the high-cost estimate. Renewable capacity additions account for more than 50% of the investment in power generation capacity. Around 36% of total power investment will be used for T&D networks.

Energy transport accounts for 9% of the total investment, more than half (53%) of which is in gas transport. Downstream investment requires the least investment, about 5% of the total, of which 60% is for expansion of LNG export terminal capacity.

Figure 8.4 • Energy investment requirements by sub-sector, 2015-40



Source: APERC analysis.

Upstream investments (low-cost estimate)

Upstream investments are separated into three categories: offshore and onshore shares of both oil and gas production; and open-pit and underground shares of coal production. Such classifications are necessary to take into account different costs of production; they reflect only capital costs.

Table 8.1 • Cost range assumptions for upstream energy production by fuel

		Low-cost estimate	High-cost estimate
Oil production (USD per barrel)	Onshore	10	15
	Offshore	20	30
Gas production (USD per toe)	Onshore	20	60
	Offshore	40	120
Coal production (USD per toe)	Open pit	14	45
	Underground	28	91

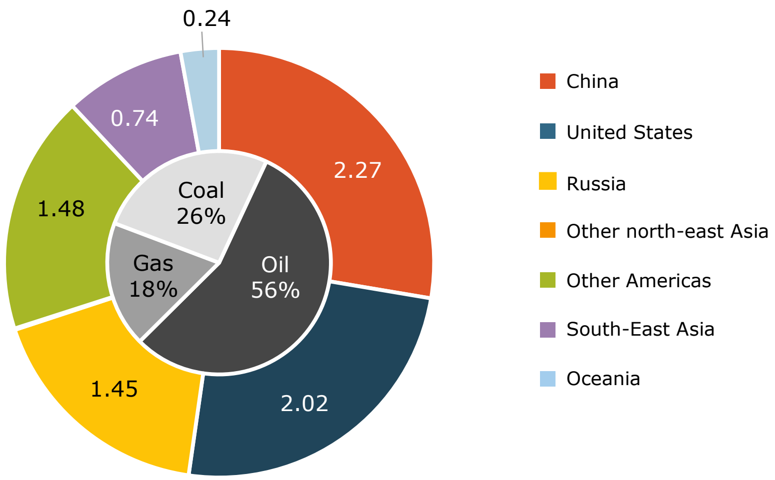
Note: toe = tonne of oil equivalent.
Sources: IEA (2014), Reuters (2009) and CNN (2015).

APEC includes leading global producers of oil, gas and coal. Regions that are currently net exporters of these fuels require higher investments in the upstream sub-sector. China, as one of the world's top producers of fossil fuels (particularly coal), accounts for the highest share at 28%, or USD 2.3 trillion. In 2013, China provided nearly half of the world's coal production (BP, 2014). Over the Outlook period, China allocates 64% of its upstream investment for coal production.

As a top producer of oil and gas, the United States requires the second-largest share (25% or USD 2.0 trillion) of upstream investment. Some 91% of this is allotted for oil and gas production, the remainder for coal. Possible expansion of shale oil and gas production could drive up investment in the upstream sub-sector significantly. Under the BAU, gas production increases at 2.1% a year over the Outlook period. Other major upstream investors include other Americas (USD 1.5 trillion) and Russia (USD 1.4 trillion). Canada is a leading producer of oil and natural gas, Mexico of oil and Russia of oil, natural gas and coal.

Among fossil fuels, oil requires the highest share of upstream investment, with 56% or USD 4.6 trillion, followed by coal (26% or USD 2.1 trillion) and natural gas (18% or USD 1.5 trillion). However, the current low oil price could have a significant effect on upstream investment, particularly for oil and gas as many companies are reacting to the low oil price by reducing capital expenditure. In 2015, upstream budgets were cut heavily; with no indication of oil price recovery, budgets could further dwindle in the coming years (IEA, 2015a). Several oil companies in non-OPEC economies decreased upstream investment by more than 20%, which affects the medium-term outlook of oil production (IEA, 2015b). Given this situation, gas production could experience a setback.

Figure 8.5 • Total upstream investments by regional grouping and by fuel, 2015-40 (2012 USD trillion)



Note: Other north-east Asia = USD 0.01 trillion
Source: APERC analysis.

Downstream investments (low-cost estimate)

Downstream investments are based on future requirements for oil and biofuels refineries in each economy, and the need to construct additional LNG import and export terminal facilities. The analysis is based primarily on planned capacity additions by individual economies (as available).

To estimate future capacity additions, APERC used historical figures to calculate average density or intensity such as oil refinery capacity to total petroleum demand, LNG import/export terminals to net imports/exports, and biofuel refinery capacity to biofuels demand. If available, planned capacity additions are included in the calculation of density/intensity. The density/intensity coefficient is used in projecting capacity additions.

The downstream sub-sector requires the smallest share of total investments among the sub-sectors, at only 4.8%, or USD 84 billion. About 60% of total downstream investment is used to construct LNG export terminals,[1] reflecting significant growth in the LNG industry. The largest downstream investors are the United States (USD 248 billion), other Americas (USD 152 billion) and China (USD 144 billion). With an expected surge in gas production, the United States needs to add 214 million tonnes per year (Mtpy) of LNG export terminal capacity, while Canada requires 108 Mtpy. China requires 146 Mtpy of import terminal capacity to match its increasing natural gas demand. Additional oil refinery capacity[2] requires 30% of total downstream investments, while LNG import terminals and biofuels refinery capacity share the remaining 10%.

Table 8.2 • Cost range assumptions for downstream investments

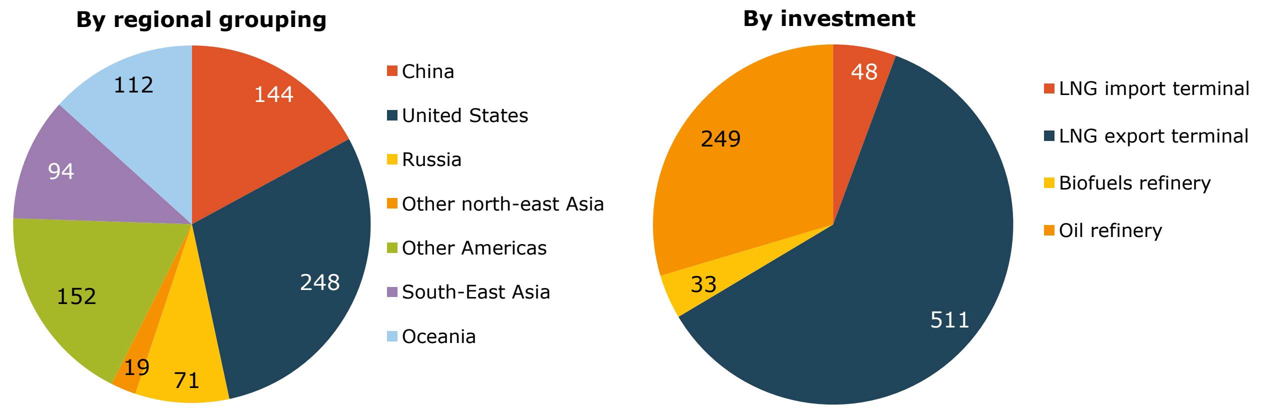
	Low-cost estimate	High-cost estimate
Refinery (USD per barrel per day)	20 000	140 000
Biodiesel (USD per litre per day)	0.36	0.55
Bioethanol (USD per litre per day)	0.47	0.64
LNG import terminals (USD per tonne per year)	115	255
LNG export terminals (USD per tonne per year)	1 000	1 800

Sources: OGJ (2010-14), OIES (2014) and IISD (2013).

South-East Asia devotes about 70% of its downstream investment to oil refinery capacity, while other north-east Asia allocates 66% of investment to oil refinery and 34% to LNG import terminals. Other north-east Asia relies heavily on LNG imports for its domestic supply requirements, which contribute about 23% to the region's primary supply mix.

If the current low oil prices persist, resulting in declining gas production and lower LNG prices, investments in the downstream sub-sector will be affected, particularly investments in LNG export terminals. Several LNG projects have already been abandoned or postponed because the current price of LNG would not cover the capital costs of new LNG plants. If prices do not pick up, there could be tightening in LNG markets from 2020 (IEA, 2015c).

Figure 8.6 • Total downstream investments by regional grouping and by investment, 2015-40 (2012 USD billion)



Source: APERC analysis

[1] LNG export terminal includes projects that are expected to be constructed until 2020, based on World LNG Report 2014 by the International Gas Union (IGU, 2014).
[2] Oil refinery capacity includes projects that are expected to be constructed until 2019 based on IEA Oil Medium-Term Market Report 2015.

Electricity investments (low-cost estimate)

APERC calculations of electricity generation capacity additions are based on the results of the power optimisation model, which reflect a combination of modelling and information from economy plans. Cost ranges per megawatt (MW) are obtained from economy and other resource publications (see Annex I). The large variability in cost per megawatt reflects the different types of power plant per technology. Nuclear, for example, covers pressurised water reactors and other advanced nuclear technologies; solar includes solar photovoltaic (PV), utility PV and concentrating solar power (CSP); and hydro includes pumped storage in some economies. Based on historical costs trends, capital costs for wind and solar are assumed to decline over the Outlook period. The costs of onshore wind have dropped by 18% since 2009, while cost of wind turbines has decreased by nearly 30% since 2008. The costs of solar PV modules have declined by 80% since 2008, and are projected to keep falling (IRENA, 2014). Capital costs for wind are assumed to decline at 0.3% per year in the BAU and 0.7% per year in the High Renewable Scenario, while solar capital costs decrease annually by 1.5% in the BAU and 1.9% in the High Renewables Scenario. China has the lowest average cost per MW for solar; China and the United States have the same low cost per MW for wind.

Table 8.3 • Cost range assumptions for electricity generation

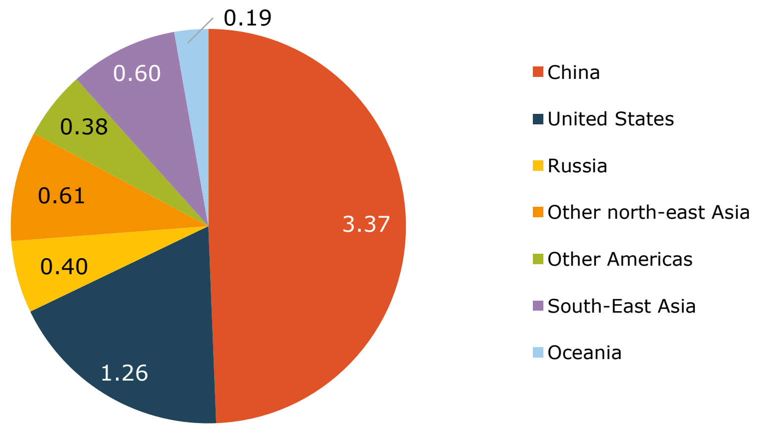
Million USD/MW	Low-cost estimate	High-cost estimate
Nuclear	1.70	7.17
Coal subcritical	0.60	3.89
Coal supercritical	0.71	5.66
Gas turbine	0.33	1.25
Gas combined cycle	0.42	1.49
Oil	0.28	2.28
Hydro	0.60	13.22
Wind	0.77	5.43
Solar	1.61	7.57
Biomass and others	0.58	5.67
Geothermal	1.68	10.16
Coal with CCS	1.33	6.24
A-USC/IGCC	0.98	6.09
A-USC/IGCC with CCS	1.60	7.11

Notes: CCS = carbon capture and storage; A-USC = advanced ultra-supercritical; IGCC = integrated gasification combined cycle.
Sources: IEA (2015c), some economies' publications, and APERC analysis.

To calculate needed investments for T&D networks, APERC used available economy plans. Where such plans were not available, APERC used historical figures to calculate density/intensity (kilometre length of line over gigawatt hour (GWh) power generated). The historical growth rate of density is used to estimate future density, which in turn is used to project network capacity requirements based on the economy's projected electricity generation (in GWh) over the Outlook period.

Cost ranges per unit capacity were sourced from published studies and reports, and from the economy (if available). These estimates assume additional line development costs, such as substations and land permits. In some instances, uniform cost ranges and proxies are used to approximate the investment in both the low-cost and high-cost estimates. Refurbishments of existing T&D lines are also assessed and considered in total investment for networks, as well as additional transmission costs for variable renewables (solar and wind), and for hydro and geothermal (from source to grid tapping point).

Figure 8.7 • Total electricity investments by regional grouping, 2015-40 (2012 USD trillion)

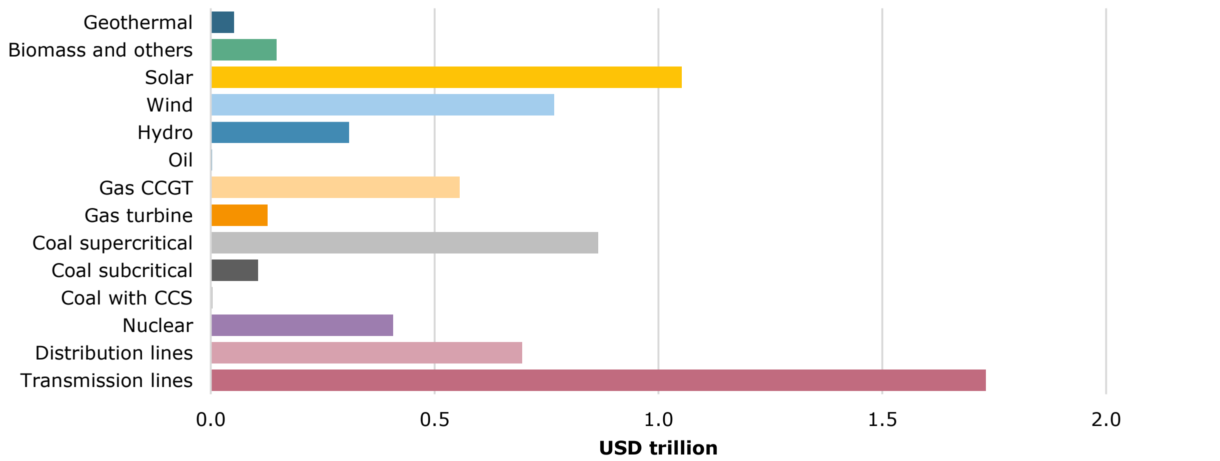


Source: APERC analysis.

Power investments require the second-largest share of total investments over the Outlook period, at 39% of the total, or USD 6.8 trillion. Of total investment for generation capacity, non-emitting sources (nuclear and renewable technologies) account for 62%, or USD 2.7 trillion. The largest share of generation capacity investments are in China (USD 2 trillion) and the United States (USD 0.73 trillion). South-East Asia and other north-east Asia together require USD 465 billion to USD 558 billion, while Russia needs USD 262 billion and other Americas, USD 219 billion. Oceania requires the least investment, only USD 145 billion. Encompassing network expansion and refurbishment, as well as additional transmission costs for renewables, T&D networks take about 36% of total power investment.

Among renewable technologies, solar receives the highest share of total power generation capacity investment at 24%, equal to 45% of total renewables generation capacity investment. Wind takes 17% of total generation investment (33% of renewables investment). By the end of the Outlook period, total solar power capacity reaches 522 GW (additional of 470 GW) and total wind capacity at 593 GW (additional of 423 GW). China requires more than 50% of total renewable generation capacity investment.

Figure 8.8 • Investment requirements in the electricity sub-sector, 2015-40



Source: APERC analysis.

Energy transport investments (low-cost estimate)

Energy transport capacity, covering oil and gas pipelines, oil and coal trains and coal ports, is calculated based on maximum operating capacity assumed in the Outlook projection. To determine future capacity requirements, this operating capacity is then applied to oil, gas and coal production and supply requirements, including exports and imports (specifically for coal ports), of each economy.

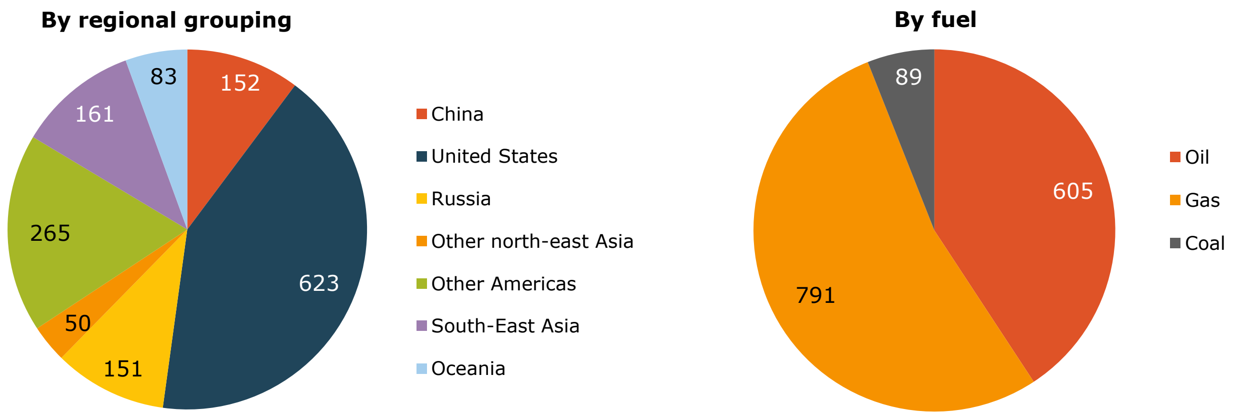
Table 8.4 • Energy transport cost assumptions

	Low-cost estimate	High-cost estimate
Gas pipelines (million USD per million cubic metres per year)	733	2 040
Oil pipelines (million USD per thousand barrels per year)	0.75	1.52
Coal ports (million USD per million tonnes per year)	23	64
Oil trains (million USD per million barrels per year)	110	129
Coal trains (million tonnes per year)	18	36

Sources: Reuters (2015b), OIES (2014a), IEA (2013), CAPP (2014), and BNN (2014).

The energy transport sub-sector requires 8.6% of total investments, or USD 1.5 trillion. About 80% of energy transport investments are needed in the United States, other Americas, South-East Asia and China. As one of the largest regions in APEC, the United States requires the largest investment in energy transport at USD 623 billion, or 42% of total transport investment. Other Americas invests USD 265 billion, South-East Asia USD 161 billion and China USD 152 billion. Russia, which has the largest land mass in the region, requires USD 151 billion for transport. With limited fossil fuel resources other north-east Asia has the lowest investment needs at only 3.4% of the total. Nearly 95% of transport investment is used for oil and gas infrastructure, and the remainder for coal (which includes ports).

Figure 8.9 • Investment requirements in the energy transport sub-sector by regional grouping and by fuel, 2015-40 (2012 USD billion)



Source: APERC analysis.

INVESTMENT TRENDS

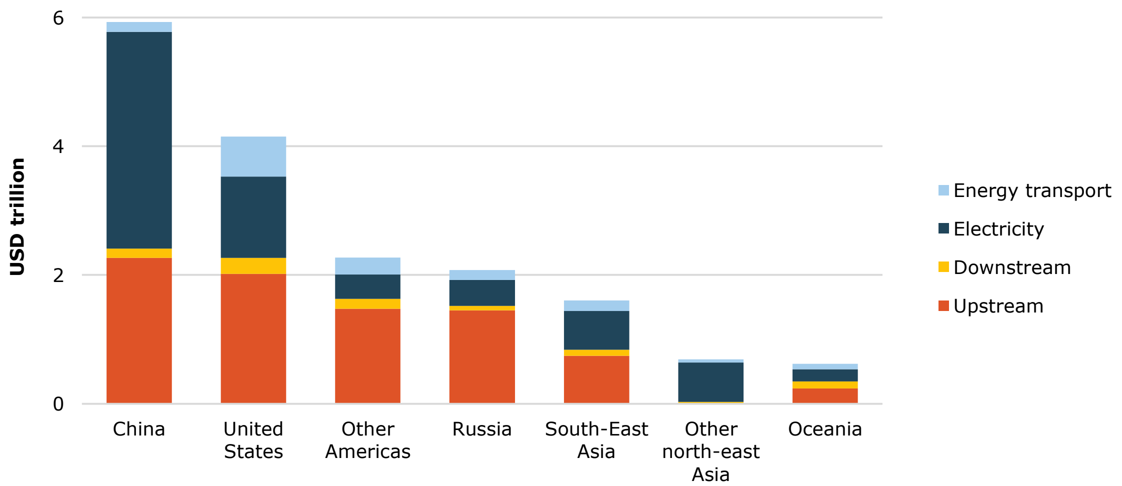
Investments by region and by sub-sector (low-cost estimate)

China's investments of USD 5.9 trillion are largely divided between the upstream (USD 2.3 trillion) and power (USD 3.4 trillion) sub-sectors. About two-thirds of upstream investments (USD 1.5 trillion) are allocated to underground coal mining. Under the BAU Scenario, China's generation capacity increases 134%, requiring 1.8 terrawatt (TW) of capacity additions, accounting for 67% of total power capacity additions in APEC over the Outlook period. China's commitment to reducing greenhouse gas (GHG) emissions increases generation from renewable technologies, specifically wind and solar. Almost 50% of the 1.8 TW of capacity additions is for generation from renewable energy sources. China also spends close to USD 463 billion on supercritical coal plants, which are more efficient than the subcritical plants that make up 57% of current generation capacity.

The United States requires the second-largest share (24%) of total energy investments, around USD 4.2 trillion, of which 49% supports the upstream sub-sector. The United States is expected to allocate USD 1.8 trillion for the development of domestic oil production (which increases by 18%) and gas (76%). These new domestic resources also boost growth in the LNG industry, with US investment of USD 214 billion to build additional LNG export terminals, mainly on the Gulf Coast and the West Coast. About 53% of power generation capacity additions over the Outlook period are combined cycle gas facilities, requiring USD 235 billion of investment.

Other Americas will need to invest USD 2.3 trillion in energy development, of which two-thirds is allocated to the upstream sub-sector, with the main drivers being Canada (USD 1.2 trillion) and Mexico (USD 0.88 trillion). Mexico is of note for an abrupt change in trends: from 1990 to 2013, production in Mexico grew only 11%. Over the Outlook period, Mexican production increases by 71%. To enable this production increase, Mexico is expected to invest USD 666 billion on upstream development, all of it for oil and gas resources. Canada, having the third-largest proven oil reserves in the world, will allocate 62% of its total investments to the upstream sub-sector. Other Americas also has one of the highest shares (18%) in energy transport investments in APEC. About 72% of these investments are required by Canada to support its upstream sub-sector, particularly for oil and gas. Canada needs to add an estimated 6 533 million barrels of oil per year (Mbbl/y) of oil pipeline capacity by 2040, as well as oil train capacity of 1 636 Mbbl/y (NEB, 2014; CAPP, 2014). Mexico directs 89% of total transport investment towards developing its gas pipeline grid.

Figure 8.10 • Total investment requirements by regional grouping and by sub-sector, 2015-40



Source: APERC analysis.

Of the total investment in Russia, 70% is devoted to the upstream sub-sector, specifically for oil and gas resources, production of which increases by 10% over the Outlook period. The power sub-sector receives 13% for generation capacity additions of 63 GW. Transport’s share is 7.3% and the downstream sub-sector’s is 3.4%, the bulk for additional LNG export terminals.

The growing economy of South-East Asia drives substantial growth in energy demand. This necessitates total investment of USD 1.6 trillion over the Outlook period. The upstream sub-sector requires 46% of the total, as some economies (such as Indonesia and Malaysia) are major fossil fuel producers. The region’s fossil fuel production increases by an AAGR of 1%, with the largest contribution coming from coal

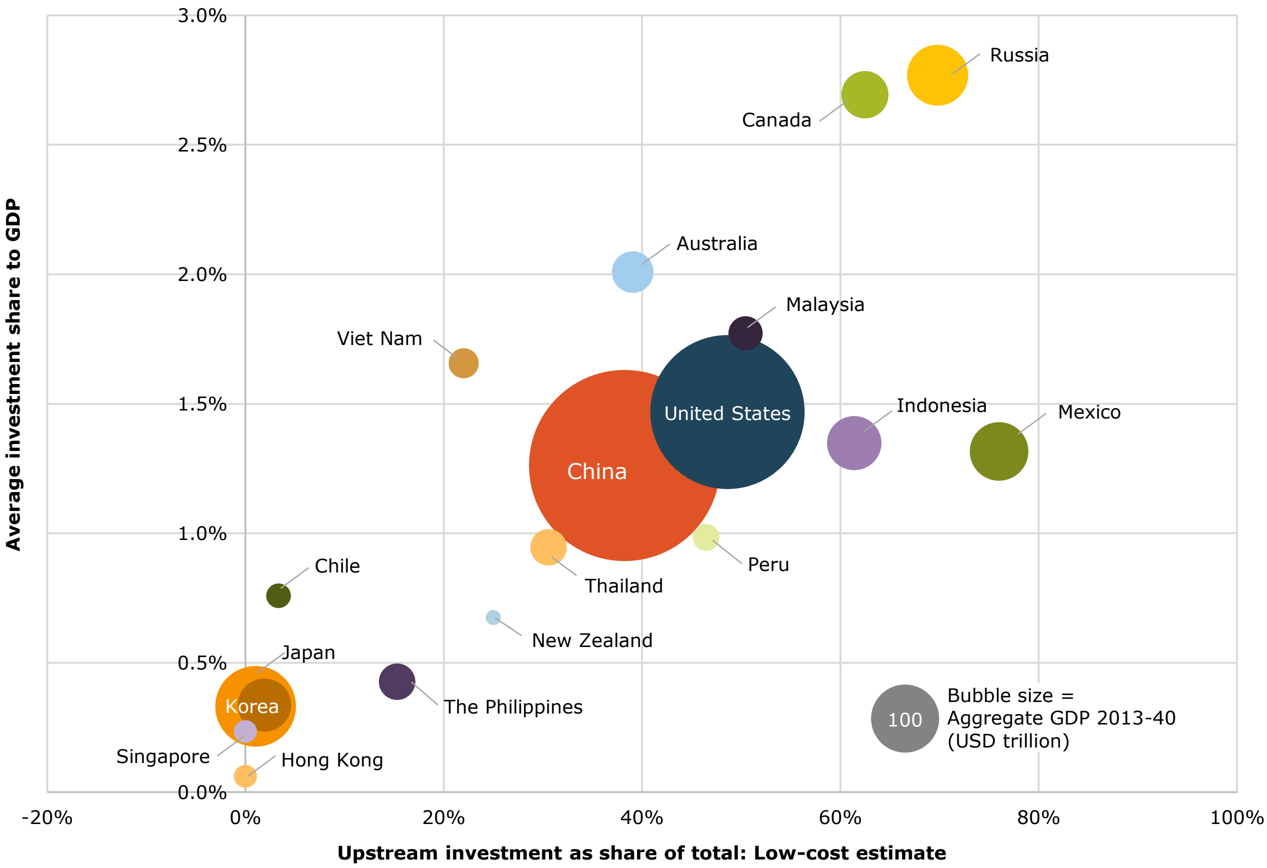
(AAGR of 1.5%). The power sub-sector needs 38% of total investment, to add generation capacity of 325 GW as electricity demand rises by almost 4% AAGR.

The two regions with the smallest portions of total investment are other north-east Asia (4%, or USD 692 billion) and Oceania (3.6%, or USD 620 billion). Other north-east Asia is poor in energy resources and has the least energy reserves of any APEC region. Of the total investment in other north-east Asia, almost 90% is allocated to the power sub-sector, 62% of which is invested in Japan. In Oceania, Australia alone accounts for 93% of the region's projected investment requirements, to develop its large deposits of coal, oil and gas, and install supporting transport infrastructure. Around 85% of Papua New Guinea's investment in the upstream sub-sector is allocated to develop its gas reserves.

TOTAL ENERGY INVESTMENTS ARE ONLY A SMALL PORTION OF GDP

The investment in energy systems required over the Outlook period accounts for an average of 1.8% of projected GDP for individual APEC economies. For APEC as a whole, investment reflects 0.89% of aggregate regional GDP. Economies where investments make up more than the average share of GDP include Brunei Darussalam, Canada, Malaysia, Papua New Guinea and Russia. For the most part, the larger shares of these economies can be attributed to higher upstream investments. Brunei Darussalam and Russia direct around 70% of their total investment requirements to upstream, Canada about 62% and Malaysia 50%. Brunei Darussalam's investments account for a high share of GDP (11%) because oil and gas production contributes more than 60% of annual GDP and 90% of government revenues (TE, 2015).

Figure 8.11 • Average share of energy investment to GDP and upstream share of total investment, 2040



Notes: Brunei Darussalam: average investment share to GDP = 11%, upstream investment as share of total = 71%, aggregate GDP 2013-40 = USD 0.69 trillion; Papua New Guinea: average investment share to GDP = 4%, upstream investment as share of total = 30%, aggregate GDP 2013-40 = USD 1.64 trillion; Both economies excluded as projections are outliners.

Source: APERC analysis.

Economies where investment accounts for a low share of GDP are Chile, Hong Kong, Japan, Korea, the Philippines, Singapore and Chinese Taipei. These economies have limited domestic energy resources to be explored and developed; as such, most of the energy investments are required in the power and downstream sub-sectors. More than 70% of the total investments of Chile, Hong Kong, Japan, Korea and Chinese Taipei are allotted for power sub-sector, while Singapore divides its investment almost equally for downstream and power sub-sectors. As a major exporter of petroleum products, Singapore needs slightly more investment in downstream (53%) for additional oil refinery capacity, and the remaining for LNG import terminals. The Philippines directs 62% of its total investment to power and 15% to upstream.

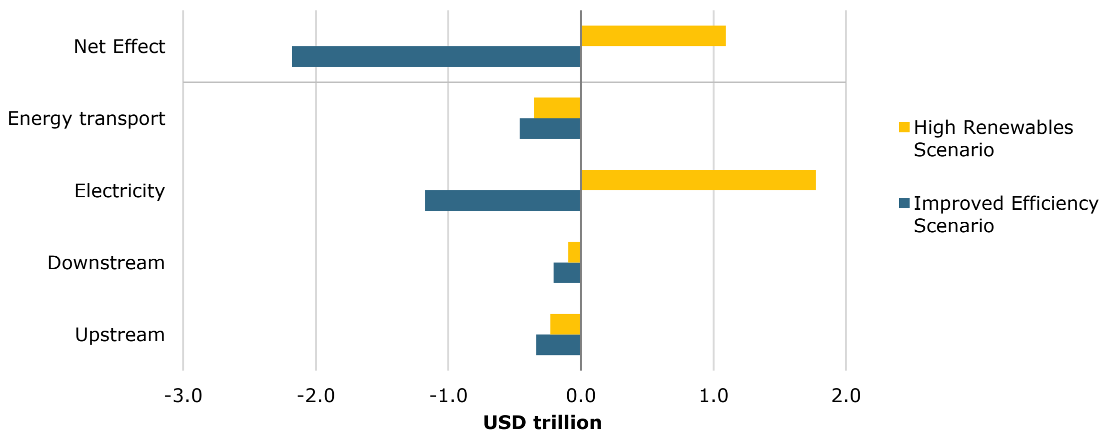
INVESTMENTS UNDER THE ALTERNATIVE SCENARIOS

IMPROVED EFFICIENCY SCENARIO RESULTS IN SAVINGS OF USD 2.2 TRILLION

Under the Improved Efficiency Scenario, APEC energy demand is 13.2% lower; this reduces the region's investment requirement by 12.6%, a saving of USD 2.2 trillion. More than 50% of savings are in the power sub-sector, where investment is 17% lower than in the BAU, at USD 5.6 trillion. Electricity demand is 18% lower, bringing the required power capacity additions down to 1 786 GW (899 GW less than in the BAU). Expansion of T&D networks also decreases, saving USD 447 billion.

The upstream sub-sector realises savings of 4.1%, or USD 337 billion, due to the reduction in production of oil, gas and coal from 8 050 million tonnes of oil equivalent (Mtoe) in the BAU to 7 144 Mtoe. Savings from downstream investment account for 24%, or USD 205 billion, while savings from energy transport reach 31%, or USD 462 billion. Refinery capacity additions fall to 8.1 million barrels per day (bbl/d) from the BAU level of 9.8 million bbl/d, while biofuels refinery capacity is 165 million litres per day (L/d) lower than the BAU level of 222 million L/d. Similarly, LNG import terminal capacity decreases to 128 Mtpy, around 60% lower than the BAU, while LNG export terminal capacity declines to 408 Mtpy, 20% lower than the BAU.

Figure 8.12 • Changes in energy sector investment requirements in the Improved Efficiency and High Renewables Scenarios compared with the BAU, 2015-40



Source: APERC analysis.

Among the regions, South-East Asia and Oceania demonstrate the largest decreases in investment under the Improved Efficiency Scenario, with savings of 16% from the BAU, followed by other north-east Asia (15%), the United States (13%), other Americas (12%), China (12%) and Russia (11%). This reflects the drops in energy demand being most significant in South-East Asia (13%) and Oceania (16%).

Some regions realise greater investment savings in the power sub-sector; in both other north-east Asia and China, for example, the savings are around 90%. The power sub-sector accounts for 57% of total savings in South-East Asia, 43% in other Americas, 34% in Oceania and 22% in the United States.

Russia's primary savings, more than 30% of the total, are in the upstream sub-sector as lower energy demand prompts significant savings in energy transport, in turn reducing fossil fuel production.

HIGH RENEWABLES SHOWS SMALL INCREASE IN TOTAL ENERGY SECTOR INVESTMENTS

In the High Renewables Scenario, total energy sector investment requirements increase by 6.3% from the BAU, to USD 18 trillion. Power sub-sector investments rise by 26%, or USD 8.6 trillion, to bring more renewables into the power mix, specifically solar and wind. Renewables capacity additions increase by 1 057 GW, reaching 3 210 GW by 2040 (compared with 2 153 GW in the BAU).

Capital costs for solar and wind fall much faster in the High Renewables Scenario than in the BAU, but this decline is offset by the need to add more capacity to compensate for the lower capacity factors of these technologies. Solar capacity additions increase to 912 GW from the BAU level of 522 GW, while wind capacity reaches 994 GW from 592 GW in the BAU. Solar and wind together make up almost 78% of total renewable capacity additions. Investment in T&D networks expands by 23% to USD 3 trillion from USD 2.4 trillion in the BAU. This is because solar and wind require more transmission reinforcement and storage facilities, and hydro and geothermal require more transmission from point source to main grid tapping point.

In this scenario, the upstream sub-sector savings are 2.8% while those in downstream reach 11%. Adding more renewables to the capacity mix displaces generation capacities of coal (9%) and natural gas (14%), decreasing upstream production of these fossil fuels. Higher biofuels blends also lead to lower oil production, as demand for bioethanol and biodiesel blends reduce gasoline and diesel demand. Downstream investment declines as natural gas displacement reduces requirements for LNG import and export terminals, and higher biofuels demand reduces requirements for oil refinery capacity (the investment needed for biofuels refineries is not enough to make downstream investment rise). Declining fossil fuel production and lower supply requirements for coal, natural gas and oil lead investment in energy transport to fall by 24% from BAU levels.

Most regions exhibit increases in investment, particularly in the power sub-sector. In other north-east Asia, investment increases by 19% from BAU levels, primarily because of a 22% investment increase in the power sub-sector. The region requires an additional 54 GW of renewable capacity under this scenario, on top of the BAU level of 127 GW. The United States investment requirements rise by 11%, with power sub-sector investment up by almost 70%. Additions of renewables capacity in the United States rises threefold from BAU levels, 93% of which are solar and wind. The total increase in investment for the United States is to some extent offset by lower upstream and transport investments, due mainly to renewables displacing natural gas generation capacity. The investment requirements grow by 6.8% in China, as power investment surges by 12%. Capacity additions of renewables expand by 32%, of which solar and wind have a combined share of 77%. South-East Asia shows a 5.7% increase in total investment, with a 26% increase in power investment. Downstream investment rises by 8.3% due to increases in biofuels blends, up to 20% to 30% for bioethanol and 20% to 25% for biodiesel, particularly in Indonesia, the Philippines and Thailand.

The lowest increases in investment are seen in other Americas (1.4%) and Oceania (0.9%), despite a higher investment requirement for the power sub-sector than in the BAU. These low levels are due to declines in investment in the upstream and energy transport sub-sectors. In Russia, total investment falls by 0.6% in this scenario, even though power investment increases, reflecting a large decrease in upstream investments as renewables displace some natural gas and coal generation capacities and energy transport investment decline.

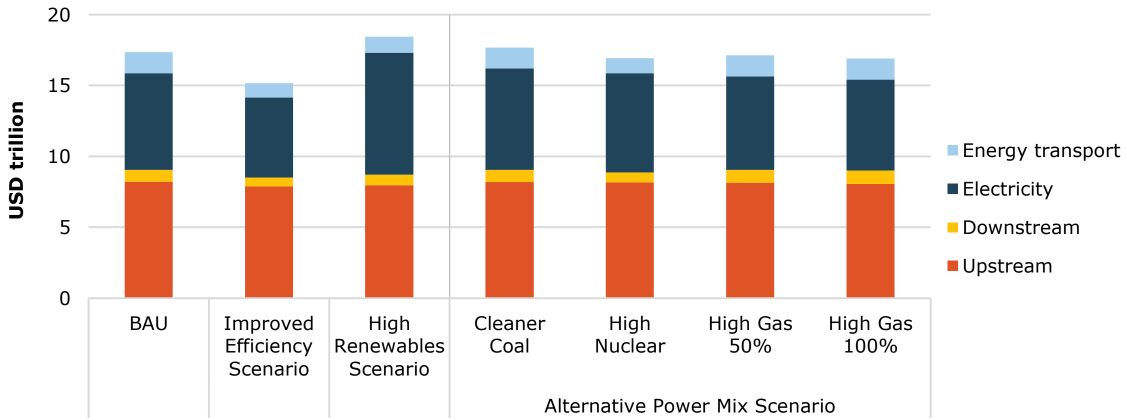
INVESTMENT IN THE ALTERNATIVE POWER MIX SCENARIO

Of the four cases in the Alternative Power Mix Scenario, the High Nuclear and High Gas 100% Cases require the lowest overall investment, at USD 16.9 trillion. The High Nuclear Case has the second highest capital requirement for power generation, after the Cleaner Coal Case. The higher cost of nuclear power plants is offset by displacement of coal and natural gas power plants due to the higher efficiency level of nuclear. Investments in the other sub-sectors also decline as coal and gas demand for power falls, with lower gas demand reducing the requirement for LNG export and import terminal expansion.

In the High Gas 100% Case, investment for power generation capacity is almost 10% lower than the BAU level as gas displaces coal in the power capacity mix. Capital costs are 40% to 50% higher on average for coal technology power plants than natural gas-based plants (gas combined cycle and gas turbine). The rise in downstream investment to expand LNG export and import terminals to accommodate the additional gas supply requirement is not enough to push the investment higher than the Cleaner Coal and High Gas 50% cases.

The High Gas 50% Case demands around USD 17.1 trillion, as a portion of the power generation capacity will still come from coal technology. Under this scenario, coal contributes more than 30% to generation. The additional capital requirement to expand LNG export and import terminals and to boost transport for additional gas supply contributes to the higher investment requirements for this case.

Figure 8.13 • Investment requirements in the Alternative Power Mix Scenario by sub-sector and by Case, 2015-40



Source: APERC analysis.

The Cleaner Coal Case requires the highest investment, at USD 17.7 trillion. In this case, some economies introduce coal power plants with technologies that require substantial extra investment, such as advanced ultra-supercritical (A-USC), integrated gasification combined cycle (IGCC) and carbon capture and storage (CCS). Investment in the power sub-sector is 34% higher than in the BAU. However, upstream and transport investments are 1% lower than in the BAU, mainly because the higher efficiency of advanced coal technology lowers coal supply requirements.

Similar general trends are seen in terms of investment requirements. In fossil fuel producing economies—such as other Americas, Russia and the United States—investment is affected by increases or decreases in coal and gas production as one displaces the other in the Cleaner Coal and High Gas Cases, or both are displaced in the High Nuclear Case. In the United States and Russia, upstream and transport investments drop under the High Nuclear Case as demand for gas in power generation falls. In other north-east Asia, downstream investment increases to build additional LNG import terminals in the High Gas cases, raising investment in the High Gas 50% Case by 14% and in the High Gas 100% Case by 38% over BAU levels.

In South-East Asia, which has both producers and importers of fossil fuels, total investment in the Alternative Power Mix Scenario is affected by changing investments in the upstream, downstream and transport sub-sectors. China's investment trends may be affected by changes in the upstream, downstream and energy transport sectors as the economy is both a producer and a large importer of gas.

ENERGY INVESTMENT FINANCING

Energy projects require huge, long-term investments, and access to affordable funding is often an obstacle to their implementation and completion. In addition, project finance is highly tailored, so choosing the best financial structure can be difficult. The possible sources of financing for energy projects include:

- Self-financing: For a private investor, these funds come from retained earnings that are not yet distributed to shareholders. If the main investor is the government, the funds come from the public budget appropriated for such purposes.
- Banks: In project finance, banks offer long-term loans subject to the financial strengths of the applicant and the proposed guarantees. The interest applied by the banks is based on the associated risk of the project, maturity, returns, financial structure and the regulatory framework where the investment will take place. For certain energy projects, the government may grant an additional guarantee to reduce the financial cost to the investor.
- Capital markets: Bonds involve less financial cost to the investor and may have a longer period of maturation than bank loans. Equity instruments offer the option of selling shares in the project and thus incorporating new investors, which reduces financial risk but also reduces the participation in final benefits.

Table 8.5 ● Ratio of loans and bonds in debt financing by regional grouping[3]

	Loans	Bonds
United States	55%	45%
Other developed	69%	31%
Other developing Asia	79%	21%
Latin America	81%	19%
Japan	82%	18%
China	92%	8%

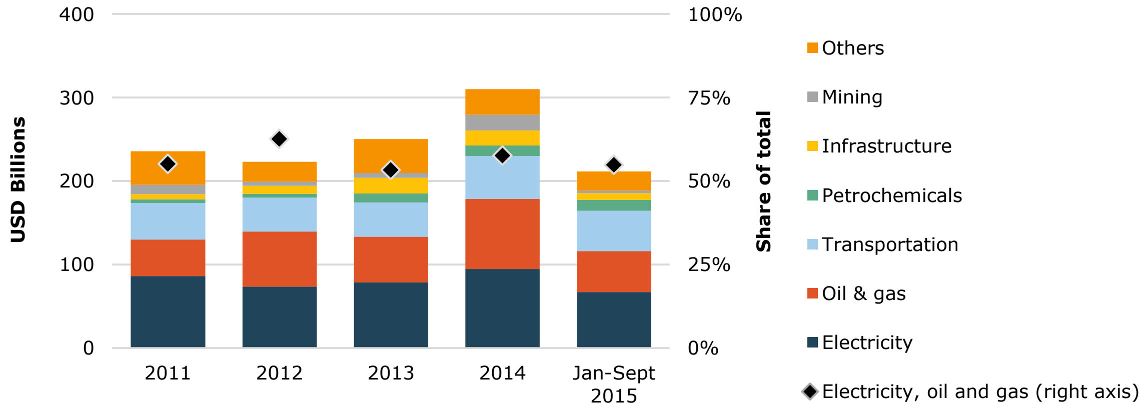
Source: Group of Thirty (2013).

The share of bank loans and bonds in the total financing structure varies depending on the region where the investment will take place, and on the development and maturity of the financial market in each region. Where financial markets are more sophisticated and liquid, such as in the United States, the use of bonds dominates over the use of loans. In regions where bank loans have a central role, investors may face shorter maturity instruments and volatile loan conditions. Large and capital-intensive infrastructure projects have low initial equity injection requirements, which makes investment in such projects an attractive proposition, as the associated risk is low (Gardner and Wright, 2010).

Project Finance International (PFI) reports that the power sector and the oil and gas sector accounted for about 57% of bond issuance and bank loans to finance projects between 2011 and September 2015. Resources obtained through the financial system and banks were around USD 180 billion in 2014, of which 33% was bond issuance and 67% bank loans (Reuters, 2015a).

[3] Regional grouping is defined by Group of Thirty and not based on APEC definition

Figure 8.14 • Global bank loans and bond issuance by sub-sector, 2011-September 2015



Note: Transportation refers to non-energy related transport.
Source: Reuters (2015a).

The Asia-Pacific region (including non-APEC economies) remains the primary target for foreign direct investment (FDI). In 2014, the region received 38% of total capital investment of USD 649 billion, or around USD 250 billion. In the same year, FDI in the coal, oil and natural gas sector was USD 79 billion, equalling 12% of total FDI and making it the second-largest sector for FDI after real estate. FDI in renewable energy projects accounted for USD 45 billion (i.e. equal to more than half of FDI for fossil fuels) (FDI Intelligence, 2015).

The Doing Business index

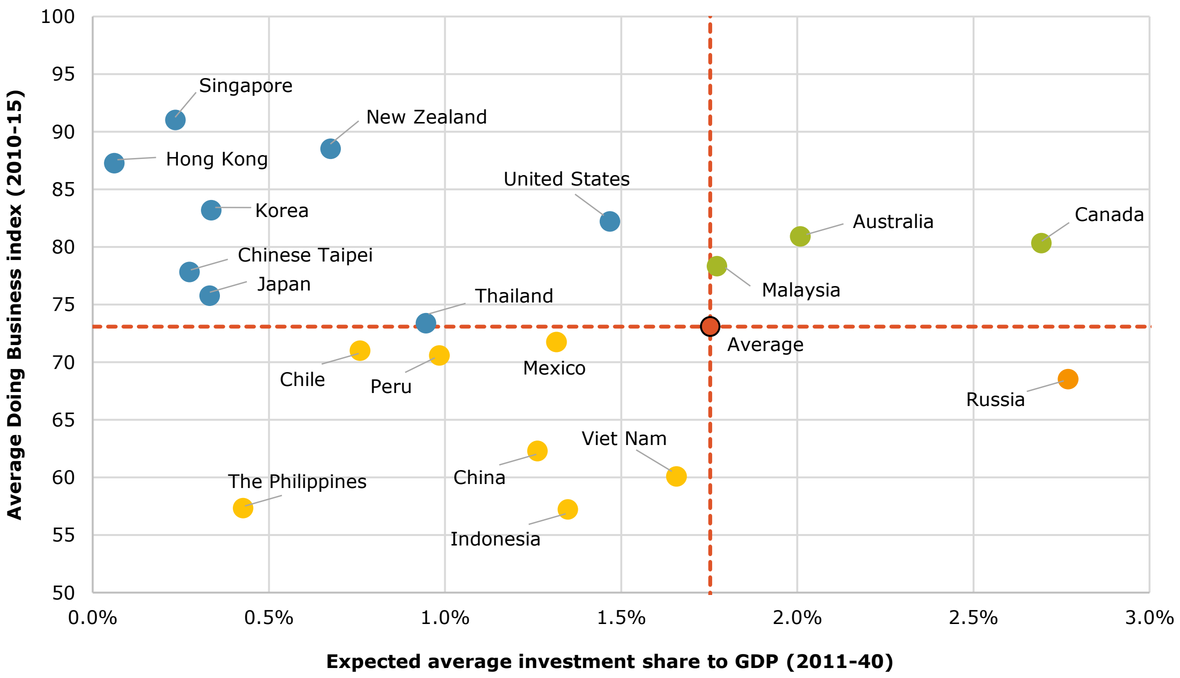
A potential obstacle to increasing energy investments is the difficulty in starting the investment process in some economies. The World Bank's Doing Business index provides an indication of how easily an investment can be made in each economy in the long term (World Bank, 2014). This indicator 'measures the presence of rules that establish and clarify property rights, minimise the cost of resolving disputes, increase the predictability of economic interactions and provide contractual partners with core protections against abuse.' The indicator covers 10 areas: starting a business; dealing with construction permits; getting electricity; registering property; getting credit; protecting minority investors; paying taxes; trading across borders; enforcing contracts; and resolving insolvency.

A higher index for the economy means that investors have less difficulty in initiating investments. The APEC economies average Doing Business index is at 73.1. For individual economies, the lowest index is 55.7 and the highest 91.0. The Doing Business index charts each economy, based on its average level from 2010 to 2015, against the average energy investment requirement by each economy as a proportion of GDP (Figure 8.15).

Quadrant I (blue) contains economies having a high Doing Business index (above the APEC average of 73.1) and requiring a level of investment relative to GDP lower than the APEC average of 1.8%. These economies have the easiest access to financial markets to fund energy projects. Quadrant II (green) indicates economies having a high Doing Business index and an above average share of investment to GDP. These economies have the same access to financial markets as those in Quadrant I, but need to make extra effort to attract investors.

In Quadrant III (yellow) are economies that have a low Doing Business index and a low level of investment relative to GDP. They could have trouble obtaining financial resources for their energy investment requirements, which may affect the pace at which investment can be made. Economies in Quadrant IV (orange) have a low Doing Business index and above average investment share relative to GDP, and are likely to require greater effort to attract investments. Economies in Quadrants III and IV will need to institute reforms in investment policies and processes. Policy makers in these economies should ensure that stable, clear regulatory and investment-friendly policies are crafted and effectively implemented to create a better business environment. Streamlining processes is also necessary to reduce the burden investors face in starting business ventures.

Figure 8.15 • Doing Business index and average required energy investment (% of GDP)



Notes: Brunei Darussalam: average Doing Business index (2010-15) = 62 and expected average investment share to GDP (2011-40) = 11%; Papua New Guinea: average Doing Business index (2010-15) = 56 and expected average investment share to GDP (2011-40) = 4%; Both economies excluded as projections are outliers.
Sources: World Bank Doing Business index and APERC analysis

RECOMMENDATIONS FOR POLICY ACTION

Many factors influence energy investments in APEC economies. The World Bank's Doing Business index offers a yardstick to determine how attractive business environments are to investors. Factors considered in the index must be taken seriously by each economy, as they provide an indication of what needs to be improved in the business climate to encourage more investment. Considering that energy projects are highly leveraged investment undertakings, securing financing sources through long-term loans is a significant challenge. Multilateral and development banks play a crucial role in providing access to funds for energy investments. Economic performance is also a crucial factor in investment decisions, as it affects the real interest rate and the inflation rate, and thus the amount of investment needed to expand capacity and improve the energy system.

Many investment decisions depend on whether government regulatory policies affecting energy markets ensure a conducive business environment. Such policies should seek to lower investment risk and thus encourage greater capital investment and private sector participation in every aspect of the energy system. Though some economies still maintain state-owned energy companies (particularly in oil and gas, and in power), the gradual introduction of reforms has allowed more private players to engage in the domestic energy business. Mexico's constitutional reforms, for instance, allow private companies to participate in the production and refining of oil, and in the transport, storage and distribution of petroleum products and natural gas. Additionally, private power companies are permitted to engage in electricity generation (except nuclear) and distribution, including participation in T&D networks (PEMEX, 2013). In Japan, the updated Strategic Energy Plan (approved in April 2014) will implement reforms in the electricity and gas systems to make markets more liberalised and competitive. Full retail competition in the power sector will be introduced in 2016. The gas retail market will be fully liberalised in 2017 and the gas pipes owned by three city gas utilities will be unbundled by 2022 (METI, 2015). The Philippines deregulated the downstream oil industry in 1998 and enacted the Electricity Power Industry Reform Act in 2001, privatising the state-owned power corporation and paving the way for a more competitive electricity supply market.

Stable regulatory policies, more liberalised energy markets and fiscal and non-fiscal incentives provide security for the private sector. One of the recommendations of the Group of Thirty on long-term financing and economic growth is for policy makers to consider the systematic impact of ongoing and future regulatory policy changes on long-term investment (Group of Thirty, 2013).

Bridging the gap between the amount of investment required and finance available is a challenge for most economies, especially developing economies. Regional cooperation may be necessary to create a business or investment framework that helps economies to attract private sector investment within a suitable long-term financing structure. APEC would do well to establish a regional investment framework to help member economies access capital investment, or even promote joint investment ventures between and among private energy companies in the region. The APEC Committee on Trade and Investment should be strengthened to include a sub-committee on energy to serve as a platform for discussing and resolving business and investment issues, facilitating investment and enabling dialogue with financing institutions. Regular region-wide business dialogue among governments, private energy companies and financing institutions would help governments understand how to make their policy and business frameworks more favourable for investors and financing.

The investment figures presented in the different scenarios in this Outlook pose a challenge for all economies not only in securing the necessary funds but also in achieving the goals of their policy agendas, such as reducing CO_2 emissions, diversifying energy supply and ensuring energy security. As the ambition of these goals affects the investment needed, each economy should carefully assess the investment implications of its policy agenda and initiatives.

9. ENERGY SECURITY AND CLIMATE CHANGE

KEY FINDINGS

- **Diversity of primary energy supply in APEC is expected to improve in 2040, as a result of a higher share of renewables in the fuel mix.** The level of primary energy self-sufficiency, however, will decrease from 93% to 92% as rapid energy demand growth causes imports to rise in some regions.

- **Further improvement in energy security can be achieved under the Improved Efficiency Scenario, particularly with respect to gas self-sufficiency.** Strengthening and expanding regional cooperation and trade within APEC can play important roles.

- **APEC CO_2 emissions in the BAU Scenario reach 25.3 $GtCO_2$ by 2040, with a 24% increase in energy-related emissions.** Emissions in the High Renewables Scenario rise before levelling off at 23 $GtCO_2$ around 2035. The Improved Efficiency Scenario shows emissions peaking at 22 $GtCO_2$ in 2023, then declining to be on par with 2013 levels by 2040.

- **Commitments made by APEC economies under their Intended Nationally Determined Commitments would result in estimated emissions of 19.6 $GtCO_2$ to 21.7 $GtCO_2$ by 2030.** This is more than double the emission level needed in 2050 to limit the global temperature increase to 2°C, highlighting the need to strengthen future commitments.

- **To improve energy security and also address climate change, APEC will need to accelerate both energy efficiency improvements and measures aimed at decarbonising energy supply,** including higher shares of renewables and nuclear, switching to lower-carbon fossil fuels and adopting CCS.

INTRODUCTION

Asia-Pacific Economic Cooperation (APEC) Energy Ministers met in October 2015 in Cebu, the Philippines, under the theme 'Towards an Energy Resilient APEC Community'. Ministers highlighted the importance of energy resiliency in promoting energy security, the role of energy systems in addressing the impacts of climate change, and the need to develop a more sustainable energy sector. Results of the Business-as-Usual (BAU) Scenario presented in previous chapters clearly show that APEC economies are not on a sustainable path. Rising dependence on imported fossil fuels will place pressure on both energy security and environmental sustainability. Rapid growth in energy-related carbon dioxide (CO_2) emissions would push long-term temperature rise to levels that could increase the frequency of energy supply disruptions and leave APEC exposed to greater energy security risks.

Improving energy security and reducing the energy sector's impact on climate change will require numerous collective solutions, including improving energy efficiency, increasing the deployment of renewables in the power and end-use sectors, and deploying other low-carbon technologies such as carbon capture and storage (CCS) and nuclear. This chapter evaluates the energy security and climate change implications of both the BAU and Alternative Scenarios to examine whether current APEC targets contribute sufficiently to a more secure and sustainable energy sector.

The energy security portion of the chapter presents indicators that can be used to analyse energy security across APEC and developments within each economy under the BAU Scenario, highlighting existing APEC activities. It evaluates the implications of the Alternative Scenarios in terms of energy security and identifies ways to enhance it. The climate change section provides an overview of energy-related CO_2 emissions trends under the BAU Scenario and analyses changes across the Alternative Scenarios. It also gives an overview of and sums up the Intended Nationally Determined Contributions (INDCs) of member economies and evaluates the relative level of ambition across economies and of APEC overall. The results of a combined Improved Efficiency and High Renewables Scenario for APEC are also summarised.

ENERGY SECURITY

The APEC region is home to around 2.8 billion people. In 2012, it represented approximately 57% of world gross domestic product (GDP) and 47% of world trade. Since 1989, the year of APEC inception, the region's GDP doubled from USD 16 trillion to USD 31 trillion in 2013. Over the same period, economic development boosted per-capita income by 45%, lifting millions out of poverty and creating a growing middle class. Secure energy supply underpinned all of these achievements (APEC, 2015).

Energy security has been one of the highest priorities for all governments in APEC, even though the concept is subject to various interpretations and setting a clear definition remains a challenge. The International Energy Agency (IEA) defines energy security as 'the uninterrupted availability of energy sources at an affordable price', which covers many dimensions. Long-term energy security typically addresses the need for timely investments to ensure energy supply in line with economic development goals and sustainable environmental commitments. Short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance.

APEC has not set a specific definition of energy security, but recognises that energy supply disruptions can have negative impacts on economic and social development. In 2001, APEC Leaders endorsed the Energy Security Initiative (ESI) in order to strengthen regional energy security, emphasising longer-term policy responses that address the broad challenges facing the region's energy supply. The initiative focuses on actions that are practical in a policy context and acceptable in a political context (EWG, 2001). Over the years, the ESI evolved and expanded; by 2008, there were 13 ongoing initiatives under the Energy Working Group (EWG), including the Joint Organisations Data Initiative (JODI), the Real-Time Emergency Information Sharing Initiative (RTEIS) and a program for Energy Emergency Responses. In

2014, the Energy Ministerial Meeting (EMM) officially recognised four elements that are vital for energy security and sustainable development in this region: diversified energy supply and stable demand; safe energy transportation routes; innovation in energy technologies; and effective forums to discuss energy policy (APEC, 2014).

Improving access to data through JODI has been a key achievement under the ESI. Recognising that the lack of transparent and reliable oil market data aggravates price volatility, the EMM took steps to address this issue. Six international organisations—APEC, Eurostat, the IEA, OLADE, OPEC and the UNSD[1]—jointly took up the challenge and launched the Joint Oil Data Exercise in 2001. By 2002, the effort had evolved to become JODI-Oil. More than 10 years later, it is now evident that access to timely, accurate and reliable data supports sound and informed decision making in relation to the oil market. JODI-Oil clearly addresses investor uncertainty, contributes to global harmonisation of energy data, and strengthens producer and consumer dialogue, thereby supporting concrete action. In 2012, JODI-Gas was permanently established for greater natural gas data transparency (JODI, 2015).

Physical integration or connectivity of energy flow as a mechanism for energy security in APEC has also been at the top of the agenda for the EMM. Several existing sub-regional power interconnections in APEC, such as the ASEAN Power Grid (APG) and North America interconnections, provide participating economies with more options for securing energy supply.

Recent events in oil and other markets have brought the issue of energy security to the forefront. Volatile prices raise concerns about short-term risks to economic growth and about longer-term ability to acquire sufficient energy to support development goals. While achieving energy security will mean different things to different economies, APEC members share a strong common interest in ensuring sufficient production at reasonable costs to support sustainable use, thereby supporting a high quality of life for citizens.

DEFINING ENERGY SECURITY: AN ONGOING GLOBAL DISCUSSION

Attempts to define energy security have prompted endless discussions among policy makers, intellectuals and industry players, and led to different organisations proposing a range of definitions (Table 9.1).

Table 9.1 • Definitions of energy security

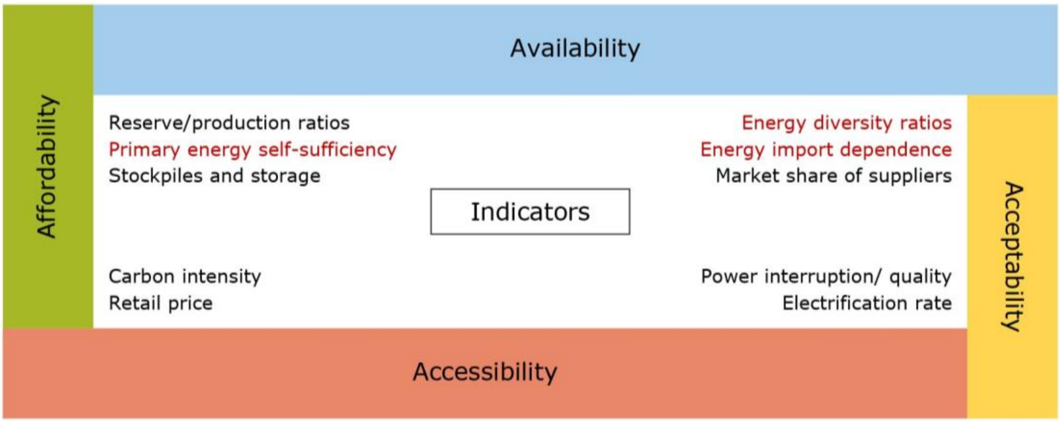
	Definition
International Energy Agency (IEA)	Uninterrupted physical availability of energy at a price that is affordable, while respecting environmental concerns.
Asia Pacific Energy Research Centre (APERC)	Adequate energy supplies at reasonable and stable prices to sustain economic performance and growth. APERC assess energy security in terms of availability, accessibility, acceptability and affordability.
World Bank	Sustainable production and use of energy at reasonable cost in order to facilitate economic growth and improve the quality of people's lives.
United Nations Development Program (UNDP)	Continuous availability of energy in varied forms, in sufficient quantities and at reasonable prices.
Institute of Energy Economics, Japan (IEEJ)	Ability to secure adequate energy at reasonable prices necessary for people's lives, and economic and industrial activities.

Sources: IEA (2011), APERC (2007), World Bank (2005), UNDP (2000) and IEEJ (2012).

Most organisations define energy security as encompassing four common dimensions: availability, affordability, accessibility and acceptability (Figure 9.1).[2] Availability is closely related to diversification of supply while affordability is closely related to the type of fuel chosen and price volatility. In terms of accessibility, infrastructure readiness plays an important role. Acceptability is linked to issues such as retail prices, environmental friendliness and social objectives.

[1] Eurostat is the statistical office of the European Union; IEA is the International Energy Agency; OLADE is the Organizíon Latinoamericana de Energía; OPEC is the Organization of the Petroleum Exporting Countries; and UNSD is the United Nations Statistics Division.
[2] Other indicators can also be explored, such as the effect of world oil price on supply security, the relation of poverty reduction to energy security and other social-energy security relations.

Figure 9.1 • Dimensions of energy security



Notes: This is an non-exhaustive list of indicators. Indicators in red font are those used in this Outlook.
Sources: APERC (2007) and APERC analysis.

In 2007, APERC published A Quest for Energy Security in the 21st Century which focused on the energy security dimensions stated above and included indicators created to assess the situation at that time. For this Outlook, APERC analysed three interrelated factors: primary energy fuel diversification, fuel input diversification for the electricity sector, and self-sufficiency of total primary energy supply (TPES). The latter assesses the level of domestic energy supply security, as measuring energy diversification alone may not provide sufficient insight. APERC's intention in creating the indicators was to support assessment of energy security, not to judge the level of energy security for any particular economy or to compare levels of security among economies. APERC recognises that energy security is unique to each economy.

MEASURING ENERGY SECURITY: INDICATORS APPLIED UNDER THE BAU SCENARIO

Identifying ways to measure energy security is as challenging as establishing a definition—if not more so. In this Outlook, APERC puts forward some simple, straightforward measurements that deliver insightful information for policy and decision making. The index introduced in this chapter draws on available data and can be used to probe the fundamentals of energy supply security in diverse economies.

To adequately consider the diversity of energy characteristics among APEC members, APERC developed two main energy security indices. The first represents fuel diversity in TPES and in fuel input for electricity. The second assesses the level of an economy's energy production self-sufficiency. The logic behind this combination is that some economies have a high concentration of one particular fuel (for primary supply and/or electricity)—i.e. low diversity—but a high level of self-sufficiency for that particular fuel. In such a situation, high self-sufficiency reduces the risk of low diversity. By contrast, some economies have a very diverse fuel supply that is mostly imported, reflecting a lack of indigenous resources.

Fuel diversity: Fossil fuels continue to dominate APEC energy supply

APERC measures fuel diversity by applying the Herfindahl-Hirschman Index (HHI) to assess whether a given economy is particularly dependent on one particular fuel (details on HHI methodology can be found in Annex I). The HHI is widely used in the energy industry as a means of tracking monopolies. In Global Tracking Framework 2013, which was prepared for the UN Sustainable Energy for All (SE4ALL) program, the World Bank uses the HHI to assess levels of primary fuel diversity around the world, including in APEC economies (World Bank, 2013). The HHI can also be applied to projected changes over the Outlook period.

By indexing fuel diversity, economies should be able to identify whether a particular fuel is dominant and, if yes, to what degree. This may prompt action to investigate what other fuel options are available, bearing in mind that a dominant fuel does not necessarily indicate low energy security, but does imply a higher risk for energy supply. An economy that produces enough of a particular fossil fuel to meet energy demand, for example, may face higher risk if a domestic interruption to that supply creates overall supply disruptions.

Using historical data and projections to 2040, APERC created an index based on projected primary fuel production and consumption, which can be used to assess each economy in relation to the level of fuel diversity for TPES (Table 9.2). Results of this energy security analysis can serve indirectly as an indicator for future investment needed. Low levels of self-sufficiency may lead to higher import requirements in the future, suggesting a need to invest in receiving infrastructure, such as regasification terminals for liquefied natural gas (LNG).

Generally, economies with huge energy reserves tend to have a lower level of TPES diversity than economies that need to import most of their energy sources. By 2040, under the BAU Scenario, diversity in five economies that currently sit above 0.30 on the HHI (Brunei Darussalam, Mexico, Peru, Russia and Chinese Taipei) is projected to decline slightly.[3] By contrast, three economies (Japan, Korea and Chile) that import most of their energy supplies show higher diversification. The city-state economies of Hong Kong and Singapore demonstrate slight diversity improvement, even with limited space for different types of fuel extraction and/or storage.

Table 9.2 • Diversity of primary energy supply based on HHI, 2000-40

	2000	2010	2013	2020	2030	2040	Dominant fuel in 2040
Australia	0.33	0.32	0.31	0.29	0.29	0.30	Oil (36%)
Brunei Darussalam	0.65	0.71	0.69	0.68	0.70	0.72	Natural gas (84%)
Canada	0.24	0.24	0.24	0.25	0.28	0.29	Natural gas (40%)
Chile	0.27	0.31	0.28	0.28	0.27	0.26	Oil (37%)
China	0.42	0.48	0.49	0.39	0.35	0.32	Coal (51%)
Hong Kong	0.38	0.37	0.44	0.37	0.34	0.41	Natural gas (56%)
Indonesia	0.31	0.27	0.29	0.27	0.26	0.26	Oil (33%)
Japan	0.32	0.27	0.33	0.28	0.25	0.26	Oil (34%)
Korea	0.36	0.28	0.27	0.26	0.25	0.24	Oil (28%)
Malaysia	0.40	0.33	0.34	0.31	0.30	0.30	Natural gas (39%)
Mexico	0.44	0.39	0.38	0.38	0.39	0.39	Natural gas (50%)
New Zealand	0.25	0.25	0.25	0.27	0.28	0.29	Renewables (48%)
Papua New Guinea	0.67	0.56	0.62	0.46	0.38	0.38	Oil (48%)
Peru	0.42	0.29	0.31	0.36	0.39	0.39	Oil (52%)
The Philippines	0.38	0.30	0.29	0.29	0.30	0.30	Coal (38%)
Russia	0.35	0.38	0.37	0.36	0.37	0.38	Natural gas (56%)
Singapore	0.87	0.56	0.51	0.51	0.50	0.50	Oil (59%)
Chinese Taipei	0.35	0.32	0.31	0.33	0.34	0.33	Coal (40%)
Thailand	0.31	0.28	0.29	0.29	0.29	0.29	Oil (40%)
United States	0.27	0.26	0.26	0.26	0.27	0.31	Natural gas (43%)
Viet Nam	0.34	0.25	0.23	0.27	0.28	0.33	Coal (47%)
APEC	**0.25**	**0.26**	**0.27**	**0.25**	**0.25**	**0.24**	**Coal (31%)**

Notes: Energy sources considered in the primary energy mix are natural gas, oil and oil products, coal, hydropower, other renewables and nuclear. Higher index values indicate lower diversity in the primary energy mix and, therefore, increased vulnerability to changes.
Sources: APERC analysis and IEA (2015b).

New Zealand is the only economy in which renewables become the dominant fuel—making up 48% of TPES by 2040. With this high reliance on renewable energy, the level of fuel diversity in New Zealand is

[3] This does not suggest that these economies are less secure in their energy supply; compared with net energy importer economies, they have a higher index, which indicates less diversity (although the differences can be small).

projected to be on par with that of net energy producer economies. While promoting renewables as a source of energy is vital to mitigating emissions, it does not necessarily translate into a more diverse energy supply. Some forms of renewable energy depend heavily on local environmental factors such as the amount of rain or sunshine. Still, renewable energy that is produced domestically can help economies shield themselves from other supply risks, such as over-dependence on energy imports and fluctuating fuel prices.

The measure of diversity for electricity generation input fuels established by APERC follows the same principal as the primary energy supply index (Table 9.3). It does not establish the level of electricity supply security, but serves as an indicator and reference that policy makers can use to plan for development of future plants. The Malaysian government, for example, adopted a target of bringing the HHI to below 0.5 for electricity fuel supply mix (EPU, 2015). Future development of new generation plants in Malaysia must contribute to this target, which will help to prevent any fuel from becoming dominant in the input mix.

Viet Nam shows a deterioration of fuel supply diversity over the Outlook period, reflected in a rise of HHI measure from a low of 0.23 in 2013 to 0.33 in 2040. This is due to overreliance on coal, which is expected to supply 47% of primary energy shares as electricity demand increases rapidly. The effect is magnified when the assessment is narrowed to diversity in electricity generation input fuel mix, in which coal contributes 71%. The HHI measure in Viet Nam's power generation mix deteriorates from 0.31 in 2013 to 0.53 in 2040.

Table 9.3 • Diversity of electricity generation input fuel based on HHI, 2000-40

	2000	2010	2013	2020	2030	2040	Dominant input fuel in 2040
Australia	0.77	0.67	0.58	0.52	0.44	0.37	Coal (47%)
Brunei Darussalam	0.99	0.98	0.98	0.97	0.97	0.98	Natural gas (99%)
Canada	0.28	0.26	0.26	0.29	0.28	0.28	Renewables (47%)
Chile	0.29	0.29	0.28	0.30	0.35	0.39	Coal (56%)
China	0.79	0.76	0.73	0.57	0.51	0.45	Coal (65%)
Hong Kong	0.53	0.55	0.69	0.58	0.50	0.60	Natural gas (73%)
Indonesia	0.25	0.27	0.31	0.36	0.37	0.38	Coal (50%)
Japan	0.26	0.25	0.30	0.25	0.25	0.28	Coal (37%)
Korea	0.38	0.37	0.33	0.35	0.35	0.34	Coal (41%)
Malaysia	0.65	0.46	0.44	0.43	0.42	0.42	Coal (51%)
Mexico	0.30	0.29	0.34	0.47	0.55	0.56	Natural gas (73%)
New Zealand	0.31	0.35	0.36	0.42	0.46	0.49	Renewables (85%)
Papua New Guinea	1.00	0.36	0.39	0.30	0.40	0.56	Natural gas (72%)
Peru	0.41	0.37	0.37	0.46	0.51	0.54	Natural gas (68%)
The Philippines	0.43	0.32	0.33	0.37	0.44	0.49	Coal (66%)
Russia	0.55	0.57	0.41	0.40	0.41	0.42	Natural gas (59%)
Singapore	0.71	0.53	0.72	0.82	0.88	0.88	Natural gas (94%)
Chinese Taipei	0.31	0.33	0.35	0.43	0.49	0.46	Coal (60%)
Thailand	0.45	0.53	0.46	0.41	0.39	0.39	Natural gas (50%)
United States	0.39	0.36	0.31	0.29	0.28	0.33	Natural gas (49%)
Viet Nam	0.25	0.35	0.31	0.40	0.40	0.53	Coal (71%)
APEC	**0.34**	**0.38**	**0.36**	**0.33**	**0.32**	**0.31**	**Coal (47%)**

Notes: Energy sources considered in the electricity generation input fuel are natural gas, oil and oil products, coal, hydropower, other renewables and nuclear. Higher index values indicate lower diversity in the electricity generation input fuel mix and, therefore, increased vulnerability to changes.
Sources: APERC analysis and IEA (2015b).

With the exceptions of Japan and Korea, by 2040 all APEC economies show dependencies of nearly 50% in one particular fuel input for power generation (Table 9.3). Brunei Darussalam and Singapore will be highly dependent on natural gas (both at above 90%); renewables will be a major fuel input for electricity generation in Canada (47%) and New Zealand (85%). Still, APEC as a region will rely heavily on coal as the dominant fuel input for electricity generation with a share of 47% in 2040 (a decrease from 54% in 2013).

This focus on input fuel shares (rather than power mix or output shares) is important, as it determines the volume of fuel that needs to be secured (especially natural gas and coal) in the power mix prior to transformation (in this case, for electricity generation). Thus, the diversity (HHI) levels will differ with shares of power mix, particularly when hydropower accounts for significant shares. In evaluating Chile's power mix, for example, an efficiency of 100% is applied for hydropower while average coal power plant efficiency is 40%. From a power mix or output shares perspective, by 2040 hydropower, with only a 10% share in fuel input, will deliver 21% of generated electricity while other renewables show the opposite trend: the input fuel share stands at 23% while the share in the power mix is 22% in 2040.

Self-sufficiency declines as energy imports rise in most APEC economies

APERC also assessed the energy security of APEC members based on projections of primary energy production over primary energy demand. This reveals the level of self-sufficiency of an economy and the overall import level needed to sustain adequate supply to meet demand. The assessment also makes it possible to examine the level of risk exposure linked to factors such as geopolitical issues and trading route choke points, among others. For this Outlook, APERC did not pursue an in-depth assessment of primary energy supply self-sufficiency. It does, however, strongly recommend that another, separate study be undertaken to develop a more comprehensive picture of the external factors that will affect energy imports. (Volume II of this Outlook provides, in each economy chapter, a more detailed assessment of self-sufficiency for each fossil fuel, within the energy security sub-section.)

Table 9.4 • Self-sufficiency of primary energy supply, 2000-40 (%)

	2000	2010	2013	2020	2030	2040
Australia	100	87	80	77	72	69
Brunei Darussalam	100	100	100	100	100	100
Canada	100	100	100	100	100	100
Chile	34	30	39	33	31	29
China	95	89	85	77	77	77
Hong Kong	0	1	1	1	1	1
Indonesia	100	90	84	78	70	64
Japan	20	20	6	15	19	14
Korea	18	18	16	20	22	23
Malaysia	96	82	84	75	67	57
Mexico	97	92	86	89	92	98
New Zealand	78	81	77	77	77	78
Papua New Guinea	100	70	52	58	47	53
Peru	77	90	73	89	70	67
The Philippines	49	59	55	55	43	37
Russia	100	100	100	100	100	100
Singapore	1	2	6	2	2	2
Chinese Taipei	14	12	12	10	4	5
Thailand	61	60	59	41	33	27
United States	73	76	84	92	93	93
Viet Nam	100	96	100	74	53	33
APEC	**88**	**92**	**93**	**93**	**93**	**92**

Sources: APERC analysis and IEA (2015b)

Energy self-sufficiency under the BAU improves in some economies, such as the United States and Mexico. Others, including Brunei Darussalam, Canada and Russia, will maintain a self-sufficiency level of 100% (Table 9.4). Most economies, however, show decreasing self-sufficiency for the next few decades due to increasing demand in the face of depleting resources. APERC analysis finds that nearly half of APEC members will have self-sufficiency levels below 60% by 2040. Most traditional energy exporters will continue to have surplus to put on the market. A few economies show a decline from current levels of self-sufficiency.

Japan and Korea show some improvement in primary energy supply self-sufficiency, reflecting an increase of nuclear energy shares. In the case of Japan, the nuclear share in primary energy rises from 1% in 2013 to 11% in 2030, then falls back down to 5% in 2040 (partially reflecting reopening of plants closed following the Fukushima accident). In Korea, the nuclear share rises from 14% in 2013 to 19% in 2040. Some economies, by contrast, show a sharp reduction in self-sufficiency. Malaysia's self-sufficiency, which was previously quite high at 84% in 2013, drops to 57% in 2040; Viet Nam's self-sufficiency shows an even sharper reduction, from 100% in 2013 to 33% in 2040.

Box 9.1 ● APEC Oil and Gas Security Initiatives (OGSI)

To enhance regional collaboration in support of energy security, the APEC Oil and Gas Security Initiative (OGSI) was launched in late 2014. The initiative covers three areas: the Oil & Gas Security Exercise (OGSE), which is carried out on a voluntary basis; the Oil & Gas Security Network (OGSN), led by officials in charge of oil and gas security policy; and the Oil & Gas Security Studies (OGSS), which undertake research on topics related to oil and gas security in the APEC region.

The initiative has three key objectives: to provide vital information on global developments and issues on oil and gas security; to share experiences and insights on the challenges confronting economies relating to oil and gas security and supply emergency threats; and to perform the Oil and Gas Security Exercise model procedure as a guiding framework for response to different emergency supply scenarios.

The outputs of these activities are beneficial to policy makers, government officials/agencies, and other stakeholders (e.g. local government units and industry players) involved in energy security. They can be used to craft and design necessary policies, plans, programs, measures and structures, and to put in place critical infrastructure so economies can manage emergency supply situations.

The main objectives of OGSE are to: investigate domestic systems for emergency preparedness in each APEC economy; develop possible scenarios of oil and gas emergency situations; and accumulate the necessary information and analysis by mobilising capable experts in the APEC region. With these objectives in mind, APERC has successfully conducted two APEC Oil and Gas Security Forums (which served as the kick-off and wrap-up meetings) and two Case Study Exercises (the Joint South-East Asian Exercise and the Indonesia Exercise) (APERC, 2014).

The comments and recommendations given by the experts in each exercise can help APEC economies to improve their oil and gas emergency preparedness, and can be adopted as part of broader emergency mitigation measures. APERC has prepared the Oil and Gas Security Exercise Model Procedure (EMP) to guide economies that plan to voluntarily undertake the exercise, which can be found online at: http://aperc.ieej.or.jp/file/2015/12/4/Oil_and_Gas_Security_Exercise_Model_Procedure.pdf/.

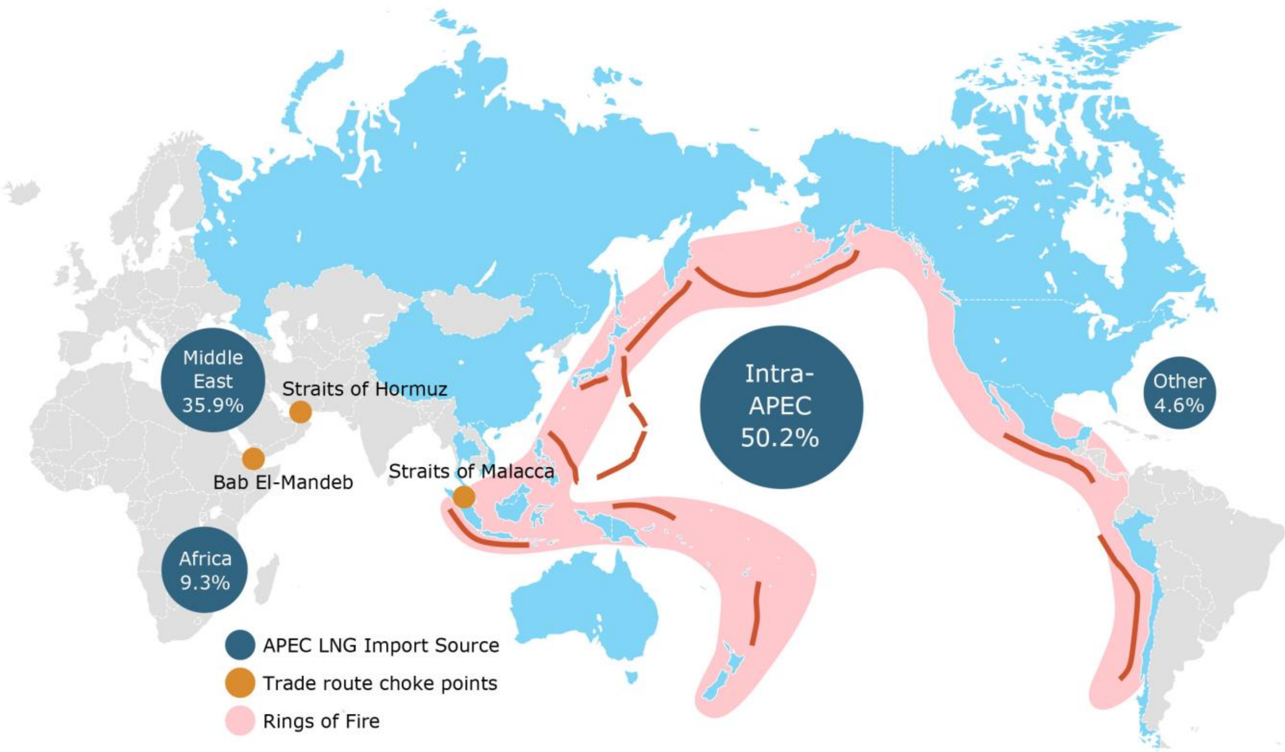
Despite showing lower levels of self-sufficiency individually and collectively, cooperation among APEC members can help to mitigate energy supply disruptions in the future. The APEC Oil and Gas Security Initiatives (OGSI) is an example of the type of measure APEC members can take to boost energy supply security (Box 9.1). This initiative (approved as an APEC self-funded project in EWG 48 in November 2014 in Port Moresby, Papua New Guinea) covers three areas: the Oil & Gas Security Exercise (OGSE), the Oil & Gas Security Network (OGSN) and Oil & Gas Security Studies (OGSS). The OGSI recommends taking steps to strengthen the energy system, which is pertinent for readiness in emergency situations. Conducting an emergency exercise is one way to test system resiliency.

Diversifying energy import sources and increasing inter-APEC energy trade can improve energy security

Under the BAU Scenario, fossil fuels remain the dominant energy source through to 2040, with an 83% share of TPES being only a slight dip from 86% in 2013. To boost energy supply security under this level of single-source dominance, APEC members can pursue regional cooperation and integration. Both objectives can be achieved in many ways, such as: physical connections through electric transmission lines or pipelines; collaboration among exporters and importers (for example, through seminars and dialogue); and improving trade ties among APEC members.

A major share of energy imported to APEC comes from economies in the Middle East and North Africa, meaning most tankers need to go through a few straits and canals (such as the Suez Canal and the Straits of Malacca) that are considered trade route choke points. Congestion on these limited routes creates higher supply risks for importers. In 2014, nearly half of APEC LNG imports came from outside the region, requiring transit through such choke points (Figure 9.2).

Figure 9.2 • LNG delivery routes among APEC economies, 2014



Notes: In addition to geopolitical challenges along energy transport routes, the APEC region sits on the Pacific 'Ring of Fire', a string of volcanoes and sites of seismic activity (earthquakes) around the edges of the Pacific Ocean. Roughly 90% of all earthquakes occur along the Ring of Fire, and the ring is dotted with 75% of all active volcanoes on Earth. APEC demand for oil and natural gas significantly exceeds internal production, making the region dependent on imports and thus exposed to supply disruptions caused by natural disasters or geopolitical conflicts.

Sources: BP (2015), National Geographic (2015) and APERC analysis.

As highlighted in the chapter on BAU Primary Energy Supply, the APEC region is projected to be able to meet nearly 92% of its gas demand in 2040 (a slight decline from 100% in 2013). APEC could explore the possibility of increasing gas trade among its members to help secure gas supplies. This approach could serve an overarching, two-pronged objective: increasing intra-APEC trade value and reducing the risk of supply disruptions. It must be borne in mind, however, that higher levels of uncertainty in energy supply will translate into higher costs (e.g. for cargo rerouting or insurance). Despite LNG markets becoming more flexible with increasing numbers of suppliers and consumers, encouraging more energy trade among APEC members would give energy-importing economies the advantage of bypassing routes considered to be hot spots and categorised as high-risk in insurance rates. At the same time, LNG producers could benefit from improved predictability and stability of demand from buyers within the APEC network.

IMPLICATIONS OF THE ALTERNATIVE SCENARIOS FOR ENERGY SECURITY

Alternative scenarios boost APEC energy security

Using the same indicators as in the BAU Scenario, APERC assessed the energy security outcomes of the three alternative scenarios that form the basis of this Outlook: the Improved Efficiency Scenario, the High Renewables Scenario and the Alternative Power Mix Scenario (including the Cleaner Coal, High Nuclear, High Gas 50% and High Gas 100% Cases). All three scenarios show improvement in both diversity of primary energy supply and electricity input fuel mix, and in supply self-sufficiency, suggesting overall security gains for APEC as a whole if any of the alternative scenarios were implemented (Table 9.5). The impact for each economy is covered in Volume II of this Outlook.

Table 9.5 • Energy security indicators in the BAU and alternative scenarios by Case, 2040

	BAU	Improved Efficiency	High Renewables	Cleaner Coal	High Nuclear	High Gas 50%	High Gas 100%
Primary energy supply diversity (HHI)	0.24	0.23	0.23	0.24	0.23	0.24	0.24
Primary energy supply self-sufficiency (%)	92	95	94	92	94	88	85
Coal self-sufficiency (%)	100	100	100	100	100	100	100
Oil self-sufficiency (%)	75	80	76	75	76	75	75
Gas self-sufficiency (%)	92	100	92	92	93	83	75
Input fuel for electricity generation diversity (HHI)	0.31	0.28	0.27	0.31	0.28	0.29	0.29

Legend: Largest gains | Improvement | Unchanged | Deterioration

Notes: The energy sources considered in the primary energy mix are natural gas, oil and oil products, coal, hydropower, other renewables and nuclear. Higher index values indicate lower diversity in primary energy mix and, therefore, increased vulnerability to changes. Fossil fuels production in alternative scenarios were estimated based on the primary energy demand in each scenario in order to avoid oversupply in production.
Source: APERC analysis.

APERC analysis shows all alternative scenarios boosting energy security, but to different degrees. Compared with the BAU, diversity of primary energy supply in the High Renewables Scenario shows a slight improvement in 2040, from 0.24 under the BAU to 0.23 due to higher shares of renewable energy, while self-sufficiency also improves. Across all scenarios and cases, the Improved Efficiency Scenario shows a better primary energy supply diversity and higher self-sufficiency; the High Nuclear Case and the High Renewables Scenario show the next highest levels on both measures.

Under the BAU Scenario, primary energy supply self-sufficiency decreases from 93% in 2013 to 92% in 2040; in contrast, the Improved Efficiency and High Renewables Scenarios, as well as the High Nuclear Case, all show some improvement. Higher reliance on gas causes APEC's overall self-sufficiency to deteriorate under both High Gas Cases, from 93% in 2013 to 88% in the High Gas 50% Case and to 85% in the High Gas 100% Case. Given that APEC has one of the highest volumes of oil imports globally, the Improved Efficiency Scenario delivers higher diversity by reducing the level of oil and gas imports compared with other scenarios.

OVERCOMING ENERGY SECURITY CHALLENGES

APEC economies can apply various approaches to overcome the energy security challenges identified above. They first need to examine the domestic energy demand requirement and available supply options. Economies that hold huge energy reserves will face different challenges than those that are highly dependent on energy imports; moreover, the degree of the challenges is likely to differ among economies in either situation. What is clear is that considerable opportunity exists for APEC members to reduce the risk of energy supply disruptions through collaboration and cooperation.

Regional cooperation can boost energy security

To make informed decisions on future energy security matters, APEC Leaders need access to sufficient data. This need for solid data collection prompted six organisations (APEC, IEA, OLADE, OPEC, Eurostat and UNSD) to initiate the Joint Oil Data Exercise in 2001, the success of which led to the permanent reporting mechanism known as JODI. While JODI initially targeted oil data collection, in 2012 it was expanded to include gas data collection.

To foster closer collaboration among APEC members, the APEC EWG has set up a number of expert groups that create platforms to exchange knowledge and information and present best practices. These groups keep APEC members focused on activities that potentially help to diversify energy sources and thus improve energy security. The four expert groups currently operating are:

- **The Expert Group on New and Renewable Energy Technologies (EGNRET)** is the main cluster to promote greater use of renewable energy in APEC. Established in 2012, EGNRET is considered one of the best platforms in APEC for sharing knowledge and best practices on new and renewable energy technologies. Among notable achievements are the APEC Low Carbon Model Town, which aims to refine the 'Concept of the Low-Carbon Town' and promote effective approaches for reducing CO_2 emissions. A second notable activity is the APEC Biofuels Task Force, a platform that pushes biofuel use to diversify the transport fuel mix. The group has also launched smart grid utilisation programs (EGNRET, 2015).

- **The Expert Group on Energy Efficiency and Conservation (EGEE&C)** promotes energy conservation and the application of energy efficiency practices and technologies by developing and enhancing trade of products and services among APEC economies. Notable achievements of this group include the Vehicle Fuel Efficiency Labelling (VFEL) program, which evaluates vehicle labelling schemes in APEC and enables economies to improve or set up their own schemes based on best practice. Another achievement is the Nearly (Net) Zero Energy Building Initiative (which shares findings on the latest policies, codes and standards for energy-efficient buildings) (EGEE&C, 2015).

- **The Expert Group on Clean Fossil Energy (EGCFE)** has a mission to encourage the use of technologies that reduce emissions associated with fossil fuels; these efforts contribute to both sound economic performance and the achievement of high environmental standards. This group has carried out multiple studies on reducing energy subsidies, produced the APEC Unconventional Natural Gas Census Report, and investigated CO_2 emissions mitigation technologies, such as CCS and clean coal technologies (EGCFE, 2015).

- **The Expert Group on Energy Data and Analysis (EGEDA)** is responsible for providing policy-relevant energy information to APEC bodies and the wider community, largely through the collection of energy data. It played a role in the establishment of JODI (EGEDA, 2015).

These efforts to cooperate and collaborate improve information and experience exchange among APEC members, and help to build the trust needed to tackle other matters, such as energy security. Initiating activities to boost renewable energy and energy efficiency will help APEC members broaden the range of fuels that can contribute to diversifying supply and reducing import dependency. Access to transparent and timely data enables informed decision making, including choosing cleaner energy technologies that can help reduce fossil fuel consumption in the long term.

Strategic investment can enhance energy security

As demonstrated in this chapter, the Improved Efficiency and High Renewables Scenarios resulted in better energy security projections than the BAU or the various cases in the Alternative Power Mix Scenario (with the exception of the High Nuclear Case, another low-carbon option). As investing in these two areas—energy efficiency and renewable energy—will clearly enhance energy security, APEC economies should formulate policies to incentivise public and private sector investment in green technologies that are more efficient and optimise renewable energy. Though the High Nuclear Case shows improvement in all aspects of energy security, implementing it would be challenging to most economies, especially to new entrants in the nuclear energy sector; launching nuclear programs requires a high degree of political will and strong public approval.

The scenarios explored show that APEC remains dependent on fossil fuels over the Outlook period. Thus, it is important to direct investment towards cleaner options, whether it be preferring extraction and use of unconventional gas over coal or oil, or deploying technologies that reduce emissions (such as CCS). Besides investment in physical infrastructure, soft investment is needed for training and developing energy managers, and undertaking public communication to educate people on green energy.

CLIMATE CHANGE

The impacts the energy sector has on environmental sustainability and climate change are well-documented. Unabated use of fossil fuels has caused CO_2 and other greenhouse gas (GHG) emissions to rise sharply over the past century, resulting in irreversible climate change impacts. Many APEC economies have already experienced first-hand the effects of climate change, with the increasing frequency and severity of natural disasters (including droughts, flooding and forest fires), extreme temperatures (heat waves and polar vortex), and increased intensity of storms.

These events create major challenges for existing energy systems, threatening system integrity and robustness. As impacts of climate change continue to increase in frequency and severity, future energy systems need to be built to be more resilient. Additionally, economies need to be better prepared to react to emergency energy situations, including oil and gas supply disruptions, loss of refinery capacity, power outages and shortages, and network disruptions. Making energy systems more resilient will require greater attention to their complexity.

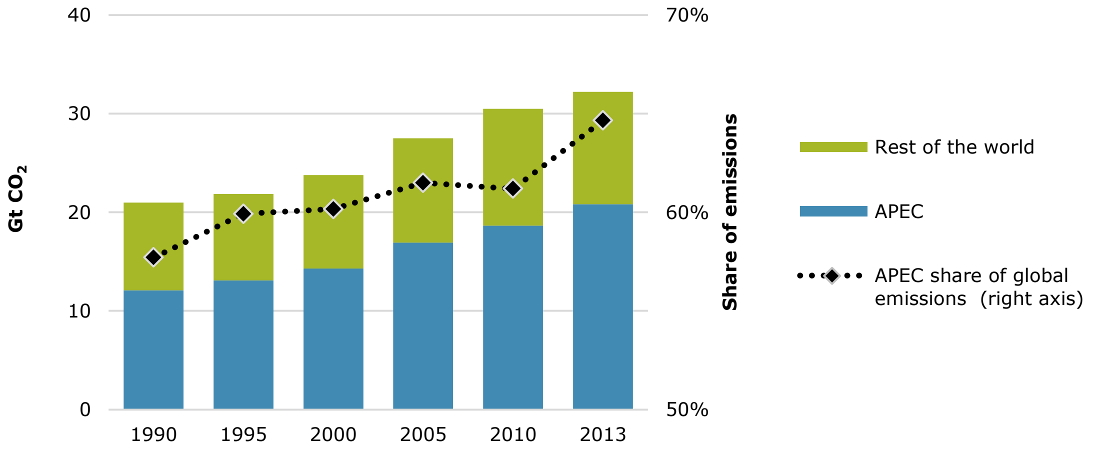
Moreover, if the ambition of a global low-carbon economy is to be achieved, a major transition in the energy sector will be needed. The energy sector accounts for about two-thirds of all man-made emissions, making it the largest contributor. Deep cuts in GHG emissions are required to achieve the goal of limiting the long-term temperature increase to less than 2°C, as agreed in 2010 at the 16th Conference of the Parties (COP 16) of the United Nations Framework Convention on Climate Change (UNFCCC) in Cancun, Mexico. Achieving this ambitious goal will require a halving (at least) of energy-related CO_2 emissions by 2050 compared with 2013 levels (IEA, 2015a).

APEC Energy Ministers have recognised the impacts climate change is having on the resiliency of energy systems, and the need to take appropriate measures to minimise such impacts. In 2012, as part of the St. Petersburg Energy Ministerial Declaration, APEC Energy Ministers stated that 'a cleaner energy supply continues to be a priority to boost both sustainable development and energy security while adjusting to climate change'. APEC's two energy goals, of reducing energy intensity by 45% in 2035 compared with 2005 levels and doubling the share of renewables by 2030 compared with 2010 levels, are central to efforts to improve both energy security and reduce the impacts of climate change.

APEC EMISSIONS: RECENT TRENDS AND OUTLOOK IN THE BAU SCENARIO

Since 1990, APEC's energy-related CO_2 emissions have risen 72%, reaching 20.3 gigatonnes of carbon dioxide ($GtCO_2$) in 2013. Much of the rapid economic development in many APEC economies has been fuelled by coal, which has the highest emissions rate among fossil fuels and is known to be an environmentally unsustainable energy source. APEC's share of global energy-related emissions reached 64% in 2013, from 58% in 1990 (Figure 9.3). Accounting for a majority share highlights the importance of APEC action in combating global climate change.

Figure 9.3 • CO_2 emissions from fuel combustion, 1990-2013

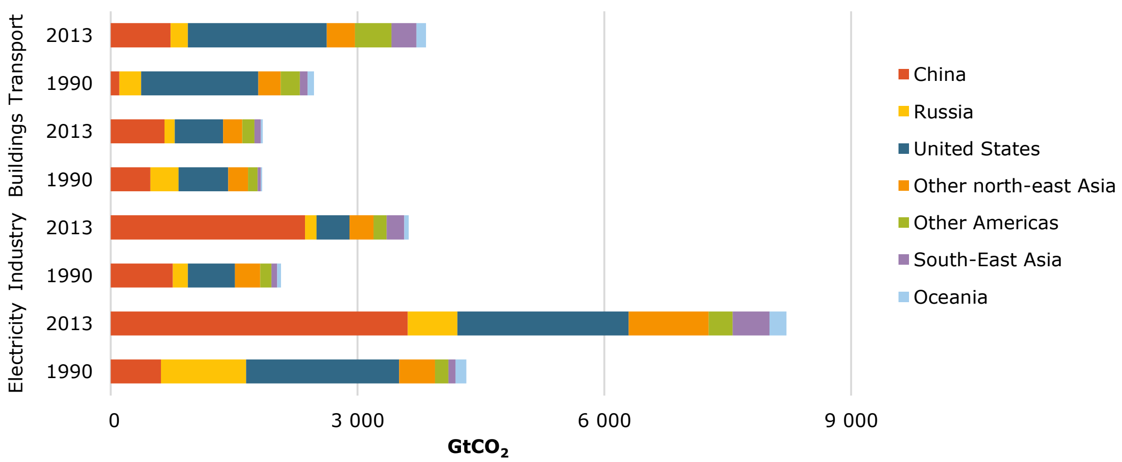


Sources: APERC analysis and IEA (2015a).

China's electricity sector emissions drive up total APEC emissions

China's power sector, to which 770 gigawatts (GW) of coal-fired capacity was added between 1990 and 2013, is the single largest contributor to APEC emissions (Figure 9.4). But China does not shoulder all of the increase: rapid growth in electricity consumption in the buildings and industry sectors across all economies led to sharp increases in emissions. The exception is Russia, where emissions declined in line with a sharp reduction in industrial activity following the breakup of the Soviet Union. The shutdown of all nuclear plants in Japan following the Great East Japan Earthquake in 2011 pushed up electricity sector emissions in other north-east Asia, which more than doubled between 1990 and 2013.

Figure 9.4 • Energy-related CO_2 emissions by sector, 1990 and 2013



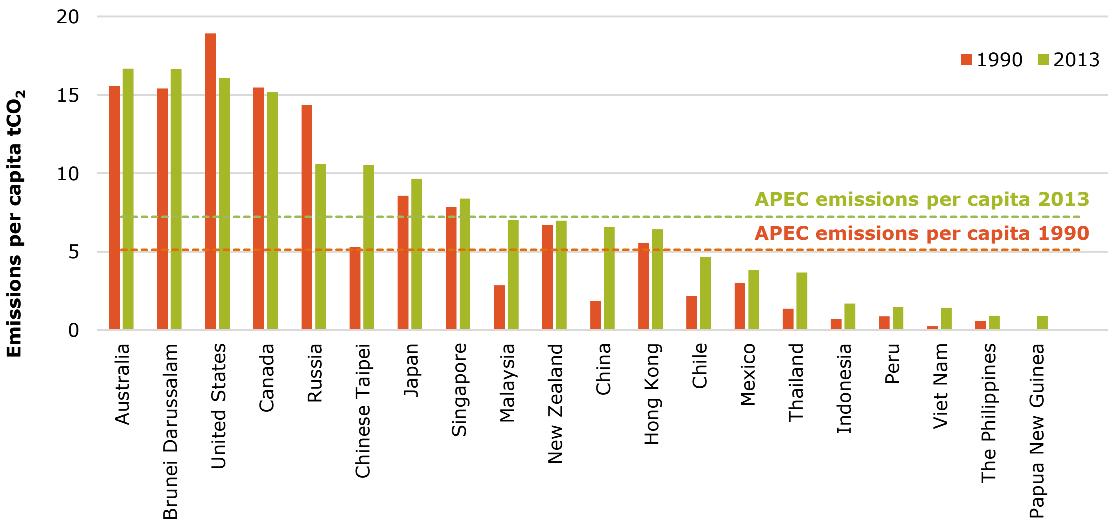
Sources: APERC analysis and IEA (2015b).

All sectors exhibited an increase in emissions between 1990 and 2013, with the exception of buildings. Efficiency improvements in the United States and other north-east Asia, coupled with a sharp reduction in energy use in Russia, helped overall emissions in the buildings sector remain flat. In terms of direct emissions, transport represented the second-largest sectoral emissions (after electricity generation) reaching 3.9 $GtCO_2$ in 2013. In terms of growth in direct emissions, a 75% increase pushed industry into second place (behind electricity generation).

Emissions per capita rising in APEC

Since 1990, emissions per capita in most APEC economies have grown significantly, following an anticipated increase associated with economic development and rising income levels sharply driving up energy demand. Only Russia, the United States and Canada, all of which were among the top four per-capita emitters in 1990, show a decline in this measure (Figure 9.5). The three economies (Viet Nam, China and Thailand) with the largest increases in per-capita emissions over this period were among the least carbon-intensive economies at the start; all three still reported 2013 per-capita emissions well below the APEC average.

Figure 9.5 • CO_2 emissions per capita, 1990 and 2013



Note: Data for Papua New Guinea is not available for 1990.
Sources: APERC analysis, IEA (2015b) and UNDESA (2015).

In 2013, emissions per capita across the APEC region ranged from as low as 0.9 tCO_2 in Papua New Guinea to 17 tCO_2 in Australia and Brunei Darussalam, with an APEC average of 7.2 tCO_2. As many APEC economies continue to develop, per-capita emissions are set to rise. Economies that already have high per-capita emissions will need to reduce their carbon footprint to counteract the overall impact of rising emissions in developing economies. The debate on what constitutes equitable distribution of emissions and emissions reduction is beyond the scope of this analysis, but it is clear that larger reductions will be needed from economies that are currently among the most carbon-intensive.

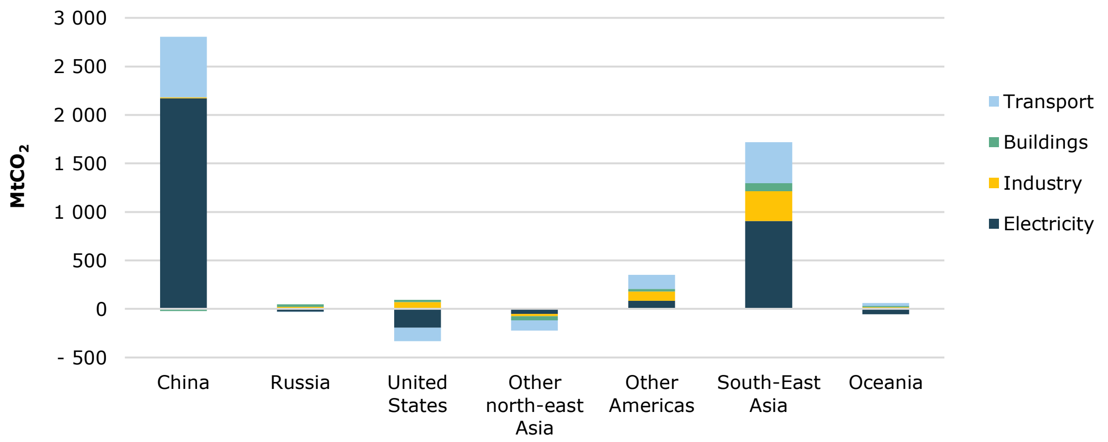
Electricity to remain largest source of sectoral emissions in APEC

Energy-related emissions under the BAU reach 25.3 $GtCO_2$ in 2040, an increase of 24% over 2013 levels, the result of high energy demand and growing reliance on coal-fired power in many APEC economies. The power sector contributes the largest share (64%) of the increase in APEC emissions as over 670 GW of net additional coal-fired and 800 GW of net additional gas-fired capacity are added between 2013 and 2040.

As vehicle ownership rises in line with higher income levels, the number of vehicles in the APEC region increases by 610 million between 2013 and 2040, pushing transport-related emissions up by nearly 1 $GtCO_2$ by 2040 and making transport the second-fastest growing emitter (Figure 9.6). China and South-East Asia show the largest increases in transport emissions as their combined vehicle stock increases by

453 million by 2040. But the trend is not universal: while APEC transport emissions rise overall, many regions (including the United States, other north-east Asia and Russia) show a reduction thanks to fuel economy improvements and the introduction of advanced vehicles.

Figure 9.6 • Changes in energy-related CO_2 emissions, 2013-40



Sources: APERC analysis and IEA (2015b).

Historically, industry showed the second-largest increases in emissions growth in China and South-East Asia (behind the power sector); over the next decade, an expected peaking in demand for steel and cement will help control future growth in industry-related emissions. Emissions continue to rise in all sectors in South-East Asia as industrialisation and economic development are at much earlier stages in these economies. In fact, emissions growth to 2040 in South-East Asia (+160%) is higher than that of China (+34%), indicating the need for greater effort to help control the overall growth in emissions. Alternatives to coal-fired power and fuel economy standards are two of the most important measures for economies in the region to pursue.

The United States and other north-east Asia are the only two regions in which overall energy-related emissions decline. The ongoing switch from coal- to gas-fired power generation and rapid uptake of renewable power, coupled with improvements in fuel economy, cause US emissions to decline 3% by 2040 compared with 2013. In other north-east Asia, slowing economic growth, a declining population and energy efficiency efforts (particularly in Japan and Hong Kong) help to reduce emissions by 12% over 2013 levels.

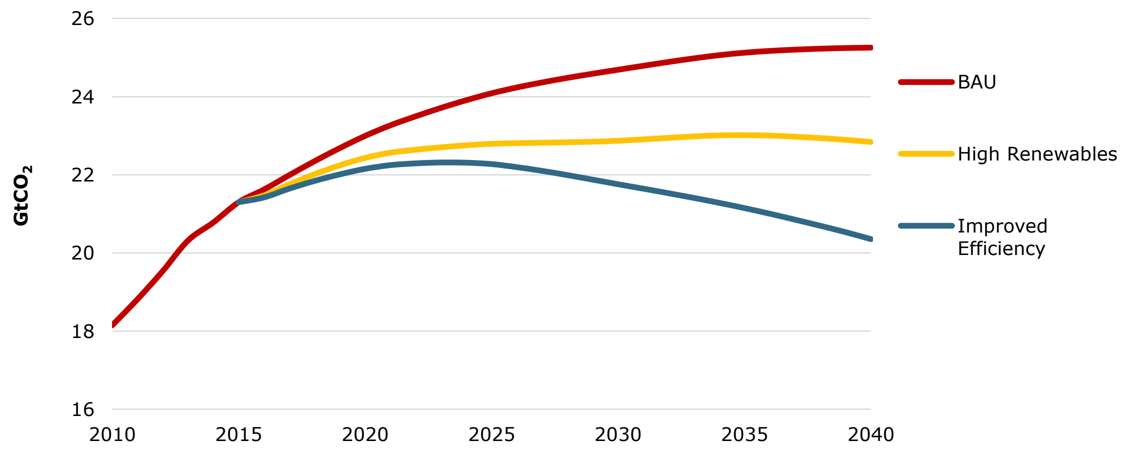
As the sector with the fastest-growing emissions, urgent action is needed to support decarbonisation of the power sector in APEC, particularly in Asia where coal remains the preferred source given its relative abundance and low cost. Early transition away from coal will have long-lasting benefits, particularly avoiding the 'lock-in' associated with the long (40+ years) lifespan of coal-fired plants. Energy efficiency and conservation efforts also need to be prioritised, as lower energy demand will help to reduce the need for new power plants.

EMISSIONS REDUCTION UNDER THE ALTERNATIVE SCENARIOS

The alternative scenarios assessed by APERC show the opportunity to stem the growth of emissions in APEC. Under the High Renewables Scenario, CO_2 emissions continue to grow, reaching 23 $GtCO_2$ in 2035 and declining afterwards to 22.8 $GtCO_2$ in 2040, a 10% savings compared with the BAU and an increase of only 12% from 2013 levels (Figure 9.7). While doubling the share of renewables in APEC can help to control the overall growth of emissions, the net addition of new coal-fired (500 GW) and gas-fired (560 GW) capacity means emissions continue to rise under the High Renewables Scenario.

With higher shares of renewable electricity generation, the High Renewables Scenario causes the average CO_2 intensity of the power sector in 2040 to drop 19% compared with the BAU. Actual carbon intensity in 2040 is 369 grams per kilowatt hour (gCO_2/kWh), a noteworthy decline from 556 gCO_2/kWh in 2013. This improvement, however, is insufficient to offset the sharp increase in electricity demand, which rises 65% over the Outlook period.

Figure 9.7 • Energy-related CO_2 emissions in the BAU, Improved Efficiency and High Renewables Scenarios, 2010-40



Sources: APERC analysis and IEA (2015b).

Under the Improved Efficiency Scenario, CO_2 emissions peak in 2023 and then decline to 20.4 $GtCO_2$ in 2040, a reduction of 19% compared with the BAU level and in line with 2013 emissions of 20.4 $GtCO_2$. By reducing demand for additional energy, including the need for new electricity generation capacity, enhanced energy efficiency efforts clearly have the largest impact on reducing overall emissions.

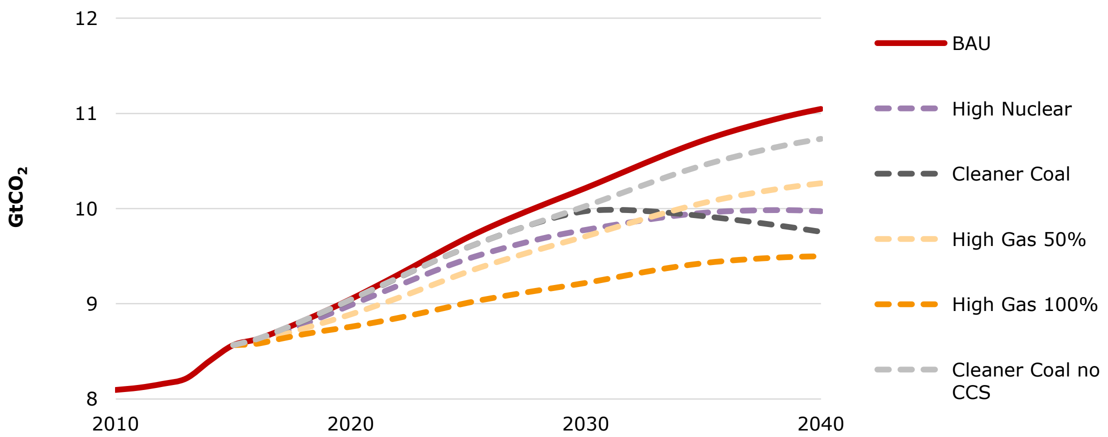
While efficiency alone can maintain emissions at current levels, neither scenario results in an overall reduction. This highlights the need to pursue a combined strategy of energy efficiency improvements and measures to decarbonise energy supply. Pursuing even higher shares of renewables must be combined with other measures to decarbonise emissions from energy supply, including a switch to lower-carbon fossil fuels (i.e. from coal or oil to gas), the deployment of nuclear energy and the development of CCS.

Importance of decarbonising the power sector

The Alternative Power Mix Scenario evaluates the trade-offs among cleaner coal, nuclear and gas as options for reducing emissions in the power sector. Replacing all new coal-fired plants with gas, as in the High Gas 100% Case, results in the lowest emissions of 9.5 $GtCO_2$ by 2040, 14% below the BAU levels (Figure 9.8). Over the longer term, however, emissions would continue to rise as electricity production grows. Increasing the share of nuclear generation, as in the High Nuclear Case, leads APEC emissions to peak around 2038; as higher amounts of new nuclear capacity are added post-2030, emissions begin to decline, falling to 10 $GtCO_2$ in 2040, a savings of 10% over the BAU.

With the deployment of CCS on all new coal-fired plants from 2030, emissions peak in the Cleaner Coal Case and decline after 2030 as CCS helps to reduce the average intensity of coal-fired plants. Deployment of CCS delivers a reduction of 12% to total emissions compared with the BAU; without CCS, total emissions fall just 3%. In the longer term, the adoption of CCS on new coal-fired capacity with high efficiency could lead to even lower emissions than replacing all new coal plants with gas. With CCS, the average intensity of a coal-fired plant (85 gCO_2/kWh) is four times lower than that of a gas-fired plant (410 gCO_2/kWh) without CCS.

Figure 9.8 • CO_2 emissions in the electricity sector by Case, 2010-40



Sources: APERC analysis and IEA (2015b).

While gas offers the most attractive option to reduce emissions over the next decade (to 2025), longer-term emissions from gas-fired plants would exceed those of cleaner coal; hence, gas would either need to be phased out or fitted with CCS technology. The Alternative Power Mix Scenario evaluates non-renewable options to reduce emissions from the power sector and assumes that renewable deployment would remain the same as in the BAU. To truly decarbonise the power sector, a combination of all low-carbon power options would need to be pursued. While beyond the scope of this edition of the Outlook, future analysis could include a scenario to decarbonise emissions in the power sector.

UNDERSTANDING THE INTENDED NATIONALLY DETERMINED CONTRIBUTIONS

It is clear that under the BAU Scenario, growth in energy-related emissions is on an unsustainable path, leading to a global temperature increase of 5°C to 6°C. The UNFCCC aims to stabilise GHG concentrations in the atmosphere at a level that would curb dangerous human interference with the climate system. As part of the post-2020 framework discussed at the 21st Conference of the Parties (COP21) held in Paris in December 2015, APEC economies submitted their INDCs, which outline voluntary commitments to reduce future emissions. These targets formed the basis of a new global agreement. COP21 achieved the expected outcome of establishing a starting point of discussion for the post-2020 framework, and further negotiations on the new global climate framework will take place in coming years.

Summing up APEC economy commitments

In total, 19 economies from the APEC region are party to the UNFCCC process, all of which submitted INDCs for COP21 in December 2015.[4] Chinese Taipei, while not party to the UNFCCC process, has also announced its own INDC. The scope, timeframe and coverage of submissions vary considerably. The types of commitment can, however, can be categorised into three major groups: those based on absolute reductions compared with a reference year; those based on reductions compared with a BAU level; and those based on intensity reductions compared with a reference year. Most economies based their commitments on GHG reductions, with three notable exceptions: China's INDC is based solely on CO_2 emissions, Papua New Guinea submitted a commitment covering only its power sector, and Brunei Darussalam submitted commitments covering the energy, land transport and forestry sectors. The reference year to which commitments are tied varies and includes 1990, 2005, 2007, 2013 and Business as Usual 2030. All APEC INDCs are based on 2030 targets, with the exception of the United States (2025) and Brunei Darussalam (2035). (Details on individual economy INDCs can be found in Volume II of this Outlook).

Some of the INDCs include emissions linked to land use, land-use change and forestry (LULUCF), which for most APEC economies represent only a small share of total GHG emissions (the vast majority are

[4] Chinese Taipei is not part of the UNFCCC process and Hong Kong's submission is included as part of China's INDC.

linked to fossil fuel combustion). Two economies are exceptional for having high shares of LULUCF emissions, Indonesia (60%) and Peru (54%).

Many economies provided either ranges for emissions reduction or unconditional targets together with more aggressive conditional targets they would pursue depending on the availability of financial resources, technology transfer and assistance to achieve higher reductions.

Given the varying scope and range of INDCs, calculating an aggregate APEC INDC is challenging. Based on an evaluation of all INDCs, APERC estimates the total emissions in 2030 to range from 19.6 $GtCO_2$ to 21.7 $GtCO_2$, representing an increase in energy-related emissions of between 8% and 19% compared with the 2010 level of 18.5 $GtCO_2$.

Table 9.6 • INDCs and estimated emissions from fossil fuel combustion, 2030

	Reduction level (%)	Reference year	Emissions 2030 based on INDCs ($MtCO_2$)	Change 2010 to 2030 (%)
Australia	26 to 28	2005	287 to 279	-22.6 to -24.7
Brunei Darussalam	63 (energy use in 2035)	Business-as-Usual	n/a	n/a
Canada	30	2005	371	-26
Chile	30 to 45 (intensity)	2007	91 to 71	35 to 5.9
China	60 to 65 (intensity)	2005	11 715 to 10 250	64 to 43
Indonesia	29 to 41	Business-as-Usual	411 to 341	7.2 to -10.9
Japan	26	2013	927	-25
Korea	37	Business-as-Usual	449	-18.4
Malaysia	35 to 45 (intensity)	2005	327 to 277	55 to 31
Mexico	25 to 40	Business-as-Usual	411 to 337	1.4 to -16.8
New Zealand	30	1990	17	-39
Peru	20 to 30	Business-as-Usual	99 to 87	214 to 124
Papua New Guinea	100% renewable power by 2030 conditional to financial support			
The Philippines	70*	Business-as-Usual	193 to 38	63 to -51
Russia	25 to 30	1990	1 495 to 1 395	6.7 to -0.4
Singapore	36 (intensity)	2005	65	27
Chinese Taipei	50	Business-as-Usual	214	20
Thailand	20 to 25	Business-as-Usual	330 to 309	48 to 38
United States	26 to 28	2005	3 870 to 3 818	-27.9 to -28.9
Viet Nam	8 to 25	Business-as-Usual	396 to 323	221 to 162
APEC	**-**	**-**	**21 653 to 19 555**	**19 to 8**

Notes: The Philippines target is conditional to funding and technology transfer, with no unconditional target given; hence BAU values were used to show the upper range of emissions. INDC emission levels were not calculated for Brunei Darussalam and Papua New Guinea due to lack of sufficient information in the INDC. Higher reduction levels for Chile, Indonesia, Malaysia, Mexico, Thailand and Viet Nam are conditional to receiving financial support. For Singapore, 65 million tonnes of CO_2 equivalent ($MtCO_2e$) includes all sources.
Source: APERC analysis based on economy INDC submissions to UNFCCC (2015) and EPA ROC (2015).

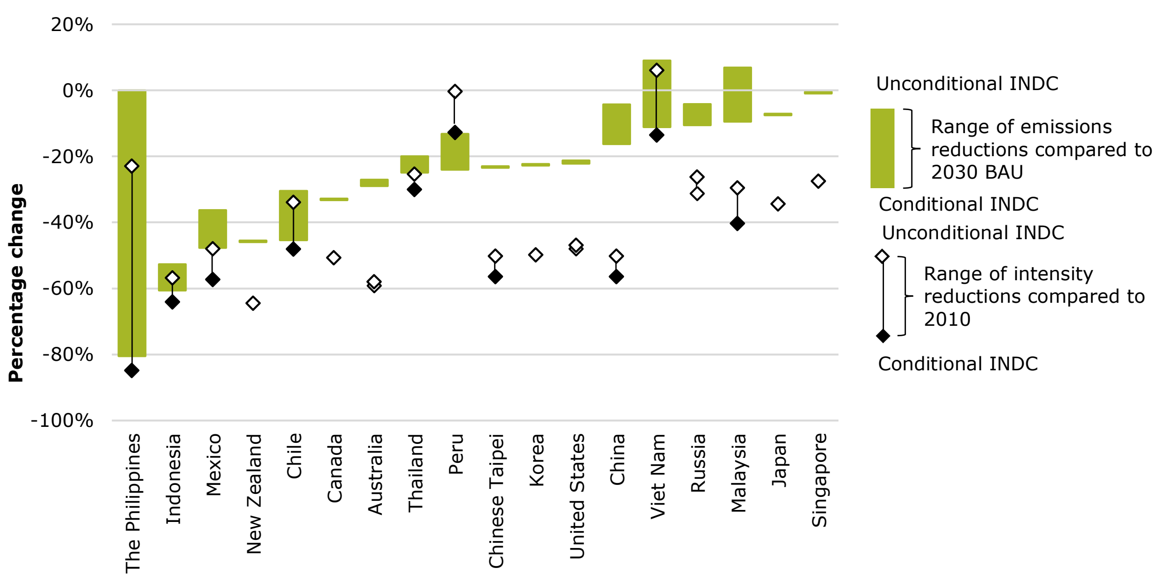
How ambitious are the INDCs?

Evaluating the level of ambition of the INDCs among APEC economies is rather subjective, as the level of economic development and energy use varies considerably across the region. The ability of individual economies to cut future emissions will depend on numerous factors such as resource endowment, economic development, capacity for low-carbon technology deployment and access to affordable capital.

In developing economies, particularly Viet Nam and Indonesia, which are at relatively early stages of economic development and have low levels of energy consumption, both energy use and emissions rise sharply. While potential exists to move directly to more efficient and low-carbon technologies, these are generally more capital-intensive and currently beyond the reach of many developing APEC economies, particularly those already struggling to add sufficient capacity to meet growing electricity demand. While developing economies will account for the largest share of emissions growth, the bulk of historical emissions are the result of energy- and carbon-intensive industrialisation from developed economies. The argument is thus made that industrialised economies need to further cut their own emissions while leaving room for developing economies to grow, and that mechanisms will be needed to facilitate deployment of low-carbon technologies in economies where emissions reduction can be achieved at the lowest cost.

APERC developed two indicators to assess the relative levels of ambition among APEC economy INDCs (Figure 9.9). The first compares the level of emissions reduction against the APERC BAU Scenario, while the second measures the degree of change in emissions intensity between the INDC in 2030 [5] and the historical level in 2010. Many other indicators, including emissions per capita or change in emissions, could also be used to evaluate and compare the relative ambition of the INDCs; each option, as with the two selected for this analysis, has advantages and shortcomings. Ideally, such an evaluation should include a cost component, but current data limitations make this difficult.

Figure 9.9 • Changes in emissions and emissions intensity based on INDCs



Notes: The figure depicts the range between unconditional and conditional commitments (as well as between high and low targets) of economy commitments. Conditional commitments are based on financing and technology transfer being made available. The Philippines target is conditional to funding and technology transfer, with no unconditional target given; hence BAU values were used to show the upper range of emissions.
Source: APERC analysis.

Based on the first indicator comparing estimated INDC emissions in 2030 against those in the APERC BAU Scenarios, the largest reduction potentials are in the Philippines (80%) and Indonesia (61%), but both are conditional on financing and technology transfer. The lack of an unconditional commitment from the Philippines could be interpreted as showing a low level of ambition. The regional APEC outcome based on this indicator is a 2030 emissions reduction ranging from 12% to 21% against the BAU, which falls short of the level required to put APEC on a clear 2°C trajectory. The APERC BAU results assume rather ambitious energy efficiency improvements for certain economies (such as China and the United States); hence, this indicator shows a lower reduction than in other economies, as much of the improvement is already assumed to take place in the BAU. This situation highlights a main shortcoming of this indicator.

[5] As the US INDC is based on a 2025 target, APERC estimated 2030 emissions based on the 2025 pledge trajectory.

An evaluation of the second indicator, which examines the 2030 reduction in emissions intensity compared with 2010, shows some interesting differences. Most economies show larger reductions than with the first indicator, with Peru and Viet Nam being exceptions. The focus on emissions intensity means that economies projected to undergo significant changes in economic structure (i.e. from energy-intensive industry to services) tend to show larger reductions, as is the case for China. Peru, one of the least-developed economies in APEC, shows rapid economic development led by the mining sector, which results in higher energy and emissions intensity. All APEC economies show a significant improvement in emissions intensity under the INDC commitments, with about half showing reductions of over 50%. APEC's average emissions intensity declines between 40% and 46% over the period from 2010 to 2030. In relation to this indicator, the Philippines, Indonesia and New Zealand have the most ambitious commitments.

TRANSITION TO A 2°C ENERGY FUTURE

While the INDC commitments of APEC economies for 2030 are encouraging, unless strengthened over the longer term they risk falling short of what is required to meet a 2°C target. Hence, it is important that economies regularly monitor and review progress on these commitments, and actively look for opportunities to increase the level of future ambitions.

To limit global temperature increases to 2°C, a halving of global energy-related emissions is required between 2013 and 2050 (IEA, 2015a). APERC estimates that this is equivalent to a 55% to 60% reduction in APEC emissions by 2050, or approximately 8 $GtCO_2$ to 9 $GtCO_2$ (Figure 9.10). Even the alternative scenarios developed in this edition of the Outlook fall short of this 2°C trajectory, demonstrating the need for APEC economies to consider more ambitious energy and emission reduction targets to achieve the 2050 climate goal (Box 9.2).

Decarbonising the power sector and accelerating energy efficiency policy implementation are two of the most important priorities. While doubling the share of renewables helps to reduce growth in power sector emissions, it is not sufficient to achieve long-term decarbonisation of the power sector; even higher shares of renewables will be needed in the long term. Analysis of APEC economies shows heavy reliance on coal, which brings to the fore the need to limit the addition of new coal capacity and ensure that any coal plants built will apply the most efficient technologies and include CCS. Nuclear power can also provide stable, zero-carbon baseload power generation and should be considered by economies where it is a viable option.

Energy efficiency and conservation measures in the near term offer the largest potential to lower future demand growth and associated emissions while also improving energy security. While many APEC economies have implemented minimum energy performance standards (MEPS), others either have not or show insufficient enforcement. In addition, while most economies have standards covering appliances, fewer have mandatory fuel economy policies, which are needed to limit growth in transport energy demand. Considerable know-how exists within APEC in respect to improving energy efficiency in heavy industry, creating an opportunity for economies to share experience and support the deployment of best available technologies as well as energy efficiency and conservation practices.

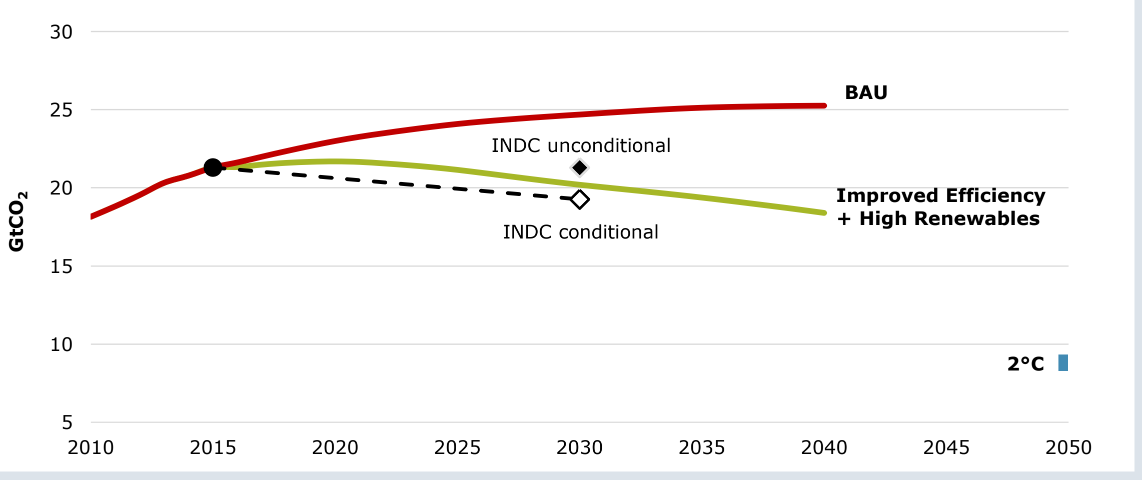
Box 9.2 • Combining the Improved Efficiency and High Renewables Scenarios

Within this Outlook, modelling of the alternative scenarios evaluates separately the impact of enhanced efficiency and efforts to reach a doubling in renewables by 2030. In reality, many economies will pursue both objectives in tandem.

To understand the effects of doubling the share of renewables in parallel with accelerated energy efficiency, APERC ran an additional scenario to examine the CO_2 impacts. As demand for electricity and transport energy falls in the Improved Efficiency Scenario, applying the renewables capacity expansion reflected in the High Renewables Scenario results in a higher share of renewables in both electricity generation and in the primary energy mix. In this combined scenario, efficiency pushes down demand and associated emissions while a greater share of renewables reduces the carbon intensity of the energy supply.

Declining demand means it is possible to reach the goal of doubling the share of renewable electricity generation earlier—even by 2025. Keeping up the projected effort, the share would actually reach 39% by 2040. At the same time, the use of fossil fuels in primary energy supply would decline by 15% compared with the High Renewables Scenario, saving 1 530 million tonnes of oil equivalent (Mtoe) of fossil fuels, equivalent to nearly 70% of current fossil fuel consumption in the United States.

Figure 9.10 • Emissions under a combined Improved Efficiency and High Renewables Scenario, 2010-40



Sources: APERC analysis and IEA (2015b).

The decline in fossil fuel consumption in the combined scenario delivers a 27% reduction in emissions compared with the BAU in 2040, at which time total emissions of 18.5 $GtCO_2$ are actually 9% lower than in 2013. While encouraging, emissions remain more than double the estimated 8 $GtCO_2$ to 9 $GtCO_2$ needed to achieve the global 2°C goal. In 2030, the resulting emissions of the combined scenario are 20.2 $GtCO_2$ and fall between the conditional and unconditional level of APEC INDC commitments. Additional efforts will be required to further decarbonise energy supply and further reduce energy consumption if APEC is to realise the ambitious emissions reduction needed to achieve the 2°C target.

RECOMMENDATIONS FOR POLICY ACTION

Accelerating energy technology development and deployment is central to establishing more secure and environmentally sustainable energy systems. APEC economies should continue working together to share best practices and lessons learnt, and enhance collaboration on a range of low-carbon technologies including renewables, energy efficiency, nuclear and clean fossil fuel technologies. They should also support capacity building across member economies in order to accelerate the transition. As enhancing energy efficiency will be a core element of this transition, governments need to provide greater support to facilitate the adoption of cost-effective energy-efficient technologies.

Enabling frameworks are needed to attract sufficient investment in both low-carbon energy technologies and in measures to enhance energy security. Public-private partnerships can help to spur greater investments from the private sector. Investment should not be confined to physical infrastructure, but should also include soft investments such as improving data availability, developing domestic capabilities and know-how, and supporting research and development.

Regional cooperation can improve energy security in APEC. Energy security exercises, such as the OGSI program conducted by APERC, can build skills for short- and mid-term security, while training in energy policy planning can address long-term security. Both are needed to help economies always be prepared for unexpected incidents. These exercises also train policy makers and industry to be vigilant in global energy scenarios, and prepare them to adapt quickly to unexpected supply disruptions.

Combining the impacts of the two APEC goals under the combined Improved Efficiency and High Renewables Scenario illustrates that while energy-related emissions will peak and begin to fall, they remain well above the levels needed to limit global temperature increase to 2°C. APEC should consider increasing the level of ambition of its existing energy targets and potentially introducing additional targets that could help to support a more dramatic transformation of the energy sector. Individual APEC economies should monitor and re-evaluate their INDCs, strengthening where possible commitments that will lead to a faster decarbonisation of the energy sector.

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:

$$\mathrm{r} = \left[\left(\frac{Pn}{Po}\right)^{\frac{1}{n}} = 1\right] \times 100$$

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

1. INTRODUCTION

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Published for APEC Secretariat
35 Heng Mui Keng Terrace, Singapore 119616
Telephone: (65) 68 919 600
Fax: (65) 68 919 690
E-mail: info@apec.org
Website: http://www.apec.org

APEC#216-RE-01.8   ISBN 978-981-09-8921-7