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APEC Energy Demand and Supply Outlook
7th Edition - Volume I

APEC Energy Working Group

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APEC ENERGY DEMAND AND SUPPLY OUTLOOK

7TH EDITION

VOLUME I

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FOREWORD

The first *APEC Energy Demand and Supply Outlook* was published more than 20 years ago, in September 1998, when the Asia Pacific Energy Research Centre (APERC) was just two years old. Over these past two decades, the Outlook has evolved to present data and analysis through periods of unprecedented growth and rapid change in the energy sector of the Asia-Pacific Economic Cooperation (APEC) region.

Today, the global energy sector is undergoing a rapid transformation as it moves toward more sustainable and lower-carbon systems. The *APEC Energy Demand and Supply Outlook*, 7th Edition highlights the reality that energy choices made in the APEC region will have impacts on energy security and environmental sustainability on the global level. This report examines the gaps between the region's shared goals and current trajectories of APEC economies individually and collectively. Importantly, through scenario modelling, it lays out pathways that can deliver on these goals.

The Business-as-Usual (BAU) scenario illustrates the development pathway that APEC is currently on, which meets the APEC aspirational goal of reducing energy intensity by but falls short of APEC's goal to double the share of renewables in the energy system. The BAU also shows APEC economies failing to meet their Nationally Determined Contribution (NDC) targets under the Paris Climate Agreement.

Recognising the enormity of the challenge ahead for APEC economies, APERC asked *'what will it take?'*. To answer this question, it then modelled two alternative pathways—the APEC Target (TGT) and 2-Degree Celsius (2DC) scenarios—that reveal ways for APEC economies to simultaneously meet their development and sustainability goals.

The primary aim of this Outlook is to support APEC economies in achieving their stated energy goals as they continue to develop and grow. It also aims to serve as a point of reference for those wishing to become more informed about recent energy trends in the APEC region. To that end, the report includes two volumes: Volume I explores key risks and opportunities facing the APEC region as a whole while Volume II presents 21 economy-specific outlooks.

I am pleased to present this Outlook, thanks to the hard work and collaboration by the APERC research team, under the leadership of Mr. James Kendell and Dr. Melissa Lott, and with contributions from experts across the 21 APEC economies and beyond.

Kazutomo Irie

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President

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EXECUTIVE SUMMARY

In the bid to transition to a low-carbon energy system, three challenges stand out: a) affordably meeting increasing energy demand associated with population growth and rising incomes; b) reducing the negative environmental impacts of energy production and consumption; and c) enhancing energy security and resilience. Accounting for around 60% of world energy demand, the 21 economies that make up the Asia-Pacific Economic Cooperation (APEC) have the opportunity to lead the rapid changes already underway in the global energy system. To fulfil their potential in meeting these challenges, APEC economies will need to develop and deploy new technologies, establish new policies and secure substantial investments.

In this 7th Edition of the *APEC Energy Demand and Supply Outlook*, the Asia Pacific Energy Research Centre (APERC) first examines the likelihood of meeting these three challenges if current energy sector trends continue through 2050—i.e. under the Business-as-Usual (BAU) Scenario. The modelling results show this scenario achieving the goal of reducing energy intensity (as set by APEC Ministers and Leaders), but falling short on two other key ambitions. At the regional level, the BAU does not meet the APEC aspirational goal to double the share of renewables in the energy mix, including in electricity generation. Beyond APEC, this scenario also fails to meet the ambitions set forth in Nationally Determined Contributions (NDCs) and Mid-Century Strategies established by APEC economies in support of the agreement reached during the 21st Conference of the Parties (COP21) to the UN Framework Convention on Climate Change (UNFCCC), hereafter referred to as the 'COP21 Paris Agreement'.

To address these gaps, APERC modelled two additional scenarios: the APEC Target (TGT) Scenario and the 2-Degrees Celsius (2DC) Scenario. The TGT tests a transition pathway to simultaneously meet APEC's dual goals of reducing regional energy intensity by 45% between 2005 and 2035, and doubling the share of renewables in the APEC energy mix between 2010 and 2030. Importantly, the TGT identifies synergies and opportunities inherent in the pursuit of these two goals. For the first time in the Outlook publication, the 2DC investigates the level of ambition required for APEC to lead the global transition to low-carbon energy systems

To capture additional insights from these scenarios, APERC added several new capabilities to its modelling system. Reflecting notable trends, the model analyses changed in fossil fuel refining, energy production and trade, and demand-side investment. The time horizon has been extended by another decade (i.e. to 2050) to better project trends leading into the second half of the century to assess whether the Mid-Century Strategies that APEC economies are currently preparing as a part of the COP21 Paris Agreement support long-term aims.

Overall, analysis of the three scenarios in this 7th Edition reveals five Key Trends that either support or hinder the ambitions of APEC economies in the energy sector. In response, APERC offers Key Messages on how policymakers can lead in steering policy, technology and finance to launch a more sustainable path for the energy system. These messages focus on the next 5 to 10 years, when critical decisions will support, stall or undermine achievement of APEC energy ambitions. Unless otherwise stated, the Key Trends identified in the Executive Summary refer to findings that arise from the BAU Scenario. The Key Messages reflect modelling results from the TGT or the 2DC that identify how policymakers can seize opportunities to influence the rapid evolution of the region's energy systems towards regional and global goals.

KEY TREND 1: ENERGY DEMAND GROWS AND APEC SHIFTS FROM COAL TO NATURAL GAS

In the BAU Scenario, final energy demand (FED) in APEC rises to 6 562 million tonnes of oil equivalent (Mtoe) in 2050, a 21% increase from 2016 levels. Overall, however, energy demand growth slows to a compound annual growth rate (CAGR) of 0.57% from 2016 to 2050, about one-quarter the 2.1% growth rate seen from 2000 to 2015.

Projected actual growth in APEC is driven primarily by demand growth in China and south-east Asia. In south-east Asia, growth nearly doubles (98%) driven by rapid economic development as gross domestic product (GDP) per capita rises almost fourfold (from USD 12 247 to USD 44 859) over the Outlook period. In 2016, China represented the largest share (37%) of FED in APEC with 1 979 Mtoe, followed by the United States (28%, 1 515 Mtoe) and Russia (8.7%, 472 Mtoe). In 2050, China's share is marginally lower (35%) but grows in absolute terms to 2 332 Mtoe. The United States also has a lower share (26%, 1 676 Mtoe) despite moderate growth while growth in Russia barely changes its overall share (8.6%, 565 Mtoe).

Fossil fuels remain dominant in APEC in the BAU, representing 64% of FED in 2050, but several factors prompt fuel switching from coal to natural gas, especially in buildings for water heating and cooking. Three factors contribute to demand for coal decreasing by 27%: the rapidly declining cost for renewables technologies; government policies to support clean energy (including major air quality action in China); and the abundance of cheap natural gas supporting robust growth in the liquefied natural gas market—particularly from the United States.

Looking specifically at renewables, a contrasting story emerges. The ongoing transition away from traditional biomass for household cooking and heating drives down direct use of household renewable energy in APEC, from 203 Mtoe in 2016 to 153 Mtoe in 2050 in the BAU. This decline is more than countered by rising use of modern renewables in transformation sectors, including rapid uptake of renewables for electricity generation. If the calculation is adjusted to include use of renewables in electricity generation but exclude use of traditional biomass, total demand for renewables doubles over the Outlook period, from 400 Mtoe to 801 Mtoe. Even so, this growth is insufficient for APEC to achieve its aspirational goal of doubling the share of modern renewables in the energy mix by 2030. As a result, CO_2 emissions fail to decline enough to meet the NDCs submitted by APEC economies as a part of the COP21 Paris Agreement.

Importantly, APEC energy demand continues to decouple from economic growth over the Outlook period, even under the BAU. This allows APEC to achieve its aspirational goal of reducing energy intensity by 45% between 2005 and 2035. In fact, this goal is reached in 2029, raising the question of whether APEC will boost this ambition for a second time; the original goal set by APEC Leaders in 2007, which aimed for a 25% reduction by 2030, was subsequently revised in 2011. The BAU reveals additional, cost-effective opportunities to improve APEC energy intensity, in turn signalling opportunities for policymakers to boost the region's ambitions.

KEY MESSAGE: ENERGY EFFICIENCY, LOW-CARBON FUELS OFFER OPPORTUNITIES TO MODERATE DOMESTIC DEMAND AND IMPROVE TRADE BALANCES

Increasing energy efficiency and transitioning to renewables can moderate domestic demand and improve APEC's trade balance. The 2DC shows that by shifting its investments to energy efficiency and low-carbon fuels, APEC can become a net exporter of energy, with growing opportunities to increase exports of renewable fuels (e.g. ethanol, biodiesel). In the BAU and TGT Scenarios, by contrast, APEC remains a net energy importer throughout the Outlook period.

Critically, the 2DC demonstrates that this transition can be cost-effective, as it results in net cost savings over the Outlook period. The additional USD 12 trillion of capital investment required in the 2DC (compared with the BAU) is more than offset by USD 16 trillion in fuel savings resulting from demand reduction. Early actions by governments, industry and end-users to identify opportunities to improve energy efficiency and transition to low-carbon fuels are vital to achieving these savings. In particular, efforts to enhance energy efficiency in the transport sector are key.

Across APEC, several economies have already documented fuel savings and improved trade balances as a result of fuel economy standards and mandatory blend rates for biofuels. Governments in these economies should work to strengthen these standards as quickly as is politically viable. Those economies lacking fuel economy standards should strive to adopt similar standards and evaluate the potential to boost the use of renewable fuels. Additionally, governments should introduce strategic urban design and public transport planning to foster the simultaneous and mutually supportive goals of economic development and environmental sustainability.

In buildings, many APEC economies have also implemented mandatory building codes and minimum energy performance standards (MEPS) as well as appliance labelling programs to improve energy efficiency in buildings. Governments should take steps to publicise such schemes, using multiple communication platforms in order to help consumer groups grasp the impacts of appliance purchase decisions. They should also strive to continuously improve these schemes and programs, as they are the most effective way to improve energy efficiency performance in buildings.

In industry, policymakers should prioritise the adoption of best available technologies (BATs) in both existing and future facilities. In existing facilities, policies should focus on supporting accelerated upgrades and retrofits. For future facilities, priority should be placed on ensuring that energy efficient equipment is adopted and utilised at the onset of the design process, and that plans are put in place to upgrade facilities as BATs improve.

Efforts to improve collaboration among economies, such as the APEC Peer Reviews on Energy Efficiency (PREE) and the Low Carbon Model Town (LCMT) project, can help to achieve energy efficiency gains more rapidly and effectively. These projects can also help governments to increase awareness of the value of energy efficiency both within their own departments and among the general public. Awareness programs in schools can help to spread understanding of the benefits of energy efficiency among young people, including beyond classroom walls. Governments should also support further research and development efforts for improving energy efficiency across all sectors.

KEY MESSAGE: ACHIEVING APEC ASPIRATIONAL GOALS HELPS ECONOMIES TO REDUCE GREENHOUSE GAS EMISSIONS

In the TGT Scenario, achieving the two APEC aspirational goals (i.e. reducing energy intensity and doubling the renewables share) helps APEC economies reduce their GHG emissions and move towards their commitments under the COP21 Paris Agreement, initially through short-term NDCs. As with the 2DC, fuel savings offset the additional investment needed: in the TGT, fuel savings valued at USD 10 trillion over the Outlook period more than offset the additional USD 7.0 trillion investment needed. This highlights the mutually supportive nature of these regional and global aspirations, as well as the economic benefits of shifting to a more efficient and lower-carbon energy system as quickly as possible.

In the electricity sector, rapidly decreasing costs for renewables—particularly wind and solar—have stimulated their uptake. Some economies have set targets and offered incentives to support accelerated adoption of renewables, thereby also boosting energy security and improving local air quality (which helps to achieve their international commitments in the COP21 Paris Agreement). To limit deployment of fossil fuel power plants that risk becoming stranded assets and compromise the ability for APEC to achieve its decarbonisation goal, policymakers need to provide strong policy direction, including near- and long-term targets for renewables adoption and GHG emissions reduction. Efforts to improve collaboration among economies is vital: the APEC Peer Review on Low-Carbon Energy Policies can help to support increased adoption of renewables while the LCMT project can help to support sustainable development across APEC as the rate of urbanisation accelerates.

KEY TREND 2: TRANSPORT DRIVES DEMAND GROWTH ACROSS APEC

Over the Outlook period, transport's CAGR of 0.77% is more than twice that of industry (0.29% CAGR), which in 2005 surpassed buildings as the largest energy-consuming sector in APEC. Rapid industrial growth in China at the start of the 21st century pushed industry into first place: its dominance deteriorates in the BAU, as its share falls, from 51% of this economy's FED in 2016 to 38% in 2050, reflecting declining demand as China pursues structural reforms. Industry remains the top energy-consuming sector in APEC, but its share declines from 33% in 2016 to 30% in 2050.

Across developing economies in APEC, rising standards of living push up demand for personal and public transport, leading to increased numbers of road vehicles and expansion of other modes of passenger transport. In parallel, increasing global trade boosts freight activity. Under the BAU, domestic transport energy demand grows by 25% to 1 786 Mtoe in 2050, with road freight by heavy trucks increasing by 48% (1.2% CAGR). Rapidly increasing per-capita GDP in China, which reaches USD 50 267 in 2050 (compared with USD 15 094 in 2016), is the main driver of domestic transport FED growth. Existing transport policies in China that improve efficiency only partially offset the effect: transport demand still grows by 70%. Conversely, existing fuel efficiency policies moderate transport demand growth in Oceania (+1.0% CAGR, with Australia at -8.3%) and stimulate a demand decline in the United States (-8.3%) and in other north-east Asia economies (-0.02% CAGR, especially in Japan at -15.1%).

For passenger transport, average energy efficiency improves by 34%, reflecting policy-driven adoption of fuel-efficient conventional vehicles and a growing share of advanced vehicles. Between 2016 and 2025, the United States, Canada and Mexico implement Corporate Average Fuel Economy (CAFE) standards to mandate short-term fuel economy improvements in new light-duty vehicles (LDVs). In Japan, government support boosts the uptake of hybrids and plug-in hybrid electric vehicles (EVs), with associated electricity demand increasing 113% over the Outlook period.

Electrification of passenger transport spurs rapid growth (4.5% CAGR) in electricity demand from transport as the light EV fleet grows at 9.2% CAGR, driven by China (17% CAGR) and the United States (4.8% CAGR). Some APEC economies have adopted policies that support shifts towards more advanced technologies in road transport. The United States offers subsidies for the purchase of EVs (CA 2012), as does Japan for hybrid vehicles (MLIT 2018); other APEC economies use policy instruments to promote switching from conventional liquid-fuel vehicles to EVs and hybrids. In rail, there is a clear trend towards electrification or switching to natural gas (from oil) in non-electrified areas.

Road congestion, already a trademark of cities such as Jakarta and Moscow, worsens as more cities expand and become denser. Many municipal authorities are already taking action to mitigate congestion by supporting public over private transport options. Jakarta, for instance, is establishing a bus rapid transit system (ITDP 2018), while a sustainable urban transport program in Bangkok aims to integrate transportation systems and improve the logistics of delivering goods (BMA 2015).

KEY MESSAGE: FUEL ECONOMY STANDARDS INCREASE ENERGY SECURITY AND SUPPORT SUSTAINABLE GROWTH IN ROAD TRANSPORT

Energy efficiency in transport is one of the most cost-effective tools that APEC economies can employ to reduce energy demand, dependence on imported crude oil and CO_2 emissions. Wider deployment of fuel economy standards for road vehicles is key in the TGT and 2DC, both of which show an overall decrease in road transport energy demand over the Outlook period. Early action to support adoption of energy efficiency and advanced vehicles in the 2DC delivers a demand decrease of -1.2% annually, compared with a CAGR of 0.67% in the BAU.

In all scenarios, APEC remains a net importer of crude oil, with most economies continuing to rely on the Middle East and North Africa as their main source of imports. Overall, net imports of crude oil under the BAU decrease slightly from 799 Mtoe in 2016 to 792 Mtoe in 2050. With imports of just 473 Mtoe in 2050, the TGT demonstrates how improving transport energy efficiency curbs growth of crude oil imports, thereby improving energy security in the APEC region. Most dramatically, the 2DC shows rapidly decreasing transport demand stimulating an actual decline in crude oil imports to 173 Mtoe in 2050, with the APEC region transitioning from a net importer of fossil fuels to a net exporter position.

In the short term, governments should strengthen current energy efficiency policies for all demand sectors, particularly in transport. Economies that do not currently have energy efficiency policies can evaluate the applicability of examples successfully implemented by other economies through initiatives such as the APEC PREE. Three proven approaches deliver benefits in different ways: effective and achievable fuel economy standards can promote technological advancements and change in automotive manufacturing; economic incentives can encourage the purchase of efficient and advanced vehicles; and alternative fuel mandates can boost uptake of renewables to achieve APEC aspirational goals.

KEY TREND 3: DEMAND FOR ELECTRICITY RISES IN ALL SCENARIOS AND GHG EMISSIONS ARE CURBED

Electricity demand in APEC grows by 45% over the Outlook period in the BAU, driven predominately by China and south-east Asia. In developing economies, rising per-capita income and increasing electricity access lead to higher electricity consumption in the residential sector. In buildings, electricity demand increases by 66% over the Outlook period as APEC developing economies (particularly Papua New Guinea) strive to meet ambitions under the UN Sustainable Development Goal No. 7 for energy access.

In transport, quickly growing uptake of EVs also drives up demand, particularly in China and the United States. In China, EV charging accounts for almost 10% of total electricity demand in 2050. This level of penetration makes it critical to establish operational rules that coordinate charging activities to maintain grid stability and avoid excessive investment in peak power plants.

More than 3 200 gigawatts (GW) of new power plant capacity is built in APEC between 2016 and 2050 to keep pace with this increasing demand in the BAU; in parallel, ageing plants are replaced and renewables deployment is accelerated. This rapid expansion creates large investment opportunities. China accounts for 39% of total electricity investments over the Outlook period. In South-east Asia 159 GW of new coal, 68 GW of new gas and 150 GW of new renewables capacity are added to meet soaring electricity and heat demand from increased access and higher electrification. Indonesia shows the greatest need in this subregion, requiring USD 466 billion to build 215 GW of electricity capacity between 2016 and 2050.

CO_2 emissions from power generation peak as alternative fuels are rapidly deployed, even as coal and gas remain the two largest fuel sources for power generation in APEC. Average CO_2 emissions intensity in APEC continuously declines from 5146 grams of CO_2 per kilowatt-hour (gCO_2 per kWh) in 2016 to 398 gCO_2 per kWh in 2050, which is almost equivalent to the average emissions level for natural gas combined-cycle power plants.

KEY MESSAGE: INCREASING ELECTRIFICATION REQUIRES A MORE FLEXIBLE POWER SYSTEM

The rapid electrification of APEC's transport sector, in conjunction with demand growth across other sectors and accelerated adoption of variable renewables, puts pressure on the electricity system. In the BAU, the total light EV fleet grows at 15% CAGR, driven by China (16% CAGR) and the United States (13% CAGR) with corresponding growth in electricity demand. In the TGT, the share of EVs (including battery and plug-in technologies) grows to 20% (from 13% in the BAU) while hybrids rise to 9.1% (from 6.4% in the BAU). Transport electrification is a key strategy in the 2DC to reduce CO_2 emissions from passenger vehicles, together with other measures that facilitate more rapid deployment of low-carbon fuels. Shares of light EVs grow to 42% in the 2DC by 2050.

In response, economies must focus on improving power system flexibility through energy storage technologies, increasing supply-side ramping capability, improving the transmission and distribution networks, and enhancing demand-side management. Governments should set clear policies to support a diverse mix of technologies that ensure a more flexible system.

Growing shares of solar photovoltaic (PV) power generation will require daily-cyclic ramping operation of coal- and/or gas-fired plants to absorb the output surge during the daytime. Ramping operation of flexible plants is likely to be the main integration measure in many APEC economies. Energy storage systems can also play an important role in providing electric system flexibility, particularly in Japan, the United States and China, which have installed significant amounts of pumped hydro storage (PHS).

KEY TREND 4: THE APEC TARGET SCENARIO ACHIEVES ASPIRATIONAL GOALS AT A NET COST SAVING

The TGT sets out a clear pathway by which APEC economies can achieve—at a net cost saving—both of the aspirational energy goals set by APEC Leaders and the NDCs they have individually set. Policy measures taken in the TGT result in APEC energy demand peaking by 2028, then falling to 13% lower than the BAU in 2050. This energy demand reduction of 840 Mtoe is almost equivalent to the combined consumption of Russia and south-east Asian economies in 2016.

The TGT requires 15% (USD 7.0 trillion) greater capital investment than under the BAU, but the value of fuel savings—which reaches USD 10 trillion over the Outlook period—more than offsets the up-front costs. In fact, compared with the BAU, the TGT delivers a net cost saving of almost USD 3.2 trillion.

On the demand side, investment requirements increase from USD 14 trillion in the BAU to USD 22 trillion in the TGT. In this case, additional investment in buildings to improve efficiency and accelerate the uptake of modern renewables is offset by declining transport investments. This cross-sector balancing is particularly important in China, as increased fuel efficiency in vehicles results in reduced need for fuelling stations (i.e. buildings). Conversely, as energy demand peaks in the TGT, investment requirements decline in the transformation and supply sectors. Transformation investments decline slightly in the TGT, although required investment in new electricity capacity remain high. Supply-side investment decreases from USD 18 trillion in the BAU to USD 17 trillion in the TGT as less new infrastructure is needed.

KEY MESSAGE: ADDITIONAL ACTION IS NEEDED TO MEET COP21 PARIS AGREEMENT TARGETS

Despite meeting the APEC aspirational goals and the stated NDC commitments, the TGT falls short of achieving the APEC contribution needed to meet the COP21 Paris Agreement goal of constraining global temperature increase to less than 2°C. Analysis completed for the 2DC identifies what additional efforts are needed, and uncovers substantial opportunities to increase efficiency and deploy more renewables in all end-use sectors.

Sector-by-sector analysis of industry shows significant opportunities to improve the efficiency of production technologies and processes. Increasing steel recycle rates, for example, facilitate greater use of electric arc furnaces. Substituting renewables for fossil fuels and electrifying processes across industry subsectors can also contribute to decarbonisation goals.

Energy demand in buildings can be cost-effectively reduced by implementing MEPS for buildings themselves as well as standards and labelling schemes for appliances. In particular, governments should take urgent action to increase efficiency in building cooling technologies, as the use of space cooling grows dramatically along with economic prosperity and rising temperatures. Given the slow turnover (50 to 100 years) of buildings in most economies, capturing the near-term opportunities in this sector is particularly critical. For transport, in which vehicle turnover is much faster (5 to 15 years), it is still vital for economies to adopt new and enhance existing fuel economy standards. Gradually improving engine efficiency standards has been shown to be one of the most effective ways to save fuel, cut oil imports and reduce consumer fuel costs. At the same time, tailpipe emissions, which are responsible for significant GHG emissions, can be significantly reduced.

As it strives to meet its contributions to achieve the COP21 Paris Agreement, APEC must shift more rapidly to deep decarbonisation goals, which can largely avoid the potential risk of stranded assets. The longer that action is delayed, the higher the likelihood that economies will invest in technologies that effectively lock in a business-as-usual energy future—or at minimum, result in higher costs to achieve deep decarbonisation (e.g. through the early retirement of capital-intensive energy investments such as low-efficiency coal-fired power plants). By acting now to set the decarbonisation trajectory, economies can achieve their long-term COP21 Paris Agreement goals to 2050 and beyond.

KEY TREND 5: THE POWER SECTOR IS VITAL TO REDUCING CO_2 EMISSIONS

Increased levels of electrification across all demand sectors (i.e. transport, buildings and industry) make it imperative to pursue rapid decarbonisation of power generation to curb associated emissions. Investments to increase energy efficiency and accelerate fuel switching to low- and zero-carbon fuels underpin this pathway.[1]

Fuel switching plays the central role in decarbonising power in APEC. In fact, in the 2DC, the electricity sector shifts from being dominated by fossil fuels in 2016 to renewables and nuclear power accounting for the majority share by 2050. Key technologies in this transformation include both variable renewable technologies (e.g. rooftop and utility solar PV, concentrated solar power for generating electricity and heat, onshore and offshore wind power) and the application of carbon capture and storage (CCS) to both fossil fuels and biomass power plants. The 2DC shows a 44% reduction of all-sector coal demand over the Outlook period, even with the introduction of CCS technologies after 2030. In parallel, natural gas is increasingly used to provide flexibility to the power system (rather than for baseload generation), with capacity increasing by 106% (from 802 GW in 2016 to 1 653 GW in 2050) over the Outlook period to fulfil this role. The average capacity factor for natural gas plants decreases, however, from 42% in 2015 to 25% in 2050. For the remaining share of fossil fuels, the commercial viability of CCS technology by 2030 is paramount to achieving the necessary emissions reduction. Increased use of PHS and batteries is also likely in the 2DC to support reliable power grid operation.

Within end-use sectors, the transition to electrification must be coupled with improved efficiency and fuel switching to reduce both energy demand and emissions to levels that satisfy the COP21 Paris Agreement goals. In buildings, energy demand is 36% lower in the 2DC than in the BAU in 2050, mostly due to improvements in building envelopes, increased electrification and improved energy efficiency in appliances.

Electrification of short-to-medium transport modes (e.g. LDVs and 2-/3-wheelers) is essential for CO_2 emissions reduction in transport, together with other measures that facilitate more rapid deployment of low-carbon fuels (e.g. renewables and hydrogen) in long-distance and heavy-duty vehicles. In the 2DC, in combination with increased fuel efficiency, these measures reduce transport sector emissions by 40% from 2016 to 2050, despite a more than doubling in demand for freight movement and a 28% increase in domestic passenger movement.

As APEC economies more quickly adopt BATs in the 2DC, decarbonisation of industry shows rapid energy demand reduction. Switching from fossil fuels to lower-carbon fuels (mostly renewables and electricity) accelerates emissions reduction as do increased recycling rates and waste reduction measures.

KEY MESSAGE: INVESTMENT MUST SHIFT TO LOW-CARBON POWER GENERATION TECHNOLOGIES

The USD 15 trillion in power plant investment decisions made through 2030 in the BAU should consider the expected operational lifespan of assets against the longer-term APEC and global energy transition and decarbonisation targets. To avoid higher costs in the future, governments should rapidly adopt policies to move towards decarbonisation goals, including policies that stimulate additional investment in low-carbon technologies in the short term (i.e. next 5 to 10 years). This is particularly vital for the electricity sector as power plants built in the near term will supply all demand sectors for years to come. As projects typically have long

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[1] The 2DC also includes small behaviour change assumptions in transport and service buildings as discussed in Chapter 6.

lifespans and payback periods (i.e. more than 30 years), assertive policy action now will avoid technology lock-in and enable deep decarbonisation.

By pursuing a decarbonisation pathway, APEC economies will open themselves to global markets for low-carbon goods and services. Economies that move early to get ahead of the curve, by establishing methods to achieve this increased ambition, can secure a strategic advantage in the growing low-carbon marketplace.

1. INTRODUCTION

KEY FINDINGS

- **APEC has a prominent role in shaping the global energy sector, accounting for 57% of global final energy demand in 2016. The region includes four of the world's five largest energy users (China, Japan, Russia and the United States).** Decisions made in the region significantly influence global energy sector development and trade over the Outlook period (2016-50).

- **Continued economic and social development in China and south-east Asia dominates APEC energy trends.** In 2016, China represented the largest share (37%) of APEC FED, followed by the United States (28%) and Russia (8.7%). From 2016 to 2050, south-east Asia drives energy demand growth.

- **Coal fuelled much of the recent economic growth in APEC, but its use has declined since 2014.** South-east Asian economies, however, continue to expand use of coal for power generation; additional ambition is needed to develop more sustainable energy systems.

- **Growing LNG markets shape trade across APEC, which has some of the most active gas trade dynamics in the world.** The region is home to three of the world's top five exporters (Russia, the United States and Canada) and three of the world's top five importers (Japan, China and the United States).

- **This edition of the Outlook presents a BAU Scenario and two alternatives aimed at achieving APEC aspirational goals and global decarbonisation targets: the TGT and 2DC Scenarios.** These scenarios investigate the additional efforts needed to reach these goals and targets, highlighting opportunities for short-term action.

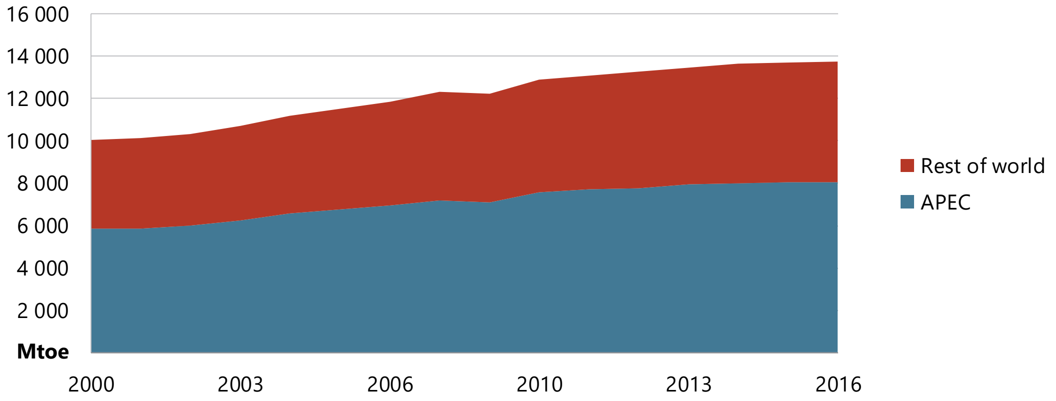
- **APEC is poised to achieve its aspirational goal to reduce (by 45%) the region's energy intensity.** But it is falling short of achieving its goal to double the share of renewables in the energy system and targets set in the COP21 Paris Agreement.

RECENT TRENDS IN THE APEC ENERGY SECTOR

The Asia-Pacific Economic Cooperation (APEC) region represented 39% of global population, more than half (54%) of gross domestic product (GDP) and 58% of global primary energy supply in 2016 (Figure 1.1). As such, decisions made in the region have significant impacts on global energy sector development and trade.

The 7th Edition of the *APEC Energy Demand and Supply Outlook* presents the latest energy trends in APEC and models potential future trajectories in the energy sector between now and 2050. A key benefit of such modelling, as described in the following section of this chapter, is that it makes it possible to compare current trends against what needs to change to meet particular targets—and helps to identify opportunities and risks associated with each trajectory. To set the scene, it is useful to first examine some recent data and information about APEC economies and their energy systems.

Figure 1.1 • Global total primary energy supply, 2000-16



Sources: IEA (2018a).

APEC'S ENERGY SUPPLY IS DOMINATED BY FOSSIL FUELS

The 21 economies in APEC are diverse, including some of the world's most energy-intensive (Canada, Korea and Russia) and some of the least energy-intensive (Papua New Guinea, Peru and the Philippines) (Table 1.1). The group also has some of the world's fastest-growing economies, with associated energy supplies in Chile, Papua New Guinea and Peru growing at more than eight times the average global rate from 2015 to 2016. This diversity makes it possible to draw a range of insights from analysis of energy use across the region and presents significant opportunities for knowledge sharing.

In 2016, APEC's total primary energy supply (TPES) grew to more than 8 000 million tonnes of oil equivalent (Mtoe), an increase of 37% since 2000 and 1.4% since 2013, the base year used in the 6th Edition of the Outlook. Since 2013, with the exception of coal, primary energy supply of all fuels used in APEC increased: 10% growth in renewables, 4.8% growth in natural gas and 4.0% growth in oil, compared with a 5.2% decline in coal (Figure 1.2). These numbers highlight a regional shift away from coal towards renewables for electricity generation as well as robust growth in the liquefied natural gas (LNG) market.

The energy supply mix in APEC remains dominated by fossil fuels (i.e. coal, oil and natural gas), which grew to represent 86% of TPES in 2016 compared with 82% in 2000. The share of coal in APEC's TPES grew from 27% to 38% from 2000 to 2013; while it remains the top fuel in APEC, more recent trends saw coal's share fall to 35% in

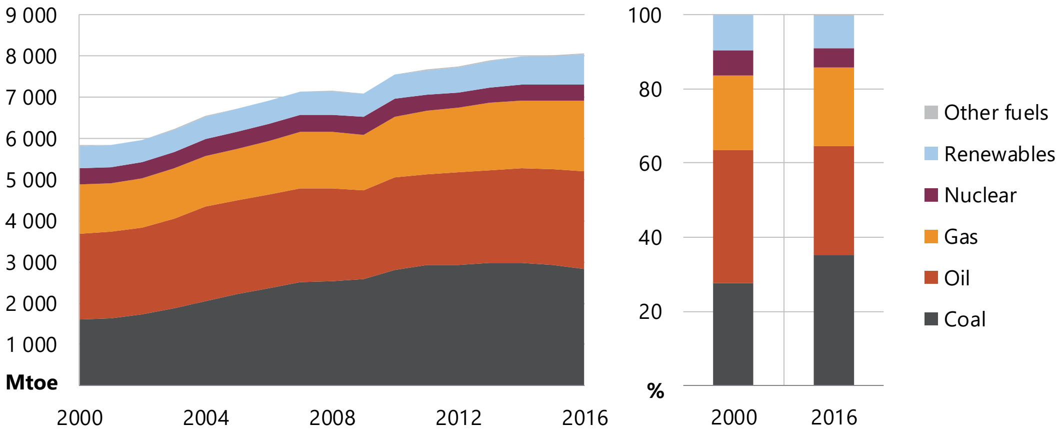
2016. Despite this recent decline, use of coal continued to grow in absolute terms (by 39% in 2013-16) in south-east Asia as it was preferred to natural gas supplies for electricity generation.

Table 1.1 • Key energy statistics for APEC economies, 2016

	Total primary energy supply (Mtoe)	Energy production (Mtoe)	Electricity consumption (TWh)	Energy intensity (toe/unit GDP)	Energy intensity (toe/capita)
Australia	130	390	257	116	5.4
Brunei Darussalam	3.2	15	4	102	7.6
Canada	282	475	667	173	7.8
Chile	38	12	79	89	2.1
China	2 983	2 359	6 200	144	2.1
Hong Kong, China	13	0.11	39	32	1.8
Indonesia	233	434	262	80	0.89
Japan	436	35	1 072	86	3.4
Korea	285	51	560	153	5.6
Malaysia	83	96	138	100	2.7
Mexico	189	180	320	83	1.5
New Zealand	22	17	43	124	4.6
Papua New Guinea	2.2	11	4	69	0.27
Peru	24	26	52	60	0.76
Philippines	55	28	91	70	0.53
Russia	731	1 372	1 089	196	5.1
Singapore	27	0.74	52	56	4.8
Chinese Taipei	110	11	263	100	4.7
Thailand	138	79	191	122	2.0
United States	2 174	1 915	4 306	121	6.7
Viet Nam	79	69	165	138	0.84
APEC	**8 043**	**7 578**	**15 854**	**123**	**2.8**
World	13 761	13 764	24 973	115	1.8

Notes: Mtoe = million tonnes of oil equivalent. TWh = terawatt-hours. toe = tonnes of oil equivalent.
Source: APERC analysis, IEA (2018a) and World Bank (2018).

Figure 1.2 • APEC total primary energy supply by fuel, 2000-16



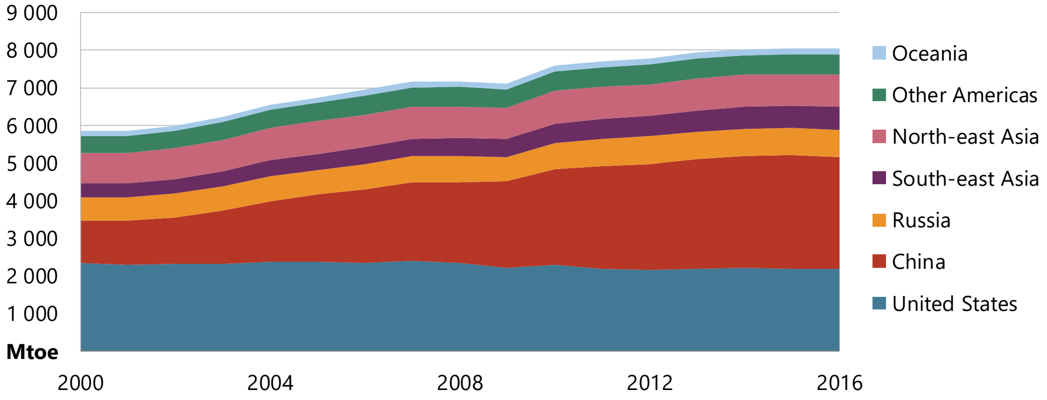
Sources: APERC analysis and IEA (2018a).

CHINA CONTINUES TO LEAD GROWTH IN ENERGY SUPPLY

Overall, TPES grew 37% from 2000 to 2016 in APEC, with per-capita energy supply increasing by 22%. This growth has slowed in recent years: after rising at a compound annual growth rate (CAGR) of 2.2% from 2000-09, TPES growth was only 1.0% from 2010-16 (Figure 1.3).

Together, China and the United States represented nearly two-thirds (64%) of TPES in APEC in 2016. Since the turn of the century, rapid economic growth in China has underpinned growing demand for energy supply (6.2% CAGR), though more slowly in recent years (0.69% CAGR in 2013-16). Still, China's share of TPES in APEC almost doubled from 19% (1 135 Mtoe) in 2000 to 37% (2 983 Mtoe) in 2016. Conversely, energy supply in the United States has decreased (-0.44% CAGR) to 2 176 Mtoe in 2016. In south-east Asia, energy supply grew (3.5% CAGR) from 2000 to 2016, reaching 618 Mtoe.

Figure 1.3 • APEC total primary energy supply by region, 2000-16



Sources: APERC analysis and IEA (2018a).

APEC INCREASINGLY TRADES FOSSIL FUELS WITHIN THE REGION

The value of intra-APEC imports of fossil fuels grew from USD 464 billion in 2000 to USD 741 billion in 2016, the majority (65%) being oil trade followed by natural gas (27%) and coal (8.6%) (UN Comtrade, 2018). In 2016, intra-APEC trade represented 48% of total fossil fuel trade in the region, up from just 37% in 2000.

The APEC region has some of the most active gas markets in the world, including three of the world's top five exporters (Russia, the United States and Canada) and three of the world's top five importers (Japan, China and the United States) (IEA, 2018a). Natural gas imports have grown by 94% in APEC since 2000, reaching 382 Mtoe in 2016, with 53% of imported volumes being traded via LNG. In 2016, north-east Asia was the biggest natural gas importer in APEC, representing 41% (158 Mtoe) of total imports with the majority (99 Mtoe) delivered to Japan. In the same year, the United States was the world's largest gas producer and consumer; Russia remained the largest gas exporter globally but trailed the United States in both production and consumption (IEA, 2018a).

MAJOR DRIVERS OF ENERGY USE IN APEC

In APEC, as in virtually all regions of the world, economic development, population and fuel prices are major drivers of energy use.[2] As with the 6th Edition of this Outlook, the energy projections in this edition are demand-driven and all sub-models use a consistent set of assumptions: GDP, population and energy prices. Energy prices used are from the Institute of Energy Economics, Japan (IEEJ).

ECONOMIC DEVELOPMENT (GDP)

This *Outlook 7th Edition* uses GDP projections from the Organisation for Economic Co-operation and Development (OECD) for its member economies and other significant non-member economies. The Asia Pacific Energy Research Centre (APERC) modelled GDP growth for the remaining economies using a Solow-Swan growth model based on a Cobb-Douglas production function. In turn, GDP is a function of labour inputs (population structure and economic activity rates), capital inputs (GDP, depreciation and savings rates), and total factor productivity (technological progress). Total factor productivity is modelled based on historical trends.

Table 1.2 • GDP assumptions for APEC economies, 2000-50

	Compound annual growth rate (%)			GDP USD billion (PPP)	
	2000-16	2016-30	2030-50	2016	2050
Australia	2.9	3.2	2.8	1 149	2 959
Brunei Darussalam	0.66	1.4	1.0	32	45
Canada	1.9	2.1	2.0	1 673	3 281
Chile	3.9	4.1	3.1	432	1 238
China	9.5	4.5	3.5	21 184	68 586
Hong Kong, China	3.6	2.5	2.3	426	913
Indonesia	5.3	5.8	5.1	3 000	16 417
Japan	0.8	1.2	1.1	5 187	7 649
Korea	3.9	2.8	2.2	1 915	3 960
Malaysia	4.8	4.5	4.0	854	3 232
Mexico	2.0	2.8	3.2	2 342	6 817
New Zealand	2.9	2.6	2.4	179	402
Papua New Guinea	4.5	5.4	5.2	33	186
Peru	5.2	3.7	3.2	410	1 188
Philippines	5.3	5.4	4.7	797	3 861
Russia	3.5	2.8	1.8	3 821	6 939
Singapore	5.1	3.5	2.9	494	1 293
Chinese Taipei	3.3	2.0	1.1	1 133	1 646
Thailand	4.0	3.8	3.6	1 154	3 852
United States	1.8	2.4	2.1	18 427	37 161
Viet Nam	6.4	5.2	4.7	589	2 776
APEC	**4.0**	**3.5**	**2.9**	**65 232**	**174 405**

Note: PPP = purchasing power parity.
Source: World Bank (2018).

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[2] See Annex I: Methodology and key assumptions for more details.

Overall, GDP in APEC grew by 87% from 2000 to 2016 (4.0% CAGR) to reach USD 65 232 billion. In the Outlook, this growth continues at 3.5% CAGR from 2016 to 2030, then slows somewhat to 2.6% CAGR to 2050. In turn, the region's total GDP almost triples, reaching USD 174 449 billion by 2050 (Table 1.2). China accounts for 43% (USD 47 403 billion) of this growth, despite its growth rate slowing from the 9.5% CAGR seen from 2000 to 2016 to 4.5% CAGR from 2016 to 2030 and then 3.5% CAGR to 2050. Combined with the United States and Indonesia, these three economies account for 73% of total GDP growth in APEC over the Outlook period. In Indonesia and Papua New Guinea, GDP grows more than fivefold while the Philippines and Viet Nam show more than fourfold growth.

POPULATION

Population projections in the *Outlook 7th Edition* are from the United Nations Department of Economic and Social Affairs (UNDESA). Across APEC, population has increased by 12% since 2000 (0.73% CAGR), with the fastest growth seen in south-east Asian economies. This overall growth slows in the coming decades, with 0.43% CAGR to 2030 and 0.05% CAGR thereafter, in part because six economies (China, Japan, Korea, Russia, Chinese Taipei and Thailand) show declining populations (Table 1.3).

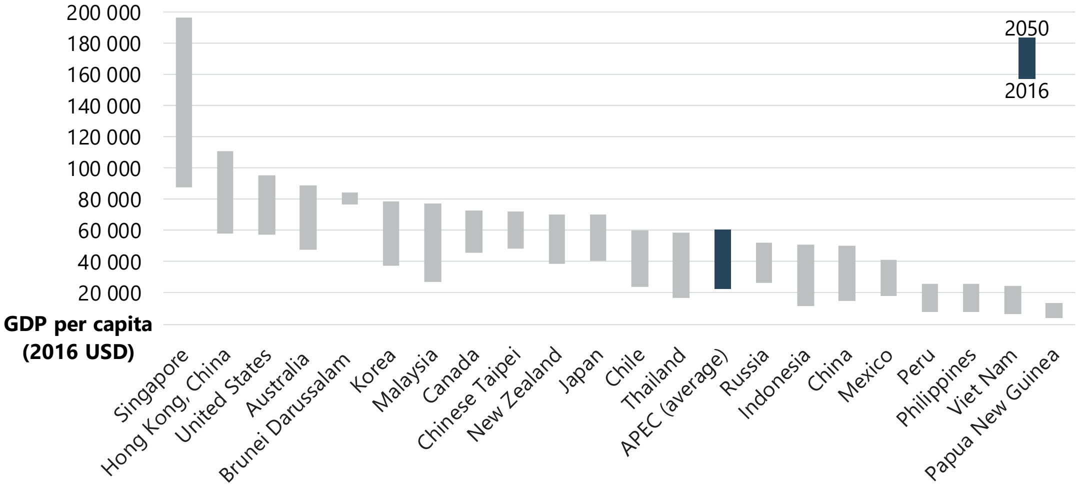
Table 1.3 • Population assumptions for APEC economies, 2000-50

	Compound annual growth rate (%)			Population (millions)	
	2000-16	2016-30	2030-50	2016	2050
Australia	1.5	1.1	0.81	24	33
Brunei Darussalam	1.5	1.1	0.46	0.42	0.54
Canada	1.0	0.81	0.51	36	45
Chile	1.0	0.66	0.27	18	21
China	0.56	0.19	-0.27	1 404	1 364
Hong Kong, China	0.57	0.64	0.16	7.30	8.25
Indonesia	1.3	0.89	0.42	261	322
Japan	0.01	-0.35	-0.55	128	109
Korea	0.43	0.26	-0.22	51	50
Malaysia	1.9	1.2	0.63	31	42
Mexico	1.4	1.0	0.54	128	164
New Zealand	1.2	0.80	0.46	4.7	5.7
Papua New Guinea	2.4	1.9	1.4	8.1	14
Peru	1.3	1.1	0.62	32	42
Philippines	1.8	1.4	0.94	103	151
Russia	-0.10	-0.17	-0.29	144	133
Singapore	2.3	0.86	0.18	5.6	6.6
Chinese Taipei	0.47	0.18	-0.29	24	23
Thailand	0.56	0.08	-0.31	69	65
United States	0.84	0.69	0.47	322	390
Viet Nam	1.0	0.84	0.38	95	115
APEC	**0.73**	**0.43**	**0.05**	**2 895**	**3 103**

Source: UN DESA (2018).

Importantly, APEC populations become richer over time, with per-capita GDP growing by 149% (2.7% CAGR) from 2016 to 2050 to reach USD 56 218 (Figure 1.4). As average incomes grow, demand for energy services also rises. People increasingly buy and use personal vehicles, appliances for their homes, and personal electronics. In China, per-capita incomes rise by 233% from USD 15 094 in 2016 to USD 50 267 in 2050. In south-east Asia, incomes steadily grow by 267% over the same period.

Figure 1.4 • GDP per capita by APEC economy, 2016-50



Sources: World Bank (2018) and UN DESA (2018).

SCENARIO MODELLING TO SUPPORT DECISION MAKING

To explore the potential implications of the energy transition in APEC economies, the 7th edition of the *APEC Energy Demand and Supply Outlook* examines three scenarios (Table 1.4). The Business-as-Usual (BAU) Scenario is based on key energy demand and supply assumptions that reflect current trends and relevant polices already in place or planned. It provides a baseline against which other scenarios can be compared.

Table 1.4 • Overview of Outlook scenarios

	Business-as-Usual (BAU)	APEC Target (TGT)	2-Degrees Celsius (2DC)
Definition	Recent trends and current policies.	Enhanced efficiency measures and accelerated adoption of modern renewables to achieve APEC aspirational goals.	Development of low-carbon energy systems to provide a 50% chance of limiting average global temperature increase to 2°C.
Purpose	Illustrates the likely future energy systems if no significant changes occur. Provides a baseline for comparison with and decision making in relation to the alternative scenarios.	Outlines a pathway to simultaneously achieve the APEC aspirational goals to reduce energy intensity and double the share of modern renewables in the energy system, including in electricity generation.	Explores the degree of additional ambition needed to support development of low-carbon energy systems.
Limitations	Assumes that recent trends largely remain consistent in coming years. APEC aspirational goal for doubling renewables is not met.	GHG emissions are not constrained.	Does not achieve targets under COP21 Paris Agreement to keep global temperature rise to "well below 2°C" or to reach net-zero emissions.

Box 1.1 • Model developments incorporated into the *Outlook 7th Edition*

- Model projections have been extended to 2050 in order to capture additional insights on both renewables and emissions trends, particularly in the 2DC Scenario.
- For 11 economies—which represent 95% of APEC energy demand—models now use GDP forecasts from the OECD, enabling more direct comparison of results with other global outlooks.
- The buildings model is primarily activity-driven, allowing for more detailed analysis of the impacts of increasing energy access, fuel switching, technology shifts and social change (e.g. increased teleworking).
- The industry model is now bottom-up, enabling direct analysis of best available technology adoption and structural shifts, as well as explicit accounting of industrial product outputs.
- In the power model, the number of technologies represented was expanded from 19 to 33, and includes two types of energy storage (pumped storage hydro power and batteries) as well as combined heat and power facilities. Daily load curves are included, allowing the model to capture variability in supply and demand while also providing additional insights on the impacts of renewables integration.
- The transport model includes activity-based analysis for both passenger and freight transport, allowing for improved understanding of mode shifting. Light- and heavy-duty vehicle technologies were disaggregated, allowing for detailed analysis of fuel efficiency policies.
- Renewables are distributed among the demand-side and electricity models. Renewable supply potential is included for first- and second-generation biofuels.
- A refinery model was added, including a biorefinery submodel that explicitly captures the operation of these facilities and evaluates investment and trade potential to 2050.
- A production and trade model was incorporated that captures trade balance dynamics within APEC.
- The investment module was expanded to capture demand-side investment and fuel savings, to complement previous capabilities on supply-side investment.

To investigate how specific targets or goals might be achieved, two alternatives analyse different possible trajectories. The APEC Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals, set by APEC Ministers and Leaders, to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level) (APEC EWG, 2018).

The 2-Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of further reducing energy intensity, expanding renewables deployment and curbing carbon dioxide (CO_2) emissions. Modelling for the 2DC is underpinned by targets for energy sector emissions reduction that would provide at least a 50%

chance of limiting the global average temperature increase to 2°C by 2050. The 2DC is aligned with both APEC aspirational goals as well as global commitments set in the agreement reached in Paris in 2015 during the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC), hereafter referred to as the COP21 Paris Agreement.

These alternative scenarios illustrate how the region could meet such goals while also highlighting the opportunities and risks associated with delayed action. As both alternative scenarios require substantial additional investment, the *7th Edition* modelling investigates capital investments and the energy savings incurred through reductions and shifts in energy consumption. Importantly, both scenarios show that on an APEC-wide basis, additional capital costs are more than offset by demand-side savings through reduced fuel costs.

To both improve the usability of these tools and enhance the insights that can be drawn from scenario results, APERC made a number of updates to the modelling suite since the 6th Edition (Box 1.1). All scenarios are explored with a time horizon to 2050, whereas the 6th Edition of this Outlook included analysis to 2040.

APEC ENERGY OUTLOOK IN THE THREE SCENARIOS

Energy demand in APEC grows by 21% in the BAU Scenario—reaching 6 562 Mtoe in 2050—in large part due to trends in south-east Asia, where population grows 1.2 times (from 565 million to 702 million) and per-capita GDP rises 3.7 times (from USD 12 247 in 2016 to USD 44 922 in 2050). Final energy demand (FED) in south-east Asia grows 428 Mtoe, almost doubling over the Outlook period. Other subregions in APEC show slow to moderate demand growth, as economies become increasingly energy efficient.

In 2016, China represented the largest share (37%, 1 979 Mtoe) of APEC FED, followed by the United States (28%, 1 515 Mtoe) and Russia (8.7%, 472 Mtoe). In 2050, China maintains the highest share (35%) and the second-highest absolute growth (to 2 322 Mtoe); the United States shows a lower share despite moderate growth (26%, 1 676 Mtoe) while lower growth in Russia does not substantially change its share (8.6%, 566 Mtoe). The FED share in south-east Asia changes substantially, from 8.0% in 2016 to 13% in 2050. On the sectoral side, industry remains the largest demand sector throughout the Outlook, while buildings passes domestic transport for second-largest early in the projection.

Projections in the BAU show APEC meeting the ambition set by APEC Ministers and Leaders to reduce energy intensity by 45% by 2035 (compared with 2005 levels) in 2029—i.e. ahead of the proposed deadline. However, the region falls short of two other ambitions. First, it does not meet the APEC aspirational goal to double the share of modern renewables in the energy mix, including electricity generation, by 2030 (against 2010 levels); renewables are doubled, but by 2038, well past the aspirational target date. Second, in this scenario APEC also fails to meet the broader international goal to reduce greenhouse gas (GHG) emissions as set forth in the COP21 Paris Agreement. In related Nationally Determined Contributions (NDCs) and Mid-Century Strategies submitted by APEC economies to the UNFCCC Secretariat, individual APEC economies and the region as a whole fall short of necessary contributions.

APEC TARGET SCENARIO EXPLORES HOW APEC CAN ACHIEVE ITS ENERGY GOALS

APEC Energy Ministers and Leaders have held focused discussions on the growing importance of energy efficiency and cleaner energy supplies as a means of achieving interlinked and mutually beneficial goals of strengthening energy security, supporting economic growth and reducing CO_2 emissions, including at their

9th Meeting (Fukui, Japan; June 2010) (APEC EWG, 2018). By committing to two important aspirational goals, they have demonstrated strong leadership in the development of more sustainable energy systems. 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 EWG, 2018).

The TGT Scenario simultaneously includes both of these two aspirational goals, a significant change from the 6th Edition, in which APERC looked at each goal independently. The new approach allows for more detailed exploration of the ambition needed to achieve these two goals, while also revealing opportunities for additional action and increased ambition from APEC Ministers and Leaders.

Of note is that the energy denominator for the doubling goal is still under discussion within APEC—it could be primary energy, final energy or final energy excluding non-energy use. In order to construct this scenario and evaluate progress towards these two goals, APERC has chosen to use final energy as the basis for modelling. With regards to the doubling renewables goal, APERC retained definitions used in the 6th Edition of this Outlook, which includes modern renewables as defined by the United Nations but excludes traditional biomass (Gritsevskyi, 2009).[3]

2DC SCENARIO EXPLORES HOW APEC CAN ACHIEVE ITS CLIMATE AMBITIONS

APEC recognises the need to strengthen existing low-carbon policies and to introduce an even wider range of strategic policies to support both climate change mitigation and adaptation. With the aim of tackling climate change through regional cooperation, as early as 1993, APEC Leaders voiced their commitment to protecting the environment including the quality of air, water and green spaces through effective management of energy resources and the use of renewable resources to ensure sustainable growth and security (APEC, 1993). Subsequent initiatives by APEC Energy Ministers and Leaders have included fostering collaborations to boost deployment of renewable energy and reduce energy consumption (i.e. to achieve the APEC aspirational goals), while also promoting ocean and forest conservation, encouraging trade of environmental goods, and helping farming and fishing communities adapt to changing weather patterns (APEC, 2015).

In response to these discussions, as well as commitments made by APEC economies in the COP21 Paris Agreement, this edition of the Outlook—for the first time in the Outlook's history—explicitly modelled a 2DC Scenario for the APEC energy sector. This scenario investigates the additional effort needed for economies to significantly reduce GHG emissions from the energy sector as a first step toward achieving their targets in the COP21 Paris Agreement.

The 2DC is broadly in line with the emissions reduction pathway included in *Energy Technology Perspectives* (ETP), published by the International Energy Agency (IEA) (IEA, 2017). Assuming global action, this pathway provides a 50% chance of limiting average global temperature increases to 2°C. Using outputs from the ETP, which applies an integrated cost-optimised modelling approach, the 2DC sets sub-targets for each energy subsector, which determine the proportion of total CO_2 emissions reduction that each would be expected to achieve. This integrated approach shows that it is most cost-effective if some sectors achieve greater CO_2 emissions reduction than others as a proportion of their current emissions levels (Figure 1.5).

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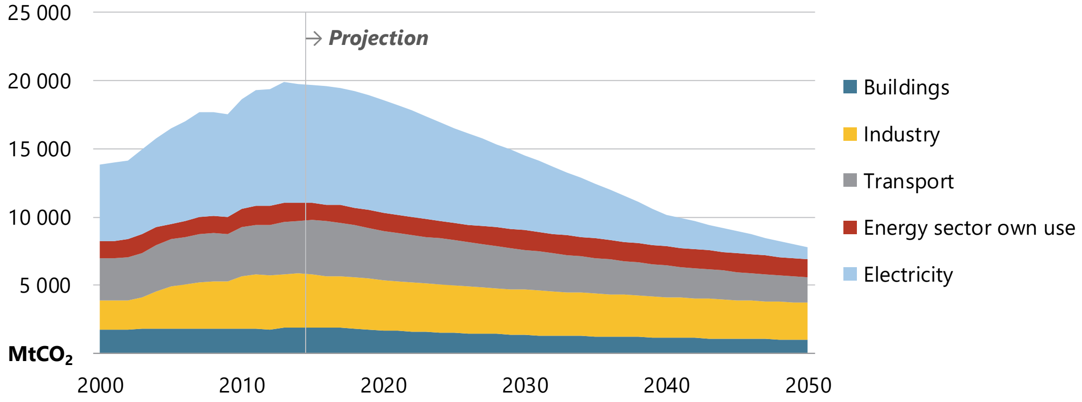
[3] See Appendix I for more details.

The 2DC is also aligned with the COP21 Paris Agreement aims to reduce energy intensity, boost renewables and reduce CO_2 emissions in the quest to constrain global temperature increase to 2°C, in which additional effort needed to reduce GHG emissions from the energy sector plays a critical role.

Figure 1.5 • APEC CO_2 emissions pathway constraints for the 2DC Scenario



Source: APERC Analysis and IEA (2018a).

STRUCTURE OF THE 7TH EDITION

Like the 6th Edition of the *APEC Energy Demand and Supply Outlook*, the 7th Edition comprises two volumes. Volume I focuses on major energy trends and projections for APEC overall. Volume II is a compendium of energy outlooks for each of the 21 APEC economies.

Volume I includes three parts. Part 1 examines the outlook for energy demand (Chapter 2), the electricity sector (Chapter 3) and energy supply (Chapter 4) in the BAU Scenario, which reflects existing policies and largely assumes that recent trends continue. Part 2 explores two alternative energy sector development pathways, namely the TGT Scenario (Chapter 5) and 2DC Scenario (Chapter 6). The potential implications of these scenarios are investigated in Part 3 with regards to energy investments (Chapter 7), energy security (Chapter 8) and energy trade (Chapter 9). Part 3 concludes with discussion of strategies by which APEC could mitigate climate change (Chapter 10).

Volume II includes a detailed outlook for each of the 21 APEC economies, with each chapter comparing major energy demand and supply trends under all three scenarios. Mirroring Volume I, each chapter then examines the implications of these scenarios in terms of energy investment, security and trade. Each chapter in Volume II concludes with recommendations for future policy action that could support energy security and sustainable development in line with APEC aspirational goals and the COP21 Paris Agreement.

2. ENERGY DEMAND OUTLOOK

KEY FINDINGS

- **Under the BAU, FED in APEC grows to 6 562 Mtoe in 2050, a 21% increase from the 2016 level.** This growth is driven primarily by south-east Asia, where GDP per capita rises more than threefold (from USD 12 247 in 2016 to USD 44 922 in 2050) and population grows 24% (from 565 million to 702 million).

- **Industry FED in APEC grows more gradually, rising from 1 802 Mtoe in 2016 to 1 988 Mtoe in 2050 (0.29% CAGR).** This slower rate largely reflects transition from energy-intensive industrial activity to high value-added manufacturing in China associated with shifting economic structure from industry towards the services.

- **Buildings FED increases by 28% to 1 805 Mtoe in 2050 and accounts for 28% of FED.** Space cooling is the fastest-growing source of energy demand in buildings, as rapid economic development makes air conditioners more affordable in south-east Asia.

- **Transport FED grows by 25% (0.67% CAGR) to 1 786 Mtoe in 2050; demand for trucks to move freight, which grows by 48% (1.2% CAGR), is the key driver.** Electrification of transport spurs rapid growth (4.5% CAGR) in electricity demand, mainly driven by passenger travel, as the total light EV fleet grows at 16% CAGR, driven by China (16% CAGR) and the United States (13% CAGR).

- **Agriculture and non-specified energy demand increases by 21% to 234 Mtoe by 2050, representing 3.6% of total FED.** China plays a key role, with its agriculture FED accounting for about one-third of the APEC total.

INTRODUCTION

The Business-as-Usual (BAU) Scenario investigates energy demand trends in the Asia-Pacific Economic Cooperation (APEC) region and reflects existing trends and policies; thus, its projections largely extend the past into the future. Considering the two aspirational goals set by the APEC Ministers and Leaders—to reduce APEC's aggregate energy intensity[4] by 45% by 2035 (from the 2005 level) and to double the share of renewables in the APEC energy mix, including in power generation, by 2030 (from the 2010 level)—analysing the BAU provides insights as to whether current policies are likely to be effective or need to be adapted (APEC, 2018).

Following an overview of final energy demand (FED) in APEC by region, demand sector and fuel type for the BAU, this chapter investigates in detail 2050 projections for each of the four demand sectors: industry, buildings, transport, and agriculture and non-specified. Subsequent sections probe the implications of these projections for each sector, while Volume II of this Outlook provides in-depth information about demand trends in each APEC economy.

Over the Outlook period (2016-50) in the BAU, APEC FED rises from 5 406 million tonnes of oil equivalent (Mtoe) in 2016 to 6 562 Mtoe in 2050, primarily driven by energy demand growth in south-east Asia. Industry remains the highest sectoral contributor to APEC FED throughout the Outlook period, with buildings and transport following behind. While fossil fuels continue to dominate FED in APEC, an increasing share is met with electricity and renewables.

OUTLOOK FOR APEC ENERGY DEMAND

Between 2000 and 2016, FED in APEC grew from 3 910 Mtoe to 5 406 Mtoe, a compound annual growth rate (CAGR) of 2.0%, despite a sudden demand reduction in 2009 because of the global financial crisis. Under the BAU Scenario, FED grows to 6 562 Mtoe in 2050—an CAGR of just 0.57%. This is lower than historic CAGR for two main reasons: the APEC population is projected to peak in 2043 and then remain relatively steady to 2050, and there is an overall trend of decreasing energy intensity of 55% from 2016 to 2050 across the region.

The BAU projections were constructed using five individual models: industry, transport, residential buildings, services buildings, and agriculture and non-specified. The 7th edition of the Outlook uses gross domestic product (GDP), in 2016 USD purchasing power parity[5], from the World Bank for historic data with projections from the Organisation for Economic Co-operation and Development (OECD) and Asia Pacific Energy Research Centre (APERC). Population data and projections are from the United Nations, with the exception of Chinese Taipei, which was projected by APERC. Both GDP and population projections are kept the same across scenarios to facilitate comparison. Detailed methodologies for the macroeconomic model and each demand sector model are available in Annex I.

SOUTH-EAST ASIA CONTINUES TO DRIVE APEC ENERGY DEMAND GROWTH

By 2050, FED in APEC reaches 6 562 Mtoe in the BAU, a 21% increase from 5 406 Mtoe in 2016 (0.57% CAGR) (Figure 2.1). In 2016, the People's Republic of China represented the largest share (37%) of APEC FED with 1 979 Mtoe, followed by the United States (28%, 1 515 Mtoe) and Russia (8.7%, 472 Mtoe). In 2050, China and the United States both show lower shares (35% for China and 26% for the United States) with an absolute growth

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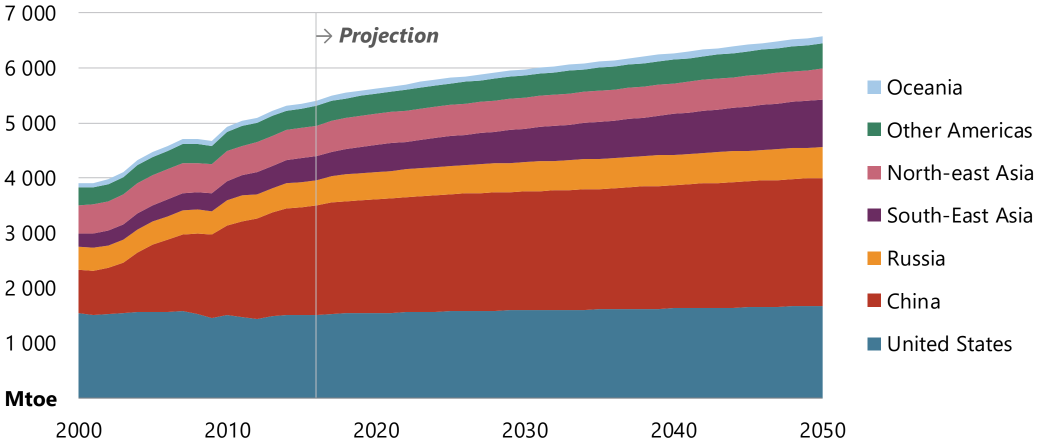
[4] Energy intensity refers to energy use relative to gross domestic product (GDP). Energy efficiency, economic activity and structure of the economy are all important components of energy intensity.

[5] GDP is measured in constant 2016 USD billion, using purchasing power parity to facilitate comparison across economies.

to 2 322 Mtoe (China) and 1 676 Mtoe (United States), while south-east Asia's share increases from 8.0% in 2016 to 13% in 2050.

Figure 2.1 • APEC final energy demand by regional grouping in the BAU, 2000-50



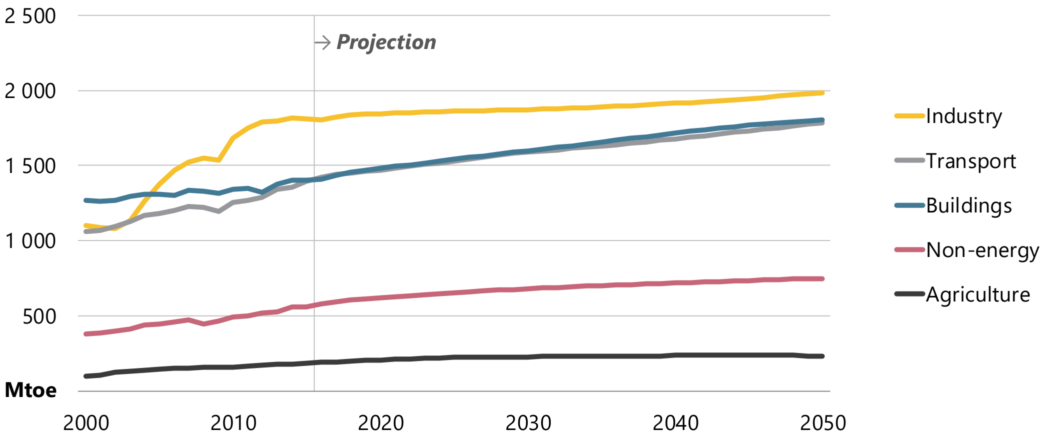
Sources: APERC analysis and IEA (2018a).

Energy demand in south-east Asia grows rapidly under the BAU, from 432 Mtoe in 2016 to 860 Mtoe in 2050 (2.0% CAGR) and is the main driver of APEC FED growth. The growth in south-east Asia is linked to a steep increase in per-capita GDP, which more than triples from USD 12 247 in 2016 to USD 44 922 in 2050, and steady population growth. Other APEC regions show more moderate demand growth with an CAGR of 0.74% in Oceania and 0.70% in other Americas. Demand in north-east Asia grows slightly (0.04% CAGR), reflecting a declining population and energy efficiency improvements in buildings and transport.

INDUSTRY REMAINS THE LARGEST DEMAND SECTOR

Industry has been the largest energy-consuming sector in APEC since 2005, when it overtook buildings largely because of rapid industrial growth in China at the start of the 21st century. Under the BAU, industry remains the largest demand sector despite its moderate growth of 10% in 2050. The second-largest demand sector, buildings, shows larger growth of 28% over the Outlook period, as does the third-largest demand sector, transport, with growth of 25% (Figure 2.2).

Figure 2.2 • APEC final energy demand by sector in the BAU, 2000-50



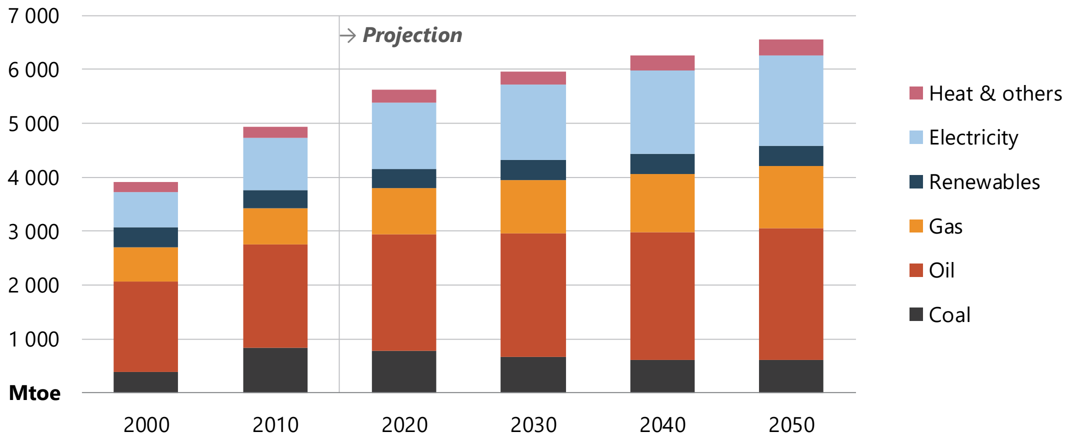
Sources: APERC analysis and IEA (2018a).

The main driver of FED growth in buildings is rapidly increasing floor area and GDP in south-east Asia, where floor area more than doubles over 2016 levels while per-capita GDP reaches USD 44 922 in 2050 compared with USD 12 247 in 2016.

FOSSIL FUELS REMAIN DOMINANT BUT FUEL MIX SWITCHES TO CLEANER FUELS

Fossil fuels remain the dominant energy source in APEC FED over the Outlook period; fossil fuel demand rises by 14% to 4 212 Mtoe in 2050 while the share of fossil fuels declines by 4.2% to 64% (Figure 2.3). Significant switching from coal to gas is projected, prompting the share of coal to decline from 15% to 9.2% while that of gas rises from 14% to 18%. This shift occurs mainly in buildings (for water heating and cooking end-uses). Fuel switching also occurs in transport, where demand for clean fuels such as hydrogen and electricity increases against that for oil products. The electricity share in FED increases from 21% in 2016 to 26% in 2050, linked to its use in space cooling and cooking, as well as growing uptake of electric vehicles (EVs).

Figure 2.3 • Final energy demand by fuel in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

Renewables show overall growth in direct use by end-use sectors (i.e. buildings, industry and transport) from 331 Mtoe in 2016 to 376 Mtoe in 2050 in the BAU, largely driven by the transition away from conventional fuels to biofuels in transport. This growth is in line with the increasing use of modern renewables in transformation sectors. When the use of renewables in electricity generation is included and that of traditional biomass in buildings is excluded, total demand for renewables grows from 400 Mtoe to 801 Mtoe.

INDUSTRY ENERGY DEMAND

Industry is currently the largest end-use energy demand sector in APEC, accounting for 1 802 Mtoe of FED in 2016. Non-energy demand, most of which is associated with industrial processes, accounted for a further 577 Mtoe in 2016. The industry model used to project energy demand to 2050 includes eight energy-intensive subsectors: iron and steel, non-metallic minerals, chemical and petrochemical, paper and pulp, aluminium, mining, others[6] and non-specified.[7]

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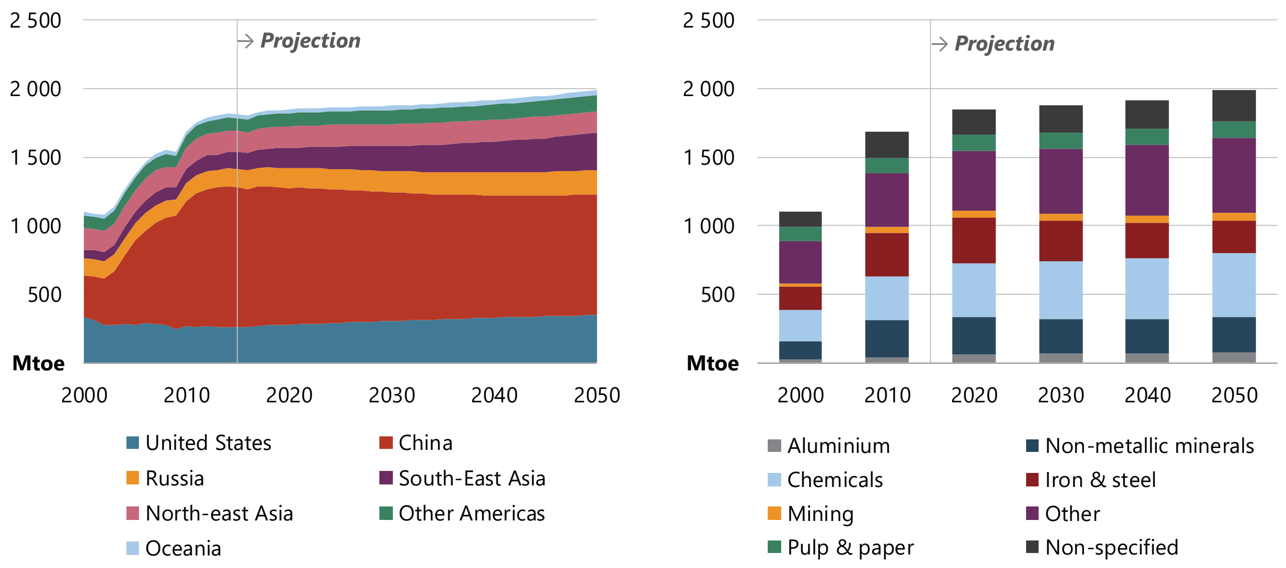
[6] Energy consumption for producing non-ferrous metals (except for aluminium) as well as transport equipment, machinery, food and tobacco, wood and wood products, construction, textiles, and leather.

[7] Energy consumption for subsectors not covered above, including manufacture of rubber and plastics products, furniture, jewellery, bijouterie and related articles, musical instruments, sporting goods, games and toys, medical and dental instruments and supplies, and other manufacturing not classified elsewhere.

INDUSTRY GROWS MOST QUICKLY IN SOUTH-EAST ASIA

Industry FED grew steadily from 1 103 Mtoe in 2000 to 1 802 Mtoe in 2016 (3.1% CAGR), with a notable drop in 2009 as the financial and economic crisis led to lower activity and declining demand in APEC—except in China. Over the Outlook period, industry demand in APEC grows more gradually in the BAU, rising to 1 988 Mtoe in 2050 (0.29% CAGR) (Figure 2.4). Energy demand for industry grows most quickly in south-east Asia, from 124 Mtoe in 2016 to 271 Mtoe in 2050 (CAGR 2.3%), underpinned by rapidly expanding GDP per capita (3.9% CAGR over the Outlook period).

Figure 2.4 • Industry final energy demand by region and subsector in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

In 2016, the three largest energy consumers in APEC were China (1 003 Mtoe, 56%), the United States (264 Mtoe, 15%) and north-east Asia (154 Mtoe, 8.5%). In 2050, FED volumes grow and shares change but the ranking of the top two spots stays the same: China (878 Mtoe, 44%) and the United States (349 Mtoe, 18%). By 2023, south-east Asia (157 Mtoe, 8.5%) overtakes north-east Asia to claim the third spot.

CHEMICAL AND PETROCHEMICAL SUBSECTOR TO LEAD INDUSTRY GROWTH

In the APEC region, chemical and petrochemical, iron and steel, and non-metallic minerals are the three largest energy-consuming subsectors in industry.[8] In 2016, FED in the industry sector reached 1 802 Mtoe. Chemical and petrochemical was the largest industrial subsector, representing 360 Mtoe (20%) of industry FED, followed by iron and steel (19%), non-metallic minerals (15%), non-specified (10%), pulp and paper (6.2%), and aluminium (3.4%). Industry energy demand rises to 1 988 Mtoe in 2050 in the BAU Scenario. Chemical and petrochemical grows the most rapidly at an CAGR of 0.74%, followed by mining (0.57%). As production is cut in China, declines are projected in iron and steel (-1.0% CAGR) and non-metallic minerals (-0.18% CAGR) (see next section for more details).

Growth in the chemical and petrochemical subsector comes mainly from Indonesia, where demand almost triples, from 3.4 Mtoe in 2016 to 13 Mtoe in 2050 because of expansion of chemical and petrochemical plants. Industry energy demand grows rapidly in south-east Asia (2.3% CAGR) and Russia (0.79% CAGR). In Russia, this reflects

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[8] The discussion excludes the 'other' subsector because it includes various industrial subsectors and different products.

the promotion of an import substitution program, which boosts energy demand in the chemical and non-metallic minerals subsectors (TASS, 2017).

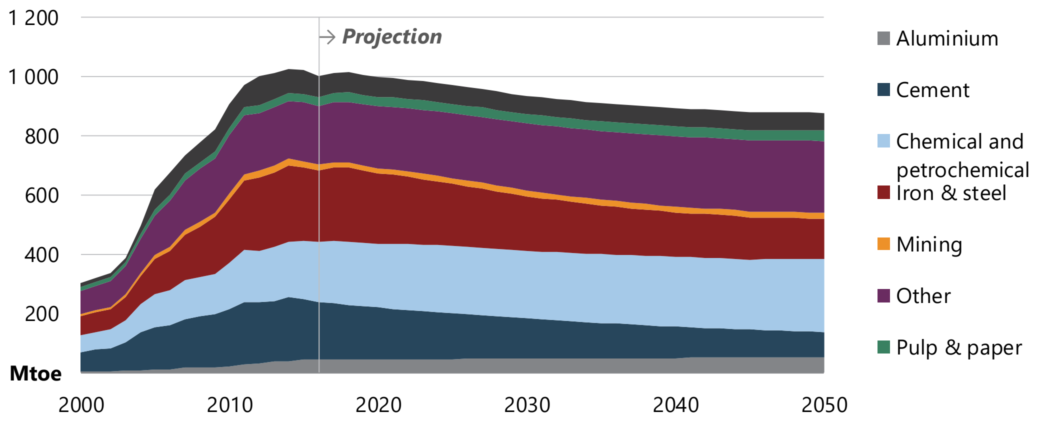
CHINA'S INDUSTRY STRUCTURE CHANGES FROM 2016-50

China's energy demand from industry grew rapidly from 302 Mtoe in 2000 to 1 003 Mtoe in 2016 (7.8% CAGR). This rapid growth slows in the BAU Scenario, primarily because the economy is shifting away from energy-intensive industrial activity and towards modern manufacturing and services; the latter shifts energy away from industry to buildings.

In 2016, iron and steel consumed more energy than any other industry subsector in China, accounting for 24% of total demand, followed by chemical and petrochemical (20%) and non-metallic minerals (19%). As China's demand for buildings construction is declining along with the gradually saturated real estate market, iron and steel declines by 43% and non-metallic minerals by 56% over the Outlook period, while other industrial subsectors show steady growth between 8.5% and 22% in 2050.

These structural changes result in negative FED growth of 13% for Chinese industry in the BAU Scenario, from 1 003 Mtoe in 2016 to 878 Mtoe in 2050. The share of energy demand for the chemical and petrochemical subsector increases, overtaking iron and steel as the largest energy-consuming subsector by 2023 (Figure 2.5). The share of chemical and petrochemical continues growing through 2050 with FED reaching 246 Mtoe (28% of total industry demand). In second place, iron and steel reaches 136 Mtoe (16%), followed by non-metallic minerals at 86 Mtoe (9.8%).

Figure 2.5 • China's industry final energy demand in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

BUILDINGS ENERGY DEMAND

In 2000, the buildings sector (residential and services) was the largest consumer of energy in APEC, with 1 269 Mtoe (32% of total FED). Over the following 16 years, buildings demand grew by 11% to 1 409 Mtoe, driven mainly by population growth. Despite this, the buildings FED share dropped to 26% in 2016, as industry and transport sectors grew at higher rates. Together, the United States and China accounted for 61% of buildings FED in 2016.

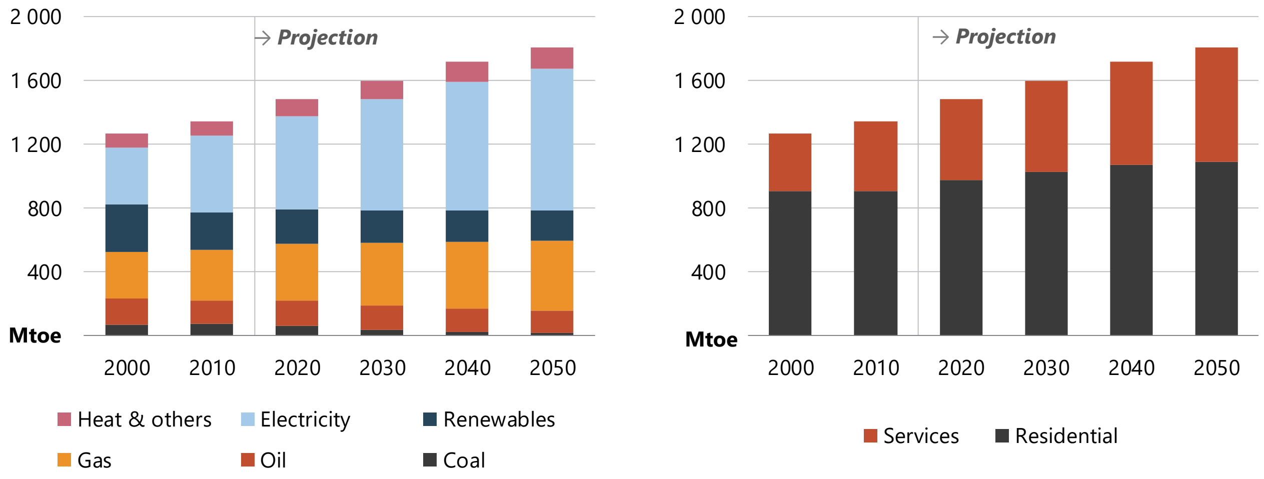
By 2050, buildings energy demand in APEC increases to 1 805 Mtoe under the BAU and accounts for 28% of FED. Rising demand (0.73% CAGR) is driven by the two-pronged effect of growing population, which pushes up demand for residential dwellings as well as services, and economic growth in APEC's developing economies, which increases the population's ability to supply and consume energy services. Demand in south-east Asia grows most quickly from 2016 to 2050, increasing by 101 Mtoe (79%), an CAGR of 1.7%. However, the United States and China still dominate energy demand in buildings in 2050, together representing 63% of total demand in APEC in the BAU.

Energy demand in the services subsector[9] grows more quickly than in residential buildings because of two dynamics. Increasing population and rising urbanisation drive up demand for services such as schools, health-care facilities and commercial spaces at the same time that a shifting economic structure, particularly in China, results in services growing relative to other sectors such as heavy industry. Overall, 61% of APEC energy demand growth in buildings over the Outlook period comes from services, resulting in its share increasing to 40% in 2050, from 34% in 2016.

ELECTRICITY AND NATURAL GAS CONTINUE TO DISPLACE COAL AND BIOMASS

While overall energy demand growth in buildings rises by 28% from 2016 to 2050 under the BAU, significant changes occur in terms of fuel use (Figure 2.6). This scenario projects a general shift away from the traditional use of biomass and direct use of coal in order to improve indoor air quality and reduce resulting negative health impacts. Traditional biomass is replaced by higher-quality energy forms such as electricity and natural gas, which tempers energy demand increases,[10] particularly for residential buildings.

Figure 2.6 • Buildings final energy demand by fuel and subsector in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

This trend is reflected in a 77% reduction in coal from 2016 to 2050, and a 13% reduction in renewables. For the latter, reductions in demand for traditional biomass are somewhat masked by increases in other modern renewables (such as solar thermal). Reductions in the use of lower-quality fuels are outweighed by a 66% increase in electricity demand and a 32% increase for natural gas.

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[9] The services subsector includes buildings used for conducting businesses such as offices, shops, restaurants, etc., as well as those that provide services such as government premises, schools, hospitals, etc.

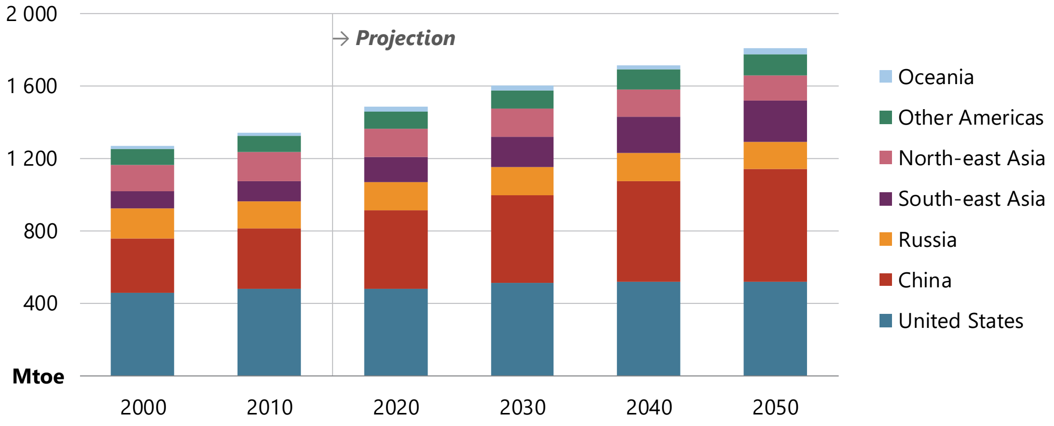
[10] Since biomass is much less efficiently converted to final energy than electricity, gas or oil products.

THE UNITED STATES REMAINS LARGEST BUT SOUTH-EAST ASIA GROWS FASTEST

China, the United States and Russia were the three largest energy consumers in the APEC buildings sector in 2016, collectively representing 72% of FED, which was 1 409 Mtoe. From 2000 to 2016, China dominated buildings growth, increasing from 407 Mtoe to 623 Mtoe (its share rising from 29% to 35%). The United States, other Americas and north-east Asia showed slower relative growth, leading to a smaller share of total buildings demand. Russia was the only economy to show demand decline over that period.

This dynamic is projected to change over the Outlook, with south-east Asia becoming the engine of APEC buildings energy demand growth (Figure 2.7). Projected population growth of 0.64% (CAGR) and even more rapid GDP growth (4.6% CAGR) in that region results in increasing floor area (more than doubling) and higher energy use associated with greater penetration of appliances (air conditioners in particular). Structural shifts in south-east Asian economies towards the services subsectors (from industry) and increasing urbanisation also contribute to higher energy demand and a changing fuel mix.

Figure 2.7 • Buildings final energy demand by region, 2000-50



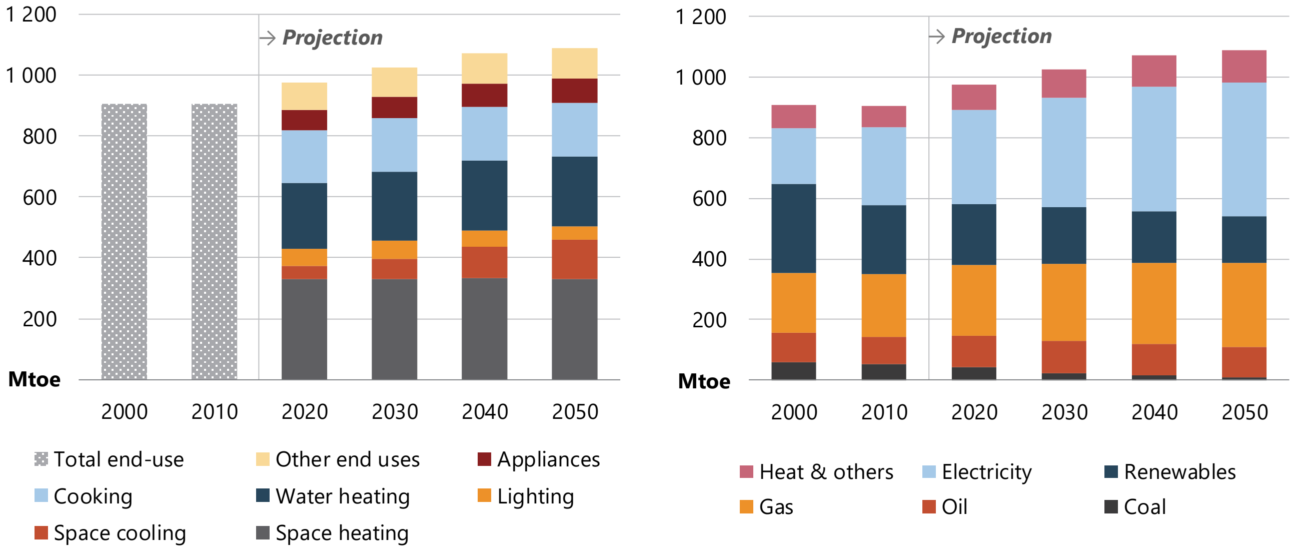
Sources: APERC analysis and IEA (2018).

Buildings energy demand growth tapers somewhat over the Outlook period in the United States (14%) because of stricter energy efficiency standards and slowing growth in floor area and population, but grows strongly in China (53%), mainly due to structural change in the economy. Demand also grows in the other Americas and Oceania regions, mainly because of GDP and population growth in Mexico and Australia. Between 2016 and 2050, energy use contracts in Russia (-3.3%) and north-east Asia (e.g. -18% in Japan) as populations decline.

HEATING REMAINS DOMINANT BUT COOLING DRIVES RESIDENTIAL GROWTH

Space and water heating and cooking are the dominant end-uses in residential energy demand, together accounting for three-quarters of total demand. At a share of 34%, space heating was the largest end-use in 2016, with demand mainly concentrated in a few large economies with cold climates, including Russia, the United States, China, Canada, Japan and Korea. As heating is extensively developed in these economies, decreasing populations (in both Russia and Japan) and increased use of more efficient technologies (e.g. heat pumps and improved building envelopes) moderate demand growth to only 4.6% over the Outlook period (Figure 2.8). Overall APEC demand grows slightly for cooking (0.73%) and water heating (9.5%); in 2016, cooking accounted for 19% of buildings energy demand and water heating 22%. Fuel switching in cooking helps to drive efficiency improvements, particularly in developing economies, while technology improvements help to curb demand growth in water heating.

Figure 2.8 • Residential subsector final energy demand by end-use and fuel in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

Space cooling is the fastest-growing source of buildings energy demand in the BAU, as rapid economic development makes air conditioners more affordable in south-east Asia. In Indonesia, Thailand and Viet Nam, ownership rates of air conditioners more than double. APEC space cooling demand increases by 257% over the Outlook, all of which is supplied with electricity.

The largest reductions in buildings FED come from increased efficiency in lighting, as APEC economies switch from incandescent bulbs to more efficient options (such as LEDs). In many APEC economies, recent policies now ban the sale of incandescent bulbs or extend subsidies and other incentives to promote efficient lighting (APEC, 2017a).

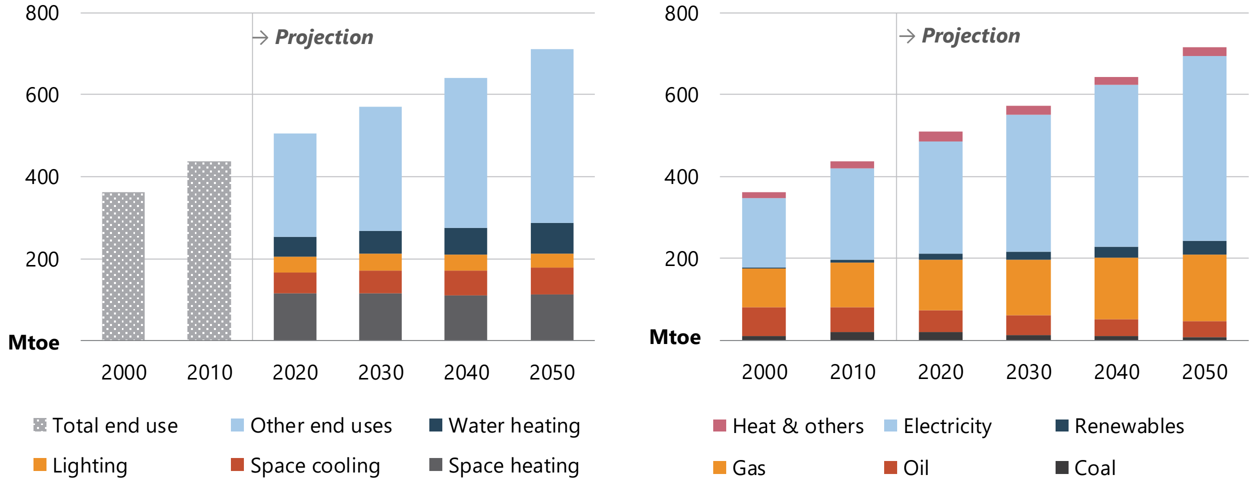
SERVICES DEMAND GROWS STRONGLY TO 2030 BECAUSE OF RISING GDP

Rising GDP and growing populations in APEC stimulate a 51% increase in services FED from 2016 to 2050 in the BAU (Figure 2.9). Growth occurs steadily through the Outlook period despite population growth plateauing (0.05% CAGR) after 2030, when shifting economic structure, away from industry towards the services subsector (resulting in floor area increasing by 100% by 2050), becomes the key driver. Most (86%) of this increased demand for services is met using electricity.

The government of China has targeted the services subsector as a critical area of economic growth in its current five-year plan. The plan targets expansion of the services subsector portion of total GDP from 50.5% in 2016 to 56% in 2020, coupled with 'innovation driven development' underpinning economic growth. This focus is assumed to drive long-term expansion in services, reaching 71% of GDP by 2050. Reflecting the changes in services GDP, services sector FED more than triples from 82 Mtoe in 2016 to 249 Mtoe in 2050.

The tightening and enforcement of building energy codes, coupled with the uptake of more efficient appliances (e.g. motors, heating and cooling systems, lighting devices), improve overall efficiency in services buildings to moderate some of this rapid growth in service floor area. Across APEC, 17 economies[11] have already implemented energy efficiency codes or standards for services buildings (APEC, 2017b).

Figure 2.9 • Services subsector final energy demand by end-use and fuel in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

Space heating demand in services declines by 0.89% over the Outlook period as appliance and buildings improvement rates slightly outpace the increase in floor area. Conversely, space cooling demand increases by nearly 41% by 2050, driven by high growth in economic activity that outpaces technology improvements. Similarly to residential buildings, lighting demand declines as more efficient options (such as LEDs) are introduced more widely across APEC, leading to a decline of 5.6% by 2050. Demand grows for water heating (66%) and other end-uses (84%) over the Outlook as increasing floor area outpaces technology efficiency improvement.

TRANSPORT ENERGY DEMAND

Since 2000, APEC's domestic transport energy demand has increased at an CAGR of 1.9%, largely because of growth in China and south-east Asia, to reach 1 425 Mtoe in 2016, with road transport accounting for the largest share (84%). Freight represents 44% of domestic transport demand, with a road freight share of 79% in 2016, followed by pipelines (8.3%). Passenger travel accounts for the remaining 56% of domestic transport demand with the light road vehicle share reaching more than 80% in 2016, while a corresponding decline is seen in the share of public transport.

This trend continues in the BAU Scenario, with transport FED increasing by 25% to 2050. Rising incomes (GDP per capita increases by 149%) prompt a steep increase in the APEC vehicle stock, particularly of light-duty vehicles (LDVs). By 2050, there are 385 million more LDVs on APEC roads than in 2016 (an additional 204 million in China, 48 million in the United States and 30 million in Indonesia), an increase of 74%.

Increasing global trade boosts freight activity in APEC while rising standards of living push up demand for personal and public transport, leading to an increased number of road vehicles and other modes of passenger transport. Road congestion, already a trademark of cities such as Jakarta and Moscow, worsens with increasing

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[11] APEC economies with building energy codes as of 2017: Australia; Canada; China; Hong Kong, China; Indonesia; Japan; Korea; Malaysia; Mexico; New Zealand; Peru; Philippines; Singapore; Chinese Taipei; Thailand; the United States and Viet Nam.

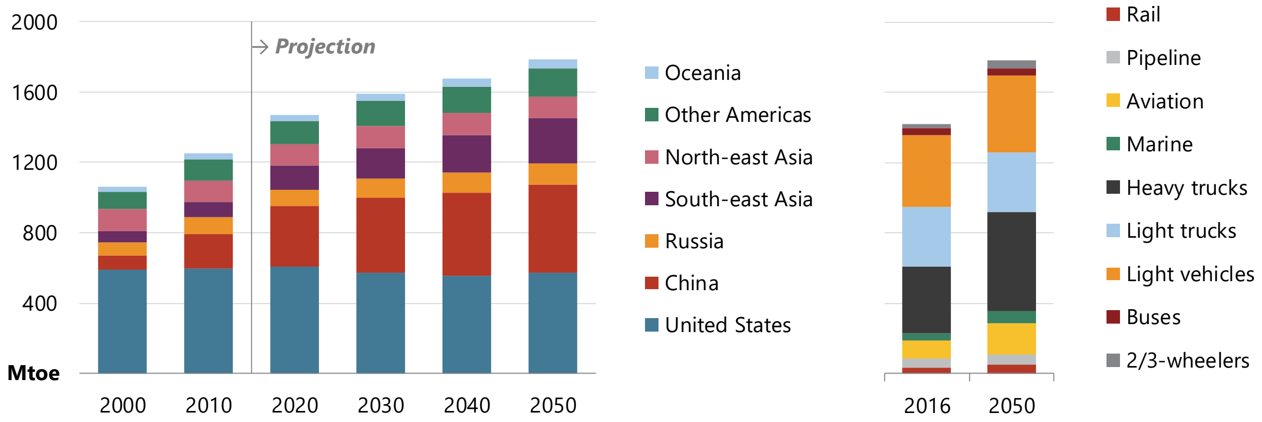
urbanisation and densification. Municipal authorities are mitigating congestion by supporting public over private transport options. Jakarta, for instance, is establishing a bus rapid transit system (ITDP, 2018), while a sustainable urban transport program in Bangkok aims to integrate transportation systems and improve the logistics of delivering goods (BMA, 2015).

Some APEC economies have adopted policies that support shifts towards more advanced technologies in road transport. The United States offers federal tax credits for the purchase of EVs (CalEPA, 2012) and plug-in hybrids, as does Japan for hybrid and hydrogen vehicles and EVs (MLIT, 2018). Other economies use other policy instruments to promote switching from conventional liquid-fuel vehicles to EVs and hybrids. In rail, there is a clear trend towards electrification and switching from conventional to hybrid diesel locomotives and natural gas in non-electrified areas.

ROAD REMAINS DOMINANT IN FREIGHT AND PASSENGER TRANSPORT

In the BAU Scenario, energy demand in domestic transport grows 25%, from 1 425 Mtoe in 2016 to 1 786 Mtoe in 2050 (0.67% CAGR), driven by rapid growth in south-east Asia (111%) and China (70%) (Figure 2.10). This increase reflects growing economies and populations, the effects of which are only partially offset by improved fuel efficiency. Conversely, fuel efficiency policies and switching to advanced vehicles[12] stimulate declining domestic transport energy demand in Japan (-15%) and the United States (-8.3%).

Figure 2.10 • Domestic transport final energy demand, by region and mode in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

Road transport continues to dominate transport FED by 2050, accounting for 80% of freight and 80% of passenger demand, but its share declines from 84% in 2016 to 80% while that of domestic aviation grows from 7.0% to 9.9%. Substantial economic growth drives up demand for freight services, which increases by 81%. Overall, the share of energy demand for road freight transport grows from 42% to 51% of total road transport, because of a strong reliance on heavy-duty vehicles (HDVs) to move freight, and relatively smaller improvements in their fuel economy (compared with efficiency gains for LDVs).

Energy demand for freight transport grows from 632 Mtoe in 2016 to 908 Mtoe in 2050 (1.1% CAGR); demand growth for passenger transport is much lower, from 788 Mtoe to 873 Mtoe (0.30% CAGR), due to fuel economy standards for new passenger vehicles. Economies driving this growth are Indonesia (249% freight demand

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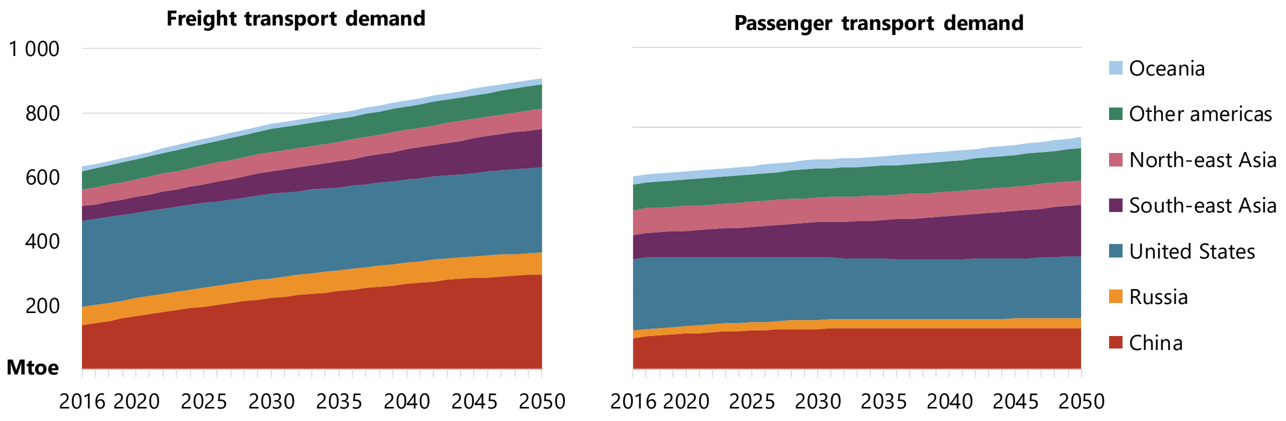
[12] Advanced vehicles are gasoline and diesel hybrid, plug-in hybrid, battery electric and fuel cell electric vehicles.

growth and 68% passenger demand growth) and China (115% freight and 31% passenger), offset by reductions in the United States (-1.9% freight and -13% passenger).

ENERGY EFFICIENCY AND FUEL SWITCHING BOTH INCREASE

Overall energy efficiency of freight operation in APEC improves by 21% from 2016 to 2050 in the BAU, as the HDV fleet gradually renews with more fuel-efficient engines, load utilisation increases, and route optimisation that reduces vehicle mileage (Figure 2.11). For passenger transport, average energy efficiency improves by 34%, reflecting policy-driven adoption of fuel-efficient vehicles and a growing share of advanced vehicles. Between 2015 and 2025, the United States, Canada and Mexico implement Corporate Average Fuel Economy (CAFE) standards to mandate short-term fuel economy improvements in new LDVs. In Japan, government support boosts the uptake of hybrids and plug-in hybrids.

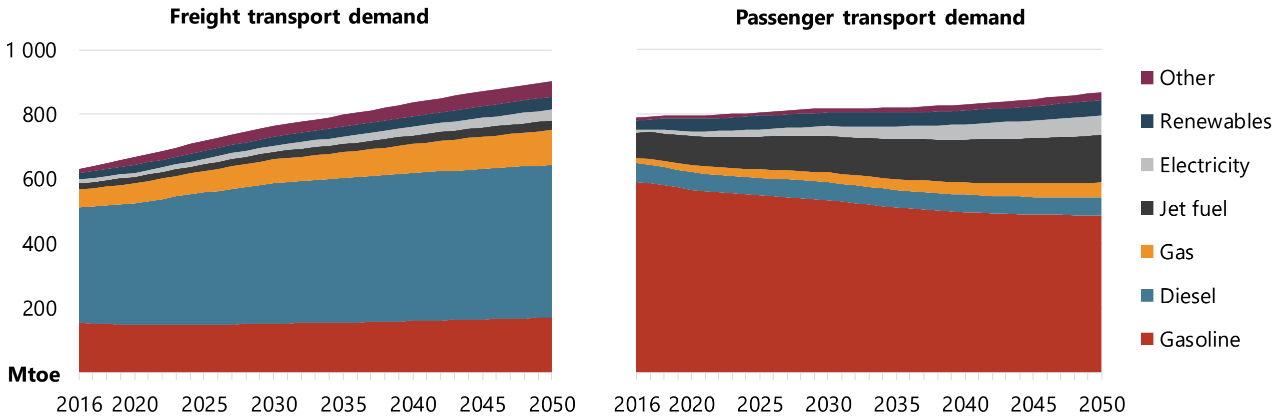
Figure 2.11 • Energy demand for freight and passenger transport, by region in the BAU, 2016-50



Sources: APERC analysis and IEA (2018a).

Oil continues to dominate transport in the BAU, though its share in transport FED declines from 90% in 2016 to 80% in 2050, while the share of natural gas rises from 5.1% to 8.7% and electricity grows from 1.5% to 5.4% (Figure 2.12). Following this general trend, the share of oil for freight declines from 86% to 79%, natural gas rises from 9.0% to 12%, and electricity increases from 1.9% to 3.7%. In passenger transport, the share of FED supplied by oil declines from 93% to 81%, with part of the resulting gap filled by natural gas, which rises from 2.0% to 5.4%, and by renewables (i.e. biofuels), which grow from 3.6% to 5.4%. Electricity use for passenger transport shows meteoric growth, increasing from 1.0% to 7.1% of transport FED. This is driven by the light EV fleet growing at 16% CAGR, becoming 15% of total fleet by 2050; most of the fleet increase occurs in China (16% CAGR) and the United States (13% CAGR).

Figure 2.12 • Fuel shares for freight and passenger transport in the BAU, 2016-50



Sources: APERC analysis and IEA (2018a).

Gasoline and diesel remain the dominant fuels for road transport, although their share drops from 93% (62% gasoline and 31% diesel) to 79% (46% gasoline and 33% diesel) of domestic transport FED. Gasoline demand also declines in absolute terms, from 742 Mtoe to 657 Mtoe, because of fuel efficiency policies and fuel switching in passenger vehicles. Diesel demand remains robust, increasing from 418 Mtoe to 534 Mtoe, mainly due to the growth of freight transport pushing up diesel demand for HDVs.

Heavy trucks provide the bulk (92%) of road freight service in 2050, reflecting their long-distance hauling capabilities. Light trucks provide urban and suburban delivery services. In the BAU, the HDV stock increases from 35 million to 81 million vehicles over the Outlook period while average annual mileage decreases from 34 333 kilometres (km) to 31 030 km per year, per vehicle.

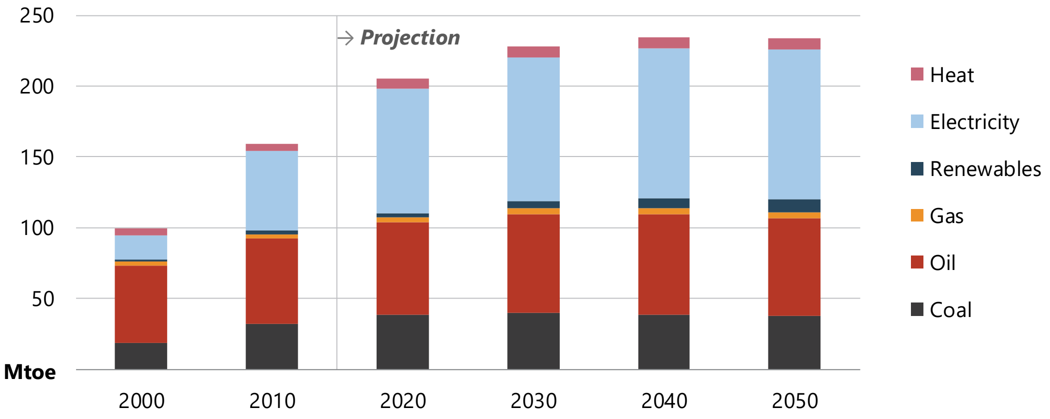
AGRICULTURE AND NON-SPECIFIED ENERGY DEMAND

At present, oil products (diesel, gasoline and liquefied petroleum gas) supply the bulk of agriculture energy demand, followed by electricity. Both fuels are used to operate agricultural machinery, power water-pumping motors, and in activities such as sowing, irrigating, harvesting and fishing. Use of renewables in agriculture is small but growing. Some economies also use coal and natural gas, mainly for low-temperature heat (such as in greenhouses).

For non-specified energy demand, this Outlook follows the International Energy Agency (IEA) definition referring to ‘all fuel use not elsewhere specified for which separate figures have not been provided.’ Generally, it is a residual value or statistical discrepancy that varies significantly from economy to economy and includes military fuel use for mobile and stationary consumption (e.g. ships, aircraft, road transport and energy used in living quarters) (IEA, 2018a).

In 2016, agriculture and non-specified energy demand was 193 Mtoe in APEC—just 3.6% of FED (Figure 2.13). Under the BAU, energy demand for this sector grows by 21% (0.57% CAGR), reaching 234 Mtoe in 2050 (3.6% of FED).

Figure 2.13 • Agriculture and non-specified final energy demand by fuel in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

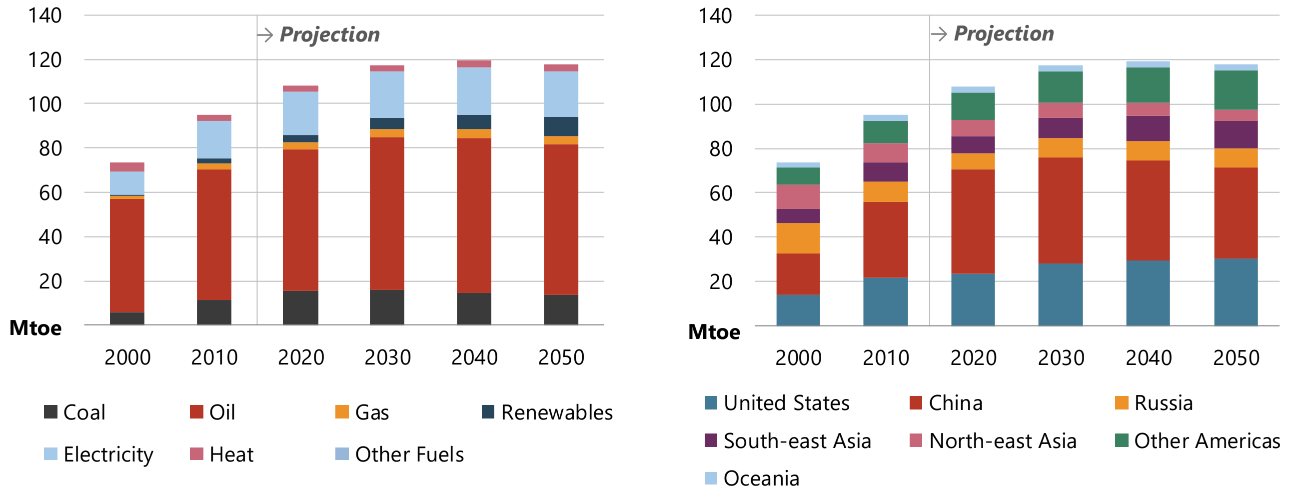
AGRICULTURE ENERGY DEMAND MAINLY DRIVEN BY TRENDS IN CHINA

In 2016, agriculture accounted for 102 Mtoe of demand across APEC, just 1.9% of FED across all sectors. Under the BAU, it grows by 16% to 118 Mtoe by 2050 (1.8% of FED) (Figure 2.14). Adoption and intensified use of agricultural machinery, such as tractors and harvesters as well as irrigation systems and heating systems in greenhouses, drive up demand, particularly in cold temperature regions (Bartok, Jr., 2018). In 2016, oil was the dominant fuel in agriculture, representing 58% of demand. In the BAU, oil maintains its dominance of FED and grows by 16%, while demand for electricity increases by around 5.7%.

China accounted for the bulk (42%; 43 Mtoe) of APEC agriculture energy demand in 2016, followed by the United States (20%) and Russia (8.6%). In the BAU, China's agriculture energy demand quickly grows 12% by 2030 but then decreases thereafter to 41 Mtoe in 2050 (35% of APEC total) (Figure 2.14). The United States remains second at 30 Mtoe (35%) and Russia remains third at 8.9 Mtoe (7.6%) of agriculture FED. On a regional basis, demand in south-east Asia (12 Mtoe) and other Americas (18 Mtoe) considerably surpass that of Russia (8.9 Mtoe).

In some APEC economies, a significant share of agriculture is still done by traditional means, using animal and human power, particularly in south-east Asia and other Americas. These economies show growth in energy demand during the Outlook period, partly driven by the modernisation of the sector—with increased machinery and water pumping—rather than an increase of agricultural activity. On the other hand, the technological advancement and increased fuel efficiency of agricultural machinery are projected to decrease energy demand in the sector.

Figure 2.14 • Agriculture energy demand by fuel and region in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

Two APEC economies—Hong Kong, China and Singapore—are assumed to have zero energy demand in agriculture throughout the Outlook period. Hong Kong, China has historically reported agricultural energy demand as being zero; Singapore has done so since 2005. Modelling results for Canada, New Zealand and the United States were adjusted in response to economy feedback as discussed in Annex I.

Machinery accounts for most energy consumption in agriculture; its energy efficiency depends on technological improvements. An opportunity exists in promoting fuel switching to electricity or the use of biofuels. However, without additional policy support, this sector presents challenges similar to those of HDVs in transport—namely, few options to substitute oil products to fuel agriculture machinery.

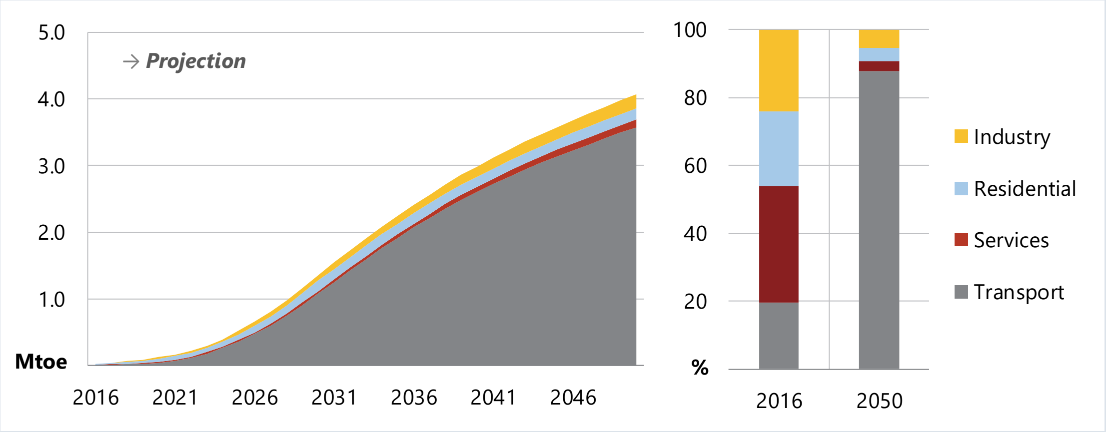
Increased use of renewables for local electricity and heat generation could reduce agriculture's dependence on fossil fuels. Solar technologies, for example, could be used in some regions to generate electricity for water pumping, reducing fossil fuel use with relatively low investments (Chandel, Naik, & Chandel, 2015). Bioenergy or solar heating technologies could supply direct heating needs in greenhouses, offsetting coal demand.

Electricity and oil product use by agricultural producers is subsidised in most APEC economies, which directly influences agriculture energy demand and can lead to excessive or wasteful use. Eliminating these subsidies could represent an opportunity to significantly improve the efficiency of energy use in agriculture across APEC, but additional study is required.

Box 2.1 • Use of hydrogen in APEC

Hydrogen and fuel cell technologies are being increasingly deployed in APEC economies, particularly in China, Japan, Korea and the United States. These technologies have significant potential across buildings (residential and services), industry and transport as a supplement to or replacement for other fuels. For example, hydrogen can power high-efficiency fuel cell batteries (FCBs) in buildings or fuel cell electric vehicles (FCEVs) in transport. It can also provide emergency backup power in the services subsector, especially for telecommunications (data centres and communication towers), warehouses with cold storage, and in certain manufacturing processes (e.g. wafer fabrication) that have a high sensitivity to power outages. Detailed assumptions about hydrogen use in APEC for the three scenarios are found in the Annex I.

Figure 2.15 • Hydrogen demand by sector and share in the BAU, 2016-50



Source: APERC analysis.

In 2016, buildings accounted for the largest share of hydrogen demand in APEC, due in large part to Japan's successful fuel cell commercialisation program. By 2050, transport represents 88% of total hydrogen demand in the BAU, with the majority (79%) of this demand coming from China. The increase of hydrogen use in transport has the largest impact on passenger vehicles: FCEVs make up 2.1% of the vehicle fleet by 2050. Hydrogen demand from buildings increases in absolute terms (from 0.016 Mtoe to 0.28 Mtoe) but decreases dramatically in overall share of hydrogen (from 56% to 6.8%). Total FCB deployment reaches 9.8 GW in 2050, almost equal to the electricity generation capacity of New Zealand in 2016.

PROGRESS ON APEC ASPIRATIONAL GOALS

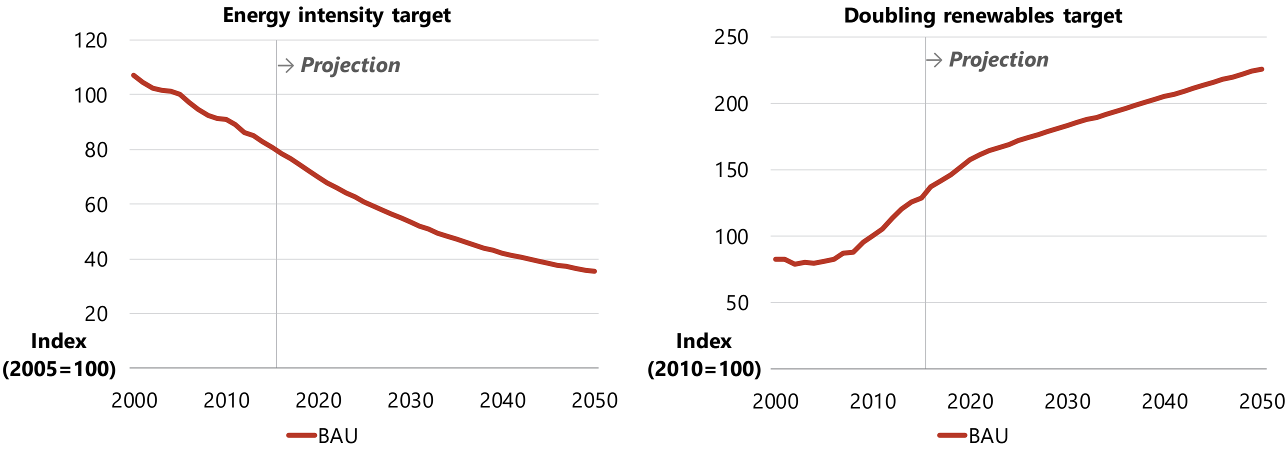
As set out in the 2011 and 2014 APEC Economic Leaders' Declaration (and covered in more detail in Chapter 5), APEC Ministers and Leaders have identified two aspirational goals for the region:[13]

- To reduce APEC's aggregate energy intensity by 45% from 2005 levels by 2035.
- To double the share of renewables in the APEC energy mix, including in power generation, by 2030 (compared with 2010 levels).

To achieve the APEC energy intensity reduction goal by 2035, member economies have adopted a range of energy efficiency improvement policies, as well as measures and incentives to reduce energy intensity in key demand sectors. China, for example, has implemented supply-side reform to reduce iron and steel production, its most energy-intensive industry subsector. In buildings, most APEC economies have started moving towards more efficient lighting technologies and have adopted more energy efficient building codes and appliance standards. In transport, some APEC economies have become leaders in supporting advanced technologies in road transport, including more efficient drive trains, such as hybrids, and switching from conventional liquid fuel vehicles to EVs. Rail transport shows a clear trend towards electrification, with potential switching from conventional diesel to diesel hybrids and natural gas in non-electrified areas.

As a result of these efforts, APEC FED under the BAU reaches the energy intensity goal of 45% reduction against the 2005 level in 2029—six years ahead of the 2035 target (Figure 2.16).

Figure 2.16 • BAU: Energy intensity and doubling renewables targets, 2000-50



Sources: APERC analysis and IEA (2018a).

Progress on increasing the share of renewables has been slower; in fact, this APEC aspirational goal is not met in the BAU Scenario. There are incremental advances, however, with the two largest contributions of incremental renewables growth coming from transport and power generation. In transport, the share of renewables increases from 3.0% in 2016 to 4.2% in 2050 with greater adoption of biofuels. The renewables share in power generation grows from 21% in 2016 to 32% in 2050, reflecting greater deployment of wind power and solar photovoltaic. It seems clear, however, that additional policy action is needed to accelerate adoption of renewables to meet the APEC aspirational goal.

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[13] Both of these goals are APEC-wide collective targets and do not specify particular targets for individual economies.

OPPORTUNITIES FOR POLICY ACTION

As APEC population and GDP per capita continue to grow, energy demand under the BAU Scenario rises by 21% from 2016 to 2050. This growth highlights the importance of energy efficiency improvements to help lessen the pressure on limited energy resources and to support goals of using more renewables and reducing greenhouse gas emissions.

In the BAU, the APEC energy intensity target is successfully met in 2029—six years ahead of schedule—suggesting that existing energy efficiency policies are likely to be effective. The doubling renewables goal, however, is not achieved during the Outlook period, highlighting the need for additional policy action.

To achieve the renewables goal, as well as support other sustainable development goals, APEC member governments should design both short-term (5 to 10 years) and long-term (10 years or more) policy plans that focus on accelerating the adoption of renewables to meet demand. In parallel, continuing improvement in energy efficiency can help reduce overall demand, thereby boosting the share renewables represent within supply.

In the shorter term, governments should strengthen current energy efficiency policies for all demand sectors, particularly in transport where energy demand rises sharply in the BAU. Economies that do not currently have energy efficiency policies can gather successful examples from other economies through processes such as the APEC *Peer Review on Energy Efficiency*, which has plans for each demand sector. Incentive schemes and financial support have been shown to help industrial manufacturers adopt best available technologies when retrofitting their facilities or investing in new capacity. Effective and achievable fuel economy standards can promote change in automotive manufacturing while economic incentives can encourage the purchase of advanced and efficient vehicles. Renewable portfolio standards and economic incentives to support the use of non-traditional renewable fuels in end-use demand can boost the uptake of renewables.

In the longer term, significant opportunities exist for governments to implement stricter efficiency measures, such as revising minimum energy performance standards. Regular energy efficiency assessments for each demand sector can help identify if any measures need to be revised. It is also crucial to launch long-term investment strategies for research and development and encourage international cooperation to support the transfer and sharing of new technologies and learning.

Several APEC economies still have both explicit, direct fossil fuel subsidies and implicit, indirect subsidies that artificially inflate demand for all fossil fuel-based energy and suppress the uptake of energy efficiency measures. In 2009, APEC Leaders committed to rationalise and phase out inefficient fossil fuel subsidies that encourage wasteful consumption, while recognising the importance of providing essential energy services to vulnerable energy consumers. Removing fossil fuel subsidies across the APEC region could free up considerable finances for governments, which could enable them to deliver other poverty-alleviation measures that would protect the poor from any impacts of the subsidy removal. Similarly, domestic businesses could be protected by replacing the existing subsidy with one that allows them to invest in energy efficiency measures, thereby curbing increased energy expenditures that result from the removal of the initial subsidy. To help governments that wish to implement subsidy reform, the APEC Energy Working Group proposed (in 2013) a voluntary peer review of reform initiatives to eliminate inefficient fossil fuel subsidies. Four economies (Chinese Taipei, New Zealand, Peru and the Philippines) and have gone through the peer review process; others are strongly encouraged to participate in the near future.

3. ENERGY SUPPLY OUTLOOK

KEY MESSAGES

- **In the BAU Scenario, TPES in the APEC region increases by 22%, from 8 043 Mtoe in 2016 to 9 783 Mtoe in 2050.** China and south-east Asia account for 70% (1 220 Mtoe) of supply growth, roughly equivalent to three years of Japan's energy supply at the 2016 level.

- **While fossil fuels dominate at 80% of APEC's fuel mix in 2050 under the BAU, the energy system shifts towards cleaner fuel options** (such as natural gas and renewables). Coal's share in TPES declines from 35% to 25% while that of oil also decreases marginally, from 29% to 28%.

- **Natural gas supply grows by 57% from 2016 to 2050, providing a lower-cost and cleaner alternative to coal.** Demand for natural gas by end-users and in power generation increases in all APEC economies, except Japan and New Zealand.

- **Fossil fuel production in APEC closely follows the supply needs of the region.** Natural gas production increases by 44% over the Outlook, while oil production rises by 19%. Coal production, by contrast, declines by 7.8%.

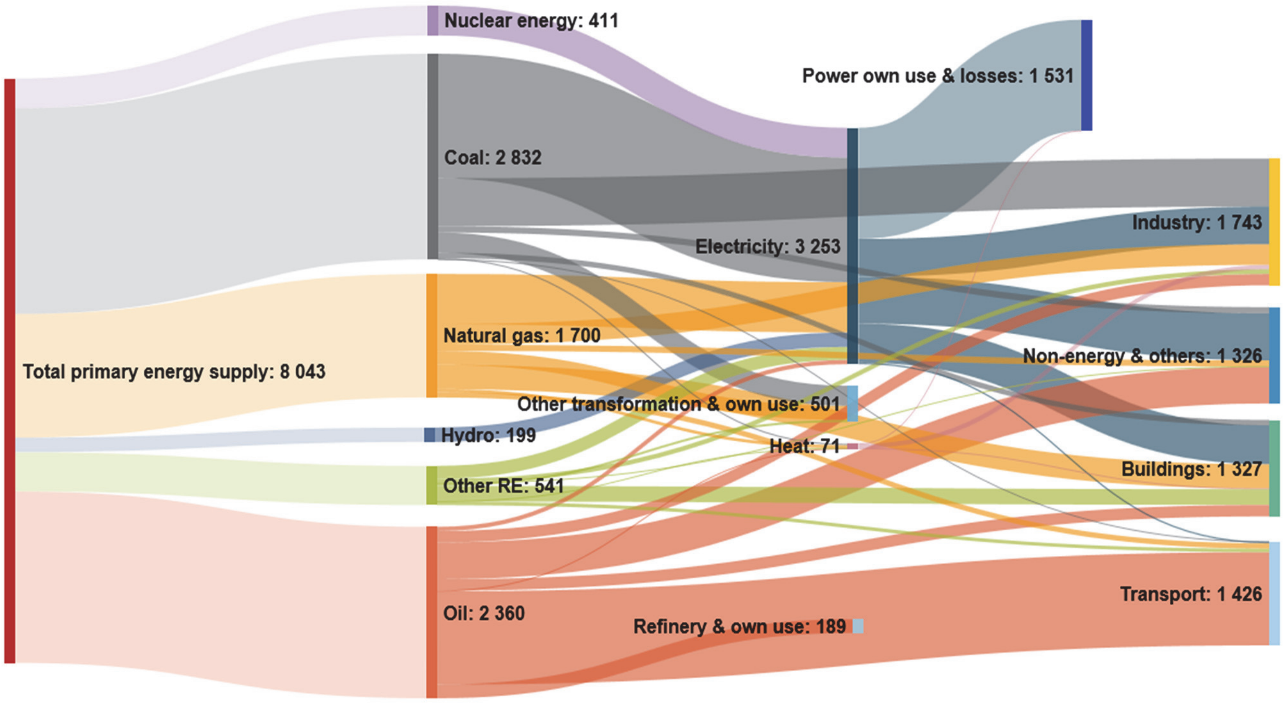
- **Renewable energy expands more quickly than any other fuel (1.7% CAGR) and represents 13% of TPES in 2050.** Despite the strength of this growth—underpinned by expanding solar and wind power in the electricity generation sector—abundant renewable potential remains untapped in many APEC economies.

- **China replaces the United States as the region's largest nuclear energy producer in 2033**, driven by strong policy support and rising electricity demand.

OUTLOOK FOR APEC ENERGY SUPPLY

Fossil fuels currently dominate the energy supply in the Asia-Pacific Economic Cooperation (APEC) region, having accounted for 84% of total primary energy supply (TPES) in 2000 and 86% in 2016 (Figure 3.1). Despite more efforts to increase the use of renewables and reduce greenhouse gas (GHG) emissions from APEC energy systems, low oil and natural gas prices have driven their continued use across the region. While the use of renewables has increased significantly in absolute terms since 2007, the proportion of fossil fuels in APEC's energy supply has stayed in the range of 86% to 87%.

Figure 3.1 • APEC total primary energy supply and demand by fuel and sector, 2016



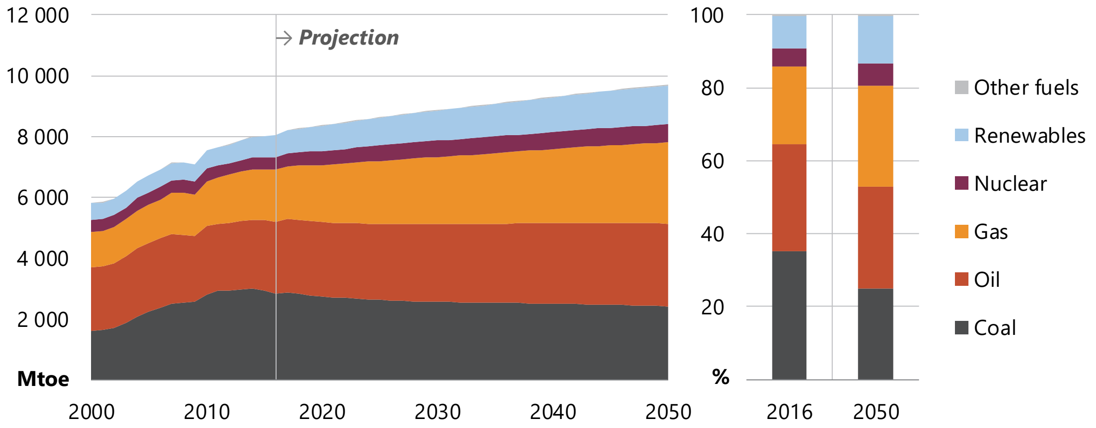
Note: RE = renewables.
Sources: APERC analysis and IEA (2018a) using a Sankey diagram from http://sankeymatic.com/.

This chapter presents energy supply projections for APEC to 2050 in the Business-as-Usual (BAU) Scenario, as modelled by the Asia Pacific Energy Research Centre (APERC) (Figure 3.2). The underlying model includes existing policies across APEC's 21 economies as well as those that are very likely to be implemented in the foreseeable future. In addition to presenting the development of energy supply for both fossil fuels (oil, natural gas and coal) and non-fossil fuels (renewables and nuclear), this chapter specifically examines the development of APEC refinery and biorefinery capacity in order to identify any potential opportunities and risks to refinery investment in the region. This investigation is new for the *Outlook 7th Edition* and was enabled by the development of a new refineries and biorefineries model at APERC.

While it is unlikely that future energy policies will strictly follow the pathway laid out in the BAU Scenario, the modelling results provide insights on how current policies would likely influence the development of the energy system and set the stage for future collaboration among APEC members. The BAU results also provide a baseline for the comparison of two alternative scenarios presented in this Outlook. The APEC Target (TGT) Scenario focuses on APEC goals to improve energy intensity by 45% by 2035 (against the 2005 level) and to double the share of renewables, including in power generation, by 2030 (in relation to the 2010 level) (see Chapter 5). The 2-Degrees Celsius (2DC) Scenario represents an ambitious effort to move APEC economies towards a pathway that reduces CO_2 emissions to a level that supports a 50% chance of constraining the global average temperature increase to 2°C by 2050 (see Chapter 6). Combined, these three scenarios support an investigation of how APEC members can take action—individually and collectively—to develop energy systems that achieve local, regional and global targets.

Under the BAU, projected APEC TPES shows robust growth of 1 740 million tonnes of oil equivalent (Mtoe) over the Outlook period, rising from 8 043 Mtoe in 2016 to 9 783 Mtoe in 2050 (Figure 3.2). This reflects a compound annual growth rate (CAGR) of 0.58%, significantly lower than the 2.0% CAGR observed from 2000 to 2016. Rising total energy supply in China (0.54% CAGR) and south-east Asia (2.1% CAGR) is the key driver of projected growth.

Figure 3.2 • Total primary energy supply by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Fossil fuels dominate APEC energy supply throughout the projection to 2050, with an overall increase of 922 Mtoe (13%), equivalent to 53% of overall TPES growth. While fossil fuels grow in absolute terms, their share of APEC energy supply declines from 86% in 2016 to 80% in 2050 as the use of both renewables and nuclear increases across the region. Overall, the share of renewables in TPES rises from 8.9% in 2016 to 13% in 2050.

The share of fossil fuels undergoes several noteworthy regional changes. In particular, China has adopted an aggressive policy to accelerate the reduction of fossil fuels in its energy mix, resulting in a decline from 89% in 2016 to 77% by 2050. However, in south-east Asia, increasing the use of renewables as part of a strategy to enhance supply security does not prompt a decline in the share of fossil fuels. Instead, the fossil share hovers around 74% to 77% of TPES throughout the projection period.

RENEWABLES AND NATURAL GAS BOOM AS COAL DECLINES IN APEC

In the BAU Scenario, natural gas in the APEC region grows more than any other fossil fuel, with supply rising by 57% (from 1 700 Mtoe in 2016 to 2 663 Mtoe in 2050) because of rising demand, particularly in China where it more than triples. In 2050, natural gas supplies 27% of APEC TPES, compared with 21% in 2016. The growing availability and accessibility of liquefied natural gas (LNG), price competitiveness, and efforts to reduce the carbon intensity of the energy system are key factors driving natural gas supply growth.

The share of oil in the APEC energy supply mix decreases slightly from 29% to 28% of TPES over the Outlook period, despite the oil supply increasing by 16% in absolute terms, from 2 361 Mtoe in 2016 to 2 738 Mtoe in 2050. Conversely, APEC coal supply decreases both in share and absolute terms, driven by a combination of low oil and natural gas prices and efforts to promote cleaner energy across APEC.

Under the BAU, the renewables[14] supply in APEC grows more strongly than any other fuel (1.7% CAGR), rising from 718 Mtoe (8.9% of TPES) in 2016 to 1 282 Mtoe (13%) in 2050 (Table 3.1). (For comparison, natural gas grows at 1.3% CAGR.) China and south-east Asia represent approximately 63% of all APEC renewables supply in 2050.

Table 3.1 • Share of total primary energy supply by fuel, 2000-50

(%)	2000	2016	2020	2030	2040	2050
Coal	28	35	33	29	27	25
Oil	36	29	29	29	28	28
Gas	20	21	23	25	26	27
Fossil fuels	**84**	**85**	**85**	**83**	**81**	**80**
Nuclear	6.7	5.1	5.5	6.0	6.0	6.1
Renewables	9.4	8.9	9.7	11	12	13
Non-fossils	**16**	**14**	**15**	**17**	**18**	**19**

Note: Fuel shares do not sum to 100% due to rounding.
Sources: APERC analysis and IEA (2018a).

Net nuclear energy supply in APEC increases from 410 Mtoe in 2016 (5.1% of TPES) to 595 Mtoe by 2050 (6.1%) as large increases in China are offset by retirements in other economies in the region. Nuclear-generated electricity demand in China increases nearly fivefold over the Outlook period as supportive policies encourage the addition of new nuclear power plants. In the United States, nuclear supply declines from 219 Mtoe to 194 Mtoe as an ageing nuclear power fleet is retired. Similarly, Korea shows declines in nuclear power from 2016 to 2050 while Chinese Taipei nuclear generation ceases by 2025.

ENERGY SUPPLY GAP WIDENS ACROSS APEC

In the BAU Scenario, total APEC energy production increases by 21% over the Outlook period, from 7 578 Mtoe in 2016 to 9 192 Mtoe in 2050, with fossil fuel production increasing by 14% (Table 3.2). Coal production decreases by 7.8% because of waning demand, while natural gas production increases by 44%, driven mainly by increasing production in the United States, China, Russia and Australia. Oil production also grows by nearly 19%, led by the United States, Russia, Canada and China, offsetting decreasing production in south-east Asia.

Table 3.2 • Fossil fuel production by fuel, 2016-50

(Mtoe)	2016	2020	2030	2040	2050
Coal	2 892	2 936	2 826	2 767	2 665
Oil	1 808	1 984	2 128	2 170	2 143
Gas	1 729	1 942	2 255	2 384	2 485
Fossil fuels	**6 429**	**6 862**	**7 209**	**7 321**	**7 293**

Source: APERC analysis and IEA (2018a).

Overall, despite increasing fossil fuel production in APEC results in a 73% increase in net energy imports, from 530 Mtoe in 2016 to 916 Mtoe in 2050 (Table 3.3). APEC remains a net exporter of coal and a net importer for crude oil. Although APEC is currently a natural gas net exporter and exports grow by 60% over the Outlook period, growing demand, particularly in China, causes imports to grow even faster and more than double by 2050. As a result, natural gas net exports shrink fast and APEC becomes a net importer by around 2033. Similarly,

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[14] Renewables includes hydro, solar, wind, geothermal, biomass and marine power.

because of surging demand for gasoline, liquefied petroleum gas (LPG) and other refined products in south-east Asia, north-east Asia and other Americas, APEC becomes a net importer of oil products after 2031. Net exports of coal increase from 169 Mtoe in 2016 to 255 Mtoe by 2050.

Table 3.3 • Net energy imports and exports by fuel, 2016-50

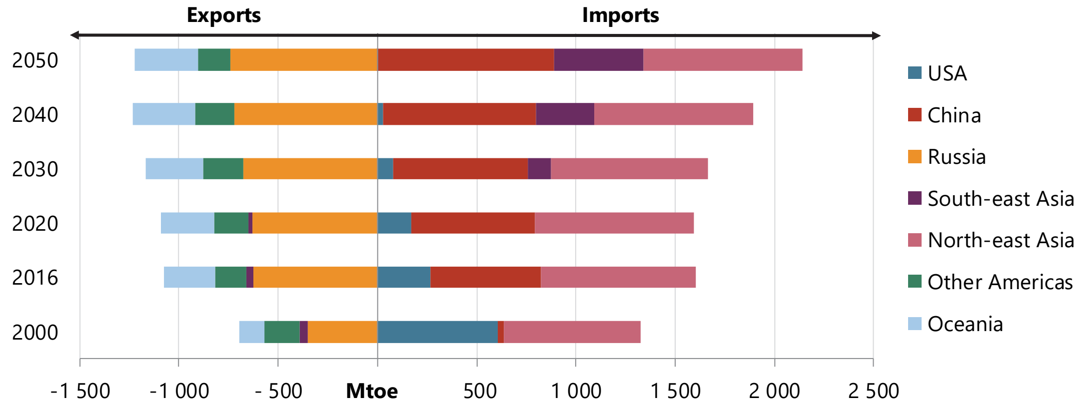
(Mtoe)	2016	2020	2030	2040	2050
Coal	–169	–197	–262	–266	–255
Crude oil	799	806	794	768	793
Oil products	–68	–66	–6.5	79	160
Gas	–34	–48	–39	66	195

Note: Negative indicates net export; positive indicates net import.
Sources: APERC analysis and IEA (2018a).

Although all five APEC fossil fuel net exporting economies (Australia, Brunei Darussalam, Canada, Indonesia and Russia) maintain net energy export positions in 2050, overall APEC net energy imports increase by 73% from 530 Mtoe in 2016. The net increase reflects strong demand for imports from China and south-east Asia, even as the United States turns into a net energy exporter, with net energy imports falling from 265 Mtoe in 2016 to zero in 2050.

China, north-east Asia and south-east Asia lead APEC's growing energy imports and contribute to the widening supply gap over the Outlook period (Figure 3.3). From 2016 to 2050, China's net energy imports rise by approximately 59% while north-east Asia net imports increase marginally, by 2.3%, despite a 16% decrease in Japanese net energy imports. Converse to what happens in the United States, south-east Asia shifts from being a net exporter in 2016 to becoming a fast-growing net importer totalling 454 Mtoe of net energy imports by 2050. This shift is evident as south-east Asia's TPES more than doubles, with particularly high increases in coal (177%), oil (92%) and gas (51%) supply. The resulting supply gap could be partially offset through the development of renewables and nuclear power (see Chapter 6). These changing trade dynamics present an opportunity for APEC economies to expand intra-regional trade (see Chapter 9).

Figure 3.3 • Energy supply gap by regional grouping, 2000-50



Sources: APERC analysis and IEA (2018a).

OIL SUPPLY

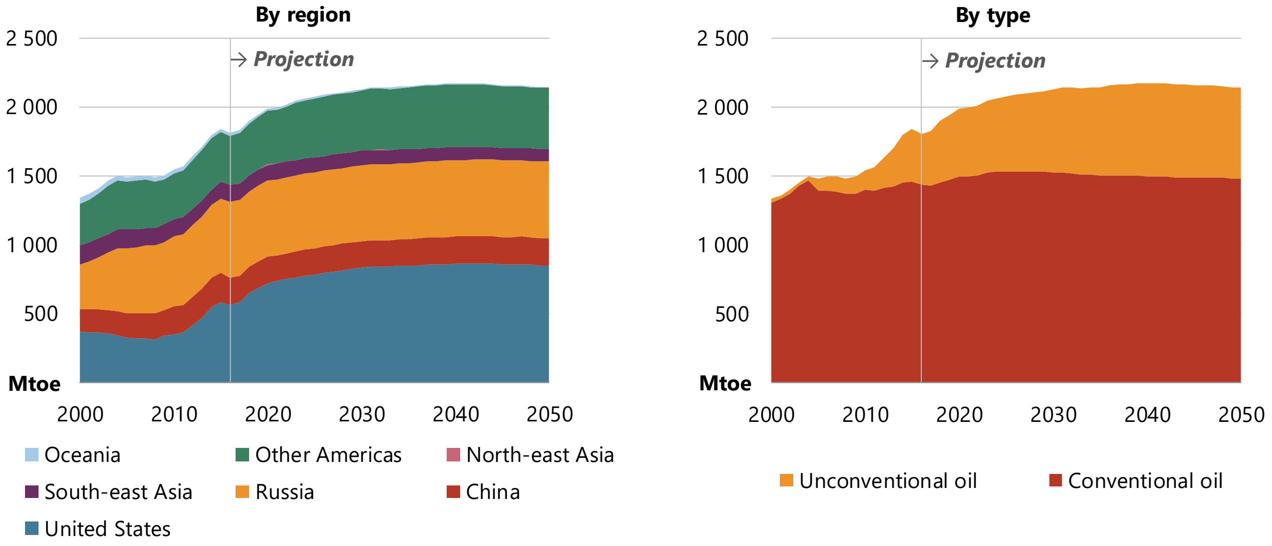
Oil remains a major supply resource in the APEC region under the BAU Scenario, with its overall share staying between 28% and 29% through 2050. In the BAU, crude oil production in APEC increases from 1 808 Mtoe in

2016 to 2 143 Mtoe by 2050, mostly because of increases in shale oil production in the United States and oil sands production in Canada. While total primary oil supply in the BAU increases modestly (0.44% CAGR) across APEC, its share in the energy mix drops slightly because of the high growth in renewable and natural gas supplies as well as government efforts to decrease oil consumption (e.g. fuel efficiency standards in transport) as discussed in Chapter 2. These projections are subject to many uncertainties, including the future trajectory of international oil prices, fuel switching trends (e.g. to electricity and biofuels in transport), political shifts, and fluctuations in global economic growth.

APEC CRUDE OIL PRODUCTION INCREASES TO 2039, THEN FLATTENS

APEC crude oil production increases by 19% in the BAU, from 1 808 Mtoe in 2016 to peak at 2 170 Mtoe in 2040 (Figure 3.4), then starts slightly declining to 2 143 Mtoe by 2050. The United States and other Americas drive growth, increasing production by 51% and 25%, respectively, for a combined 60% share of total APEC production in 2050. Over the same period, oil production in Russia (1.3% growth) and China (1.1% growth) remain virtually constant, while production in south-east Asia drops by 27%.

Figure 3.4 • Crude oil production in APEC by region and type, 2000-50



Note: Unconventional oil includes: oil shale; oil sands; bitumen; and derivatives such as synthetic crude products, liquids derived from natural gas such as gas-to-liquid, or coal-to-liquid.
Sources: APERC analysis and IEA (2018a).

REFINERIES AND BIOREFINERIES

A key addition in this 7th edition of the *Outlook* is the development and implementation of a refineries and biorefineries model. This tool allows APERC to investigate how the three scenarios could influence refinery capacity and production across the APEC region, including the opportunities and risks associated with refinery investment.

In 2016, APEC had a refinery capacity of 54 million barrels (Mbbl) per day (2 682 Mtoe[15]) and a refinery utilisation rate of 93% (Figure 3.5). APEC economies fed 2 485 Mtoe of crude oil into their refineries in 2016 to produce

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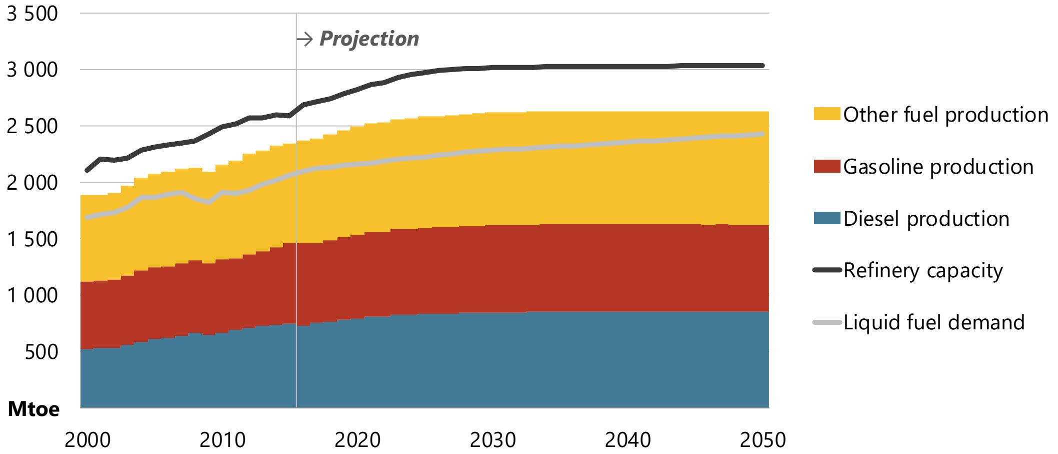
[15] Using 7.33 barrels per ton (BP, 2018)

2 366 Mtoe of petroleum products (734 Mtoe gasoline, 728 Mtoe diesel, 88 Mtoe LPG, 207 Mtoe jet fuel and 609 Mtoe of other products). Most production occurred in the United States, Russia, and China.

Figure 3.5 • APEC refinery capacity, liquid fuel production and demand in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

In the BAU, APEC refinery capacity increases by 13% to 61 Mbbl per day (3 031 Mtoe) in 2050 to meet a growing demand for refined oil products. In parallel, the utilisation rate decreases slightly to 90%. Diesel production increases by 17% because of the greater demand for light-duty trucks and freight transport. Gasoline production increases by only 5.5%, reflecting relatively slower uptake of gasoline-fuelled vehicles as the use of alternative fuels (i.e. electricity) grows. The additional refinery capacity built in the projection period requires a total investment of USD 805 billion, with south-east Asia, China and Russia representing 95%, (USD 762 billion) of this total.

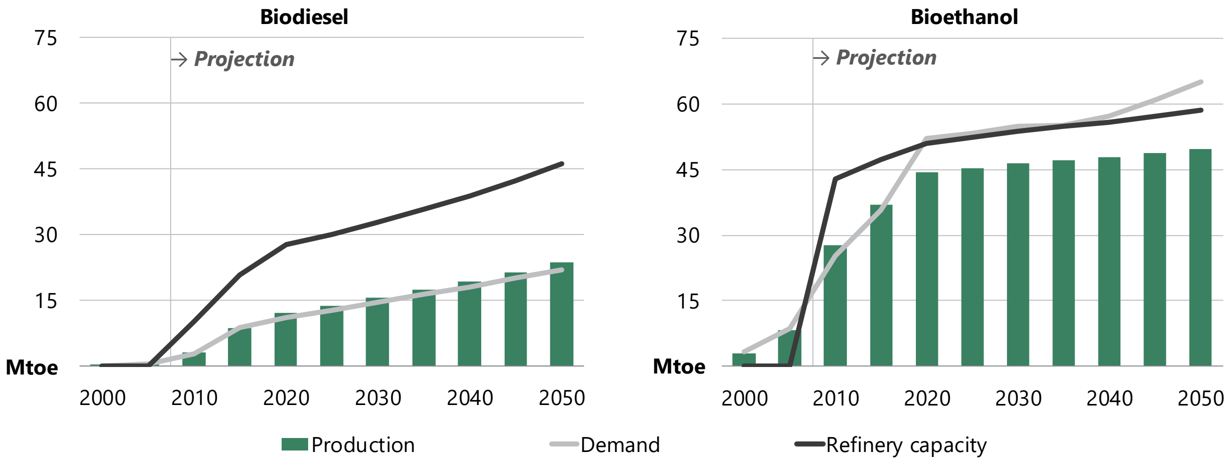
The projected 10% underutilisation of APEC refineries represents a potential opportunity for increased export of oil products in the BAU, depending on the development of global product markets and the physical condition of the refinery units. Alternatively, excess capacity could be mothballed or retired in the case of low or negative margins for additional production. These decisions depend largely on the economics of individual refineries as well as global markets, factors that are currently beyond the scope of analysis in the APERC refinery model. (For a more detailed explanation of the refinery model, please see Annex I: Methodologies and Key Modelling Assumptions, 7. Refinery Model).

Additional refinery expansion is required in the BAU to meet rising demand for oil products in APEC. In the TGT and 2DC Scenarios, however, decreasing demand for oil products drives down utilisation of existing refineries. Both alternative scenarios show APEC liquid fuel demand over the entire Outlook period falling below existing refining capacity, suggesting the potential for utilisation risk for new investment. In the TGT, some economies may decide to maintain production levels in order to capture export market opportunities. As the 2DC is designed in the context of a broader global reduction of carbon dioxide (CO_2) emissions, it shows APEC liquid fuel demand decreasing at an CAGR of 1.2%, which implies that such export opportunities would be much more limited (see Chapter 9).

For biorefineries, key production outputs include biodiesel to replace diesel oil and bioethanol to replace gasoline. As of 2016, 72 Mtoe (24 Mtoe of biodiesel and 48 Mtoe of bioethanol) of biorefinery capacity existed in APEC, mostly in the United States, Indonesia, China, Thailand and Malaysia. These economies have pursued biorefining with the aims of enhancing domestic energy supply security, stimulating employment in the agricultural sector, and/or increasing alternative fuel use. In 2016, crude palm oil and rapeseed were used to produce 11 Mtoe of biodiesel, while sugarcane juice, molasses and cassava produced 39 Mtoe of bioethanol. On average, the biorefineries operated at a 69% utilisation rate, highlighting the seasonality effect of using crop products as feedstock.

In the BAU, APEC biorefinery capacity increases by 45% to 105 Mtoe (46 Mtoe of biodiesel and 59 Mtoe of bioethanol) in 2050, with investments of USD 12 billion for biodiesel capacity and USD 6.0 billion for bioethanol (Figure 3.6). The observable demand drift in bioethanol in 2020-30 reflects declining gasoline demand, as a result of the improving efficiency of gasoline-powered vehicles, after which demand resumes its increasing trend. In 2050, nine APEC economies have biorefineries with the United States, China and Indonesia representing 89% of total capacity. Significant driving forces behind the capacity expansion are supply security, social benefits, environmental concerns, raw materials availability, investment costs and oil prices.

Figure 3.6 • APEC biorefinery capacity, bioliquid production and demand in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

In the TGT Scenario, demand for biofuels is higher than in the BAU because of increasing demand in the transport sector. In turn, overall utilisation rates in 2050 for biorefineries, which are 70% in the BAU, rise to 76%. These projections highlight an opportunity for economies that have diverse raw inputs to invest in biorefining capacity with the aim of increasing exports of refined biofuels.

NATURAL GAS SUPPLY

Natural gas has become the fastest-growing fuel in terms of supply in the APEC region, increasing 17% from 2010 to 2016. Increased availability of low-cost supplies, coupled with the relatively low GHG emissions and air quality effects of natural gas (compared to other fossil fuels), are primary drivers of rising demand. Natural gas produces about half the CO_2 emissions of coal and around 30% less than oil products. It also emits lower levels of other air pollutants such as sulphur oxides, nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide and mercury (IEA, 2017b).

The United Nations Intergovernmental Panel on Climate Change (IPCC) recognises the mitigation benefits of using 'highly efficient natural gas combined-cycle power plants or combined heat and power plants' to replace coal-fired power plants (IPCC, 2014). Likewise, the International Energy Agency (IEA) and the International

Renewable Energy Agency (IRENA) recognise the potential role of natural gas as a 'bridge' to greater deployment of renewable energy in efforts to reduce GHG emissions (IEA and IRENA, 2017).

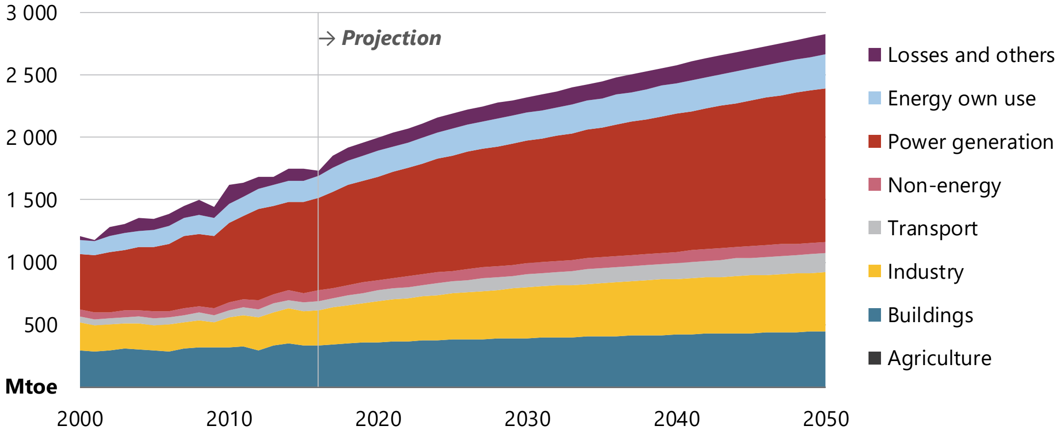
In 2016, the APEC region accounted for more than half (56%) of global gas consumption, 3.0% more than in 2005 (IEA, 2018a). Moreover, three out of the four main gas producers are APEC members (the United States, Russia and Canada) and more than half (57%) of global gas is produced in the region. In terms of trade, the APEC region has some of the most active gas trade dynamics in the world, including three of the top five world exporters (Russia, the United States and Canada) and three of the top five world importers (Japan, China and the United States). In 2016, APEC as a whole was a natural gas net exporter; 70% of gas exports were piped while the remainder was LNG. On the natural gas imports side, by contrast, 47% was piped and 53% was LNG (see Chapter 9).

GAS IS THE FASTEST-GROWING FUEL IN APEC TO 2050

In the BAU Scenario, APEC natural gas supply grows by 57% over the Outlook period, reaching 2 663 Mtoe by 2050. The share of natural gas in the APEC fuel mix also grows from 21% in 2016 to 27% in 2050, as coal demand declines and oil demand shows slow growth. Power generation drove 41% (693 Mtoe) of APEC natural gas supply in 2016, with an additional 20% coming from the buildings sector and 17% from industry.

Power generation by natural gas remains the main driver of natural gas supply growth in this scenario and represents about 43% of total primary gas supply in 2050. Additionally, every demand sector contributes to this growth, with industry demand increasing by 68% to reach 472 Mtoe by 2050 (Figure 3.7).

Figure 3.7 • Total primary gas supply by use, 2000-50



Sources: APERC analysis and IEA (2018a).

On a regional basis, the United States and China have historically driven APEC natural gas growth. In the United States, total primary gas supply grew by 28% over the last decade, from 507 Mtoe in 2005 to 652 Mtoe in 2016. China showed remarkable supply growth of 346% over the same period, from 38 Mtoe to 169 Mtoe, and now have the third-largest gas supply in APEC, behind the United States and Russia (IEA, 2018a).

In the BAU, natural gas represents at least 10% of TPES in every APEC economy by 2050, with the exception of the Philippines (Figure 3.8). While the United States and China dominate growth, 19 of the 21 APEC economies[16] show total gas supply growth from 2016 to 2050. Total primary gas supply in China, mainly driven by increasing

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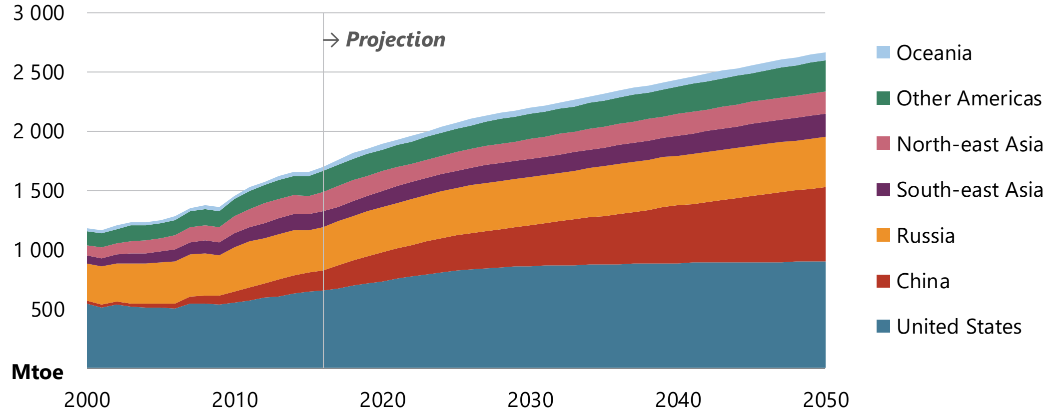
[16] The two exceptions are Japan and New Zealand.

demand from power generation and, to a lesser extent, industry, almost quadruples by 2050 at 627 Mtoe, which leads gas supply growth in the APEC region. Natural gas supply in the United States increases by 38% to reach 899 Mtoe in 2050 and is mainly driven by increases in gas-fired power generation. Russia total supply grows 16%, reaching 423 Mtoe by 2050.

Figure 3.8 • Total primary natural gas supply by region, 2000-50



Sources: APERC analysis and IEA (2018a).

In the other Americas region, total primary gas supply increases by 48% to 259 Mtoe by 2050.This is led mainly by growth in Mexico's power generation sector and Canada's energy-intensive oil and gas upstream industry. South-east Asia sees 51% growth to reach 201 Mtoe by 2050, surpassing north-east Asia in 2025. However, significant uncertainty exists regarding this projection for south-east Asia due to the high amounts of investment in infrastructure needed to increase gas supply, competition with low-cost coal and some economies' policies supporting coal for power generation. Finally, consumption in north-east Asia increases modestly (12%), resulting mainly from the mixed effect of decreasing demand in Japan and demand growth in Korea, an important contrast in this subregion compared with the last decade's growth rate of 52%.

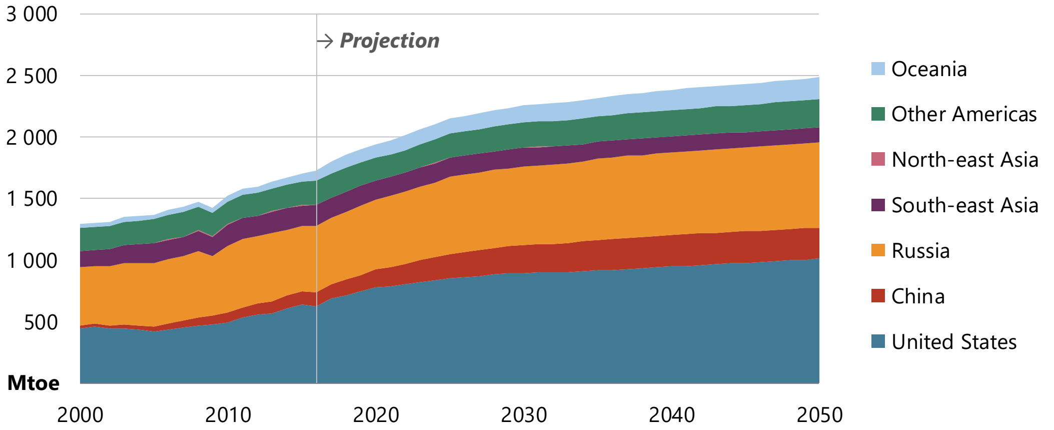
GAS PRODUCTION GROWS IN THE UNITED STATES, RUSSIA AND CHINA

Natural gas production in APEC has grown robustly over the past 10 years, led by growth in the United States, China and Australia. US natural gas production rose from 422 Mtoe in 2005 to 627 Mtoe in 2016, a 49% increase, which resulted in it becoming the largest natural gas producer in the world (IEA, 2018a). Over the same period, China's gas production almost tripled (178%) and Australia's more than doubled (131%).

In the BAU Scenario, APEC natural gas production reaches 2 485 Mtoe in 2050, an overall increase of 44% from 2016 (Figure 3.9). At an CAGR of 1.1% from 2016 to 2050, natural gas is the fastest-growing fossil fuel in the APEC region. By 2021, natural gas production surpasses that of oil on an energy equivalent basis.

Natural gas production in the United States continues to grow over the projection period, rising 61% from 2016 to 2050 to reach 1 012 Mtoe. Russia shows an increase of 28%, reaching 690 Mtoe. China natural gas production almost doubles by 2030, surpassing Canada by 2020 to become the third-largest natural gas producer in APEC. In the other Americas region, natural gas production grows by 18% up to 226 Mtoe by 2050, with around 65% of the growth coming from Canada and the remainder mostly from Mexico. Gas production in Oceania (predominantly Australia) more than doubles from current levels up to 180 Mtoe by 2050. South-east Asia is the only major producing subregion to show decreasing production under the BAU; an overall decline of 27% is linked to assumed resource depletion in Malaysia and Indonesia in the absence of increased investment in exploration activities.

Figure 3.9 • Natural gas production by region, 2000-50

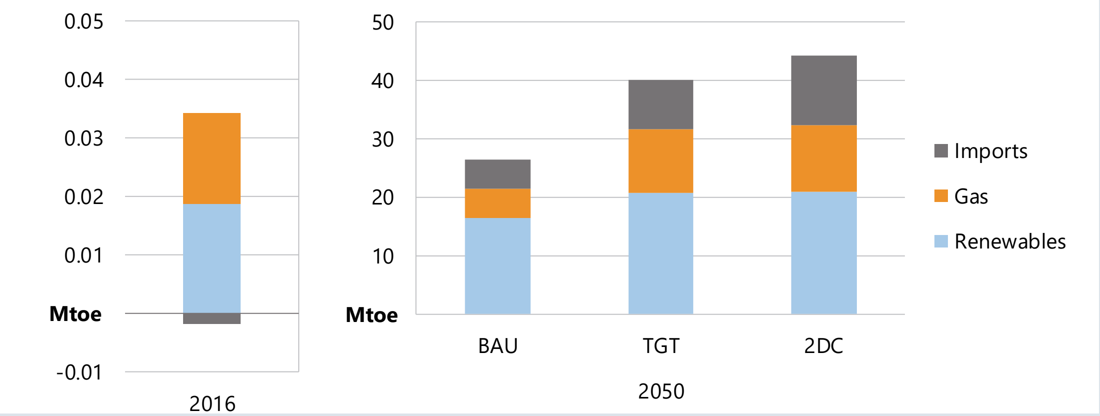


Sources: APERC analysis and IEA (2018a).

Box 3.1 • Natural gas and renewables used to meet hydrogen demand

In the BAU Scenario, hydrogen production rises to 21 Mtoe by 2050 (from 0.034 Mtoe in 2016), requiring a total 16 Mtoe of renewables and 5.0 Mtoe of natural gas as inputs (Figure 3.10). The estimated capacity of fuel cell batteries in this scenario reaches 9.8 gigawatts (GW) by 2050 compared with 11 GW in the TGT Scenario and 19 GW in the 2DC (also covered in Chapters 5 and 6 of this Outlook). Overall, the amount of electricity needed to produce hydrogen in all scenarios is relatively small (0.03% in BAU) compared with total APEC renewable electricity generation. Although hydrogen can technically be produced from fossil fuels (i.e. coal, oil and gas), the BAU Scenario considers only hydrogen production using two production technologies: steam methane reforming of natural gas and electrolysis from solar photovoltaic (PV). (More details on this methodology are in the Annex I: Methodologies and Key Modelling Assumptions, 10. Supply Model).

Figure 3.10 • Hydrogen production in the BAU, TGT and 2DC, 2016-50



Source: APERC analysis.

Development of shale gas resources has brought major changes to production patterns and international natural gas flow trades, particularly in the United States, which surpassed Russia in 2009 to become the world's largest natural gas producer (IEA, 2018a). Unconventional gas production is underway in other economies (such as China and Canada) but it remains to be seen whether it will match the impressive production growth rates of the Marcellus or Permian basins in the United States (see Chapter 9).

COAL SUPPLY

Coal has played a very important role in realising economic growth in APEC and remains the backbone of power systems in numerous economies. Coal is plentiful in the Asia-Pacific region; being accessible and broadly affordable, it has been an important fuel resource for the energy sector, despite high levels of air pollution associated with its use—including PM, NO_x and GHG emissions.

APEC economies accounted for nearly 76% of global coal supply in 2016, an increase from the 70% share in 2000 (IEA, 2018a). In 2016, APEC coal total supply declined by 3.3% compared with 2015, despite economic growth of 3.5%, indicating waning demand.

Peak coal production (3 209 Mtoe) was seen in APEC in 2014, followed by a decline to reach 2 892 Mtoe in 2016. Five economies produced 97% of APEC's coal production in 2016: China (59%), the United States (12%), Australia (10%), Indonesia (8.6%) and Russia (7.2%). While the region as a whole produced enough coal to meet its demand in 2016, some individual economies are net importers.

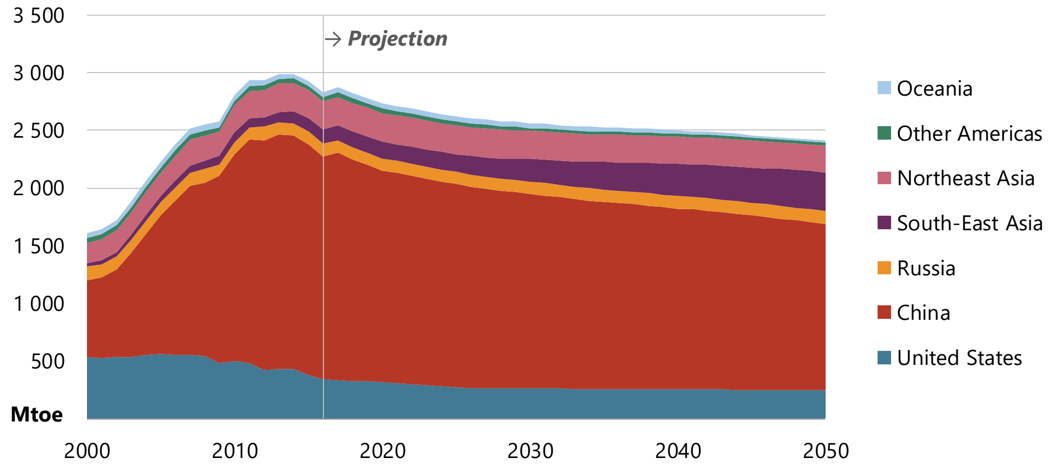
Coal production in the United States has been undergoing significant changes, reaching peak production (579 Mtoe) in 2008 and subsequently declining to 348 Mtoe (-6.8% CAGR) from 2010 to 2016. Three main factors underpinned this trend: low natural gas prices; the retirement of some coal-fired generators within the United States; and lower international coal demand (EIA, 2017). Australia, by contrast, has experienced increasing export demand from south-east Asia and India, prompting consistent growth in coal output, from 165 Mtoe in 2000 to 292 Mtoe in 2016. Over the same period, Indonesia's coal export grew more than sixfold from 34 Mtoe in 2000 to 206 Mtoe in 2016, mostly to meet a growing demand for thermal coal from China, India, north-east-Asia and south-east Asia (MEMR, 2018).

COAL SUPPLY: GROWTH IN SOUTH-EAST ASIA COUNTERS OVERALL TREND

Coal supply in APEC declines by 15% in the BAU Scenario over the projection period, although there is variability across APEC subregions. Of particular note, coal supply grows almost threefold in south-east Asia from 124 Mtoe in 2016 to 344 Mtoe in 2050. Despite marginal increases in Chinese Taipei, north-east Asia supply decreases 5.4% by 2050. China continues to contribute a sizeable share of coal supply to the region, but domestic policies targeting a decrease in the share of coal in the energy mix lead to an overall decline of 25% in 2050 compared with 2016 (Figure 3.11).

By 2050, the APEC region continues to be a net coal exporter with net exports accounting for 255 Mtoe. This trend highlights potential opportunities to increase intra-regional trade (see Chapter 9).

Figure 3.11 • Coal supply by region in the BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

Box 3.2 • Coal-to-liquid industry in China

China's government describes its current primary energy resources as 'rich in coal, poor in oil, lack of natural gas' (China Mineral Resource, 2017). With proved coal reserves of 139 billion tonnes but high dependence on crude oil imports (its import share of total crude demand was 69% in 2016), China established a coal-to-liquid (CTL) initiative with three aims: reduce import dependency, improve energy security and help coal producers redirect their output to a value-added industry.

Despite some encouragement from the government, China lacks specific regulations for coal liquefaction. However, the National Development and Reform Commission (NDRC) and the State Council have issued guidelines and/or circulars. In 2006, the NDRC banned CTL projects with an annual output less than 3.0 million tonnes (Mt) and suspended all coal liquefaction project approvals until the government could finalise a development plan for the industry (NDRC, 2006).

On 22 July 2014, the National Energy Administration issued the *Circular on Standardizing the Scientific and Orderly Development of Coal-to-Liquid and Coal-to-Gas Industries*. This circular banned local governments from constructing CTL projects with an annual output of less than 1.0 Mt and banned CTL projects not on the National Model Projects List. This circular also emphasised that CTL facilities must adhere to existing law regarding energy efficiency, energy consumption, water consumption and CO_2 emissions (NEA, 2014).

In China, only a few large conglomerates are allowed to invest in CTL because of the 1.0 Mt minimum capacity for CTL facilities. In 2016, the total CTL capacity in China was recorded at 8.8 Mt (1.2% of total coal demand of 713 Mt) (Chyxx, 2018), with targets for CTL capacity to reach 21 Mt per year by 2020 (NDRC, 2017).

NUCLEAR SUPPLY

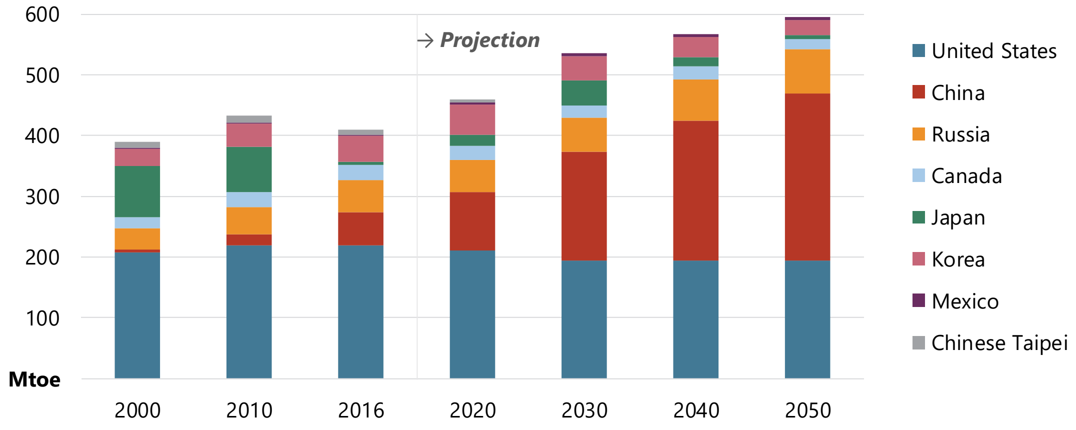
Nuclear energy supplied 390 Mtoe (6.7%) of APEC TPES in 2000 and reached a peak of 432 Mtoe (1 658 terawatt-hours [TWh]) in 2010. After the Fukushima accident in 2011, nuclear energy in APEC experienced a decline in both share and amount as Japan suddenly shutdown 44 GW of nuclear power plant capacity on May 2011 (WNA, 2018). Future additions were also slowed with the temporary suspension of construction work of new nuclear plants in China between 2011 and 2015, while Chinese Taipei announced that it would phase out nuclear power by 2025. Construction restarted in China in February 2015, and some nuclear reactors in Japan that were shut down after Fukushima began to re-enter operation in August 2015.

NUCLEAR ENERGY SUPPLY RISES RAPIDLY, DRIVEN BY CHINA

Nuclear energy supply in the APEC region grows from 410 Mtoe (1 573 TWh) in 2016 to 595 Mtoe (2 282 TWh) in 2050 under the BAU (Figure 3.12). In 2016, nuclear power supply in the United States was 219 Mtoe (840 TWh), about 53% of APEC's total. By 2033, China overtakes the United States to become APEC's top nuclear energy consumer, spurred by proactive policy support and high levels of investment. Conversely, nuclear power in the United States gradually declines as retirements outstrip new additions. In Chinese Taipei, nuclear power is phased out by 2025, as operating reactors reaching 40 years of service are retired and the Lungmen nuclear plant is written off (TPC, 2018).

In the BAU, China's nuclear energy supply expands nearly fivefold in just 34 years, from 56 Mtoe in 2016 to 274 Mtoe in 2050. After achieving the 13th Five-Year Plan target of 58 GW of nuclear power capacity in the rapid growth period (2016-20), the annual construction rate in China is assumed to decrease from the 5.0 GW to 6.1 GW rate from 2016-30 to a more moderate annual average rate of 2.7 GW to 3.3 GW towards the end of the projection period.

Figure 3.12 • Total nuclear energy supply by selected economies, 2000-50



Sources: APERC analysis and IEA (2018a).

FUELLING NUCLEAR: URANIUM DEMAND GROWS STEADILY IN APEC

Uranium is the fuel stock for nuclear power plants. The APEC region is currently both a major uranium producer and consumer. In 2016, five APEC economies held 52% of the world's known recoverable uranium resources, the equivalent of 3 200 kilotonnes (kt). Among these economies, Australia has the largest reserves (30% of the global total), while the remaining 22% is spread among Canada, Russia, China and the United States. On a production basis, in 2016 Canada and Australia were the second- and third-largest producers in 2016 behind only Kazakhstan, with Canada producing 23% of the global total (14 kt) and Australia delivering 10% (6.3 kt) (WNA, 2018).

Demand for uranium for nuclear power increases significantly in the BAU Scenario, from 36 kt (410 Mtoe) in 2016 to 52 kt (595 Mtoe) in 2050 (Table 3.4). At least 80% of APEC uranium demand is assumed to be supplied through intra-APEC production. After 2030, Australia overtakes Canada as the leading uranium producer in APEC.

Table 3.4 • Uranium demand in APEC, 2016-50

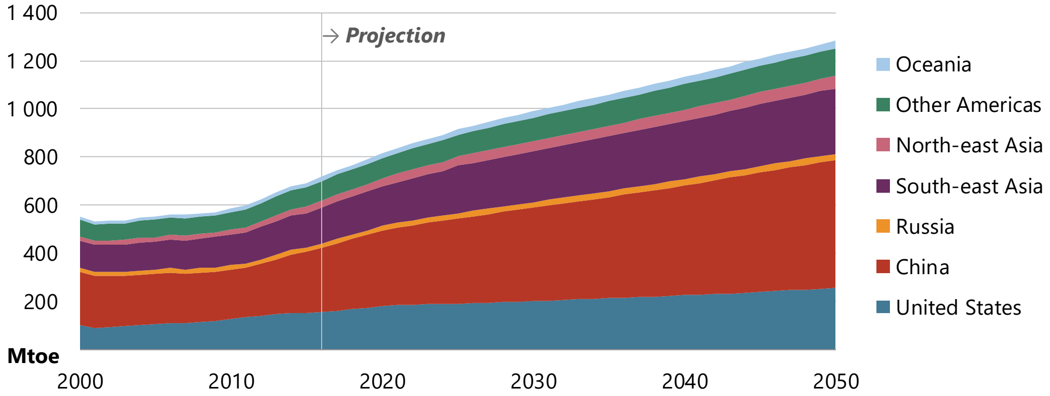
(tonnes)	2016	2020	2030	2040	2050
USA	19 000	19 000	17 000	17 000	17 000
China	4 900	8 500	16 000	20 000	24 000
Japan	420	1 500	3 700	1 400	590
Russia	4 600	4 800	5 100	6 100	6 500
Korea	3 800	4 500	3 500	2 900	2 200
Canada	2 300	2 000	1 600	1 900	1 500
Chinese Taipei	730	560	0	0	0
Mexico	250	250	450	450	450
APEC total	**36 000**	**41 000**	**47 000**	**50 000**	**52 000**

Sources: APERC analysis and IEA (2018a).

RENEWABLE ENERGY SUPPLY

Under the BAU Scenario, the share of renewables in APEC TPES rises from 8.9% in 2016 to 13% in 2050 because of rising use for power generation, making it the fastest-growing resource (1.7% CAGR). In absolute terms, the total supply of renewables almost doubles, from 718 Mtoe in 2016 to 1 282 Mtoe in 2050, with bioenergy being the leading source (52% in 2016 and 42% in 2050). Although traditional biomass demand falls significantly (see Chapter 2) because of electrification in buildings and increased use of modern biomass such as wood pellets, biofuel in power and transport reinforce the role of bioenergy in TPES during the Outlook period. China is the dominant supplier in APEC across the entire projection period; after representing 37% of total renewables supply in 2016, it increases to 42% in 2050 (Figure 3.13). South-east Asia, Oceania and north-east Asia show similar growth rates (around 1.7% CAGR) in renewable energy supply, mainly coming from substantial annual additions of solar, geothermal and wind sources, especially in the power sector.

Figure 3.13 • TPES of renewables by region in the BAU, 2000-50



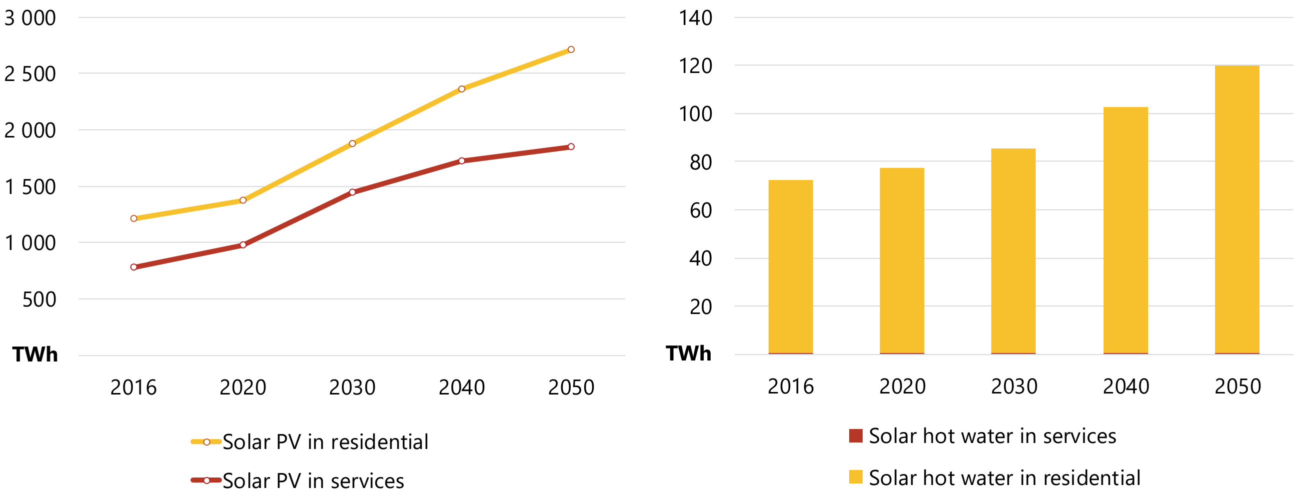
Sources: APERC analysis and IEA (2018a).

ROOFTOP SOLAR POTENTIAL IN APEC IS ABUNDANT BUT UNDER-UTILISED

Among the renewable resources for electricity, solar energy grows the most rapidly (6.8% CAGR) in the BAU. While hydro power capacity in 2016 is almost 3.5 times larger than solar, future expansion is limited because of land area limitations and topographic requirements. Conversely, the scalability and declining costs for solar panels (i.e. PV) and solar thermal support rapid future growth (IEA, 2011). At least two-thirds of APEC economies have more than 2 000 hours of sunshine annually, boasting rich solar resources that can be utilised by installing rooftop solar systems (WMO, 2010).

Based on APERC analysis, building rooftops in APEC had the potential to generate an estimated 2 000 TWh of electricity using solar PV in 2016 (Figure 3.14).[17] This quantity is comparable with the total electricity that APEC generates from hydro power, which is currently the largest renewable generation source. By 2050, APEC has the potential to simultaneously meet the entirety of its hot water demand in residential buildings using rooftop solar water heater (SWH) units and install over 2 200 GW of solar panels. In services, commercial buildings alone could provide 1 846 TWh of electricity in 2050.

Figure 3.14 • APEC total estimated potential from solar energy in buildings, 2016-50



Sources: APERC analysis and IEA (2018a).

BIOENERGY COULD SUPPLY UP TO 22% OF APEC ENERGY NEEDS IN 2050

Biomass residues[18] represented an estimated 1 132 Mtoe in 2016, with the largest volumes in China, the United States and Indonesia. This estimate includes four types of waste: agricultural, forestry residues, animal residues, and municipal solid waste (MSW). More than half of the potential supply comes from agricultural residues and 27% is MSW, which includes a mixture of organic, plastic, paper and other materials. The majority of these residues went unused in 2016, representing a significant untapped potential to increase bioenergy's role in the APEC energy mix.

Over the Outlook period, bioenergy potential can increase to 1 442 Mtoe by 2050 (0.71% CAGR) (Figure 3.15). MSW supply potential increases more quickly than any other bioenergy source from 2016 to 2035 because of rapid urbanisation in developing economies; after that, bioenergy growth gradually slows to 2050. Forestry residues, including mostly industry roundwood, wood fuel, and wood chips and particles, represent 15% of total

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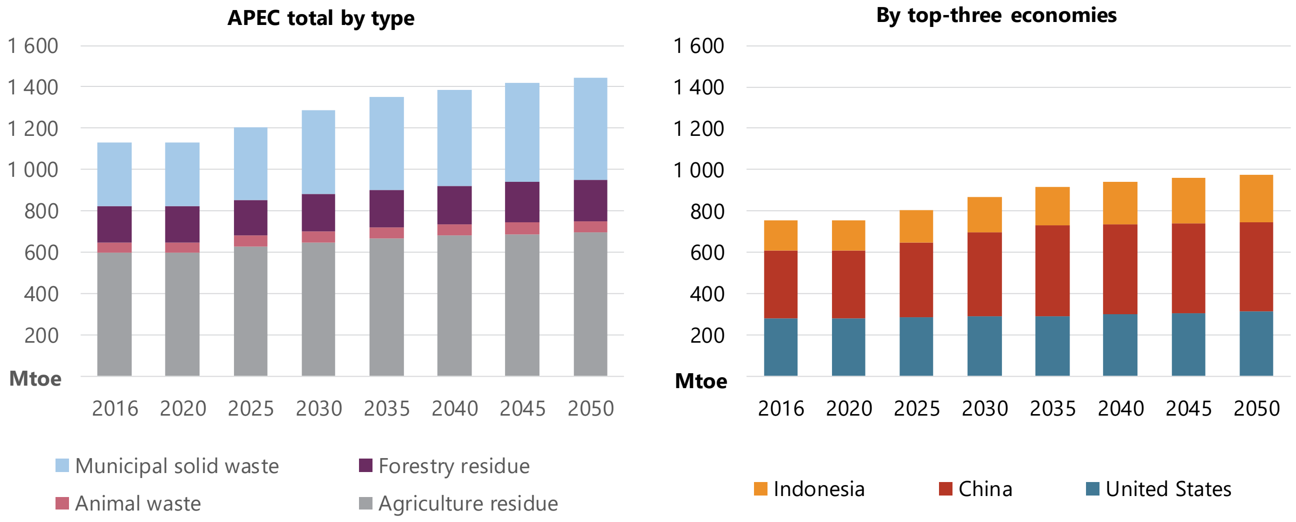
[17] This estimate accounts for rooftop space that is already occupied by solar water heaters (SWH) in APEC.
[18] All biomass potential except energy and food crops.

bioenergy supply potential in 2016 and 14% in 2050. Animal waste represents around 4.0% of total supply potential throughout the Outlook period. If 20% of this bioenergy were used to produce bioethanol[19], the volume of second-generation biofuels could be 56 billion litres (71 Mtoe) in 2016 and rise to 69 billion litres (88 Mtoe) in 2050. Given the rising potential for biomass, this resource could supply up to 22% of APEC's total FED in 2050 (6 564 Mtoe).

Figure 3.15 • Biomass potential in APEC and top three economies, 2016-50



Sources: APERC analysis and IEA (2018a).

OPPORTUNITIES AND CHALLENGES

Continued use of fossil fuels in the APEC region is a given: while some economies have increased the share of renewable energy and have achieved important milestones in decarbonisation, particular in the power sector, other subsectors such as transportation or heating will need to rely on fossil fuels, until at least 2050. Most evidently, oil remains as the main fuel component of TPES in APEC as it continues to be indispensable in the transportation sector, especially for road transport.

APEC economies can capitalize on the increased availability and cost competitiveness of natural gas. LNG markets are currently oversupplied because of rising production in Australia, Russia, the United States and other producing economies and are projected to remain so until at least 2022. In turn, LNG prices in Asia are expected to remain competitive. This situation of abundant LNG volumes, new suppliers and competitive prices represents a significant opportunity to APEC member economies, particularly in south-east Asia, to increase their natural gas supply through the development of LNG regasification terminals, taking advantage of competitive LNG imports. For economies with low natural gas penetration (e.g. the Philippines and Viet Nam), the development of LNG import infrastructure not only provides source flexibility, reduces significantly GHG emissions and improves air quality, but also enhances fuel diversity and energy security.

Natural gas demand has increased in APEC economies in recent years—a trend that continues over the Outlook period. To date, natural gas demand has been mostly concentrated in power generation and industry in these economies. The opportunity to boost consumption in other sectors (notably, the buildings sector) has been stymied by, among other factors, insufficient infrastructure, including transmission and distribution pipelines for

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[19] Applied to only certain types of feedstock; for example, straw, husks bagasse or wood chip.

the entire population of residential consumers. Providing natural gas access to all citizens across territories and regions remains both a significant challenge and opportunity in these economies.

Some APEC economies that are already net importers of natural gas also show increased demand over the Outlook period, particularly China, Japan, Korea and Mexico. Opportunities exist for other economies that are natural gas net exporters to coordinate through intra-APEC trade. As Russia and Canada see decreasing demand for gas imports in their traditional markets (i.e. Europe and the United States, respectively), they could look to APEC to find new destinations, which could be mutually beneficial for several APEC economies.

While coal consumption creates environmental challenges, the opportunity exists to reduce its impacts while continuing to serve markets. The high share of coal-fired power plants represents a substantial challenge in several APEC economies (e.g. Australia, China, Indonesia and Malaysia) as they strive to reduce associated negative health impacts and to meet their commitments under the agreement reached from the 21st Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (COP21 Paris Agreement).

For those economies in which coal demand grows, such as Indonesia, Malaysia and Thailand, it is rational for governments to focus on higher-efficiency coal technologies for electricity generation, such as the ultra-supercritical technologies now being deployed in some APEC economies. As coal demand declines in other APEC economies—particularly in the United States and China—opportunities will arise to re-evaluate production strategies to focus on the investment for higher-quality (i.e. metallurgical) coal and more efficient mining practices. The growing demand for coal in some APEC economies, mainly for power generation, constitutes an important challenge in the region. Growth in coal demand will not only make it extremely unlikely to meet international environmental goals and augment the risks associated with climate change, but it will also further contribute to worsening air quality in major cities, already a major health issue in some regions.

Renewable energy faces multiple challenges in the APEC region. While considered as almost ‘free of cost’ as the raw material inputs come from natural sources, renewable energy sometimes requires substantial infrastructure investment, especially for hydro, offshore wind, geothermal and marine power, and is thus a great challenge for developing economies. Given the abundant potential of solar power in many parts of APEC and the steady decline of installation costs, significant opportunity exists to increase the use of solar energy to replace fossil fuels, such as in residential and services buildings. Solar energy is poised to grow more rapidly than any other renewable energy resource in the region, which could create huge opportunities for green jobs in the near future. Additionally, an abundant potential for bioenergy (to offer a supply source), coupled with mandatory targets for biofuel in some economies (to create demand; see Table 5.1 in Chapter 5), opens up new prospects for domestic markets and intra-regional trade.

Considering APEC’s position in the context of international markets, projected changes in demand and supply under the BAU Scenario create significant opportunity to expand intra-APEC trade across all energy sources. For example, APEC can take advantage of the rise of shale oil and gas supply in the United States to match up with the surge in demand from China and south-east Asia.

RECOMMENDATIONS FOR POLICY ACTION

Fossil fuels continue to dominate energy supply across APEC in the Outlook period. This raises significant questions as to how the region can achieve its goal to double the share of renewables in the energy mix by 2030 as set out in the 2014 APEC Economic Leaders Declaration. Together, APEC economies have set numerous targets for transitioning to an energy system that produces lower levels of GHGs, reduces local air pollution and improves energy intensity while also ensuring affordable energy access to wider populations. In turn, two overarching questions are: a) what should be done in the policy arena to more quickly reduce fossil fuel dependence in the region; and b) what intra-regional actions could support this goal?

Natural gas, due to its versatility and current abundance, represents one near-term option to support reduced GHG emissions and improve local air quality. While the cost of coal-fired electricity generation might seem lower than gas, fully accounting for factors such as air quality, GHG emissions and public health impacts suggests that replacing coal with natural gas-fired electricity can contribute to GHG and local air quality ambitions. Despite being a fossil fuel, gas emits less CO_2 and other types of air pollution than coal does when used for power generation. The rapidly developing LNG market presents an opportunity to promote its consumption as a bridge fuel for economies moving towards increasing levels of renewable power and to improve source diversity for importing economies.

In order to increase use of natural gas in their economy, governments can directly adopt policies to incentivise fuel switching towards it, both as a substitute for coal-fired power generation and as a substitute for traditional biomass in buildings and industry. Some APEC economies have supported this type of fuel switching by creating reliable legal frameworks, developing partnerships with local communities and advocating for transparency in order to minimise investment risks. Combined, these types of actions can create a favourable environment for investments in natural gas infrastructure, such as new natural gas power plants and distribution networks.

APEC economies could pursue a comprehensive approach to reach the renewables doubling goal by developing policies to support own-economy ambitions while pursuing cooperation with other APEC economies. Variable renewable energy, especially solar, is now the leading solution for shifting to renewables in both heat and power. Bioenergy is also a prospective source; to boost shares of waste-to-energy, governments should take action on sustainable source management, such as municipal waste. APEC economies could develop strategies and enable policies and programs to fulfil the region's bioenergy potential and capture the opportunity for boosting solid and liquid biomass production and trade. They could also increase public awareness of waste management and to foster acceptance of a biofuel transition. Ensuring that such support is stable in the long term is vital to attracting investors to the renewables industry, which many currently perceive as costly and high risk.

4. OUTLOOK FOR ELECTRICITY

KEY FINDINGS

- **Electricity demand in APEC grows by 45% in the BAU Scenario over the Outlook period, driven by China, south-east Asia and the United States.** Generation capacity in APEC increases by 83% from 2016 to over 7 200 GW by 2050. Demand in south-east Asia grows the most rapidly; its share of APEC demand doubling to 12% in 2050 from 2016.

- **Electric vehicle uptake has large impacts in China,** as charging accounts for 6.6% of total electricity demand in 2050. It is critical to have in place operational rules that coordinate charging activities to maintain grid stability.

- **Coal and gas remain the two largest sources for electricity throughout the Outlook period, but non-fossils show robust growth,** accounting for almost half (42%) of generation in 2050. VRE contributes 15% of generation in 2050, which is smaller than their share in the capacity mix (35%) due to lower capacity factors than fossil fuel power plants.

- **Additional policy action is needed to achieve the APEC aspirational goal of doubling the share of renewables by 2030.**

- **Cumulative capital investments in generation capacity and networks range between USD 9.5 trillion to USD 20 trillion.** Renewables account for about 70% of total investments for power plants and storage facilities in both low- and high-cost estimates. Under the BAU, investments for solar reach USD 2.2 to 3.3 trillion while those for wind power are USD 0.69 to 1.2 trillion.

- **Average generation cost increases by 25% from 2016 to 2050,** because of rising fossil fuel prices (both coal and gas) and capital investments for new power generation capacity. Policies to manage fuel price impacts and encourage cost reductions for renewables will be important.

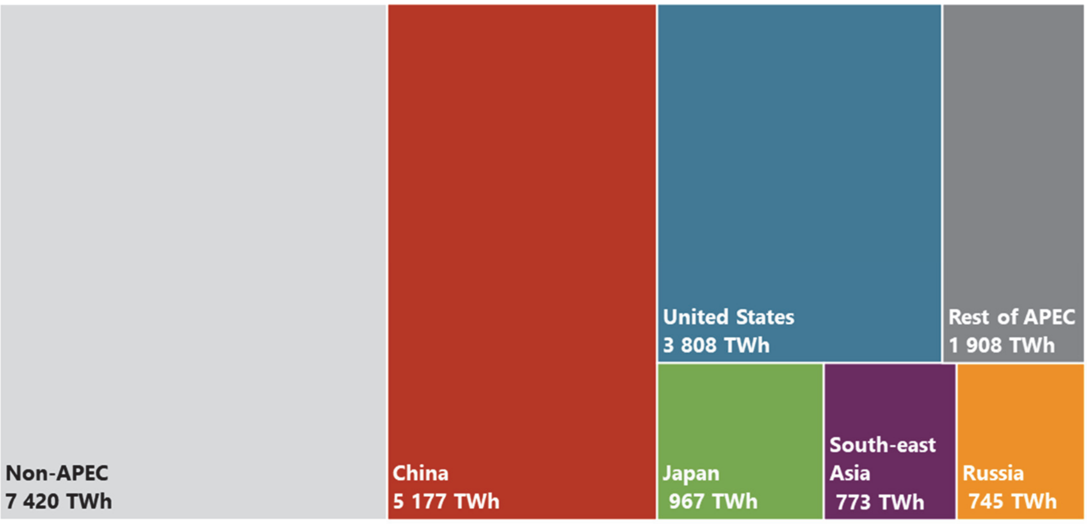
- **Uncertainties associated with electricity markets and energy policies could discourage investments in a low-carbon and reliable electricity supply.** Economies should formulate transparent and adaptable policies with long-term perspectives.

INTRODUCTION

The Asia-Pacific Economic Cooperation (APEC) includes major electricity markets that together accounted for 63% of global electricity generation in 2016. Power generation is a key sector in APEC from both energy and environmental perspectives: in 2016, electricity generation consumed about 40% of total primary energy supply and energy-related carbon dioxide (CO_2) emissions. Electricity demand is projected to grow for the foreseeable future, driven predominately by economic growth in APEC's developing economies. To support sustainable development, the APEC Energy Ministers agreed (in 2014) to a collective goal to 'double the share of renewables in the APEC energy mix, including in power generation, from 2010 to 2030.' (APEC, 2014)

In APEC, the three largest electricity-consuming economies in 2016 are China (5 177 terawatt-hours [TWh]), the United States (3 808 TWh) and Japan (967 TWh) (Figure 4.1) (IEA, 2018a). China's demand for electricity increased almost fivefold from 2000 to 2016, as strong economic growth pushed the compound annual growth rate (CAGR) to 11%. In 2011, China became the largest electricity consumer in APEC, surpassing the United States and is projected to remain in this position throughout the Outlook period. Economic growth in south-east Asia has also led to strong electricity demand growth, with aggregated demand more than doubling in 2016 compared with 2000 levels. Within south-east Asia, Viet Nam showed the fastest rise (13% CAGR), followed by Malaysia (9.7%), Indonesia (6.5%), Thailand (5.1%), the Philippines (4.5%) and Singapore (3.7%). In contrast, electricity demand in developed economies—including Canada and Japan—has essentially plateaued over the last 16 years. Growth was relatively modest in Japan (0.16% CAGR), while electricity demand in Canada slightly decreased (-0.09%). Japan's low growth was partially because of continuous energy-saving efforts after the Fukushima Daiichi nuclear accident in 2011.

Figure 4.1 • Global electricity demand by region, 2016

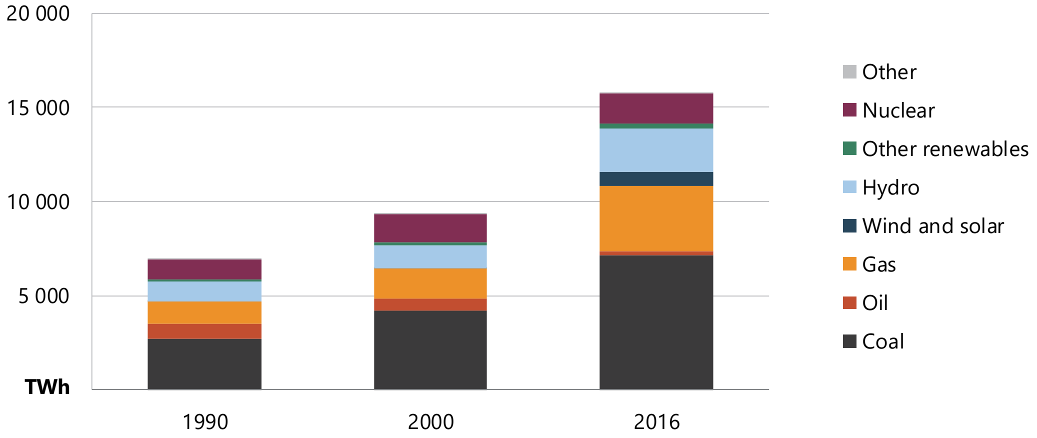


Source: IEA (2018a).

Despite efforts to reduce negative environmental impacts from the electricity sector over the last two decades, use of fossil fuels has significantly increased in APEC generation, largely to satisfy the rapidly growing demand in developing economies, especially China in the 2000s (Figure 4.2). In APEC, both coal and gas generation more than doubled in absolute terms from 1990 to 2016: coal from 2 738 TWh to 7 163 TWh and gas from 1 146 TWh to 3 477 TWh.

Still, use of renewables and nuclear power shows progress. Between 2010 and 2016, cost reductions, in combination with targeted policy support, helped accelerate deployment of 182 gigawatts (GW) of wind power and 168 GW of solar photovoltaics (PV) in APEC,[20] with China contributing more than half (57%) of APEC wind and solar PV capacity additions (IRENA, 2018). Nuclear power generation in the region showed a gradually increasing trend before the Fukushima accident, driven by new reactors in Japan, Korea and the United States in the 1990s and by China's accelerated installation of new nuclear in the 2000s. While reactor shutdowns caused a subsequent decline in nuclear generation in Japan, new installations in China[21] still boosted the net total in APEC.

Figure 4.2 • Electricity generation by fuel type, 1990, 2000 and 2016



Source: IEA (2018a).

This chapter presents electricity sector projections to 2050 in the Business-as-Usual (BAU) Scenario, which includes existing policies and policies that are highly likely to be implemented. It does not incorporate targets, goals or policy proposals that remain uncertain. Key assumptions for electricity supply in the BAU are summarised in Annex I. The chapter also highlights the impacts of connecting power grids in south-east Asia (Box 4.1). Alternative electricity sector projections are examined in the chapters on the APEC Target (TGT) Scenario (Chapter 5) and the Two-Degrees Celsius (2DC) Scenario (Chapter 6).

APEC ELECTRICITY DEMAND

DEMAND GROWTH DRIVEN BY CHINA, THE UNITED STATES AND SOUTH-EAST ASIA

Electricity demand in APEC more than doubled from 1990 to 2016; over the Outlook period, it continues to grow by 45% (Figure 4.3). China, the United States and south-east Asia are the key drivers, together contributing 90% of the incremental demand growth. Although China and the United States remain the two largest economies in terms of electricity demand, south-east Asia grows the most rapidly; its share of APEC demand reaches 12% in 2050, compared with 6.2% in 2016. Economic development and rising per-capita income drive growth in China and south-east Asia, largely through accelerating penetration of electric appliances in the residential subsector. In China, the shift to electric vehicles (EVs) in the transport sector also has a large impact (Figure 4.5). Demand growth in the United States, one of APEC's mature economies, is relatively modest at a 0.59% CAGR from 2016

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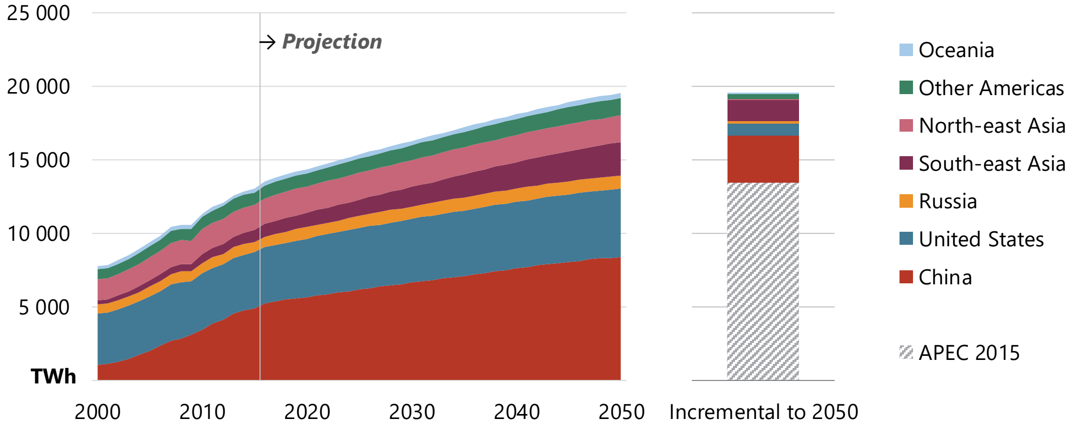
[20] In the APEC region, wind capacity grew from 79 GW in 2010 to 261 GW in 2016, and solar PV from 8.8 GW to 177 GW. The combined share of wind and solar PV in the generation mix increased from 1.3% (173 TWh) to 4.7% (737 TWh).

[21] After the nuclear accident in Fukushima, China conducted a thorough safety assessment for existing reactors, reactors under construction and planned reactors (State Council, 2011). The economy subsequently resumed new reactor construction, with the result that electricity generated from nuclear almost doubled between 2011 and 2016, increasing from 87 TWh (12 GW at the year end) to 213 TWh (34 GW) (IAEA, 2016; IEA, 2018a).

to 2050, which is lower than China (1.4%) and south-east Asia (3.0%); however, the United States remains a major driver in absolute growth (in TWh) given the large market size. The growth is led by trends in services (due to economic growth), industry (due to rising demand in the chemical and petrochemical and non-metallic minerals subsectors) and transport (from higher penetration of EVs).

The share of population with access to electricity is estimated to be 100% in 12 economies in 2016, while the other 9 economies, mainly in rural areas in south-east Asia and South America, range from 89% to 99.7% except for Papua New Guinea (PNG) (15%). Improved access to electricity grids—100% in 15 economies and more than 99% in 5 economies in 2050—is another driving factor for incremental rises in electricity use under the BAU in these regions. Electricity demand is projected to grow in all APEC economies under the BAU, except for Japan where decreasing population, moderate economic growth and continuous efforts to boost energy efficiency result in a 9.4% decline over the Outlook period.

Figure 4.3 • Electricity demand growth in APEC by subregion, 2000-50



Sources: APERC analysis and IEA (2018a).

The APEC electricity demand projection of 18 079 TWh for 2040[22] in this Outlook (7th Edition) is significantly lower than the figure of 21 062 TWh published in the 6th Edition. Moderated economic growth and more detailed modelling of energy efficiency are two of the main factors behind the revised trend. China's gross domestic product (GDP) growth in 2016-40, for example, was lowered from a CAGR of 4.5% in the 6th Edition to 4.0% in this Outlook. In addition, methodological enhancements in the demand-side models—from simplified top-down approaches driven by macroeconomic indicators to bottom-up models considering end-use activities under the BAU—facilitated more detailed analysis of future energy efficiency trends.

Per-capita electricity consumption is projected to grow in APEC developing economies, although it remains below that in developed economies (Figure 4.4). Current per-capita electricity consumption in 2016 varied by economy, ranging from 496 kilowatt-hours (kWh) per year in Papua New Guinea to above 13 000 kWh per year in Canada, reflecting various socioeconomic factors, including lifestyle, local climates, availability of affordable electricity and stage of infrastructure development.

In the BAU, China and south-east Asia show the strongest electricity demand increases over the Outlook period, with per-capita consumption rising by 66% in China, more than doubling in Indonesia, Thailand and the Philippines, and increasing by almost 85% in Viet Nam and 43% in Malaysia. Gaps remain between developed and developing economies. Despite rapid economic growth, per-capita electricity demand in Indonesia, the

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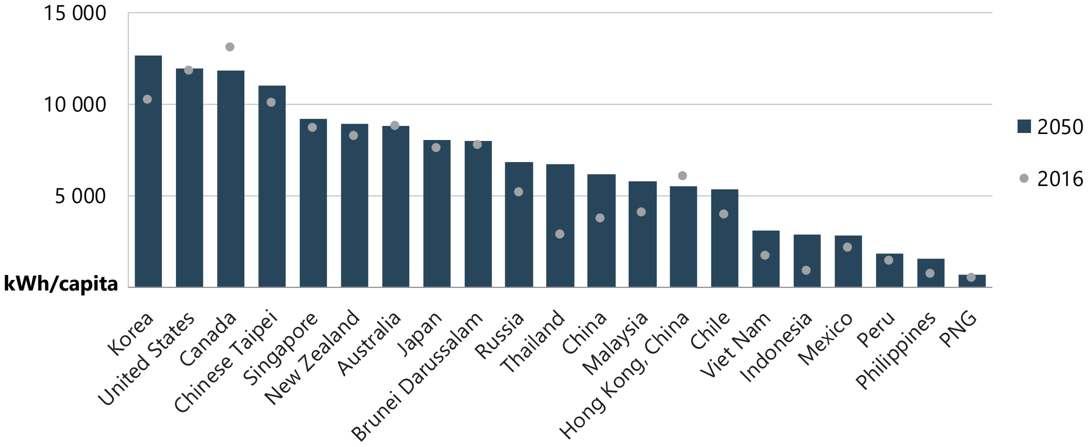
[22] 2040 was the end of the projection period in the 6th Edition.

Philippines and Viet Nam remains within the range of 1 500 kWh to 3 100 kWh per year in 2050, much lower than in south-east Asian economies with higher per-capita GDP (such as Brunei Darussalam and Singapore). In the other Americas, the economies of Chile, Mexico and Peru also continue to have relatively low per-capita demand rates relative to the APEC region, implying potential for additional demand growth beyond 2050.

Figure 4.4 • Per-capita electricity demand by economy, 2016 and 2050



Sources: APERC analysis and IEA (2018a).

Growth of per-capita demand is relatively modest (less than 10% over the period) in eight APEC economies—Australia; Brunei Darussalam; Hong Kong, China; Japan; New Zealand; Singapore; Chinese Taipei; and the United States—where relatively high per-capita GDP growth is tempered by energy efficiency improvements. Canada's electricity demand per-capita is projected to decrease by 9.4% over the Outlook period. The trend is driven by the residential subsector in Canada, Japan, Chinese Taipei and the United States. For example, building efficiency codes and appliance standards in the United States lead to improved energy efficiency of building envelopes and household appliances. Efficiency improvements in commercial buildings lead the decline in Brunei Darussalam; Hong Kong, China; and Singapore.

ELECTRIC VEHICLE GROWTH AFFECTS ELECTRICITY DEMAND

Since mid-2017, several economies around the world have announced policies to accelerate a transition away from traditional fossil fuels in road transport. France and the United Kingdom have announced bans on the sale of gasoline and diesel vehicles by 2040 in parallel with efforts to increase the share of EVs. India plans to ban the sale of traditional vehicles even earlier, by 2030. Among APEC economies, China, which is projected to be the largest vehicle market over the coming decades, is promoting the uptake of EVs through buyer subsidies. It also plans to promote production of alternative-fuel vehicles via a minimum production share requirement for domestic car manufacturers. While inertia in the vehicle stock transition is projected to temper shorter-term impacts of EV adoption, the shift to alternative-fuel vehicles, especially EVs,[23] are projected to have significant impacts on electricity markets moving forward. In the BAU, annual electricity demand for road transport jumps from 49 TWh (0.36% of total APEC electricity consumption) in 2016 to 805 TWh (4.1%) by 2050—more than Korea's total electricity consumption in 2016. This growth is mostly driven by China and the United States (Figure 4.5). In China, road transport's share of total electricity demand reaches 6.6% by 2050, and the on-board battery capacity of light-duty vehicles (LDVs) amounts to about 3 TWh.[24] This level of penetration may have

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[23] Electric vehicles (EVs) and plug-in hybrid vehicles (PHEVs). This Outlook includes EV and PHEV technology options for light-duty vehicles (LDVs) and EV options for light-duty trucks and heavy-duty trucks.

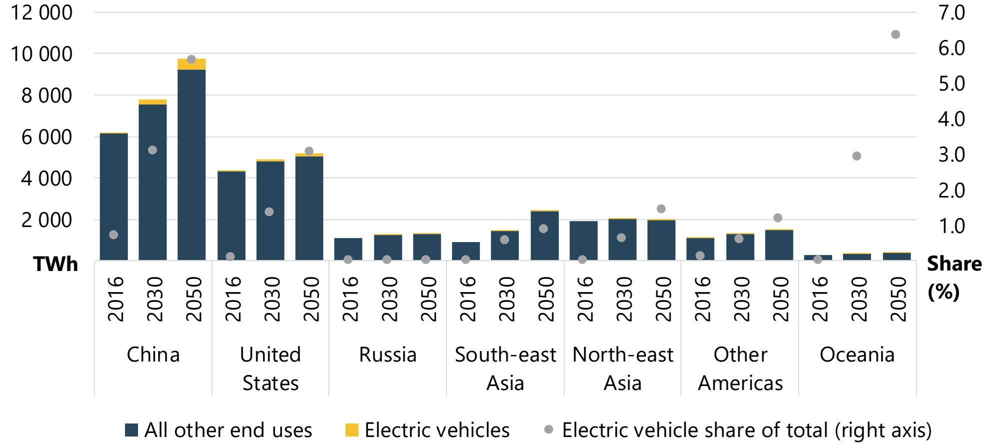
[24] In China, LDV stock of EVs reaches almost 90 million and PHEVs almost 45 million by 2050. This Outlook assumes average battery power capacity of 30 kWh for EVs and between 6 kWh and 7 kWh for PHEVs. Total on-board battery capacity is estimated by multiplying the vehicle stock and battery capacity.

large impacts on the electricity grid from a network infrastructure and operations perspective; it becomes increasingly important to enhance distribution infrastructure as well as establish new tariff schemes and operational rules to coordinate and accommodate EV charging activities. The BAU assumes that a majority of EVs are charged during night-to-morning hours (20:00 to 08:00) in a coordinated manner (see Annex I).

By 2050, 3.4% of electricity demand in the United States comes from road transport, compared with less than 0.1% in 2016. Although their impacts on the whole APEC trend are relatively modest, EVs show strong growth in Australia, Chile and New Zealand; over the outlook period, share of road transport in electricity demand increases from roughly 0% to 7.8% in Australia, 5.9% in New Zealand and 3.9% in Chile. In the rest of APEC economies, road transport's share remains limited (0.001% to 2.5%) by 2050.

It must also be considered that the emissions intensity of electricity generation affects life-cycle CO_2 emissions of EVs. Average emissions intensity of electricity generation in China improves from 674 grams of carbon dioxide per kWh (gCO_2 per kWh) in 2016 to 412 gCO_2 per kWh in 2050, almost equivalent to the emissions level for natural gas combined-cycle power plants, thanks to growing low-carbon electricity sources as discussed below (for example, see Figure 4.9). Emissions intensity of electricity generation in the United States also improves, from 437 gCO_2 per kWh to 342 gCO_2 per kWh over the projection period.

Figure 4.5 • Electricity demand for electric vehicles and other end-uses by subregion, 2016-50



Sources: APERC analysis and IEA (2018a).

ELECTRICITY SUPPLY

OVERALL TRENDS

APEC includes a diverse set of economies in terms of domestic energy resource endowment, socioeconomic structure and environmental priorities. These economies also differ significantly in the total size of their electricity markets (Figure 4.1), with the larger economies being the drivers of energy trends. Although the BAU Scenario falls short of achieving global climate targets set in the Article 2 of the COP21 Paris Agreement, it does show a gradual transition toward a cleaner electricity supply. Over the Outlook period, fossil fuels without carbon capture and storage (CCS) continue to be the largest source of electricity; yet their share in generation declines steadily from 69% in 2016 to 57% by 2050 (Table 4.1). Coal-fired power generation shows a declining trend, due to a combination of strong political initiatives and economics: China closes ageing coal-fired plants and decelerates new installations to address air-pollution issues, while the United States focuses on retirement of ageing coal-fired plants due to their inability to compete with low-cost natural gas and renewable power generation. Gas-fired generation, with its lower CO_2 emissions compared with coal and oil generation, grows by 81%.

Table 4.1 • Electricity generation and share by fuel, 2010-50

	Generation (TWh)				Share (%)			
	2010	2016	2030	2050	2010	2016	2030	2050
Fossil fuels	**9 596**	**10 894**	**11 599**	**12 915**	**71**	**69**	**61**	**57**
Coal	6 569	7 163	6 748	6 535	49	45	36	29
Gas	2 701	3 477	4 761	6 301	20	22	25	28
Oil	325	255	90	78	2.4	1.6	0.47	0.35
Nuclear	1 658	1 573	2 054	2 282	12	10	11	10
Renewables	**2 118**	**3 299**	**5 223**	**7 249**	**16**	**21**	**28**	**32**
Hydro	1 766	2 313	2 782	3 112	13	15	15	14
Wind	163	536	1 087	1 495	1.2	3.4	5.7	6.6
Solar	10	200	865	1 862	0.07	1.3	4.6	8.3
Geothermal	53	47	121	196	0.40	0.29	0.64	0.87
Biomass and other renewables	127	204	369	584	0.95	1.3	1.9	2.6
Other	58	72	79	79	0.43	0.46	0.42	0.35
Total	**13 430**	**15 839**	**18 954**	**22 524**	**100**	**100**	**100**	**100**

Note: This table includes data from 2010, the base year of the APEC doubling renewable energy goal.
Sources: APERC analysis and IEA (2018a).

APEC has a collective goal for renewable energy, aiming to double the share in the energy mix, including power generation, from 2010 to 2030. In this Outlook, the goal is calculated as share of renewables in FED (see Chapter 5). Although the BAU is insufficient for achieving the goal, renewable energy generation shows the highest growth rate among generation resources thanks to existing policy support and improved economics over the Outlook period. Renewables' share in total electricity generation in APEC nearly doubles from 16% in 2010 to 28% in 2030; however, the doubling goal is defined over all FED and not only the electricity sector. The share of renewables in FED is projected to achieve the goal in the late 2040s under the BAU, which implies that stronger policies would be needed to achieve the goal even within the electricity sector.

Nuclear also increases but at a slow pace, with new reactor additions being partially offset by the retirement of ageing reactors (as in Japan) and phase-out policies in several other economies, including Korea and Chinese Taipei. Overall, share of low-carbon fuels, including renewables and nuclear, grow to 42% of total power generation in APEC by 2050.

INSTALLED CAPACITY GROWS BY MORE THAN 3 000 GIGAWATTS

To satisfy rising electricity demand, power generation capacity in APEC increases by 83%, from 3 958 GW in 2016 to 7 243 GW by 2050 (Figure 4.6). Renewables show the fastest growth at a CAGR of 3.4% over the Outlook period, driven by variable renewable energy (VRE).[25] The share of renewables in APEC capacity expands from 28% in 2016 to 48% by 2050. Growth of VRE is driven by economies with larger electricity markets and supportive policies, including China, the United States and Japan.

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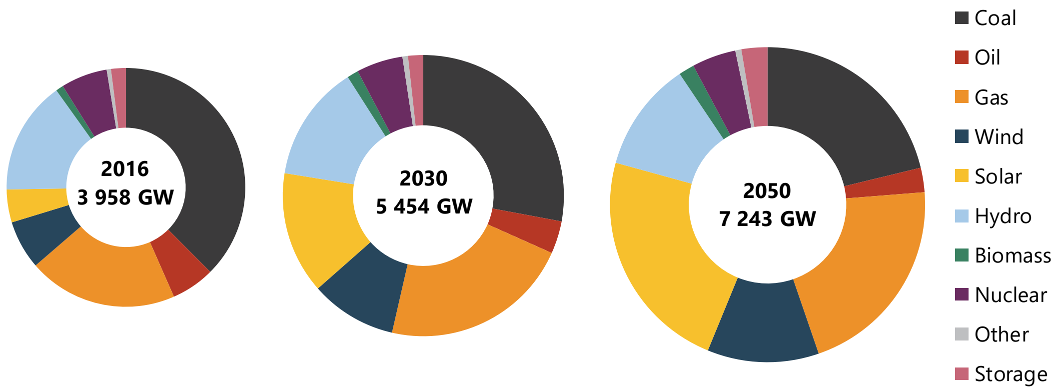
[25] This Outlook defines solar PV and wind power (onshore and offshore) as VRE.

In China, VRE has grown rapidly since the late 2000s, increasing from 30 GW in 2010 to 227 GW in 2016, thanks to cost reductions and strong policy support (e.g. feed-in tariffs [FiTs] for solar PV). In 2017, estimated solar PV capacity in China reached 131 GW, exceeding the target of at least 105 GW in 2020 set out in the 13th Five-Year Plan (NEA, 2016a; 2018). Onshore wind, in contrast, has faced challenges in China as limited grid access led to curtailments. To effectively integrate the abundant renewable resources available in remote regions, the Chinese government plans to enhance transmission networks (NEA, 2016b). Backed by cost reductions and network enhancements, VRE's growth remains robust in the BAU, in which China contributes half of incremental VRE capacity in APEC. VRE is projected to reach 1 536 GW (5.8% CAGR) by 2050, of which 980 GW is solar PV and 556 GW is onshore wind (Figure 4.7).

Figure 4.6 • Electricity generation capacity in APEC, 2016, 2030 and 2050



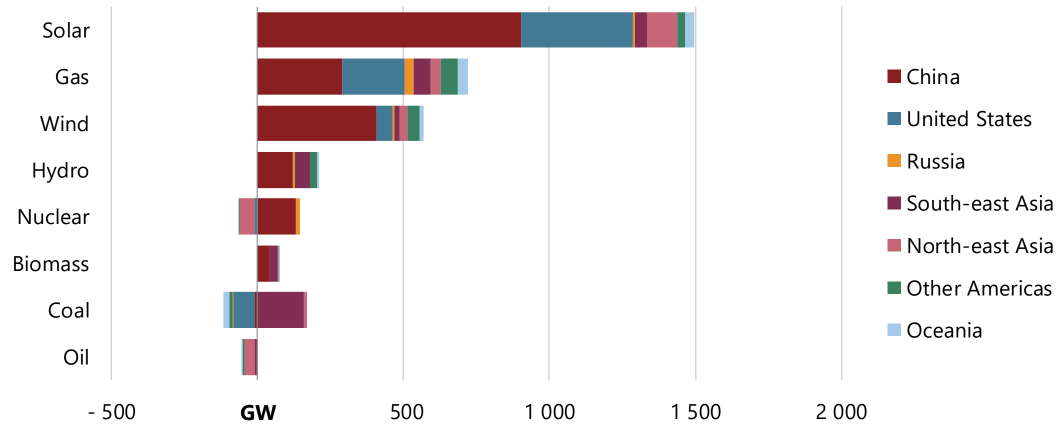
Note: Pumped hydro power plants are included in the storage category in this chart.
Sources: APERC analysis and IEA (2018a).

The United States shows the second-largest growth in VRE capacity in the BAU, although wind power capacity additions slow down because of recent tax code changes. The phase-out of the federal production tax credit, for example, poses economic and financing challenges for wind power in the medium term. Initially, wind capacity jumps from 84 GW in 2016 to 130 GW by 2022 (7.5% CAGR), after which the CAGR plummets to just 0.25% with expansion reaching only 139 GW by 2050. By contrast, further cost reductions for solar PV modules spur strong growth in the long term; new solar PV capacity additions amount to nearly 400 GW by 2050, most of which is installed after 2030. Solar PV also drives VRE growth in Japan, where the capacity of authorised solar PV under a FiT system had already reached 71 GW as of June 2018 (METI, 2018). The recent partial revision for Japan's FiT system (e.g. improved price predictability for wind) is encouraging for future development, although grid access issues remain a major challenge.

Other types of renewables, including hydro and concentrating solar power (CSP), show slow but steady growth in several economies. Hydro developments are again driven by China, where hydro-electricity in south-west regions is transmitted to satisfy demand in eastern provinces (State Council, 2016). New hydro plant additions in China amount to 122 GW of the 209 GW seen in APEC from 2016 to 2050. Chile is one of the APEC economies that develops not only solar PV but also 0.54 GW of CSP plants by 2050, capturing abundant solar resources in the Atacama Desert area. Geothermal resources are abundant in several APEC economies such as the United States, Indonesia, Japan and New Zealand (APERC, 2016b); Indonesia drives development, with new additions of 12 GW by 2050 (57% of the APEC total). In contrast, geothermal developments in Japan are relatively modest as most resources are located in National Park areas. Although environmental regulations have been relaxed somewhat, geothermal development in Japan faces long lead times because of resource exploration, environmental assessments and construction timelines.

Coal-fired power plants, in contrast to renewables, see modest development in terms of new capacity under the BAU. Coal expands in south-east Asia economies such as Indonesia, the Philippines, Thailand and Viet Nam because of the domestic availability of this low-cost fuel resource. In Thailand, coal-fired additions are part of a fuel diversification strategy (Ministry of Energy of Thailand, 2015). In APEC as a whole, however, coal additions slow down due to retirements in developed economies such as Australia, Canada, New Zealand and the United States. For example, the United States retires 74 GW of ageing coal-fired plants under the BAU as other fuels, including natural gas, become more cost competitive. New carbon tax policies and environmental regulations in Canada encourage retirements of traditional coal plants by 2030 (Government of Canada, 2018). Coal growth further slows as China decelerates new capacity additions and retires ageing plants in order to reduce air pollution, curb overcapacity and shift to cleaner fuels. New coal-fired capacity additions in China (117 GW by 2050) are offset by retirements of ageing plants, resulting in the modest changes over the projection period (Figure 4.7).

Figure 4.7 • Electricity generation capacity changes by subregion and fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

Among fossil fuels, installation of gas-fired plants increases across APEC, driven primarily by availability of low-cost gas in North America and Mexico while environmental considerations and fuel diversification are key drivers in China and Japan. Korea is expected to increase its reliance on gas-fired generation, reflecting its policy to phase out coal and nuclear (MOTIE, 2017).

Nuclear power capacity increases in absolute terms in APEC, from 248 GW in 2016 to 328 GW in 2050 in the BAU. Nuclear policies vary significantly by economy. Eight APEC economies[26] used nuclear power generation in 2016. Among them, China and Russia continue to develop new reactors over the Outlook period. China shows the largest growth, surpassing the United States in 2027 to become the largest installed nuclear capacity holder; China's total installed nuclear capacity reaches 166 GW in 2050. The BAU includes a new reactor (1.4 GW) in Mexico in the late 2020s, one of the three reactors outlined in the government's power development plan (Secretary of Energy, 2017).

Conversely, nuclear capacity plateaus in Canada and the United States. Canada continues to use existing reactors through refurbishment (Bruce Power, 2015; WNN, 2016) while projections for the United States account for lifetime extensions to 80 years for existing reactors and the addition of two new reactors (Vogtle units 3 and 4). Yet the planned retirement of seven reactors in the United States—Oyster Creek, Pilgrim, Three Mile Island,

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[26] Canada, China, Japan, Korea, Mexico, Chinese Taipei, Russia and United States.

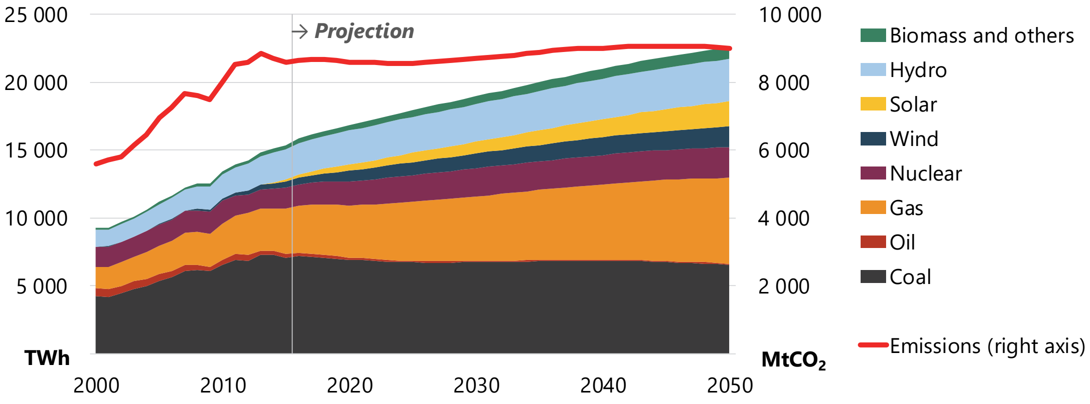
Indian Point units 1 and 2, Diablo Canyon units 1 and 2—offsets these additions. Japan, Korea and Chinese Taipei reduce nuclear dependencies in the medium to long term. Japan's existing nuclear reactors, except for the one for which a lifetime extension has already been approved, follow the '40-year operation rule' in the economy's Nuclear Reactor Act. Korea also shuts down ageing reactors as directed in the 8th Plan (MOTIE, 2017), while Chinese Taipei follows its Electricity Business Act, which includes a phase-out of nuclear by 2025. There are no newcomers to nuclear power in the BAU; nuclear projects in Viet Nam are not included as the economy decided to halt the projects in 2016.

POWER GENERATION WITH CLEANER FUELS EXPANDS, CURBING CO_2 EMISSIONS

Although coal and gas remain the two largest sources for electricity throughout the Outlook period, non-fossils show robust growth, accounting for almost half (42%) of generation in 2050 (Figure 4.8). The share of electricity generated from coal and gas declines from 67% in 2016 to 57% in 2050. VRE contributes 15% of generation in 2050, which is smaller than their share in the capacity mix (35%) due to lower capacity factor than fossil fuel power plants.

Growing shares of cleaner fuels under the BAU reduce CO_2 emissions intensity in APEC, which contributes to curbing absolute emissions from the electricity sector (Figure 4.8). APEC emissions intensity associated with power generation declines from 547 gCO_2 per kWh in 2016 to 399 gCO_2 per kWh in 2050, which is almost equivalent to the level of electricity generated at a combined-cycle gas power plant. Current policies, however, are not on track to meet global climate objectives set out in the COP21 Paris Agreement, which aim to constrain the global average temperature increase to well below 2°C as discussed in Chapter 10 (UNFCCC, 2015). Cumulative emissions from the electricity sector in the BAU reach 308 gigatonnes of CO_2 ($GtCO_2$) over the period 2016-50, almost 90% above the level in the 2DC (163 $GtCO_2$). Emissions intensity under the 2DC is estimated to be just 45 gCO_2 per kWh in 2050, with reductions achieved via significant switches to lower-carbon technologies, including deployment of CCS.

Figure 4.8 • APEC electricity generation mix and CO_2 emissions from power, 2000-50



Sources: APERC analysis and IEA (2018a).

Although coal remains China's largest generation fuel through the Outlook period in the BAU, its use continuously declines because of aggressive policy to use less-polluting fuels to mitigate air pollution. The share of less-polluting fuels, including renewables, nuclear and gas, continuously increases in the BAU to reach 70% of the generation mix in 2050. This trend results in China's CO_2 emission intensity from electricity generation falling by almost 40% over the Outlook period (from 674 gCO_2 per kWh in 2016 to 412 gCO_2 per kWh by 2050) as well as a peak in absolute emissions from electricity generation. China's coal generation projections are significantly changed from the *Outlook 6th Edition*, which continued to increase to 2040. Substantially lower electricity demand is a key driver of this change; projected demand in 2040 of 10 155 TWh in the 6th Edition is adjusted down to 7 592 TWh in the 7th Edition, because this edition assumes more moderated economic activities and higher energy efficiency in both industry and buildings than in the 6th Edition. Modelling in this edition shows a slowdown or peak in industrial activities in several energy-intensive subsectors, including iron and steel and non-metallic minerals, which reduces overall growth of electricity consumption.

In the United States, market mechanisms encourage the expansion of gas-fired power plants because of abundant availability of low-cost domestic gas resource, thanks to booming gas production. After 2020, natural gas contributes the largest share of the US generation mix. The share of VRE in the United States reaches 18% of total electricity generation in 2050, of which 11% is solar PV and the rest is wind power. The economy gradually reduces nuclear share from about 20% in 2016 to 14% in 2050 as retirements outpace new reactor starts.

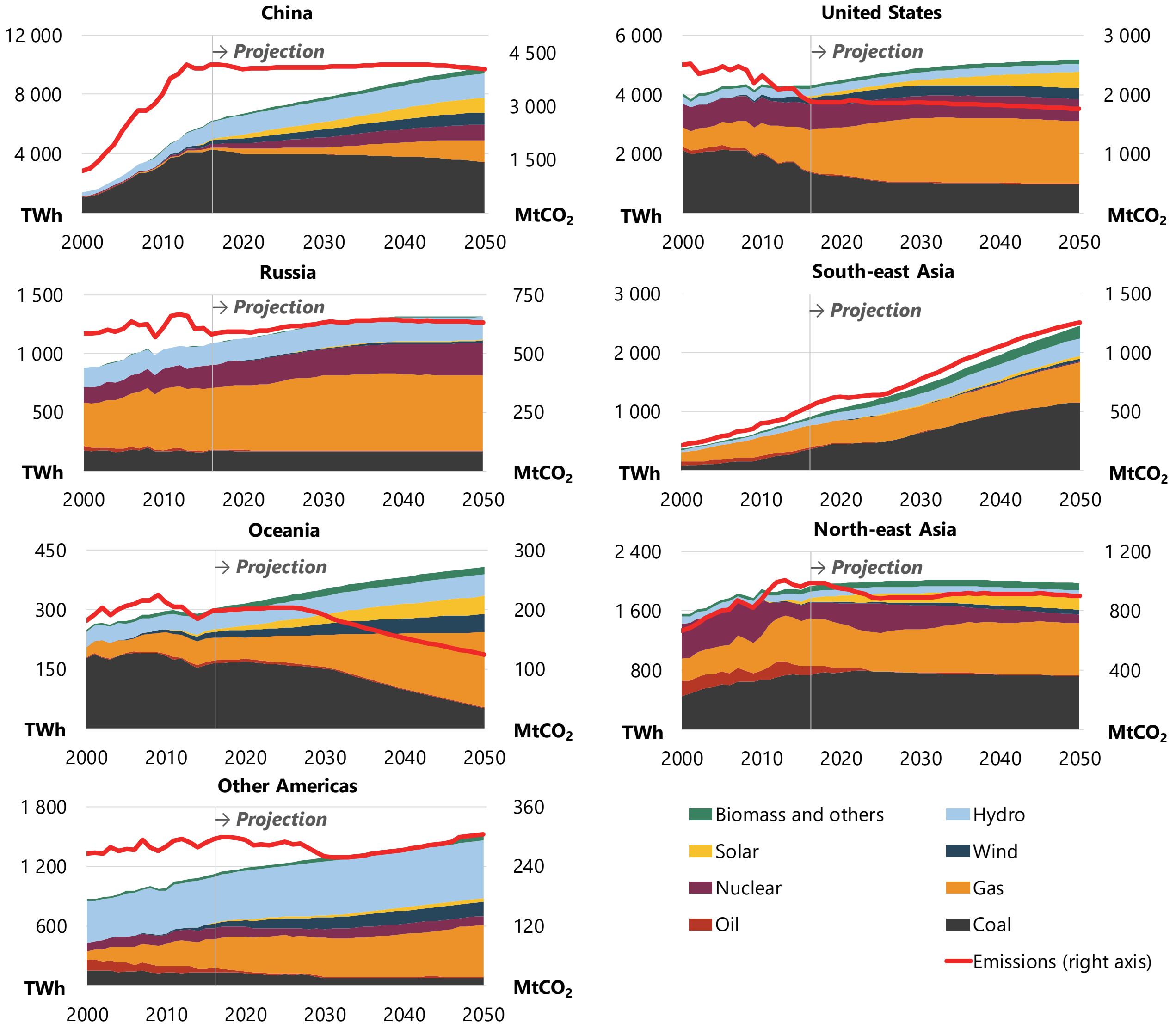
Russia develops combined heat and power (CHP) plants and district heating networks to supply electricity as well as heat during cold winter seasons. Fuel choices for CHP reflect domestic resource availability: natural gas CHP dominates in the western part of Russia, while both natural gas and coal are used in Siberia and in the far eastern parts of the economy. CHP plants, mainly high-efficient combined-cycle natural gas, are expanded under the BAU to satisfy demand for electricity and heat. Electricity generated from natural gas CHP increases by 11% over the Outlook period, from 512 TWh in 2016 to 571 TWh in 2050; heat generation also increases in parallel, from 70 million tonnes of oil equivalent (Mtoe) to 76 Mtoe.

Nuclear retirements in north-east Asia in the BAU have significant impacts from both environmental and energy security perspectives, even though nuclear surges in the early 2020s because of reactor restarts in Japan plus the installation of new reactors in Korea (including Shin Kori and Shin Hanul, under construction as of 2018). This contributes to reducing natural gas consumption in the electricity sector and helps the sector reduce CO_2 emissions from power generation by the mid-2020s, from 988 million tonnes of carbon dioxide ($MtCO_2$) in 2016 to 882 $MtCO_2$ in 2025. From the late 2020s, however, nuclear shifts to a declining trend because of retirements in Japan, Korea and Chinese Taipei. These retirements result in higher CO_2 emissions and a larger dependency on gas-powered generation, which may pose environmental and energy security concerns.

Trends in Oceania are driven by Australia, which accounts for approximately 84% of Oceania's power generation over the Outlook period. The generation mix in Australia becomes less carbon-intensive in the BAU, due to the retirements of ageing coal-fired plants and the growth of cleaner fuels including gas-fired generation, solar PV and wind power. New Zealand has already realised an 83% renewables power supply as of 2016; the share of RE in New Zealand increases further through accelerating additions of hydro, wind and geothermal capacity, reaching nearly 100% (99.6%) by 2050.

In other Americas, hydro power remains the dominant fuel, thanks to abundant resources in Canada and Peru. Gas remains an important resource, encouraged by environmental regulations in Canada and domestic resource availability in Peru. Availability of low-cost gas imports from the United States pushes Mexico towards expanding cross-border pipeline infrastructure and gas-fired generation. A gradual drop in nuclear generation in the early 2020s reflects shutdowns for refurbishment in Canada; subsequently, restarts of these refurbished reactors plus new additions in Mexico stimulate nuclear growth around 2030. This shifting use of nuclear and some shutdowns of existing coal-fired power plants in Canada decrease CO_2 emissions in in other Americas around 2030. In the longer term, increased natural gas generation in Mexico and Peru lift absolute CO_2 emissions.

Figure 4.9 • Subregional electricity generation mix and emissions from power, 2000-50



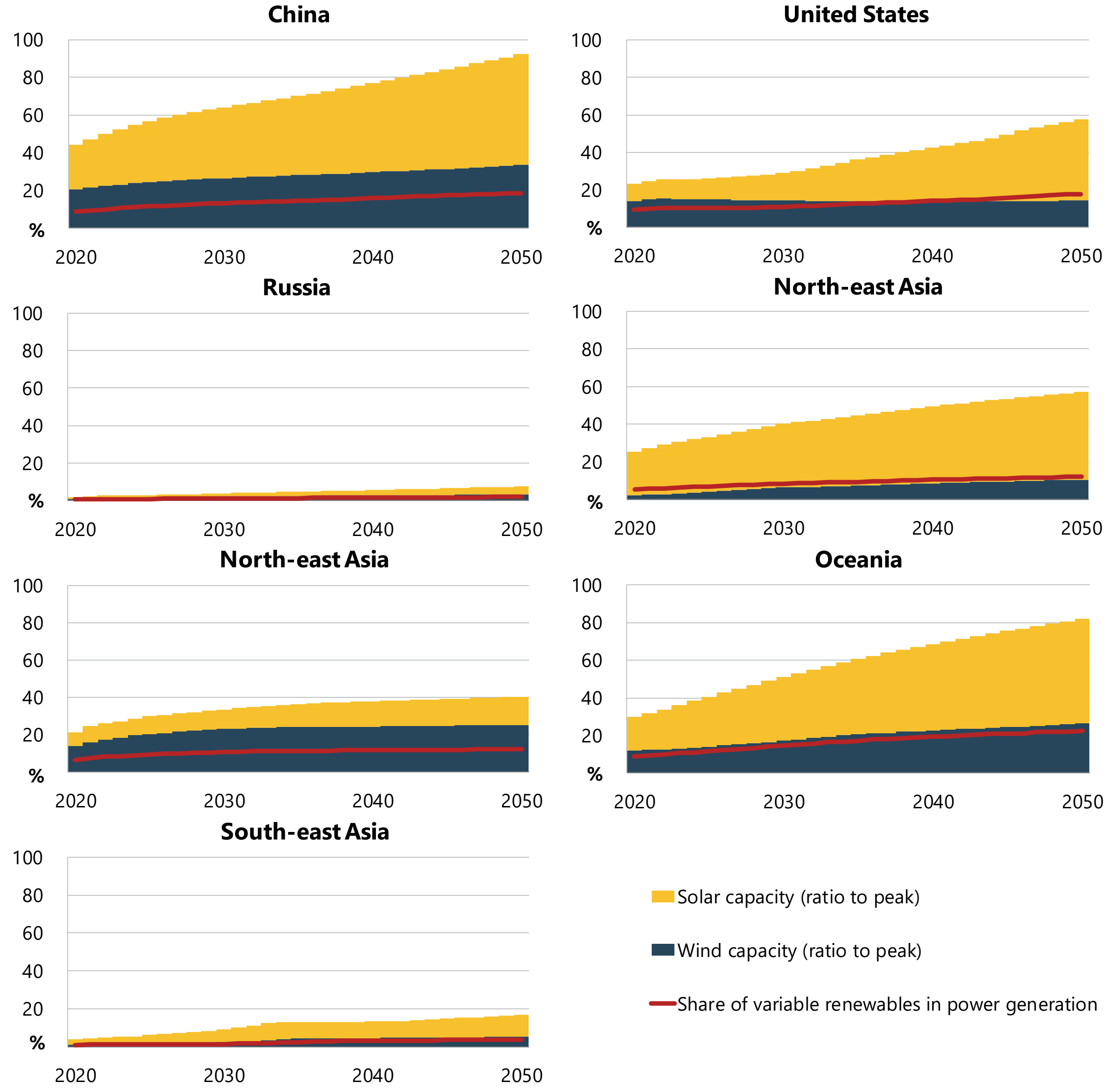
Sources: APERC analysis and IEA (2018a).

Electricity demand in south-east Asia grows the fastest of any region (3.0% CAGR), more than doubling the second-fastest growth in China (1.4% CAGR). To meet rising demand, south-east Asia rapidly increases fossil fuel power generation in the BAU, resulting in steep increases in coal consumption (by almost 2.7 times in absolute terms over the projection period) and gas (1.7 times larger by 2050). This rapid increase may pose energy security challenges for energy-importing economies in other regions, as higher consumption in south-east Asia could put pressure on supplies and increase prices for coal and natural gas.

INTEGRATION MEASURES FOR VARIABLE RENEWABLE ENERGY BECOME INCREASINGLY IMPORTANT

Among renewables, VRE shows the largest growth in terms of capacity in APEC over the Outlook period: VRE capacity expands more than fivefold, from 438 GW in 2016 to 2 503 GW in 2050, much larger growth compared with, for example, hydro power (new additions of 209 GW over the period) (Figure 4.10). The VRE capacity in 2050 is almost equivalent to 66% of aggregated peak load level in APEC. Although VRE output characteristics vary by site-specific conditions,[27] the level of penetration in 2050 highlights the increasing importance of system integration measures to manage variability in both the short term (e.g. less than 20 minutes) and the long term (hourly, daily, seasonally and annually). Economies may be required to implement flexibility options to smooth system operations, including ramping up of flexible plants, improvements of operational parameters for power plants (e.g. relaxation of minimum output level for coal-fired power plants), energy storage, demand-side management and VRE output curtailments. Technologies and operational rules to optimise the transmission and distribution (T&D) network—for example, dynamic ratings or 'connect and manage' rules to maximise the capacity factor of transmission lines—are also crucial for system integration of VRE.

Figure 4.10 • Variable renewable capacity and share in peak load by subregion, 2020-50



Sources: APERC analysis and IRENA (2018).

Among APEC regional groupings, four regions expand VRE markedly in relation to its share of peak load in 2050: China (almost 90% of peak load), Oceania (80% of peak load), the United States (almost 60%) and north-east Asia (almost 60%). Growing shares of solar PV in these regions require daily-cyclic ramping operation of coal-

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[27] For example, spatially distributed PV panels and wind turbines contribute to smoothing aggregated output—a phenomenon commonly called 'smoothing effects'.

and/or gas-fired plants to absorb the output variability during the daytime. These plants also contribute to maintaining the supply-demand balance on cloudy and rainy days, covering any loss of solar PV outputs. Energy storage systems could also play an important role in electricity system flexibility. Japan (categorised in north-east Asia), the United States and China are the three largest economies in the world that have installed pumped hydro storage as of 2016. Total installed pumped hydro capacity in 2016 was 22 GW in Japan, 19 GW in the United States and 23 GW in China (IRENA, 2018); these existing storage facilities largely contribute to managing variable generation under the BAU. In China, accelerated penetration of EVs has significant impact for integrating VRE; electricity load for night-time charging, for example, pushes up the baseload, making use of wind power that would otherwise be curtailed.

As VRE penetration is relatively modest in other APEC regions, ramping up operation of flexible plants is projected to be the main integration measure. Russia shows particularly limited VRE deployment; aggregated VRE capacity remains less than 7.6% of peak load. Although a capacity auction scheme has been implemented, the economy limits new capacity additions to control impacts on electricity costs. Additionally, Russia has installed CHP plants and district heating infrastructure to satisfy local electricity and heat demand; such systems are very difficult to replace with VRE, which generate only electricity.

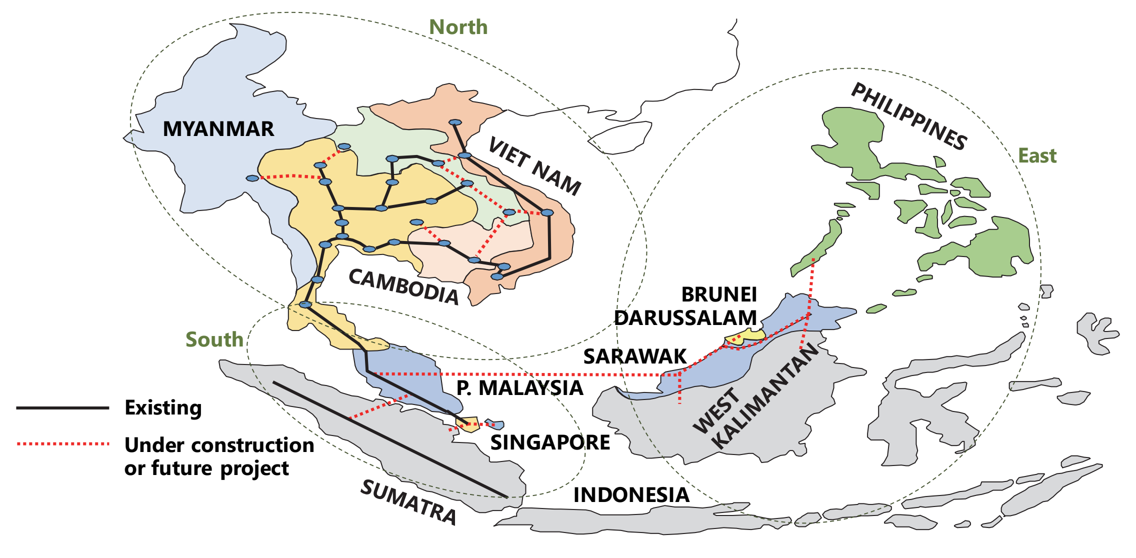
Box 4.1 • Impacts of integrating power grids in the ASEAN region

In 1997, 10 south-east Asian economies established the Association of Southeast Asian Nations (ASEAN) Power Grid (APG), a cross-border interconnection network that aims to effectively use regional energy resources, including fossil fuels and renewables. The group includes seven APEC economies: Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore, Thailand and Viet Nam. Other ASEAN economies that have substantial hydro power resources are Myanmar, Cambodia and Lao People's Democratic Republic (Lao PDR). Together, the Heads of ASEAN Power Utilities/Authorities (HAPUA) promotes the APG, which consists of 16 cross-border transmission projects distributed over northern, southern and eastern corridors, totalling 28 GW capacity (Figure 4.11) (ACE, 2015). The APG was incorporated into the ASEAN Plan of Action for Energy Cooperation 2016-2025, which received endorsement by the ASEAN Energy Ministers in 2014 (ACE, 2015).

To quantitatively assess how integrating power grids could affect electricity trade and CO_2 emissions in south-east Asia in 2030, Asia Pacific Energy Research Centre (APERC) employs a multi-region power system model based on linear programming techniques. Assessing two options, the Base and HAPUA Scenarios, this model minimises single-year system costs, consisting of capital investment costs, operation and maintenance (O&M) costs, and fuel costs. This approach is described in detail in Annex I and in Otsuki et al. (2016).

The Base Scenario includes only four existing interconnections: between Brunei Darussalam and Sabah (Malaysia); from West Kalimantan (Indonesia) to Sarawak (Malaysia); linking Cambodia and Thailand; and connecting Laos PDR and Thailand. Assumptions from the Base Scenario are harmonised with the BAU Scenario of this Outlook. As an alternative, the HAPUA Scenario includes all the future projects (Figure 4.11), except for the two connections (between peninsula Malaysia and Sarawak, and between the Philippines and Malaysia).

Figure 4.11 • Existing and planned interconnections in the ASEAN region as of 2015

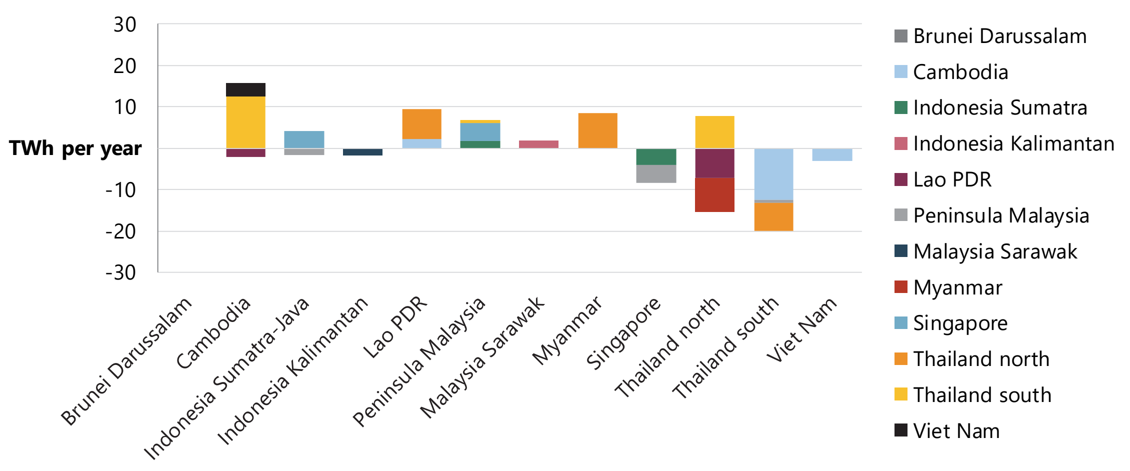


Source: ACE (2015).

RESULTS: ELECTRICITY TRADE GROWS ON THE NORTHERN AND SOUTHERN CORRIDORS UNDER THE HAPUA SCENARIO

Total electricity trade among the ASEAN economies is estimated to be 17 TWh per year under the Base Scenario. The annual revenues for exporters are USD 862 million in 2030. This estimation assumes the reference price for the multi-lateral electricity trade among Laos PDR, Malaysia and Thailand. Under the HAPUA Scenario, total electricity trade expands to 41 TWh per year. Thanks to low-cost hydro power resources and geographical advantages close to demand centres, in the HAPUA Scenario Cambodia, Lao PDR and Myanmar become the top three electricity exporters. The results also imply opportunities for the Sumatra region (Indonesia) and peninsula Malaysia to export electricity to Singapore. On the eastern corridor, in contrast, electricity trade is relatively modest, representing only 4.0% of total trade across the ASEAN region, partially because of smaller electricity markets compared with the other corridors. Under the HAPUA Scenario, estimated annual revenues for exporters are USD 2.1 billion, of which 96% are in the northern and southern corridor regions.

Figure 4.12 • Annual electricity trade under the HAPUA Scenario



Source: APERC analysis.

POLICIES NEEDED TO PREVENT CO_2 EMISSIONS FROM INCREASING UNDER THE HAPUA SCENARIO

Interconnections in the region encourage hydro power developments in Lao PDR and Myanmar. This scenario analysis, however, also suggests that grid integration could contribute to expanding the capacity factor of fossil fuel-powered plants. Under the HAPUA Scenario, Indonesia increases coal- and/or gas-fired generation for electricity exports, contributing to the slight increase in CO_2 emissions from power generation for the ASEAN region as a whole. Overall, the region sees a 2.3% increase in emissions, from 920 MtCO2 per year to 941 MtCO2 per year in the Base Scenario, as shown beneath for selected ASEAN economies (Table 4.2).

Table 4.2 • CO_2 emissions from power generation under the Base and HAPUA Scenarios

Scenario		Brunei Darussalam	Indonesia	Malaysia	Singapore	Thailand	Viet Nam
Base	Emissions [$MtCO_2$]	2.6	462	112	31	121	66
HAPUA	Emissions [$MtCO_2$]	2.6	479	107	26	124	63
Base	Intensity [$kgCO_2/kWh$]	0.67	1.7	1.2	0.55	1.4	1.1
HAPUA	Intensity [$kgCO_2/kWh$]	0.67	1.8	1.2	0.47	1.4	1.0

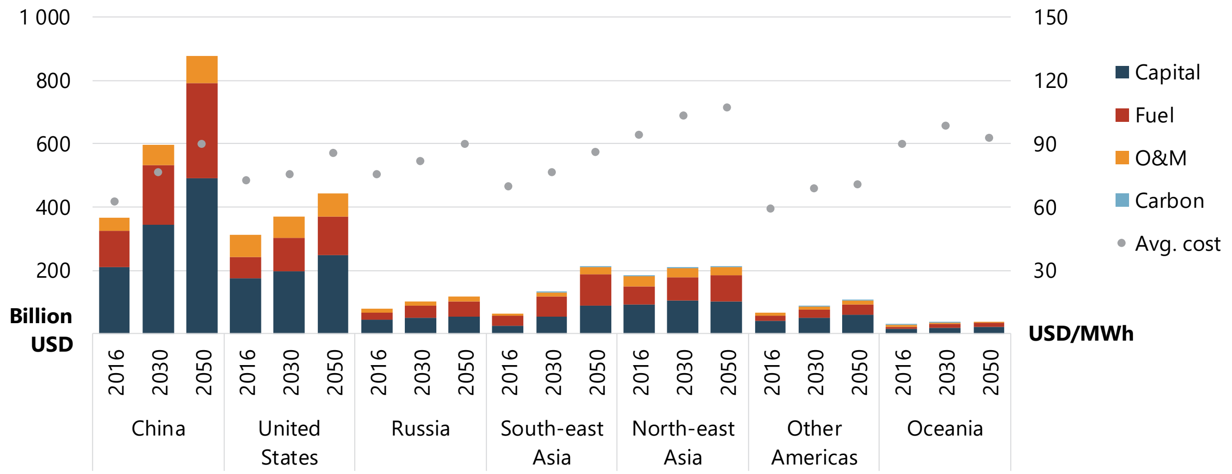
Source: APERC analysis.

EXAMINING THE COST OF POWER GENERATION

In this Outlook, calculations of the cost of power generation cover multiple elements: capital costs (defined as annual payments to recover initial capital investments and future asset refurbishment costs) for both existing and new power plants; fuel costs; O&M costs; and CO_2 prices. Regional factors are considered in each cost component. CO_2 prices for fossil fuel combustion, for example, are considered only in the economies that have (or will implement) carbon taxes or emissions trading schemes on power generation, including Canada (from 2018), Japan and New Zealand. The average generation cost, estimated by dividing total annual cost by annual generation, provides the basis for projections of the average wholesale electricity price.

Average electricity generation costs in APEC increase by 25% over the Outlook period in the BAU, from USD 71 per megawatt-hour (MWh) in 2016 to USD 89 per MWh in 2050, driven by rising energy prices (see Annex I) and capital recovery payments for new capacity additions (Figure 4.13). Regional generation costs vary: energy-producing regions tend to show lower costs thanks to availability of low-cost domestic fuels; in contrast, energy importers typically face higher costs. In 2016, estimated average generation costs in China, the United States, Russia, other Americas and south-east Asia were within the range of USD 59 per MWh to USD 75 per MWh, while the costs in north-east Asia, which heavily relies on imports, were USD 94 per MWh. These regional price gaps remain over the Outlook period. In Oceania, average cost declines from 2030 to 2050 thanks to retirements of ageing coal-fired plants and installation of high-efficiency gas-fired plants and cost-competitive renewables.

Figure 4.13 • Power generation costs by subregion, 2016, 2030 and 2050



Note: O&M = operating and maintenance.
Source: APERC analysis.

ELECTRICITY INVESTMENTS: RENEWABLES AND NETWORK INFRASTRUCTURE

The global electricity sector has attracted significant capital of late; in 2016, an estimated two-fifths (USD 750 billion) of global energy investments were directed to the electricity sector (IEA, 2018b). To meet future demand for electricity, the BAU shows large investment opportunities in APEC for both power generation and storage facilities. Required investments for power plants and storage facilities range from USD 5.1 trillion (in a low-cost estimate) to USD 7.8 trillion (high-cost estimate); investments needed for T&D networks range from USD 4.4 to 12 trillion (Figure 4.14).

In both the low- and high-cost estimates, China—because of its market size and projected growth—shows the largest total projected investments, attracting USD 4.3 to 7.4 trillion in the BAU. The second-largest investments are in the United States (USD 1.8 to 5.0 trillion), followed by other Americas (USD 0.9 to 1.8 trillion), south-east Asia (USD 0.8 to 1.2 trillion) and north-east Asia (USD 0.7 to 1.3 trillion). Investments in south-east Asia and other Americas are used to satisfy rising demand in developing economies, while those in developed economies (such as the United States and north-east Asia) are driven by accelerated deployment of renewables and refurbishment and/or replacement of ageing assets. Investment cost per unit of capacity is usually higher in developed economies due to expensive labour and costs related to engineering, procurement and construction, which also push up total investment needs.

Renewables become the main driver of investments in APEC's electricity sector over the Outlook period, accounting for about 70% of total investments for power plants and storage facilities in both low- and high-cost estimates. Under the BAU, investments for solar reach USD 2.2 to 3.3 trillion while those for wind power are USD 0.7 to 1.2 trillion. Accelerated deployment, thanks to policy support, cost reductions and costs associated with replacing ageing[28] solar panels and wind turbines, prompt the need for large capital expenditures. Investments for fossil fuel plants reflect regional energy situations: the United States, Russia, Oceania and other Americas invest mainly in gas-fired power plants while China, north-east Asia and south-east Asia show investments for both coal- and gas-fired generation. Although China decelerates coal-fired capacity additions, the economy still builds 117 GW by 2050 as illustrated in Figure 4.7. China and Russia are the two major investors

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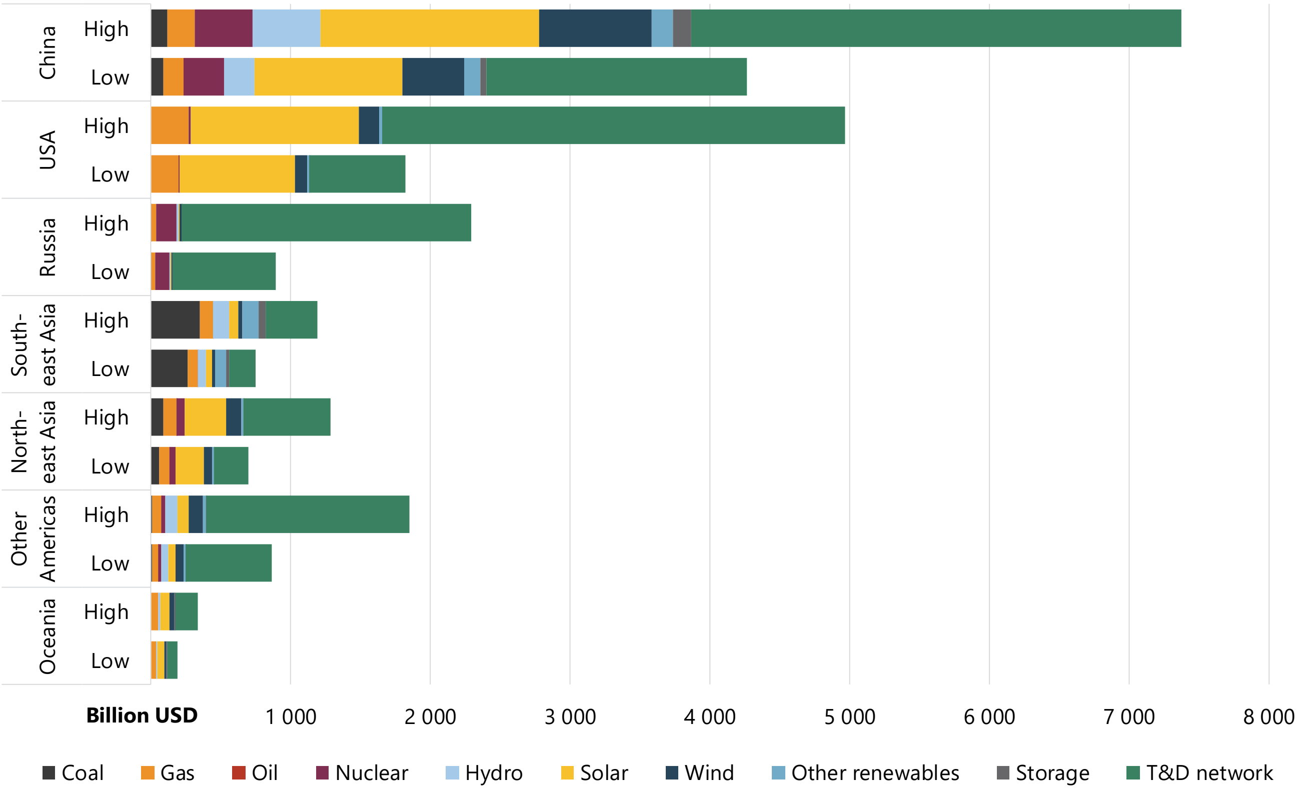
[28] Assumed operational lifetime is 20 years for both solar PV and wind turbines.

in nuclear power, together representing 84% of APEC nuclear investments. To ensure grid access for consumers and improve system adequacy and flexibility, enhancement and refurbishment of T&D networks are critical, representing 47% to 60% of total electricity investments. Storage facilities, which also contribute to system adequacy and flexibility, are estimated to require investments ranging from USD 0.07 to 0.19 trillion.

Figure 4.14 • Cumulative electricity investments, low- and high-cost estimates, 2016-50



Note: T&D = transmission and distribution
Source: APERC analysis.

OPPORTUNITIES AND CHALLENGES

APEC electricity consumption continues to increase under the BAU, driven by economic growth that delivers lifestyle improvements for people in developing economies. Per-capita electricity consumption grows particularly in China and south-east Asia, although gaps still exist between developed and developing economies. Some economies in other Americas, such as Mexico and Peru, continue to have low per-capita consumption relative to the APEC region, implying potential growth in terms of market volume even beyond 2050. The transition away from traditional fossil fuels in road transport has significant impacts on electricity demand projections in several economies, including Australia, Chile, China, New Zealand and the United States. Operational rules to coordinate EV charging need to be established, otherwise charging activities may create unexpected demand surges and fluctuations and could pose grid operations challenges.

Low-carbon fuels, including renewables and nuclear, expand to 42% of generation, due to current policies to address environmental and energy security concerns and declining costs for renewables. These trends in the sector contribute to a steady decline in CO_2 emissions intensity in APEC. Projections for the BAU, however, show this scenario falling short of the APEC doubling renewable energy goal and global climate objectives set out in the COP21 Paris Agreement. Although emissions intensity decreases during the Outlook period, absolute emissions remain above the level required for an environmentally sustainable pathway. Cumulative emissions by 2050 under the BAU amount to 309 $GtCO_2$, almost 90% above the level needed to move to a 2°C trajectory (Chapter 6).

The growing share of variable renewable energy, which reaches 66% of estimated APEC peak load in 2050, highlights the increasing importance of system integration measures to maintain reliable electricity supply. Designing adequate markets to encourage integration measures will be challenging for policymakers. That said, variable renewable energy does provide substantial investment opportunities, amounting to USD 2.9 to 4.5 trillion by 2050. New capacity additions, as well as costs associated with replacing ageing solar panels and wind turbines, contribute to the capital expenditure.

The BAU shows substantial opportunities for gas-fired power generation, which increases by 81% over the Outlook period. This growth is because of low-cost gas availability in gas-rich economies, while environmental considerations and fuel diversification are key drivers in some other economies (such as China and Japan). Flexibility of gas-fired plants is also important for integrating VRE. Although coal-fired power generation is expanded in south-east Asia to meet rising demand and diversify the generation mix, it shows a declining trend in APEC overall, driven by strong policy to address environmental issues (such as air pollution in China) and retirements of ageing and less-competitive coal-fired plants (as in the United States). Nuclear increases, but at a slow pace. China and Russia drive new reactor additions, but these are partially offset by the retirement of ageing reactors and phase-out policies in other economies. Constructing and operating nuclear power plants requires advanced engineering technologies, knowledge and skills. As technological learning (learning-by-doing and learning-by-research) requires continuous capacity addition, modest growth or contraction of nuclear power may pose challenges in terms of human resource development and knowledge transfer, making it difficult to use widespread nuclear power to support low-carbon ambitions.

RECOMMENDATIONS FOR POLICY ACTION

Individually and collectively, APEC economies have been implementing policies to promote renewables in the electricity sector, thereby supporting progress towards the APEC aspirational goal of doubling renewables in energy more broadly. In addition, APEC economies are contributing to ambitions set forth in the COP21 Paris Agreement, through policies to reduce greenhouse gas emissions (Chapter 10). The BAU Scenario shows current policies to be insufficient to achieve either of these goals. APEC electricity consumption grows steadily, driven by economic development; the share of renewables falls short of the APEC goal; and cumulative emissions exceed—by a large margin—a sustainable pathway. Clearly, APEC economies need to strengthen policies to accelerate low-carbon measures from both demand and supply perspectives. In the short term, measures are needed to increase the share of renewables and curb fossil fuel combustion in the power system.

Energy efficiency improvements should be considered a priority area for action. Efficiency is particularly important in developing economies, such as China and south-east Asia, which account for 76% of demand increases over the Outlook period. Importantly, several efficiency measures have been evaluated as cost-competitive even without carbon policies (McKinsey&Company, 2010). Efficiency standards (such as Japan's Top Runner program [METI, 2015]), labelling programs and public education need to be continued and strengthened. Technology and knowledge transfer, through APEC cooperative policy frameworks, would foster effective sharing of best practices among economies.

On the supply side, APEC economies need to enhance renewables policies, including those that can encourage cost reductions. Renewable energy auctions, by combining competitive pricing and volume control, can support cost-effective deployment of renewables, and should be considered a preferred policy option for both developed and developing economies. Support for technologies and project development is crucial to accelerate the transition. Deregulation or faster siting procedures (e.g. accelerated environmental assessments) and better coordination across grid enhancement timelines (e.g. aligning the approval, procurements and construction procedures to accommodate new generation facilities) could shorten the lead time for renewables projects.

Uncertainties associated with electricity markets and energy policies could discourage investments in a low-carbon and reliable electricity supply. To improve predictability of the investment return and foster investment opportunities, economies need to formulate clear and stable policies with long-term perspectives. Explicit long-term carbon taxes (as in Canada from 2018), for example, could support robust development of not only renewables but also of nuclear and CCS. The BAU also highlights the importance of VRE system integration, especially over long timelines. A wide range of flexible measures, on both supply and demand sides—such as energy management systems to control end-use technologies including EVs and household appliances—should be considered to optimise the whole electricity system. Accelerated penetration of EVs would make it increasingly important to enhance distribution infrastructure and establish new tariff schemes and operational rules to coordinate EV charging. As integration issues affect various stakeholders, economy-specific conditions (such as market design and consumer characteristics) should be carefully considered when determining grid operation rules and providing any supports for specific technologies or infrastructure, with fairness and transparency being underlying principles.

Finally, innovative technologies not included in this Outlook—such as next-generation nuclear reactors, nuclear fusion, space solar power and large-scale hydrogen power generation—may, if commercialised, drastically change the electricity system. Policy support should highlight the importance of ongoing research and development to continue broadening the range of mitigation options available to APEC.

5. ACHIEVING APEC TARGETS

KEY FINDINGS

- **Policy measures to improve energy efficiency result in APEC energy demand growing by 5.9% over the Outlook period in the TGT Scenario, compared with** 21% in the BAU. This results in energy savings of 840 Mtoe over the Outlook period, almost twice the size of south-east Asia FED in 2016.

- **Under the TGT, CO_2 emissions are 19% lower in 2050 compared with the BAU.** Policies aimed at efficient use of energy and fuel switching to renewables help reduce cumulative emissions by 85 $GtCO_2$. This brings APEC economies closer to their NDCs under the COP21 Paris Agreement; for some, it signals the potential to increase the ambition set in their NDC.

- **Transport delivers the majority (46%) of TGT demand reduction in 2050 compared with the BAU, followed by buildings (29%) and industry (22%).** Fuel efficiency standards and technology switching, largely from road vehicles, are essential to demand reduction in transport. Buildings demand is reduced largely via MEPS, building envelope improvements, and standards for space heating and cooling systems. In industry, uptake of advanced technologies is key.

- **The APEC goal of doubling the share of renewable energy by 2030 (from 2010 levels) is achieved in the TGT through improving economics for renewables, adopting more supportive policies and reducing energy demand.** The TGT Scenario sets a pathway to meet this goal, which requires an extra 851 GW of renewables power capacity (doubling the share of renewable electricity), 38 Mtoe of additional biofuels for transport and 24 Mtoe for industry.

INTRODUCTION

The Target (TGT) Scenario considers the changes required to achieve Asia-Pacific Economic Cooperation's (APEC) two aspirational goals to improve energy intensity and increase renewables deployment. These goals, which represent greater ambition beyond the Business-as-Usual (BAU) Scenario, were established to reduce energy-related carbon dioxide (CO_2) emissions and improve energy security in the region.

APEC's joint effort to improve energy efficiency started when APEC Leaders agreed in 2007 on an aspirational goal to reduce the region's energy intensity by 35% by 2035 (compared with 2005). As it became apparent this target would be achieved ahead of schedule, in 2011 APEC Leaders set a more ambitious goal of reducing energy intensity by 45% over the same period (APEC, 2011).

In 2014, APEC Energy Ministers issued a joint declaration 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 achieve this target, member economies need to enhance cooperation and promote innovation in renewable energy technologies, and to reduce costs and improve the competitiveness and sustainability of renewables in energy markets (APEC, 2014).

Energy demand projections in Chapter 2 find that the BAU Scenario falls short of achieving the doubling renewables target during the Outlook period. Reaching the goal requires additional policies and support measures to promote adoption of renewable energy. In turn, this chapter explores an accelerated APEC TGT Scenario that slightly enhances energy intensity reductions and meets the renewable doubling goal, including within the electricity sector. Key areas targeted for energy efficiency improvements include the adoption of best available technologies (BATs) and practices in industry; improvements in appliance efficiency and in building envelopes in buildings; and increased vehicle fuel efficiency and better urban planning in the transport sector.

While energy intensity is not a true measure of energy efficiency (which is more appropriate at an end-use or activity level), this metric is used as a proxy to help facilitate a regional goal and encourage collective action. For renewables development, key targets include more capacity in power generation and additional contribution by the demand sectors. These changes improve the sustainability of APEC energy production and consumption in the TGT, underpinned by goals of reducing energy intensity and increasing the share of renewables.

APEC TARGET SCENARIO

The TGT Scenario was designed to identify possible pathways to achieve the dual objectives of the APEC Leaders' aspirational goals through a combination of energy efficiency improvements and greater deployment of renewable energy technologies. The TGT explores the additional efforts needed to achieve the renewables goal as well as opportunities to further reduce demand across all sectors, including in energy transformation.

All APEC economies have some form of commitment to improve energy efficiency (thereby reducing demand) and promote renewables. Because of extensive trading among APEC and non-APEC economies, even those economies with less-ambitious energy efficiency policies acquire 'technology spill-overs' through trade. For instance, as of 2017, Russia does not apply a specific policy for fuel efficiency of road vehicles, only emissions regulations. However, fuel efficiency is being 'passively' implemented in this economy through direct imports and domestic assembly of vehicles designed in Europe and Japan that incorporate more advanced engine and material technologies.

The TGT accounts for energy efficiency measures already in place as well as those being actively considered by APEC economies. The modelling also introduces measures that have proven effective where already deployed in other economies to assess how their uptake could be further boosted. Key measures include minimum energy performance standards (MEPS) for building envelopes and appliances (in both the residential and services subsectors), fuel efficiency standards in transport, and BAT requirements and/or mandates in industry. Higher improvement rate assumptions are applied in the heat and refinery models.

Commitment to promote renewable energy is near-universal in APEC. Policy instruments such as feed-in tariffs, renewable portfolio standards, renewable auctions, grants for R&D, and tax incentives can all act directly to increase penetration of renewables, particularly in electricity generation. Carbon prices and energy security policies act less directly but can still promote renewables and energy efficiency targets. Boosting renewables can also enhance the security of energy supply by diversifying an economy's energy mix and capturing the potential of technologies, such as solar and wind, that have zero fuel cost.

To assess progress towards the doubling renewables goal, the Asia Pacific Energy Research Centre (APERC) has adopted the following assumptions to differentiate 'traditional' and 'modern' renewables. All biomass in the residential and services sectors is assumed to be 'traditional', and therefore is not counted towards the doubling goal (but is counted in total renewable energy use). Data limitations regarding how this fuel is consumed (in open pit fires versus high-efficiency closed burners, for example) make necessary a broad, but imperfect assumption. On the other hand, biomass used in industry, transport and transformation sectors (power, heat and refineries) is all assumed to be 'modern'.

In the TGT, economies further develop modern renewables to meet the APEC-wide target in demand sectors, based on expert estimates and feasible potential. In the power sector, individual economies use the levelised cost of electricity to analyse and make choices on the least-cost approach for additional renewable capacity. After the target year of 2030, it is assumed that the share of renewable capacity keeps increasing. Current policies for renewable power generation and transport biofuels are summarised in Table 5.1. Overall, 15 APEC economies implement and/or mandate the use of renewables in transport, including first- and second-generation, bioethanol and biodiesel.

To investigate APEC's dual goals, the TGT simultaneously analyses further improvements in energy efficiency and accelerated adoption of renewables. The TGT sees an energy demand reduction of 419 million tonnes of oil equivalent (Mtoe) by 2030 and 840 Mtoe by 2050, compared with results in the BAU. This is equivalent to an energy intensity improvement of 56% by 2035 and 69% by 2050 (both compared with 2005), far exceeding the APEC goal. Increased penetration of renewables, prompted mainly by more proactive policy, boosts their share of final energy demand (FED)[29] to 14% by 2035 and 17% in 2050 (from 7.4% in 2016), achieving the APEC goal in 2025. The combination of reduced FED through efficiency improvements and increased penetration of renewables in the TGT results in cumulative CO_2 emissions that are 85 gigatonnes (Gt), or 11%, lower than in the BAU. Still, this scenario falls short of achieving the APEC contribution needed to meet the emissions pathway outlined in the 2DC Scenario (to give a 50% chance of constraining the global temperature increase to 2°C by 2050).

The TGT Scenario shows that to reach the renewables doubling goal, APEC needs to add an average 119 gigawatts (GW) of renewable generation capacity (excluding pumped hydro) each year from 2016 to 2030.

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[29] Since electricity forms a large component of FED, renewables are allocated a share based on the proportion generated: i.e. for the purposes of calculating the doubling goal, if 50% of an economy's electricity generation comes from renewable sources, then APERC assumes 50% of the electricity in FED is renewable.

This is 10% higher than the 108 GW of renewable capacity additions in 2016 (IRENA, 2018), but a 25% increase on the average additions in the BAU. In addition, APEC would need 38 Mtoe of additional biofuels for transport and 24 Mtoe of renewable fuel use in industry.

Table 5.1 • Selected APEC renewable energy policies

Economy	Most influential policy framework	Renewable energy target in power	Biofuels in transport	
			Currently available	Target
Australia	Australia's Renewable Energy Target (2001)	33 TWh by 2020	(state level, e.g. E6 in NSW, E3 in Queensland)	-
Brunei Darussalam	Energy White Paper (2014)	10% of generation by 2035	-	-
Canada	Pan-Canadian Framework on Clean Growth and Climate Change (2016)	-	E8.5 and B4	-
Chile	Energy 2050 (2015); Energy Roadmap (2015)	Minimum of 60% by 2035 and 70% by 2050	-	-
China	13th Five-Year Plan, 2016-2020	15% by 2020 and 20% by 2030	E0 to E10 2.1 Mt/yr (E) 0.8 Mt/yr (B)	E15 (2020) 4 Mt/yr (E) 2 Mt/yr (B)
Hong Kong, China	Future Fuel Mix for Electricity Generation Consultation Document (2015)	Fuel mix 1% (2023)	-	-
Indonesia	Presidential Regulation 22/2017 General Plan of National Energy (2015-50)	Renewables electricity as a share of TPES: 11% in 2025 and 17% in 2050	E0 (E3 as pilot) and B30	E20 (2025)
Japan	4th Strategic Energy Plan (2014); Long-term Energy Supply and Demand Outlook (2015)	22%–24% of generation by 2030	Min. of 0.50 MLOE limit of E3	E15
Korea	4th National Basic Plan for New and Renewable Energy (2014); 8th Electricity Demand and Supply Basic Plan (2017)	20% generation and 34% capacity by 2030	E0 and B3	
Malaysia	National Renewable Energy Policy and Action Plan (2009); Renewable Energy Act (2011); Sustainable Energy Development Authority Act (2011); 11th Malaysia Plan (2016-2020); National Biofuel Policy (2006)	7.8% of generation and 11% of capacity by 2020, 17% of generation by 2030, and 21 GW of capacity by 2050	E0 B0, B5, B7	B15 (2020)
Mexico	Mexico's Energy Transition Law (2015)	At least 35% of generation by 2024 and 50% by 2050	B2	-
New Zealand	New Zealand Energy Strategy 2011-2021; National Policy Statement for Renewable Electricity Generation (2011); Climate Change Response (Emissions Trading) Amendment Act 2008	90% of generation by 2025	-	-
Papua New Guinea	Vision 2050 (2009)	100% of generation by 2050	-	E7.8 and B5
Peru	Legislative Decree No. 1002	Reach 5% share (excluding large hydro) by 2023	-	-

Economy	Most influential policy framework	Renewable energy target in power	Biofuels in transport	
			Currently available	Target
Philippines	Renewable Energy Act (2008); Biofuels Roadmap 2017-2040; Biofuels Act (2006)	20 GW of capacity by 2040	E10 B2 to B5	E20, B10 (2020) E85, B20 (2025)
Russia	The Basic Directions of a State Policy of Renewable Energy Utilisation up to 2020 (2009); Energy Strategy 2030 (2009)	4%-6% (excluding large hydro) of generation by 2030	-	-
Singapore	Handbook for PV Systems (2011); White Paper on Renewable Energy (2014)	PV reaches ~4.5% of peak electricity demand (350 MWp) by 2020	-	-
Chinese Taipei	Renewable Energy Development Act (2009); New Energy Policy (2016)	20% of generation by 2025	E0 to E3	-
Thailand	Alternative Energy Development Plan 2015-2036 (AEDP)	30% of generation by 2036	E0 to E85 B7	B10 4.1 GL/yr (E) 5.1 GL/yr (B) (2036)
United States	US Energy Independence and Security Act (2007); RPS: 29 states + Washington, DC + 3 territories, RPG: 8 states and 1 territory	RPS up to 100% (2045 in HI) 50% (2030 in CA, NY, NJ) 50% (2040 in OR)	E10 to E15 B0-B20	Min. of 136 GL (2022)
Viet Nam	Renewable Energy Development Strategy (2015); Biofuels Development Scheme (2007) and Roadmap (2017)	38% of generation by 2020, 32% by 2030 and 43% by 2050	E0 (A95) and E5 (A92)	E10

Notes: TWh = terawatt-hours. NSW = New South Wales; E = bioethanol (volumetric blend rate with gasoline); B = biodiesel (volumetric blend rate with diesel); Mt/yr = million tonnes per year. MLOE = million litres of oil equivalent; GW = gigawatts. PV = (solar) photovoltaic; RPS = renewable portfolio standard; RPG = renewable portfolio goal; HI = (state of) Hawaii; CA = (state of) California; NY = (state of) New York; NJ = (state of) New Jersey; OR = (state of) Oregon; GL = billion litres; A92 and A95 = gasoline with 92 and 95 octane rating or octane number.
Source: APERC analysis.

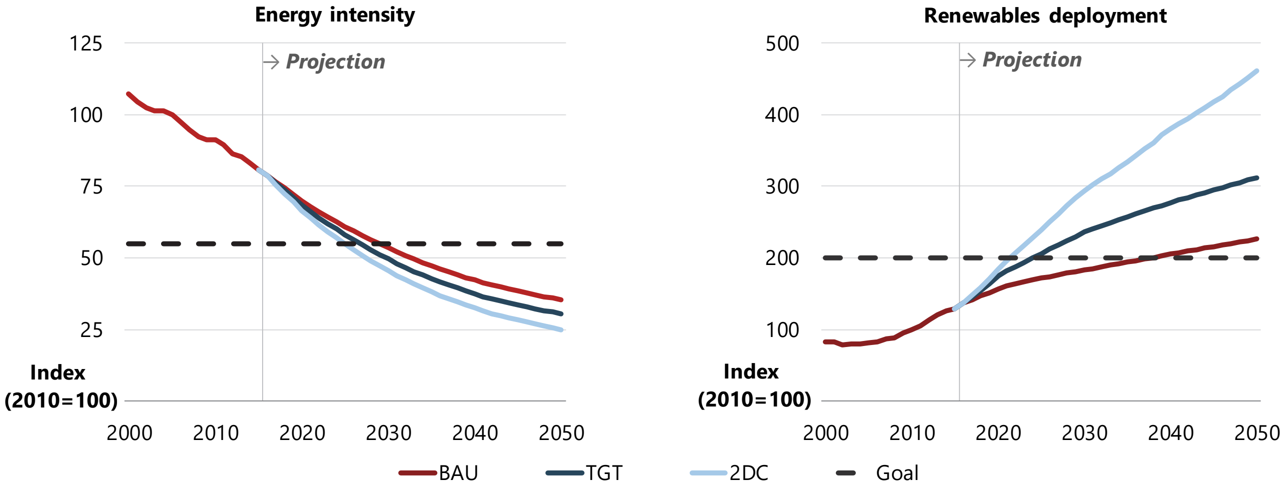
Under the TGT, APEC energy demand increases at a compound annual growth rate (CAGR) of 0.17% over the Outlook (compared with 0.57% CAGR under the BAU), even though APEC economies become more energy efficient. Energy efficiency policies, educational programs, economic subsidies and market access policies enable APEC to largely decouple economic and population growth from energy demand and greenhouse gas (GHG) emissions. The importance of this should not be underestimated, considering the urgent need to address the negative impacts (e.g. social costs, health impacts, energy supply insecurity) of ever-growing energy demand.

Investments in renewable energy can likewise deliver significant returns for APEC, such as improved energy security, increased sustainability within the energy system, lower GHG emissions, and less air pollution from production of heat and electricity. The APEC region is endowed with abundant solar, wind, biomass, geothermal and hydro resources; with recent technology advancements, significant opportunities exist to use more of this potential in all sectors.

OVERALL TRENDS

Energy demand gradually increases over the Outlook period in the TGT, to reach 5 722 Mtoe in 2050, 5.9% higher than in 2016. Despite this gentle growth, cumulative FED is 840 Mtoe lower than the BAU over the Outlook, a 13% decrease (Figure 5.1). This is roughly twice the combined energy demand of south-east Asia in 2016. Demand for renewable energy reaches 963 Mtoe in 2050, to account for 17% of FED.

Figure 5.1 • APEC progress towards energy intensity and doubling renewables goals, 2000-50



Source: APERC analysis and IEA (2018a).

Within the overall demand reduction compared with the BAU, transport delivers a 46% share, of which China, the United States and Russia together account for 65%. Buildings energy demand reduction accounts for 29%, with China contributing 30%. Industry accounts for 22% (and non-energy 3%), with China accounting for a third of the improvement. China and the United States combined, because of the size of their economies and their shares of FED, provide the largest energy demand reductions in all sectors (around 58% across the Outlook). By 2050, these two economies represent a combined 50% of all energy demand reduction. Demand reduction occurs primarily in transport in both China (26% lower in the TGT compared with the BAU in 2050) and the United States (18% lower).

South-east Asia, despite being the region with the fastest-growing gross domestic product (GDP), makes a significant contribution (14% of total) to lower energy demand in the TGT, with gains coming largely from transport (48%), buildings (27%) and industry (22%). The remaining regions (Russia, other Americas, Oceania and other north-east Asia) account for the remaining 28% of demand reduction, although different sectors dominate in different regions.

ENERGY EFFICIENCY AND RENEWABLES SECTORAL ANALYSIS

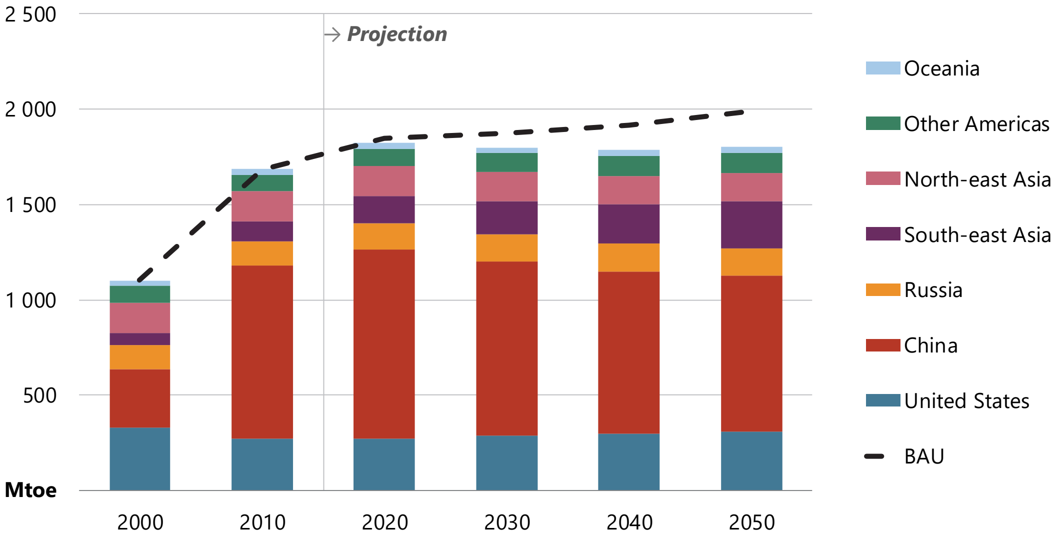
This section examines the TGT Scenario projections for the industry, buildings (residential and services), and transport sectors. It places particular focus on improved energy efficiency and renewable penetration beyond that shown in the BAU. An extensive investigation of renewables in the electricity sector, which is vital to achieving APEC's doubling renewables goal, can be found in Chapter 4.

INDUSTRY ENERGY DEMAND PLATEAUS

Industry is the largest FED sector in APEC, accounting for 1 802 Mtoe or 32% of energy demand in 2016 and 1 805 Mtoe in 2050 in the TGT (Figure 5.2). Non-energy use, most of which occurs in industrial processes, accounts for a further 577 Mtoe in 2016 and 723 Mtoe in 2050. Industry is perhaps the most difficult of the demand sectors in which to improve energy efficiency and boost renewables penetration: strong market pressure towards BATs in developed economies, the uniqueness of many processes, and the lack of viable substitutes or alternatives all present specific challenges.

APERC's industry model calculates FED based on production levels and energy intensity of production processes. A key assumption is that APEC maintains the same level of output across all three scenarios. This ensures that any reduction in energy demand from the sector does not reflect decreased activity or structural change (although some intermediate products, such as clinker in the non-metallic minerals subsector, do decrease because of improved efficiency). More details on this methodology are in Annex I.

Figure 5.2 • TGT: Industry final energy demand by region versus BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

Increasing the adoption of BATs and the blend rates for renewables in the fuel mix are the main drivers of the lower energy consumption and higher renewables penetration in the TGT. This does not require the invention of new technologies or processes, but rather wider deployment of those that are currently available.

In 2050, APEC total industry FED is 183 Mtoe lower in the TGT than in the BAU, with almost three-quarters of this reduction coming in three economies—China, Russia and the United States. Industry energy demand marginally peaks in 2020 in the TGT in contrast to growing continuously through the BAU. In the TGT, industry FED hovers around 1 800 Mtoe across the Outlook period as improved efficiency offsets increased output. As in the BAU, the TGT sees increased production of chemicals (29%), aluminium (16%) and paper (9.4%) between 2016 and 2050, in contrast to decreased production of steel (-23%) and cement (-14%).

China accounted for 56% of APEC industry energy use in 2016, mainly in the non-metallic minerals, iron and steel, and other sectors. Under the TGT, this share declines slightly (to 45%) by 2050, due to faster growth in other economies, manly in south-east Asia. While China's industrial base has grown rapidly in recent years—and is therefore fairly modern—considerable opportunities remain for further improvement. In the TGT, China accounts for 33% of the APEC demand reduction in 2050 (relative to the BAU). Demand for renewables in APEC industry also grows more rapidly in the TGT, rising by 52 Mtoe compared with 28 Mtoe in the BAU by 2050. China accounts for 28 Mtoe (53%) of this increase.

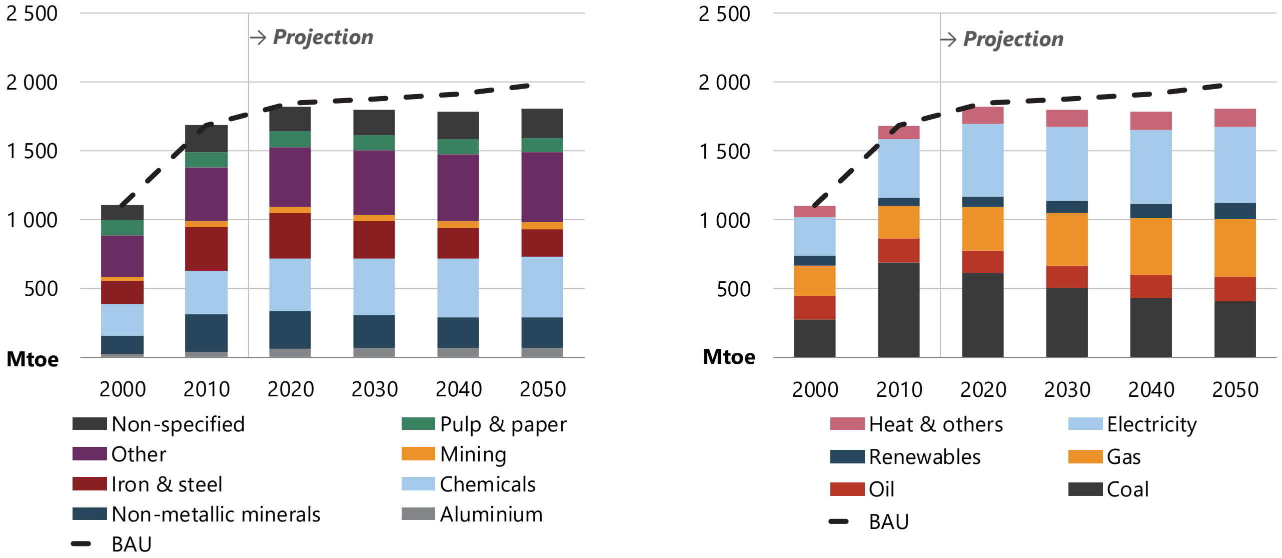
Russia and the United States are also large contributors to improved industrial energy efficiency but not growing renewables in the TGT. Relative to the BAU, the United States accounts for 23% of demand reduction, but renewables decline, while in Russia, energy use declines by 16% but renewables only increase 2.6% in 2050. Most of the US demand reduction is in the chemical subsector, which accounts for 32% of the total reduction in that economy in 2050. Russia makes considerable efficiency improvements in the non-metallic minerals (27% reduction) and iron and steel (29%) subsectors.

Fast-growing south-east Asia achieves a significant demand reduction (26 Mtoe lower in TGT compared with BAU by 2050) despite growing to account for 14% of APEC industry total in 2050 (from 6.9% in 2016). South-east Asia also accounts for 37% of renewables growth over the Outlook (but only marginally more in the TGT compared with the BAU). With less opportunity for energy efficiency improvements, demand reduction in developed north-east Asia accounts for 6.4% of APEC total, other Americas only 6.1% and Oceania for only 1.4%. The total contribution of those three regions to renewables growth in the TGT is only 6.9% over the Outlook period.

IRON AND STEEL AND NON-METALLIC MINERALS SUBSECTORS DRIVE IMPROVEMENTS

In the iron and steel subsector, a higher steel recycle rate allows for greater use of electric arc furnaces instead of blast furnaces, which reduces coal consumption and improves efficiency (Figure 5.3). Likewise, increasing the recovery rate of gas by-products (such as coke-oven and blast furnace gas) and replacing small-scale furnaces with larger, more efficient varieties, helps to deliver efficiency gains.

Figure 5.3 • TGT: Industry final energy demand by subsector and fuel versus BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

In the non-metallic minerals subsector, the key assumption affecting energy consumption is the clinker-to-cement ratio: a lower ratio means less clinker is required to produce the same amount of cement. Currently, the ratio ranges from 95:5 in Viet Nam to 78:22 in the Philippines. In the TGT, depending on the given economy, it is assumed to improve by up to 5.0% over the Outlook period. Improving this ratio requires investment in modern dry-process kilns and the phase-out of old, less efficient wet kilns. The share of renewable biomass (replacing coal) in non-metallic minerals energy consumption is assumed to increase to between 1.7% and 13% by 2050, depending on the economy.

The chemical and petrochemical subsector, which overtakes iron and steel as the second-largest energy demand subsector in APEC industry, is assumed to improve the efficiency of ammonia and olefins production (which are key inputs) by 10% in the TGT. Minimising heat losses and optimising heat recovery through exchangers, combined with improvements in motor efficiency, drive these improvements. By continuing to substitute biomass for coal, the renewables share increases to between 0.35% and 6.8% in 2050.

In the pulp and paper subsector, faster retirement of existing mills accelerates implementation of newer technologies, supports better pulp recovery rates and increases uptake of BATs. These changes all underpin efficiency improvements that allow the TGT to surpass the BAU. In the aluminium subsector, the transition from older technologies (Søderberg) to more efficient pre-baked production drives efficiency gains, mainly in Russia. The remaining industry subsectors—mining, non-specified and others—are modelled as residuals and assumed to achieve efficiency improvements of 10% beyond the BAU by 2050. These subsectors show marginal opportunity to increase use of renewables: the pulp and paper subsector already demonstrates high uptake, while processes used in aluminium and residual subsectors make it more difficult to integrate renewables.

INDUSTRY AND THE APEC TARGETS

Ultimately, industry is not a large contributor to the APEC doubling renewables goal due to a lack of viable renewable alternatives in many industrial processes. Replacing small amounts of coal and gas with biofuels in industrial processes can be achieved via different approaches. These include third-party production or investment schemes to defer and dilute risk (since renewables projects generally face higher up-front capital costs or represent less established technology), improved grid planning and integration to allow excess renewable electricity to be sold to the grid, and increased R&D and awareness (IEA, 2017b).

By contrast, the APEC region features a wealth of examples of successful industrial energy efficiency programmes. Adoption of energy management protocols, MEPS for electric motors, measures to promote energy efficiency in small- and medium-sized enterprises, and complementary financial policies are being widely used to drive significant energy efficiency gains (IEA, 2011).

In China, policies such as those designed to 'eliminate backward industrial production capacities' have prompted the shutdown of older, less efficient factories so newer ones can run at higher capacity. Additionally, to support technical retrofits, central government subsidies that are based on the amount of energy demand reduction have driven huge efficiency improvements (Zhu, Bai and Zhang, 2017).

Japan's Top Runner program, first developed in response to the oil crises of the 1970s and 1980s, has long been one of APEC's premier energy efficiency policies (METI, 2015). Originally targeting the residential, services and transport sectors, Top Runner now also sets targets for manufacturers based on the most efficient machinery or equipment on the market. All other producers are then required by law (over a given period) to improve their own products to meet this level. Japan has expanded Top Runner to include equipment such as AC motors, transformers and heaters used in many industrial processes. The commitment to constantly revisit, revise and update the Top Runner program has been instrumental in its success and offers a strong reminder to other economies that energy efficiency policy is never 'done'.

The Canadian Industry Program for Energy Conservation (CIPEC) is an award-winning voluntary program that has been in place since 1975 and is noted for having a very low burden on government (NRCAN, 2018). CIPEC promotes energy efficiency leadership and cooperation. For example, providing co-funding for organisations to undertake ISO 50001 energy management systems standards and ENERGY STAR assessments, and to promote information sharing and host workshops. The program has been successful in raising awareness and highlighting the opportunities and benefits of energy efficiency to Canadian industry.

In striving to prioritise energy efficiency in industrial development policy, rapidly developing APEC economies, particularly in south-east Asia, would do well to capitalise on lessons learned by other APEC members. Adopting BATs; promoting energy management systems and performance standards; and improving data quality, reporting and assessment can all contribute to reducing energy demand, costs and CO_2 emissions.

IN BUILDINGS, STANDARDS HELP REDUCE ENERGY DEMAND

The buildings sector, comprising the residential and services subsectors, is the third-largest FED sector in APEC, accounting for 1 408 Mtoe in 2016. Assuming that GDP, population, household numbers and service floor area remain unchanged from the BAU, FED in APEC buildings grows by 11% in the TGT Scenario to 2050, compared with a 28% increase in the BAU. Buildings FED is 240 Mtoe less in the TGT by 2050 than in the BAU. Increased efficiency of appliances due to stricter and broader coverage of labelling schemes and MEPS are major drivers of the decrease. More stringent standards for building energy codes also prompt improved building design (passively and through the adoption of better building envelope elements), which results in lower demand particularly for space heating and cooling.

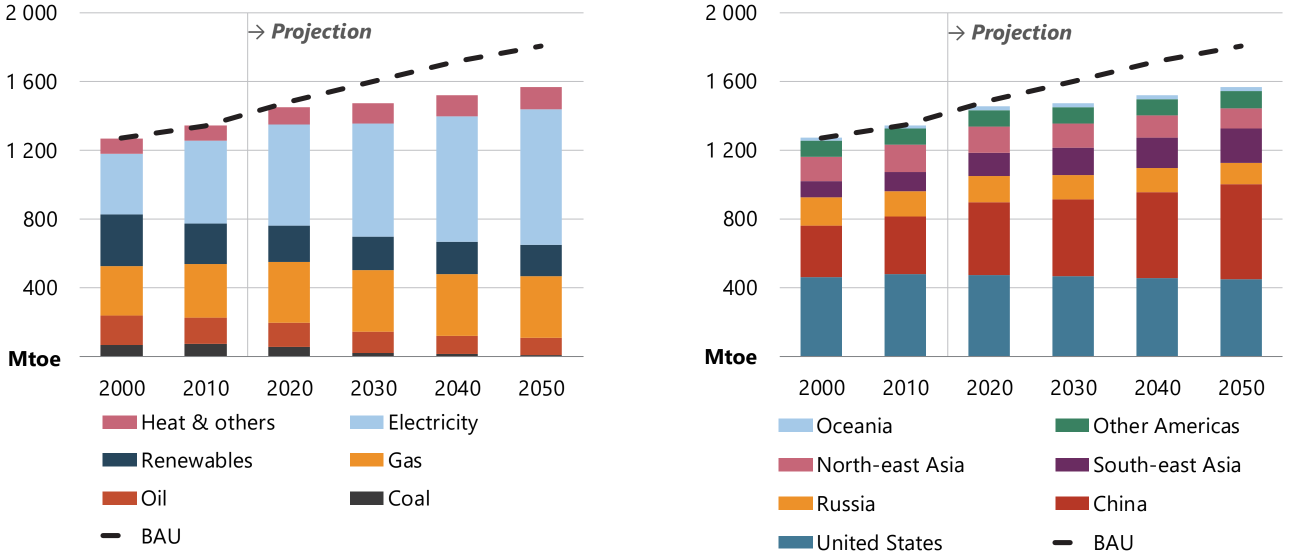
In the TGT, the pace of modern renewables (including solar PV and solar water heating [SWH]) deployment accelerates with attractive feed-in incentives and declining costs, while the use of traditional biomass declines (particularly for heating and cooking in residential buildings). In 2010, demand for modern renewables in buildings was 22 Mtoe; in the TGT, it climbs to 57 Mtoe by 2030—surpassing the APEC renewables doubling goal.

ALL APEC REGIONS CONTRIBUTE TO BUILDINGS DEMAND REDUCTION

By 2050 in the TGT, the United States contributes the largest share (31%) of the total demand reduction in buildings compared with the BAU, followed closely by China (30%) (Figure 5.4). Combined, the United States and China achieve a reduction of 145 Mtoe, equivalent to 10% of total APEC buildings demand in 2016. However, this demand reduction compared with BAU does not counteract the significant demand growth for services in China and south-east Asia, leading to buildings energy demand increasing by 157 Mtoe between 2016 and 2050.

The largest proportional reduction occurs in Oceania—in 2050, TGT demand is 18% lower than in the BAU (compared with 14% in the United States and 12% in China). In absolute terms this is relatively insignificant, because overall demand in Oceania is much less than other economies. The improvement reflects implementation of more stringent building standards in Australia and New Zealand, which drives down space heating and cooling demand, as well as the adoption of more efficient heat pumps and instantaneous hot water systems.

Figure 5.4 • TGT: Buildings final energy demand by fuel and region versus BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

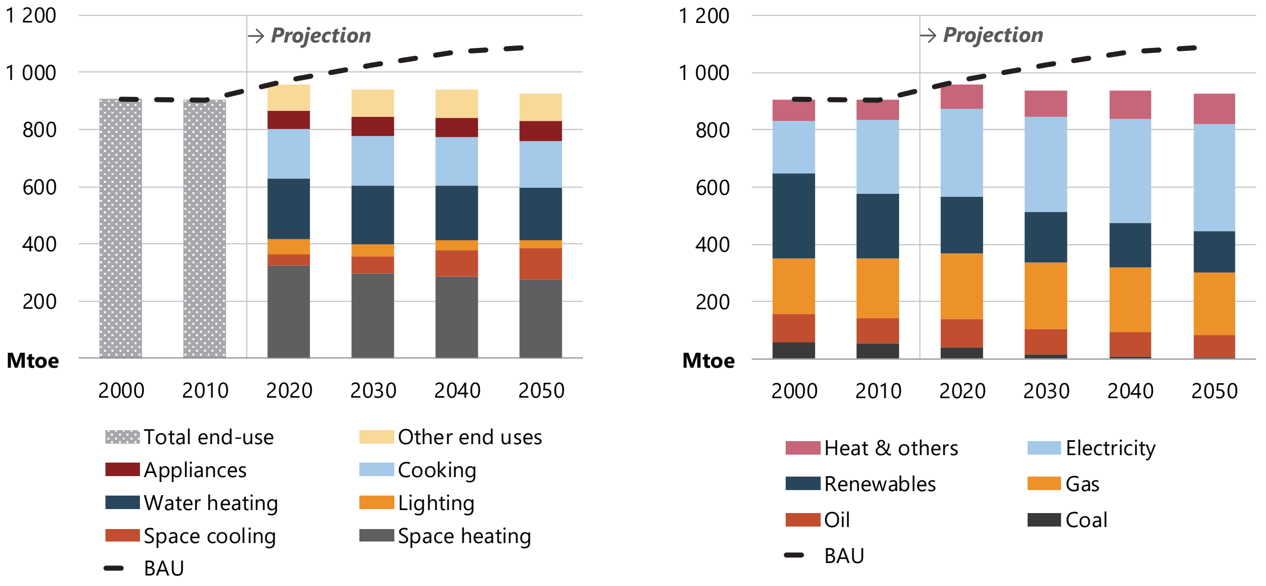
The main change in the buildings fuel mix through the Outlook is the increasing share of electricity—from 31% in 2016 to 41% in 2050—against coal, oil and renewables, which all lose share. Strong demand growth from appliances and increasing electrification (both in terms of reaching more of the population and fuel-switching) underpins electricity's expanding share, which still outweighs the effects of increased efficiency and improved building envelopes in the TGT. This dynamic is accentuated by the household transition from traditional biofuels towards more efficient options for cooking and space heating, which is also accelerated in the TGT compared with the BAU.

LESS HEATING DEMAND UNDERPINS FALLING RESIDENTIAL ENERGY USE

Residential energy demand in the TGT shrinks marginally over the Outlook period, to 926 Mtoe in 2050 (from 933 Mtoe in 2016), compared with growing to 1 089 Mtoe in the BAU (Figure 5.5). The reduction in demand for residential buildings by 2050 represents 9.0% (163 Mtoe) of buildings FED in the BAU and accounts for 68% of the energy demand decrease relative to the BAU over the Outlook (with the remainder in services). As efficiency measures mainly affect appliances using electricity and gas, these fuels see the largest improvement: 63 Mtoe less demand for electricity and 58 Mtoe less for gas when compared with the BAU. Demand for other fuel types shows smaller reductions, reflecting their lower shares of the total.

Technological advances, stricter appliance labelling schemes, more stringent MEPS and more aggressive implementation of buildings standards all contribute to the fall in demand across all end-uses in residential buildings. The two largest end-uses show substantial reduction compared with the BAU: space heating at 54 Mtoe by 2050 and water heating at 45 Mtoe. Improved building envelopes drive most of the decline in space heating demand while fuel and technology shifting—from oil to more efficient gas and electric water heaters (as well as greater deployment of instantaneous water heaters)—reduces water heating demand.

Figure 5.5 • TGT: Residential final energy demand by end-use and fuel versus BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

While having only a moderate demand reduction in absolute terms, lighting shows the greatest relative decline (33% in 2050) when compared with the BAU as inefficient devices (such as incandescent bulbs) are replaced by more efficient options (such as LEDs). The other end-uses remain closer to their BAU levels with reductions in water heating (20% lower in 2050), space cooling (16%), space heating (17%), appliances (13%), cooking (7.4%) and other end-uses (5.4%). All of these reductions in energy use are reflected in energy intensity, which declines by 14% over the Outlook (from 11 287 kWh per household in 2016 to 9 653 kWh per household).

ELECTRICITY MEETS SURGING SERVICE DEMAND

Energy demand from services grows steadily under the TGT, to reach 639 Mtoe in 2050, but is 77 Mtoe (11%) less than the BAU (Figure 5.6). Since service buildings consume less energy than residential buildings overall, this reduction is significantly less than that seen in the residential subsector. Most of the decrease is in electricity (38 Mtoe lower in 2050), followed by gas (25 Mtoe), oil (15 Mtoe) and coal (5.2 Mtoe).

By 2050 under the TGT, other end-uses shows the highest absolute demand reduction at 45 Mtoe, reflecting its high share of total services demand. Space heating (14 Mtoe lower in 2050), space cooling (8.3 Mtoe), lighting (5.2 Mtoe) and water heating (4.2 Mtoe) all decrease from the BAU as well. Lighting has only a moderate absolute demand reduction with respect to the BAU (as in residential), but it is still the greatest proportional decline—15% lower in 2050. Energy intensity reflects these improvements, with energy use per service floor area improving by 32% over the Outlook (from 263 kWh per square metre [kWh per m^2] in 2016 to 177 kWh per m^2).

Services demand for renewables grows in the TGT; by 2050, it is 8.0 Mtoe more than in the BAU. Furthermore, there is a more rapid switch away from traditional biomass in the TGT compared with the BAU. Biomass is substituted for cleaner fuel types such as electricity, gas and other forms of modern renewables, particularly solar PV[30] and SWH. The declining costs of equipment and stronger government support drive growth in modern renewables beyond that seen in the BAU.

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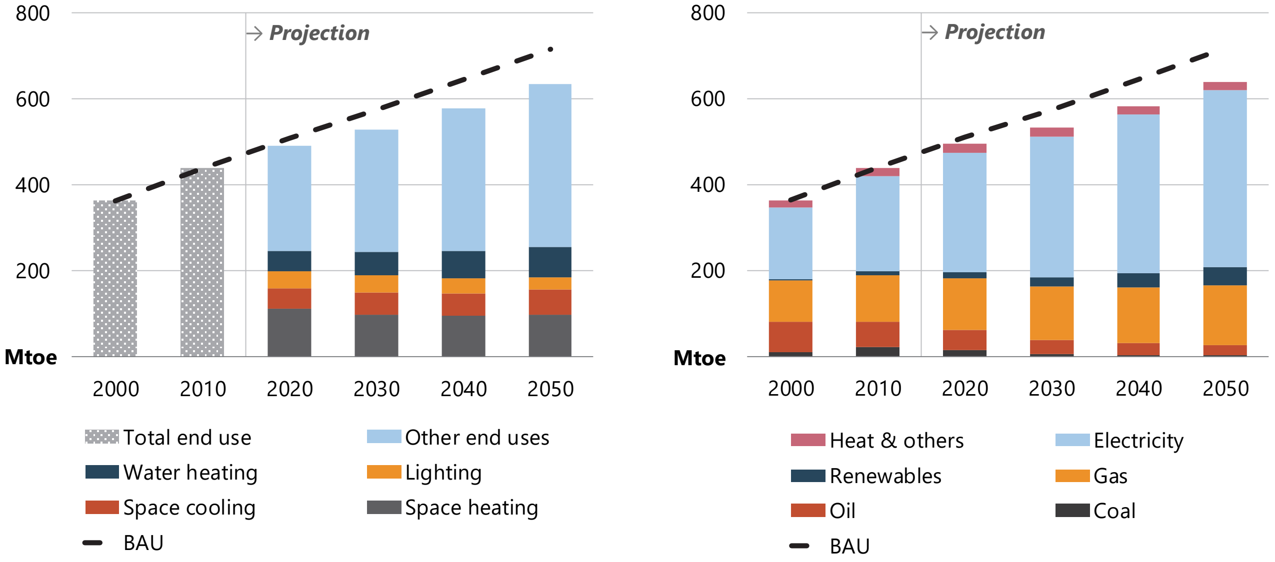
[30] Solar PV is modelled in the electricity sector, so strong growth in that fuel type is reflected in increased electricity demand rather than for renewables in residential buildings.

Figure 5.6 • TGT: Services final energy demand by end-use and fuel versus BAU, 2000-50



Sources: APERC analysis and IEA (2018a).

PERFORMANCE STANDARDS CENTRAL TO BUILDING ENERGY EFFICIENCY

MEPS for equipment used in buildings are an essential tool for improving building energy efficiency in the TGT. They are commonly used in APEC economies and are particularly effective when combined with education and awareness-building programs that highlight the benefits of choosing the most efficient option when purchasing a new appliance. Implementing or strengthening MEPS and increasing awareness of the benefit of appliance efficiency are key to achieving the TGT outcomes. This instrument is most useful where variation in device efficiency is considerable. One such example can be found in the lighting subsector where (to reduce the prevalence of inefficient lighting technologies) some APEC members, including Australia, Canada, Chile and Mexico, have implemented legislation to gradually phase out older incandescent bulbs in favour of LED and compact fluorescent lamp alternatives. For smaller economies, cooperating on MEPS and efficiency labelling systems can reduce the cost of implementation and operation. The E3 program used in New Zealand and Australia is an example of such cooperation. This program encompasses both a MEPS and appliance labelling, which lowers both the cost of regulation and compliance for companies working in both economies.

The growth of modern renewables is driven by increasing electricity demand coupled with greater renewables deployment in the electricity sector (primarily from China and non-OECD[31] economies). Economic development underpins this demand growth and results in an increasing number of people who are able to afford appliances (including heating and cooling appliances such as heat pumps) that need electricity. MEPS and labelling programs both help to incentivise fuel switching in favour of electricity and therefore renewables growth, while ensuring that devices are efficient. The drivers of renewables deployment in the power sector are discussed in Chapter 4.

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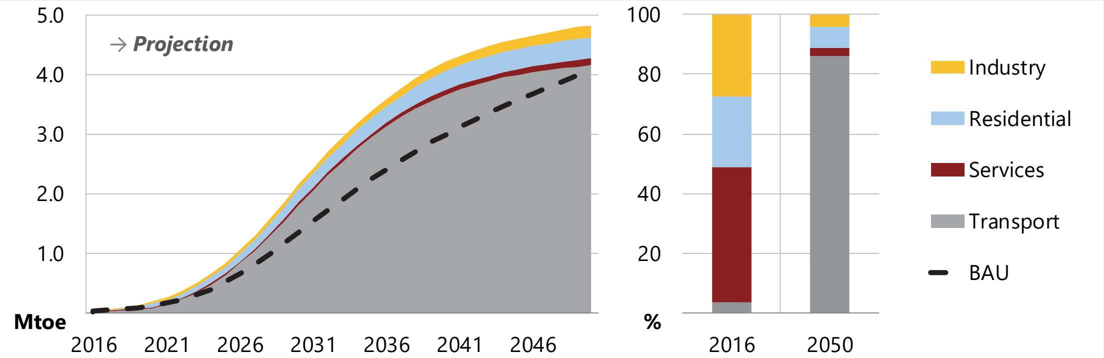
[31] Eight APEC economies (Australia, Canada, Chile, Japan, Korea, Mexico, New Zealand and the US) are also members of the Organisation for Economic Co-operation and Development.

Box 5.1: Hydrogen demand in the Target Scenario

Hydrogen demand in the TGT grows rapidly from around 2025 as APEC economies deploy hydrogen and fuel cell technologies more proactively in the TGT as they have potential to reduce CO_2 emissions from the buildings (services and residential), industry and transport sectors. Hydrogen demand reaches 4.8 Mtoe in 2050 in the TGT, compared with 4.1 Mtoe in the BAU (Figure 5.9). As in the BAU, these developments are largely localised in China, Japan, Korea and the United States.

Figure 5.9 • TGT: Hydrogen FED by sector and share versus BAU, 2016-50



Source: APERC analysis.

The transport sector is the major hydrogen user in the TGT with FCEVs accounting for 0.57% of total APEC vehicle stocks (2.8% of total advanced vehicles stock) by 2050. Japan, which leads the current FCEV market in APEC, has set a target of having 800 000 on the road by 2030 while China aims to reach 1.0 million by the same year. In Korea, the government has set targets to increase the share of low-emission car sales (including FCEVs) from around 2.0% in 2016 to 20% by 2020, projecting 9 000 FCEVs deployed by 2020 and 630 000 by 2030. As of May 2018, the United States had 61 hydrogen stations installed. The government of California offers rebates for FCEVs to support the target of 1.5 million zero-emissions vehicles on the road by 2025. California is also developing a state-wide network of refuelling stations, which included 35 hydrogen stations as of early 2018; by year-end, an additional 29 stations are planned in California and 5 in the US northeast.

Hydrogen demand in residential buildings rises to 0.34 Mtoe by 2050 in the TGT, more than 40 times the 2016 level. This projection assumes adoption of 6.7 million fuel cell batteries (FCBs), predominately driven by Japan where the government aims to deploy more than 5.3 million residential units by 2030. In Korea, FCB deployment reaches 500 000 installed units in residential buildings by 2050. Industry hydrogen demand grows at a slower pace than under the BAU, reaching 0.21 Mtoe in 2050, reflecting the efficiency improvements from strengthened BATs in the TGT.

TRANSPORT: HIGHER FUEL STANDARDS AND MORE EFFICIENT LOGISTICS

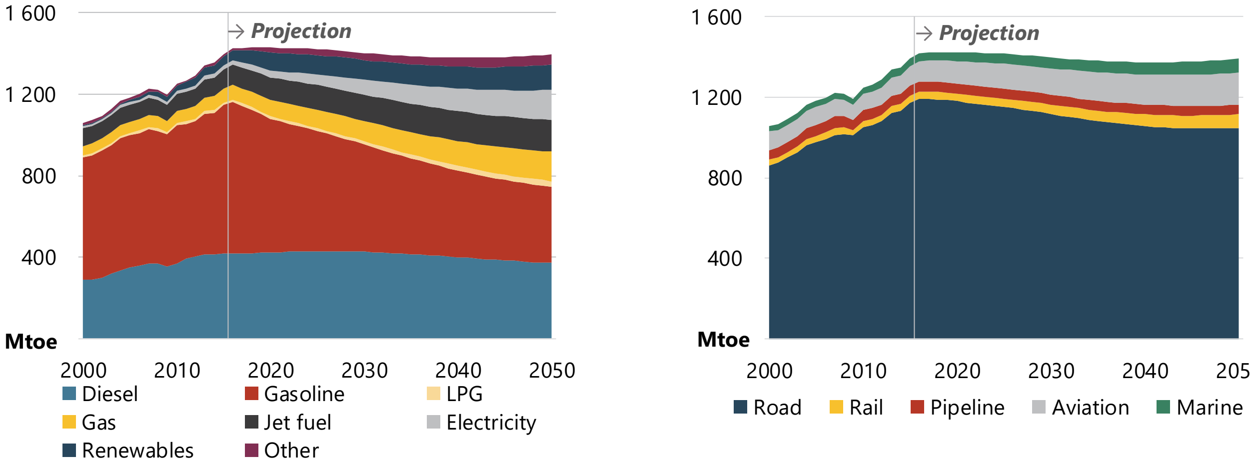
Under the BAU Scenario, transport has the fastest energy demand growth over the Outlook period, with a CAGR of 0.77%. This rapid growth, in addition to strong fuel and modal shifts, creates an opportunity for transport to be an energy efficiency leader (by adopting more ambitious fuel economy standards and improving passenger and freight logistics) and renewable fuel adoption (by introducing additional biofuel mandates).

The TGT Scenario includes different assumptions on the mode shares of different types of transport in order to reduce energy demand growth. Both freight and passenger transport are linked with economic (GDP) growth and income (GDP per capita) growth. Several key developments underpin the TGT. Advances in engine and motor manufacturing, lightweight materials, and improved utilisation drive fuel economy improvements for all types of vehicles and power trains. The introduction of jet biofuel in both international and domestic aviation and mandates (introduced on an economy-by-economy basis) for higher blend rates of biodiesel and bioethanol increase the penetration of renewables.

SIGNIFICANT REDUCTIONS IN DOMESTIC TRANSPORT ENERGY DEMAND

Under the TGT, domestic transport FED declines from 1 425 Mtoe in 2016 to 1 395 Mtoe in 2050, compared with 1 786 Mtoe in the BAU (Figure 5.7). Cumulative energy demand is 11% (7 350 Mtoe) lower in the TGT which mostly (96%) results from advances in road transport. Overall, domestic transport FED in the TGT declines by a 2.1% reduction from the base year.

Figure 5.7 • TGT: Domestic transport final energy demand by fuel type and end-use, 2000-50



Sources: APERC analysis and IEA (2018a).

Road continues to dominate domestic transport in the TGT, accounting for 75% of FED in 2050 (from 84% in 2016). This is 4.8% less than in the BAU, as energy efficiency gains in road outpace those in domestic air, sea and pipeline transport. Significantly lower energy demand in both domestic freight and passenger transport, especially during 2025-40, result in transport energy demand shrinking at a CAGR of -0.06% over the Outlook period (versus 0.67% CAGR in BAU). Passenger transport declines faster than freight transport, as more light-duty vehicles (LDVs) switch to cleaner and more efficient fuels.

With the introduction and implementation of fuel standards and biofuel mandates within the APEC region (see Table 5.1), the share of oil declines to 69% in 2050, from 94% in 2016. Gasoline demand falls at -2.0% CAGR, as the use of electricity and renewables increases. Diesel demand declines more slowly (-0.35% CAGR), which is still a significant improvement from the BAU (0.72% CAGR) as stricter fuel standards counter increasing demand in freight and public transport in developing economies. In aviation, biofuels reach 1.3% of energy demand, seven times that of BAU.

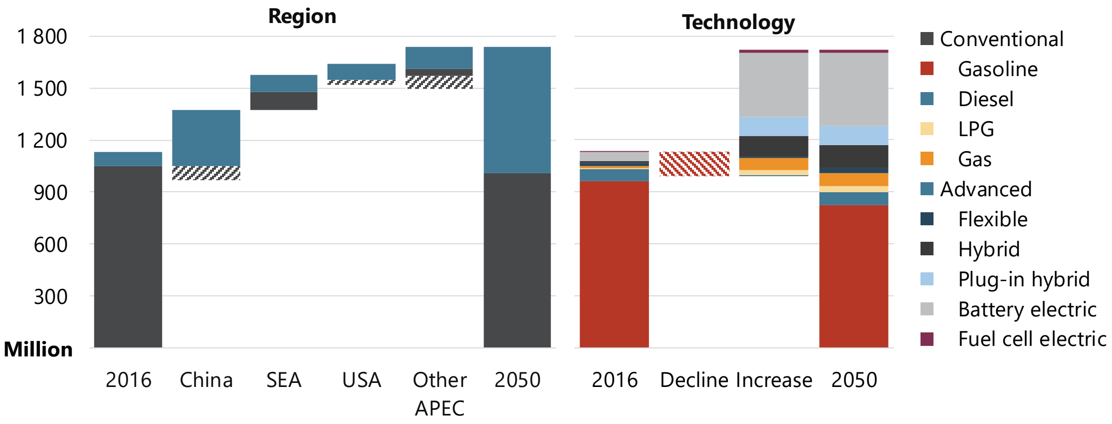
STRONG FUEL AND MODAL SHIFTS IN ROAD TRANSPORT

APEC total vehicle stock in the TGT increases from 1 132 million to 1 740 million over the Outlook period, similar to the BAU but with a noticeably different composition. Because of strong efforts to reduce emissions, there are 297 million fewer gasoline vehicles and 28 million fewer diesel vehicles by 2050. The share of electric vehicles (EVs), including battery and plug-in technologies, surges to 32% in 2050 (compared with 18% in the BAU), while hybrids rise to 7.9% (compared with 6.4%). In parallel, natural gas and LPG vehicle stocks are around 1.0% higher in the TGT compared with the BAU. This reflects policies to subsidise cleaner vehicles and the assumption that costs to manufacture advanced vehicles will decline—both elements making such vehicles more affordable for end-users.

Additional biofuel mandates within APEC help to push the 2050 share of renewables in transport from 4.9% in the BAU to 8.9% in the TGT. In domestic transport, the primary contributor to this advancement, biofuel demand rises by 75 Mtoe (or 2.5 times) over the Outlook, mainly due to growth in the United States (41 Mtoe) and Indonesia (18 Mtoe). China, the Philippines, Thailand, and Viet Nam also see strong transport renewables demand growth, which is driven by government efforts to stimulate flexible vehicles, increase biofuel production and reduce oil imports.

Modal shift in transport is more obvious in the TGT than in the BAU (Figure 5.8). The biggest change is in the use of gasoline-powered light vehicles, which shrink over the Outlook, from 482 million to 347 million, rather than growing (to 531 million) as they do under the BAU. Total stock of LDVs is unchanged under both scenarios as additional battery electric and plug-in hybrid vehicles enter the fleet in the TGT. There are also significantly more buses in 2050 in the TGT (12 million compared with 9.6 million in the BAU) as demand for public transport grows due to stronger government support.

Figure 5.8 • Vehicle stock change by region and technology in the TGT, 2016-50



Note: SEA = South-east Asia; hashed areas represent stock decline.
Source: APERC analysis.

THE UNITED STATES AND CHINA CONTINUE TO DOMINATE TRANSPORT DEMAND

Domestic transport energy demand in the United States remains the largest in APEC through the Outlook period in all scenarios, followed by China, south-east Asia and other Americas. However, China undergoes the greatest reduction in domestic transport energy demand in the TGT compared with the BAU, achieving a cumulative demand reduction of 2 552 Mtoe (about 75 Mtoe less per year). In the short term, this is underpinned by the central government's top-down approach and driven by targets outlined in the 13th Five-Year Plan (2016-2020). Cumulative demand in the United States is 1 999 Mtoe lower over the TGT compared with the BAU, because of gradually rising fuel efficiency standards.

The three most populous economies in APEC (China, the United States and Indonesia) are projected to own 65% of road vehicles in 2050 in the TGT Scenario. Indonesia has the highest number of 2- and 3-wheelers (190 million), accounting for 38% of APEC total in 2050. China accounts for 50% of the increase in advanced (e.g. hybrid or electric) vehicle stock over the Outlook. In 2050, 14 million fuel cell electric vehicles (FCEVs)—almost double the stock in the BAU—are rolled out in just five APEC economies: Canada, China (which alone has 8.4 million), Korea, Japan and the United States. By the end of the Outlook, conventional light vehicle stock in the United States is still 94% of the base year and the largest in APEC (in contrast to the BAU, where China has the largest stock of conventional LDVs through the Outlook).

POLICY IN CHINA DRIVES DEPLOYMENT OF 'NEW ENERGY' VEHICLES

A wide variety of targets, policies and regulations across APEC aim to improve the efficiency of vehicles and increase deployment of renewable energy in transport. In the TGT, effective initiatives are extended across the region to drive significant reductions in fossil fuel use and hence in CO_2 emissions and pollution.

China's 13th Five-Year Plan for Energy Development (2016-2020) mandates a 15% reduction in energy intensity in transport, with improvements predominately coming from development of urban public transport, options for greener travel, and improving infrastructure for EVs and FCEVs (such as charging stations to serve 5.0 million units by 2020). China, which is the world's largest vehicle market, also puts deployment of new-energy vehicles among the 10 priorities in the 'Made in China 2025' plan. The Chinese government has provided a significant subsidy (from USD 13 000) (CAW, 2017) for each domestic EV purchased while the incentive for US or Japanese brands is usually around USD 7 500. This subsidy has encouraged rapid uptake of domestically built EVs in China.

Fuel economy standards are becoming stricter in several economies. The US Environmental Protection Agency established standards for heavy-duty vehicles in 2011 (on top of those existing for LDVs) under two phases, and forecasts a fuel consumption reduction of 16% to 30% by 2027 (EPA, 2011). Influencing the trajectory of transport energy demand is more challenging for the US federal government than for China, because energy program implementation depends on individual state regulations. To improve fuel economy standards, Chile has introduced a carbon tax—payable upon purchase of a vehicle—based on its CO_2 and nitrogen oxides emissions. Energy labelling of vehicles is also increasingly popular, with new schemes rolled out in Viet Nam and Thailand.

Government-introduced mandates to promote biofuel use also drive the shift towards non-conventional vehicles across APEC. Mandates are already in place in the Philippines and the United States (E10), Canada (E8.5 and B4), Viet Nam (E5), Indonesia (E3 pilot and B30), Mexico (B2) and other economies[32] (see Table 5.1). The

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[32] E = bioethanol (volumetric blend rate with gasoline); B = biodiesel (volumetric blend rate with diesel)

mandatory renewable mix also helps boost awareness of environmental protection in developing economies, and indirectly introduces consumers to cleaner vehicle choices.

OPPORTUNITIES AND CHALLENGES

Across the APEC region, significant opportunities exist to exceed the energy intensity goal and achieve the renewables doubling goal. The first requires strategic development of technologies to implement energy efficiency measures and sufficient support for their deployment. For renewables, the biggest opportunities lie in advancing the operational efficiency and dispatchability of renewable technologies, which in turn reduces barriers to project financing. Promoting behavioural change and rolling out educational programs are also important to achieving both goals.

While the APEC energy intensity target is achieved in the BAU Scenario, the renewables doubling goal is not. The challenge of achieving the renewables goal is linked to the large variety of renewable resources in each region, the cost of technology, energy density, and the difficulty of introducing intermittent, non-dispatchable plants (such as wind and solar) into electricity grids.

Understanding the long-term prospects of energy technologies is especially important for developing economies as they are actively adding capacity in demand sectors. They would do well to avoid the lock-in effect of deploying low-cost but already obsolete technologies that could damage the economic competitiveness of low-carbon technologies in the future. Developed economies, in contrast, might find it more difficult to accelerate the application of upgrades as capacities are already in place; a consideration in this case is to implement policies which promote early retirement.

The transport sector highlights multiple opportunities for energy demand reductions. For instance, with the economics of EVs improving against conventional vehicles, an early retirement policy (e.g. applicable for vehicles older than six years), such as those implemented in Hong Kong, China, can accelerate uptake. Without large-scale deployment of flex-fuel vehicles (which can use both biofuels and fossil fuels), renewable fuel demand in transport is projected to decline due to improved efficiency and higher EV deployment. It might therefore be most beneficial to focus biofuel mandates on the heavy freight subsector, which is less likely to switch to EVs. A strict fuel efficiency policy for new vehicles could also be very effective in relation to energy demand and air quality. However, as it takes time for stock turnover to filter through the economy, the impacts of such policies would only be realised over time. Parallel development of public transport can boost demand reduction. In Japan, fuel economy policy drives demand for hybrid passenger vehicles while a variety of surface and underground public transport provides access to energy efficient travel.

For buildings, energy efficiency policies can improve living conditions while also reducing future energy demand. This opportunity is critical to capture as demand for energy services such as cooling grows strongly with rising economic prosperity. As buildings have a much slower turnover rate (around 30 to 100 years) than vehicles (around 5 to 15 years), availability of financing is crucial to retrofit existing buildings while ensuring that efficiency standards are continually increasing for new buildings.

With such a slow turnover rate, buildings present a number of efficiency challenges. Improvements to building envelopes can have a positive medium- to long-term effect, but this requires availability of long-term capital. Several economies (such as Australia, China and the United States) are implementing direct use of renewables as buildings support mechanisms. Residents, however, might find it more economical to install a solar PV system rather than a SWH. Either option affects daily electricity load curves and might result in mixed system-wide effects. Several APEC economies (such as Australia) and regions (such as California) are already facing the challenge of maintaining a consistent and reliable energy system in the face of rapidly changing residential demand curves.

Due to the competitive nature of industry, it is not uncommon for BATs to have the same, or better, lifetime economic performance as older, less costly technologies. Competition in global markets generally prompts manufacturers to minimise their expenses and apply long-term rational thinking. However, this is not always the case, particularly in economies undergoing rapid economic development where timeliness may be prioritised. Introducing forward-looking policies to support sustained energy efficiency progress is therefore important to avoid locking in already-dated technologies. In developed economies, promoting energy efficiency improvements at existing plants (such as via Australia’s Energy Efficiency Opportunities program) can reduce fuel use and improve competitiveness.

Balancing multiple objectives—such as stable employment, socioeconomic development and environmental protection—is always difficult for policymakers. As such, the scope for further ambition should be analysed using a multidisciplinary approach, which requires that different stakeholders (such as government, the private sector and academia) collaborate to support coordinated action and policy development, backed by improved data collection.

In some instances, the magnitude of a policy effect depends on whether society accepts new measures or technologies. For example, a ‘not in my back yard’ (NIMBY) attitude is common, in which some people support change but are not willing to have new infrastructure installed nearby. This highlights the importance of energy educational programs, which are currently under-delivered throughout the APEC region. Similarly, social acceptance of new energy technologies and fuels, policy support, and energy literacy are very important as population and urbanisation grow across APEC. On the energy efficiency side, people should be made aware of simple energy practices that allow them to achieve the same service from lower energy input, or how to lower the service demand without affecting productivity and performance. In terms of renewables, educational programmes should explain the positive and negative aspects of modern and traditional renewable energy sources. Surveys that explore people’s preferences and choices provide useful feedback to policymakers.

As highlighted in past editions of the Outlook, all policies need a comprehensive approach that is tailored to local conditions: this helps to achieve cost-effective solutions and optimise sector-specific advantages. This is especially true for renewables. To reduce GHG emissions, for example, is it better to aggressively promote EVs or focus on very efficient conventional vehicles? The appropriate answer may depend on many different variables, such as the power generation mix of a given municipality, economy or region. The overarching challenge is to find appropriate solutions that are tailored to energy sector development on an economy-by-economy basis.

RECOMMENDATIONS FOR POLICY ACTION

It is easy to emphasise the importance of ambitious goals and targets; ultimately, however, policies must be feasible with respect to current energy practices, cultures and governance systems. A centralised market with a few players (or only one), seen in many developing APEC economies, may be regulated directly. In developed economies, the energy sector typically involves multiple players and increasingly complex systems, which demand a comprehensive and holistic policy development approach. Policies should be designed to closely link capturing potential for energy demand reduction and accelerating the deployment of renewable energy.

Industry is very diverse in terms of technologies. Sectoral analysis shows that many existing and mature technologies could be implemented to improve energy efficiency, drive up the share of renewables and boost competitiveness. Policy for the iron and steel subsector should aim to increase steel recycle rates to facilitate greater use of electric arc furnaces, which lowers energy demand per volume of product while improving quality. Where technologically feasible, boosting recovery of gas by-products and substituting fossil fuels with renewables should be pursued. In the non-metallic minerals industry, achieving world-leading clinker-to-cement ratios should be a focus in all economies. More broadly, equipping industry with variable frequency drive electric motors would dramatically reduce industry electricity demand while also minimising heat loss and maximising heat recovery (this would be applicable in most subsectors). The aluminium industry would benefit from faster adoption of the pre-baked production cycle while pulp and paper, which is rich in renewable feedstock, should aim to minimise waste and maximise its use in processes. Expertise with implementing BATs should be shared among APEC economies and industry experts.

Buildings energy demand could be gradually reduced by ratcheting up appliance standards and labelling schemes (which are already common across APEC). Revision of buildings sector codes to continue promoting thermal performance would enhance comfort while reducing energy demand. As space heating and cooling, as well as water heating, are major end-uses, policies should aim to minimise their intensity per capita and per square metre, while maintaining building comfort. Many APEC economies have significant potential for direct use of renewables, especially for water and space heating. Although this applies mainly to residential buildings, all economies could use it to offset overall buildings energy demand. Modern renewables, including solar PV, are already seeing significant cost reductions, making them a viable substitute for traditional biomass for heating and cooking. Finally, buildings information and energy monitoring systems, such as smart meters, will be essential to managing changing electricity grids and should be prioritised.

Policy recommendations to support the energy intensity goal in transport are very diverse. Mandating minimum fuel economy standards for new vehicles provides strong improvements over time. Promoting alternative modes of transport (such as rail instead of bus and bus instead of private car) would help reduce both city congestion and energy demand. As the urban population in APEC continues to grow significantly, cities would benefit greatly from the roll-out of smart transport technologies, such as multimodal transport systems and interactive information services. The concept of mobility as a service might help reduce the number of privately-owned vehicles while delivering the same level of service. Similarly, lower demand for liquid fuels helps reduce the space needed for infrastructure but could also reduce demand for biofuels. Focusing on biodiesel deployment in the heavy freight subsector may therefore be most beneficial to achieving renewable goals, since it is unlikely to be displaced by electricity, which occurs mainly in light vehicles.

6. LOW-CARBON SCENARIO

KEY FINDINGS

- **APEC FED decreases 11% over the Outlook period in the 2DC, falling from 5 406 Mtoe in 2016 to 4 798 Mtoe in 2050.** The largest share of demand reduction is in transport (35% below 2016), followed by buildings (18%) and industry (1.4%).

- **Transport energy demand decreases quickly (-1.2% CAGR),** largely through improvement in fuel economies of internal combustion engines, electrification of light vehicles, and switching from private to public transport modes.

- **Buildings energy demand in 2050 in the 2DC is 36% lower than in the BAU,** as electrification, building envelope improvements, and the use of high efficiency appliances and equipment drive energy efficiency improvements.

- **Despite significant improvements in energy efficiency, industry accounts for the largest share of total CO_2 emissions in 2050.** Increased electrification, boosting renewables as fuel inputs, and introducing CCS to capture CO_2 emissions are key to meeting 2DC targets.

- **The APEC electricity sector evolves from being based largely on fossil fuels in 2016 to being dominated by renewables and nuclear in 2050.** To achieve 2DC emissions reduction goals, achieving commercial viability of CCS technology for fossil fuel generation by 2030 is paramount.

- **The 2DC shows that low-carbon measures can reduce CO_2 emissions and open new trade and investment opportunities,** particularly in cleaner technologies and fuels (e.g. EVs, renewable power and storage, biofuels and hydrogen) and new infrastructure. This opens significant opportunities for trade and investment, particularly for economies that continue to have rapid growth in energy demand in the 2DC.

- **Total capital investment of USD 60 279 billion is required to achieve the CO_2 emissions reduction target in the 2DC.** This amount is 26% higher than in the BAU, but is partially offset by a fuel cost saving of USD 16 316 billion compared to the BAU.

INTRODUCTION TO THE TWO-DEGREES CELSIUS SCENARIO

For the first time in the Outlook, APERC examines energy demand and supply trends in the Asia-Pacific Economic Cooperation (APEC) to specifically analyse a pathway toward a low-carbon energy sector. This chapter explores what additional effort is needed for APEC economies to reduce greenhouse gas emissions from the energy sector as a first step toward achieving their long-term targets in the Paris Climate Agreement.

The APERC 2-Degrees Celsius (2DC) Scenario broadly follows sectoral carbon budgets as laid out in *Energy Technology Perspectives 2017* (ETP) 2017, published by the International Energy Agency (IEA, 2017a). The 2DC is target-based: with the aim of having at least a 50% chance of limiting the average global temperature increase to 2°C by 2100, it maps out an energy system for APEC economies as a whole that constrains annual CO_2 emissions to 13 gigatonnes (Gt) by 2050— a level 56% lower than actual CO_2 emissions in 2013 – while assuming that reductions in APEC are part of broader, global action to mitigate climate change[33].

The 2DC Scenario illustrates the additional effort – in terms of technology, energy policy, and investment – that is needed to transform the energy demand and supply system of APEC economies as they move toward their Paris Agreement targets. This chapter summarises key mechanisms to achieve a low-carbon energy demand and supply system, focusing on differences between the 2DC and the two other scenarios explored in this Outlook: the Business-as-Usual (BAU) and APEC Target (TGT) Scenarios.

The following analysis highlights key assumptions of technologies and processes in each energy demand and supply sector. After providing key findings, the text offers policy recommendations that APEC governments should consider, which are covered in more detail in Chapter 10 on Climate Change Policy.

This chapter also reflects the ways in which APEC economies have shown their commitment to the COP21 Paris Agreement reached in 2015 at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC). Most APEC economies have submitted Nationally Determined Contributions (NDCs), which outline actions they will take post-2020 to mitigate the effects of climate change to achieve the goal of constraining the temperature increase to 2°C (UNFCCC, 2015). It should be noted that CO_2 emissions will have to continue to decline after 2050—until carbon neutrality is reached.

Having been published shortly after COP21, the *APEC Energy Demand and Supply Outlook 6th Edition* evaluated changes in emissions and emissions intensity of APEC economies based on climate actions proposed in what were then 'Intended Nationally Determined Contributions (INDCs)' (APERC, 2016). The analysis found that the INDCs fall short of achieving a 2DC future, even when taking account of APEC goals to reduce energy intensity by 45% by 2035 (against the 2015 level) and to double the share of renewables in the energy system. This finding was a primary motivation for constructing a model to map out the 2DC—i.e. a low-carbon energy future—scenario presented in this chapter.

To model the APEC 2DC—including a carbon budget for the energy sector—the Asia Pacific Energy Research Centre (APERC) used information from the CO_2 emissions pathway in ETP 2017 (IEA, 2017a). In its own modelling, ETP 2017 applied an integrated cost-optimised approach to determine what proportion of total CO_2 emissions reduction each sector and/or subsector would need to achieve. APERC uses this output to set sub-targets for

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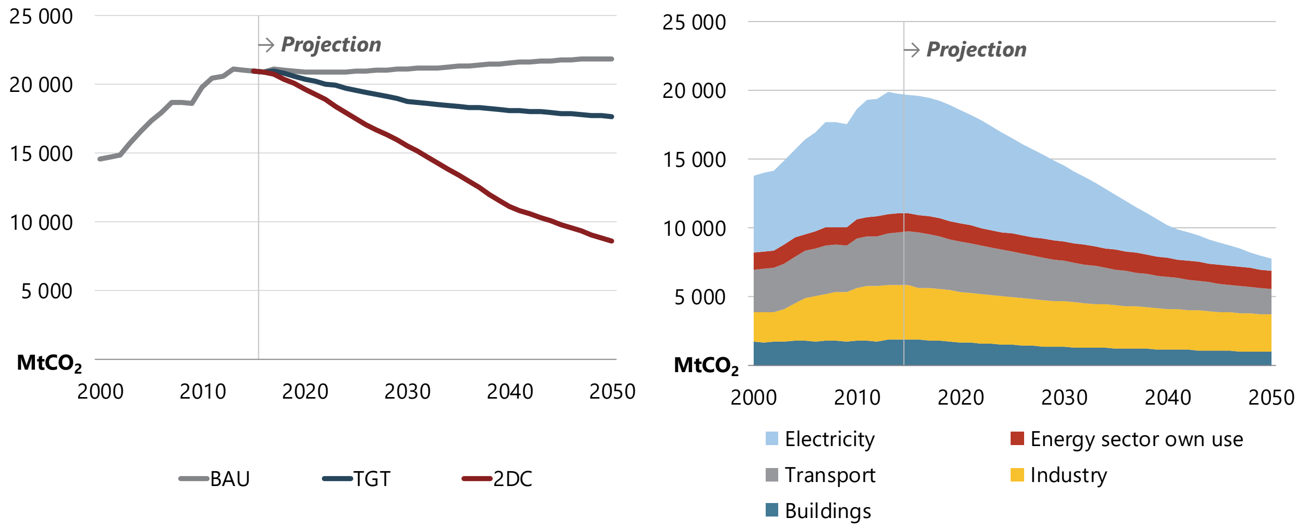
[33] The 2DC Scenario applies varied decarbonisation between energy sectors. Electricity is assumed to reach around 90% of CO_2 emission reductions by 2050 than in 2013, followed by the transformation sector (85%) and transport sector (41%). Industry has the lowest CO_2 emission reduction (7.9%).

each energy demand subsector. This integrated approach shows some sectors achieving greater CO_2 reduction than others, both in absolute terms and as a proportion of their current emissions levels.

Figure 6.1 • Total CO_2 emissions under the BAU, TGT and 2DC, 2000-50



Sources: APERC analysis, IEA (2016a and 2018a), and IPCC (2018).

In the 2DC, total CO_2 emissions across all APEC economies by 2050 are 59% lower than in 2016, with actual amounts falling from 20 689 million tonnes of CO_2 ($MtCO_2$) to 8 549 $MtCO_2$ (Figure 6.1). Over the Outlook period, CO_2 emissions decline at a compound annual growth rate (CAGR) of -2.6%, which is substantially accelerated relative to the -0.46% CAGR in the TGT and in sharp contrast to emissions rising at 0.17% CAGR in the BAU. By 2050, total APEC CO_2 emissions in the 2DC are 52% lower than in the TGT and 61% lower than in the BAU.

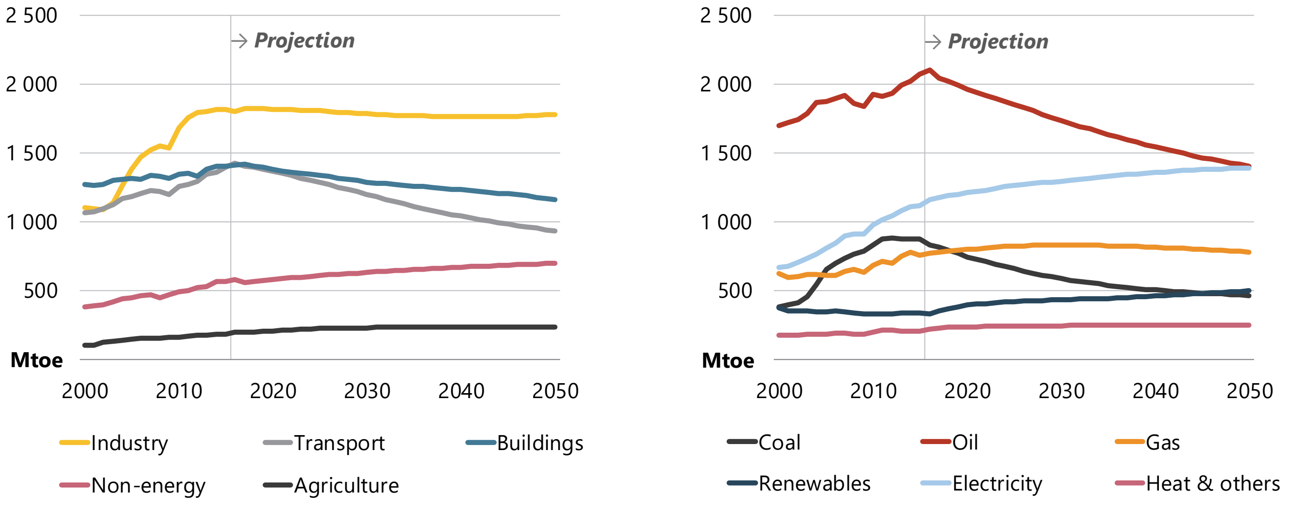
OVERVIEW OF A LOW-CARBON ENERGY FUTURE

FINAL ENERGY DEMAND DECREASES IN THE TWO-DEGREES CELSIUS SCENARIO

In the 2DC, APEC final energy demand (FED) is examined across four main demand sectors: industry, transport, buildings, and agriculture and other (Figure 6.2). Over the Outlook period, APEC FED decreases (-0.35% CAGR) in the 2DC, falling by 11% from 5 406 million tonnes of oil equivalent (Mtoe) in 2016 to 4 798 Mtoe in 2050. The largest share of demand reduction is seen in transport (35% reduction against 2016), followed by buildings (18%) and industry (1.4%). Transport energy demand decreases the most quickly (-1.2% CAGR) driven mainly by switching from private vehicles to public transport modes, fuel switching from oil to low-carbon fuels technologies, and lower freight activities.

Transport accounts for the third-largest energy demand in the 2DC, even as its 26% share in 2016 declines to 19% in 2050. Transport demand in 2050 under the 2DC is 48% lower than in the BAU and 33% lower than in the TGT. This reduction is supported by fuel switching from oil to low-carbon fuels technologies such as electricity, biofuels and hydrogen (for light vehicles) and greater uptake of biofuels (for trucks and busses), fuel economy improvements across the entire vehicle fleet, and mode switching from private vehicles to public transport.

Figure 6.2 • APEC final energy demand in the 2DC by end-use and fuel type, 2000-50



Sources: APERC analysis and IEA (2018a).

Transport energy demand in 2050 is between 35% to 49% lower in the 2DC relative to the BAU, depending on the region. By percentage, China shows the largest relative reduction at 49%, followed by Oceania (46%), other Americas (45%) and the United States (42%). In absolute terms, the United States shows the largest share of APEC transport energy demand (30%), followed by China (23%) and south-east Asia (19%). Against the TGT, diesel and gasoline consumption in the 2DC declines significantly across APEC, while electricity demand from electric vehicles (EVs) increases thirty times from 4.2 Mtoe in 2016 to 126 Mtoe in 2050. Overall, CO_2 emissions in domestic transport decline to 1 862 $MtCO_2$ in 2050 (22% of the total APEC CO_2 emissions) compared with 4 018 $MtCO_2$ in 2016 (19%).

Buildings energy consumption – which accounts for the second-largest energy demand in APEC - decreases modestly (-0.57% CAGR), from 1 409 Mtoe (26% of total demand) in 2016 to 1 158 Mtoe (24%) in 2050. By 2050, buildings energy demand in the 2DC is 36% lower than in the BAU and 26% below the TGT. CO_2 emissions in buildings decrease more rapidly in the 2DC to 637 $MtCO_2$, which is 58% lower than in the BAU and 46% lower than in the TGT scenarios.

Key drivers for lower energy demand in buildings include the increased application of building energy codes to improve efficiency in both new builds and retrofits, rapid deployment of energy efficient appliances, and fuel switching from fossil fuels to electricity and/or modern biomass. APEC economies in north-east Asia experience the largest buildings FED reduction in the 2DC (43% lower than in the BAU by 2050), followed by the United States (41% lower) and Oceania (40% lower).

Industry represents the largest share of total energy demand in the 2DC, with its 33% share in 2016 increasing to 37% in 2050. Overall energy demand in industry only decreases modestly (-0.04% CAGR) and mostly occurs in the first 15 years of the Outlook period from 2016-2030 (-0.08% CAGR). Energy demand reductions are driven by improving material and energy efficiency in industrial processes and deploying best available technologies (BATs). Industry accounts for the largest share of total CO_2 emissions in the demand sectors from 2020 to 2050 and represents 47% of total CO_2 emissions in 2050, showing the relative difficulty of achieving deep decarbonisation in industry.

The share of electricity in APEC FED increases rapidly from 1 159 Mtoe (21% of total energy demand) in 2016 to 1 391 Mtoe (29%) in 2050, and is primarily driven by the electrification of buildings and transport. Switching from coal to cleaner sources (e.g. electricity and renewables) pushes down coal consumption in APEC FED from 825 Mtoe (15% of total fuel demand) in 2016 to 464 Mtoe (9.7%) in 2050. Natural gas demand remains steady, increasing only slightly (by 0.91%) from 773 Mtoe in 2016 to 780 Mtoe in 2050.

A total capital investment of USD 60 279 billion is required to achieve the CO_2 emissions reduction target in the 2DC. This amount is 26% higher than in the BAU, but is partially offset by a fuel cost saving of USD 16 316 billion compared to the BAU. The buildings sector requires USD 11 trillion more capital investment than under the BAU, followed by electricity and heat which requires USD 2.3 trillion more. The United States and China accounts for a combined 69% of buildings (equivalent to 22% of total capital investment in APEC) in the 2DC. Transport capital investment in the 2DC is USD 6.5 trillion (1.2 trillion more) than in the BAU. China accounts for most of the increase, which is 0.83 trillion more than the BAU. A detailed investment analysis is discussed in Chapter 7.

LOW-CARBON ELECTRICITY KEY TO DECARBONISATION IN APEC

The electricity sector is a key enabler of decarbonisation in the 2DC, with demand rising by 20% from 2016 to 2050, despite increasing levels of energy efficiency across the demand sectors. Buildings accounts for the largest share of electricity demand over the Outlook (46% of the total demand in 2016 and 41% in 2050), where accelerated adoption of high-efficiency electric appliances for space heating, cooling and cooking leads to a 5.6% increase in demand over the Outlook period. The fastest growth of electricity demand comes from the transport sector (6.4% CAGR), driven largely by the electrification of light-duty vehicles (LDVs) and light-duty trucks (LDTs), which represent 33% of total electricity demand in domestic transport.

In the 2DC, the carbon intensity of the electricity generation decreases by 92%, from 547 grams of CO_2 per kilowatt-hour (gCO_2/kWh) in 2016 to 46 gCO_2/kWh in 2050, substantially lower than levels reached in the BAU (27% lower than in 2016) and the TGT (35% lower). This level of steep decarbonisation in the electricity sector requires consolidated efforts and cooperation by all APEC economies.

CO_2 emissions from the electricity sector fall substantially in the 2DC, from 8 675 $MtCO_2$ (42% of total CO_2 emissions) in 2016 to 851 $MtCO_2$ (10%) in 2050, representing 36% of the total CO_2 emissions reduction seen in the APEC energy sector (Figure 6.3). A cumulative 26 645 $MtCO_2$ is captured by carbon capture and storage (CCS) technologies, which start to be deployed in 2030 in the sixteen APEC economies that have identified CO_2 storage potentials[34]. The electricity sector accounts for 76% of the total CO_2 emissions captured by CCS technologies followed by refineries (16%) and industry (8.1%).

Electricity system decarbonisation requires deployment of a range of technologies, including variable renewable technologies (rooftop and utility solar photovoltaics [PV], concentrated solar power [CSP], and onshore and offshore wind power) as well as the installation of CCS on both fossil fuel and biomass power plants. In parallel with these technologies, the larger deployment of electricity storage[35] helps support electricity grid operation—i.e. optimising the variable supply of solar PV and wind power while also avoiding their curtailment (IRENA, 2017).

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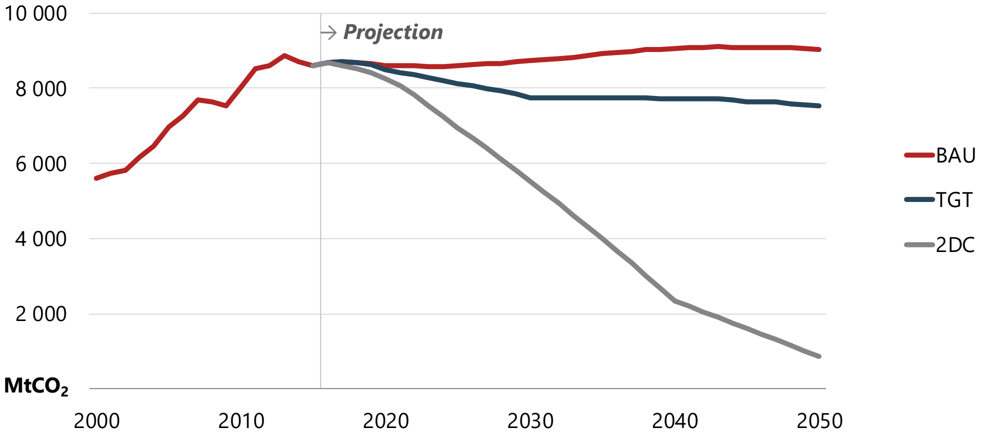
[34] To date, significant CO_2 storage potential has been identified in all APEC economies except for Chile and Singapore.

[35] Analysis in the Outlook considered two types of electricity storage technologies - pumped hydro and batteries.

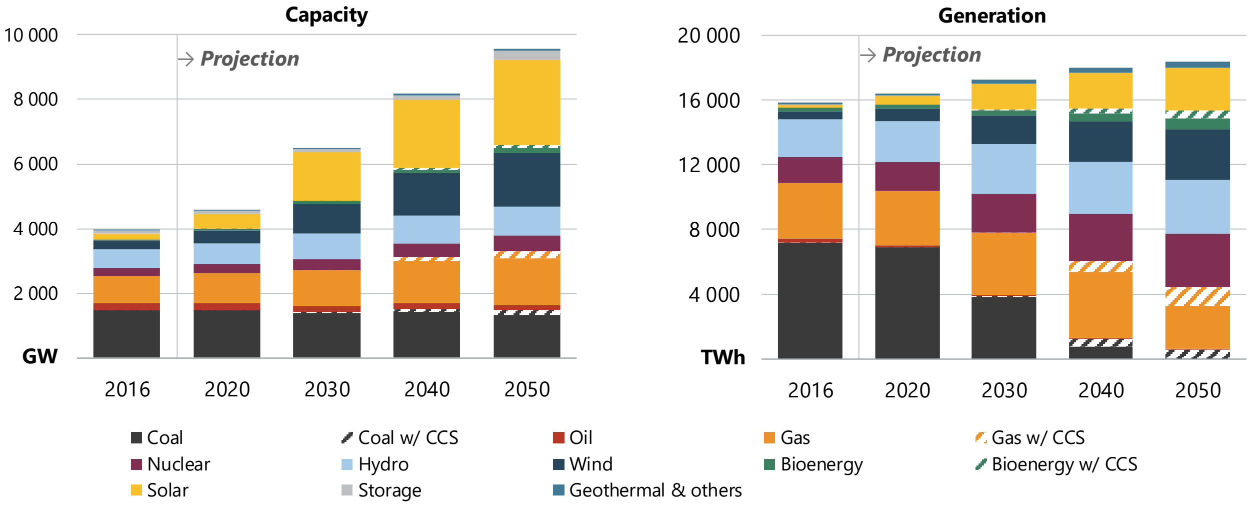
Figure 6.3 • APEC electricity CO_2 emissions in the BAU, TGT and 2DC Scenarios, 2000-50



Sources: APERC analysis, IEA (2016a and 2018a), and IPCC (2018).

Coal-fired power capacity without CCS drops by 9.9% in the 2DC – reflecting an annual coal power plant retirement rate of 0.31% from 1 483 gigawatts (GW) in 2016 to 1 336 GW in 2050. Retirements occur mainly for subcritical coal power plants, which have the lowest efficiency, and accelerate from a CAGR of -1.4% in the 2016-2030 period to -1.7% in the 2030-2050 period. Overall, coal capacity decreases from 37% of total APEC electricity generation capacity in 2016 to 22% in 2030 and then 14% in 2050.

Figure 6.4 • APEC power capacity and electricity generation in the 2DC by fuel, 2016-50



Sources: APERC analysis and IEA (2018a).

In 2016, coal accounted for the largest source of electricity in APEC, generating 7 171 terawatt-hours (TWh) (45% of total generation). In the 2DC, coal generation plummets in both total and share to 589 TWh (3.2%) in 2050. As coal's share in total generation declines, a domino effect occurs: as coal plants are called upon to generate less, they no longer operate at optimal capacity factors. As it is generally not commercially feasible to operate coal power plants at a capacity factor below 50%, retirements accelerate (Figure 6.4).

In contrast to coal, the total capacity of natural gas power plants increases in the 2DC from 802 GW in 2016 (20% of total share) to 1 653 GW (17%) in 2050 (2.2% CAGR). Yet the absolute volume and share of electricity generation from gas power plants peaks in 2040 at 4 734 TWh (26% of total generation) and gradually declines to reach 3 793 TWh (21% of total generation) in 2050.

The average capacity factor of natural gas power plants decreases from 49% in 2016 to 26% in 2050. However, gas-fired plants can serve as base load, load follower and peak power generation resources, giving natural gas a key role in the transition to a low-carbon energy future. The 2DC assumes technology advancement in gas turbine power generation technologies, including higher thermal efficiency and more flexible ramp-up and ramp-down operation to quickly compensate for generation variability from solar PV and wind power. Natural gas combined-cycle power plants are assumed to provide base-load power.

The accelerated transition from coal to gas power plants begins after 2030 when increasingly stringent carbon budgets come into effect. The 2DC assumes that CCS technology becomes commercially viable by this time (Global CCS Institute, 2017). By 2040, the installation of renewables capacity outpaces the total installed capacity of fossil fuel plants; at this point, gas power plants need to include CCS technology to meet the carbon budget allotted to the electricity supply system in the 2DC.

In 2050, coal, gas and biomass power plants with CCS have a combined capacity of 460 GW (4.8% of total) and produce 12% of total electricity generation. From 2016-2050, CCS systems in these power plants capture and sequester a total of 20 178 $MtCO_2$. To achieve this level of CO_2 capture in this timeframe, APEC economies need to introduce policy support that will advance CCS technology from its current demonstration stage to commercial viability by 2030.

Variable Renewable Energy (VRE) - including solar PV and wind power - shows the fastest capacity growth among power generation technologies in the 2DC, with a total installed capacity of 4 291 GW by 2050. Solar PV grows more quickly than any other technology (7.9% CAGR), followed by wind (5.3% CAGR). By 2050, the total installed capacity of solar PV is 15 times higher than in 2016, expanding from 177 GW to 2 648 GW. Wind power capacity also expands rapidly, from 261 GW in 2016 to 1 643 GW in 2050. By 2050, VRE represents 45% of total installed capacity in APEC economies.

The share of electricity generation from VRE in the 2DC reaches 31% by 2050. This share is substantially higher than in the BAU (15%) and TGT (20%). The 2DC CO_2 emissions reduction target is achieved by installing solar PV and wind power in place of the fossil fuel-based power plants that would be added in the BAU. While VRE represents the largest share of installed capacity (45%) in 2050 in the 2DC, electricity from VRE accounts for a smaller share (31%) of total generation, prompting rising need for increasing capacity factor of the VRE (i.e. through electricity storage technologies, smart grid management, and enhanced output forecasting).

Electricity storage capacity is added to support reliable power grid operation and improve the utilisation rates of solar PV and wind power. The 2DC requires a total installed capacity of 255 GW of electricity storage by 2050, compared to the 80 GW of storage available in 2016. Electricity storage capacity in the 2DC increases at 3.5% CAGR over the projection period such that total storage capacity by 2050 is 35% higher than in the BAU and 28% higher than in the TGT.

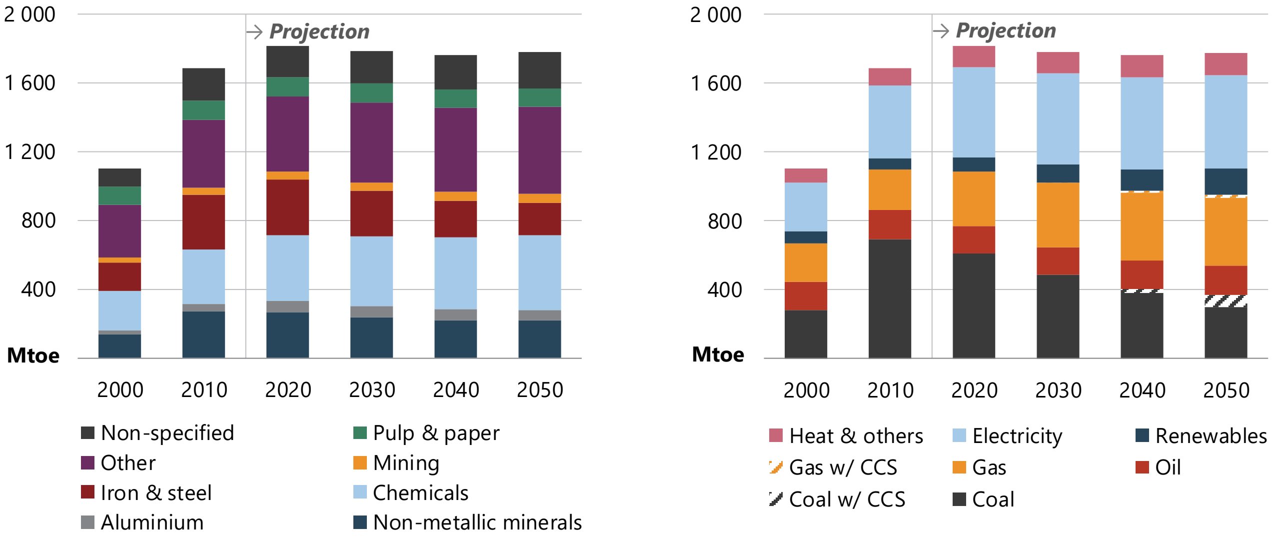
For some economies, nuclear power technologies support electricity sector decarbonisation. China adds 210 GW of new nuclear over the Outlook period, growing to seven times higher than 2016 levels. Four APEC developing economies in south-east Asia (Indonesia, Malaysia, Thailand and Viet Nam) that do not use nuclear in the BAU install 8.0 GW of nuclear power capacity post-2030 in the 2DC. Nuclear power capacity also increases in Mexico (five times higher compared to 2016) and Russia (82% higher) while it decreases in north-east Asia (12% lower) and the United States (1.6% lower). Chinese Taipei continues to operate the 5.2 GW of existing nuclear power that is scheduled to be retired in the BAU scenario.

Reducing carbon emissions does present challenges to some APEC economies in the 2DC. Particular challenges include the limited availability of domestic resources for natural gas or renewable energy, and less opportunity to use CCS technology due to limited geological CO_2 storage potentials. Additionally, developing these resources may not be a commercially viable option in absence of a price on CO_2 emissions or other policies to restrict emissions. This situation may present trade opportunities for natural gas, renewables and cleaner energy sources between APEC economies.

ADVANCING THE LOW-CARBON TRANSITION IN INDUSTRY

Similar to the BAU and TGT scenarios, industry consistently accounts for the largest share of APEC FED in the 2DC. It consumes 1 802 Mtoe (33% of FED) in 2016 and, despite a small decrease in energy demand to 1 777 Mtoe in 2050, its share slightly increases to 37% of FED (Figure 6.5). Industry energy demand in 2050 falls to 11% below BAU levels and at that time, China accounts for 46% of APEC industry demand, followed by the United States (17%) and north-east Asia (8.3%). Chemical and petrochemical, cement, and iron and steel are the three largest energy-consuming subsectors, together accounting for 47% of industry FED in 2050.

Figure 6.5 • Industry final energy demand in the 2DC by end-use and fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

Chemical and petrochemical has the largest industry subsector energy demand in the 2DC, despite its consumption decreasing to 6.9% below BAU levels by 2050. With demand growing at a 0.73% CAGR over the Outlook period, this subsector accounts for 431 Mtoe (24% of industry FED) in 2050. In contrast, energy demand decreases in the cement (-0.75% CAGR) and iron and steel (-1.7% CAGR) subsectors. Energy demand and CO_2 emissions reduction in the industry sector is driven by deploying BATs, improving material efficiency (e.g. by increasing steel recycling rates), and adopting CCS technologies.

China is projected to consume the most energy (246 Mtoe in 2050) for chemical and petrochemical production in the 2DC, followed by the United States (72 Mtoe) and Russia (46 Mtoe). Energy demand reduction in this subsector is mainly driven by replacing retiring plants with new facilities that consume 20% less energy due to technology improvements.

In iron and steel production, FED decreases by 45% below 2016 levels, largely due to more adoption of electric arc furnaces (EAFs) and BAT technologies. The operation of existing blast furnace-basic oxygen furnaces

(BF-BOFs) is limited to 40 years in the 2DC, with the assumption that new iron and steel production plants utilise BAT technologies. While BF-BOF systems use coal as the main fuel input to produce crude steel from iron ore, EAFs consume electricity to produce high-quality steel from recyclable steel (IEA, 2017a). In the 2DC, the share of plants equipped with EAFs rises from an APEC average of 39% in 2016 to 55% in 2050. The increase in the EAF share may require structural changes in the material supply chain for iron and steel production, such as policies to prevent copper and other elemental contamination of recycled steel scrap for steel reprocessing (Bataille et al, 2018). A more detailed explanation of industry's assumption is presented in Annex I.

EAF technologies for iron and steel production are assumed to drive energy demand reductions in the 2DC. Russia and New Zealand show the highest share of EAF deployment, with shares reaching 85% in 2050. In China, the largest source of industry energy demand in APEC, energy demand for iron and steel production decreases over the Outlook from 239 Mtoe in 2016 to 112 Mtoe in 2050 because the economy retires inefficient BF-BOFs existing plants and replaces them with EAFs while iron and steel production levels are maintained in all scenarios. In the 2DC, the share of EAFs in China expands to 30% over this period, largely in line with the shutdown of inefficient plants.

On the emissions side, the 2DC assumes both BF-BOFs and EAFs are equipped with carbon capture technologies. Other steel-making technologies such as direct reduced iron (DRI), which consumes gas to melt recycled steel, are not considered economically competitive to decarbonise iron and steel in the 2DC.

Energy demand for cement production in APEC is 215 Mtoe (12% of industry FED) in 2050, which is 18% lower than in the BAU. Lower CO_2 emissions are achieved by improving energy efficiency to meet BAT performance levels, promoting clinker substitution, and increasing the share of renewable energy in the fuel mix.

Two actions are essential to cement production in the 2DC: improving energy efficiency in clinker production, which is the main ingredient in cement and accounts for the highest energy consumption in the process, and reducing the ratio of clinker to cementitious materials. The latter is the most effective strategy to reduce both energy intensity and CO_2 emissions (IEA, 2017a). Changing this ratio, however, depends on the availability of clinker substitutes, which often come from the waste of other industry or energy transformation processes (e.g. fly-ash and bottom-ash from coal power generation or granulated blast furnace slag from iron and steel production). Natural pozzolanic minerals presently account for most of the raw materials used as clinker substitutes. The 2DC requires additional research to identify lower-carbon materials for clinker substitutes.

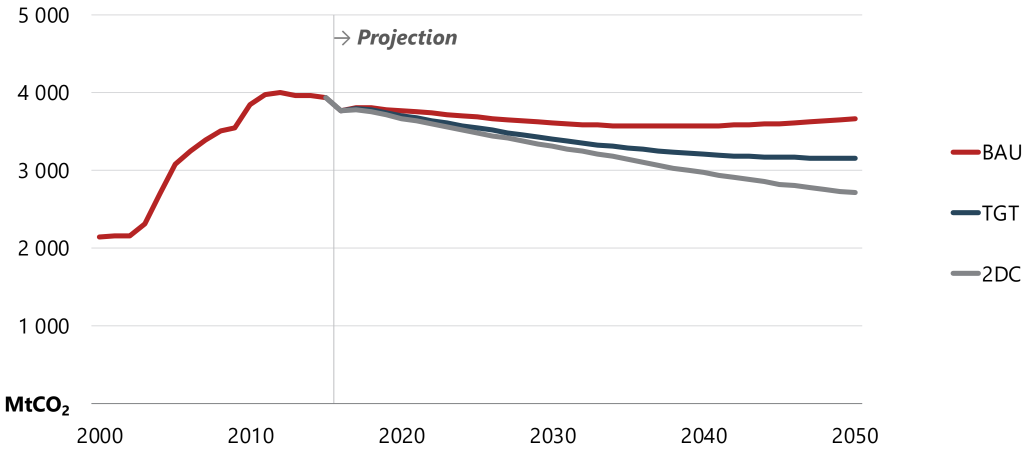
The process of liming calcium carbonate and subsequent combustion processes cause a high volume of CO_2 emissions from cement production. These sources cannot be fully eliminated by improving energy efficiency or fuel switching from fossil fuels to renewable energy—additional measures are also needed. The 2DC assumes that new cement facilities install a six-stage pre-heater and pre-calciner, both of which are considered BATs for the cement industry (Oda et al, 2012). As a result, the ratio of clinker to cement production gradually decreases from an average of 79% in 2016 to 70% in 2050, leading to lower energy consumption. In addition, upon reaching 40 years of operation, existing clinker kilns—which are commonly equipped with rotary, wet or vertical kilns—are refitted with a six-stage pre-heater and pre-calciner. In the 2DC, China is expected to achieve the lowest clinker-to-cement ratio of 57% while Viet Nam has the highest ratio of 85% in 2050.

In the 2DC, energy demand from industry falls 11% below projections for the BAU. Coal demand declines sharply (-1.7% CAGR) yet remains the third-largest industry fuel in 2050. Electricity becomes the largest (31% of the total) industry fuel, even though its volume only increases slightly from 519 Mtoe in 2016 to 543 Mtoe in 2050. Fuel switching away from coal pushes up natural gas consumption by 47% over the Outlook period from

281 Mtoe to 412 Mtoe (1.1% CAGR). Use of renewables in industry grows faster than other fuels (2.5% CAGR), but still represents only 8.5% of industry FED in 2050.

By 2050, CO_2 emissions in APEC industry in the 2DC are 2 712 $MtCO_2$, 28% lower than actual emissions in 2016, which is 26% below projections in the BAU and 14% below those in the TGT (Figure 6.6). In addition to the efficiency improvements, fuel switching from fossil fuels to renewables plays a vital role in reducing CO_2 emissions in the industry sector. The share of renewables in industry's fuel mix rises from 3.6% in 2016 to 8.5% in 2050. APEC's industry sector consumes 152 Mtoe of total renewables in 2050, of which China accounts for 35%, followed by south-east Asia (20%), and the United States (20%).

Figure 6.6 • Industry CO_2 emissions under the BAU, TGT and 2DC, 2000-50



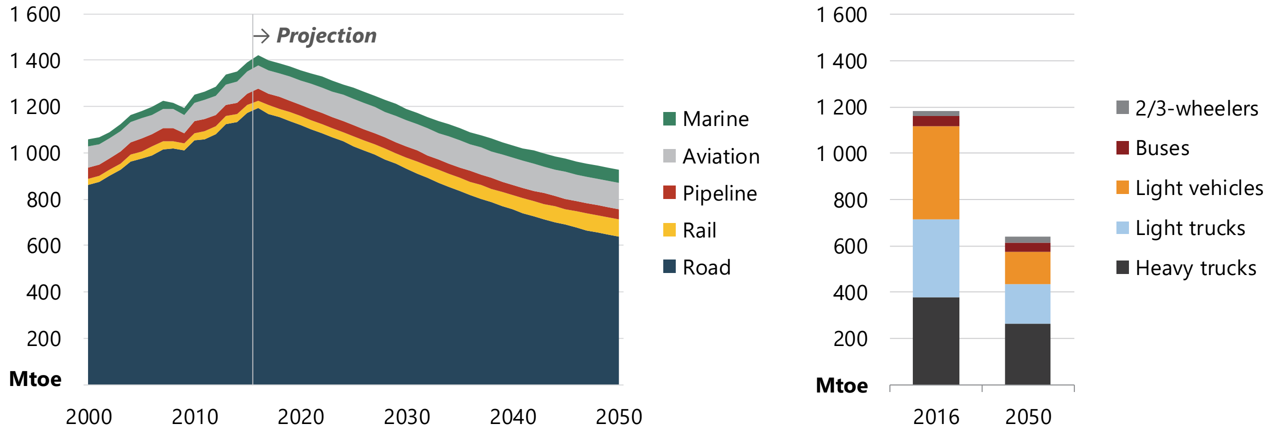
Sources: APERC analysis, IEA (2016a and 2018a), and IPCC (2018)

CCS is also deployed to further reduce CO_2 emissions from the industry sector. By 2050, industrial processes that consume coal and gas are equipped with CCS, representing 4.8% (86 Mtoe) of industry FED. By 2025, CCS is standard BAT in newly installed ammonia production plants in the chemical and petrochemical subsector, where ammonia is mostly produced from natural gas except for China, which uses coal. After 2030, carbon capture technologies are installed in existing and newly installed clinker production in the cement subsector and in BF-BOF production plants in the iron and steel subsector. The total amount of CO_2 emissions captured from industry in the 2DC is 2 158 $MtCO_2$. This significant amount of CO_2 will need to be transported and permanently contained in CO_2 storage or utilised (e.g. in enhanced oil recovery [EOR]).

LOW-CARBON TRANSITION IN DOMESTIC ROAD TRANSPORT

Reduced energy demand in domestic road transport is the most important strategy of decarbonising transport. FED for APEC domestic transport is reduced 35% over the Outlook period in the 2DC to 933 Mtoe, in sharp contrast to both the BAU, where demand increases 25%, and the TGT, where FED only declines by 2.1% (Figure 6.7). Annual CO_2 emissions from domestic transport are 1.9 Gt in 2050, which is 54% lower than in 2016. Again, the 2DC is dramatically different from the BAU, where emissions rise 16% to 4.7 $GtCO_2$ and the TGT, where they decrease 19% to 3.2 $GtCO_2$.

Figure 6.7 • Domestic transport final energy demand in the 2DC Scenario by end-use, 2000-50



Sources: APERC analysis and IEA (2018a).

The United States accounts for the largest percentage reduction in transport energy demand, with 2050 FED being 50% lower than in 2016, followed by north-east Asia (47% lower), and Oceania (37% lower). The United States accounts for the largest energy demand in transport sector both in absolute terms and percentages over the Outlook period (44% at 622 Mtoe in 2016 and 33% at 309 Mtoe in 2050), followed by China (21% at 297 Mtoe in 2016 and 26% at 241 Mtoe in 2050).

Key drivers of CO_2 emission reductions in the 2DC include: increasing vehicle fuel efficiency, the electrification of vehicles, a stronger shifting from private passenger vehicles to public transport, and reducing freight activities through further decoupling economic growth and freight activities. In the 2DC, energy demand for domestic road transport is 46% lower in 2050 than in 2016; demand peaks in 2016 at 1 192 Mtoe (84% of transport demand) and gradually decreases to 639 Mtoe (68%) by 2050. Most of this demand reduction comes from light vehicles (which show a decline of 65% against 2016) and light trucks (50%). Freight activities shift away from trucks to rail as the share of rail activities in the 2DC increases to 43% from 27% in the BAU by 2050, reducing energy demand for inter-city freight activities by trucks.

Electrification of domestic road transport is applied to various modes, especially for short-to-medium distance transport such as light cars, light trucks, and 2-/3-wheelers. As a result, electricity demand in domestic transport grows strongly (6.4% CAGR) over the Outlook period, rising from 21 Mtoe in 2016 (1.5% of domestic transport demand) to 175 Mtoe (19%) by 2050. By contrast, gasoline demand shows a 77% decline, from 742 Mtoe in 2016 to 173 Mtoe in 2050 and diesel consumption drops by 46%, from 418 to 225 Mtoe. The 2DC shows the highest EV deployment of the three scenarios, which drives electricity demand in 2050 to be 82% above that in the BAU and 20% above that in the TGT.

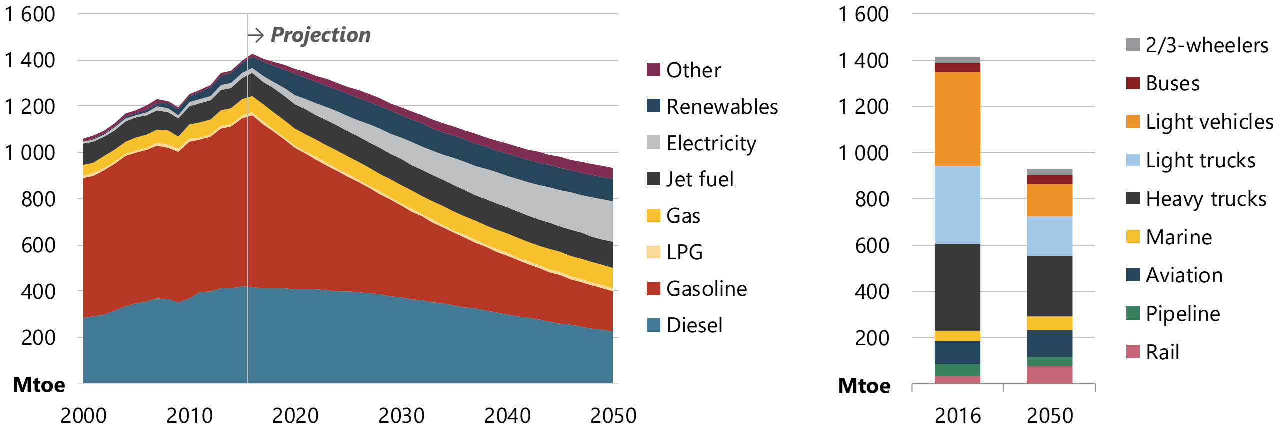
China shows the strongest growth (7.0% CAGR) of electricity demand in transport in the 2DC, growing almost ten times higher than 2016 levels. This growth is driven mainly by electrification of LDVs and LDTs. The stock of battery electric vehicles (BEVs) increases from 811 000 in 2016 to 206 million in 2050. Electricity demand for LDTs increases from essentially zero Mtoe in 2016 to 23 Mtoe in 2050, which is four times the electricity demand for LDVs.

The share of transport activity that shifts from private passenger to public transport (bus and rail) increases significantly in the 2DC, with the greatest change in APEC urban areas. Passenger travel on buses increases from 2.6 trillion passenger kilometres (pkm) in 2016 to 7.9 trillion pkm in 2050, compared to 4.3 pkm in the BAU. Over the same period, passenger rail activity increases from 2.1 trillion pkm to 5.4 trillion pkm, compared to 3.5 pkm in the BAU. The share of bus activity doubles to 23% by 2050 while the share of rail activity increases to 16%. In 2050, China accounts for the largest energy demand for rail transport (42% at 31 Mtoe), followed by the United States (28% at 21 Mtoe) and Russia (12% at 9.1 Mtoe).

In the 2DC, the share of renewable energy in transport doubles due to the significant expansion of biofuels to replace diesel (for rail and light trucks) and fuel oil (for shipping). Advanced biofuels are introduced for jets and provide 3.8% of total fuel mix in domestic aviation in 2050. The United States accounts for the largest share of biofuels in transport at 61% of the APEC total (67 Mtoe) in 2050, followed by south-east Asia (21%), China (10%) and Other Americas (3.5%). Within the United States, domestic freight accounts for 55% of biofuels consumed and passenger vehicles for 45%. South-east Asia shows the highest growth (4.4% CAGR) of biofuels demand, driven mainly by biodiesel demand in Indonesia and bioethanol in Thailand.

The share of advanced transport fuels, such as hydrogen, also increases in the 2DC but at 7.5 Mtoe they represent only 0.62% of transport FED in 2050. In absolute terms, the United States drives hydrogen energy demand in transport to 3.6 Mtoe by 2050, followed by China (2.9 Mtoe) and north-east Asia (1.0 Mtoe). Total APEC hydrogen demand for transport is driven by hydrogen energy demand in LDVs, LDTs and busses. The stocks of hydrogen LDVs in Japan is expected to grow at 35% CAGR to reach 2.8 million by 2050 while the United States accounts for the highest growth in the stock of LDTs that consume hydrogen at 20% CAGR to reach 2.3 million by 2050. The stock of hydrogen LDVs in China is projected to reach 8.5 million by 2050. Box 6.1 presents hydrogen demand projections in the 2DC Scenario and shows that demand from the transport sector accounts from the largest share of hydrogen demand over the Outlook period.

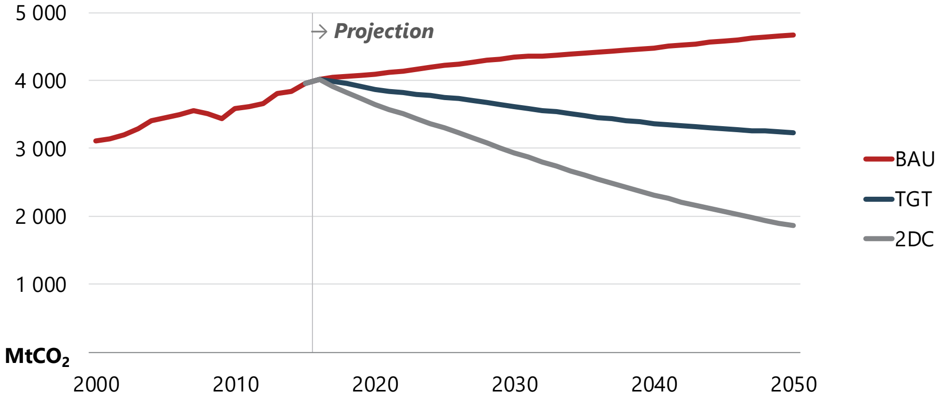
Figure 6.9 • Transport final energy demand in the 2DC Scenario by fuel and mode, 2000-50



Sources: APERC analysis and IEA (2018a).

Total CO_2 emissions from domestic transport decrease substantially in the 2DC; at 1 862 $MtCO_2$, they are 54% lower in 2050 than in 2016, which is 60% below the BAU level and 42% below the TGT level (Figure 6.10). Accelerated decarbonisation of transport may be possible if other cleaner energy sources, such as hydrogen and bioenergy, become economically competitive with existing fuel and transport technologies.

Figure 6.10 • Domestic transport CO_2 emissions in the BAU, TGT and 2DC, 2000-50



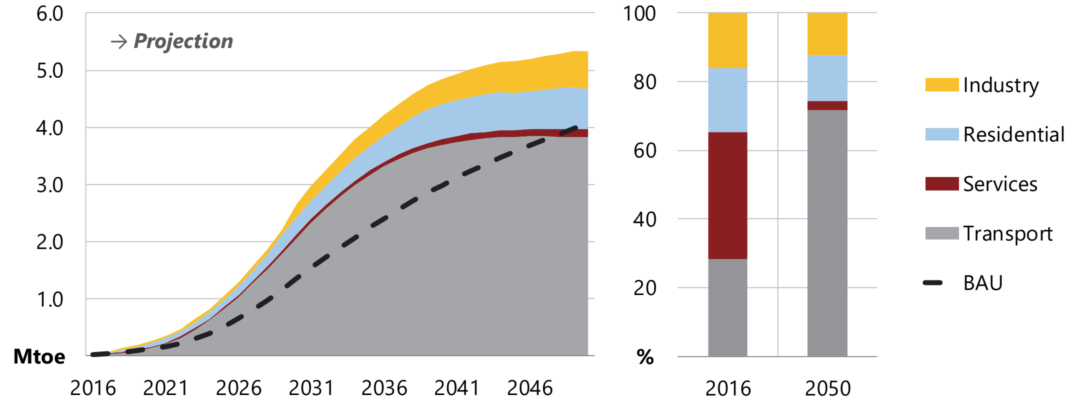
Sources: APERC analysis, IEA (2016a and 2018a), and IPCC (2018).

Box 6.1: Hydrogen demand in the 2DC

In the 2DC, hydrogen demand in transport is expected to grow steadily before stabilising in 2040 and peaking in 2042 (Figure 6.11), as the fuel economy of fuel cell electric vehicles (FCEVs) improves. Subsequently, hydrogen demand declines (-0.34% CAGR) as efficiency gains outpace increases in the vehicle stock.

Demand for hydrogen in residential buildings increases steadily (12% CAGR), from 0.01 Mtoe in 2016 to 0.71 Mtoe in 2050, spurred by the higher uptake of fuel cell batteries. In services buildings, hydrogen replaces 0.07% of electricity demand in 2050, largely due to increased use in data centers.

Figure 6.11 • Hydrogen demand and share in the 2DC, 2016-50



Source: APERC analysis.

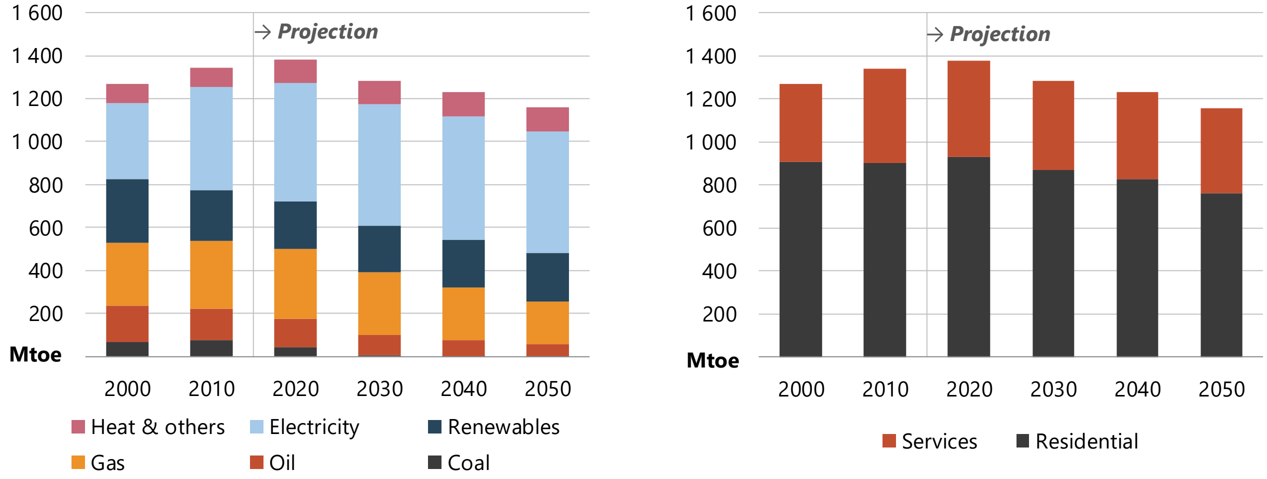
Overall demand for hydrogen in the 2DC is 75% (3.2 Mtoe) higher than in the BAU, with transport dominating the sectoral share; however, the transport share (73%) of overall demand in the 2DC is lower than in the BAU (88%). This reflects more rapid growth in hydrogen use in residential buildings and industry in the 2DC.

In the BAU and TGT, higher hydrogen penetration is assumed in economies with existing programs to foster hydrogen adoption. In the 2DC, its uptake is also seen in economies that do not deploy hydrogen in the BAU (such as New Zealand).

LOW-CARBON TRANSITION IN BUILDINGS: BUILDING CODES AND APPLIANCES

In the 2DC, energy demand for buildings represents 24% of APEC total FED in 2050, a slight decrease from 26% in 2016. Relative to the BAU, energy demand in buildings declines by 36% in the 2DC,) from 1 409 Mtoe in 2016 to 1 158 Mtoe in 2050 (Figure 6.12). This trend is evident in both residential and services buildings. Residential buildings consume 761 Mtoe in 2050, an 18% reduction from 933 Mtoe in 2016; in services buildings, consumption decreases from 475 Mtoe in 2016 to 398 Mtoe in 2050, a 16% reduction.

Figure 6.12 • Buildings final energy demand in the 2DC Scenario by fuel, 2000-50



Sources: APERC analysis and IEA (2018a).

The use of coal and oil declines sharply in buildings in the 2DC. The rate of switching from coal and oil to electricity, gas or heat in the 2DC is higher than that projected in the BAU and TGT scenarios. In residential buildings, coal consumption decreases rapidly at -17% CAGR from 53 Mtoe in 2016 to nearly zero (0.10 Mtoe) by 2050, faster than in the BAU (-5.0% CAGR) and TGT (-7.5% CAGR). In contrast, the share of electricity in residential and services buildings increases from 38% in 2016 to 49% in 2050. Electricity demand increases 5.6% over the Outlook period to 566 Mtoe in 2050.

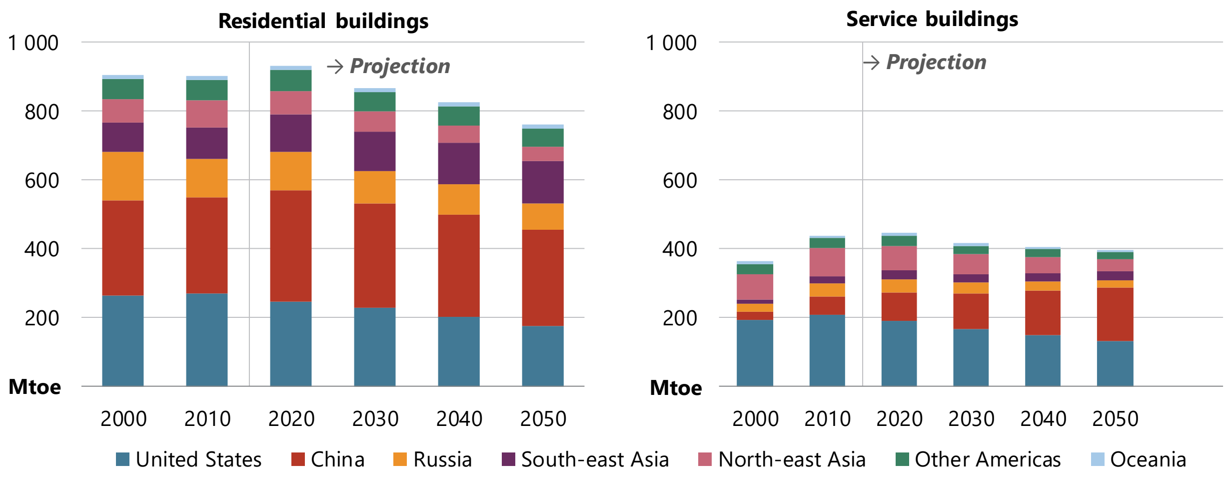
The 2DC scenario assumes that energy demand reductions in residential and services buildings are enabled through the widespread implementation of mandatory building codes for both new builds and retrofits as well as rapid deployment of energy efficient appliances (e.g. space heating and cooling equipment, electric motors, and LED lighting). Demand for heat in buildings increases in both actual energy demand and share, rising from 90 Mtoe (6.4% of total fuel share) in 2016 to 110 Mtoe (9.5%) in 2050. A fundamental fuel shift from fossil fuels to cleaner energy sources occurs in the 2DC, as the combined share of renewables and electricity comes to represent 69% of buildings FED in 2050, at the expense of the share of fossil fuels, which decreases to 22% from 40% in 2016.

Heating and cooling accounts for the highest end-use share, between 58-60%, of total energy demand in residential buildings. In the 2DC, heating and cooling energy demand decreases to 439 Mtoe in 2050 (21% lower than in 2016), in contrast to rising consumption in the BAU (23% higher) and the TGT (1.6% higher). Lower energy consumption for heating and cooling in the 2DC is mainly driven by building envelope improvements for new and retrofitted buildings and the widespread deployment of high-efficiency heating and cooling equipment.

Electricity is the main fuel used in services buildings in 2DC, reaching 245 Mtoe in 2050 (62% of total demand), followed by gas (18%) and renewables (16%). This reflects a fuel switching trend, away from fossil fuels and towards renewables and electricity. Shares of fossil fuels plummet over the Outlook period, with coal falling from 4.7% to just 0.09%, and oil from 12% to 1.9%.

Regionally, APEC buildings FED decreases at the fastest rate in north-east Asia (-1.9% CAGR), followed by Russia (-1.3% CAGR), and the United States (-1.1% CAGR), in contrast to the rising buildings FED in south-east Asia (0.44% CAGR) and China (0.19%). The United States accounts for 32% of the APEC buildings FED in 2016 and decreases to 27% by 2050 while China represents 37% of APEC buildings FED by 2050, an increase from 29% in 2016 (Figure 6.13).

Figure 6.13 • 2DC: Buildings final energy demand by region, 2000-50



Sources: APERC analysis and IEA (2018a).

North-east Asia shows the largest percentages of energy demand reduction over the Outlook period, at 48%, while the United States accounts for the largest buildings energy demand reduction in absolute terms at 148 Mtoe. The percentages of energy demand reduction in buildings in other APEC economies varies from 20% to 35%, except in China where it is 6.6% higher and south-east Asia (16% higher).

In residential buildings, three economies (the United States, China and Russia) accounted for 74% of total demand in 2016. This share shrinks slightly to 70% by 2050. While a general trend of declining demand (-0.60% CAGR) is evident across APEC in the 2DC, south-east Asia's residential energy demand increases 18% over the Outlook period, as substantial floor areas additions (155% higher than in 2016) from a rapid residential buildings boom outweigh efficiency improvements in the region.

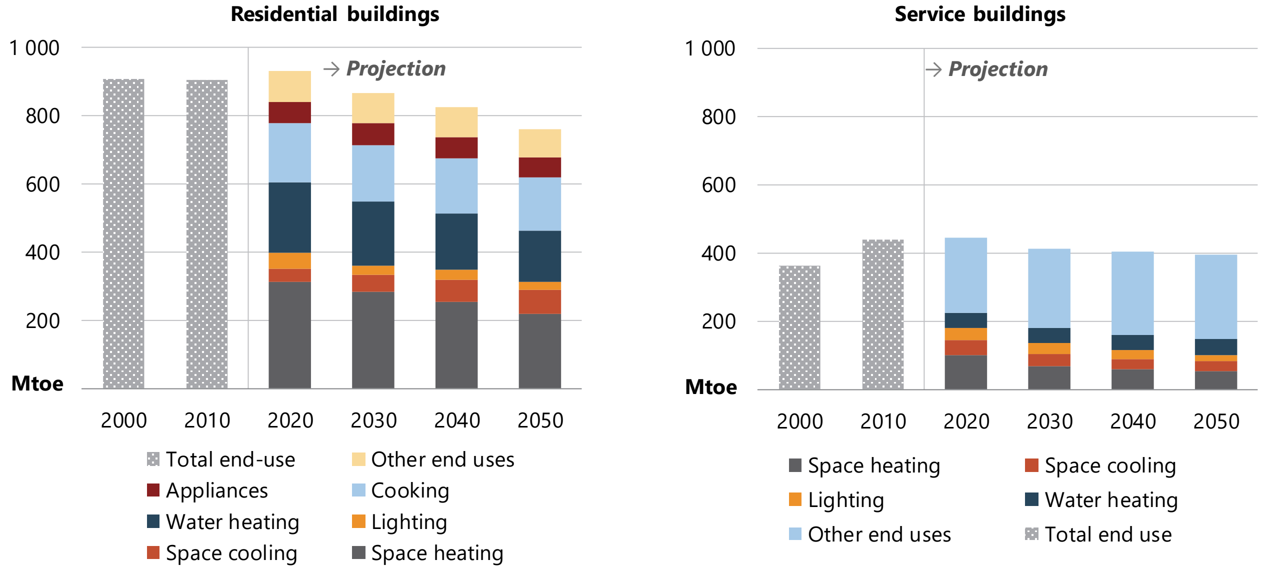
Services energy demand accounted for 34% of total APEC buildings demand in 2016 and this share remains fairly stable throughout the 2DC. Declines in services demand varies across APEC economies, between CAGR of -1.1% to -2.3%, except for China, where FED for services buildings increases at a CAGR of 1.9% and south-east Asia (0.16% CAGR). North-east Asia shows the highest percentage of energy demand reduction from the services buildings (-2.3% CAGR), followed by Russia (-1.8% CAGR) and the United States (-1.3% CAGR). APEC developing economies in south-east Asia show a considerable increase in buildings energy demand, in line with rapid population growth (0.64% CAGR) and rising GDP per capita (3.9% CAGR). In parallel, the buildings stock in the region grows rapidly—1.7% CAGR for a total increase of 75% over 2016—reaching 3 399 million m^2 by 2050.

In the 2DC, near-zero emissions (NZE) buildings are assumed to progressively make up 30% of total floor area in APEC developed economies and 15% in APEC developing economies. Energy demand of NZE buildings is assumed to be 30% of that of non-NZE buildings. Details about key assumptions for energy demand in services buildings are documented in Annex I.

Examining FED by end-use in residential buildings shows decreasing demand for lighting, as it falls steadily (-2.0% CAGR) in the 2DC, from 49 Mtoe (5.2% of total residential demand) in 2016 to 25 Mtoe (3.2%) in 2050 (Figure 6.14). Energy demand for space heating also declines (-1.0% CAGR) although it remains the largest share of end-use, accounting for 315 Mtoe (34% of total demand) in 2016 and 220 Mtoe (29%) in 2050. By contrast, energy consumption for space cooling increases (1.9% CAGR), from 36 Mtoe (3.8% of total demand) in 2016 to 68 Mtoe (8.9%) in 2050.

For services buildings, substantial energy demand reductions are seen across space heating (-2.2% CAGR), lighting (-2.0%) and space cooling (-1.4%) over the Outlook period (Figure 6.14). Space heating consumes 54 Mtoe (14% of total demand) in 2050 in the 2DC, a 53% reduction from 113 Mtoe (24%) in 2016. Energy demand for water heating is relatively constant at around 45 Mtoe, accounting for 12% of total services demand in 2050.

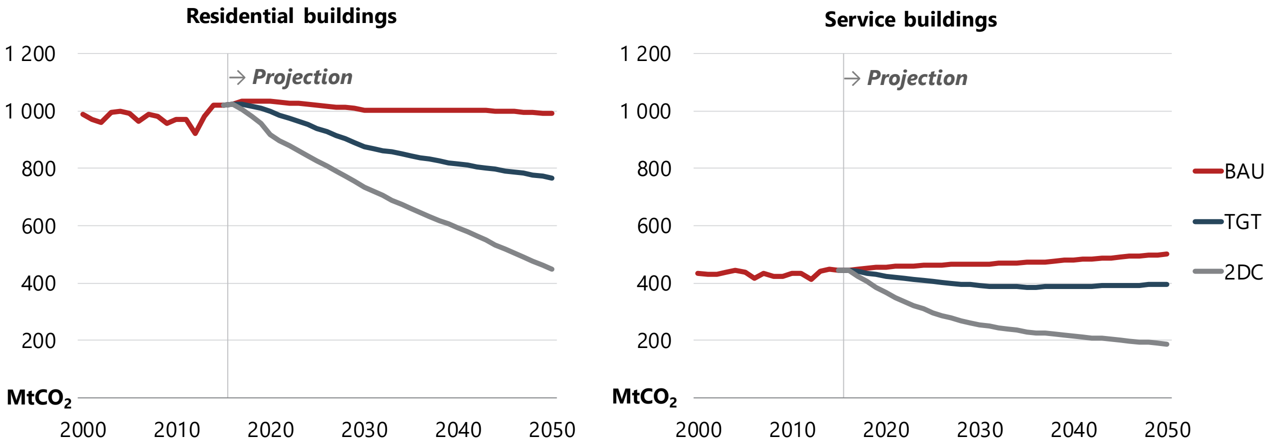
Figure 6.14 • Residential and service buildings FED in the 2DC by end-use, 2000-50



Sources: APERC Analysis and IEA (2018).

The energy transition in buildings in the 2DC delivers a substantial reduction in CO_2 emissions: by 2050, emissions are 58% lower than in the BAU and 46% lower than in the TGT (Figure 6.15). Buildings CO_2 emissions in the 2DC are 637 $MtCO_2$ in 2050; they decline gradually in the early years of Outlook period, with the rate accelerating after 2030 through to 2050 as the effects of mandatory building codes and appliance standards are realised.

Figure 6.15 • Residential and service buildings CO_2 emissions in the BAU, TGT and 2DC, 2000-50



Sources: APERC analysis, IEA (2016a and 2018a), and IPCC (2018).

In the 2DC, residential CO_2 emissions plummet from 1 025 $MtCO_2$ in 2016 to 449 $MtCO_2$ in 2050, a 56% reduction. By 2050, total CO_2 emissions in residential buildings in the 2DC are 55% lower than in the BAU and 41% lower than in the TGT. In services buildings, CO_2 emissions decrease at 2.5% CAGR, faster than the 2.4% CAGR in residential buildings. In absolute terms, CO_2 emissions from services buildings account for 187 $MtCO_2$ in 2050, representing 29% of the total CO_2 emissions from buildings. By 2050, services buildings CO_2 emissions in the 2DC are 58% lower than in 2016, in contrast to the TGT (11% lower) and BAU (12% higher).

OPPORTUNITIES AND CHALLENGES

This chapter examines energy demand and supply trends in APEC to analyse the 2DC, which offers a pathway to a low-carbon energy future. The accelerated deployment of clean technologies and a transition from fossil fuels to renewable energy and other clean energy sources are essential to achieving these goals, which introduces opportunities and challenges in all demand sectors and the electricity system. Concerted efforts are needed across all energy demand and supply sectors to leverage the most cost-efficient approaches to achieving a low-carbon energy sector in APEC.

It should be noted that low-carbon actions in one sector may affect energy demand and CO_2 emissions in other sectors. For example, electrification of transport to reduce CO_2 emissions leads to increases in electricity demand, which then needs to be managed to ensure that additional electricity generation comes from renewable or low-carbon sources. Furthermore, increasing levels of teleworking may push up consumption in residential buildings but lower energy demand in service buildings and transport. Collective actions and cooperation across all energy demand and supply sectors are required to produce economic solutions to achieve a low-carbon emissions target in the 2DC.

INDUSTRY SECTOR

In the 2DC, industry accounts for the highest FED in APEC economies. Even though the sector shows reductions in both demand and CO_2 emissions over the Outlook period, additional opportunities exist to further reduce energy demand and CO_2 emissions by improving efficiency in industrial processes, increasing the use of renewables in the fuel mix, and intensifying research activities for technologies that are not yet commercially viable in order to improve current BATs and deploy CCS technologies.

Improving energy efficiency is a key strategy to reduce energy demand in the petrochemical and chemical subsector. In the 2DC, new production plants deploy BATs and apply production processes that consume 20% less energy than existing plants. Energy demand reductions in iron and steel are mostly achieved through the deployment of electric arc furnaces (EAFs) in both new iron and steel production plants as well as in existing facilities that currently use less-efficient blast furnace-basic oxygen furnaces (BF-BOFs).

New and retrofitted cement production plants include six-stage pre-heaters and pre-calciners in the 2DC, which reduce thermal energy intensity and electricity consumption. Reducing the clinker-to-cement ratio is the most effective strategy to reduce energy consumption and CO_2 emissions in cement production. This requires research on identifying low-carbon materials as clinker substitutes as current substitutes mostly come from the waste of other industry or energy transformation processes (e.g. fly-ash from coal power plants).

TRANSPORT SECTOR

Improving fuel economy standards and electrifying road transport are key to reducing CO_2 emissions in this sector and should be policy priorities in APEC economies in tandem with efforts to decarbonise the electricity sector. Electrification can be applied to various modes of road transport including LDVs, LDTs and 2-/3-wheelers.

Electrification of light vehicles (e.g. cars and 2-/3-wheelers) provides trade opportunities among APEC economies, where two-thirds of the global automotive industry is located. Improving the commercial viability of EVs in relation to conventional gasoline- and/or diesel-based transport modes is vital. The strong growth of BEVs seen in the 2DC may require sustained supplies of lithium-ion batteries, which makes raw material (e.g. nickel and cobalt) supplies for battery production essential for decarbonisation. Cumulative battery production in transport offers more learning opportunities to drive down the price of EVs.

Further development of unconventional transport fuels (e.g. biofuels and hydrogen) for long-distance transport modes can reduce emissions while also providing future trade opportunities in the 2DC (see Chapter 9). The 2DC assumes a significant expansion of biofuels to replace diesel (for rail and light trucks) and fuel oil (for shipping). Hydrogen is also introduced for use in fuel cells in LDVs and LDTs, mainly in China, the United States, and north-east Asia.

Transport energy demand is also reduced through the shift from private passenger to public transport. The share of bus activity doubles in the 2DC while rail activity remains relatively constant. Economies should pursue opportunities to increase investment in public transport, particularly in urban areas.

BUILDINGS SECTOR

Energy savings in buildings in the 2DC are driven by a combination of three trends: a higher adoption rate of energy efficient technologies in residential and services buildings, improvements in building envelopes and fuel switching toward less carbon-intensive fuels. Energy consumption for space heating, water heating and cooking represents 69% of total energy consumption in residential buildings in 2050. Economies should adopt mandatory minimum performance standards for home appliances (e.g. refrigerators, air conditioners and LEDs) in order to lower energy consumption in buildings.

In the 2DC, improvements in building envelopes are accelerated for both new builds and retrofits through mandatory building codes. These codes are progressively applied from the start of the Outlook period and fully deployed in all APEC economies by 2030. In south-east Asia, however, rapid growth in building floor area and increasing demand for space cooling quickly outpace energy saving from improved building envelopes. As a result, buildings energy demand in the region continues to grow in the 2DC. Additional action is needed in APEC to adopt comprehensive building codes to improve energy efficiency.

Energy demand for heating and cooling is consistently the largest share of residential FED over the Outlook period, representing 60% of demand in 2016 and 58% in 2050. Policies that support fuel switching from fossil fuels to renewables and electricity can reduce CO_2 emissions from energy consumption for space heating and cooling. Parallel incentives to support the direct use of modern renewables (e.g. solar thermal, geothermal and biomass), phase-out coal, and reduce oil and gas consumption for heating can drive down emissions. Policy support for the deployment of high-efficient cooling appliances through mandatory labelling and minimum energy performance standards can reduce energy demand for space cooling, especially in south-east Asia and China, which are projected to have the highest growth of energy demand in space cooling in APEC.

ELECTRICITY SECTOR

Decarbonisation of the electricity sector is essential to achieve the emission reduction goals of the 2DC. This requires more rapid deployment of renewable power plant technologies and additional action to ensure reliable electricity grid operations given large-scale VRE generation. It also means finding cost-effective solutions for battery storage technologies, smart grid systems, and transmission network reinforcement (including ultra-high voltage alternating current and direct current transmission networks). Cross-border electricity grid interconnections are projected to improve electricity system stability and support increasing levels of VREs. A contractual power purchasing model for cross-border electricity trade can facilitate private power generation in regional electricity trade integration.

Opportunities also exist to make biofuels more commercially viable, particularly through more aggressive action to improve technology for larger capacity additions of biomass-fired power plants with carbon capture, which are an important source of negative CO_2 emissions in the 2DC. Further expansion of biomass-fired power plants may be constrained by the adequacy of biomass stocks to meet the sustained fuel needs of power plants. Accordingly, it is important to find sustainable sources of biomass feedstock for power plants without increasing CO_2 emissions from land-use change or from converting forests into biomass plantations.

CARBON CAPTURE AND STORAGE (CCS)

Additional effort is also required to ensure that CCS technologies are commercially viable as soon as possible. Research on commercial business models and infrastructure financing is needed to encourage private sector investment in carbon capture utilisation and storage (CCUS), such as public-private partnership schemes for CCS for enhanced oil recovery (CCS-EOR) (Atmo, Otsuki, & Kendell, 2018). Deployment of industrial CCS and its integration into industrial processes is necessary but effort is also needed to develop CO_2 transport and storage infrastructure. Identifying available CO_2 storage locations and obtaining support from local communities and government authorities for storage utilisation, will also support the successful deployment of CCUS.

7. ENERGY INVESTMENT

KEY FINDINGS

- **Energy capital investments over the Outlook period in APEC reach USD 48 trillion in the BAU Scenario, USD 55 trillion (14.6%) in the TGT Scenario and USD 60 trillion (26%) in the 2DC Scenario.**

- **Higher capital investments in the TGT and 2DC are partially offset by fuel savings as a result of lower energy demand.** Cumulative fuel savings increase in the TGT (18%) have a value of USD 10 trillion; savings increase in the 2DC (26%) to USD 16 trillion.

- **Demand-side capital investments increase from USD 14 trillion (29% of total capital investment) in the BAU to USD 22 trillion (40%) in the TGT and USD 26 trillion (42%) in the 2DC**. Increases stem from significant additional investment in buildings, particularly in the United States. Across APEC, the increase is partially offset by declining transport investments, mostly in China and the United States.

- **Transformation capital investments are USD 16.3 trillion (34% of total investment) in the BAU. They decrease slightly to USD 16.1 trillion (29%) in the TGT, but increase to USD 18.3 trillion (30%) in the 2DC.** In the short term, all three scenarios require significant new electricity capacity; any decision in the short term to meet demand growth with new fossil fuel capacity could lead to stranded assets in the 2DC.

- **Supply capital investments are USD 18 trillion (37%) in the BAU. They decrease to USD 17 trillion (31%) in the TGT and USD 17 trillion (27%) in the 2DC.** As energy demand decreases across the three scenarios, less new infrastructure (upstream, downstream and energy transport) is needed.

INTRODUCTION

Access to adequate, sustainable and affordable energy resources is an essential element of economic prosperity, socio-economic well-being and geopolitical stability. The Asia-Pacific Economic Cooperation (APEC) region is home to almost 60% of global gross domestic product (GDP) and includes four of the world's largest energy users—China, the United States, Russia and Japan (APEC, 2018; World Bank, 2018). Within this context, and considering the imperative to meet growing energy demand across APEC economies, *the Outlook 7th Edition* assesses investment requirements for supply-side energy infrastructure and demand-side energy efficiency across three scenarios: the Business-as-Usual (BAU) Scenario, the APEC Target (TGT) Scenario and the Two-Degrees Celsius (2DC) Scenario.

Supply-side investments reflect those made expressly to deliver energy demanded by consumers, i.e. for transformation (e.g. power plants, refineries) and supply (e.g. oil production). Carrying forward the analysis in the *Outlook 6th Edition*, such investments are once again included in their entirety. The *7th Edition* expands the definition of energy investment, where data are available, to include the additional capital necessary to meet the energy demand levels in each of the three scenarios.

Demand-side capital investments reflect capital spending that results in energy consumption although the investment is made to serve another primary purpose. Examples might include construction of a building for office space or the purchase of a vehicle for transportation. Demand-side projections in this analysis include only the additional investment requirement, defined as the increase (or decrease) in cost necessary to achieve higher energy efficiency, which usually reduce energy costs, thereby off-setting part of the initial investment. The alternative scenario modelling also accounts for business decisions or lifestyle changes that alter the type or level of end-service demanded (e.g. opting for public transport or using less commercial office space) in a way that reduces the required energy investment.

This chapter first investigates future investment in energy systems under the BAU Scenario, which extends recent trends into the future. The TGT and 2DC Scenarios chart alternative paths with the specific goals of reducing energy intensity, boosting the shares of renewables in APEC energy systems, and reducing energy-related carbon dioxide (CO_2) emissions to constrain global average temperature increase to below 2°C. The value of modelling scenarios is that it demonstrates how, by setting policy and regulations in the near future, APEC economies commit to particular future trajectories. The BAU serves the important purpose of setting a baseline against which to compare the alternative scenarios, including the magnitude of additional capital investment they represent. As energy efficiency improves in the alternative scenarios relative to the BAU, the *7th Edition* also includes projections of the cumulative value of future savings on input fuel costs (noted hereafter as 'fuel cost savings'). These projections represent gains acquired as a result of higher up-front capital spending; thus, they are essential to evaluating both the costs and benefits associated with transitioning to a lower-carbon energy future.

INVESTMENT BOUNDARIES AND METHODOLOGY

To complement the exercise of quantifying the capital cost of supply-side energy investments, the 7th Edition modelling quantifies demand-side energy investments needed to achieve higher energy efficiency and thereby curb the overall growth of energy demand. In each scenario, potential savings arise from lower input fuel costs as well as behavioural change that reduces demand for a given service and the energy required to provide that service.

Demand-side energy investments are quantified in relation to a baseline of the technology mix in place in 2016. Maintaining this technology mix, the three scenarios assess only the additional energy investment required to achieve energy reductions. In each scenario, fuel costs are calculated by multiplying demand for each fuel by the price for each fuel. Fuel costs in transformation and primary energy supply are based solely on own-use in these sectors. Overall fuel cost savings are allocated to the demand sectors in each scenario, rather than to the transformation or supply sectors. Prices for heat and electricity are calculated based on the weighted share of coal, oil, gas and bioenergy used to produce the heat or electricity multiplied by the price of each fuel. More details on these methodologies and assumptions are found in Annex I.

Demand-side energy investments vary widely by sector, with each subsector depending on different types of energy inputs. In the buildings sector, energy uses include spending on building envelopes, cooking, space heating and cooling, lighting, and water heating. In the residential subsector, cooking accounts for a large share of demand; in the services subsector, other appliances, equipment and motors are also considered. In the industry sector, projections include activities specific to various subsectors as follows: aluminium, cement, iron and steel, and pulp and paper. Domestic transport investments include rail locomotive, powertrains for light vehicles (LV) and light trucks (LT), refuelling stations for conventional (gasoline, diesel, liquid biofuels, compressed natural gas) and advanced fuels (electric, hydrogen).

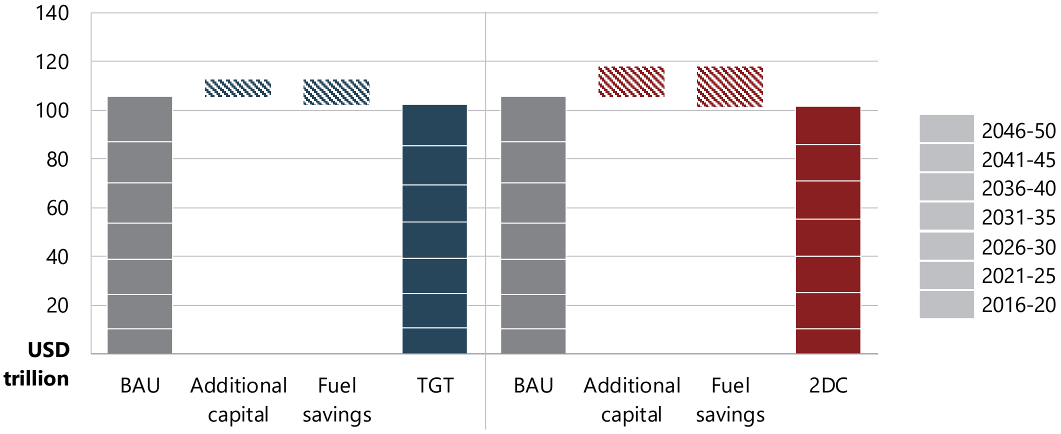
Energy transformation investments include power plants, combined heat and power plants, transmission and distribution upgrades and extensions, electricity storage, district heating and cooling plants, and oil refineries and biorefineries. Supply-side energy investment includes upstream production and downstream activity including LNG liquefaction and regasification terminals and gas pipelines.

All projections and figures are presented in 2016 USD purchasing power parity (PPP) unless otherwise indicated. For a more detailed description of the investment boundaries, please refer to the Investment Methodology section in Annex I.

OVERALL INVESTMENT RESULTS

The APEC region accounted for almost 55% of global energy demand in 2016. Projected economic growth over the Outlook period implies rapidly rising energy demand, which would require substantial investment in additional energy production and delivery infrastructure (IEA, 2018b). In the BAU Scenario, after allowing for more energy efficient technologies, APEC final energy demand (FED) rises at a compound annual growth rate (CAGR) of 0.57% from 5 406 Mtoe in 2016 to 6 562 Mtoe in 2050. Under the BAU, this growth creates a total capital investment requirement of USD 48 trillion over the Outlook period, approximately USD 1.5 trillion annually. In addition to capital for energy infrastructure and more energy efficient technologies, the BAU implies accumulated fuel costs of USD 58 trillion from 2017-50. Thus, overall investment in the BAU reaches USD 105 trillion (Figure 7.1).

Figure 7.1 • Capital investment and fuel cost savings in APEC, BAU vs TGT and 2DC, 2017-50



Source: APERC analysis.

An additional USD 7.0 trillion of up-front capital investment is required in the Target Scenario, increasing the total to USD 55 trillion (14.6% above the BAU). This capital investment is offset by the value of fuel savings realised through reduced energy demanded, which reduces total fuel costs by USD 10 trillion (-18% from the BAU). The capital investment required in the TGT is an average of USD 1.7 trillion annually 2017-50; fuel costs add an average of USD 1.4 trillion. Taking into account the fuel savings between the BAU and TGT Scenarios, overall energy outlays (investments plus fuel costs) in the TGT are USD 102 trillion, 3.0% lower than in the BAU.

The 2DC requires the highest capital investment: USD 60 trillion. This is USD 12.4 trillion (26%) above the BAU (Table 7.1). Again, this additional capital investment is offset by the value of fuel savings from reduced energy demand in the 2DC, which amounts to USD 16 trillion from 2017-50 (-28% from the BAU). The capital investment required in the 2DC averages at USD 1.8 trillion annually from 2017-50 while fuel costs add an average of USD 1.3 trillion annually. After accounting for fuel savings, overall energy outlays in the 2DC are USD 102 trillion (3.7% lower than in the BAU).

Table 7.1 • Capital investment and fuel costs in BAU, TGT, 2DC by sector, 2017-50 (USD trillion)

Sector	BAU		TGT		2DC	
	Capital	Fuel Costs	Capital	Fuel Costs	Capital	Fuel Costs
Demand	13 628	49 201	21 508	39 130	25 460	32 253
Buildings	8 378	15 281	15 747	11 097	19 088	9 246
Transport	5 286	28 537	5 951	23 264	6 530	17 649
Industry	- 36	5 383	- 190	5 133	- 158	5 471
Transformation	16 315	5 144	16 153	5 250	18 282	5 934
Electricity & Heat	15 492	2 365	15 543	2 443	17 853	2 582
Refinery	823	2 779	610	2 807	430	2 807
Supply	17 966	3 262	17 249	3 071	16 566	3 104
Total	**47 910**	**57 607**	**54 910**	**47 451**	**60 309**	**41 291**

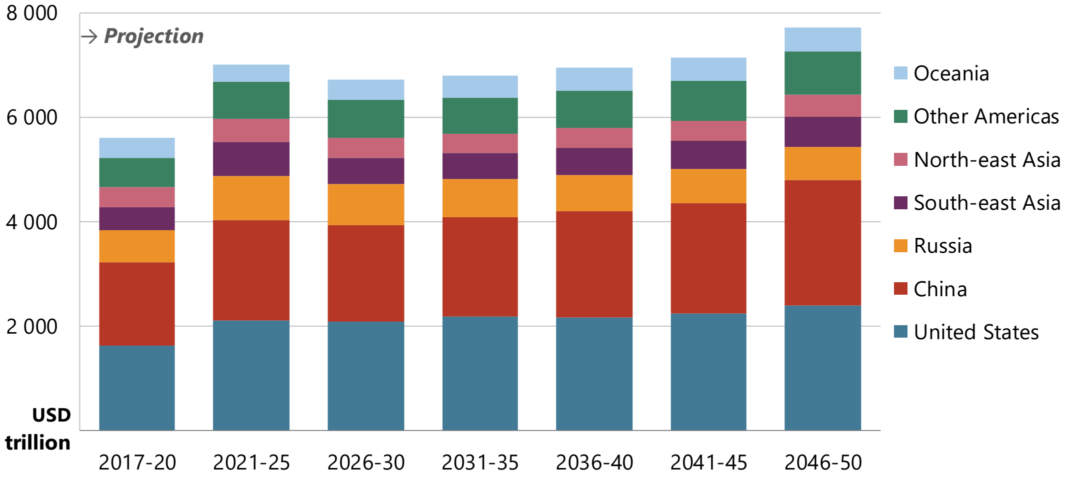
Note: Demand-side energy investment requirements are quantified relative to a 2016 baseline; negative investment requirements represent a decrease relative to this 2016 baseline. Fuel costs in transformation and supply are for energy industry own-use.
Sources: APERC analysis and IEA (2018a).

BUSINESS-AS-USUAL SCENARIO RESULTS

Under the BAU, capital investment in supply accounts for the largest portion (37%) of total capital investment, at USD 18 trillion over the Outlook period (Figure 7.2). Energy transformation capital investment is slightly lower at USD 16 trillion (34%), while demand side accounts for the remaining USD 14 trillion (29%). In the short term, more capital spending is directed towards transformation (electricity and heat, and refineries) while investment in demand-side energy efficiency (buildings, transport and industry) and supply infrastructure occurs towards the latter portion of the Outlook period (Figure 7.3).

Regionally, in the BAU, 60% of total capital investment requirements are in China (29%) and the United States (31%). China's investment requirements total USD 14 trillion, with 44% in electricity and heat, 21% in the supply sector, 18% in buildings, 16% in transport and the remainder in industry and refineries. As the demand for transportation services increases, China requires significant transport investments in LDVs and to continue expanding conventional refuelling infrastructure. Capital investment requirements in the United States total USD 15 trillion, with supply investments accounting for the largest share (42%), led by investment in upstream oil production (USD 6.2 trillion).

Figure 7.2 • Total capital investment in the BAU by region, 2017-50



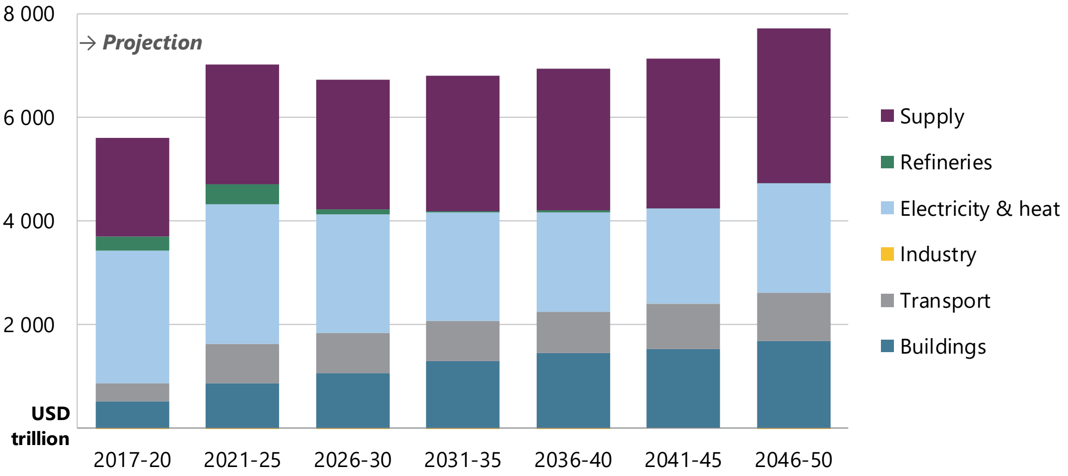
Source: APERC analysis.

Other Americas account for 10% of total APEC capital investment requirements, driven by supply investment in upstream oil and gas production in Mexico (USD 1.3 trillion) and Canada (USD 1.2 trillion). The supply sector accounts for 54% of total investment requirements in other Americas, followed by electricity and heat at 27%, buildings (10%) and transport at 8%. Russia requires capital investments of USD 5.0 trillion, also led by electricity and heat (46%), followed by supply (43%) and buildings (4%).

Over the Outlook period, south-east Asia requires 8% of total APEC capital energy investments, or USD 3.7 trillion. Supply investment accounts for 35% of the total, led by Indonesia at USD 0.545 trillion, of which USD 0.27 trillion is directed towards new gas infrastructure. Soaring electricity demand, resulting from increased access and higher electrification, drives investments in electricity and heat in south-east Asia (26% of total capital investments), as capacity expansion includes 157 gigawatts (GW) of new coal, 68 GW of new gas and 150 GW of new renewables. Indonesia shows the greatest need in this region, requiring USD 0.47 trillion to build 213 GW of electricity capacity from 2017-50.

Oceania's total capital investment requirements reach USD 2.8 trillion (79% in supply), led by Australia at USD 2.2 trillion. North-east Asia accounts for the share at 6% or USD 2.7 trillion, driven primarily by electricity and heat (37%) buildings (25%), and transport (22%). Other than the top three economies (China, the United States and Russia), the next largest projections for overall capital spending are in Australia (USD 2.7 trillion), Canada (USD 2.6 trillion), Mexico (USD 1.9 trillion) and Japan (USD 1.6 trillion).

Figure 7.3 • Total capital investment in the BAU by sector, 2017-50



Source: APERC analysis.

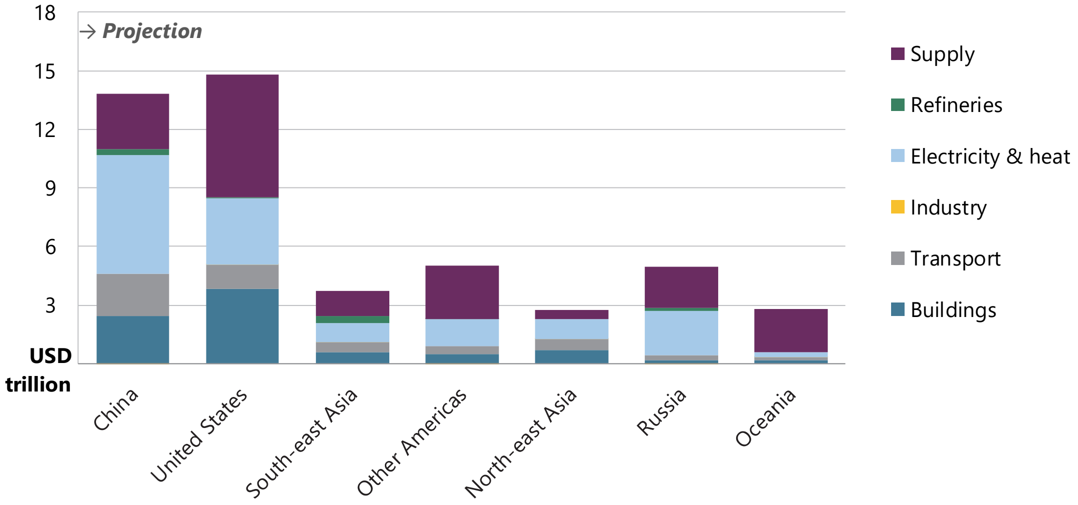
INCREASING MOBILITY DRIVES DEMAND-SIDE ENERGY INVESTMENT

Capital investment requirements in domestic transport in the BAU are directed primarily to LDV drivetrains and refuelling infrastructure for conventional fuels (gasoline, diesel and biofuels). Large transport investment increases are mainly seen in China, where LDVs represent the majority of total investment and significant growth in alternative vehicles is projected. Over the Outlook period, 11% of total capital investment (USD 5.3 trillion) is for transport, of which USD 2.2 trillion is in China (Figure 7.4). In APEC more generally, conventional refuelling infrastructure is necessary to support continued growth in transport energy demand.

Buildings investment requirements in APEC reach USD 8.4 trillion in the BAU over the Outlook period, with the large majority in the United States (USD 3.8 trillion), followed by China (USD 2.4 trillion) and north-east Asia (USD 0.67 trillion). Increased spending to improve building envelopes drives the largest portion of buildings investment. In economies such as the United States, where improved building codes have already raised efficiency for new builds, expensive retrofits of existing stock are the next efficiency challenge. China's large capital investment requirement in the sector reflects high demand for new commercial buildings (which are built to higher code standards) and more stringent standards for residential buildings.

Industry capital investment requirements in the BAU decrease to USD 0.034 trillion, largely because economic incentives already exist to minimise production costs through use of use BATs. While the most of the required investment is south-east Asia (0.0051 trillion) followed by the United States (USD 0.0025 trillion) and north-east Asia (0.0012 trillion). The biggest drop is in China by USD 0.037 trillion.

Figure 7.4 • Total capital investment in the BAU by region and sector, 2017-50



Source: APERC analysis.

TRANSFORMATION AND SUPPLY-SIDE INFRASTRUCTURE REQUIREMENTS REMAIN SIGNIFICANT

Capital investment in this part includes transformation and supply, the dedicated energy infrastructure necessary to deliver energy to consumers. In the BAU, electricity and heat requires USD 15 trillion (32%) of total APEC energy capital investment requirements, with China requiring the most capital investment (USD 6.1 trillion or 39%) followed by the United States (USD 3.4 trillion or 22%).

Refineries (including oil refineries and biorefineries) capital investment requirements reach USD 0.82 trillion in the BAU. South-east Asia reaches USD 0.33 trillion, followed by China at 0.30 trillion. Russia is third at 0.15 trillion. Supply capital investment requirements total USD 18 trillion over the Outlook period, driven by APEC's major energy producers: the United States (USD 6.3 trillion), China (USD 2.8 trillion), Australia (USD 2.2 trillion), Russia (USD 2.1 trillion), Mexico (USD 1.3 trillion) and Canada (USD 1.2 trillion). This Outlook's investment requirements assume that capital is deployed efficiently, and as such is generally allocated to lower cost supply economies prior to higher-cost economies. Box 7.1 illustrates that this assumption can be challenged in practice by the presence of cost inflation inherent to economic booms; it does this through an examination of Australia's LNG export expansion and prescribes ways to limit the capital inefficiencies of cost inflation in the future.

Box 7.1 • What can be learned from Australia's LNG boom

INTRODUCTION

Australia first developed LNG for export in 1989 and attracted enough investment in the 2010s to propel it to be the world's second largest LNG exporter by 2016 (IEA, 2018a). This ascent, however, has been turbulent: export projects incurred vast cost escalations and the ramp-up of LNG exports created gas shortages and higher domestic prices in eastern Australia. This case study draws on Australian experience to prescribe how to avoid similar pitfalls when developing an LNG export industry.

COST OVERRUNS AND GAS SHORTAGES CAST A SHADOW ON AUSTRALIAN LNG BOOM

Six of the highest cost LNG projects ever built are located in Australia (OIES, 2014). All of these projects suffered from cost overruns. Labour costs surged because of Australia's low labour productivity (OECD, 2018a) and the above-average wages of Australian skilled workers, which is symptomatic of its tight labour market, where unemployment is consistently in bottom third in the OECD (OECD, 2018b). To circumvent high labour costs, equipment suppliers were contracted to build modules abroad; this instead increased total costs as they were not specialised in modular fabrication. The remote location of projects and an absence of infrastructure to efficiently house and transport both labour and materials increased project complexity and costs (OIES, 2018).

Costs escalated further because of a lack of industrial coordination. At one-point Australia was building seven LNG facilities. This increased labour competition, exacerbating the inherent cost disadvantages of a tight market. Competition across facilities also yielded duplicative infrastructure, particularly in the east, where three projects expanded their scope to include competing gathering pipeline networks to neighbouring gas fields, upping the total cost of their projects (OIES, 2014).

When eastern Australian LNG exports began in 2016, it became apparent that the coal seam gas (CSG) fields that were to fulfil the LNG contracts were less productive than expected (IEEFA, 2017). Purchases were made from third-parties to meet the shortfall, reducing eastern gas supply, and forcing domestic users to pay higher prices (OIES, 2018). Government has since introduced a security mechanism to divert gas from LNG facilities in the event of a forecasted shortage (Australian Government, 2018) and, is considering limited forms of gas reservation policy. While prices have stabilised, they are not expected to dip below LNG export parity, resulting in a number of companies proposing LNG import terminals to boost supply in the eastern market. This all resulted from Australia's regulatory process, which approves LNG export facilities prior to establishing proof of sufficient gas resources to supply both exports and the domestic market.

GOVERNMENT HAS A ROLE TO PLAY IN GUIDING LNG DEVELOPMENT

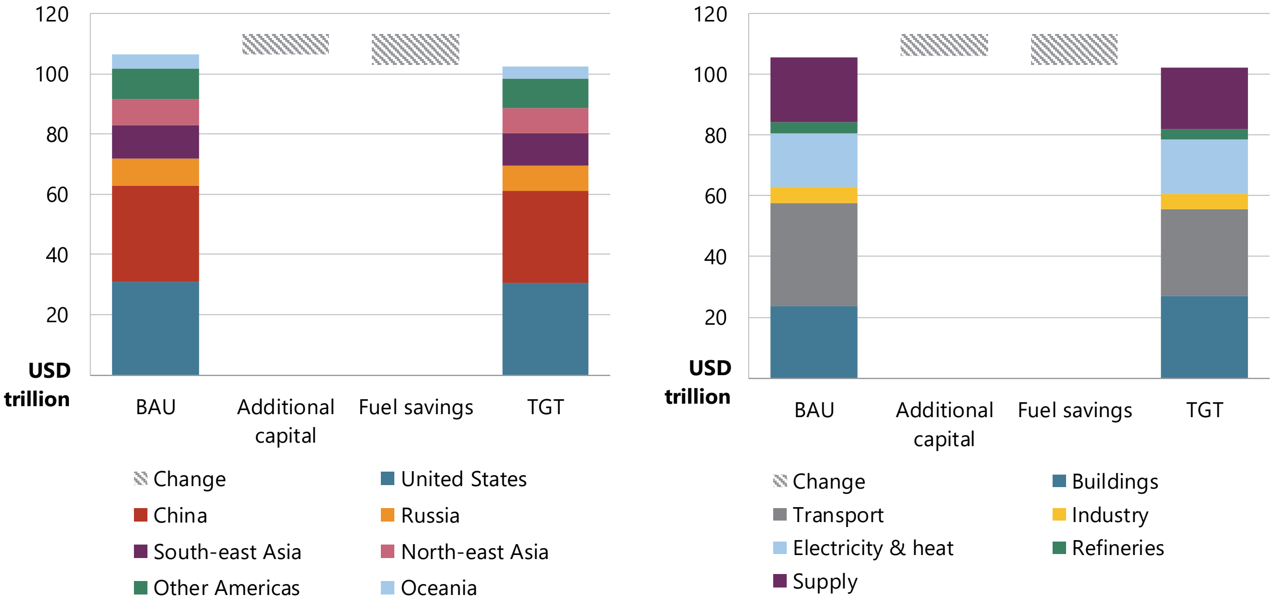
Australia's experience can be used to improve the integration of LNG export projects in prospective economies. To minimise complexity, industry should favour expansions of existing facilities or consider building in less remote, more industrialised areas, where feasible. If competition creates duplicative energy infrastructure, governments should intervene to minimise the total costs to industry. Government should also work to foster an environment of collaboration across industry to ensure that the cost of sparse capital and labour inputs are not inflated in boom periods; scheduling could mitigate the cost inflation inherent to construction races. Industry should also consider locating projects in areas where labour markets are less prone to tightness.

Regulations are needed to prevent the disruption of domestic markets by LNG exports. Facility approval must be conditional on the proof of sufficient gas resources to fulfil both export contracts and the needs of domestic users. Such policies exist in other gas exporting economies, like United States (DOE, 2018) and Canada (NEB, 2016). Removing moratoriums have been shown to increase gas supply (Deloitte, 2016) but does not preclude the necessity of this surplus test.

TARGET SCENARIO INVESTMENT RESULTS

In the TGT Scenario, an additional USD 7.0 trillion is required for up-front energy capital investment, increasing the total to USD 55 trillion (15% above the BAU) over the Outlook period. Capital requirements in China rise by USD 2.8 trillion comparing to the BAU. The United States capital investment requirement increases by USD 2.7 trillion relative to the BAU, while that of north-east Asia increases by USD 0.93 trillion. Ultimately, fuel savings delivered by the TGT in APEC offset these regional requirements by 45% (Figures 7.5 and 7.6).

Figure 7.5 • Capital investment and fuel cost savings by region and sector, BAU vs TGT, 2017-50



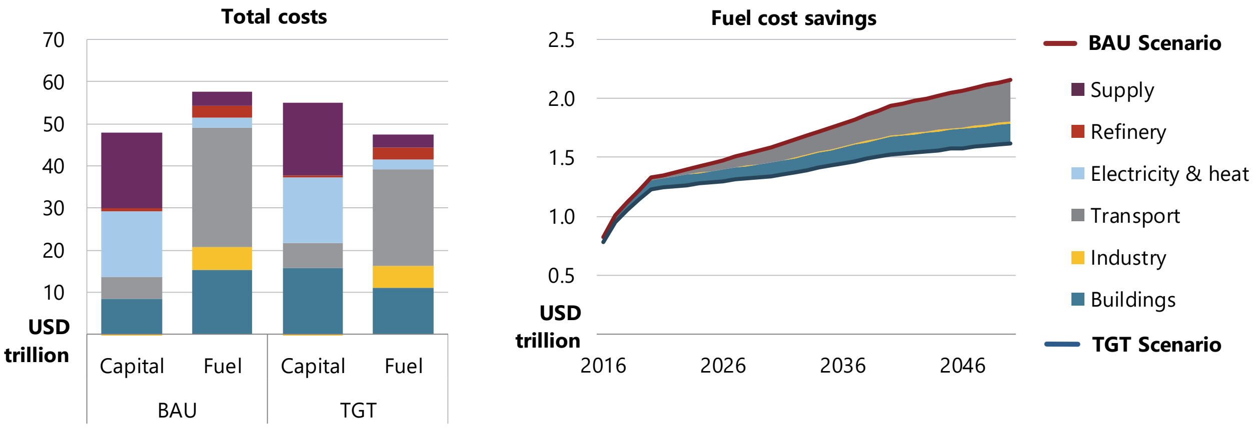
Source: APERC analysis.

Higher capital investment requirements in the TGT occur almost entirely within the building sector (USD 16 trillion) at USD 7.4 trillion more than in the BAU. Growth in capital requirements for buildings comes primarily from the United States at USD 2.8 trillion and China at USD 2.2 trillion followed by north-east Asia (USD 0.74 trillion), south-east Asia (USD 0.74 trillion) and other Americas (USD 0.43 trillion). In the electricity and heat sector (USD 16 trillion), capital investment requirement in the TGT is 0.46 trillion higher than the BAU. The growth is mainly from China (USD 0.35 trillion) and north-east Asia (USD 0.19 trillion).

The transport sector (USD 6.0 trillion) which explains 11% of capital investment requirements in the TGT, increases by 0.67 trillion more than the BAU. Capital requirements for China reach USD 2.8 trillion followed by the United States (USD 1.2 trillion) and north-east Asia (USD 0.65 trillion). In the supply sector, capital investments decrease from 17.9 trillion in the BAU to 17.2 trillion in the TGT. Capital investment requirements in supply increase only for five APEC economies: Brunei Darussalam, Chinese Taipei, Malaysia, Papua New Guinea and Peru.

Most regions show declines in capital requirements for refineries, with the most significant drop in China (USD 0.25 trillion) followed by Russia (USD 0.031 trillion). Capital investment requirements in refineries increase only for three APEC economies: the United States (USD 0.020 trillion), Indonesia (USD 0.055 trillion) and Peru (USD 0.004 trillion). Industry capital requirements decline almost across the board as less costly, more efficient technologies are deployed more widely. Industry investment requirements grow only in Peru and New Zealand.

Figure 7.6 • Total investment and fuel cost savings by sector in the BAU vs TGT, 2017-50



Source: APERC analysis.

Fuel costs in the TGT reach USD 47.5 trillion over the Outlook period, which is USD 10.2 trillion lower than BAU. More than 36% of fuel savings accumulate in China (USD 3.6 trillion) and the United States (29%, USD 3.0 trillion), followed by south-east Asia (9.8%, 1.0 trillion), Other Americas (9.4%, USD 0.96 trillion), north-east Asia (9.4%, USD 0.95 trillion), Oceania (3.3%, 0.33 trillion) and Russia (3.0%, 0.30 trillion).

Box 7.2 • Renewable energy investments in Chile's deregulated electricity market

INCREASING RENEWABLE DEPLOYMENT

Chile's renewable energy target, adopted in 2008 by Law 20 257, was initially a short-term goal stating that between 2010 and 2014, 5% of electricity energy should come from unconventional renewable energy (URE), after which annual increases of 0.50% would boost the share to 10% by 2024. In 2013, Law 20 698 increased the target share to 20% by 2025.

Globally, Chile has become a hotbed for renewable investments. In 2015, Chile ranked third among the world's top markets for energy investments, with 13 out of its 18 projects being renewables (World Bank, 2015a). In October 2017, Chile ranked eighth in the EY Renewable Energy Country Attractiveness Index, a substantial improvement from its 34th position in 2011 (EY, 2017). In November 2018, Chile was ranked first in the Climate Scope 2018 developed by Bloomberg. Chile fared well on all three main topic areas that the Climate Scope surveyed (BNEF, 2018).

POLICY MEASURES

A strong institutional framework and supportive policies underpinned recent achievements in Chile's renewable energy market. The government established numerous policies to demonstrate a firm commitment in steering the economy towards clean energy. The latest long-term energy policy, Energy 2050, stipulates targets for at least 60% of electricity from renewables by 2035 and 70% by 2050. To date, Chile has adopted a wide range of policy measures to support the entrance and uptake of renewables, with five in particular providing a strong foundation.

Hourly supply blocks in power tenders. In addition to allowing renewables to compete in power tenders, Chile modified its tender mechanism in 2014 to include hourly blocks of energy supply (in parallel to traditional 24-hour blocks). This boosted the competitiveness of intermittent renewables against baseload generation. Since 2012, the average winning price of electricity tenders has dropped by 76% (Empresas Eléctricas A.G., 2018).

Small-scale renewable developers (i.e. installed capacity less than 9 MW). Under the General Law of Electric Services (*Ley General de Servicios Eléctricos*), small-scale renewables developers have the option to sell electricity at pre-fixed nodal prices or prevailing spot prices. They can also request automatic connection to the grid to avoid curtailment of their plants and are entitled to partial or total exemption from transmission charges.

Utility obligation quotas for NCRE shares. Utility companies are obligated to demonstrate that a minimum percentage of the electricity sold was generated from URE sources. In 2013, Law 20 698 increased the minimum percentage to 20% by 2025. Non-compliant companies face a financial penalty equivalent to approximately USD 32 per MWh of URE deficit for the first three years, which rises thereafter.

Net metering for income generation. Starting in October 2014, owners of renewable energy and cogeneration systems (up to 100 kilowatts [kW]) became eligible for a net metering scheme, under which they are compensated for surplus electricity sold to the grid.

Carbon tax to boost competitiveness. Effective from 2017, Chile began imposing a carbon tax of USD 5.00 per tonne of carbon dioxide (tCO_2) emissions from thermal power plants of at least 50 megawatts (MW), excluding biomass. This further enhanced the price-competitiveness of renewables against traditional fossil fuels.

UNTAPPED RENEWABLE POTENTIAL

Since 2007, Chile has adopted several policies that demonstrate a firm commitment to shift to a more renewable energy mix. With the implementation of hourly supply blocks in power tenders, the average price per megawatt-hour has decreased 32% compared to 2016 tenders (Empresas Eléctricas A.G., 2018).

Together with policies and energy targets, the low investment cost of URE projects has help to stimulate investment in this area. Vast untapped potential for solar (both PV and concentrated solar power [CSP]), onshore wind, geothermal and small-scale hydro—estimated at 1 384 GW, one of the best in the world—makes Chile unique for the deployment of URE projects. The International Energy Agency highlights that the Atacama Desert in the north has a direct normal irradiance of more than 9 kilowatt-hours (kWh) per square metre (m2) per day, the highest in the world. In its extreme south, Chile (together with Argentina) has the world's best onshore wind resources (IEA, 2018a).

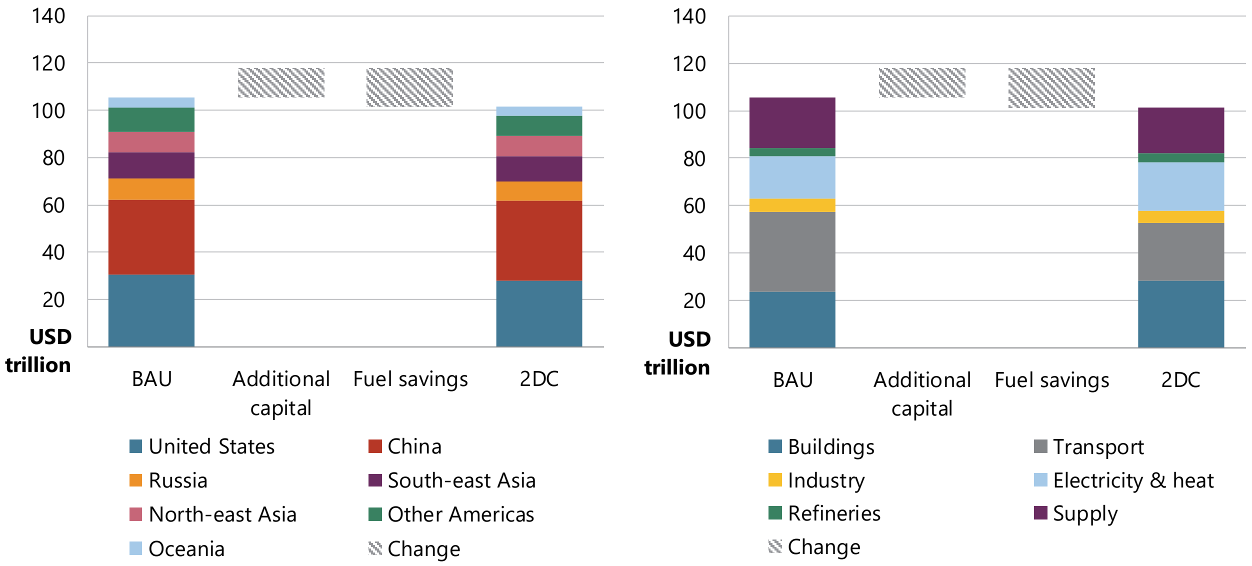
TWO-DEGREES CELSIUS SCENARIO INVESTMENT RESULTS

Of the three scenarios, the 2DC requires the highest capital investment, projected at USD 60 trillion over the Outlook period, an increase of USD 12.4 trillion (26%) over the BAU (Figure 7.7). The 2DC increase, as in the TGT, is primarily in China (USD 6.6 trillion), with the second-largest increase in the United States (USD 2.6 trillion), north-east Asia (USD 2.3 trillion) followed by north-east Asia (USD 2.3 trillion) and south-east Asia (USD 1.2 trillion).

Other Americas and Russia have lower overall requirements in the 2DC relative to the BAU: USD 0.15 trillion and USD 0.11 trillion. In other Americas, the decline is almost entirely due to reduced investment in supply and electricity and heat in Canada and lower investment in supply in Mexico. While Canada's overall requirements remain lower than the BAU by USD 0.41 trillion, the decrease in Mexico is offset by increased capital requirements in buildings and electricity and heat. In Russia, increased investment in buildings is offset by decreases in supply and electricity and heat.

In the 2DC, buildings, electricity and heat and transport require more capital investment than in the BAU. The buildings sector requires USD 11 trillion more capital investment than under the BAU. Electricity and heat requires USD 2.3 trillion more, but part of this increase is offset by lower requirements in supply (USD 1.4 trillion), refineries (USD 0.40 trillion) and industry (USD 0.12 trillion). Buildings account for 32% of total capital investment in the 2DC in APEC, with the United States and China accounting for a combined 69% of buildings (equivalent to 22% of total capital investment in APEC). Japan also requires significantly more investment (USD 1.8 trillion) in buildings.

Figure 7.7 • Capital investment and fuel cost savings by region and sector, BAU vs 2DC, 2017-50



Source: APERC analysis.

Projected growth in capital investment requirements in electricity and heat is largest in China (90% of additional capital or USD 2.1 trillion), north-east Asia (20% or USD 0.46 trillion) and south-east Asia (18% or USD 0.43 trillion). In north-east Asia, Japan (USD 0.68 trillion), Korea (USD 0.51 trillion) and Chinese Taipei (USD 0.29 trillion) drive the growth, while Mexico (USD 0.52 trillion) boosts capital requirements in other Americas. The electricity sector decarbonises significantly in the 2DC, where 8.9% of energy investment in electricity and heat is spent on carbon capture and storage (CCS) technologies. Box 7.3 examines financing a coal-fired power plant with CCS technology in Indonesia.

Transport capital investment requirements round out the increases in the 2DC, being USD 1.2 trillion more than in the BAU. Most of this increase is in China reflecting a transition to alternative vehicles. The transport requirement in China is USD 3.0 trillion in the 2DC, which is 0.83 trillion more than the BAU. In the United States, the requirement is USD 1.3 trillion in the 2DC, USD 0.11 trillion more than the BAU. Japan requires approximately USD 0.15 trillion more transport capital investment than in the BAU.

Across APEC, industry capital investment requirements are USD 0.12 trillion lower in the 2DC than in the BAU, with the most prominent declines in China (USD 0.040 trillion) and the United States (USD 0.022 trillion). The overall decline is partially offset by increases in Canada, Malaysia, Mexico, New Zealand and Australia.

Box 7.3 • Financing a coal-fired power plant with CCS in Indonesia’s electricity market

CARBON CAPTURE VIABILITY IN INCREASING SHARE OF COAL POWER IN SOUTH-EAST ASIA

Electricity markets in APEC south-east Asian economies (with the exception of Singapore) use single buyer models in which private electricity generators, known as independent power producers (IPPs), sell electricity to the state utility company through power purchase agreements (PPAs), typically under long-term contracts (25 to 30 years). Financing of recent coal-fired projects in Indonesia faced environmental opposition even though they applied ultra-supercritical technologies. The projects eventually acquired financial support from international and domestic banks, but financial closures were delayed.

It appears that future coal-fired power projects may need to include carbon capture to attract private financing. Experience to date suggests that securing investment for deployment of CCS requires comprehensive market and capital support policies. As CCS technologies are currently at the demonstration stage, they have many associated perceived and actual risks related to technology maturity, investment cost and operating performance (World Bank, 2015b).

This case study evaluates the financial viability of IPP investment in coal power plants in South Sumatera (Indonesia) under two scenarios: CCS under a carbon price policy and CCS under a carbon market for enhanced-oil-recovery (EOR). A World Bank study on potential CCS found that depleted gas fields in South Sumatera have sufficient storage capacity for storing captured CO_2. It also estimated potential demand of 243 million tonnes of CO_2 ($MtCO_2$) for EOR up to 2045. The study then used net present value (NPV) to calculate the present monetary value for each scenario to understand the returns on investment (1).

$$NPV = -Initial\ investment + \sum_{t=1}^{n} \frac{net\ cash\ flow_t}{(1+i)^t} \qquad (1)$$

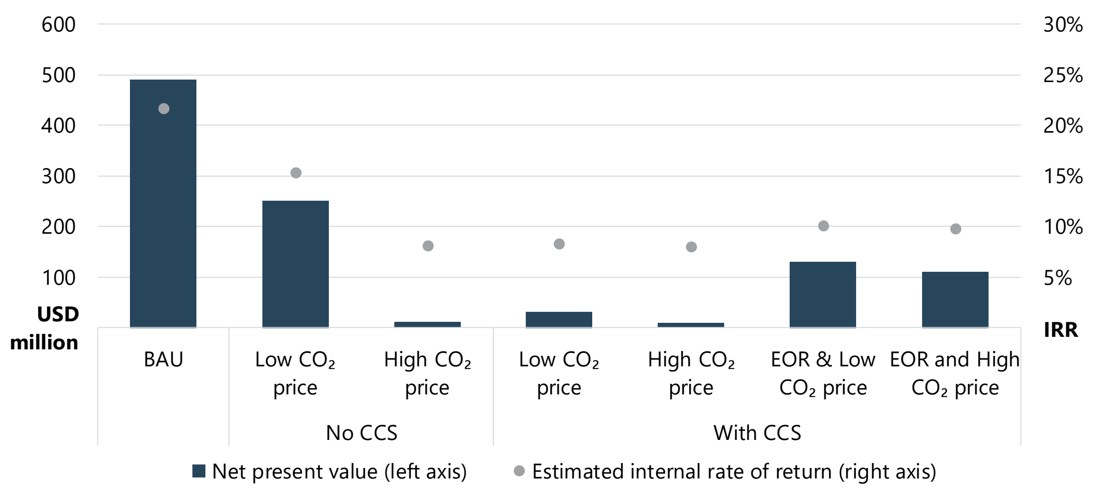
At present, there is no established carbon price in south-east Asia. Singapore, however, is taking the initiative to introduce a carbon tax from 2019 at USD 3.71 per tCO_2e (SGD 5.0 per tCO_2e) with the intention to increase its carbon tax to USD 7.42 per tCO_2e to USD 11.14 per tCO_2e by 2030. This range is applied to evaluate how a carbon price influences the commercial viability of private investment in future coal power projects. The scenarios use post-combustion capture technology to capture 90% of CO_2 emissions, which has 12% own-use electricity consumption (4% higher than conventional coal power plants). Additionally, the technology is estimated to increase the initial capital cost by 58% (Rubin, Davison, & Herzog, 2015).

CCS WITH CO_2 MARKET FOR ENHANCED OIL RECOVERY FINANCIALLY FEASIBLE

Financial assessment of this case study on seven cases (one being the BAU with no carbon price, the other six testing various prices) shows that when carbon prices (whether low or high) are applied, projected financial returns are substantially lower than in the BAU (Figure 7.8). Overall, the application of a carbon price reduces the financial viability of conventional coal power without CCS equipment. When a higher carbon price of USD 14.69 per tCO_2 is implemented, the estimated internal rate of return (IRR)—at 7.8%—of the coal power IPP is just over the discount rate threshold. Low returns on investment may prompt IPPs that traditionally developed coal power plants to seek alternative investment strategies, including coal with CCS or renewable energy.

Conversely, the project cash flow improves when a CO_2 market for purchasing CO_2 is available: the market creates a value for the captured CO_2 by allowing it to be used for other activities such as EOR (rather than just being stored). In this study, use of CO_2 for EOR creates opportunities for IPP developers to secure a higher NPV and expected IRRs than under a scenario without a carbon market. Revenues from the sales of captured CO_2 partly offset the capital investment needed to add CCS equipment, enabling IPP developers to fulfil their debt service obligations. This study assumes the government builds necessary CO_2 transportation and storage infrastructure.

Figure 7.8 • Financial analysis for coal-fired power under different investment scenarios



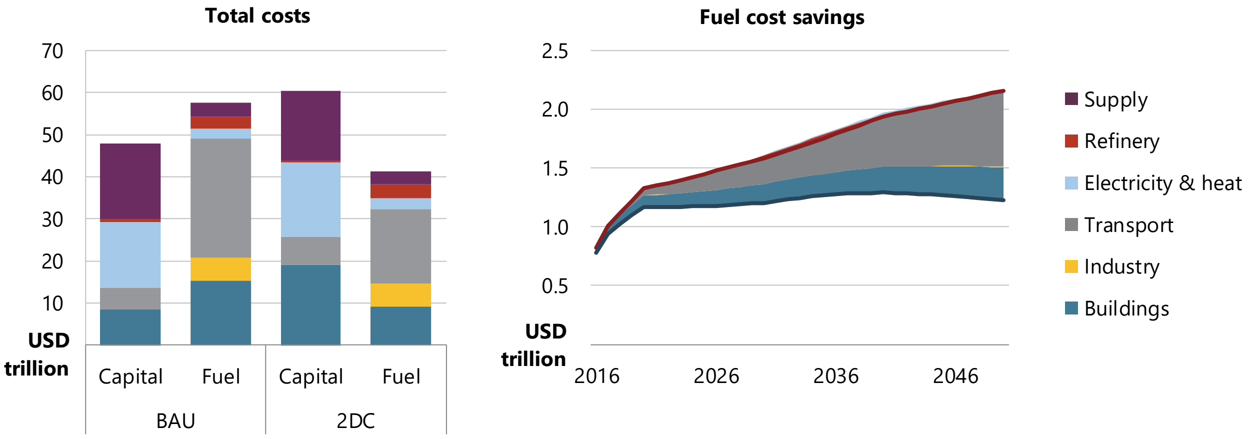
Sources: APERC analysis and IEA (2018a).

GOVERNMENT SUPPORT IS NEEDED TO MAKE CCS SYSTEMS ATTRACTIVE TO THE PRIVATE SECTOR

Overall, the financial returns of coal power plants without CCS are severely undercut with a carbon price policy, highlighting the risk of such projects in a CO_2-constrained future energy system. Without a carbon market to facilitate sale of captured emissions and thereby offset some of the required capital investment, installation of CCS is not financially feasible, primarily due to the high investment and operating costs of CCS systems. This analysis confirms that, under the current IPP business model in Indonesia, government support is needed to develop CO_2 transport and storage infrastructure and creation of CO_2 markets that can be useful for EOR (Atmo, Otsuki, & Kendell, 2018).

In the 2DC, the value of reduced energy demand reaches USD 16 trillion over the Outlook period. Almost two-thirds of fuel savings accumulate in two APEC economies: the United States (34%) and China (26%). These fuel savings reduce total investment requirements in the 2DC to USD 102 trillion, 3.7% lower than in the BAU (Figure 7.9).

Figure 7.9 • Total investment and fuel cost savings by sector in the BAU vs 2DC, 2017-50



Source: APERC analysis.

TECHNOLOGY COST TRENDS

Over the past decade, deployment of renewable power generation technologies has accelerated rapidly, increasing their competitiveness in the power sector. This trend has prompted economies to accelerate the shift from fossil fuels and nuclear to renewables through the backdrop of increasing competitive pressures driving innovation in technology and in utility business models. According to the International Renewable Energy Agency (IRENA), eight main factors are driving generation cost reductions (IRENA, 2018):

- Increasing economies of scale in manufacturing, including vertical integration and consolidation among manufacturers.
- Manufacturing process improvements that reduce material and labour needs, while optimising the utilisation of capital.
- More competitive, global supply chains that are increasingly optimised to provide tailored products that best suit local market and resource conditions.
- Technology improvements that are raising capacity factors and/or reducing installed costs.
- Experienced project developers who have standardised approaches and minimised project development risks.
- Optimised operations and maintenance (O&M) practices and the use of real-time data to improve predictive maintenance, reducing O&M costs and generation losses from planned and unplanned outages.
- Low barriers to entry and a plethora of experienced medium- to large-scale developers competing to develop projects, worldwide.
- Falling or low cost of capital, driven by supportive policy frameworks, project de-risking tools and the technological maturity of renewable generation technologies.

As demand for electricity grows, society is increasingly demanding that it be produced in a clean, safe and affordable manner. As a result, the power sector is undergoing a substantial transition: the trend is towards more unconventional, low-carbon technologies replacing the once-dominant conventional technologies.

Steadily declining costs are an important element of this transition. As solar PV technology has matured over the past seven years, more economies have started to deploy it on a large scale. PV module prices plummeted by 86% from 2008 to 2016, from USD 3 700 per kW to USD 500 per kW, generally reflecting increased experience of mature manufacturers. In addition, competitive pressures in newer markets have been a main driver of rapid cost reductions in installation services (NREL, 2017). By contrast, CSP costs have remained relatively stable at USD 6 000 per kW to USD 12 000 per kW); deployment has thus remained limited compared with other renewable technologies (IRENA, 2018). Over a much longer timer frame (1983 to 2017), the installed cost of onshore wind declined by 70%, from USD 4 880 per kW to USD 1 477 per kW (IRENA, 2018). In the past decade, battery costs decreased approximately 68%, from USD 1 500 per kW in 2005 to USD 500 per kW in 2015 (NREL, 2017).

FINANCING CONSIDERATIONS

The scale of capital investment required for energy infrastructure in APEC is substantial in all three scenarios, reaching an annual average of USD 1.5 trillion in the BAU, USD 1.7 trillion in the TGT and USD 1.8 trillion in the 2DC. In each case, the investment needs to be raised from either public or private sector funds. Diverse financing sources are available through capital markets at domestic and international levels, including corporate equity, commercial banks, institutional funds, bond markets, export credit agencies and multilateral banks. Each source of capital accommodates a different investment risk profile, which is reflected in variations in expected returns and duration of the investment.

Box 7.1 on LNG development in Australia shows an example of how cost inflation and market disruption can result from such large-scale, complex export infrastructure investments and prescribes how economies can avoid these issues when striving for private sector funding to grow their LNG export industry.

Box 7.2 on renewable energy investments in Chile highlights of private investment in a deregulated electricity market. By first establishing regulatory support to facilitate power purchases from variable renewable energy (e.g. solar PV and wind), the public sector was able to use electricity auctions to secure power sales contracts. In addition, the preferential market for small-scale renewable developers provides greater certainty of revenue, which is essential for project loan investors.

Financing a coal-fired power plant with CCS in Indonesia, as described in Box 7.3, is managed by private finance sourced from a combination of 70% debt (finance from loans) and 30% project developer equity. Private investment returns are secured through a long-term PPA contract that provides the project developers with stable revenues over the duration of the contract (typically 25 to 30 years). Using a combination of syndicated loans from commercial banks (usually with loan tenors of 7 to 10 years) and long-term bonds (10 to 15 years), project developers can structure financing to match project cash flows.

The scale and complexity of project finance varies by project size and type of technology involved. Experienced project developers are essential to attract lenders to commit to the long-term loans needed. Typically, project finance is structured as non-recourse, meaning certainty and asset collateral are limited to the respective energy project. This excludes lenders from recourse for loan payment obligations from the parent company of the project developer. Accordingly, project finance arrangements usually involve multiple layers of asset securitisation and legal agreements, as well as longer project initiation processes than traditional public procurement projects. This increases transaction costs, adding 5% to 10% of the total project value to the life-cycle cost of development.

Strategies to increase the likelihood of private sector investment in energy efficiency are highlighted in Box 7.4, which examines Korean government subsidies to promote energy efficiency in industry. ESCOs and facility/building owners receive financial incentives from the government to reduce electricity consumption during peak hours (14:00 to 16:00), so that electric utility companies can defer investment for new power generation. The financial viability of energy efficiency programs depends on the sustainability of government subsidies that enable ESCOs and building/facility owners to access financial loans from commercial banks.

Box 7.4 • Energy efficiency investments in Korea

INTRODUCTION

As Korea has high industrial electricity demand with a relatively flat load duration curve, it can provide diverse opportunities to improve energy efficiency. The Korean government has introduced various policy measures to improve energy efficiency, including demand-side management schemes for end-users, adjustments in the energy pricing system and incentives for companies to invest in energy efficiency (MOTIE, 2014a).

In 2015, the government launched the Energy Efficiency Market Pilot Programme, which aims to increase private investment in energy efficient equipment. The program uses an auction system to increase competition. The scheme includes a measurement and verification (M&V) step, which uses information and communications technology (ICT) to confirm actual efficiency gains of selected projects (this was only theoretically estimated before).

This case study explores the possibility of attracting more interest from investors through an auction system and also provides an empirical basis for possible establishment of an exchange market for efficiency gains.

1ST EXPERIMENT ON AN EXCHANGE MARKET FOR DEMAND RESPONSE

In 2014, Korea established an exchange market for demand response, which merged existing demand-response programs into a new market system. This system allowed private investors to voluntarily invest in demand-response projects, receiving their payback through the market.

With electricity demand projected to rise rapidly, the economy’s energy efficiency resource potential increases from 609 MW in 2015 to 2 716 MW by 2027 (i.e. from 0.74% of target electricity demand in 2015 under the 6th Electricity Demand and Supply Basic Plan to 2.6% in 2027) (Table 7.2) (MOTIE, 2014b).

Table 7.2 • Korean energy efficiency market potential, MW

year	Electricity demand target	Demand response prospect	Energy efficienvy potential
2015	82667	1420	609
2016	84576	1651	708
2017	88218	1912	819
2020	95316	3066	1314
2027	100886	6337	2716

Source: MOTIE (2014c).

The government of Korea preferentially applied the new pilot program to three types of energy efficient equipment in 2015: LED light bulbs, inverters and electric motors. The following year, Korea expanded the program to include electric heat pumps (EHPs) and refrigerators.

The annual budget for the pilot program was about KRW 10 billion (USD 8.7 million) in 2015. A total of 452 projects were selected, with the majority focusing on replacing inefficient light bulbs with LEDs (MOTIE, 2014b; KEA, 2017). Energy savings from the pilot program reached 100 GWh in 2015. The private investment was expected to be KRW 71 billion (USD 62 million), about seven times larger than the initail government investment (Table 7.3) (MOTIE, 2014b).

Table 7.3 • Energy efficiency potential and effect of the energy efficiency pilot program

year	Energy efficiency potential (MW)	Capacity reduction (MW)		Savings (GW)	Private investment (billion KRW)
2015	609	LED	11	32	31.5
		Inverter	10	40	13.5
		Motor	7	28	26
		sub-total	28	100	71

Source: MOTIE (2014b).

SHOWING THE POTENTIAL TO ATTRACT PRIVATE INVESTMENTS IN ENERGY EFFICIENCY

To date, energy efficiency polices of Korea have depended heavily on government subsidies and have experienced limited uptake, making it difficult to analyse their success. Korea's energy efficiency market program is an attempt to reduce dependence on subsidies and attract voluntary private investment in return for receiving compensation through a market system. Initial outcomes from several cases show that such a program could attract private investments 3 to 7 times larger than the public budget initially injected (KEA, 2017). Though it is still too early to evaluate and generalise about the effectiveness of the Korean pilot program, it seems to confirm that using a market mechanism and information technology could help stimulate private investment in energy efficiency.

CONSIDERATIONS TO EXPAND INVESTMENT

CAPITAL INVESTMENTS AND POLICY MAKING

Energy systems are enormously expensive to develop. Additionally, energy infrastructure required to manage the flow of resources is typically built for reliability: it is long-lived and durable, and as such, can be highly inflexible in the short term. Today, more than ever, energy systems also require flexibility so they can respond to changes in supply and demand, breakthroughs in technology, and shifts in social or economic priorities. When setting energy policy, many economies already prioritise strategic planning across multiple possible time horizons, using tools such as sensitivity analysis and/or scenario building to analyse possible outcomes and reduce uncertainty. Indeed, policy planners must anticipate and plan for the long term, taking into account the implications of varying projections on the level of energy investment required and the expected lifetime of new capital investments.

As energy demand continues to grow, additional energy investments will be needed to keep pace. Typically, these investments are large-scale and highly capital-intensive, requiring time to payback their initial capital. The longer action on climate change is delayed, the higher the likelihood that an economy or the region will lock itself into a business-as-usual energy future, or alternatively, commit itself to greater costs associated with early retirements and stranded assets in the future. Different policy action is required now in order to achieve commitments set out in the COP21 Paris Agreement requires different policy choices to 2050, particularly as the Agreement sets out aggressive aims to accomplish deep decarbonisation beyond mid-century.

RISK EVALUATION AND MITIGATION FOR FINANCING

Investment decisions in the energy sector carry multiple types of risks, such as market, liquidity, technology, inflation, interest rate and currency risks. To secure financing, it is usually necessary to compensate a lender for the additional non-diversifiable risk associated with a project. These unique factors are typically accounted for through a risk premium, or a higher required return on capital above the risk-free rate.

While the energy industry is undergoing a shift from traditional fossil fuels to renewables, the financial sector is learning how to evaluate new technologies and how to structure appropriate financing mechanisms to secure the required capital. Capacity building to improve the relationship between these two sectors is necessary in order to assess risk and then transfer it to the party best able to manage it in ways that secure long-term, profitable returns for all parties. Financial case studies can be used to reduce information asymmetry between the energy sector and the financial sector, especially where technologies have demonstrated commercial viability or a known investment payback.

Reduced investment in fossil fuels does not need to lower overall investment in an economy; rather, it can facilitate reallocation of capital to other parts of the energy industry or to other sectors of the economy. Other efforts to remove inefficiencies in capital allocation could also ensure that low-carbon energy investments are more competitive against fossil fuel investments (APEC, 2015). Renewable and energy efficiency investments compete not only against traditional energy investments, but also with all other sectors; therefore, they must be competitive with investments in areas such as pharmaceuticals, telecommunications, education, construction, technology or real estate. Strategic policy decisions can encourage the transition away from carbon-intensive industries. They can also have the effect of building local markets for low-carbon goods and services, ultimately increasing competitiveness for low-carbon exports in the global market.

RECOMMENDATIONS FOR POLICY ACTION

Significant investment is required to meet energy demand in APEC over the Outlook period. In contrast with many other parts of the world where energy demand growth has stagnated, projected rapid growth in the APEC region creates an opportunity to start developing cleaner energy systems now (rather than building conventional systems that would need to be decarbonised later).

Major infrastructure investment decisions made in the next 10 years (such as development of LNG liquefaction or oil and gas pipelines, or power plants) should be evaluated on a lifecycle basis. This implies considering the expected operational lifetime of such investments against the longer-term energy transition and decarbonisation targets. Projects predicated on long-term (>30 year) payback periods should evaluate risks posed to investment returns, such as those associated with higher regulatory or environmental compliance costs. Additionally, project assessments should fully consider financial options for early shutdown by either the government or the project developer.

Energy investment needs large-scale capital sourced from a combination of public funds and private sector capital. Like project finance arrangements, all financing mechanisms depend on the structure of energy markets in which the respective energy projects are being developed and on the scale of capital needed to secure financing for such investment. Public sector finance can be strategically focused on infrastructure projects that offer limited returns on investment but are essential to attracting complementary private investment. Public financing may also be more appropriate for smaller scale projects, as non-recourse project finance typically involves substantial transaction costs, making it less attractive for small-scale energy projects. APEC economies should take some actions to secure long-term financing from private capital markets at an affordable rate, but certainty of long-term revenue streams is needed.

In the long term, APEC economies will create future opportunities to participate in global markets for low-carbon goods and services. As economies strive to meet their Nationally Determined Contributions to the COP21 Paris Agreement, they will also need to increase their ambition to meet the additional reductions.

8. ENERGY SECURITY

KEY FINDINGS

- **The APEC energy supply mix remains largely reliant on fossil fuels throughout the Outlook period, particularly imported crude oil.** In the BAU Scenario, fossil fuel self-sufficiency decreases from 92% in 2016 to 91% in 2050. In 2016, 72% of crude oil is imported from outside the APEC region and despite producing enough coal and natural gas to support its demand, APEC remains a net importer of crude oil in all scenarios.

- **Electricity is more affordable in 2050 under the TGT than in the BAU.** Overall, the percentage of household income spent on electricity across APEC is 7.9% lower in the TGT. High uptake of energy efficiency drives these savings.

- **Electricity access in APEC rises from 98% in 2016 to 99.7% in 2050, thanks to government targets and policies.** Service continues to be reliable in major APEC cities; in 2016, end-use customers experienced an average of only 1.5 hours of electricity interruption.

- **Additional efforts to achieve APEC aspirational goals to reduce energy intensity and increase the share of renewables in the energy mix lead to lower CO_2 emissions per capita.** In the BAU, CO_2 emissions per capita decrease by 0.83% from 2016 to 2050, compared with a decrease of 20% in the TGT.

- **APEC's reserve gap increases over time in all scenarios. By 2030, coal, crude oil and natural gas production exceeds current reserves in all three scenarios, but not all subregions.** As APEC reserves are finite, it is important to start investing in exploration or in other non-fossil fuel technology.

INTRODUCTION

The Asia-Pacific Economic Cooperation (APEC) region is currently home to more than one-third of the global population. It also represents more than half of the world's primary energy demand and real gross domestic product (GDP) (IEA, 2018a and World Bank, 2018). Long-term sustainability of the region's prosperity hinges on the premise of a secure energy landscape, which is why energy security is a cornerstone of energy policy decisions. During the 2015 APEC Energy Ministers meeting (Cebu, Philippines), the ministerial group highlighted three considerations of major importance: 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. Energy security is the focus of this chapter; climate change and sustainability are covered in Chapter 10.

This chapter evaluates the energy security implications of the three scenarios presented in this Outlook through a set of seven indicators. APERC developed these indicators in order to benchmark energy security in the region in the context of four categories collectively known as the '4 A's of energy security' (APERC, 2007): availability, affordability, accessibility and acceptability. This chapter also examines key risks and opportunities that these indicators reveal and recommends potential measures to enhance APEC energy security.

The three scenarios have significant implications for energy security, particularly in terms of availability and acceptability of energy supply. In the Business-as-Usual (BAU) Scenario, APEC energy self-sufficiency is projected to rise over the first four years and start decreasing from 2027 to 2050 (by -4.3%). In the Target (TGT) and 2-Degrees Celsius (2DC) Scenarios, by contrast, the share of renewables in the energy system increases and self-sufficiency rises across the APEC region. In particular, south-east Asia becomes almost fully self-sufficient on a net energy basis in the 2DC, highlighting the potential for significant positive security benefits by moving to a low-carbon energy system. Combined, these scenarios and indicators illustrate the positive impacts of energy efficiency measures and the increased use of renewables in APEC.

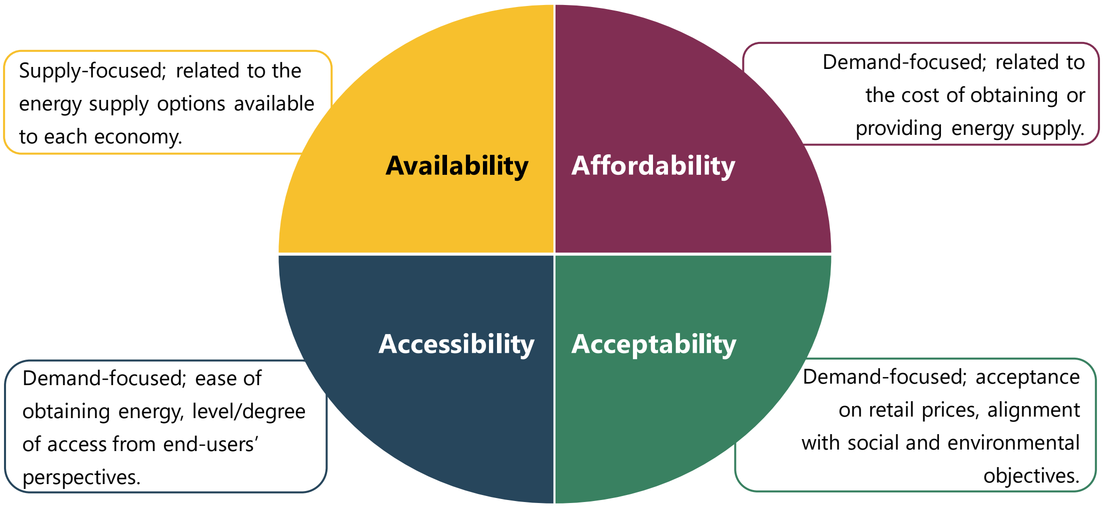
ENERGY SECURITY IN A CHANGING ENERGY LANDSCAPE

Historically, fossil fuels have dominated the APEC energy supply mix; they accounted for 86% of APEC total primary energy supply (TPES) in 2016 (see Chapter 3). Yet the region comprises a diverse set of economies from an energy supply perspective; 11 APEC economies were net importers of fossil fuels in 2016, while 10 were net exporters. Among the net importers, six (Hong Kong, China; Japan; Korea; Singapore; Chinese Taipei; and Thailand) relied on imports to supply more than half of their TPES requirements. Conversely, four of the net exporter economies (Australia, Brunei Darussalam, Indonesia and Papua New Guinea) exported more than half of their total energy production.

This dominance of fossil fuels is projected to continue through 2050, accounting for at least 61% of the APEC TPES in all three scenarios. Changes in TPES, driven by increased levels of energy efficiency and renewables, have significant implications for energy security at the APEC, subregional and economy level. To capture these impacts, this chapter adopts the definition of the 4 A's of energy security applied by the Asia Pacific Energy Research Centre (APERC) and uses a set of seven indicators to assess the level of APEC energy security relative to them (APERC, 2007). More details on the methodology used to calculate these indicators are in Annex I.

The 4 A's of energy security are availability, affordability, accessibility and acceptability (Figure 8.1). Availability is supply-focused and captures the ability of economies to maintain a reliable and uninterrupted flow of energy supply. The other three factors focus on energy demand, including the cost (affordability) and ease of obtaining energy services (accessibility) from energy sources that align with social and environmental objectives (acceptability).

Figure 8.1 • The 4 A's of energy security



Source: APERC (2007).

IMPLICATIONS OF THE 4 A'S

AVAILABILITY

Availability of supply, which relates to a reliable and uninterrupted flow of energy supply, is analysed across three indicators. The self-sufficiency ratio, the first indicator, measures the proportion of an economy's energy supply that is met using its own resources. This ratio provides a snapshot of reliance on domestic resources in a particular year. A second indicator, the reserves gap (RG), quantifies the projected total additional fossil fuel reserves (i.e. coal, natural gas or oil) that would need to be discovered over the Outlook period in order to maintain the current reserves-to-production ratio (R2P) for each fuel type. A third measure, the Herfindahl-Hirschman Index (HHI), assesses market concentration and diversity and quantifies a given economy's dependence on one fuel.

APEC SUPPLY MIX CONTINUES TO RELY ON CRUDE OIL IMPORTS

APEC's overall supply self-sufficiency ratio for fossil fuels in 2016 was 92%. Despite being fully self-sufficient in coal and natural gas, which together accounted for more than half (56%) of its 2016 supply mix, APEC was a net energy importer due to crude oil demand significantly exceeding production. Oil is the dominant fuel source for five of the seven APEC subregions (Table 8.1) and imports account for 57% of crude oil demand. However, due to significant refining capacity, APEC imports only 3.2% of FED for oil products (see Chapter 9 on energy trade).

In the BAU Scenario, APEC fossil fuel self-sufficiency decreases from 92% in 2016 to 91% in 2050 (Table 8.2). Two factors drive this trend: growth in demand for natural gas, which outstrips production increases, and continued production deficits for crude oil. Oil replaces coal as the dominant fuel in the APEC supply mix by 2050 under this scenario. Notable, however, is that natural gas fuels more than one-third of the energy supply in three subregions (Oceania, Russia and the United States) in 2050, with each of these subregions projected to have high levels (i.e. above 90%) of natural gas self-sufficiency.

Table 8.1 • Self-sufficiency ratios among APEC subregions by fuels, 2016

Subregions	Total supply	Coal	Natural gas	Crude oil	Dominant fuel source in TPES
United States (%)	87	100	96	59	Oil (37)
China (%)	80	89	68	36	Coal (65)
Russia (%)	100	100	100	100	Gas (50)
South-east Asia (%)	84	100	100	55	Oil (34)
North-east Asia (%)	12	1	2	0	Oil (41)
Other Americas (%)	95	100	100	100	Oil (41)
Oceania (%)	79	100	100	69	Oil (34)
APEC (%)	**92**	**100**	**100**	**70**	**Coal (35)**

Sources: APERC analysis and IEA (2018a).

While the APEC fuel supply mix is more diverse by 2050 in the TGT Scenario, gas still surpasses coal to become the dominant fuel by 2050, accounting for 26% of the supply mix, followed closely by oil (25%) and coal (24%). APEC becomes a net gas exporter by 2050 in the TGT, compared with importing 22% of TPES in the BAU. This trend demonstrates the positive benefits of energy efficiency and increasing use of renewables to boost the region's energy security from an availability standpoint. Even in this scenario, however, APEC achieves an 89% self-sufficiency ratio for crude oil, indicating a potential risk for regional energy security and highlighting an opportunity to strengthen energy security by adopting additional efficiency measures and fuel switching in oil-dominated subsectors (e.g. transport).

In the 2DC, gas replaces oil as APEC's dominant fuel source in TPES, leading to higher energy self-sufficiency across the region. In particular, south-east Asia becomes more self-sufficient in gas and oil resources, compared with the other scenarios, but still decreases over the Outlook. Overall, renewables supply 39% of this subregion's energy requirements in 2050, switching in oil-dominated fuel source to renewable (28%). The United States and Russia, where gas is the dominant fuel, maintain 100% self-sufficiency in all fossil fuel types through the 2DC. All other regions have decreasing self-sufficiency through the Outlook, but improving in the 2DC compared with the other scenarios.

Table 8.2 • Self-sufficiency among APEC subregions by fuels in the BAU, TGT and 2DC, 2050

Subregion	Total supply			Coal			Natural gas			Crude oil			Dominant fuel source in TPES		
	BAU	TGT	2DC	BAU	TGT	2DC	BAU	TGT	2DC	BAU	TGT	2DC	BAU	TGT	2DC
United States (%)	100	100	100	100	100	100	100	100	100	97	100	100	Gas (38)	Gas (34)	Gas (35)
China (%)	74	78	79	96	96	96	40	44	47	30	42	43	Coal (40)	Coal (37)	RE (20)
Russia (%)	100	100	100	100	100	100	100	100	100	100	100	100	Gas (48)	Gas (46)	Gas (40)
South-east Asia (%)	66	70	77	100	100	100	63	67	80	26	26	29	Oil (34)	Oil (31)	RE (29)
North-east Asia (%)	11	14	32	0.34	0.42	1.2	0.018	0.022	0.028	0.072	0.080	0.089	Oil (36)	Oil (35)	Oil (34)
Other Americas (%)	84	94	97	90	100	100	87	98	100	100	100	100	Oil (39)	Oil (37)	Oil (33)
Oceania (%)	67	71	77	100	100	100	100	100	100	19	19	18	Gas (37)	Gas (35)	Gas (39)
APEC (%)	**91**	**98**	**100**	**100**	**100**	**100**	**93**	**100**	**100**	**78**	**89**	**100**	**Oil (28)**	**Gas (25)**	**Gas (22)**

Note: RE = renewables.
Source: APERC analysis.

Box 8.1 • Energy Security: Balancing the cost of backup supply—reducing US oil stockpiles

The US Strategic Petroleum Reserve (SPR) is a crude oil stockpile established in 1975. As of April 2018, it contained 83.32 million tonnes of oil equivalent (Mtoe) of crude oil, equivalent to 178 days of net crude and product imports, based on the average 2017 net import levels (EIA, 2018a). The United States also has a north-east home heating oil reserve and a north-east gasoline supply reserve, each holding 0.13 Mtoe (1 million barrels) (DOE, 2016). Under the International Energy Programme, the treaty that established the International Energy Agency, the United States is required to hold in reserve at least 90 days of coverage for its net imports of crude oil and petroleum products (EIA, 2018b). At the current 178 days of stocks, the SPR significantly exceeds this treaty obligation.

The shale oil revolution has prompted a rapid rise in US crude oil production over the past eight years, sharply reducing US oil imports and the corresponding need for oil stockpiles to cover potential supply cut-offs. Given recent trends, the US Congress passed six laws between 2015 to 2018 that reduce, by the start of 2028, the amount of crude oil stored in the SPR to about 53.3 Mtoe, the equivalent of 109 days of net crude and product imports. This creates an opportunity to export more crude oil onto the global market. Some of the revenues from sales are earmarked to offset a portion of the US budget deficit; others are to be directed towards modernising the SPR infrastructure (EIA, 2018b).

RESERVE DEPLETION BECOMES WIDESPREAD UNDER ALL SCENARIOS

APEC's overall R2P for coal in 2016 was more than 100 years; with lower ratios for natural gas (40 years) and crude oil reserves (25 years). To measure the robustness of current reserves, the RG has been used to quantify the projected total additional fossil fuel reserves that would need to be discovered over the Outlook period in order to maintain the current R2P ratio for each type of fossil fuel. The RG shows cumulative production over the Outlook as a percentage of 2016 reserves. For example, an economy with a 100% measure for natural gas means that over the Outlook period, the total amount of discoveries needs to match the volume of reserves held in 2016.

In 2016, APEC used 0.92% of its coal reserves. Three subregions (north-east Asia, Oceania and Russia) together used 0.90% while the United States alone used 3.7%—the highest in APEC. The APEC region used only 2.5% of gas reserves and 3.9% of crude oil (Table 8.3). For natural gas reserves, north-east Asia used 9.7% in 2016, followed by the United States (8.2%) and other Americas (6.4%).

APEC's coal reserves are projected to last over the Outlook period, reaching 29% used by 2050 under the BAU Scenario, 26% in the TGT and 19% in the 2DC (Table 8.4). All three scenarios reflect declining coal use, underpinned by APEC-wide efforts to decarbonise (the 2DC specifically analyses pathways to a low-carbon energy future during the Outlook period). Among APEC subregions, the United States has the highest use of coal reserves, using 90% of 2016 coal reserves in the BAU (meaning that 10% remains in 2050). In the TGT, the United States uses 87% of its reserves, marginally lower than the BAU, and only 52% of reserves are used in the 2DC. In all three scenarios, the deployment of renewables, and improved efficiency all contribute to reduced coal use.

Table 8.3 • Cumulative production over the Outlook as a share of 2016 reserves

Subregion	Coal	Natural gas	Crude oil
United States (%)	3.7	8.2	11
China (%)	2.3	4.7	6.4
Russia (%)	0.18	1.2	4.9
South-east Asia (%)	1.0	3.0	5.8
North-east Asia (%)	0.43	9.8	15
Other Americas (%)	0.60	6.4	1.5
Oceania (%)	0.29	2.2	11
APEC (%)	**0.92**	**2.5**	**3.9**

Sources: APERC analysis and IEA (2018a).

Current natural gas reserves are not projected to last through the Outlook period: by 2045 in the BAU, APEC is projected to use 97% of its reserves, quickly rising to 115% by 2050. Only three APEC subregions do not use their entire natural gas reserves: Russia, south-east Asia and north-east Asia (Table 8.4). If they do not continue exploring for new reserves, the United States and China will need to import natural gas or invest in other technologies, as in all three scenarios their cumulative supply needs would exceed 300% of 2016 reserves by 2050. Other Americas is the third APEC subregion to use all of its natural gas reserves by 2050, largely because of efforts to lower greenhouse gas (GHG) emissions through fuel switching. The subregion reaches 100% reserves used by 2031 in the BAU, by 2032 in the TGT and by 2034 in the 2DC. Because of their low reserves, other Americas may need to increase its natural gas imports from 2030.

Crude oil reserves also decline throughout APEC, with 100% of reserves used by 2038 at the latest in all three scenarios. To maintain production, APEC economies need to continue to invest in exploration and development, otherwise they will become increasingly reliant on imports. Over the Outlook, annual production increases by 21% in the BAU, 14% (TGT) and 1.0% (2DC), however, this insufficient to keep up with growing demand, resulting in reserve depletion and growing imports in all three scenarios. Other Americas is the only APEC subregion that does not deplete its total 2016 reserves, largely owing to significant oil product imports from the US, the high deployment of renewables and efforts to boost energy efficiency leading to reduced use of crude oil.

Table 8.4 • Reserve gap among APEC subregions by fuels in the BAU, TGT and 2DC, 2050

Subregion	Coal			Natural gas			Crude oil		
	BAU	TGT	2DC	BAU	TGT	2DC	BAU	TGT	2DC
United States (%)	90	87	51	395	379	367	511	511	511
China (%)	69	63	48	313	313	313	204	204	190
Russia (%)	8.2	7.0	4.6	49	47	43	177	169	167
South-east Asia (%)	47	40	28	90	89	90	174	174	174
Other north-east Asia (%)	8.5	8.7	8.7	82	82	82	172	172	172
Other Americas (%)	15	15	11	243	210	193	60	59	55
Oceania (%)	10	8.9	6.8	156	148	131	188	187	185
APEC (%)	**29**	**26**	**19**	**115**	**110**	**105**	**155**	**153**	**149**

Note: A percentage greater than 100 indicates a reserve gap.
Source: APERC analysis.

FOSSIL FUELS CONTINUE TO DOMINATE APEC ENERGY SUPPLY

APERC measures fuel diversity by applying the HHI to assess whether a given economy is particularly dependent on one type of fuel. The HHI is widely used in the energy sector to track monopolies, assess market share or measure market concentration. An HHI score is calculated as the sum of the squares of the individual shares of every fuel in the TPES. An HHI of 1 indicates a high concentration of one or few sources; as scores move closer to 0, it shows a more diversified market with greater competition.

In 2016, APEC's overall fuel supply was quite diverse at 0.26 on the HHI and improves in all three scenarios (Table 8.5). By 2050, HHI reaches 0.23 in the BAU (a 14% improvement), 0.21 in the TGT (a 19% improvement) and 0.20 in the 2DC (a 25% improvement). A shift occurs in the dominant fuel, however: oil maintains the largest share of TPES in the BAU, while gas overtakes it in the TGT and 2DC.

Generally, economies with large reserves of one particular fuel type tend to have lower TPES diversity than economies that have a variety of good energy resources or are significant importers. For example, China, with enormous coal reserves, and Brunei Darussalam, a significant oil and gas exporter, have two of the highest HHI ratings. The current mid-range concentration (0.49) in China significantly improves, during the Outlook period, reaching 0.24 under the BAU (-50%), 0.22 in the TGT (-54%) and 0.18 in the 2DC (-63%), showing increased diversification in all scenarios. Being the world's largest net oil importer in 2016, China has a high—more than 60%—dependence on overseas oil imports. Its oil supply requirement is projected to peak post-2030, as the economy implements energy efficiency improvements that help reduce oil demand and action is taken to strengthen onshore and offshore oil and gas exploration and exploitation (NDRC, 2016).

Table 8.5 • HHI among APEC subregions in the BAU, TGT and 2DC, 2016-50

Subregion	2016	BAU			TGT			2DC		
		2030	2040	2050	2030	2040	2050	2030	2040	2050
United States	0.26	0.27	0.27	0.27	0.24	0.26	0.25	0.24	0.26	0.25
China	0.49	0.32	0.27	0.24	0.22	0.30	0.25	0.25	0.19	0.18
Russia	0.33	0.33	0.32	0.31	0.29	0.33	0.31	0.30	0.27	0.25
South-east Asia	0.26	0.25	0.26	0.26	0.24	0.25	0.24	0.24	0.24	0.23
North-east Asia	0.28	0.25	0.26	0.26	0.24	0.25	0.24	0.21	0.21	0.21
Other Americas	0.30	0.30	0.31	0.31	0.28	0.28	0.29	0.27	0.26	0.25
Oceania	0.26	0.26	0.27	0.29	0.26	0.25	0.25	0.23	0.27	0.29
APEC	**0.26**	**0.24**	**0.23**	**0.23**	**0.21**	**0.22**	**0.21**	**0.20**	**0.20**	**0.19**

Source: APERC analysis.

AFFORDABILITY

Energy affordability is highly dependent on perspective, whether one considers the viewpoints of an energy supplier versus an end-user or those of an import-dependent economy versus a major exporter. For this analysis, affordability is measured by analysing the percentage of household income spent on electricity (PISE)[36]. At the end-user level, the PISE serves as an indicator of energy services affordability; for each economy, it captures the proportion of annual household income a residential consumer spends on electricity.

ELECTRICITY BECOMES MORE AFFORDABLE IN ALL SCENARIOS

In the BAU, the PISE in APEC is projected to decrease from 0.76% in 2016 to 0.56% in 2050 (Figure 8.2). In 2016, the United States had the highest PISE (1.47%), followed by Oceania (0.98%); both decrease by 2050, with the United States falling to 0.85% and Oceania to 0.83%. As energy efficiency improves in China, PISE falls 10% by 2050. China, Russia and Oceania also show a sharp decrease (10%, 27% and 15% each), in this case reflecting income per household rising (by 215% in China, 85% in Russia and 77% in Oceania), significantly outpacing growth in energy demand. In sharp contrast, south-east Asia shows a small 2.0% decrease in PISE from 2016-50,

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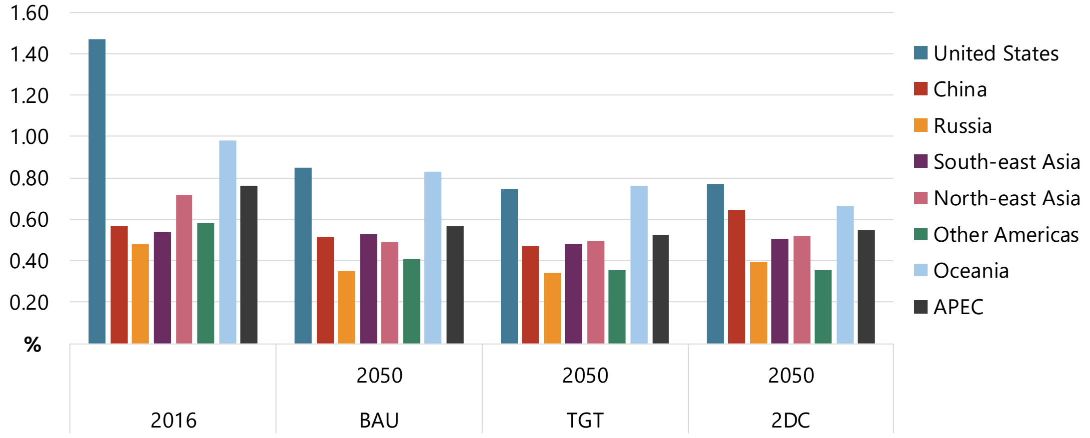
[36] See Appendix I – Security methodology for more information on how PISE is calculated.

mainly because of rising electrification rates in the Philippines (which is striving to achieve 100% electrification by 2040) and Viet Nam (which has a goal of 99% electrification by 2020) (MOIT and DEA, 2017; DOEP, 2016). Once these goals are achieved, PISE in south-east Asia levels off through the remainder of the Outlook.

This affordability indicator improves in the two alternative scenarios presented in this Outlook. As energy efficiency in households increases—in particular, because of improvements in lighting and appliance technologies as well as building envelopes—lower consumption offsets slight rises in the cost of electricity. With the rollout of more efficiency measures, PISE improves further in the TGT and 2DC. In all APEC regions, PISE improves compared with the BAU, with a notable drop in the United States (49% lower in the TGT and 47% lower in the 2DC) and more moderate declines in the Oceania (22% in the TGT and 32% in the 2DC).

Figure 8.2 • Percentage of household income spent on electricity in BAU, TGT and 2DC, 2016-50



Sources: APERC analysis and IEA (2018a).

ACCESSIBILITY

Accessibility of energy is examined from the demand perspective, focusing on the ease with which end-users can access reliable electricity supplies. Two indicators are used for this purpose: the electrification rate quantifies the number of people with electricity access as a percentage of the total population, while a tool known as a system average interruption duration index (SAIDI) tracks average electricity outage duration for each end-user over the course of a year.

APEC ELECTRICITY ACCESS APPROACHES 100% BY 2050

In 2016, APEC had an average electrification rate of 98%, with 12 economies having already achieved full electrification. Projected electrification rates have been obtained from government targets and policies for the remaining nine economies: Brunei Darussalam, Chile, Chinese Taipei, Indonesia, Mexico, Papua New Guinea, Peru, the Philippines and Viet Nam (MEC, 2017; SEM, 2017; MEMRI, 2018). Economies that have already achieved full electrification, or achieve it in the near-term, are assumed to remain at 100% throughout the Outlook period.

Oceania currently has the lowest electrification rate of APEC subregions, primarily because the rate in Papua New Guinea was just 14% in 2016. South-east Asia reaches 100% electrification before 2050, reflecting policy goals for APEC economies that set targets of full electrification by 2030, in line with the United Nations' Sustainable Development Goals. Considering these various targets and policies, electrification rates in APEC increase to 99.7% by 2050.

END-USERS EXPERIENCED AN AVERAGE OF 1.5 HOURS OF BLACKOUTS IN 2016

While electrification rates capture high-level trends related to energy access, the SAIDI tracks the average total duration of outages over the course of a year for each customer served in the major cities of APEC economies. This indicator is only measured historically, as the modelling used in this Outlook does not analyse the probability of future blackouts.

Across APEC, end-use customers experienced an average interruption of 1.5 hours to their electricity service in 2016. South-east Asia had the highest level of interruption (5.8 hours), followed by Oceania (3.9 hours) and the United States (1.7 hours). System interruptions in Papua New Guinea (175 hours) drove the high level of blackouts in Oceania, largely resulting from chronic power shortages as a result of ageing power facilities and maintenance problems, which in turn cause transmission issues (JICA, 2016). North-east Asia and Russia report less than one hour of service disruption in 2016 (World Bank, 2017).

ACCEPTABILITY

Acceptability broadly refers to the social acceptance of the energy supply, with specific definitions varying among economies given the priorities of diverse population groups. This Outlook considers total carbon dioxide (CO_2) emissions per capita to explore the social and environmental acceptability of future APEC energy scenarios. The Nationally Determined Contributions (NDCs) submitted by APEC economies as a part of the agreement reached at the 21st Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change—the COP21 Paris Agreement—illustrate APEC’s collective ambiitons to reduce GHG emisisons. Additional examination of climate change and the NDCs is included in Chapter 10.

DECARBONISATION PATHWAYS COULD ENHANCE ACCEPTABILITY AMONG END-USERS

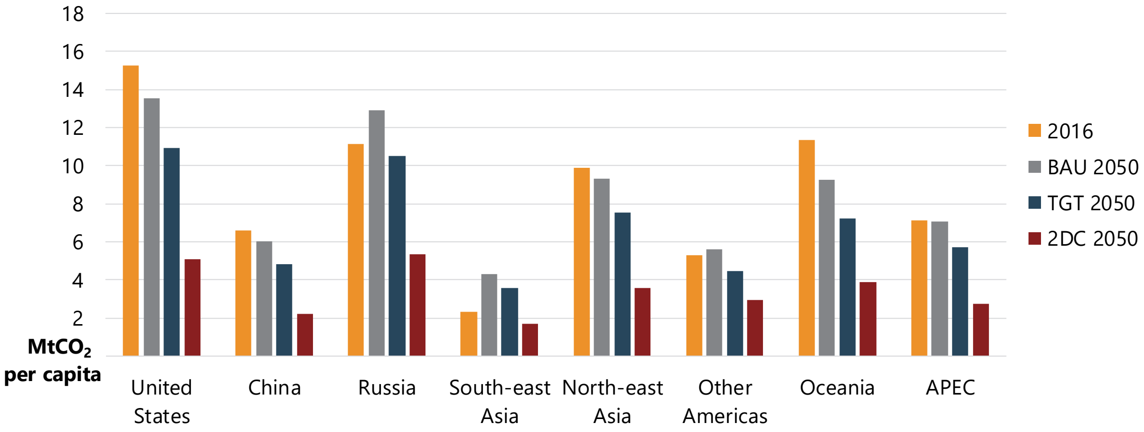
In the BAU, APEC total emissions per capita decrease from 7.5 million tonnes of CO_2 ($MtCO_2$) in 2016 to 7.1 $MtCO_2$ in 2050 (a decline of 0.83%) (Figure 8.3). The United States had the highest emissions per capita in 2016 (15 $MtCO_2$), followed by Russia and Oceania (both 11 $MtCO_2$). In this scenario, per-capita emissions in Oceania fall by 18%, the largest percentage decline among APEC subregions, with trends in three economies playing key roles. Papua New Guinea increases use of low-carbon renewables in its electricity capacity (especially hydro power, with a share of 41% by 2050, to replace fossil fuels) to meet rapidly rising electricity demand. New Zealand boosts the share of renewables (from 75% in 2016) in its electricity mix, rising to 90% by 2050. In parallel, Australia shifts from coal (decreasing to a 7.2% share in 2050) to natural gas for power generation (42% share in 2050).

In sharp contrast, per-capita emissions in Russia rise by 16% by 2050 under the BAU, driven by a rapidly declining (0.24% annually) population and total CO_2 emissions increase of 12%. As mentioned in the Russia chapter in Volume II (Chapter 16), energy-related CO_2 emissions decline in the TGT and the 2DC Scenarios, meaning Russia could achieve its NDC commitments.

China has the highest total CO_2 emissions in APEC. While it has the largest population, it ranked fifth overall in per-capita CO_2 emissions in 2016 and is projected to move to fourth by 2050. Concerns related to air pollution have prompted China to implement policies focused on decarbonising power generation, including the accelerated deployment of nuclear and renewable technologies to replace coal-fired capacity and retiring outdated capacity in industry. Additional policies and regulations aim to shift winter heating demand from coal-fired furnaces to electrical furnaces (see China chapter in Volume II [Chapter 5] for more detail).

In the TGT, APEC CO_2 emissions per capita are 12% lower by 2030 and 20% lower by 2050, compared with the BAU. While not every economy achieves their NDC commitments under this scenario, aggregate APEC emissions do fall more than the sum of all the individual targets. In the 2DC, modelled specifically to analyse pathways to a low-carbon energy future during the Outlook period, APEC per-capita emissions decrease by 27% from 2016 to 2030 (to 5.2 $MtCO_2$ per capita) and by 61% (to 2.8 $MtCO_2$ per capita) between 2030 and 2050. Further examination of these topics is included in Chapter 6.

Figure 8.3 • Total CO_2 emissions per capita under the BAU, TGT and 2DC, 2016 and 2050



Sources: APERC analysis and IEA (2018a).

RECOMMENDATIONS FOR POLICY ACTION

As the push for cleaner sources of energy increases, the traditional concept of assessing energy security in terms of fossil fuel security needs to be revisited. Additionally, the growing interdependence among economies, as shown by the increased volume of intra-APEC trade, suggests that evaluating energy security based solely on the isolated situation of individual economies is becoming outdated. If economies collaborate towards well-functioning and better-integrated markets, regional energy security can be strengthened for all participants in a given market.

Securing the investment needed to ensure supply keeps pace with growing demand is a critical element of future energy security. Public-private partnerships can help to spur greater engagement by the private sector, ultimately boosting energy trade among APEC economies. As a first step, governments need to establish enabling frameworks to attract sufficient investment in both low-carbon energy technologies and in measures to enhance energy security.

As part of APEC's effort to promote regional collaboration in fossil fuel security, the fifth Oil and Gas Security Exercise, conducted in November 2017 in Peru, focused on risk management and disaster preparedness arising from supply disruption. Similar exercises in other APEC economies and at regional levels could build domestic capabilities and know-how while also supporting research and development on energy security. Both investments in energy security and the implementation of new policies are needed to help economies develop preparedness for unexpected incidents.

In each of the Outlook scenarios, the combination of deploying energy efficiency measures and renewable energy resources is beneficial for increasing the availability of fossil fuels and improving regional security. Energy efficiency also drives improvements in energy affordability while expanding electrification improves energy accessibility. Finally, CO_2 emissions reduction in the TGT and the 2DC enhances acceptability among consumers.

Future government policy should focus on reforms designed to achieve net-zero emissions from the energy sector. In relation to the power sector, this should consider ways to increase energy access in rural areas without driving up emissions, which may include modernising the electricity network in economies with ageing infrastructure and encouraging distributed generation. A deep decarbonisation pathway would encourage the overall diversification of the APEC energy supply. Innovation and education should be encouraged to reduce CO_2 emissions and to promote energy alternatives and cleaner sources of electricity generation. Within this dynamic environment, regulators will need to adapt in order to support the necessary investment in the energy system and to be ready to respond to emergencies.

Increased use of fossil fuel reserves across all APEC subregions may result in lower energy security over the Outlook. Policymakers should pursue the deployment of other technologies or continue to invest in exploration. With higher diversification of sources, APEC subregions can use alternatives to reduce dependence on fossil fuel reserves while reducing both CO_2 emissions and local air pollution.

9. ENERGY TRADE

KEY FINDINGS

- **Over the Outlook period, APEC remains a net energy importer in the BAU and TGT Scenarios but becomes a net exporter in the 2DC Scenario.** These results highlight significant opportunities to reduce APEC members' reliance on non-APEC energy imports through increased intra-APEC trade and the adoption of policies and practices that reduce energy demand in the APEC region.

- **Crude oil continues to dominate total net energy imports.** Only a small number of APEC economies remain net crude oil exporters over the Outlook period; most others continue to rely on producers in the Middle East and North Africa as their main sources of imports.

- **Natural gas trade in APEC continues to grow in the BAU, with exports rising by 60% and imports by 126%.** APEC economies remain centre stage of the global natural gas trade. Trade of both piped gas and LNG increases robustly, with LNG growing faster and coming to represent 67% of total imported gas volumes by 2050. Pipeline trade remains dominant in the Americas and grows quickly in China.

- **APEC crude oil, gas and coal imports reach USD 1 500 billion in the BAU in 2050,** up from USD 550 billion in 2016. In the 2DC, a significant drop in crude and coal imports when compared with the other scenarios leads to fossil fuel imports (excluding oil products) valued at USD 810 billion in 2050.

- **The share of intra-APEC coal exports declines from 66% of total regional imports in 2016 to 59% in 2050 in the BAU as demand falls in the region.** The proportion of intra-APEC coal imports increases slightly, from 86% in 2015 to 87% in 2050.

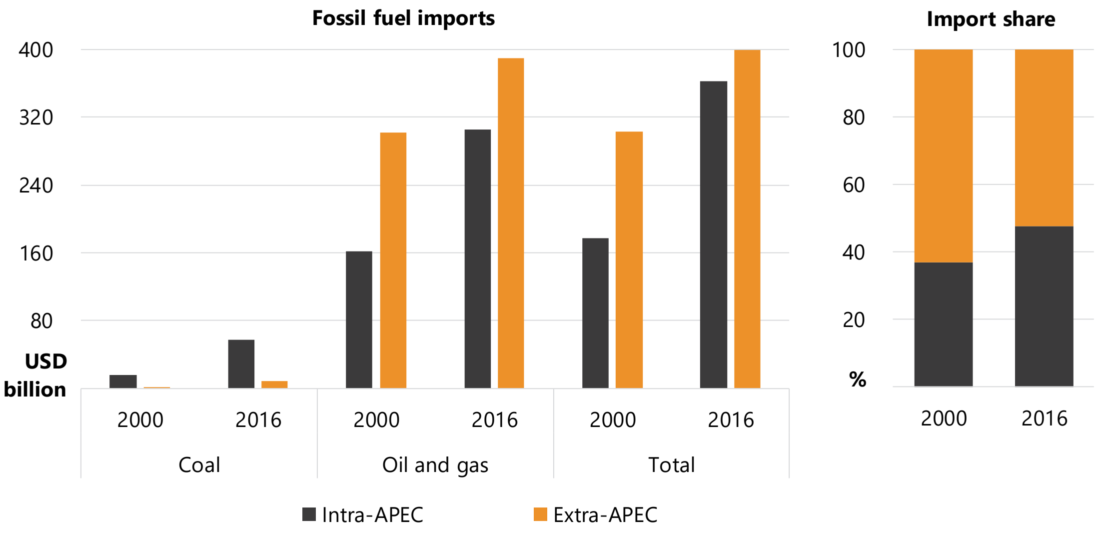
- **There is significant untapped potential for APEC members to increase the export and trade of clean fuels (e.g. hydrogen, bioenergy and electricity).** However, multiple challenges currently act as barriers to trade growth.

INTRODUCTION

The Asia-Pacific Economic Cooperation (APEC) is a regional economic forum established in 1989 to leverage the growing interdependence of the Asia-Pacific region. One of its main objectives is to ensure 'that goods, services, investment and people move easily across borders. Members facilitate this trade through faster customs procedures at borders; more favourable business climates behind the border; and aligning regulations and standards across the region' (APEC, 2018). With this in mind, the *APEC Energy Demand and Supply Outlook 7th Edition* includes, for the first time, projections on energy trade opportunities among APEC members. This chapter focuses predominantly on fossil fuel trade including crude oil, coal (thermal and metallurgical) and natural gas (piped and liquefied natural gas [LNG]), while also touching lightly on the trade potential for uranium ore and hydrogen (as an energy carrier). The text does not cover potential trade of energy services.

In 2000, the value of total APEC imports of fossil fuels[37] reached USD 464 billion, of which oil accounted for the majority (76%), followed by gas (21%) and coal (3.5%). By 2016, total fossil fuel imports had almost doubled to USD 741 billion, with the share of oil falling (65%) while shares rose for gas (27%) and coal (8.6%) (UN Comtrade, 2018). In terms of overall fossil fuel trade in the region, intra-APEC trade[38] represented 37% of the total in 2000 and 48% in 2016 (Figure 9.1).

Figure 9.1 • APEC fossil fuel imports, 2000 and 2016



Sources: UN Comtrade (2018), MFCT (2018) and APERC analysis.

OUTLOOK FOR APEC ENERGY TRADE

With regard to energy trade, the past few years have been an interesting period for APEC members and for global markets. The Trans-Pacific Partnership (TPP), a free trade agreement that aimed to liberalise trade and investment among 12 Pacific Rim economies—Australia, Brunei Darussalam, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, the United States and Viet Nam (all of which are APEC members)—was signed in February 2016 by the respective trade ministers, with the understanding that each economy would need to ratify the agreement before it would take effect. In the early days of 2017, the United States notified the

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[37] Fossil fuel trade includes coal and coal products, oil and petroleum products, and natural gas. The Harmonized Commodity Description and Coding System code used to explain the trade is HS2701 to HS2715.

[38] Intra-APEC trade is defined as trade between APEC economies and extra-APEC trade is trade between APEC members and economies outside of APEC. To avoid double counting, only data reported by importing economies are considered. All trade value is converted to USD 2016.

other economies that it was withdrawing its support (MFATNZ, 2018). This prompted the remaining 11 members to shift to the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), which closely follows the original TPP. Trade ministers signed this agreement in March 2018. As of November 2018, seven economies had ratified the agreement (NZ, 2018).

Other subregional trade agreements that cover portions of the APEC membership, and eliminate or reduce tariffs on fossil fuel trade, include the ASEAN (Association of Southeast Asian Nations) Free Trade Agreement (AFTA),[39] the Pacific Alliance,[40] and the North American Free Trade Agreement (NAFTA).[41] Most APEC members also have bilateral agreements with other economies.

To explore the potential implications of the energy transition in APEC economies, the 7th edition of the APEC Energy Demand and Supply Outlook examines three scenarios (Table 1.4). The Business-as-Usual (BAU) Scenario is based on key energy demand and supply assumptions that reflect current trends and relevant polices already in place or planned. It provides a baseline against which other scenarios can be compared.

To investigate how specific targets or goals might be achieved, two alternatives analyse different possible trajectories. The Target (TGT) Scenario is modelled to support the APEC region's two aspirational (and non-binding) goals, set by APEC Ministers and Leaders, to: a) reduce energy intensity by 45% by 2035 (from the 2005 level); and b) double the share of renewables in the region's energy mix, including in power generation, by 2030 (from the 2010 level). The 2 Degrees Celsius (2DC) Scenario is the most ambitious of the three scenarios in terms of further reducing energy intensity, expanding renewables deployment and curbing carbon dioxide (CO_2) emissions. The modelling for the 2DC is underpinned by targets for energy sector emissions reductions that, in unison with worldwide efforts, are sufficient to give a 50% chance of limiting the global average temperature increase to 2°C by 2050. Further details on the methodologies used and assumptions made in these scenarios can be found in Chapter 5 (APEC Target), Chapter 6 (2DC) and Annex I. From a trade perspective, these two alternative scenarios are useful for highlighting the opportunities and risks for APEC trade flows if the region attempts to meet its aspirational goals and to limit the impact of energy-related emissions on global warming.

RISING DEMAND COULD BOOST ENERGY TRADE AMONG APEC ECONOMIES

Under the Business-as-Usual (BAU) and APEC Target (TGT) Scenarios examined in this *Outlook*, APEC continues to be a net energy importer throughout the projection period (2016-50) (Figure 9.2). In the 2DC Scenario, it becomes a net exporter in 2026. Crude oil continues to dominate net energy imports, as very few APEC economies are able to produce crude oil in volumes large enough to support extensive net crude oil exports on a net basis[42]. Historically, APEC members have relied on the Middle East and North Africa (MENA)[43] region to meet their crude oil demand, a relationship that will likely continue over the Outlook period. In contrast, APEC economies produce enough coal and natural gas to meet demand within the region, indicating strong opportunities to increase intra-APEC trade.

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[39] Seven APEC members—Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore, Thailand and Viet Nam—are signatories to the ASEAN Free Trade Agreement (AFTA).

[40] Three APEC members—Chile, Peru and Mexico—are signatories of this Latin American commercial agreement, which also includes Colombia.

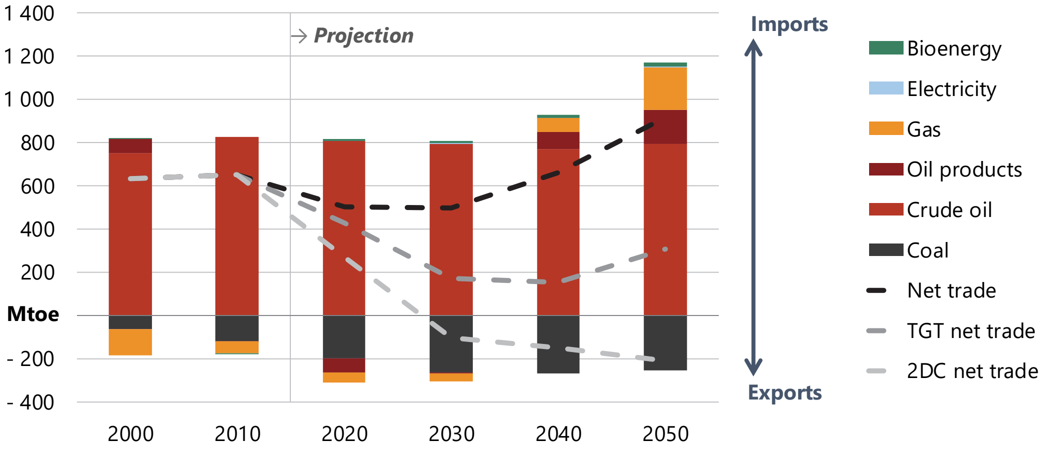
[41] Canada, Mexico and the United State were signatories to the North American Free Trade Agreement (NAFTA). In 2018, the signatories formed a new agreement, the United States-Mexico-Canada Agreement (USMCA), to replace NAFTA. The new agreement targets dairy and automotive industries and introduces updated intellectual property protections, among other modifications.

[42] The exceptions are Russia, Mexico and Canada. While the United States has extensive crude oil exports it remains a net crude oil importer both now and over the Outlook period.

[43] The World Bank classification of MENA includes: Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, the West Bank and Gaza, Qatar, Saudi Arabia, Syria, Tunisia, the United Arab Emirates and Yemen (World Bank, 2018).

In the BAU, fossil fuel production in APEC increases by 13% (from 6 429 million tonnes of oil equivalent [Mtoe] in 2016 to 7 294 Mtoe in 2050) in parallel with a 13% increase in primary energy supply of fossil fuels[44]. Net imports of crude oil decrease marginally over the same period, from 799 Mtoe to 792 Mtoe. While APEC natural gas net exports accounted for 34 Mtoe in 2016, APEC turns into a natural gas net importer in 2033, and then net imports grow fast, reaching 195 Mtoe by 2050. However, coal dominates fossil fuel exports, as net exports increase by 52% over the Outlook period up to 255 Mtoe.

Figure 9.2 • APEC net energy imports in the BAU, TGT and 2DC, 2000-50



Sources: IEA (2018a) and APERC analysis.

TRADE POTENTIAL STILL LIES WITHIN FOSSIL FUELS

Excluding oil products, total import value for fossil fuels in APEC reaches USD 1.5 trillion (2016 dollars) in 2050 in the BAU, almost tripling from USD 0.55 trillion in 2016. Crude oil contributes 74% of that total fossil fuel import value, followed by natural gas (22%) and coal (4.4%). The import value drops 26% to USD 1.1 trillion by 2050 under the TGT and further to USD 0.81 trillion under the 2DC, 47% lower than the BAU. In the 2DC, the value of coal imports is USD 18 billion in 2050, only 38% of the USD 47 billion value in 2016, largely due to lower demand in the power sector.

Over the same period, the value for fossil fuel exports more than doubles from USD 290 billion to USD 733 billion in the BAU and is 10% lower, USD 657 billion, in the TGT. This increase reflects higher natural gas exports from APEC members, especially from major LNG producers including Australia, Russia and the United States. Higher crude oil and gas prices projections also factor into the export value increase. In the 2DC, the total export value in 2050 increases to only USD 622 billion, as the value of declining crude and coal exports outweighs a slight increase in natural gas exports.

CRUDE OIL CONTINUES TO BE A MAJOR IMPORT FOR MANY APEC MEMBERS

APEC economies imported 57% of their crude oil refinery intake in 2016, relying mainly on producers from the MENA region (Saudi Arabia, United Arab Emirates, and Kuwait, among others), a trend that continues in all scenarios. APEC crude oil imports decrease very slightly by 0.85%, from 1 407 Mtoe in 2016 to 1 396 Mtoe in

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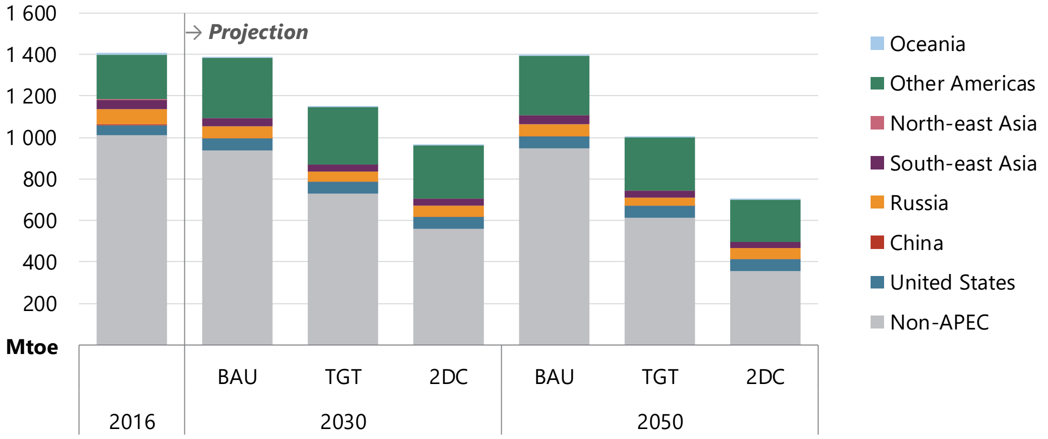
[44] Primary energy supply refers to all energy used in an economy including final energy demand and transformation.

2050. The 2DC projects the lowest crude oil imports among the three scenarios, shrinking to 703 Mtoe, compared with 1 006 Mtoe in the TGT and 1 396 Mtoe in the BAU by 2050.

To secure future crude oil export relationships, some major state-owned oil companies from the MENA region are already investing heavily in the downstream sector of some APEC economies. Saudi Aramco, for example, agreed in 2017 to buy a USD 7.0 billion stake in the PETRONAS Petrochemical Integrated Development project in Malaysia, which is expected to include 300 000 barrels per day (15 Mtoe per year) of refinery capacity (The National, 2018). Together with Indonesia's state-owned PT Pertamina, Saudi Aramco has also signed a Heads of Agreement to upgrade the Cilacap Refinery located in Central Java, with an investment of USD 5.5 billion (Saudi Aramco, 2018). Both developments are clear cases of Middle Eastern crude oil exporters deepening their relationships in the APEC region, particularly in south-east Asia, where oil demand is projected to grow significantly (by 92% in 2050).

Figure 9.3 • Total APEC crude oil imports by exporting region in the BAU, TGT and 2DC, 2016-50



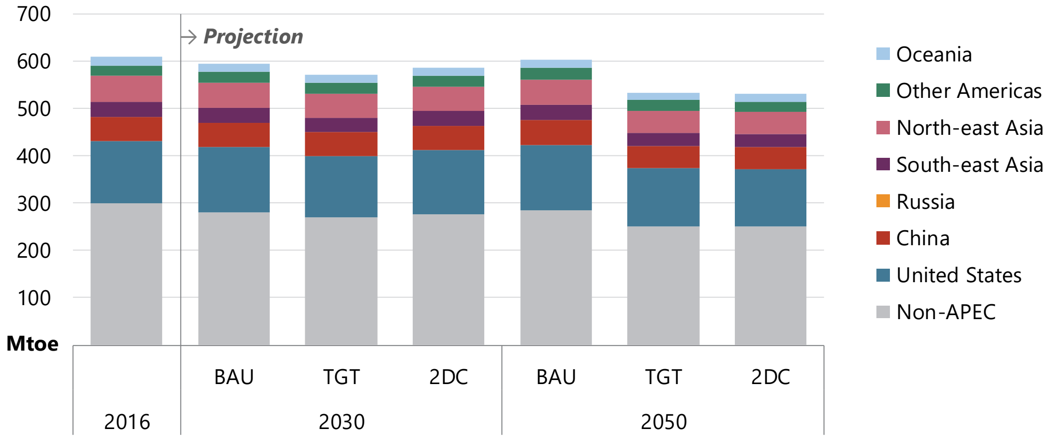
Sources: Sources: IEA (2018a), UN Comtrade (2018) and APERC analysis.

Starting in 2018, China becomes the biggest crude oil importer in APEC, and remains so for the projection period, reaching 456 Mtoe in 2050. Despite increasing shale oil production, the United States continues to be a net crude oil importer in all scenarios. However, its import volume declines substantially to 257 Mtoe by 2050 (from 437 Mtoe in 2016). The economy's sources for imported crude are already shifting away from the Organization of the Petroleum Exporting Countries (OPEC) members and towards Canada and Mexico. In 2010, the United States imported an average of 4.6 million barrels (bbl) per day (227 Mtoe) of oil from OPEC (49% of total crude imports); by 2017, imports from OPEC members were down to 3.1 bbl per day (155 Mtoe, 39% of total). Over the same period, oil imports from Canada increased from 2.0 million bbl per day (98 Mtoe, 21%) to 3.4 million bbl per day (172 Mtoe, 43%), with Canada alone surpassing OPEC as the primary US import supplier (EIA, 2018).

Within the APEC region, economies export 603 Mtoe of crude oil in 2050 in the BAU, 5.3 Mtoe less than in 2016. More than half (51%) of these crude oil exports are directed to other APEC members, for example Canada and Mexico are significant exporters to the USA and Russia to China. Crude oil exports from APEC economies to non-APEC economies are dominated by Russian exports to Europe. APEC crude oil exports decrease to 533 Mtoe by 2050 in the TGT and to 530 Mtoe in the 2DC, about 70 Mtoe lower than in the BAU.

Oil exports from Canada to the United States increase under the BAU until 2030, highlighting challenges for Canada to diversify its export opportunities beyond the United States post-2030. Since many existing refineries in Asia are unable to process its heavy crude oil, Canada will probably need look for alternatives such as finding new markets or upgrading their refineries.

Figure 9.4 • Total APEC crude oil exports by importing region in the BAU, TGT and 2DC, 2016-50



Sources: Sources: IEA (2018a), UN Comtrade (2018) and APERC analysis.

NEW REFINERY CAPACITIES REDUCES GASOLINE IMPORT DEPENDENCY

Despite being a major net crude oil importer, APEC only imports a small proportion (3.2% of final energy demand in 2016) of its oil products in net terms. Some APEC economies that lack abundant crude oil resources (e.g. Japan, Korea and Singapore) have developed large refinery capacities to improve supply security. At present, all APEC members have oil refineries (with the exception of Hong Kong, China). As a consequence, the APEC region was in 2016 a net exporter of some oil products like diesel and jet fuel but a net importer of gasoline, liquefied petroleum gas (LPG) and other refined products, resulting in total net exports for oil products of 68 Mtoe in 2016.

In the BAU, total refinery capacity increases by 13% to 61 million bbl per day (3 031 Mtoe[45]) in 2050 and refineries run at an average utilisation rate of 90%. Despite this, net oil product exports decrease fast as demand outpaces growing refining production and APEC becomes an overall net oil products importer after 2035 (Figure 9.3). While the trends vary significantly by fuel, gasoline net imports decrease steadily until 2023, when they start growing through 2050, increasing more than sevenfold while LPG imports more than double.

With regard to imports, higher demand (up 12%) for oil products in transport drives growth, with a rise in oil product imports by 2050 as follows in the BAU: gasoline, 26%; diesel, 41%; LPG, 19%; and jet fuel, 17%. In the BAU, net imports for oil products in Australia, Mexico, and Viet Nam lead growth in the region and reach approximately over 40 Mtoe in each economy, driven mainly by rapid demand growth in the transport sector for diesel and gasoline.

In the TGT, while APEC net oil product exports decrease at a slower pace than in the BAU, APEC also becomes a net oil products importer in 2049 as increased adoption of advanced-fuel vehicles reduces overall demand (see Chapter 5). Unlike the other scenarios, in the 2DC, APEC remains a net oil products exporter by 2050, as decarbonisation efforts reduce global demand for fossil fuels.

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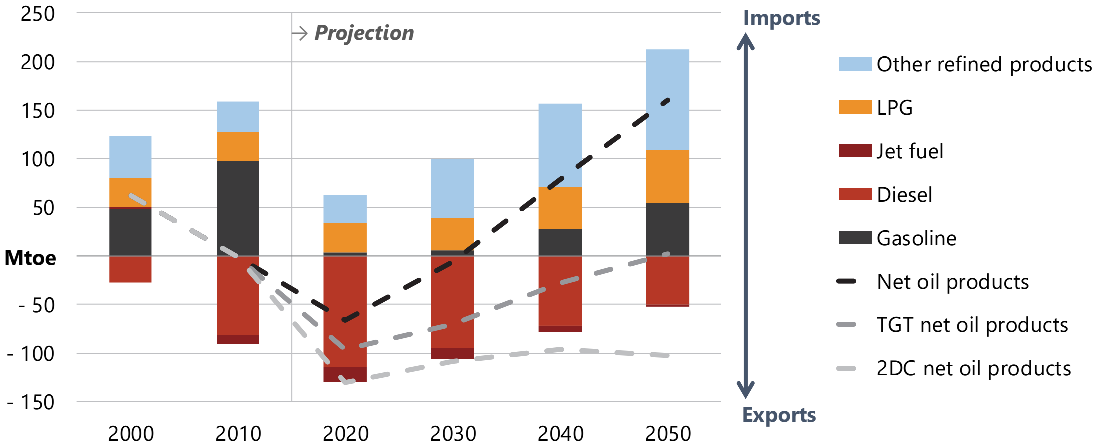
[45] Using 7.33 barrels per tonne (BP, 2018)

Figure 9.5 • Net oil product imports in BAU versus TGT and 2DC, 2000-50



Note: LPG = liquefied petroleum gas.
Sources: IEA (2018a) and APERC analysis.

GAS TRADE CONTINUES GROWING IN APEC, DRIVEN MAINLY BY BOOMING LNG IMPORTS TO CHINA

Although most (71%) of the natural gas produced in the world is consumed domestically, some 933 Mtoe were exported in 2016 (IEA, 2018a). In fact, traded gas volumes grew by 73% from 2000 to 2016 (IEA, 2018b). In 2016, LNG represented about 30% of total traded natural gas volumes, while 70% was exchanged via pipeline and a negligible share by truck.

These trends were quite similar in APEC, where 76% of total natural gas production was used domestically in 2016 and only 24% (416 Mtoe) was exported. In 2016, the United States was the world's largest gas producer and consumer in the region, and while Russia was second in both production in consumption, it remained the global largest gas exporter (IEA, 2018a). The APEC region has some of the most active gas trade dynamics in the world, including three of the top five world exporters (Russia, the United States and Canada) and three of the top five world importers (Japan, China and the United States) (IEA, 2018a). APEC as a whole is a natural gas net exporter; 70% of gas exports were piped while the remainder was LNG. On the natural gas imports side, by contrast, 47% was piped and 53% was LNG in 2016 (Figure 9.6).

Among the 21 APEC members, 9 economies are currently net natural gas exporters, 9 are net importers and 3 do not trade gas (New Zealand, the Philippines and Viet Nam).[46] The Philippines and Viet Nam are projected to begin imports of LNG in the coming years as increased demand for power generation pushes up domestic natural gas demand; in the Philippines, the rise in domestic demand occurs in tandem with declining production.[47] Natural gas imports have grown by 94% in APEC since 2000, reaching 382 Mtoe in 2016, with LNG growing almost two times faster than piped imports. In the same period APEC's natural gas exports grew by 30%, and while LNG exports grew by 80%, the majority of gas exports are still done via pipeline. Japan was the largest natural gas and LNG importer in the world in 2016, accounting alone for 49% of LNG imports in APEC and 31% globally (IEA, 2018a).

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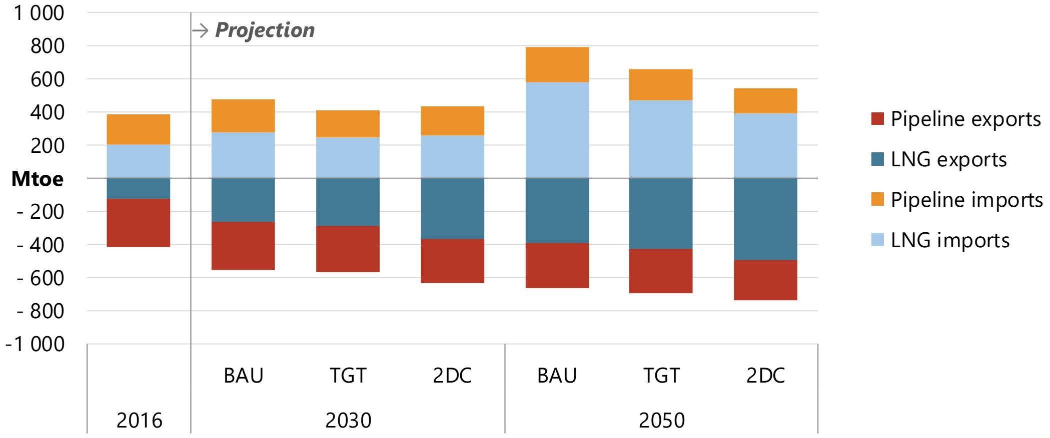
[46] The 9 APEC economies that are gas net exporter economies are: Australia, Brunei Darussalam, Canada, Indonesia, Malaysia, Papua New Guinea, Peru, Russia and the United States. The 9 net importers are: Chile; China; Hong Kong, China; Japan; Korea; Mexico; Singapore; Chinese Taipei; and Thailand.

[47] In the case of Viet Nam, natural gas production is highly sensitive to gross domestic products (GDP) assumptions; hence, any adjustment could substantially affect natural gas trade patterns in this economy (see Annex 1 for more details).

Natural gas exports in APEC have also grown since 2000, reaching 416 Mtoe in 2016, of which 291 Mtoe was piped and 125 Mtoe was via LNG. Accounting for 42% (175 Mtoe) of these volumes in 2016, Russia was the world's top natural gas exporter (IEA, 2018b). The Yamal LNG terminal in the Arctic region started operations in December 2017, adding export capacity to the extensive natural gas pipeline infrastructure that connects Europe and Russia. Canada, which sends virtually all of its natural gas exports to the United States via pipeline, shows a decline to 69 Mtoe exported in 2016 compared with 87 Mtoe in 2005. In parallel, the United States more than doubled its natural gas exports from 2010 to 2016, mainly via pipeline to Mexico (See Box 20.1, 'United States: Soaring Gas Exports' in Volume 2, Chapter 20 coupled with fast-growing LNG exports. Australia more than doubled its LNG exports since 2010, reaching 43 Mtoe in 2016. South-east Asia, which includes other traditional LNG exporters in APEC (e.g. Indonesia, Malaysia and Brunei Darussalam), decreased its natural gas exports by 14% from 2005 to 2016. During the last decade, Peru and Papua New Guinea emerged as new LNG exporters, delivering mostly to other APEC economies (to Mexico from Peru and to Japan from Papua New Guinea).

In the BAU, natural gas trade in APEC continues to grow, with exports rising by 60% and imports by 126%. APEC as a region becomes a natural gas net importer by 2033, indicating increasing natural gas demand and trade intensification. LNG imports are projected to play a major role within APEC, growing robustly and almost tripling by 2050, accounting for 67% of total natural gas volumes imported in 2050. Yet an ongoing oversupply of LNG markets is projected to continue until at least 2023 (IEA, 2018b). However, if there are no major investments on liquefaction capacity in the next five years as LNG demand continues growing, LNG trade will most likely face tightness and volatility after 2023.

Figure 9.6 • APEC pipeline and LNG imports and exports in the BAU, TGT and 2DC, 2016-50



Sources: Cedigaz (2018), IEA (2018b) and APERC analysis.

In the BAU, China's natural gas imports grow at 5.6% compound annual growth rate (CAGR) and increase more than sixfold by 2050, with about 74% of these volumes coming via LNG. Japan remains a key LNG importer, even though its imports decrease by 17% from 2016 to 2050, as some nuclear reactors for baseload power generation restart operation and gas demand follows the economy's demographic trends. Chinese Taipei, Japan and Korea share at least 3 factors that impact directly their demand for gas imports: the totality of their imports are via LNG; gas is a key fuel for power generation; and there is relative uncertainty on their nuclear policy for power generation. Despite this, Korea's imports more than double by 2050, while Chinese Taipei's imports grow by 18% by 2030 but then decline towards the end of the Outlook. Thailand's natural gas demand more than doubles from 2016 to 2050 (from 12 Mtoe to 25 Mtoe), serving as the main driver for south-east Asia's transition to becoming a natural gas net importer by 2035. Mexico's imports grow by 90% (from 36 Mtoe to 67 Mtoe), making it the fourth-largest natural gas importer in APEC in 2050.

Under the TGT, natural gas exports are 4.0% (27 Mtoe) higher and imports are 24% (205 Mtoe) lower than in the BAU. Most of the import reduction is attributed to the United States (71 Mtoe lower than the BAU) and China (57 Mtoe) due to reduced demand from electricity generation and buildings. Lower imports in Korea (18 Mtoe) and Japan (16 Mtoe) are driven mainly by lower demand in power generation.

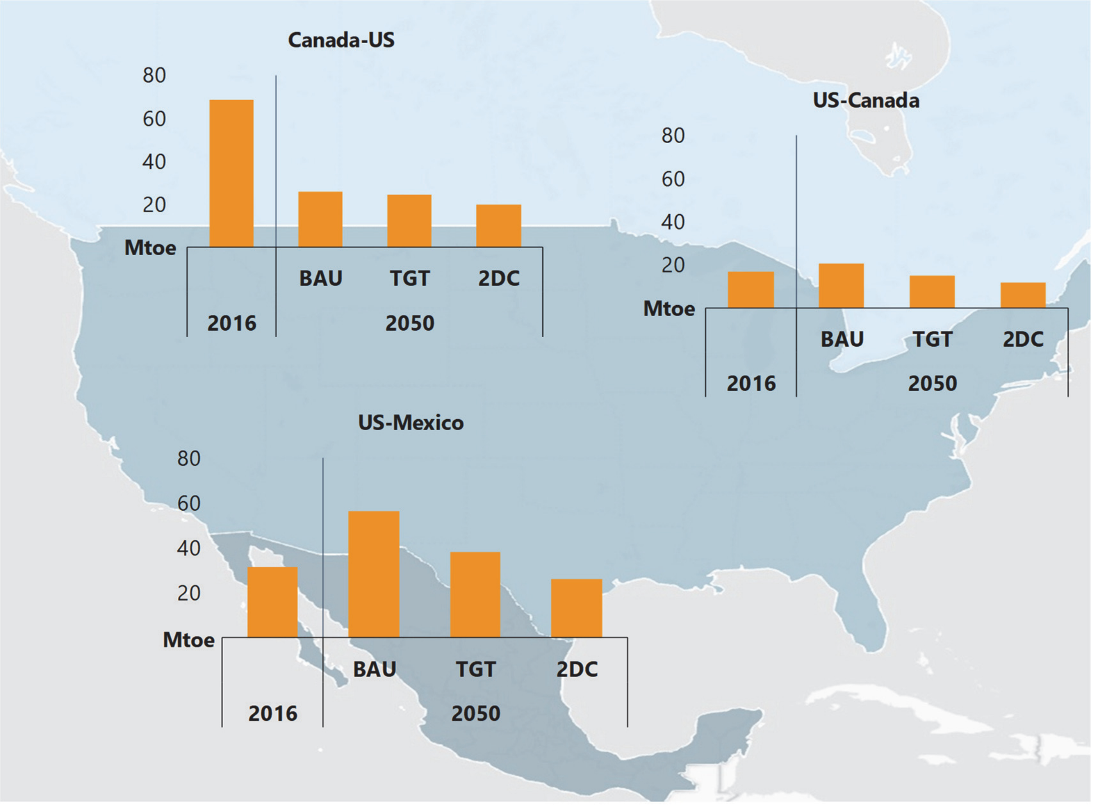
The 2DC provides the biggest opportunity for APEC economies to export natural gas outside the region, with exports increasing 11% (72 Mtoe) over the BAU by 2050. Only one-third of natural gas exports are channelled via pipelines, mainly between Russia and Europe; Russia and China; and Canada, the United States and Mexico. In this scenario LNG exports from the United States reach 244 Mtoe in 2050, almost two times the equivalent of total APEC LNG exports in 2016.

PIPELINE NATURAL GAS TRADE LED BY RUSSIA

Russia remains the leading natural gas exporter in APEC in the BAU, with its piped export volume growing 3.0% through 2050 to reach 168 Mtoe. Upon completion of the Power of Siberia pipeline (currently under construction and expected to be fully operational by 2020 with a maximum export capacity of 36 billion cubic metres [bcm] per year [32 Mtoe]), sizeable volumes of Russian piped natural gas are expected to go to China (Gazprom, 2019).

In the United States, piped natural gas exports grow to 77 Mtoe by 2050 in the BAU, even as the economy imports 26 Mtoe of natural gas (almost entirely via pipeline from Canada). As a result, net pipeline gas exports from the United States are projected to be 51 Mtoe in 2050. While robust demand growth in Mexico and the increasingly interconnected pipeline network can further strengthen this flow, US LNG exports grow faster than piped exports, driven by strong LNG demand from Asian importers, which may offer more attractive prices.

Figure 9.7 • North American pipeline natural gas trade in the BAU, TGT and 2DC, 2016 and 2050



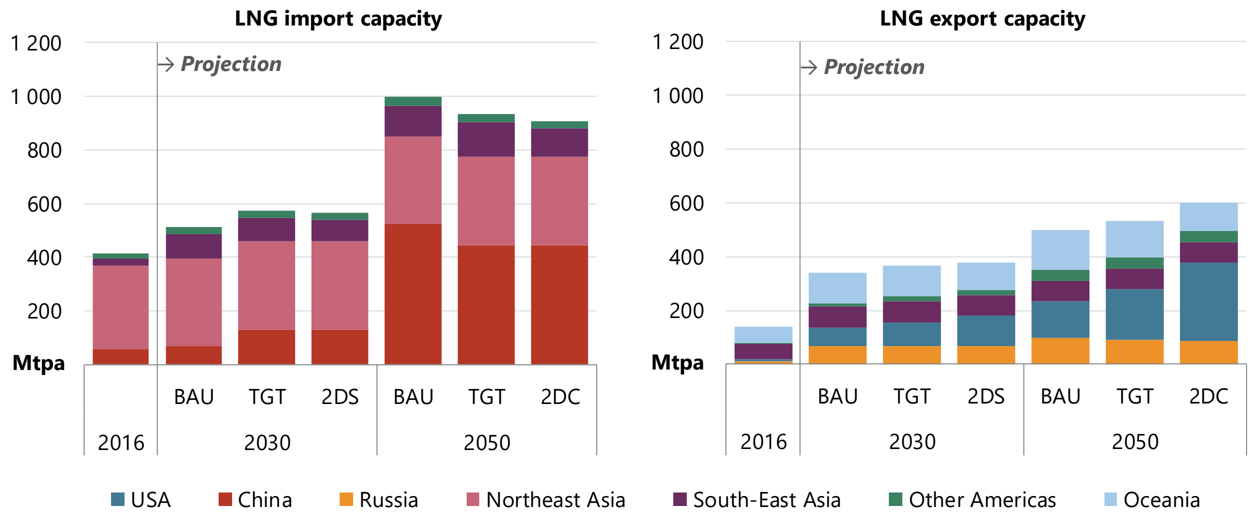
Sources: Cedigaz (2018) and APERC analysis.

APEC LNG TRADE EXPANDS IN ALL SCENARIOS, DRIVEN BY GROWING CHINESE IMPORTS

LNG trade in APEC increases across all scenarios. Historically, APEC LNG exports were dominated by south-east Asia (Indonesia, Malaysia and Brunei-Darussalam) and Australia sending natural gas to traditional north-east Asian importers such as Japan, Korea and Chinese Taipei. With a 60% increase in Australian LNG exports since 2000 and the arrival of significant new LNG exporters in the APEC region in recent years, such as the United States and Russia (as well as smaller ones such as Peru and Papua New Guinea), trade patterns have become more diversified. Moreover, on the demand side, LNG imports from China grow at a booming 7.0% CAGR, reaching 278 Mtoe by 2050. Additionally, relatively recent LNG importers such as Thailand, Mexico, and Chile, and soon-to-be importers such as the Philippines and Viet Nam, further contribute to the diversification of LNG trade in APEC.

By 2030, the majority of natural gas exports in APEC come from Oceania (mainly Australia but also PNG) and the United States, where at least 200 bcm (180 Mtoe) of liquefaction capacity begins operation between 2020 and 2025. This capacity expansion is led by the United States and Australia, as new export facilities become operational by 2022. Australia, the United States and Qatar are projected to become the world's three largest LNG exporters (IEA, 2018b). By 2050, the United States becomes the largest LNG exporter in the APEC region with an impressive 11% CAGR (a cumulative increase of 118 Mtoe) over the Outlook period. While Australia loses its position as the largest LNG exporter in APEC, exports more than double to 103 Mtoe in 2050, followed closely by Russian LNG exports which grow at a 6.4% CAGR over the Outlook period to reach 102 Mtoe. These three economies combined account for 83% of APEC LNG exports by 2050.

Figure 9.8 • APEC LNG import and export capacity by region in the BAU, TGT and 2DC, 2016-50


LNG import capacity

LNG export capacity

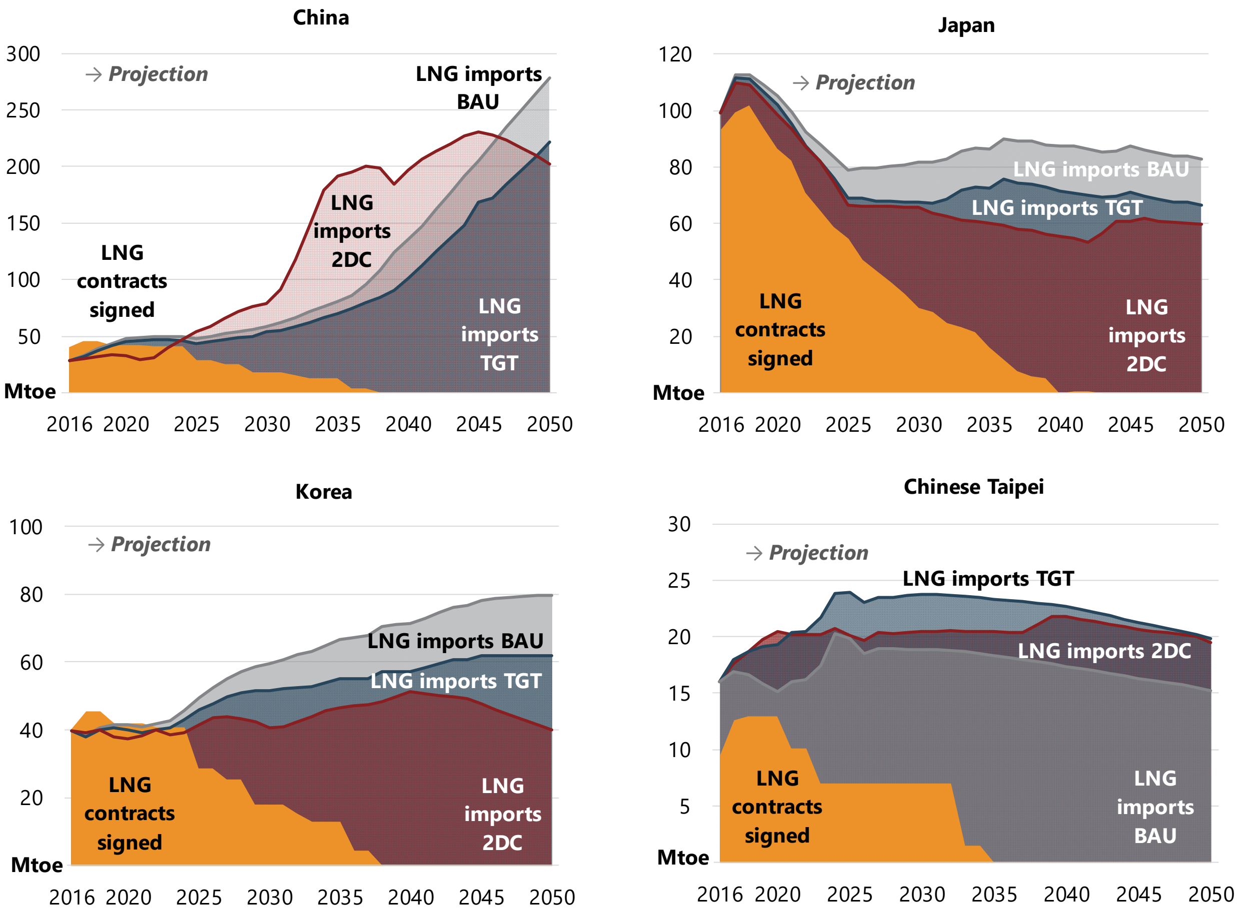
Notes: Mtpa = million tonnes per annum. LNG import capacity excludes the US capacity as the economy almost completely stops importing LNG after 2020.
Sources: Cedigaz (2018), IEA (2018a) and APERC analysis.

The competition between coal- and natural gas-fired power generation in south-east Asia will be a defining factor in future LNG markets. Relative prices of these fuels are expected to motivate investment decisions regarding the substantial development of LNG importing capacity at the expense of expanding coal-fired capacity.

APEC members are poised to remain key players in global LNG markets as demand for imports grows in China and other developing economies as supply increases from rapid growing exporters like Australia, Russia and the

United States. Major LNG importers, such as Japan, Korea, China and Chinese Taipei, continue to rely on LNG imports in all scenarios. However, current commitments via medium- and long-term contracts are insufficient to meet projected LNG demand in these economies. These gaps represent opportunities for LNG consumers and producers to collaborate on further development of LNG import and export terminals. Additionally, this provides a unique opportunity to new LNG exporters for more flexibility and competitiveness in LNG markets, particularly in Asia.

Figure 9.9 • Selected LNG supply contracts and import gaps in the BAU, TGT and 2DC, 2016-50



Sources: GIIGNL (2018) and APERC analysis.

LOWER COAL DEMAND WITHIN APEC CREATES OPPORTUNITY FOR NON-APEC EXPORTS

Falling coal demand within APEC creates an opportunity to increase exports of this fuel to other regions. In evaluating the potential for future coal exports, this Outlook considers recent information on coal production, trade and government policies in APEC, the latter of which are summarised in Table 9.1.

Under the BAU, coal demand declines in all APEC subregions except for south-east Asia. As economies such as Russia and Viet Nam expand domestic coal production, APEC net coal exports increase from 169 Mtoe in 2016 to 255 Mtoe in 2050. Large coal users beyond APEC, such as India, which plans to increase local production to reduce imports (IEA, 2017b), could affect market dynamics, resulting in an increasingly competitive environment for future coal trade.

Table 9.1 • Examples of key policy interventions on coal supply and trade (as of December 2017)

Economy	Latest policy developments
Australia	• Exports of metallurgical coal continues, mainly to Asia-Pacific economies, China, Chinese Taipei, Japan, Korea and India.
Canada	• In November 2016, plans were announced to shut down coal plants and make electricity 90% non-CO_2 emitting by 2030. • Metallurgical coal production continues until 2050, mainly for export; production of thermal coal gradually ceases.

China	• China's 13th Five-Year Plan (2016-20) and other policies set specific targets:
	  • Restrict coal resource development in the east of the economy
	  • Reduce coal consumption to less than 58% of energy consumption in 2020, compared with 64% in 2015
	  • Eliminate 500 million tonnes (Mt) of coal mining capacity and recombine 500 Mt of capacity in three to five years starting in 2016

Indonesia	• Prioritising the domestic market leads to a decline in coal exports; gradually implement plans to cap production at 400 Mt per year.
Russia	• Draft of *Russia's Energy Strategy 2035* encourages companies to make full use of domestically available energy and to expand energy exports, including coal, to the Pacific region.
Thailand	• The largest coal mine (Mae Moh) will continue to produce lignite as the associated power plant undergoes an upgrade, comprising replacement of generators 4 through 7 (from 600 megawatts [MW] to 656 MW) in November 2018 (EGAT, 2015). • Shift to importing different types of coal for the upgraded power plant.
United States	• In April 2017, the Environmental Protection Agency (EPA) announced it would review the Clean Power Plan and consider proceedings to suspend, revise or rescind it. In October 2017, the EPA formally submitted a proposal to terminate the Clean Power Plan. • On 1 June 2017, President Trump announced his intention to withdraw the United States from the COP21 Paris Agreement.
Viet Nam	• In 2015, the Coal Master Plan set strategies for 2025-30, including successively increasing coal production as follows: 41 Mt to 44 Mt in 2016; 47 Mt to 50 Mt in 2020; 51 Mt to 54 Mt in 2025; and 55 Mt to 57 Mt in 2030. • In parallel, gradually reduce coal exports.

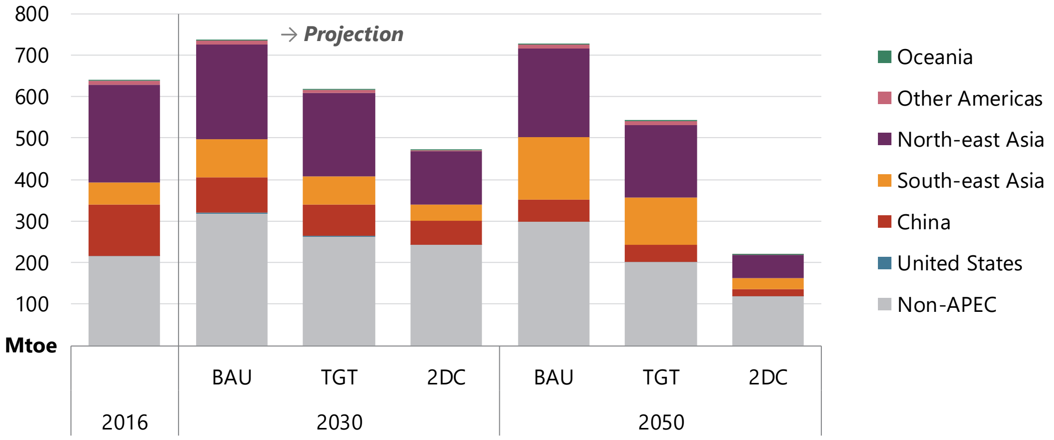
Source: APERC (2018).

AUSTRALIA CONTINUES TO LEAD COAL EXPORTS IN APEC

In the BAU, total coal exports grow by 14%, from 638 Mtoe in 2016 to 726 Mtoe in 2050. Australia remains the largest coal exporter in the APEC region, with growth in thermal coal exports (from 121 Mtoe in 2016 to 190 Mtoe in 2050), offsetting a gradual decrease in its metallurgical coal production (from 127 Mtoe to 93 Mtoe) in line with falling demand from major importers (such as China) and flat demand from other importers (such as Japan, Korea and Chinese Taipei) (IEA, 2017a). Indonesian coal exports peak in 2025, and then then decline as domestic demand more than triples by 2050, outpacing coal production growth. APEC coal exports to non-APEC members (mainly India) grow by 39% in the BAU.

In contrast to the BAU, APEC coal exports decrease by 15% by 2050 under the TGT, with notable declines in Australia (14%) and Indonesia (10%). This reflects lower demand from major coal importers such as Japan, China, Korea and Chinese Taipei. The 2DC projects a very significant departure from the BAU, with coal exports shrinking by 66% to 219 Mtoe in 2050.

Figure 9.10 • APEC coal exports by destination in the BAU, TGT and 2DC, 2016-50



Sources: IEA (2018a), UN Comtrade (2018) and APERC analysis.

COAL IMPORTS INCREASE SLIGHTLY OWING TO GROWING DEMAND IN SOUTH-EAST ASIA

In the BAU, total APEC coal imports increase very slightly to 471 Mtoe in 2050, a 0.16% rise from 2016 levels. Lower demand in China, Japan, and Korea drives this decline and offsets growing imports in south-east Asia (particularly in Malaysia, the Philippines and Thailand). Under the TGT, coal imports decrease in 2050 to 386 Mtoe, 18% lower than in the BAU, with Japan and Chinese Taipei accounting for nearly 46% of the reduction. The 2DC shows a much deeper cut of 73% in coal imports, with around 80% of the reduction driven by reductions in coal demand in five economies: Chinese Taipei, Japan, Korea, the Philippines and Thailand.

SIGNIFICANT OPPORTUNITIES TO INCREASE CLEANER FUEL TRADE IN APEC

In keeping with APEC and global clean energy transition targets, this Outlook explores opportunities and challenges for the trade of cleaner fuels and energy carriers such as hydrogen, bioenergy and electricity. For more information on hydrogen demand and supply, please refer to Box 2.1, 'Use of hydrogen in APEC' (Chapter 2) and Box 3.2, 'Natural gas and renewables and natural gas used to meet hydrogen demand' (Chapter 3); additional insights on electricity trade are found in Chapter 4.

ELECTRICITY TRADE CAN SUPPORT RELIABLE, LOW-CARBON SUPPLIES

Electricity is already traded within and across several APEC subregions and economies (Figure 9.11). In 2016, cross-border electricity transmission was particularly active in North America, where Canada continued its role as a net exporter, moving hydro power to the United States (to New England, New York and several states in the Midwest and the Western United States) (NEB, 2018). In south-east Asia, Thailand has been expanding imports from Laostap into abundant hydro resources. Cross-boundary transmission lines also exist between China and Hong Kong, China (with the latter relying on China's Daya Bay Nuclear Power Plant for 25% of current electricity demand), and between China and Russia (connecting the Heilongjiang province and Far Eastern Federal District in Russia). China's transmission company, State Grid Corporation of China, signed a contract to import 100 terawatt-hours (TWh) from Russia by 2036, although low electricity tariffs in Heilongjiang pose profitability challenges for the Russian supplier (OIES, 2016).

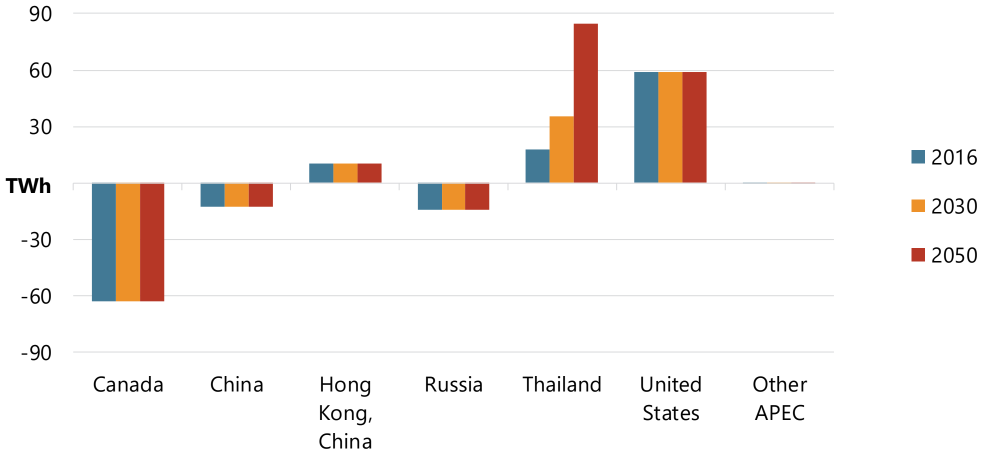
Projected electricity trade under the BAU and TGT Scenarios (Figure 9.11) is based on committed projects and government plans. Three projects warrant specific mention. From 2020, Canada exports hydro power to the New

England grid through the Northern Pass Transmission project.[48] Hong Kong, China plans to purchase electricity from new nuclear reactors being built in China (the Yangjiang Nuclear Power Plant). Thailand's Power Development Plan 2015 aims to expand power imports from Laos. In addition to these projects, the 2DC assumes that Hong Kong, China and Singapore accelerate imports of low-carbon electricity to support decarbonisation.

Under ASEAN Vision 2020, adopted in 1997, economies in the region have been cooperating to realise the ASEAN Power Grid (APG), which consists of 16 cross-border transmission line projects (ACE, 2017). Despite this ambition, the BAU and TGT Scenarios show only modest electricity trade in the region, using existing lines and those under construction in 2018. To quantify the potential impacts of the APG, the Asia Pacific Energy Research Centre (APERC) conducted a supplemental study on this power grid project (Box 4.1, 'Impacts of integrating power grids in the ASEAN region in Chapter 4).

The Fukushima Daiichi nuclear accident in Japan and China's Belt and Road Initiative have triggered discussions about a super-grid in north-east Asia to integrate renewables. In 2016, relevant organisations, including transmission companies in China, Korea and Russia, signed a Memorandum of Understanding to promote grid interconnections. This project is not included in this Outlook, due to existing economic, institutional and political challenges as well as other uncertainties.[49]

Figure 9.11 • Net electricity imports in the BAU and TGT, 2016-50



Notes: Other APEC includes Chile, Indonesia, Malaysia, Mexico and Peru.
Source: IEA (2018a).

HYDROGEN OFFERS TRADE OPPORTUNITIES FOR BOTH IMPORTERS AND EXPORTERS

This Outlook assumes across all scenarios that some APEC economies strive to use hydrogen. To meet demand, some economies produce hydrogen domestically (using natural gas or renewables) and rely on imports to fill any demand gap. Japan, for example, is projected to increase its hydrogen production by more than 250 times in the BAU, from 0.0065 Mtoe in 2016 to 1.6 Mtoe in 2050, mostly through the use of solar photovoltaic (PV) and, to a lesser extent, natural gas. Since demand growth (from 0.0065 Mtoe in 2016 to 2.2 Mtoe in 2050) surpasses expansion of domestic production, Japan would need to import hydrogen from other producers. Across scenarios, APEC is a net importer of hydrogen over the Outlook period, driven by China, Japan and to a lesser extent Korea.

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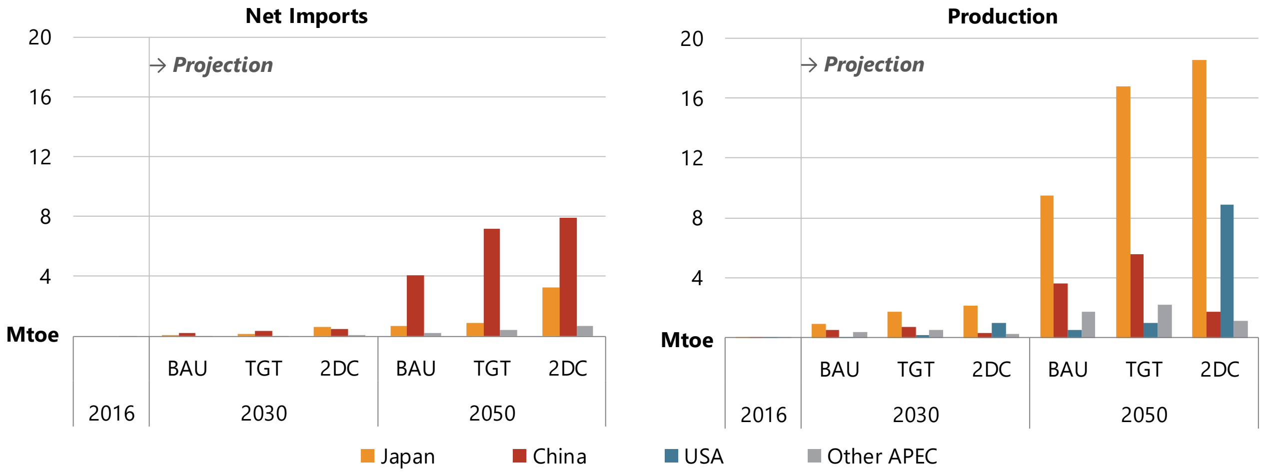
[48] This project has recently encountered obstacles to its construction, representing a significant uncertainty in the analysis presented in this Outlook (GreenTech Media, 2018).

[49] As of April 2018, no agreements had been reached among governments in north-east Asia, such as China, Korea and Russia. Regarding challenges, the economic viability is investigated by Otsuki (2017).

Figure 9.12 • Hydrogen net imports and production in APEC by economy across scenario, 2016-50



Note: Excluding hydrogen use in refineries.
Source: APERC analysis.

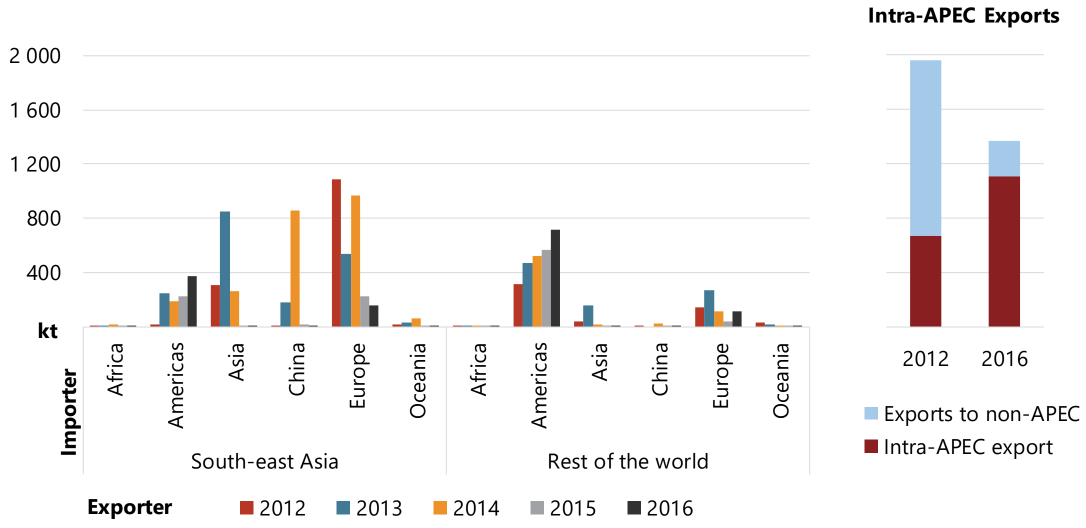
Australia and Chile show potential to export surplus hydrogen, either in the form of liquid hydrogen or ammonia, mainly to Asia and Europe. If future efforts to establish a robust global hydrogen economy succeed, most APEC members are well positioned to seize associated opportunities. Japan and Korea, for example, could be at the forefront of technology deployment (e.g. fuel cell batteries) because of current government support, including Japan's Basic Hydrogen Strategy and Korea's Plan to Supply Hydrogen to Vehicles & Market Activation (MOTIE, 2015; METI, 2017).

OPPORTUNITIES FOR BIOENERGY TRADE EXIST ACROSS APEC

In 2011, the APEC Energy Working Group, through the APEC Biofuels Task Force, produced a report, *Biofuel Transportation and Distribution Options for APEC Economies*. This report featured biofuels as an actively traded commodity, with Malaysia and Indonesia projected to become major biodiesel exporters in 2017 (APEC EWG, 2011). In 2016, biofuels trade almost hit the report's projections, but not without challenges. Recent data show that intra-APEC trade accounted for 81% of biodiesel exports in 2016, an increase from 34% in 2012 (UN Comtrade, 2018). By trade volume, however, biodiesel exported from APEC members decreased by 30%, from 1 959 kilotonnes (kt) in 2012 to 1 359 kt in 2016.

Although this Outlook does not explicitly model the potential for bioenergy trade, significant opportunity exists to expand biodiesel trade among APEC members if existing barriers can be overcome. Examples of existing barriers include the import and consumption taxes that China placed on imported biodiesel in 2014 to protect local refineries as well as Indonesia imposing taxes on biodiesel exports in 2017 (Reuters, 2014; Biodiesel Magazine, 2017). Other challenges include increasing attention, particularly by the European Union, on the sustainability of biodiesel feedstock, which has raised questions about palm oil sustainability in south-east Asia (European Parliament, 2017).

Figure 9.13 • Biodiesel exports among APEC members and to the global market, 2012-16



Sources: UN Comtrade (2018) and APERC analysis.

OPPORTUNITIES AND CHALLENGES

Energy trade among APEC economies presents several opportunities and challenges for both importers and exporters. While prices play a key role in many trade decisions, other factors are also quite relevant, such as supply source diversity, political stability, international agreements, trade barriers, and infrastructure, among others.

FILLING THE ENERGY DEMAND GAP WITH APEC RESOURCES

If expanded, intra-APEC trade could boost energy security both in individual economies and across the region. Considering that most APEC members, especially north-east Asian economies, are heavily dependent on crude oil from the MENA region, these economies could diversify their import sources to include more APEC suppliers. Large shale production by the United States and oil sands in Canada, as well as oil production in Russia, could boost energy trade—with higher stability—among APEC members.

For natural gas, LNG markets are currently oversupplied and projected to remain so. As production rises in the United States, Russia, Australia and other economies, LNG prices in Asia are expected to remain competitive. These conditions create a prime opportunity for APEC economies, particularly in south-east Asia, to increase their natural gas supplies through competitive LNG imports. A unique opportunity may exist for economies with low natural gas penetration, such as the Philippines and Viet Nam, to construct LNG regasification and increase use of natural gas from the APEC region.

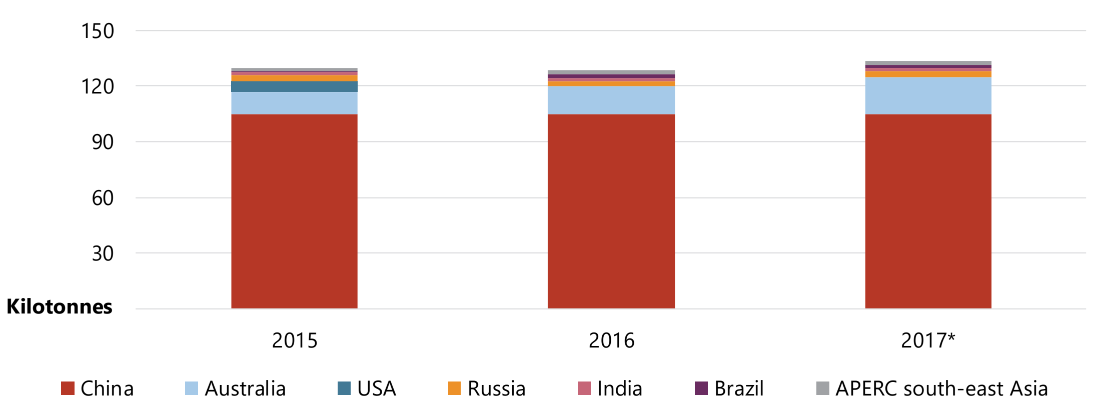
Some APEC economies that are already net importers of natural gas are projected to see demand increase over the next 35 years, particularly China, Korea and Mexico. This represents an opportunity for APEC natural gas net exporters to bolster intra-regional trade. With demand from traditional destinations declining—e.g. Russia to Europe and Canada to the United States—finding new markets will be a key challenge for natural gas exporters. Several APEC economies could mutually benefit from intra-regional trade.

As was also projected in the 6th Edition of the *Outlook*, south-east Asia sees significant growth in production, use and trade of coal. By focusing policy on support for more efficient coal generation technologies (e.g. ultra-supercritical, which has already been deployed in Malaysia), governments in this region could decrease both domestic consumption of coal resources and import dependence.

Box 9.1 • Rare earth elements trade: A major component in advancing clean energy

Rare earth elements are used in many sectors including energy, defence and electronics. In the energy sector, they are vital components of lithium-ion batteries, solar panels, wind turbines and other applications (DOE, 2017). In turn, production and trade of these elements are gaining attention in the energy industry. In 2017, global production of rare earth elements reached 134 kt, with the vast majority (97%) being produced in APEC. China alone was responsible for 79%, with much lower shares being produced in Australia (15%) and Russia (2.2%) (USGS, 2018).

Figure 9.14 • Global rare earth elements production, 2015-17



Note: * = estimates.
Sources: USGS (2018) and APERC analysis.

EXPANDING TRADE ROUTES CAN FACILITATE HIGHER TRADE VOLUME

The Straits of Malacca are one of the busiest sea lanes for global trade. The Mandatory Ship Reporting System in the Straits of Malacca and Singapore (STRAITREP) estimates that 84 456 vessels passed through in 2017, of which 37% were energy carriers (MMD, 2018). Projected higher vessel traffic may cause the Straits of Malacca to become saturated in the future, in which case energy importers may diversify trade routes or partners (if possible) for security and supply reasons.

The expansion of the Panama Canal (completed in 2016) and a 2018 regulation allowing the transit up to four LNG vessels per day may also help to improve intra-APEC energy trade. As the canal now supports transit of the Neopanamax class vessels, including LNG tankers, new opportunities exist to export energy from the Atlantic Rim to the Pacific Rim and to increase the energy related transits in this canal. By comparison, of 10 590 transits through the expanded Panama Canal between October 2017 and June 2018, just 14% were energy carriers; however, LNG vessels crossings increased almost doubled from 2017 to 2018 (Pancanal, 2018).

The melting of the Arctic sea ice due to global climate change may provide opportunities for economies located in the area, including the United States (Alaska), Canada, Russia, Norway, Denmark (Greenland), Iceland, Sweden and Finland, to expand their trade routes. Russia its taking advantage of this opportunity by developing the first major energy project in the Arctic region, the Yamal LNG export facility. With the Arctic sea ice melting, the length of time LNG tankers need to travel from Yamal to Japan would be cut by more than 50%: 16 days through the Arctic as opposed to 33 days going through Europe and the Straits of Malacca (Novatek, 2016). If massive LNG production is pursued in Alaska and northern Canada, the melting sea ice could also improve opportunities for the United States and Canada to export LNG to north-east Asia. However, environmental concerns and geopolitical issues regarding an increased use of the Arctic region, remain to be solved, limiting its opportunities for becoming a major viable trade route.

ADDRESSING TRADE BARRIERS AND STRENGTHENING REGIONAL AGREEMENTS

Several challenges could impede increased energy trade among APEC economies. Trade barriers, such as import and export taxes, have been one of the main contentious issues. Recent efforts by parties to the CPTPP, which not includes the United States (as of March 2019), seek to ensure that signatories have virtually the same opportunities as in the previously proposed TPP (ATC, 2017).

Subregional agreements also highlight potential opportunities to reduce trade barriers in APEC. Under the AFTA, which covers only APEC-ASEAN economies, duties for energy imports have been brought down to the range of 0% to 5% (ASEAN, 2012). Expanding this initiative to all APEC members may have positive benefits for all economies.

INFRASTRUCTURE AND STANDARDS CAN SUPPORT TRADE

Infrastructure is the backbone of seamless energy trade. Coal ports, oil terminals, LNG receiving and exporting terminals, pipelines, and tankers are among the crucial infrastructure needed, all of which require large capital investments. To boost intra-APEC oil trade, large heavy oil producers (such as Canada) may consider adopting the MENA strategy of investing in upgrading refineries in Asia, essentially locking in the crude supply for a certain period.

Liquefaction and regasification terminals are indispensable for LNG trading, but the high initial investments required for developing such infrastructure can be a challenge for both exporters and importers. The LNG import terminal in the Philippines, initially slated for completion in 2014, has been delayed several times, as have others (PhilStar, 2017).

To support trade, APEC members should explore opportunities to share trade facilities or utilise tolling mechanisms to help reduce capital investment needs. This concept is not new to APEC members. Coal producers in the United States, for example, have been using Port Metro Vancouver, located in Canada, as the gateway for coal exports to Asia (OIES, 2015). This concept can also be applied to natural gas.

While the bio-refinery capacity in APEC is projected to grow from 72 Mtoe in 2016 to 105 Mtoe in 2050 in the BAU, some of these facilities are likely to be underutilised. Low utilisation rates present challenges to both ensuring facility maintenance and economic competitiveness. APEC could take this opportunity to boost biodiesel trade. In tandem with these efforts should be the development of appropriate standards and specifications.

TECHNOLOGY ADOPTION CAN DRIVE TRADE

Technology adoption can improve both demand and supply flexibility. Some APEC members (including Malaysia, Indonesia and China) have adopted floating storage regasification unit (FSRU) technology to provide greater flexibility than is available with stationary onshore LNG import terminals. This technology can be deployed nearer to demand centres, with the facility size built to suit local demand. If demand increases in the area, for instance, a bigger replacement unit can be installed while the original unit can be shifted to another demand centre.

On the supply side, economies with limited land (such as Singapore or Hong Kong, China), strong public opposition to having onshore terminals (such as New Zealand), and geographies that are largely archipelagic (such as Indonesia and the Philippines) may consider these types of offshore technologies to drive natural gas trade. Economies with already robust LNG infrastructure, such as China, Japan, Korea, Malaysia and Australia, may start or expand the use of FSRU to capitalise on its ability to be deployed nearer to demand centres. APEC has also been on the forefront of deploying floating LNG (FLNG) technology, with the first facility deployed in April 2017 by the Malaysian oil company PETRONAS and the Prelude FLNG to come online in Australia in 2019.

RECOMMENDATIONS FOR POLICY ACTION

Energy trade opportunities are abundant for APEC members. With the advantages of geographic proximity, fewer trade chokepoints and higher political stability, APEC members could capitalise on these strengths to improve energy trade relations through policies and partnerships. In order to do so, APEC economies need to improve coordination on trade harmonisation, standards and regulations. Removing trade barriers—without jeopardising economic security—should be a priority.

Economies should also explore ways to increase infrastructure and technology investments, as individual economies and in partnership with other APEC economies. An APEC-centred financing facility could be instrumental in providing financial assistance for infrastructure projects across the region.

In parallel, APEC economies should continue working together to share best practices and lessons learned, while also enhancing collaboration on low-carbon technology development and deployment to achieve the shared ambition of a clean energy transition. They should also support capacity building across all members.

As the world transitions towards cleaner energy, technological progress will help to accelerate the momentum. Cleaner energy alternatives to fossil fuels—including renewables, clean electricity and hydrogen—will be at the core of policies in many economies. As overall energy demand increases in the future, this will provide new trade opportunities for APEC members.

Finally, it is necessary that relevant stakeholders—particularly policymakers and government officials—to ensure stable and favourable conditions, such as the rule of law and robust institutions, are in place to develop and strengthen energy trade in the APEC region.

10. CLIMATE CHANGE POLICY

KEY FINDINGS

- **APEC Energy Ministers recognise that climate change will affect the region's energy security and the need to mitigate such impacts.** APEC leaders can support continued economic growth and improved regional sustainability by taking action to reduce greenhouse gas (GHG) emissions as soon as possible.

- **The signing of the COP21 Paris Agreement in 2015 was a historic moment for global commitment to climate action.** To meet the Agreement's commitments, climate change mitigation needs to be a long-term priority for governments, underpinned by short- and medium-term actionable targets designed to alter the current GHG emissions trajectory.

- **Given the long lifespan of energy sector assets the investment decisions made in the next decade will influence if the 2DC will be achieved and the associated costs.** Delaying action to reduce emissions will increase the cost of the transition and risk of emissions lock-in.

- **Economies will need to reach net-zero emissions as quickly as possible if global ambitions as set in the COP21 Paris Agreement are to be met.** Current policies are not enough to meet this goal. The sooner economies implement policies that shift their emissions curves to approach net zero, the better placed they will be to take advantage of strategic opportunities and to avoid facing costly challenges (e.g. large stranded assets).

- **Near-term policy opportunities include increasing energy efficiency through improved building codes, higher fuel economy standards in transport, and energy efficiency labelling for appliances and equipment.** Demand-side management programs (e.g. time-of-use pricing and educational programs) can decrease stress on the energy system, allowing economies to reduce costs, while also delivering emissions reduction.

INTRODUCTION

Major transitions are needed across the energy sector to achieve the ambition of a global low-carbon[50] economy. The energy sector is the largest contributor to man-made greenhouse gas (GHG) emissions, accounting for two-thirds of total emissions (IPCC, 2014). As shown in this Outlook, substantially more ambition is required on multiple fronts to mitigate the impacts of global climate change and establish a more sustainable energy system to support social and economic development across the Asia-Pacific Economic Cooperation (APEC) region.

APEC Energy Ministers, at their 9th Meeting (Fukui, Japan, in June 2010), focused discussion on the growing importance of energy efficiency and cleaner energy supplies as means to strengthen energy security, support economic growth and reduce carbon dioxide (CO_2) emissions (APEC EWG, 2018). APEC recognises the need to strengthen existing low-carbon policies and to introduce an even wider range of strategic policies. With the aim of tackling climate change through regional cooperation, APEC Energy Ministers specifically pledged to foster collaborative initiatives to boost deployment of renewable energy and reduce energy consumption, while also promoting ocean and forest conservation, encouraging trade of environmental goods, and helping farming and fishing communities adapt to changing weather patterns (APEC, 2017). In light of the region's growing fuel demands and the need to manage limited energy resources, as part of the 2012 St. Petersburg Declaration, APEC Energy Ministers established an updated framework on energy security, underscoring the importance of reducing energy demand while also deploying clean energy and nuclear technologies (APEC, 2012).

This Outlook, for the first time, presents a 2-Degrees Celsius (2DC) Scenario for the APEC energy sector, which is consistent with having at least a 50% chance of constraining the average global temperature rise to 2°C. The 2DC (as described in depth in Chapter 6) broadly follows sectoral carbon budgets as laid out in *Energy Technology Perspectives 2017*, published by the International Energy Agency (IEA, 2017a).

Further, this chapter examines the international efforts associated with the agreement reached during the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC), hereafter referred to as the COP21 Paris Agreement. The policy tools that some APEC economies have implemented to drive emissions reduction are examined along with reports from the nine APEC economies that participated in the Deep Decarbonization Pathways Project (DDPP) and the insights offered in relation to achieving the long-term need for a net-zero[51] economy. The last section of this chapter identifies the key policy actions needed to address the challenges—and capture the opportunities—inherent in the 2°C goal.

The 2DC Scenario projections in the *Outlook 7th Edition* show APEC's share of global emissions reducing from 64% in 2016 (the base year) to 56% by 2050, based on an assumption of global action to decarbonise the energy system (IEA, 2017a). This sets an APEC carbon budget in which energy-related emissions drop by at least 50%, from 21 $GtCO_2$ in 2016 to just 8.4 $GtCO_2$ in 2050 (Figure 10.1). Understanding the primary drivers of growing energy demand—and the resulting energy-related emissions—is crucial to ensuring APEC Leaders can make informed policy decisions to support this decarbonisation pathway.

Although the Outlook period extends to 2050, decisive shorter-term action is required to maximise the probability of staying within the carbon budget along with continued progress towards a net-zero economy post-2050. With a growing, urbanising population and increasingly industrialised economies, demand for energy is projected to rise dramatically (21% in BAU) in the APEC region. How the sector develops in response will have

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[50] References to "carbon" or "decarbonisation" refer to greenhouse gases (GHGs) including carbon dioxide (not elemental carbon).

[51] 'Net zero' carbon emissions is defined as balancing of total GHG emissions released with an equivalent amount of emissions sequestered.

significant impacts on environmental sustainability, making strategic action on climate change mitigation and adaptation crucial.

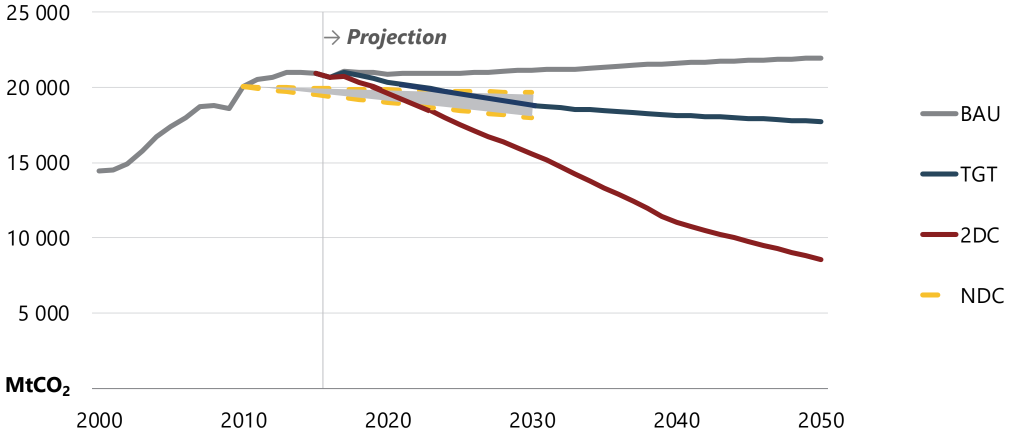
The 2DC focuses on reducing energy-related GHG emissions within APEC. Reductions outside of APEC and in other sectors are needed to reach a low-carbon future but are generally seen as more difficult to achieve or even controversial in some cases, given differing priorities for improving economic and social well-being across economies and historical pathways of economic development (IPCC, 2014). Non-energy emissions and land-use change should be an important part of future decision making and action but are beyond the scope of this Outlook.

THE COP21 PARIS AGREEMENT

Under the historic COP21 Paris Agreement, 196 parties agreed to work together to transform their development trajectories with the aim of limiting global warming to 1.5ºC to 2ºC above pre-industrial levels (UNFCCC, 2015). The Agreement also called for a long-term goal for adaptation and commitment to make financial flows consistent with these decarbonisation pathways.

As part of the COP21 Paris Agreement, parties agreed to submit details on the Nationally Determined Contributions (NDCs) that each economy makes a non-binding commitment to achieve, reflecting ambitions to reduce GHG emissions. The Agreement obliges parties to submit updated NDCs to the UNFCCC secretariat every five years, with the next round being submitted by 2020. To achieve the long-term goals, parties recognise the need to intensify individual and aggregate ambitions and efforts over time, with the expectation that peaking of emissions will happen later in developing economies. The full text of the Agreement specifies that it will be implemented recognising 'the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances' (UNFCCC, 2015).

Figure 10.1 • APEC energy-related CO_2 emissions under all scenarios, cumulative NDC, 2000-50



Notes: NDC = Nationally Determined Contributions (to the COP21 Paris Agreement). The 7th Edition calculates CO2 emissions from fuel combustion activities and a portion of industrial process emissions as defined by the IPCC. Agricultural and industrial emissions (other than for fuel combustion), other upstream fossil fuel production emissions, fugitive emissions and LULUCF are excluded. This figure includes the range between conditional and unconditional NDCs, and has been rebased to 2010 by APERC to enable comparison. See Annex I for further detail.
Sources: APERC analysis and IEA (2016a and 2018a), IPCC (2018) and UNFCCC (2018).

In April 2016, based on information from 161 NDCs submitted by 189 parties (representing 96% of parties or 99% of emissions of parties), the secretariat compiled an updated analysis of the aggregate effect. The analysis concluded that the implementation of the communicated NDCs is estimated to result in aggregate global emissions levels of 51.4 to 57.3 Gt CO_2 equivalent (Gt CO_2e) in 2025 and 52.0 to 59.3 Gt CO_2e in 2030' (UNFCCC, 2016). This is well short of what is required with an estimated 16% growth from 2010 levels. The report further stated that unless parties enhance their mitigation efforts leading up to 2030, even greater and more costly efforts will be necessary post-2030 to maintain the same likelihood of constraining global temperature rise to less than 2°C (UNFCCC, 2016).

NDC TARGETS AND IMPLEMENTATION STRATEGIES

The COP21 Paris Agreement represents increased global ambition to collectively reduce GHG emissions, while taking into account individual party circumstances and recognising the importance of a just and equitable low-carbon transition. In their NDC documentation, most parties expanded upon the requirement to set a nationally determined target with further elaboration on the planning process, including existing or planned future legislation, priority areas, policy approaches and stakeholder engagement (UNFCCC, 2016). In total, 19 of APEC's 21 economies[52] are party to the UNFCCC process, all of which submitted an NDC (Table 10.1). The targets can be grouped into four categories: six economies submitted absolute reduction targets; nine submitted reduction from 'business-as-usual' targets; four submitted intensity reduction targets; and one economy submitted a policy target for the electricity sector. Subsequent to submitting its NDC, United States indicated its intention to withdraw from the COP21 Paris Agreement. The 2018, the 24th Conference of the Parties to the United Nations Framework Convention on Climate Change in Katowice, Poland, laid out the rulebook or "operating manual" for the commitments made in the Paris Agreement. This rulebook replaced the older bifurcation system with a more flexible set of GHG accounting and finance rules common to all economies; however, the voluntary GHG market mechanisms could not be agreed upon, and negotiations were pushed forward to the 25th Conference of the Parties meeting that will be hosted by Chile in 2019.

In 2018, a facilitative dialogue commenced with the aim of deciding how to track progress towards the COP21 Paris Agreement's long-term goals. This led to the launch of efforts to conduct a global stocktake (GST), which will analyse the collective efforts of parties. Efforts are now underway to identify sources of input for the GST and to develop appropriate indicators. Beginning in 2023, and every five years thereafter, governments will conduct a GST using these inputs and indicators to take stock of the implementation of the Agreement, considering both mitigation and adaptation efforts (UNFCCC, 2018c). In this way, the GST can be used to inform the subsequent round of NDCs.

In addition to these shorter-term reviews, all parties are also encouraged to communicate long-term development strategies to reduce GHG emissions, known as Mid-Century Strategies. The secretariat has invited all parties to voluntarily submit Mid-Century Strategies by 2020, providing an opportunity to begin planning longer-term pathways to decarbonisation. To date, three APEC economies—the United States, Mexico and Canada—have submitted Mid-Century Strategies to the secretariat (UNFCCC, 2018d). Like the NDCs, Mid-Century Strategies are intended to undergo iterative development as NDCs and climate policies are revised.

While none of the Mid-Century Strategies spell out specific policies that will be implemented to decarbonise their economies by 2050, the strategies highlight issues within the economy and act as a starting point for a general road map. Given the importance of the forum for sharing and coordinating decarbonisation strategies

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[52] Chinese Taipei is not part of the UNFCCC process, but has submitted an INDC; Hong Kong, China's submission is included as part of China's NDC. Russia has submitted an INDC but has not ratified the COP21 Paris Agreement.

and plans—and the need to further strengthen current NDCs—the remaining APEC economies should prioritise this process.

Table 10.1 • NDC emissions targets and coverage in APEC economies, 2030

Economy	Type of target	Scope	Gases	Reduction
Australia	Absolute	Entire economy	All GHGs	26% to 28% below 2005 levels
Brunei Darussalam[a]	Business-as-usual	Energy, land, transport and forestry sectors	All GHGs	63% reduction in sectoral energy use in 2035[a]
Canada	Absolute	Entire economy	All GHGs	30% below 2005 levels
Chile[b]	Intensity	Entire economy	All GHGs	30% to 45% below 2007 intensity
China[c]	Intensity	Entire economy	CO_2	60% to 65% below 2005 intensity
Indonesia	Business-as-usual	Entire economy	All GHGs	29% to 41% below BAU
Japan	Absolute	Entire economy	All GHGs	26% below 2013 levels
Korea	Business-as-usual	Entire economy	All GHGs	37% below BAU
Malaysia	Intensity	Entire economy	All GHGs	35% to 45% below 2005 intensity
Mexico	Business-as-usual	Entire economy	All GHGs	25% to 40% below BAU
New Zealand	Absolute	Entire economy	All GHGs	30% below 1990 levels
Papua New Guinea	Policy	Electricity	N/A	100% renewable power by 2030, conditional on financial support
Peru	Business-as-usual	Entire economy	All GHGs	20% to 30% below BAU
The Philippines	Business-as-usual	Entire economy	All GHGs	70% below BAU, conditional on funding and technology transfer
Russia[d]	Absolute	Entire economy	All GHGs	25% to 30% below 1990 levels
Singapore	Intensity	Entire economy	All GHGs	36% below 2005 intensity, and stabilise emissions with the aim of peaking around 2030
Chinese Taipei[e]	Business-as-usual	Entire economy	All GHGs	50% below BAU
Thailand	Business-as-usual	Entire economy	All GHGs	20% to 25% below BAU
United States[f]	Absolute	Entire economy	All GHGs	26% to 28% below 2005 in 2025[b]
Viet Nam	Business-as-usual	Entire economy	All GHGs	8% to 25% below BAU

Notes: [a] Brunei Darussalam's NDC is a 2035 target. [b] LULUCF excluded. [c] Hong Kong, China is included in China's NDC. [d] Russia has submitted an INDC but has not ratified the COP21 Paris Agreement. [e] Chinese Taipei is not part of the UNFCCC process, but has submitted an INDC. [f] The United States' NDC is a 2025 target.
Source: UNFCCC (2018a and 2018b).

POLICY TOOLS

The broad range of policy tools available to APEC economies in pursuing a clean energy transition is well known and covered in detail in numerous energy policy road maps (DDPP, 2015; IEA, 2018b). In the short term, energy efficiency and other demand reduction measures are typically the most cost-effective tools at policymakers' disposal (IEA, 2018c). However, in the long run, policies are also needed to stimulate supply-side transformation.

To date, some APEC economies show a preference to put a direct price on CO_2 emissions and other GHGs across their entire economies. Others have opted for sector-specific approaches or indirect regulations (such as mandated energy performance or emissions standards) (Table 10.2). In some cases, governments are pursuing policy choices that may be easier to justify on non-carbon merits or other related co-benefits, but have positive spillover effects to carbon policies. Two examples include clean air policies targeting local health improvements or investment in research and development (R&D) for low-carbon technologies.

Table 10.2 • Examples of APEC low-carbon policy approaches with direct benefits or co-benefits

	Policy	Benefits/Co-benefits	APEC economies[a]
Direct tools	Economy-wide price on GHGs that increases over time.	Prices the negative externality created by GHG emissions and reduces allocative inefficiency of economic decisions. Reduces business uncertainty regarding the cost of future climate mitigation. Can lower marginal cost of public funds, if the revenue is used to reduce other taxes (e.g. income taxes).	Canada, Chile, China, New Zealand, Singapore
	Economy-wide cap-and-trade on GHG emissions with quantity reductions over time.	Prices the negative externality created by GHG emissions and reduces allocative inefficiency of economic decisions. Reduces business uncertainty. Can lower marginal cost of public funds, if revenue is used to reduce other distortionary taxes (e.g. income taxes).	Canada
Indirect tools	MEPS for buildings and appliances, fuel economy standards for vehicles.	Mandates a higher level of energy efficiency for durable goods that are slow to turn over in the economy.	Australia; Brunei Darussalam; Canada; Chile; China; Hong Kong, China; Japan; Malaysia; Russia; Singapore; Chinese Taipei; Thailand; United States
	Air quality control measures including GHG emissions standards.	Reduces health costs. Lessens smog and negative environmental impacts. Strengthens economic development.	APEC-wide[b]
	R&D support.	Builds a knowledge economy.	Brunei Darussalam, Canada, Chile, China, Korea, Malaysia, Mexico, Singapore, United States
	Education/awareness-building.	Increases responsiveness of consumers to pricing signals and reduces energy demand. Reduces costs of acquiring information on behaviour.	Brunei Darussalam; Chile; Hong Kong, China; Indonesia; Malaysia; New Zealand; Philippines; Russia; Singapore; United States
	Efficient vehicle subsidies.	Reduces cost of investing in energy efficient vehicles, stimulating the market towards low-carbon technologies.	Brunei Darussalam; Canada; China; Hong Kong, China; Malaysia; Russia; Singapore; United States
	Mandated renewables procurement (FiTs, renewable portfolio standards, auctions, etc.).	Improves energy security for net importers.	Australia; Canada; Chile; China; Hong Kong, China; Japan; Peru; Philippines; Russia; the United States[c]; Viet Nam

	Policy	Benefits/Co-benefits	APEC economies[a]
Other policies with carbon co-benefits	Congestion pricing for roads.	Increases the cost of driving on roads when traffic is heavy to encourage people to be more efficient (e.g. through carpooling, taking alternative routes, or switching to public transportation). Reduces traffic for less price-sensitive consumers. Provides funding for alternative public transportation systems.	Canada; Hong Kong, China; Singapore
	Electrification programs.	Reduces health costs. Improves access to education. Promotes economic development.	Papua New Guinea, Peru, Philippines, Indonesia

Notes: [a] This is not a comprehensive list of policies. [b] No known air quality control measures for Papua New Guinea. [c] Only some US states.
Source: APERC (2018).

While policy interventions often aim to correct a market failure (e.g. pricing a GHG-related externality), the ways they interact within existing institutional and regulatory frameworks must also be considered during the policy design process. Coordination across multiple departments or levels of government is often necessary to minimise any negative effects that might arise from policy choices that inadvertently alter economic decisions in ways that undermine the overarching societal goals of the government.

GHG emissions pricing, for example, tends to be a regressive tax instrument. One of its negative impacts is that, proportionately, GHG emissions pricing typically imposes a heavier burden on low-income households (i.e. cost pass-through represents a higher portion of their income) than to high earners. Coordination among multiple instruments can balance out the income effects of the emissions pricing policy, for example by implementing secondary measures that offset the regressive impacts of emissions pricing. Options include returning revenue through low-income rebates and cutting marginal tax rates. Careful policy design that takes into account institutional and regulatory frameworks, existing fiscal regimes, and desired distributional outcomes can help to ensure that climate policies achieve their intended outcomes while simultaneously supporting other policy goals.

Further challenges with GHG emissions pricing can arise when the effect of carbon pricing on internationally traded products is considered. Introducing emissions pricing in a single economy can be harmful to domestic industry, in part because the extra burden on local industry can give a significant advantage to external competitors from economies that are not subject to similar carbon pricing schemes. Furthermore, it can result in ‘carbon leakage’, a situation that sees carbon-intensive industries moving to other economies to avoid additional costs. This is particularly important in industries that are also ‘trade exposed’, such as the aluminium and steel industries. Mechanisms are available to offset or mitigate such competitiveness effects, such as issuing free emissions credits, but doing so while conforming to global legal frameworks can be challenging without creating a subsidy for industry that does not incentivise emissions reduction over time (World Bank, 2015).

Many APEC economies retain both direct and indirect subsidies for fossil fuels, which undermine the aims and effects of carbon pricing policies. Subsidies encourage wasteful energy consumption, thereby decreasing the effectiveness of energy efficiency and demand reduction policies. Eliminating fossil fuel subsidies would make alternative energy more competitive; however, with carbon pricing, removing such subsidies tends to have negative effects on low-income earners. Directing some of the revenue gained from subsidy removal to promote the uptake of more energy efficient technologies can help to alleviate this burden (Parry, Veung, & Heine, 2014). APEC Leaders have committed to rationalising and phasing out inefficient fossil fuel subsidies. Dialogues on subsidy reform are occurring at meetings of energy and finance ministries and through the Energy Working Group (EWG).

Implementing and enforcing energy efficiency standards that phase out the production of less efficient products and increasing efficiency labelling and other information campaigns can boost consumer trust in both products and policies. These standards and information campaigns assist people in making informed choices and can stimulate consumer behaviour change. Minimum energy performance standards (MEPS) for buildings, heavy industry and appliances, and labelling programs (e.g. the ENERGY STAR program in the United States) have been shown to increase the purchase of energy efficient products. Similarly, programs that promote social awareness and education about the impacts of reducing energy consumption can be effective tools for demand-side management. Lowering the cost of acquiring information related to energy demand, and providing social incentives (for example, by comparing consumption patterns across a community), can substantially and cost-effectively change behaviour (Allcott, 2011).

In recent years, a shift is evident in some policy discussions on appropriate support mechanisms for renewable electricity generation. The most prominent policy design, a feed-in-tariff (FiT), has been used in economies including Australia, Canada, and Japan. A FiT aims to guarantee necessary revenue levels for renewable energy systems, usually through a long-term contract; in turn, this helps renewable energy producers secure lower-cost financing. As the cost of renewable technologies has continued to fall—driven down by increased deployment, better supply chains, etc. (as discussed in Chapter 7)—competitive tenders or auctions have become popular alternatives. Both policy mechanisms are influencing the development of energy markets across APEC; individual economies should choose the tool most appropriate for their circumstances.

Other policies not specifically designed or implemented with energy or GHG emissions objectives can have co-benefits for climate change mitigation efforts and may be more popular with the local community. Air quality controls, for example, have become increasingly necessary and popular as developing economies industrialise and urbanise. Globally, an estimated 7 million people die prematurely each year because of poor air quality (WHO, 2018). Developing long-term air quality goals, increasing the use of air pollution controls and deploying clean air measures for the energy sector—all coupled with enforcing strict monitoring and compliance—could reduce premature deaths by an estimated 3.3 million people annually by 2040. A co-benefit is that such measures would simultaneously reduce GHG emissions, a key objective for which it is harder to secure engagement (IEA, 2016; IEA, 2017b).

There is a challenge in identifying how to separate economic development and the corresponding increase in vehicle ownership rates and transport energy demand. While higher levels of mobility are desirable, rising demand can contribute to negative impacts such as increased congestion, extended travel times and worsening local air pollution. Efficient use of pricing controls, such as congestion pricing and parking fees, can motivate people to switch to more energy efficient travel modes, thereby reducing these negative impacts. In parallel, the new measures can be structured to provide a source of revenue to fund alternative systems (e.g. public transportation). Transit-orientated urban development, which promotes higher density and mixed development near urban transit centres, also presents numerous energy efficiency co-benefits. Policies that promote energy efficiency and reduce demand, whether these aims are the primary focus or a lower priority, can be launched across diverse government ministries or levels. Ideally, they should be deployed in a coordinated manner to facilitate the most efficient and desirable outcomes.

ACHIEVING NET-ZERO EMISSIONS

The COP21 Paris Agreement boosted global momentum towards adopting low-carbon technologies in the energy sector. To have a 50% chance of limiting the average global temperature rise to 2°C, additional ambition and concrete action are needed in the near term (see Chapter 6 on the 2DC Scenario). Additionally, beyond the 2050 time horizon modelled in this Outlook, ongoing effort is needed on the longer-term goal of achieving net-zero emissions as quickly as possible. Given the long lifespan of energy sector assets (see Chapter 7), decisions made over the coming decade will profoundly impact whether this target can be achieved and the costs associated with the low-carbon transition.

Achieving net-zero emissions in the energy sector by 2060 is possible, according to *Energy Technology Perspectives 2017* (IEA, 2017a). Current policies are not sufficient to meet this goal, however, and the cost of delaying the transition is high. The sooner economies implement policies that bend their emissions curves to approach net zero, the better placed they will be to take advantage of strategic opportunities that come with moving quickly to meet their global commitments and to avoid facing costly challenges (e.g. large stranded assets).

To investigate potential pathways for achieving net-zero emissions in the energy sector, nine[53] APEC economies have already completed comprehensive reports as a part of the DDPP. This initiative highlights that limiting the global temperature rise to below 2°C 'will entail, more than any other factor, a profound transformation of energy systems' (Table 10.3) (DDPP, 2015). Combined, these nine economies represented 93% of APEC total primary energy supply (TPES) in 2016. In the 2DC Scenario presented in this Outlook, they represent 91% of TPES in 2050.

To carry out the DDPP project, research teams in each of these economies identified steps required first to achieve their stated emissions objectives, and then to achieve deep emissions reductions by mid-century on their way to net-zero thereafter. In all cases, three pillars of decarbonisation underpinned much of the emissions reduction: reducing the energy intensity of gross domestic product (GDP), reducing the emissions intensity of the electricity sector and increasing electrification of end-uses.

Combined with existing goals and stated priorities in both APEC declarations and the COP21 Paris Agreement, the DDPP reports provide insight into how APEC could feasibly transition to a more sustainable development pathway. The three initiatives also highlight key areas in which APEC Leaders can focus shorter-term ambitions to put their economies on the smoothest possible path in the transition. Three primary areas of action emerge as key to achieving these development goals: increasing the ambition of the energy intensity goal for APEC, boosting the level of renewables in the electricity sector, and accelerating demand sector (i.e. buildings, transport and industry) electrification.

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[53] Australia, Canada, China, Indonesia, Japan, Korea, Mexico, Russia and the United States.

Table 10.3 • DDPP scenarios overview, 2010-50

Economy	Total emissions reduction (2010-50) (%)	Energy intensity of GDP reduction (2010-50) (%)	Selected sectoral reduction (%)
Australia	70	50	59 (industry)
Canada	88-90	52-60	94 (electricity)
China	26-37	73	73 (electricity)
Indonesia	7	77	62 (electricity)
Japan	84	68	82 (transportation)
Korea	86	75	---[a]
Mexico	52	59	52 (buildings)
Russia	87	73	---[a]
United States	85	70	96 (buildings)

Note: [a] Deep Decarbonization Pathways Project report not available
Source: DDPP (2014).

OPPORTUNITIES AND CHALLENGES

In its mission statement, APEC is clear that its foremost goal is 'to support sustainable economic growth and prosperity in the Asia-Pacific region' (APEC, 2018a). Through this cooperative economic forum, the region has committed to numerous energy-related policy priorities, such as improving energy efficiency, increasing the deployment of renewables, phasing out inefficient fossil fuel subsidies and pursing low-carbon development strategies.

Within APEC, the mission of the EWG is to inform policymakers—through collaboration with industry experts and other international bodies—to facilitate cooperation, knowledge sharing and capacity building in the region. Efforts undertaken to date include initiatives to assist APEC economies in pursuit of these policy objectives, including through the Asia-Pacific Network for Energy Technology, the Energy Security Initiative, the Low-Carbon Model Town project, and the APEC Peer Review Mechanism on Energy Efficiency and the Peer Review on Low Carbon Energy Policies. Publication of this Outlook is another example of joint action to benefit all members (APEC, 2018b). These initiatives usually identify policy priorities that are intersectional and serve to enhance the socioeconomic development of the Asia-Pacific region and of individual member economies.

The scenarios analysed in the *Outlook 7th Edition* represent only three of an infinite number of potential pathways the region could take over the coming decades. Assumptions used in these scenarios aim to quantify the potential short- and long-term ramifications—and indeed to identify the opportunities and challenges—associated with choices policy leaders must make in the very near future about energy sector development.

The Target (TGT) and 2DC Scenarios highlight the importance of setting near-term targets that are both ambitious and actionable in order to have the best chance of remaining within the global carbon budget while minimising the overall costs of the low-carbon transition. As all policy decisions involve trade-offs, leaders must assess the feasibility of implementing sufficiently stringent policy to achieve stated goals. The need to secure public acceptance and shift societal norms is integral to the success of any decarbonisation strategy.

A degree of behavioural change is assumed in the transport and service sectors to be one of the drivers of GHG emissions reduction in the 2DC Scenario, with outcomes relying on a significant portion of an economy's population changing their attitudes and actions in relation to energy consumption. While these behaviour changes are often price-driven, the assumptions also rely on a certain level of response motivated by a change in perception of the value of a given behaviour. In the commercial sector, behavioural change assumptions reflect growth in employees 'working remotely' (including from home), thereby reducing demand for commercial office space and associated energy demand. Implicit in this assumption is that companies and their employees determine that the value of savings and convenience associated with working remotely is a desirable trade-off in exchange for less in-person contact time. Other assumptions include greater growth in online retail, which displaces energy-intensive retail areas with less-intensive warehousing. In the transport sector, the assumption is that better urban planning drives demand for public transport over personal vehicles.

Some of the challenges associated with accelerating decarbonisation are well known; no doubt, others will emerge. While the need for global collective action is likely to uncover a multitude of obstacles, regional cooperation can improve outcomes that will benefit all participants. Boosting domestic decarbonisation ambition can create new low-carbon technology markets, giving early movers a global competitive advantage. Bilateral, multilateral, regional and global alignment of standards and best practices can create a truly international market for low-carbon or energy efficient products, technologies and services. A huge opportunity exists for first movers and early adopters to quickly capture market share; latecomers are expected to struggle to catch up.

Zero-sum thinking on global challenges can derail cooperation; thus, the focus of negotiations should be steered towards fostering mutual benefits. Decreasing global demand for fossil fuels through a shift to renewable energy improves domestic energy security and reduces sensitivity to global commodity prices. The cost savings from improved energy efficiency can be used to increase energy access while also improving health and social outcomes without requiring a trade-off in spending priorities. While considerations, methods and social priorities differ across APEC economies, numerous examples exist of policies that have been tested, monitored, evaluated and demonstrated to be successful in the region. These approaches can be used as a foundation and tailored to local domestic conditions in other economies. Many of APERC's independent research projects have the explicit aim of disseminating these lessons learned.

RECOMMENDATIONS FOR POLICY ACTION

Although the signing of the COP21 Paris Agreement in 2015 was a historic moment for global commitment to climate action, the shared goal requires that governments make reducing GHG emissions a long-term priority, supported by short- and medium-term actionable targets that bend the current trajectory. Near-term priorities should seek to maximise the benefits of proven policies and regulations. Energy efficiency can be effectively improved via more stringent building codes, higher fuel economy standards for vehicles, and energy efficiency labelling for equipment and appliances. Energy demand management measures, such as time-of-use pricing, educational programs and initiatives to raise awareness, have effectively decreased peak demand, allowing economies to reduce expenditure on energy infrastructure and reduce stress on the energy system.

Targeted policy support mechanisms, such as FiTs, renewable portfolio standards, and auctions, can incentivise (alone or together) higher deployment of renewables in the electricity system. As renewable technology prices have plummeted globally, increased support and incentives can prompt other end-use sectors to electrify and capture the benefits of low-carbon electricity (for example, through supporting electric vehicle infrastructure). Clean air policies can also play a significant role, as economies tackle untenable air pollution levels and the associated health risks and social impacts.

Pricing the negative externality created by GHG emissions from energy and fossil fuel consumption is an effective tool for reducing emissions, with a range of policy tools available such as a carbon tax and emissions trading scheme. Careful consideration is necessary, however, to avoid any potential distributional effects of such policies. Removing direct subsidies to fossil fuels across the APEC energy sector would be a significant step towards capturing the full cost of CO_2 emissions and would make renewables and energy efficiency policies more competitive and effective.

Together with NDCs, Mid-Century Strategies submitted to the UNFCCC secretariat provide an opportunity for APEC economies to devise short- and medium-term goals that will support their ability to meet the long-term target of net-zero CO_2 emissions. These Mid-Century Strategies challenge economies to set clear goals for where they want to be by 2050, and to build upon or take advantage of best practices developed by other economies moving in a similar direction.

APEC economies should also prioritise devising policies to achieve net-zero emissions as soon as possible. Strategies such as those outlined in the comprehensive reports completed for the DDPP seek to inform policy decisions necessary to achieve these long-term pathways. Expanding research into key areas identified in the DDPP, such as electrifying demand and decarbonising the electricity sectors of APEC economies, would assist the policy development process.

ANNEX I: MODELLING KEY ASSUMPTIONS & METHODOLOGIES

The *APEC Energy Demand and Supply Outlook, 7th Edition* projections stem from a series of energy models, which are applied to all 21 APEC economies. There are eleven main models, which are connected via an integration module, and run sequentially: macroeconomic, industry, transport, buildings (including residential and services), agriculture and non-specified, hydrogen, electricity, heat, refineries, and production and trade. The methodology for calculating renewables supply potential, investment and security are also described. The Annex I contents are as follows:

1. Introduction
2. Common assumptions
    - GDP and population
    - Energy prices
3. Modelling methodologies
    - Integration
    - Transport
    - Industry
    - Residential buildings
    - Service buildings
    - Agriculture and non-specified
    - Hydrogen
    - Electricity
    - Heat
    - Refineries
    - Production and trade
    - Bioenergy potential
    - Rooftop solar potential
    - Investment
    - Security
4. References

To find out more about the modelling assumptions and methodologies, please either visit APERC's website (http://aperc.ieej.or.jp) or access the Annex I file on the USB version of the Outlook.

ANNEX II: DATA PROJECTION TABLES

The *APEC Energy Demand and Supply Outlook, 7th Edition* data tables show projections for energy production, trade, total 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), Target and 2-Degrees Celsius Scenarios for each economy and by regional and sub-regional totals.

To access the tables, please either visit APERC's website (http://aperc.ieej.or.jp) or access the Annex II file on the USB version of the Outlook.

REGIONAL GROUPINGS

China	
Oceania	Australia; New Zealand; Papua New Guinea
Other Americas	Canada; Chile; Mexico; Peru
North-east Asia	Hong Kong, China; Japan; Korea; Chinese Taipei
Russia	
South-east Asia	Brunei Darussalam; Indonesia; Malaysia; Philippines; Singapore; Thailand; Viet Nam
United States	

COMMONLY USED ABBREVIATIONS AND TERMS

2016 USD PPP	2016 USD purchasing power parity
2DC	2-Degrees Celsius scenario
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
CAGR	compound annual growth rate
CAFE	Corporate Average Fuel Economy
CBM	coal bed methane
CCGT	combined cycle gas turbine
CCS	carbon capture and storage
CCUS	carbon capture, utilisation and storage
CHP	combined heat and power
CNG	compressed natural gas
CO_2	carbon dioxide
COP	Conference of the Parties
COP21	21st Conference of the Parties
CSP	concentrated solar power
CTL	coal-to-liquid
ESCOs	energy service companies
ETP	Energy Technology Perspectives
EU	European Union
EV	electric vehicle
EWG	APEC Energy Working Group
FCEV	fuel cell electric vehicle
FED	final energy demand
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
$GtCO_2$	gigatonnes of carbon dioxide
GST	global stocktake
GTL	gas-to-liquid
GW	gigawatt
GWh	gigawatt-hour
HDV	heavy-duty vehicle
HHI	Herfindahl-Hirschman Index
HVAC	heating, ventilation and air conditioning
IGCC	integrated coal gasification combined cycle

INDC	Intended Nationally Determined Contribution
ktoe	kilotonnes of oil equivalent
kWh	kilowatt-hour
LCMT	Low Carbon Model Town
LDV	light-duty vehicle
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
MEEPS	minimum energy efficiency performance standards
MENA	Middle East and North Africa
MEPS	minimum energy performance standard
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
NDC	Nationally Determined Contribution
NEA	Nuclear Energy Agency
NOX	nitrogen oxides
NZE	near-zero emissions
O&M	operating and maintenance
PHEV	plug-in hybrid electric vehicle
PHS	pumped hydro storage
PISE	percentage of household income spent on electricity
PJ	petajoule
PPP	purchasing power parity
PREE	APEC Peer Reviews on Energy Efficiency
PV	photovoltaic
R&D	research and development
SAIDI	system average interruption duration index
SWH	solar water heaters
T&D	transmission and distribution
Tcm	trillion cubic metres
TGT	APEC Target scenario
toe	tonnes of oil equivalent
toe per unit of GDP	tonnes of oil equivalent per unit of GDP
TPES	total primary energy supply
TFED	total final energy demand
tU	tonnes of Uranium
TW	terawatt
TWh	terawatt-hour
USC	ultra-supercritical (coal-fired power generation)
USD	US dollar
VRE	variable renewables

COMMONLY USED REFERENCES

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