Reference Scenario in the 8th APEC Energy Demand and Supply Outlook

by

Mathew Horne, Senior Researcher

Asia Pacific Energy Research Centre (APERC)

Inui building, Kachidoki 11F, 1-13-1 Kachidoki,

Chuo-ku, Tokyo, 104-0054, Japan

Phone: +81 80 8855 1863 / Email: mathew.horne@aperc.or.jp / Website: http://aperc.or.jp

1 Overview

The 21 economies that comprise the Asia Pacific Economic Cooperation (APEC) forum are home to almost three billion people and account for 60% of global GDP. APEC is reliant on immense levels of energy supply, with a large trade component, required to enable continued strong economic growth in the region. The forum's purpose is to promote regional economic integration and trade. Understanding long-term energy market trends is fundamental to achieving this and has become increasingly important in the context of the global push toward decarbonisation.

For the 8th edition of the *APEC Energy Demand and Supply Outlook* (8th Outlook), the Asia Pacific Energy Research Centre (APERC) has constructed two potential energy futures out to 2050. The Reference scenario analyses recent trends in APEC energy consumption, production, and trade, to deliver one potential energy future. The Reference scenario explores recent market and political trends for each of the 21 APEC economies and does not constrain development via implicit or explicit carbon prices, nor does it assume market interventions unless they have already been legislatively committed to by member economies.

The spate of recent decarbonisation announcements by APEC member economies means that the Reference scenario is unlikely to come to fruition. However, there is value in understanding the trajectory of energy demand and supply in the APEC region based on currently enacted policies and programs, recent trends in energy intensity, and less ambitious deployment of renewable technologies. The Reference scenario is a useful benchmark against which to measure the effectiveness of future decarbonisation policies and may ultimately be a better estimate of future energy demand and supply if achieving carbon neutrality turns out to be more difficult and expensive than currently assumed.

2 Methods

The 8th Outlook modelling involves decomposing the APEC energy system into multiple subcomponents spanning demand sectors (such as industry, transport, and buildings), transformation (power, heat, and refining), and supply (production and trade). Demand sector modelling relies on estimates of output, energy efficiency, fuel switching rates, activity rates, technology diffusion, and multiple other variables. Calibration occurs via knowledge-based iteration, particularly with economy-level experts. When demand is finalised, the power, heat, refining and supply, sector models deliver the required energy based on assumptions about fuel cost trajectories, and policy/market intervention. In the case of the power sector, a least cost model is deployed. However, cost-based decisions and assumptions are overridden if there is political backing for certain technologies or fuels that enhances their relative economic viability. There is frequent iteration of results, with extensive review and input from economy and energy experts to arrive at final energy demand, transformation, and supply results.

Characteristics that distinguish the Reference scenario from the Carbon Neutrality scenario are energy efficiency rates that follow historic trends; gradual rates of fuel switching; and relatively slower diffusion of new technologies in demand and power sectors. Assumed output and activity is close to the same in both 8th Outlook scenarios. Additional details are provided in Table 2-1.

Table 2-1: Main assumptions in the Reference scenario.

Sector	Reference scenario assumptions
General	• Historical GDP data from World Bank World Development Indicators. • GDP projections from OECD and internal analysis. • COVID-19 impact on GDP is incorporated for 2020-2025 (IMF).
Buildings	• Gradual improvements in energy efficiency. • Gradual move away from traditional biomass.
Industry	• Small uptake of CCS for steel, cement, and chemicals subsectors starting in 2040 for some economies. • Small amount of hydrogen for steel and chemicals subsectors starting in 2035 for some economies. • Energy efficiency and electrification follow historic trends to 2050. • Small amount of fuel switching in multiple industry subsectors, primarily from coal to electricity, biomass, and gas.
Transport	• Vehicle stock remains mostly ICE. • Fuel efficiency follows recent trends.
Power and heat	• Fuel switching follows recent trends and policy direction. • No CCS.
Supply	• Global market for oil, natural gas, and coal will continue to rely on APEC exports.
Climate	• NDCs and other general targets are considered, though not strictly adhered to.

Source: APERC.

3 Results

3 – 1 Introduction

The APEC region is comprised of a diverse group of economies. Economic development is assumed to continue at a rapid pace in APEC southeast Asia and South America economies, as well as in China, with GDP more than doubling out to 2050 for the entire APEC region. However, this rapid growth in economic output leads to energy demand that is only 12% higher in 2050 relative to just prior to the pandemic. China's industrial might transitions to a more service-based economy, with energy demand slowly peaking by the early-2030s. Many other APEC economies continue to grow their economies without needing significantly more energy to do so. In fact, almost three-quarters of the growth in final energy demand out to 2050 is from the group of APEC economies in southeast Asia. Energy demand from these economies almost doubles out to 2050, though for that same period, their GDP more than triples.

Refined products remain the largest end-use fuel in APEC, reaching a peak in the late 2030s, before gradually declining out to 2050, supplanted by electricity in an increasing number of end-use applications. Electricity consumption increases from 23% of the APEC energy mix before the pandemic to 29% in 2050. Gas is the only fossil fuel to expand its share, although only by a small amount.

Electricity generation increases by almost half over the projection period to 2050, with all this additional generation attributable to solar, wind, and nuclear. Both solar and wind generation increase by almost 3 000 terawatt hours, and nuclear generation increases by over 2 000 terawatt hours. In contrast, coal-fired generation falls by almost half, with gas supplanting coal as the most prominent fuel in the generation mix in the late 2030s. Nevertheless, coal remains as an important source of baseload power generation, with much of this role locked in due to many coal-fired power plants in APEC Asian economies that have been built relatively recently.

APEC continues to account for a significant portion of global fuel production in the Reference scenario. Coal production is assumed to peak in the early-2020s and slowly declines through the rest of the projection period to 2050. In contrast, natural gas production continues to increase significantly until the mid-2030s, at which point it maintains a high plateau for the remainder of the projection. APEC's net imports position across all energy commodities initially falls due to surging natural gas exports out to 2030, but then increases due to natural gas import requirements becoming more prominent than natural gas exports. A large portion of the trade position is due to a reliance by APEC Asian economies on crude oil imports to supply their domestic refineries. It is only in the late-2040s that crude oil imports begin to gradually decline. Imports of gas more than double and continue to increase through the entire projection period. Gas exports also increase significantly, though reach a peak, and begin to decline from the early-2030s.

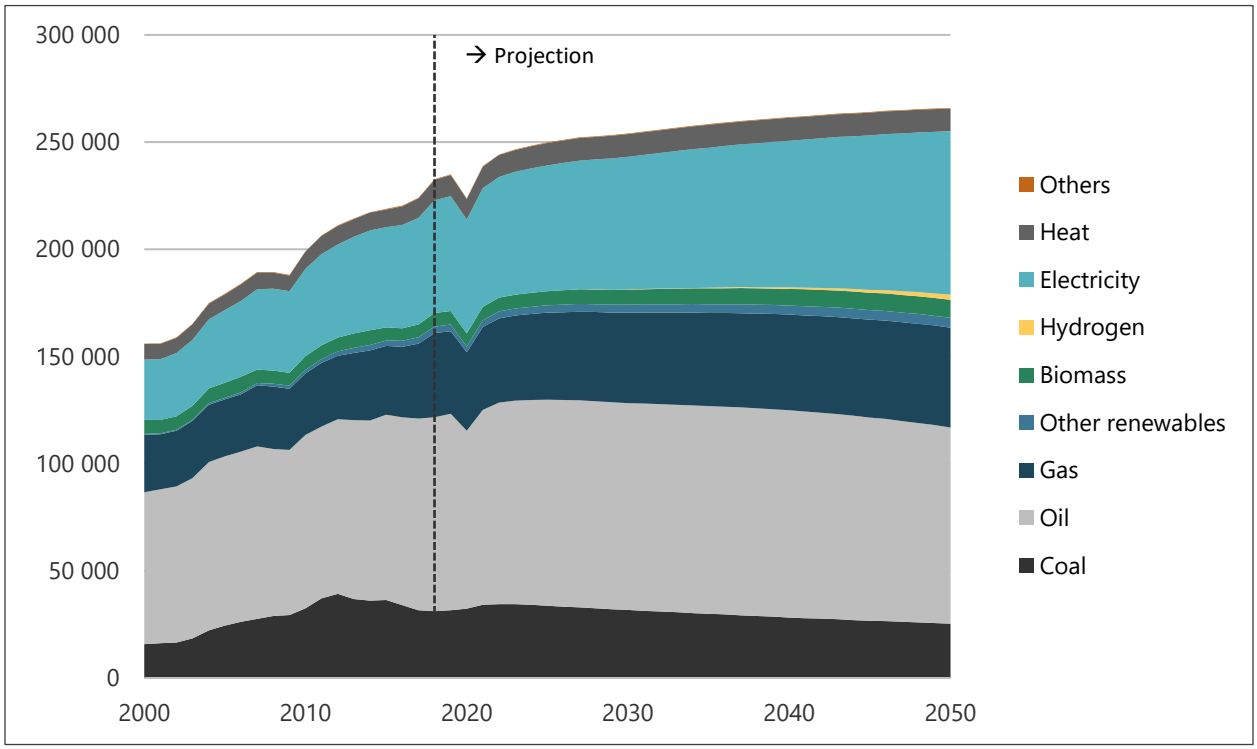
3 – 2 Demand

End-use energy demand grows by a modest amount in the Reference scenario. Refined products (oil) currently account for almost two-fifths of APEC final energy demand, with its prominence tied to moving things and people within APEC economies. Transport activity is assumed to continue to increase out to 2050, but fuel efficiency improvements and fuel switching to biofuels and electricity result in refined products consumption remaining relatively flat.

Electricity in end-use energy applications has increased from 18% in 2000 to 23% just prior to the pandemic. These electrification trends continue and see electricity's end-use share increase to 29% out to 2050.

China's industrial sector consumes massive amounts of coal in activities such as cement and steel production. In the Reference scenario, coal remains a foundational input for many industrial enterprises, though natural gas, electricity, and biomass increasingly substitute for its use. Natural gas consumption increases, though its share of the end-use mix is left relatively unchanged.

Figure 3-1: APEC energy demand in the Reference scenario, by fuel and energy carrier, 2000–2050 (PJ)



Source: EGEDA, APERC analysis. Includes non-energy.

The APEC industry sector remains the largest consumer of energy out to 2050 in the Reference scenario, with energy consumption growing by 14%. There is a projected large decline in output from China's steel and cement sectors, due to ongoing structural changes within China's economy. The vast amount of construction and infrastructure building begins to moderate. These declines are offset by the rise in industrial output for many other economies, such as in southeast Asia.

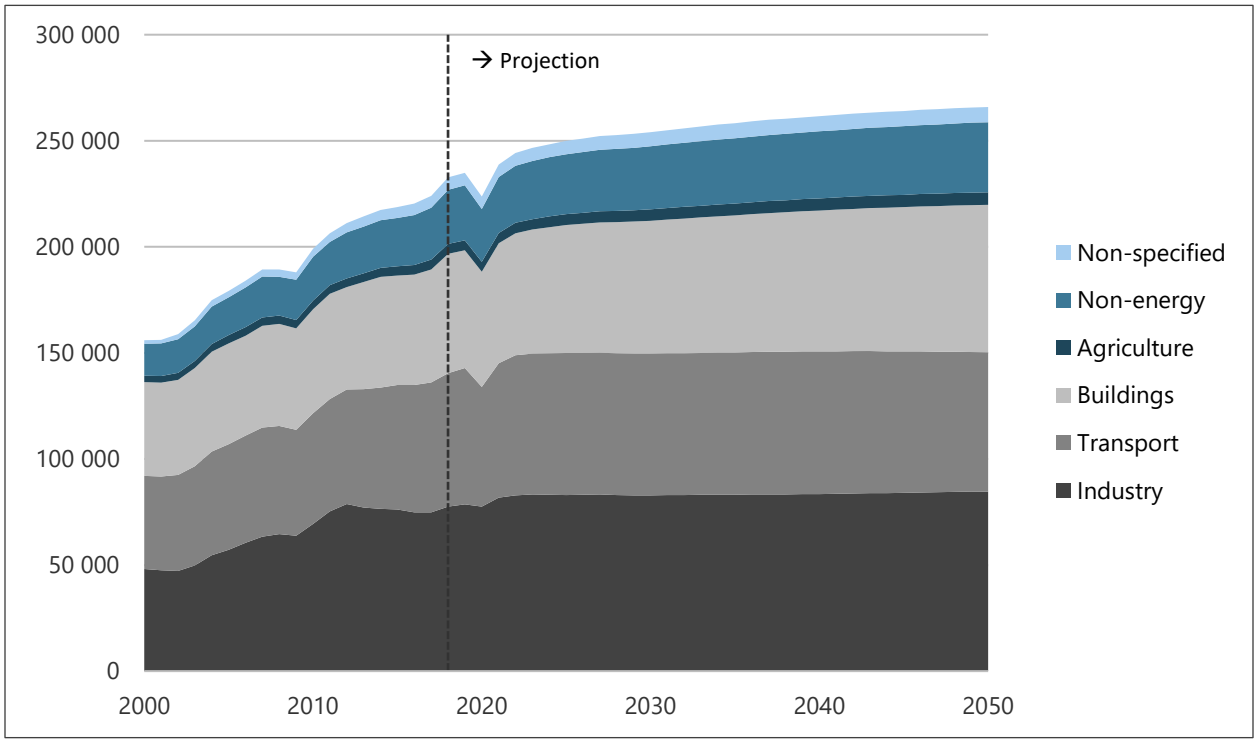
The transport sector is currently the second-largest energy consuming sector, but drops to third, mostly due to the greater efficiency that comes with the increasing electrification of road transport. Transport activity increases significantly in most APEC economies, though energy use is only marginally higher in the Reference scenario.

Energy consumption by the APEC buildings sector is expected to increase by almost one-quarter in the Reference scenario. A significant increase in space cooling activity from southeast Asia propels buildings to be the fastest growing energy consuming sector. However, appliance energy efficiency improvements and implementation of stricter building codes mean that living standards increase without a runaway increase in energy consumption.

The APEC non-energy sector, which mostly relates to chemicals enterprises that use fossil fuel inputs as a feedstock, becomes slightly more prominent in the Reference scenario, accounting

for about one-eighth of the energy demand mix. Agriculture's share of energy consumption remains relatively low, hovering near 2%.

Figure 3-2: APEC energy demand in the Reference scenario, by sector, 2000–2050 (PJ)



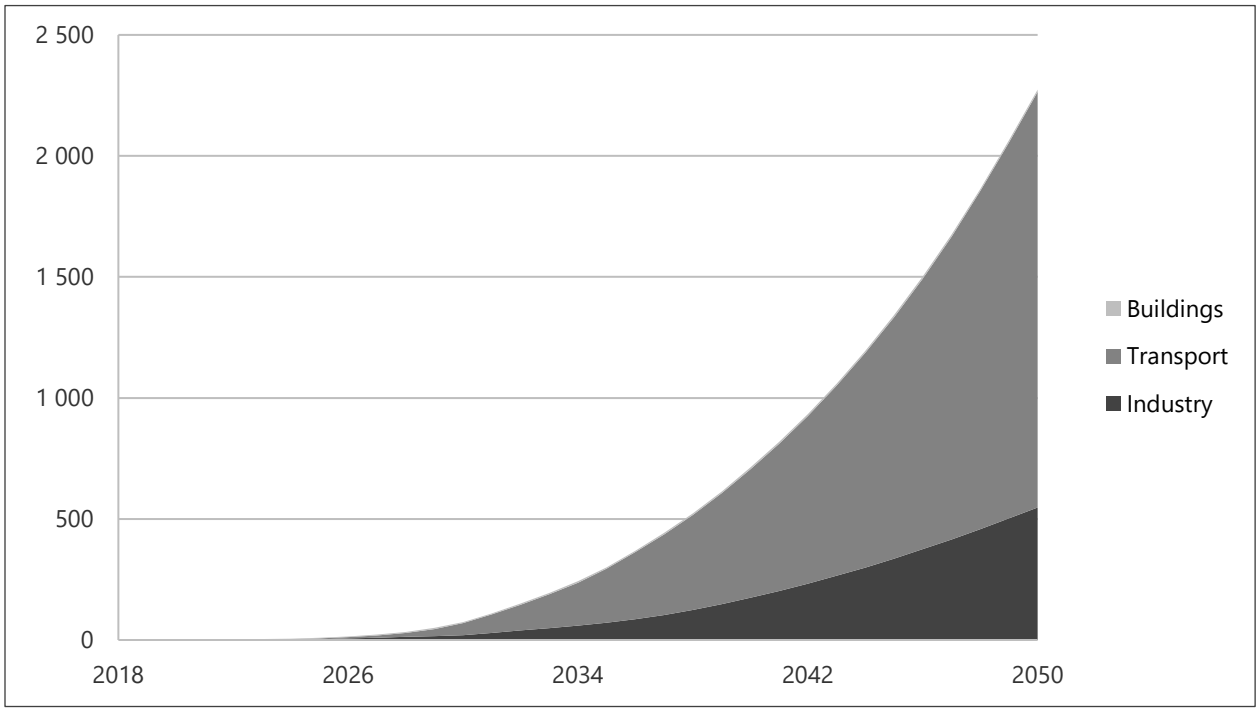
Source: EGEDA, APERC analysis.

Hydrogen is already consumed and produced for petrochemical and refining activities, but its future in terms of being incorporated in the final energy mix remains uncertain. There is significant promise within APEC, with Australia, Chile, Japan, China, South Korea, and the United States having all developed hydrogen roadmaps.

In the Reference scenario, hydrogen grows to account for 1% of APEC's final energy demand in 2050. Transport accounts for three-quarters of hydrogen demand in 2050, mostly via heavy-duty freight and passenger transport. Industry accounts for the remaining quarter of hydrogen demand in 2050. This consumption is energetic and does not include current demand for hydrogen as a feedstock for refining, or ammonia production. Hydrogen is mainly used in the iron and steel and chemicals subsectors.

There is also a very small take-up of hydrogen in the buildings sector. In Japan, residential fuel cells are used to provide electricity and heat.

Figure 3-2: APEC hydrogen consumption in the Reference scenario, by sector, 2000–2050 (PJ)



Source: EGEDA, APERC analysis. Hydrogen as an industrial feedstock is not considered as an energy carrier

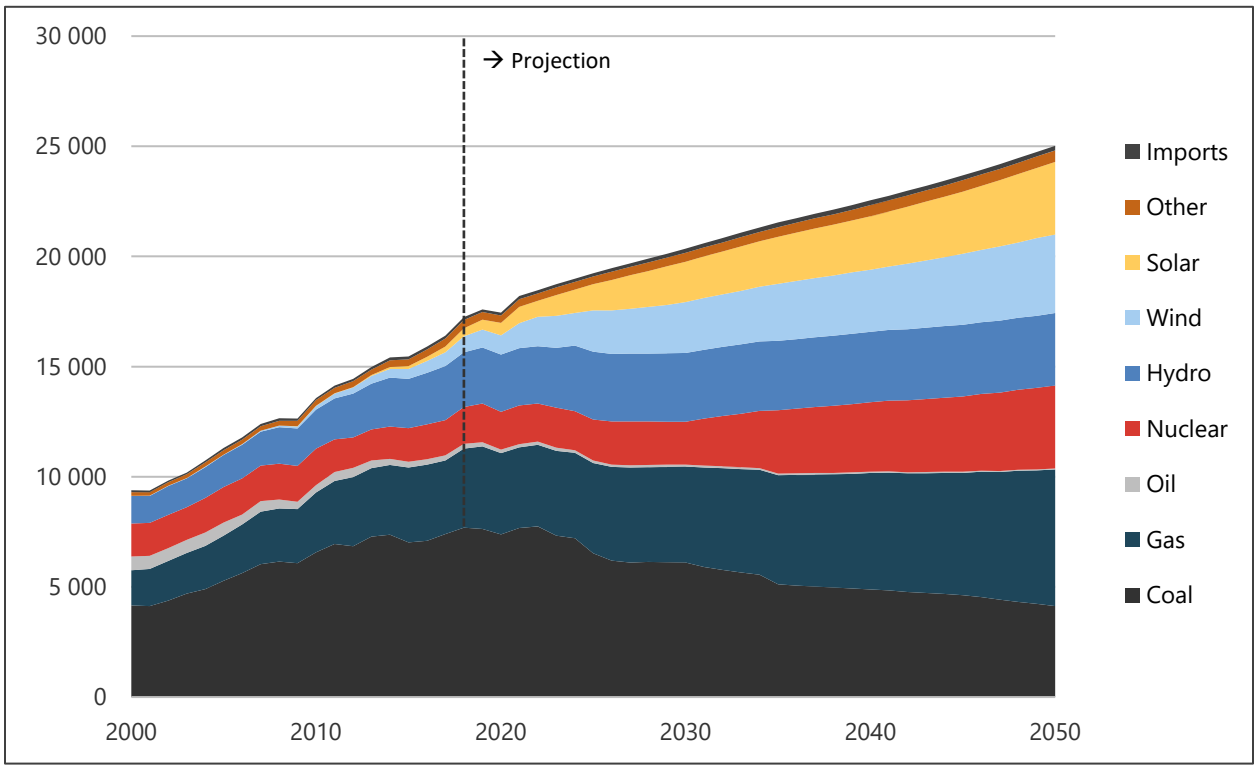
3 – 3 Power and heat

Electricity generation nearly doubled between 2000 and 2018. Two-thirds of the increase came from coal and gas-fired power plants. In the Reference scenario, electricity generation increases by 45% out to 2050. Significant changes in the generation structure are expected, with the share of thermal power plant generation decreasing by 25%. Electricity generation by coal-fired power falls by half, with the fall partially offset by gas-fired power plants.

About half of the increase in electricity generation out to 2050 will be provided by solar and wind, while additional nuclear generation will account for 20% of the increase. The share of nuclear generation grows from 10% in 2018 to 15% in 2050. The reduction in the share of thermal power plants is almost entirely compensated by the increase in the output of solar and wind, as their share increases from 8% in 2018 to nearly 30% in 2050.

In terms of what is happening in individual APEC member economies, China and southeast Asia continue to increase non-renewable generation, while the United States and northeast Asia decrease non-renewable generation. By 2050, southeast Asia's non-renewable generation exceeds its total electricity generation in 2018. Renewables contribute up to 90% of the increase in electricity generation, with two-thirds from China and the United States.

Figure 3-3: APEC electricity generation in the Reference scenario, 2000–2050 (TWh)



Source: EGEDA, APERC analysis.

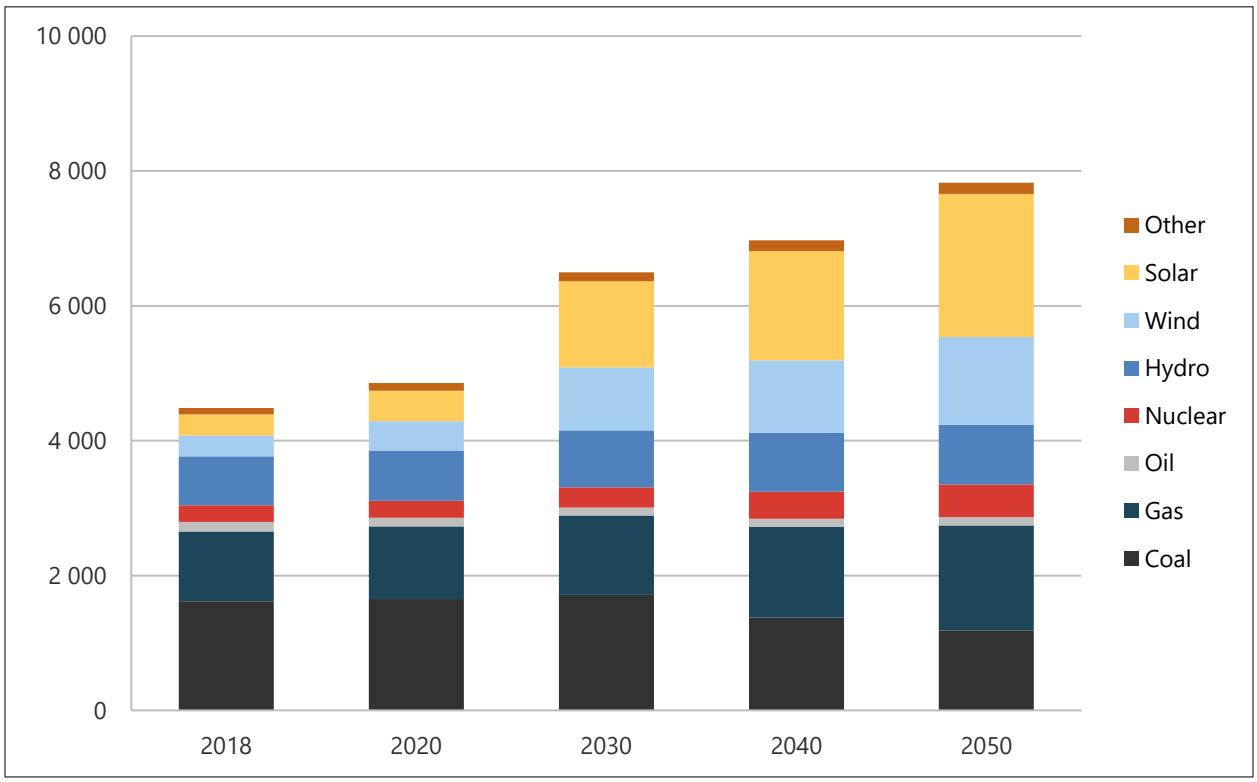
Fossil fuel plants account for more than half of the current 4 500 GW capacity in APEC. The share of renewables, comprised mostly of hydro, solar, and wind, is 30%. In the Reference scenario, the structure of installed capacity undergoes significant changes through to 2050, with capacity increasing to almost 8 000 GW.

The share of thermal power plants decreases by about 25% due to retirement of coal-fired thermal power plants and an accelerated deployment of renewables. The share of hydro power plants declines from 16% in 2018 to 11% in 2050 (though absolute capacity increases through the projection). The share of nuclear power plants increases to 6%. The installed capacity of wind increases 4-fold while solar increases nearly 7-fold. The share of renewables, including hydro, in total installed capacity reaches 55%.

Wind and solar have a significantly lower capacity factor than most other generation technologies. The large increase in capacity of these two generation technologies will cause the average APEC capacity factor to drop from 44% in 2018 to 36% in 2050.

Two-thirds of the new renewable capacity in the Reference scenario to 2050 comes from the two largest electricity producers, China, and the United States, in roughly equal shares. Another 10% of the increase will come from the economies of southeast Asia and 7% from the economies of northeast Asia.

Figure 3-4: APEC generation capacity in the Reference scenario, 2000–2050 (GW)



Source: EGEDA, APERC analysis.

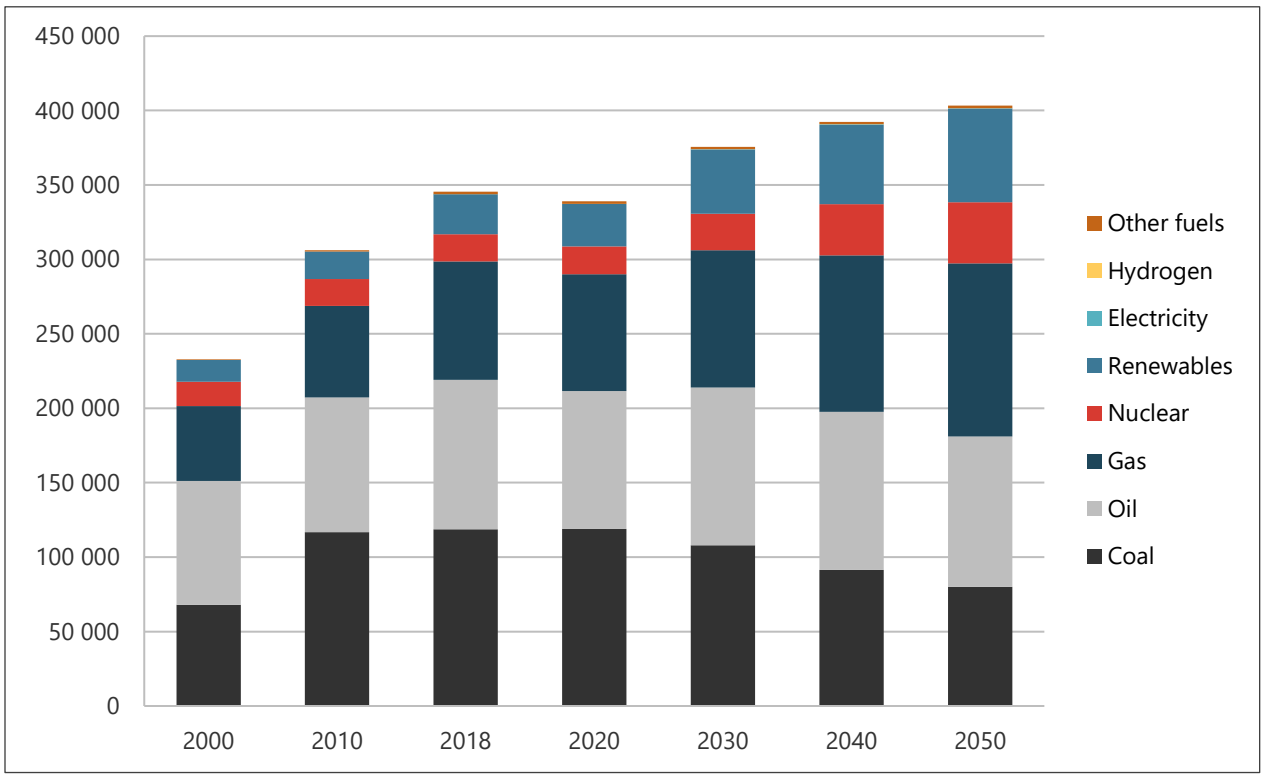
3 – 4 Supply

APEC energy supply grows a sixth to meet rising energy demand and power requirements. China and southeast Asia account for almost all supply growth, while energy efficiency results in supply declines in the US, Oceania, and northeast Asia.

Fossil fuels play a lower, but still dominant, role in the APEC energy mix in the Reference scenario. Declining use in power drives coal down to a fifth of the supply mix, while transport electrification is instrumental in reducing oil to a 25% share. The share of gas rises to 29%, mostly on higher use in China and southeast Asia.

Lower-emitting fuels play a larger role in APEC's energy system. Increases in hydroelectric and variable renewable capacity, particularly in China, southeast Asia, and the United States, double renewable supply in terms of absolute value and share. Despite the retirement of several reactors in APEC, the share of nuclear doubles to 10%, mostly due to growth in China, which surpasses the United States as top nuclear user in the late-2020s.

Figure 3-5: APEC total energy supply in the Reference scenario, 2000–2050 (PJ)



Source: EGEDA, APERC analysis.

Energy production in the Reference scenario grows slightly less than supply, increasing by an eighth out to 2050. APEC coal production closely tracked APEC consumption trends between 2000 and 2018. The relationship is expected to remain in place, with production falling from 131 000 PJ in 2018 to 86 000 PJ in 2050, representing a fall of one-third.

APEC is home to the largest coal producers in the world. While production is expected to fall out to 2050, exports as a proportion of production increases from 22% in 2018 to 24% by the end of the projection period. APEC remains a major coal supplier by 2050, exporting more than 20 000 PJ.

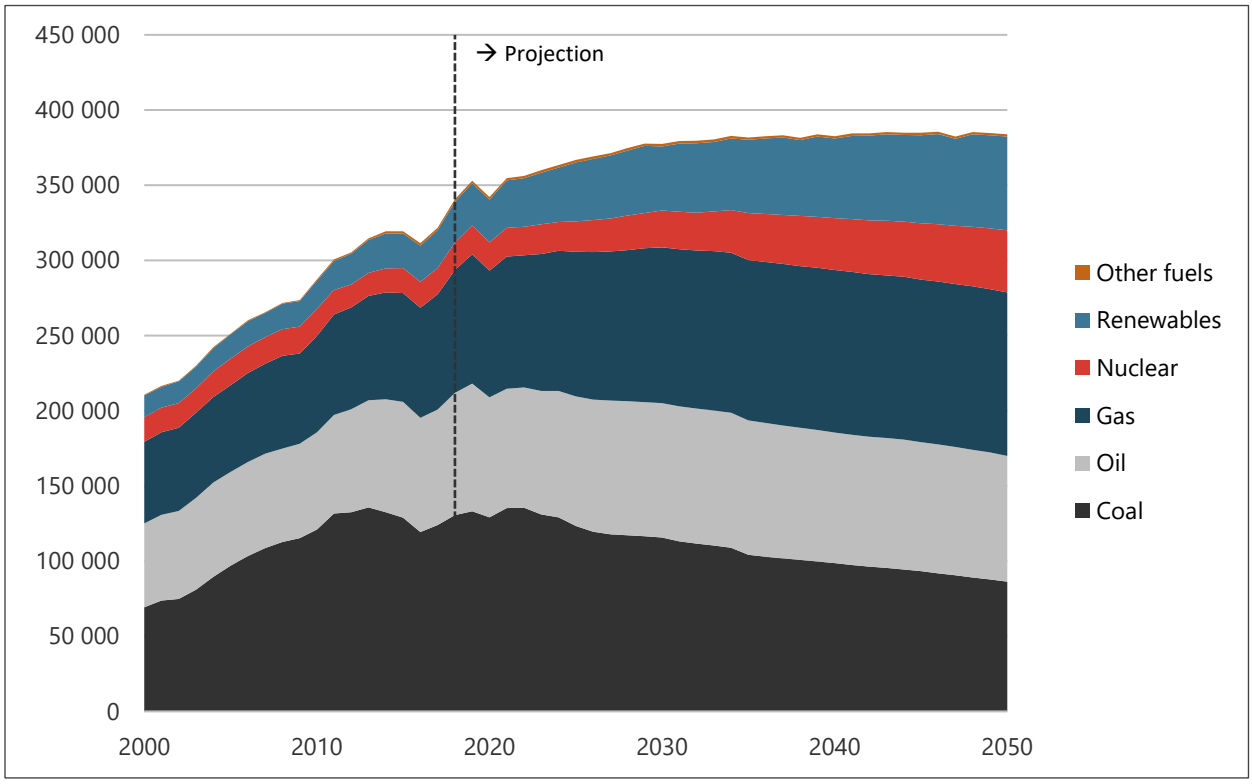
In contrast to coal, natural gas production grows by one-third to 2040 and then stabilises through to 2050. The United States, China, Russia, and Canada account for over 99% of production growth. The US surpassed Russia as the largest producer in 2009 and remains the top producer, largely due to shale gas production.

Production of natural gas in China increases by 135% to 2050, supported by investment and financial incentives to explore oil and gas fields and develop unconventional gas resources. Southeast Asia natural gas production is expected to moderate and decline after 2030 due to depleting reserves. Northeast Asia production remains negligible with supply almost completely reliant on imports.

Oil production fell 6.0% in 2020. In the Reference scenario, oil production rebounds in the United States and Russia, and with growing output from Canada, APEC oil production surpasses pre-pandemic levels in 2025. Oil production begins to fall in the 2030s due to declines in the United States, Russia, and southeast Asia. Oil production grows 11% in China and falls 11% in Mexico.

Higher United States oil production alongside lower refinery runs in the United States and northeast Asia lead to slightly lower import requirements through the Reference projection period.

Figure 3-6: APEC energy production in the Reference scenario, 2000–2050 (PJ)



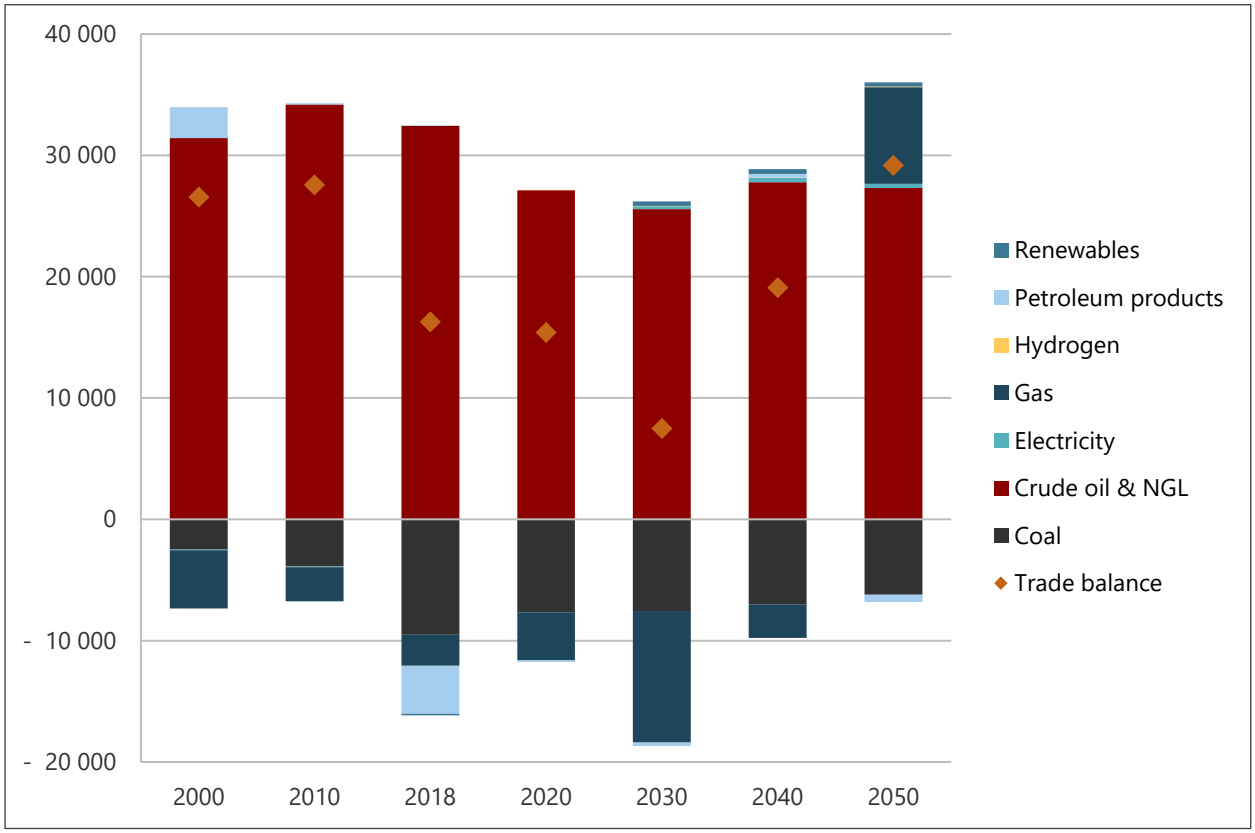
Source: EGEDA, APERC analysis.

Expansions in production and export capacity, particularly in the form of LNG from the United States, and both LNG and pipelines from Russia, play an instrumental role in reducing APEC's energy trade deficit by two-thirds in the 2020s. However, soaring gas use in southeast Asia during the 2030s and 2040s turn APEC into a net gas importer by the mid-2040s, and increase net energy imports to their highest levels since 2007. Security of gas supply will be a chief concern amongst APEC importers in the latter half of this projection.

Crude oil continues to dominate net energy imports, but production growth, mainly from the United States and Canada, reduces net crude imports by a fifth. Refined products imports increase as demand from China and southeast Asia outpaces refinery output. Electricity trade increases by almost a third, as non-APEC imports into Thailand and Viet Nam help meet surging electricity demand.

Imports of gas more than double and continue to increase through the entire projection period. Gas exports increase at an even faster rate than imports, though reach a peak, and begin to decline from the early-2030s. This leads to a net import requirement for gas by 2050 and means the net energy trade balance for all energy commodities is 80% higher than is currently the case by the end of the projection period.

Figure 3-7: APEC net energy trade in the Reference scenario, 2000–2050 (PJ)

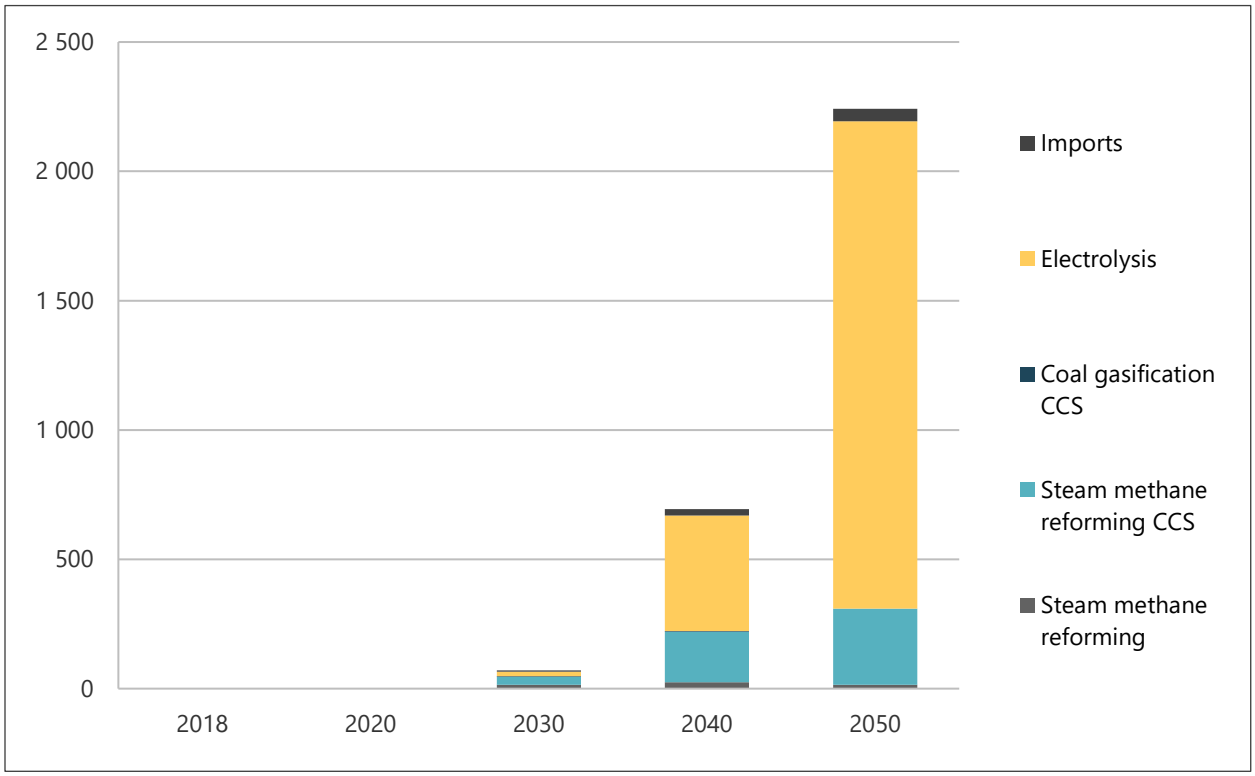


Source: EGEDA, APERC analysis. Net exports appear as negative.

The Reference scenario begins to see an increasing role for hydrogen in the end-use energy mix. This is separate to hydrogen that is already consumed and produced for refining and petrochemical activities. Transport applications and a small number of industrial applications, such as in chemicals and steel subsectors, increasingly demand hydrogen.

Blue, grey, and brown hydrogen account for more than 70% of hydrogen production in 2030, to service this new demand. Later, green hydrogen becomes the dominant production process, supplying 64% in 2040 and almost 85% in 2050. The increase in green hydrogen requires a very large increase in electrolyser capacity. In 2017, electrolysers accounted for a production of only 2.2 PJ. This will need to grow almost 1000-fold in the Reference scenario to supply end-use hydrogen applications.

Figure 3-8: APEC hydrogen production and imports in the Reference scenario, 2000–2050 (PJ)



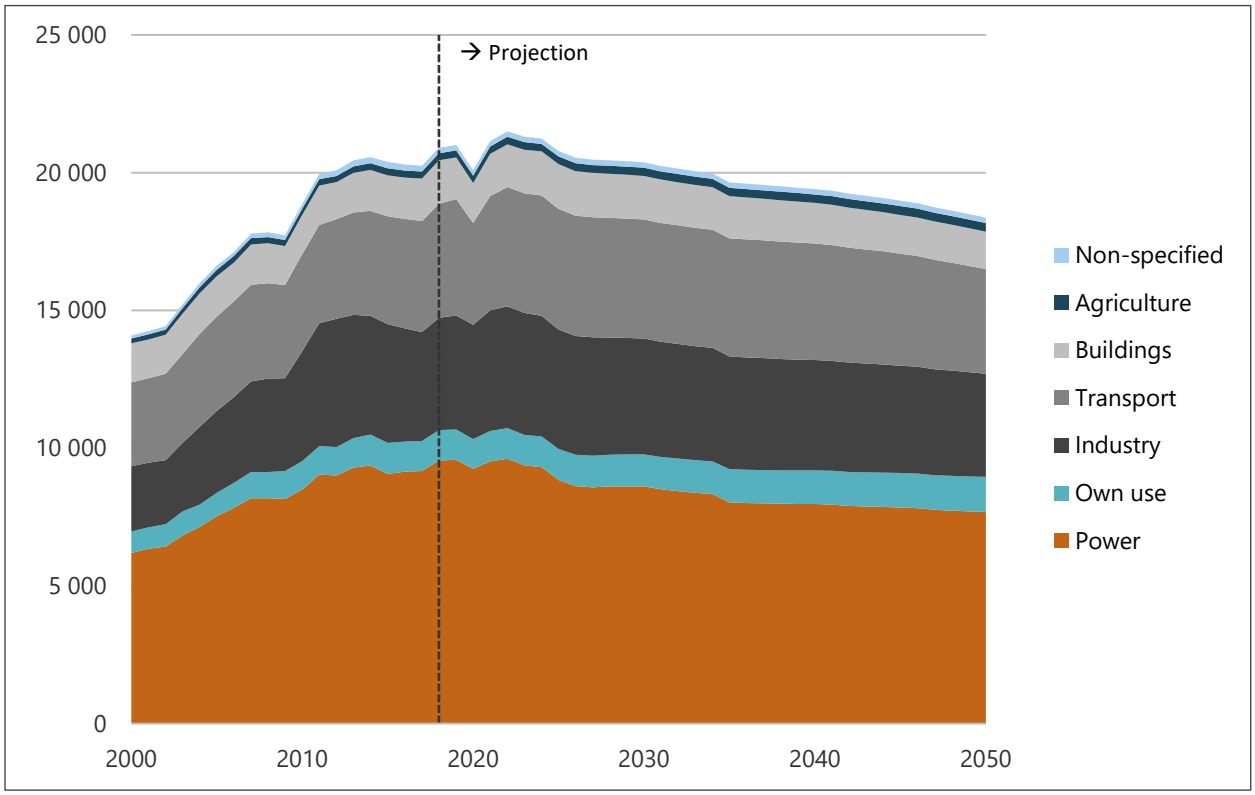
Source: EGEDA, APERC analysis.

3 – 5 CO_2 emissions

The power sector has been the largest source of energy-related CO_2 emissions in the APEC region (46% in 2018). The industry and transport sectors each emitted about 20%, while buildings emitted 8%. Coal contributed more than half of CO_2 emissions in 2018, with oil and gas contributing 27% and 20%, respectively.

In REF, the APEC region is expected to reduce its overall CO_2 emissions from 21 000 million tonnes in 2018 to 18 000 million tonnes in 2050. The largest CO_2 emissions reduction is by the power sector (20%), due mostly to a reduction in coal-fired generation. Buildings sector's CO_2 emissions reduce by 14%, driven by a decline of coal use in boilers for heating. The transport and industry sectors each contribute an 8% emissions reduction, due to electrification and fuel switching.

Figure 3-9: APEC Gross CO_2 emission in the Reference scenario, by sector, 2000–2050 (million tonnes)



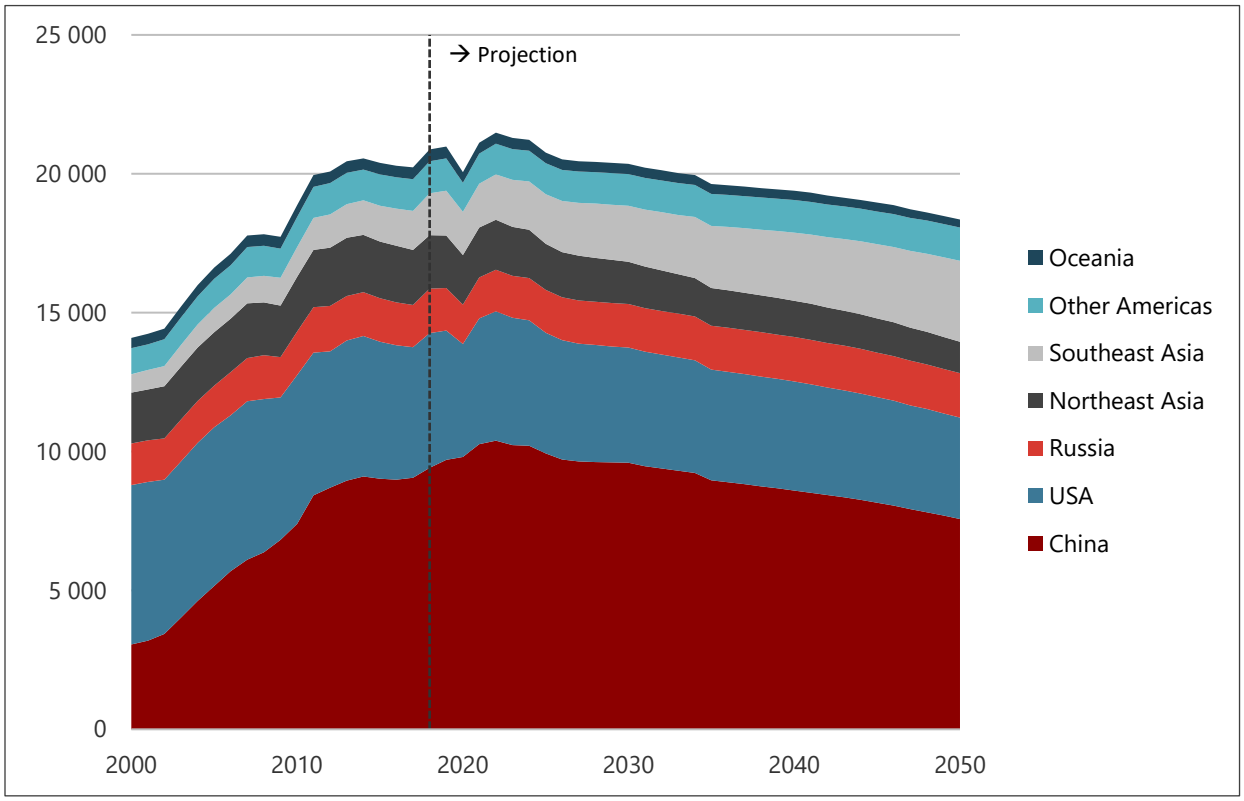
Source: EGEDA, APERC analysis.

These estimates consider only CO_2 emissions from combustion of fossil fuels in the energy sector. Fugitive emissions, such as flaring and methane leakage, and non-energy sectors are not considered.

China and the United States are the largest CO_2 emitters in APEC and the world, contributing 45% and 23% of APEC-wide CO_2 emissions in 2018. China's emissions tripled from 2000 to 2018, with a very large increase in industrial output. CO_2 emissions in southeast Asia doubled between 2000–2018, due to rapid economic development and increasing energy demand, that has been reliant on fossil fuels.

In the Reference scenario, CO_2 emissions are expected to decline for all regions except southeast Asia and other Americas between 2018 and 2050. Many of the economies will see an increase in the use of natural gas, but this increase is more than offset by a decline in coal and oil (refined products). Southeast Asia and other Americas CO_2 emissions expand by 92% and 4% between 2018 and 2050. Reliance on fossil fuels is expected to continue in these regions to meet their sectoral energy demands at the most affordable cost.

Figure 3-10: APEC Gross CO_2 emission in the Reference scenario, by region, 2000–2050 (million tonnes)



Source: EGEDA, APERC analysis.

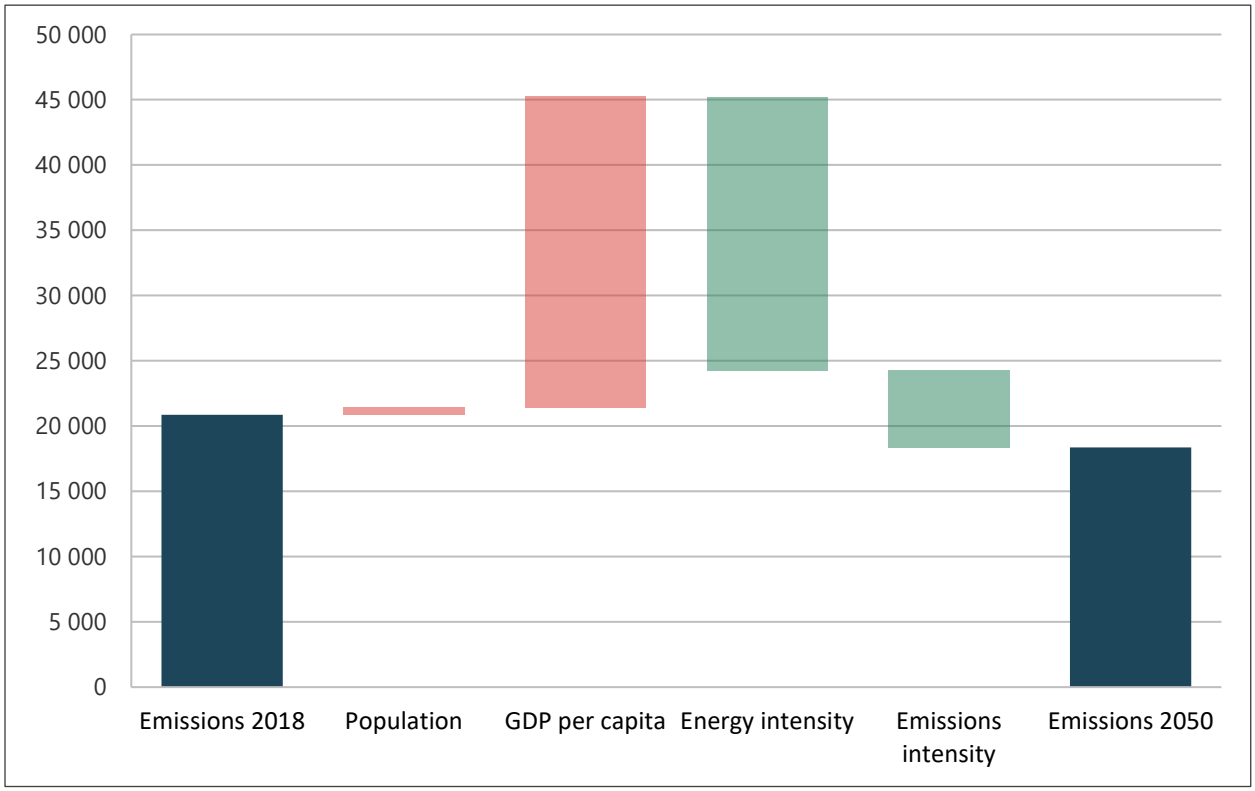
APEC population is expected to grow by 2% to 2050, despite population declines in China and northeast Asia. This marginal population increase presents only a small upward pressure on CO_2 emissions. Projected increases in living standards throughout APEC (increases in GDP per capita) is a much larger influencing factor on emissions out to 2050. Emissions would more than double due to increasing GDP per capita, were it not for improvements in energy intensity and emissions intensity.

In the Reference scenario, increases in population and economic output are more than offset by improvements in energy intensity and emissions intensity. Energy intensity improvements, such as greater fuel efficiency, and energy efficiency of appliances, are most influential in bringing about emissions reductions. Emissions intensity, such as by switching to less carbon-intensive fuels leads to emissions reductions as well. There is a small amount of carbon capture technologies that are adopted by heavy industry in some economies that contribute to a small improvement in emissions intensity as well. By 2050, the combined impact of improvements in energy and emissions intensity lead to emissions being 2 500 million tonnes lower than in 2018.

The emissions reduction in the Reference scenario is an encouraging baseline result in light of the very large increase in GDP per capita. However, the emissions reduction is not consistent

with international decarbonisation ambitions as outlined in agreements such as the 2015 Paris Accord.

Figure 3-11: APEC CO_2 emission components in the Reference scenario, 2018 through to 2050 (million tonnes)



Source: EGEDA, APERC analysis.

4 Conclusions

The Reference scenario provides a touchstone for the level of energy required for APEC to continue to prosper out to 2050. It is a scenario that assumes that improvements in energy intensity, and fuel switching to more economic and efficient fuel sources, continues at a modest pace. However, these incremental improvements that have been compounding over decades, deliver a level of energy consumption that is no longer so closely coupled to economic activity. The scale of energy consumption, and the supply sources required to deliver this consumption, remains vast, but the APEC region is increasingly able to do more with less, in an energy sense.

While energy demand and supply growth continues to slow out to 2050, there is a disparity in trends of fuel sources beneath the surface. Electricity use becomes more and more prominent in all sectors of the economy, with this prominence displacing demand for direct fossil fuel consumption. The sources that deliver this electricity are increasingly renewable, and this renewable take-up, which is primarily wind and solar, is driven largely by economics. The economics of renewables in the generation mix is clear, but there are limits to just how prominent

renewables become. Natural gas and nuclear are also relied upon, and coal continues to provide an important level of baseload generation for many economies.

The power sector becomes noticeably less carbon intensive even with significant growth in electricity consumption. In contrast, end-use sectors of energy continue to rely on significant levels of fossil fuel consumption. The continually improving intensity of energy use is the most important factor in seeing energy supply moderate and begin to reach a plateau near to 2050. Even without aggressive decarbonisation efforts, this has important implications for medium- to long-term fossil fuel production and exploration activities.

While there is a continued slow transition away from fossil fuels, fossil fuels still account for almost three-quarters of APEC energy supply, albeit with a marked movement away from coal to gas. The modelled pace of change for the Reference scenario means that emissions are marginally lower in 2050 and are not consistent with international climate commitments such as the Paris Accord.

5 References

Asia Pacific Energy Research Centre (2022), APEC Energy Demand and Supply Outlook 8th Edition [scheduled to be published in June 2022]