Coal and gas futures in the Asia-Pacific: Analysis of the impact of climate policy and technological pathways on the energy mix of China, India, Japan, South Korea and Indonesia

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Executive Summary

- Major partners of Australia in the Indo-Pacific have announced new near-term decarbonisation commitments and Net Zero pledges under the Paris Agreement, including India, Indonesia, Japan, the People's Republic of China, and South Korea.

- How these countries achieve their near-term and Net Zero decarbonisation targets is uncertain, and different trajectories will impact their regional coal and gas use, and their energy security.

- We use the Global Change Analysis Model (GCAM) to assess the impact of our trading partners' 2030 Nationally Determined Contributions (NDCs) and Net Zero pledges on their decarbonisation trajectories.

- We find coal is phased out rapidly across most scenarios as climate policies start to take effect; the timing of coal phaseout largely depends on the stringency of the NDC for 2030.

- For gas, future use depends on the viability of Carbon Capture and Storage, which differs across countries due to the availability of storage sites.

- Our assessment shows trading patterns of coal and gas may change rapidly in the lead up to 2030. While there may be a role for gas in achieving NDC targets, both coal and gas decrease notably in Net Zero scenarios where renewables can be firmed.

Coal and Gas Futures in the Asia-Pacific: Analysis of the Impact of Climate Policy and Technological Pathways on the Energy mix of China, India, Japan, South Korea and Indonesia

1. Introduction

In the 2023 National Defence Strategic Review the Australian government asserted “Climate change is now a national security issue” that “has the potential to significantly increase risk in our region.” It further notes climate change could lead to “mass migration, increased demands for peacekeeping and peace enforcement, and intrastate and interstate conflict.” (Commonwealth of Australia 2023).

A key issue in planning how to respond to climate change for national security is uncertainty. The most recent summary of the state of the global climate released by the Intergovernmental Panel on Climate Change (IPCC) states it is unequivocal humans have warmed the atmosphere, ocean, and land, leading to widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere. Yet it also shows there remains a large range of uncertainty around possible climate futures depending on the effect of future emissions on additional warming. There is also uncertainty about low-likelihood, high-impact tipping points in which the climate system or a climate sub-system crosses a critical threshold, leading to potentially abrupt and irreversible changes in natural systems (Lee et al. 2023).

One approach for assessing potential future climate change impacts, and the effect policies have on future climate trajectories, is Integrated Assessment Modelling (IAM). IAMs are quantitative models designed to study future change and the effect of policies on climate pathways. Broadly speaking, IAMs are used to understand the impact of climate change on different factors of interest, the economic impact of climate mitigation policies, or a combination of both, although there are substantial uncertainties in cost estimates depending on assumptions made about the future costs of technologies and how policies are designed and implemented (Weyant 2017).

Key trading partners of Australia have submitted new Nationally Determined Contributions (NDCs) under the Paris Agreement, and have made long-term Net Zero pledges, including Japan and South Korea (by 2050), China (by 2060), and India (by 2070).

Reflecting these international commitments, in this report we:

- Focus on a sub-set of Asia-Pacific countries that have made Net Zero pledges - Japan, South Korea, China, and India. We also analyse Indonesia given its importance to Australian interests.
- Assess how these countries' coal and gas futures differ across decarbonisation scenarios over the periods leading-up to the 2030 NDCs, up to 2050, and finally for the period between 2050 and 2070 by when India has pledged to achieve Net Zero emissions.
- We also assess the technological mix used for electricity generation across different scenarios.

Our results, which are calibrated to near and long-term commitments made by major regional partner countries under the Paris Agreement, show the firming of renewable energy and limiting of CCS causes a large decrease in coal and gas demand in the Asia-Pacific. Whether gas remains in the system in the long-term depends on the availability of carbon storage sites, which are more plentiful in the larger countries, but very constrained for South Korea and Japan. We also show a different dynamic across countries, where high-growth gas scenarios are only possible in China, Indonesia, and India with favourable assumptions for CCS.

2. Method

The Global Change Assessment Model (GCAM) is an IAM that uses projections of socio-economic variables (i.e. population and GDP) to model the possible changes to the energy and other sectors under different climate policy scenarios (see previous report ("1. Analysis, Planning for a More Uncertain Climate Future, 7 Sep 2022"). The GCAM energy system has representations of fossil resources (coal, oil and gas), and uranium and renewable sources (wind, solar, geothermal, hydro and biomass and traditional biomass). It also accounts for the processes that transform these resources to final energy carriers (electricity generation, refining, hydrogen production, gas processing and district heat). These are then used to deliver goods and services demanded by

end-use sectors (residential buildings, commercial buildings, transportation and industry) (Cui et al. 2018, 2019, 2021; Iyer et al. 2022).

In this study, we use version 6.0 of the model, which is available in a public repository (JGCRI 2022). We made key revisions to update the model for recent population and GDP projections. For China, India, Indonesia, Japan and South Korea, UN world population projections (UN Department of Economic and Social Affairs n.d.) are used to update the GCAM database. Also, recent GDP projections are taken from OECD (OECD n.d.) to update the labour productivity data used in the model. In addition, we adopted updated capital costs for key renewable energy technologies from the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO). CSIRO, with the Australian Energy Market Operator (AEMO), provide cost estimates for large-scale electricity generation, which are released annually (GenCost 2021-2022 CSIRO report; Paul Graham, Jenny Hayward, James Foster and Lisa Havas 2022).

3. Description of Scenarios

We analyse potential future worlds based on assumptions about future decarbonization pathways and technology options. We modelled four scenarios which take into account different levels of climate commitment, and have different technology assumptions for China, India, Indonesia, Japan and South Korea. Table 1 presents the NDC and NetZero commitments of the countries examined in the study, and which form the basis of the different climate commitments used in the scenarios.

Table 1. Countries' NDC and NetZero targets

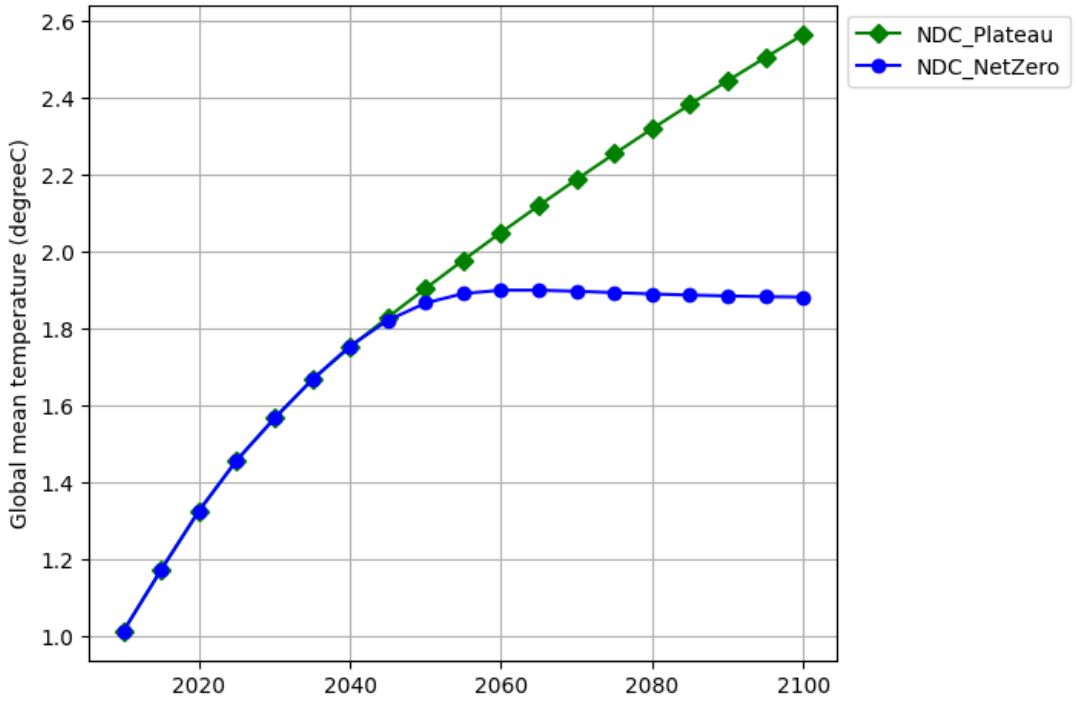
COUNTRY	NATIONALLY DETERMINED CONTRIBUTIONS (NDC)	NET ZERO PLEDGE
China	Peak CO_2 emissions in 2030	2060
India	33-35% reduction in emission intensity by 2030	2070
Indonesia	31.89% emission reduction by 2030	After 2070

Japan	46% reduction in GHG below 2013	2050
South Korea	Reduce emissions by 32% by 2030	2050

3.1. Assumptions about Climate Ambition

Global NDC and Net Zero emissions pledges have implications for the global climate trajectory. After implementing the caps following Iyer et al (Iyer et al. 2022), the global mean temperature for the "NDC Plateau" scenarios is around 2.6 0C, and around 1.88 0C for the Net Zero ("NDC Net Zero") scenario. This is shown in Figure 1.

Figure 1. Global mean temperature of considered scenarios



In terms of commitments by Australia's trading partners, we consider two levels of climate ambition:

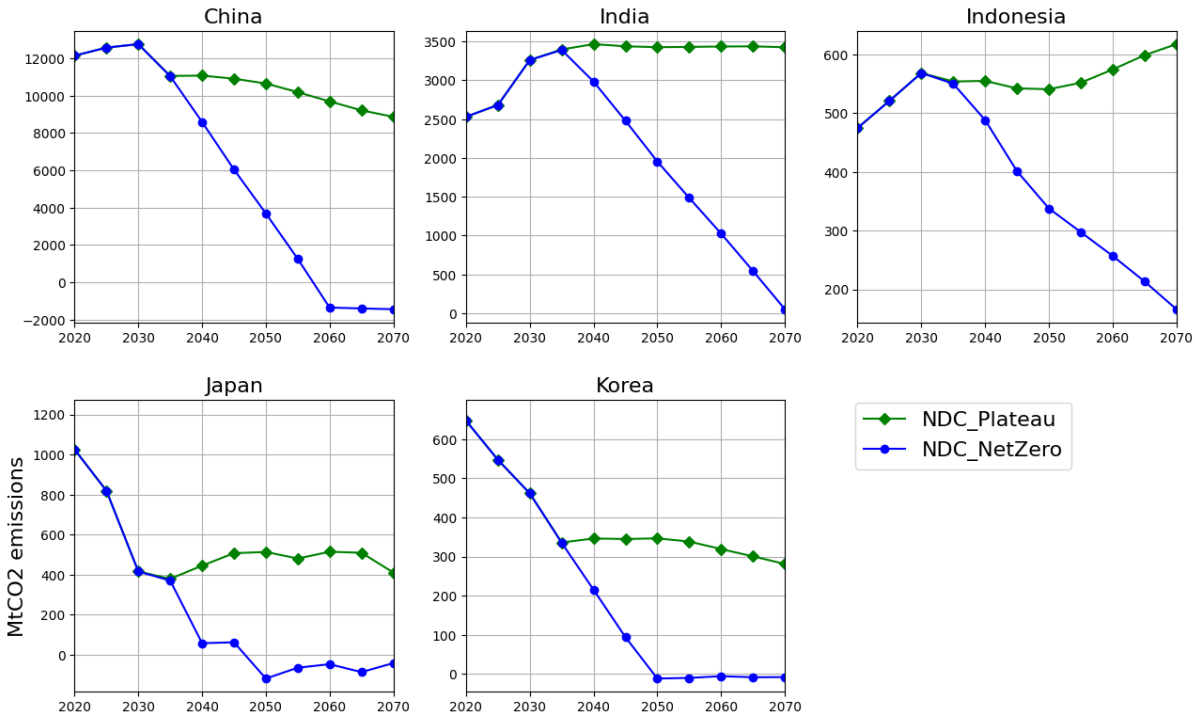
- In the first, we assume that countries achieve their near term NDC commitments, but do not implement any additional measures to reduce their greenhouse gas emissions;
- In the second, We assume that countries both achieve their near term commitments, and also go on to achieve the Net Zero commitments that they have made.

When we consider the implications of the NDC Plateau and NDC Net Zero scenarios for the countries included in the analysis (see Figure 2), we see important differences between

Australia's major trading partners in the Indo-Pacific, depending on the level of near-term ambition. China, India and Indonesia do not decrease their emissions immediately and continue their carbon intensive activities until 2030, 2040, 2030, respectively. After they peak CO_2 emissions, significant drops in emissions are observed in order to achieve their Net Zero targets for 2060 (China) or 2070 (India and Indonesia). In contrast, a fall in emissions starts suddenly the emission targets for Japan and South Korea, in order to reach Net Zero CO_2 emissions by 2050 for Japan and South Korea, while taking their NDC by 2030 and Net Zero by 2050 commitments into account.

These changes have implications for the technologies used by these countries to meet energy demand, as discussed in the next section.

Figure 2. Emission pathways of China, India, Indonesia, Japan, and South Korea depending in the scenarios



3.2. Technology Assumptions

A key question is what technologies will be used to achieve countries' emissions goals. We consider two technology options, centred on the availability of firmed renewable energy and options for Carbon Capture and Storage (CCS). The choice of these technologies is designed to represent real-world debates about the role of

- In the first Technology Future (TF1), we retain the default assumptions of GCAM, which limit the amount of firmed renewable electricity and allow for large amounts of onshore and offshore CCS.
- In the second Technology Future (TF2), we allow for higher levels of firmed renewable electricity by increasing the capacity factors[1] of solar and wind. We also limit CCS by constraining the availability of offshore CCs, and increasing the costs of onshore CCS options.

[1] Capacity factor is defined as the average output of a technology, relative to the maximum possible out output of the technology for a given period of time. Solar PV tends to have a lower Capacity Factor than fossil fuel generators given they require solar radiation to produce electricity.

This creates four different scenarios, shown below and summarized in Table 2.

- **Limited Ambition, Limited Renewables**:
  Countries meet their near-term climate commitments under their NDCs but no more; CCS is widely available and renewable electricity is not.
- **Limited Ambition, Abundant Renewables:**
  Countries meet their near-term climate commitments under their NDCs but no more; CCS is limited and there is abundant firmed renewable electricity.
- **High Ambition, Limited Renewables:**
  Countries meet both their near-term NDC and their long-term climate commitments; CCS is widely available and firmed renewable electricity is not.
- **High Ambition, Abundant Renewables:**
  Countries meet both their near-term NDC and their long-term climate commitments; CCS is limited and there is abundant firmed renewable electricity.

Table 2. Summary of Scenarios

		Climate ambition	
		NDC-Plateau: ***Achieves NDC, then uses that as a cap until 2050***	***NDC-Net Zero:*** ***Achieves NDC, then emissions reductions continue to Net Zero***
Technology assumptions	***No change to RE availability and CCS***	NDC-Plateau Technology Future 1	NDC-Net Zero Technology Future 1
	More RE available, and limited CCS	NDC-Plateau Technology Future 2	NDC-Net Zero Technology Future 2

In the next section we examine the implications of these different scenarios.

4. Results

4.1. Primary Energy Consumption

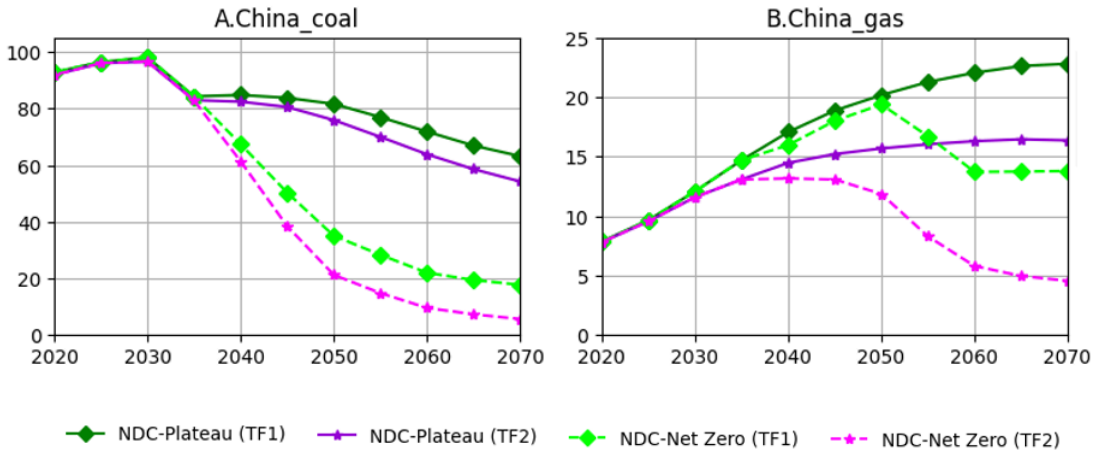
In this section we show how the primary energy consumption[2] of coal and gas in China, India, Indonesia, Japan and South Korea changes under the assumptions in the scenarios outlined above.

China is the largest producer and importer of coal globally, and it has a large share of coal in its primary energy consumption. The role of coal changes in China changes in the scenarios considered. Specifically, coal use in China falls across all scenarios after peaking in 2030 (Figure 3, Panel A). However there is a clear divergence between the less ambitious NDC Plateau and the NDC NetZero climate scenarios, with coal consumption falling rapidly after 2030 in the latter. For coal use, the most important factor is thus China's overall level of climate ambition.

Technology developments also have an effect on coal use in China, although it is more muted. Specifically, if it becomes feasible to deploy CCS technologies at scale (Technology Future 1 (TF1)), then total consumption of coal remains higher than the limited CCS option (Technology Future 2 (TF2)). In the latter scenario, the availability of firmed renewables reduces coal independently of climate action ambition.

[2] Primary energy consumption is defined as the total energy used in a country, prior to its transformation into electricity. It is measured here using Exajoules, which is a measure of the embodied energy.

Figure 3. Primary Energy Use of Coal and Gas for China in Exajoules

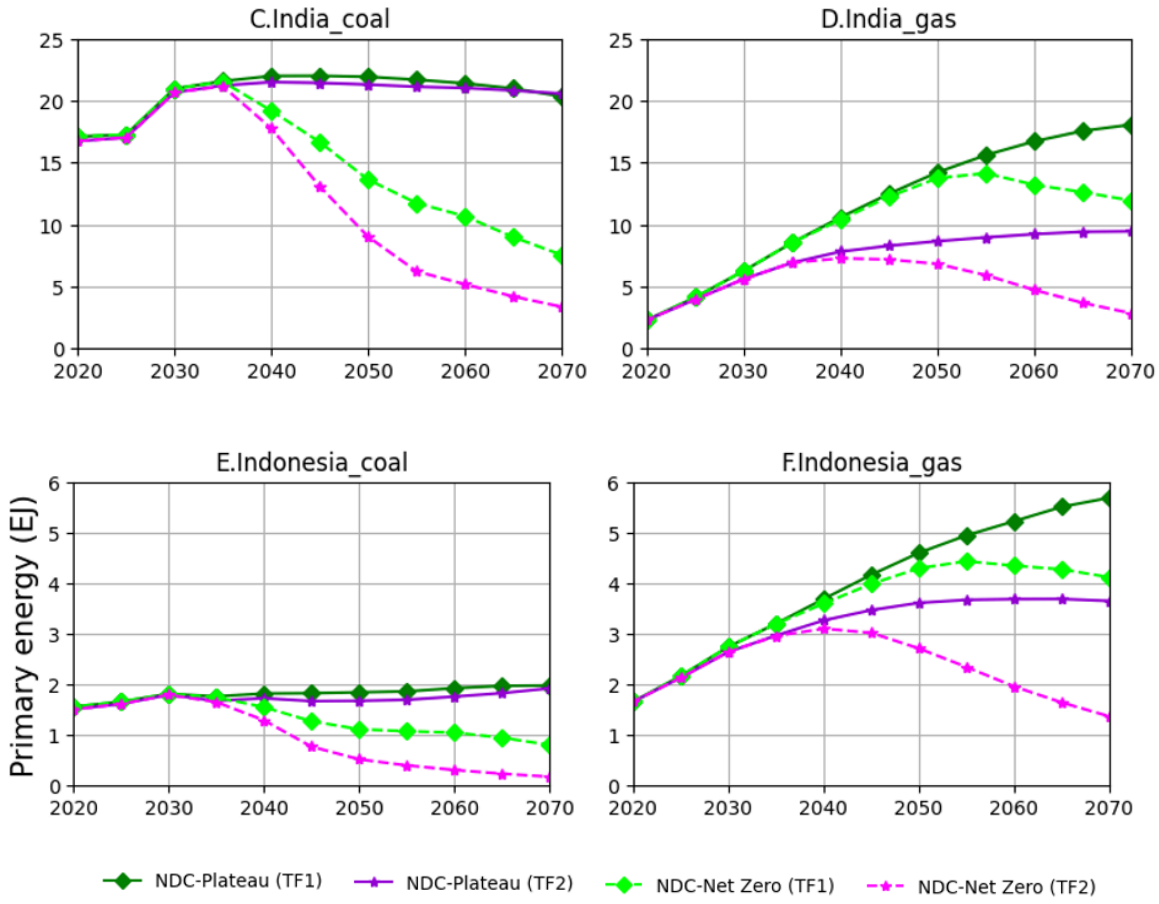


There is an important contrast when we focus on gas consumption in China. Gas remains an important part of the fuel mix to mid-century in the ambitious and less ambitious climate scenarios. Even in the Net Zero scenario with Technology Future 1 (NDC_NetZero (TF1)), gas consumption increases to 2050 before declining (Figure 3, Panel B).

The importance of technology is more pronounced for gas than for coal. The results show that the availability of firmed renewable energy coupled with limited CCS options limits the role of gas. Where there are limited renewable energy and abundant CCS options, gas use falls from 2050 in order to meet China's Net Zero commitments, but remains much higher than if these options are not available. The future role of gas in China is thus more contingent on technology developments than is the case for coal.

Turning to India and Indonesia, for coal we obtained similar results as for China. After reaching its maximum in 2030 for Indonesia and around 2040 in India, coal consumption stays stable under scenarios with weaker climate ambition, while declining in the more ambitious NDC NetZero scenarios. Similar to coal results in China, coal consumption in India and Indonesia is minimized across the four scenarios where firmed renewables are available, and there are more limited options for CCS (NDC NetZero (TF2)).

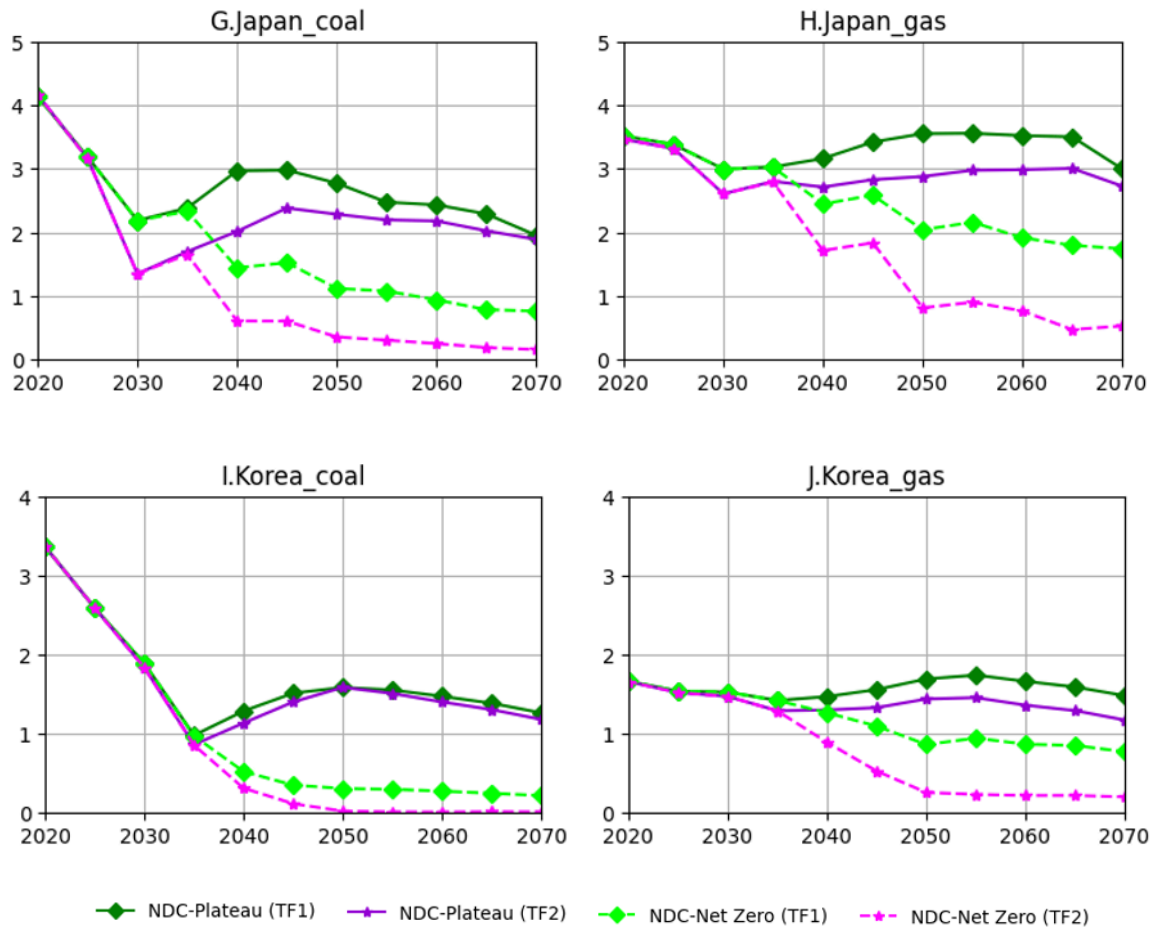
Figure 4. Primary Energy Use of Coal and Gas for India and Indonesia in Exajoules



The demand for gas in India and Indonesia also shows similar trends as in China. Future gas consumption in India and Indonesia has more reliance on future technology options than climate ambition. With the availability of CCS and limited renewable energy, for example, gas demand keeps increasing until 2055 for NetZero scenarios (NDC_NetZero (TF1)) while gas demand reaches its peak around 2040 and declines significantly with firming renewables and limited CSS options (NDC_NetZero (TF2)).

In contrast to the above countries, Japan and South Korea have different trends for coal and gas. Due to NDC commitments of Japan, a significant drop in coal demand is observed by 2030 across all scenarios. Under the more ambitious Net Zero scenarios, continued coal use is once again contingent on CCS. The importance of coal to Japanese energy security strongly depends on the level of global (and Japanese) climate ambition, even though it has a general declining trend across all scenarios.

Figure 5. Primary Energy Use of Coal and Gas for Japan and South Korea in Exajoules



If we look at the role of gas, we can see that Japan remains strongly reliant on across NDC Plateau scenarios. Even in the Net Zero scenarios consistent with a mean global increase in temperatures of 1.88 degrees Celsius, which is the most ambitious of the scenarios examined here, gas continues to play an important role in Japan if offshore CCS sites are available, as shown in NDC NetZero (TF1), although demand falls to almost half of current use. Gas use reaches its minimum in the scenario including firmed renewables and limited CCS assumptions, falling rapidly by the mid-2030s.

There are similarities between South Korea and Japan in the trajectories of coal and gas use under different levels of global climate ambition. South Korea sees a sustained fall in coal imports and use across each of the scenarios by 2035, but the rate of change and overall use of coal mid-century is strongly affected by the decarbonization pathways the country adopts. Similar to

Japan, across each of these scenarios South Korea remains reliant on gas in order to meet its domestic energy needs. As with Japan, in the NDC Plateau scenarios demand for coal falls rapidly by 2035 and does not fluctuate after that while under NetZero ambitious scenarios a continues reduction in coal occurs until it reaches NetZero by 2050.

4.2. Electricity Generation

In this section, we show how the mix of technologies used for electricity generation in China, India, Indonesia, Japan, and South Korea changes global climate ambition increases, and how this is affected by the availability of different technologies. Electricity makes up a large share of total energy use across each of these countries, and decarbonization scenarios suggest that electrifying transport and other parts of the economy currently supplied by other fuels is an important factor in overall energy system decarbonisation. Modelling has uncertainties based on future technology costs, learning rates, and other factors, but the analysis provides a view on how the overall level of ambition could affect the transition pathways of Australia's key trading partners.

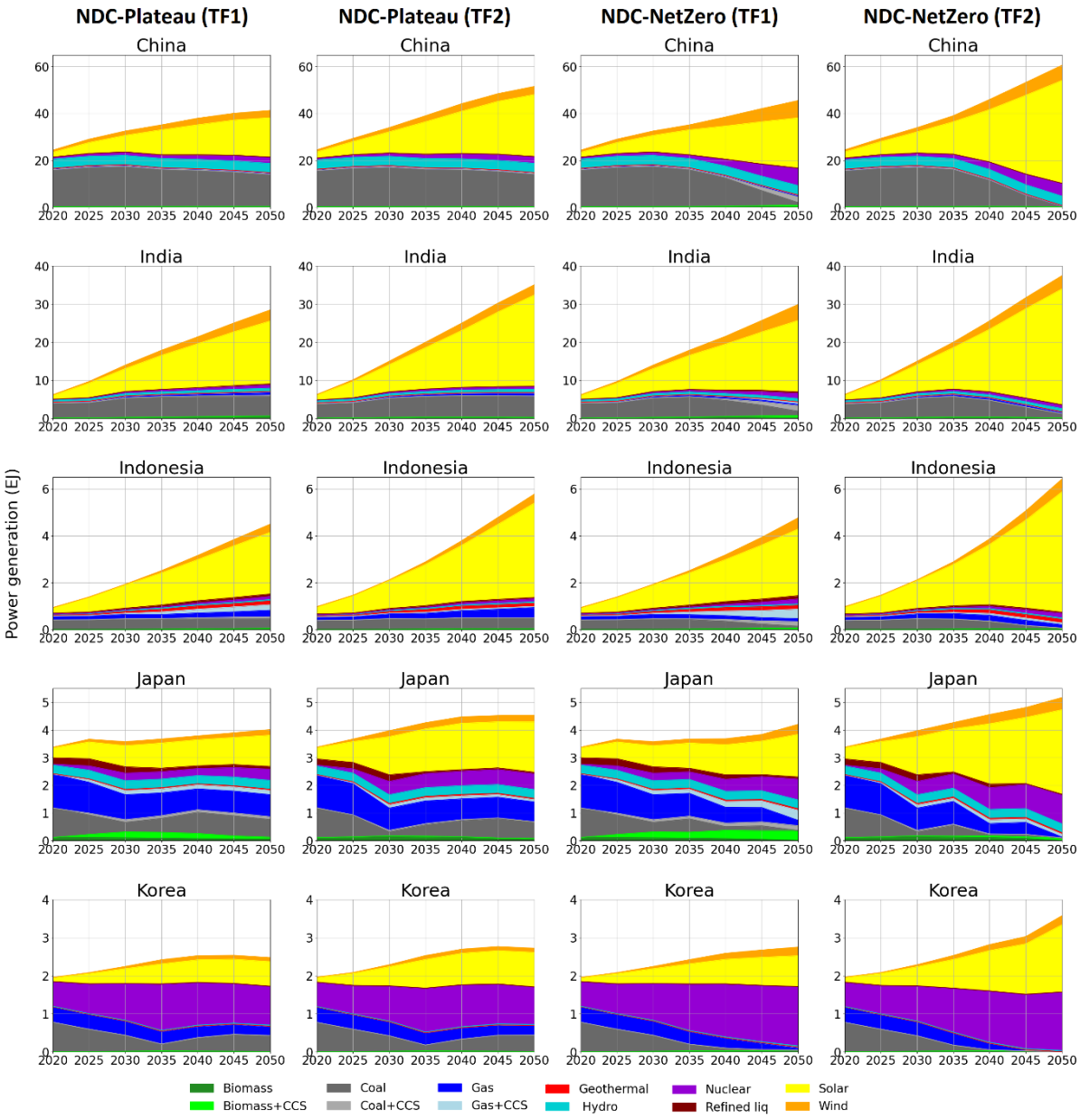
The results highlight a direct trade-off between CCS and renewable energy with storage (Figure 5). In all countries and scenarios solar photovoltaics quickly grows to meet increases in electricity demand. In China and India, as global climate ambition rises (NDC NetZero (TF1)), coal with CCS increases relative to the less ambitious scenario (NDC Plateau (TF1)), along with nuclear power, solar photovoltaics, and wind power. On the other hand, when we compare the two ambitious scenarios with different technological assumption, low deployments of CCS (NDC NetZero (TF2)) results in a much larger deployment of solar PV and wind power, and less nuclear power in the generation mix.

In Indonesia, with increasing climate target ambition, the results show that not only coal with CCS but also gas with CSS increases in the electricity mix. However, this is not the case for CCS limited scenarios (TF2 options).

For Japan and South Korea, gas use in the electricity sector shows a decrease when compared to 2020 levels as climate target ambition increases. However, for the scenarios tat do not limit CCS, gas with CCS and biomass with CCS remain in the electricity mix for Japan. Due to limited CCS availability in South Korea, we do not see any technology with CCS in any of the scenarios. Also, in

Net Zero scenarios, coal decreases in the electricity mix while nuclear, solar and wind dominates the generation mix.

Figure 4. Electricity generation of regions under different scenarios



5. Implications for Australia

The results presented here take into account countries' Nationally Determined Contributions (NDCs) under the Paris Agreement, and their long-term Net Zero pledges. We confirm that climate ambition and the availability of technology options available to meet climate commitments have large effects on the future role of coal and gas.

Our results also show there are important differences in the effect of these two factors on future demand for the two commodities. Specifically, the scenarios show that future coal use is strongly affected by the overall level of ambition in countries' climate commitments, with a rapid and near-term reduction in the use of coal in more ambitious scenarios due to the higher environmental burden of coal.

In contrast, the effect of technological developments around renewable energy and CCS has a stronger effect on future gas use. Gas use follows a similar trajectory to that of coal under the assumption of more widespread renewable energy deployment with limited CCS, but remains in energy systems for longer where CCS is widely available, and increases relative to today in most scenarios.

IMPLICATION ONE: AUSTRALIA'S ROLE AS A SUPPLIER OF THERMAL COAL SHRINKS EVEN UNDER LESS AMBITIOUS CLIMATE SCENARIOS. THIS HAPPENS REGARDLESS OF TECHNOLOGY DEVELOPMENTS

There are important implications of these changes for Australia. China, India, and Indonesia have abundant coal deposits, and the reduction in demand for coal means seaborne trade in thermal coal is likely to shrink rapidly across scenarios. Coal use also falls for Japan and South Korea. Although these countries have few domestic deposits of coal, the fuel will play a far small role in their energy systems across scenarios. Australia is a major exporter of thermal coal, and our role as a supplier of this energy product will fall.

Implication Two: Australia's Role as a Long-Term Supplier of Liquified Natural Gas is Dependent on Technology Developments

Concern over energy security amongst Australia's trading partners is larger for gas than for coal because the structure of gas supplies is less diversified. The role of gas increases in three of the four scenarios for most countries analysed. Gas use falls in the scenario with more readily available renewable energy and limited CCS, showing that Australia's role as a long-term supplier of Liquified Natural Gas is dependent on technology developments. Australia is not a significant producer of oil, and if this scenario best resembles future developments, our role as a trusted supplier of energy commodities to the region will begin to diminish in the 2030s.

IMPLICATION THREE: MAJOR COUNTRIES IN THE REGION WILL GROW INCREASINGLY CONCERNED ABOUT SUPPLY CHAIN CONCENTRATION IN SOLAR PHOTOVOLTAICS

Turning to electricity generation, the results show that solar photovoltaics will play a crucial role in meeting marginal growth in electricity demand across all countries regardless of the level of climate ambition and technology developments. This is due to the overwhelming cost advantage of solar photovoltaics compared to other technologies. From a supply chain perspective, this implies that all countries will become increasingly interested in energy security concerns related to solar PV across the supply chain. China's dominance across multiple stages of the supply chain for solar PV is likely to grow as an area of concern for regional governments. Developments such as recent consideration by the Indian government to stop building new coal power plants because of the large amount of solar photovoltaics under development indicate the importance of this emerging issue (Singh and Varadhan 2023)**.** Wind power, in contrast, plays a less significant role in meeting marginal growth in electricity demand although it still increases across scenarios and countries.

Implication Four: Australia Should Consider the Implications of a Potential Historic Shift in Our Regional Role as an Energy Commodity Supplier in the Indo-Pacific

For decades Australia has acted as a supplier of energy security to key trading partners in the Indo-Pacific region. The scenarios is examined here suggest that the low carbon energy transition

is set to transform our trading relationships with partners, with near term falls in their use of coal, and the medium to long term use of gas conditioned by technology developments. Supply chains for solar photovoltaics will become increasingly important, as will the supply chains for firming technologies in the electricity sector. Australia should consider the strategic implications of these changes as we transform our participation in global supply chains for renewable energy technologies.

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