COAL PHASE OUT

AND ENERGY TRANSITION PATHWAYS

FOR ASIA AND THE PACIFIC

7 AFFORDABLE AND CLEAN ENERGY

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Economic and Social Commision for Asia and the Pacific

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Executive summary

The Asia-Pacific region, more than any other global region, is highly reliant on fossil fuels. How it transitions away from fossil fuels will be a pivotal issue for Asia-Pacific and the world in the coming years, in light of the current and future climate impacts and the sustainable development benefits possible through an energy transition.

This paper aims to provide insights into how the region can transition away from coal to a renewable-based efficient energy system compatible with the Paris Agreement and Sustainable Development Goals (SDGs). The study brings together a systematic review of literature and data to provide a background on the current situation as well as drivers of coal expansion in the region, options for a clean energy transition and the benefits of a transition, to highlight policy options. The paper reviews the data on coal's share in the Asia-Pacific region's power generation and capacity, and assesses the benefits of a transition away from coal. It presents an analysis on the impact of greenhouse gas emissions at the regional level as well as regional impacts of global warming, illustrating the importance for the region of achieving the Paris Agreement goals. The paper concludes with a review of proven policies based on existing literature, evaluating their potential application in the region to provide recommendations for Governments to adopt best practices.

Coal generation is still expanding in Asia-Pacific – against the trend in other regions

The Asia-Pacific region has a very large share of current global coal capacity and generation as well as expansion plans. A total of 27 countries in the Asia-Pacific region account for about 76 per cent of current global coal generation capacity and for almost the entire (94 per cent) global pipeline[1] of coal-fired power plants under construction, planned or announced. The countries in the South and South West Asia subregion with coal capacity at present are all expanding their capacity, most of them have very high expansion plans compared with their current capacity, reflecting their fast-growing energy supply particularly electricity demand. The group of countries in South and South-West Asia with high expansion plans (Turkey, Pakistan and Bangladesh) include only 2 per cent of current coal capacity within the Asia-Pacific region, but 13 per cent of the expansion pipeline within this region. While India still relies strongly on coal for power generation, coal-fired power generation has decreased and the pipeline is shrinking. With strong policies to enhance renewable energy uptake, there is potential for India to move away from coal faster.

South-East Asia is characterised by particularly high growth of demand in energy, and in particular electricity demand, and is dominated by countries with expansion plans. It includes 5 per cent of the Asian and Pacific coal capacity, but 16 per cent of its coal pipeline. Most of the subregion's countries that have expansion plans already have high capacity (Indonesia, the Philippines, Thailand and Viet Nam), two have expansion pipelines larger than the current capacity (Viet Nam and the Philippines) and several have currently low capacity but large expansion plans (Cambodia and the Lao People's Democratic Republic).

1 "Pipeline" refers to coal fired power plants under construction, planned or announced., planned coal capacity includes those that are in different stages of pre-permit development or have received all necessary approvals but not yet begun construction.

Even without counting the additional capacity that is in the pipeline, emissions from coal-fired power generation in the Asia-Pacific region would continue at a very high level until after 2040, and would only be phased out by around 2060. This is in stark contrast to the needs of the Paris Agreement Long-term temperature goal which will require the global phase-out of unabated coal by 2040 and the achievement of peak coal-fired power generation by 2020 before quickly reducing afterwards to 80 per cent below 2010 levels by 2030. Existing coal plant assets are at risk of becoming stranded assets. Any new capacity will be exposed to even greater risk, threatening to unnecessarily increase the cost of the energy transition and placing a higher burden on the emerging economies that are less able to afford it. At the subregional level, this risk is particularly high in the subregions with relatively new coal capacity and large expansion plans, such as in South and South-West Asia and South-East Asia.

The global trend of declining coal capacity, now expected to be accelerated by the COVID-19 pandemic, is dominated by trends outside of the Asia-Pacific region, particular by record retirements in the European Union and the United States. The picture in the Asia-Pacific region is different, with an overall net increase of coal capacity by 10 GW in the first half of 2020 that was mainly driven by China (9.6 GW). Outside of China, net retirements in the Republic of Korea, the Russian Federation and India have been almost cancelled out by a net increase in capacity in Japan, Viet Nam, Bangladesh and Indonesia.

Looking forward, the sharp reduction in cost of solar and wind power as well as storage technologies – particularly solar photovoltaics (PV) – together with policies against air pollution, increasing adoption of climate change policies as well as awareness of the need to phase out coal to deliver the aims of the Paris Agreement, is leading to an increasing move to phase out coal for power generation at the national or subnational level. There are also clear signs of an increasing aversion towards financing new coal-fired power plants among many government and investors, given these trends and the increasing awareness of the risk of stranded assets.

Drivers in the Asia-Pacific region of support for coal and expansion of coal-fired power generation

Contrary to the global drivers retarding the use of coal, there are factors that are still driving support for coal and expansion of coal-fired power generation within many countries in the Asia-Pacific region. These include: high demand growth in South and South-East Asia; the presence of a large share (more than 60 per cent) of global coal reserves in the region; and a high dependency on income from coal exports in some of the countries in the region whose Governments support coal mining and coal-fired power generation, including through subsidies and public finance.

Support for coal in the Asia-Pacific region is driven by the geopolitical influence of four countries – China, Japan, the Republic of Korea and India – that have historically relied on coal and are large coal importers. Governments, government-owned financial institutions or government-owned utilities in those four countries are strongly supporting coal expansion in the region. The main recipients of this support are countries in South and South-East Asia – Bangladesh, Indonesia, Pakistan and Viet Nam. International support in the region and the large influence of the coal industry on national policy and decision-making has supported the continuing prevalence of the narrative of supposedly cheap coal and the need to provide “baseload power” to address the growing energy demand. This narrative is kept alive by vested interests largely favouring coal. Together with inconsistent policy signals and uncertainty regarding long-term goals as well as complex energy policy responsibilities within Governments with the strong influence of state-owned sources has led to investors holding back more than in other regions. It has also resulted in a delay in the development of policies and energy plans needed to overcome barriers to faster expansion and integration of larger shares of renewable energy, especially wind and solar.

Benchmarks and benefits – pathways to 100 per cent renewable energy in line with the Paris Agreement and Sustainable Development Goals

Based on multiple lines of evidence, a range of benchmarks for the power sector have been developed through an in-depth analysis of modelling studies, with between 50 to 80/85 per cent of renewable energy share achievable by 2030 in South and South-East Asia by 2030, on a pathway towards 100% renewable electricity generation by 2050. Utilization of solar and wind could satisfy the needs of almost all South and South-East Asian countries many times over. Renewable energy costs have rapidly fallen during the past 10 years due to technology improvements, economies of scale, competition in renewable energy supply chains and advancing industry experience. Solar PV is now the cheapest source of new electricity generation in most parts of the world, including countries in South and even South-East Asia, which had shown higher costs in the past. Feasible cost reductions of 40-50 per cent in solar PV in Indonesia, Thailand and Viet Nam as well as 15-45 per cent for onshore wind – resulting mainly from industrial learning curves throughout the world – show that there is potential for continued cost reduction.

The regional integration of power grids offers numerous further advantages for renewable energy resource sharing and cost reduction, with larger grid integration and transmission providing more flexibility and less need for additional storage. An emerging option in addition to larger regional grid integration is trade of green hydrogen produced from renewable electricity, where countries with strong renewable full load hours provide cost-efficient green hydrogen.

The Asia-Pacific region has countries that are extremely vulnerable to climate change, making it the most disaster-prone region globally. However, substantial avoidance of severity of future climate extremes can be achieved if the global temperature increase is kept to the Paris Agreement's 1.5°C limit, compared to either 2oC warming or the likely result from the NDCs – an increase of 3°C. This emphasizes the need of early and substantive efforts to curb greenhouse gas emissions, and reinforces the urgency of transformative change in the energy system of countries, regionally as well as on the global scale.

Three-quarters of all people affected by natural disasters worldwide are living in the Asia-Pacific region. The average annual economic loss from natural disasters is now estimated to be 2.4 per cent of GDP, with an expected clear upward trend when temperatures continue to rise. Increased global warming is projected to lead to substantial changes in GDP per capita. Almost half of the Asia-Pacific countries considered in this analysis are projected to experience GDP losses between 30 and 41 per cent by the end of the century compared to the baseline scenario. Clear gains in GDP per capita of up to 12 per cent in mid-century and up to 18.3 per cent by the end of the century are expected for countries in the Pacific, South-East Asia, and South and South West Asia in achieving 1.5°C rise instead of 2°C. The largest gains are expected in Thailand, Cambodia, Bangladesh, the Lao People's Democratic Republic and Viet Nam.

Renewable energy provides a large range of benefits for sustainable development:

- Renewable energy can be deployed rapidly, and in areas that are not connected to the grid, important for a region where not all of the population has access to electricity;
- Installation of renewable energy can replace fossil imports creating security and also avoid price fluctuations of fossil fuel imports;
- Renewable energy provides employment opportunities, and employment is crucial for post-COVID-19 recovery;
- Phasing out coal reduces air, water and soil pollution as well as negative impacts on water quality and water scarcity.

Policy recommendations for key actors in the Asia-Pacific region

Drawing from the analysis of current trends and drivers in the Asia-Pacific region, the gap with Paris Agreement benchmarks for phasing out coal and accelerating the transition to clean energy, as well as the overview of policy areas including best practice examples in other regions, this study has formulated the following recommendations for key actors in the Asia-Pacific region to accelerate phasing out coal in line with the Paris Agreement benchmarks:

1 National Governments: Adopt best practice policies – phase out fossil fuel subsidies, carbon pricing, renewable energy support, encourage and push shifts in investment through green recovery

Phasing out fossil fuel subsidies, combined with the development of carbon pricing and targeted adoption of key best practice policies to enhance the share of variable renewable energy and accelerate investment – particularly in wind and solar – through market design, demand-side management, transmission and distribution system enhancements, grid interconnections and support for energy storage are crucial. Green recovery needs to be at the heart of economic stimulus packages developed by Governments. This needs a focus to be placed on directing public funding and incentivising private investments towards renewable energy and related technology and infrastructure development, such as storage and transmission grids, as well as on electrification of end-use sectors and further measures to improve energy efficiency across end-use sectors.

2 National Governments: Move to transformational policies, targets and long-term planning

The need to ratchet up NDC targets and develop long-term low carbon development strategies in the context of the Paris Agreement is an important step, as these goals were due in 2020 and are expected no later than 2021. Developing coal phase-out plans by 2040 is the single most important step that needs to be included in these targets to ensure consistency with the Paris Agreement and SDGs. This needs to be combined with a process of planning and managing the transition that is developed with stakeholders from the regions affected, particularly those that currently depend on employment and income from coal mining and coal-fired power generation.

3 Clear pathways to enable anticipation of change and avoidance of more stranded assets

An important element in elaborating NDC targets and long-term strategies in line with the Paris agreement is the development of scenarios and analysis, involving and informing stakeholders and supporting a dialogue about benefits at the sectoral level. A key gap in leading the development of both national and regional strategies, plans and policies is the need to develop a range of scenarios for the energy system that are in line with the Paris Agreement and SDGs, and to aim for 100 per cent renewable energy.

4 Financial support and capacity-building

Countries in the Asia-Pacific region that are in the position to do so, need to focus their financial and other development support on shifting investments and energy system transformation towards clean energy. This holds true for Australia, Japan, the Republic of Korea, China and India, which currently play a strong role in cementing dependency on fossil fuels in poorer countries in the region, particularly in the South and South-East Asian subregions. Coordination of Government donors with philanthropy by the private sector can be an important strategy. This approach has started with a focus on South-East Asia, but it also needs to be applied to other countries in the Asia-Pacific region, particularly where investment in new coal or gas-powered generation is only just starting.

5 Regional and international cooperation – alignment with Paris Agreement Goals, engaging stakeholders, the private sector and civil society

Regional and international cooperation in the Asia-Pacific region can play an important role. Countries in the region can either join existing initiatives such as the Powering Past Coal Alliance. This and other recent initiatives in the area of energy system transformation are often successful when they include Governments at both the national and subnational levels as well as the private sector, research organisations and civil society in order to be effective in mobilising stakeholder engagement and supporting a shift in narrative and perception. An initiative at the regional level could also focus on joining efforts to overcome barriers to shifting away from coal production and dependency on coal exports among countries or by subnational legislation in the region.

6 Trans-boundary grid transmission and integration

An important area for enhanced regional cooperation is grid transmission and trans-boundary grid integration. This can build on existing examples and initiatives, and needs to be further developed with the objective of achieving 100 per cent renewable energy systems. Existing initiatives can be built on, or similar initiatives can be applied to other subregions. With some of the world's best renewable energy potentials in some subregions – for example, the Pacific (Australia), parts of South and South-East Asia, and Central and East Asia – such cooperation provides huge opportunities for faster transition to 100 per cent renewable energy. This includes countries that have lower potential or higher demand, e.g., with high population density.

7 Financial institutions – cooperation in sustainable finance, clear policies and transparency

More countries in the Asia-Pacific region are joining initiatives such as the Climate Investment Platform or the recently launched International Platform of Sustainable Finance that now has 14 members including China, India, Indonesia and New Zealand. This can be an opportunity to benefit from scaling up the mobilisation of private capital towards environmentally sustainable investments dialogue between policymakers that are in charge of developing sustainable finance regulatory measures, thereby potentially moving towards alignment of best practices.

8 Private sector engagement

The private sector can play an important role in accelerating investment in renewable energy as it is an important source of growing demand as well as by joining private-public partnerships and initiatives to finance large-scale renewable energy projects. Initiatives in the private sector have also started to develop benchmarks for decisions at the sectoral level. Incorporating climate risk is an important element in providing the right information to the private sector, and public finance institutions should set an example. ESCAP could support this effort by encouraging the development of clear benchmarks at the regional level.

Introduction

The Asia-Pacific region[2] contributes significantly to the increasing global greenhouse gas emissions, particularly through its high reliance on fossil fuels – especially coal – for power generation as well as its dynamic growth that is increasing demand for energy, particularly electricity, to meet development needs. A key issue for the region is how to reverse the fossil fuel trend, particularly in view of the current and future climate impacts and the benefits of sustainable development that are possible through energy transition as well as the unprecedented circumstances of the global COVID-19 pandemic. This report provides insights into how the region can transition away from coal to a renewable-based efficient energy system that is compatible with the Paris Agreement and SDGs.

The Asia-Pacific region dominates both current use of coal for power generation and the global expansion of coal-fired power generation, with 76 per cent of current global coal capacity and 94 per cent of global planned new coal capacity for power generation. The region also dominates coal production and consumption overall, accounting for 80 per cent of global coal production as well as of global consumption. Asia and the Pacific is therefore a crucial region in efforts to achieve the global benchmark to phase out coal-fired power generation globally by 2040 as a key step to achieving the Paris Agreement's long-term temperature goal.

With an increasing awareness of the need to halt further expansion of coal-fired power generation and transition away from coal, it is important for the Asia-Pacific region to tackle this challenge. Understanding what is driving current developments and how to join a growing global momentum against coal is essential if countries are to be able to respond to the call by the United Nations Secretary-General for a moratorium on new unabated coal-fired power generation. The growth of the Powering Past Coal

2 For the purposes of this report, the "Asia-Pacific region" is defined as comprising the 53 member States of ESCAP.

Alliance, established in 2017, now has a total of 110 members, including 34 national Governments and 33 subnational government authorities, is an indication of this increasing momentum.

Given the important role of the Asia-Pacific countries in coal-fired power generation, understanding how countries in this region can benefit from joining in and accelerating a transition away from coal and towards renewable energy is more important than ever. While coal is also used in other parts of the energy system such as industrial and residential heat, and steel production, the focus in this study is on coal-fired power generation as a key benchmark for the overall phasing out of coal. To reach a pathway consistent with the Paris Agreement, existing coal fired capacity would need to be shuttered or operated less before the end of asset lifetimes. Hence, each additional coal development increases the risk of stranded assets. The region can benefit from falling costs for renewable energy and storage technologies, providing an alternative pathway towards affordable, reliable and clean energy access.

This report brings together a systematic review of literature and data to provide a background on the current situation, drivers of coal expansion, options for a clean energy transition and the benefits of a transition to inform policy options. It extracts data on coal share in power generation and capacity in the Asia Pacific region, and details its own analysis of the impact on greenhouse gas emissions at the regional level as well as the regional economic impacts of global warming. The report also conducts a policy review to assess the proven policies in the region based on existing literature, to suggest recommendations for Governments to adopt best practices.

Chapter 1 provides an understanding of the current situation by exploring the current regional energy trends, coal expansion plans, recent trends including the impact of the pandemic, and implications of coal expansion plans for regional greenhouse gas emissions.

Chapter 2 identifies the drivers of coal expansion in the region, contextualised in contrast to the global trends away from coal. These drivers need to be identified in order for Chapter 3 to delve into the question of how the region's trends towards fossil fuels can be reversed, and to assess the options for a clean energy transition.

Chapter 3 offers a systematic literature review of published global, regional and subregional scenario pathways for renewable energy in electricity generation. This chapter develops key regional benchmarks of Paris Agreement compatible pathways for coal and renewable energy in power generation, building on an analysis in Climate Action Tracker (2020), and the feasibility of 100 per cent renewable energy systems. Chapter 3 also explores the feasibility of a renewable energy transition, assessing the large untapped potential for renewable energy across the region, and provides available information on cost at the regional level, with a focus on wind and solar.

Chapter 4 highlights the benefits of transitioning away from fossil fuels towards a renewable based efficient energy system, particularly with reference to meeting the Paris Agreement and SDGs, and a green economic recovery from the COVID-19 pandemic impacts. It provides an assessment of proven policies that need expansion and acceleration across the region, focusing on whole-of-the-economy approaches, and the research and development needed for decarbonisation

Chapter 5 concludes by offering possible solutions to decarbonising the region with best practice policies and planning for national Governments as well as regional and international cooperation.

Chapter 1

Current situation, trends and expansion plans

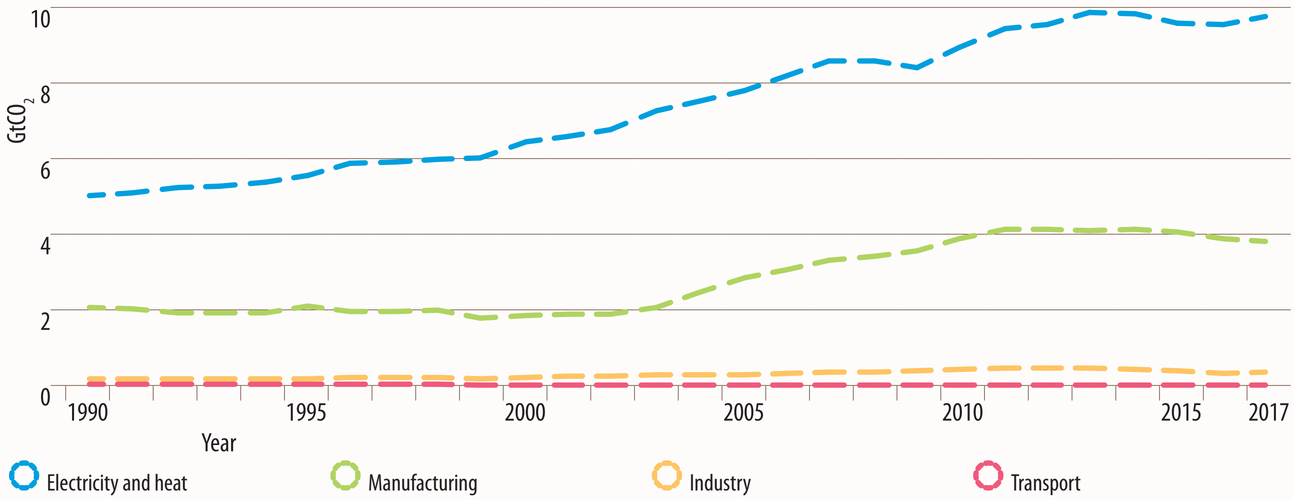
1.1 Current role of coal for power generation in the Asia-Pacific region

Global coal consumption peaked in 2013, with a rebound in 2017 and 2018 due to increased demand for power generation; however, it has been decreasing since 2007 in OECD countries. About 80 per cent of global coal is consumed in the Asia-Pacific region and consumption peaked in 2014. More than 50 per cent of demand is in China, where coal usage peaked in 2013 (BP, 2020). Two-thirds of coal consumed globally is for electricity generation (IEA, 2020d); coal consumption for this purpose was increasing until 2019.

Figure 1

CO_2 emissions from coal by sector

Lifetime: 40 years | Capacity factor: 0.5



Source: Global Carbon Project, IEA 2019.

Carbon dioxide emissions from coal combustion for electricity generation and heating accounted for 67 per cent of the total global emissions from coal combustion in 2017 (figure 1). The remaining emissions stemmed primarily from iron, steel and cement production (Peters *et al.*, 2020). In 2017, global consumption from iron and steel production constituted 16 per cent of total demand, and 47 per cent of all non-electricity and heat-related energy demand (International Energy Agency, 2019).

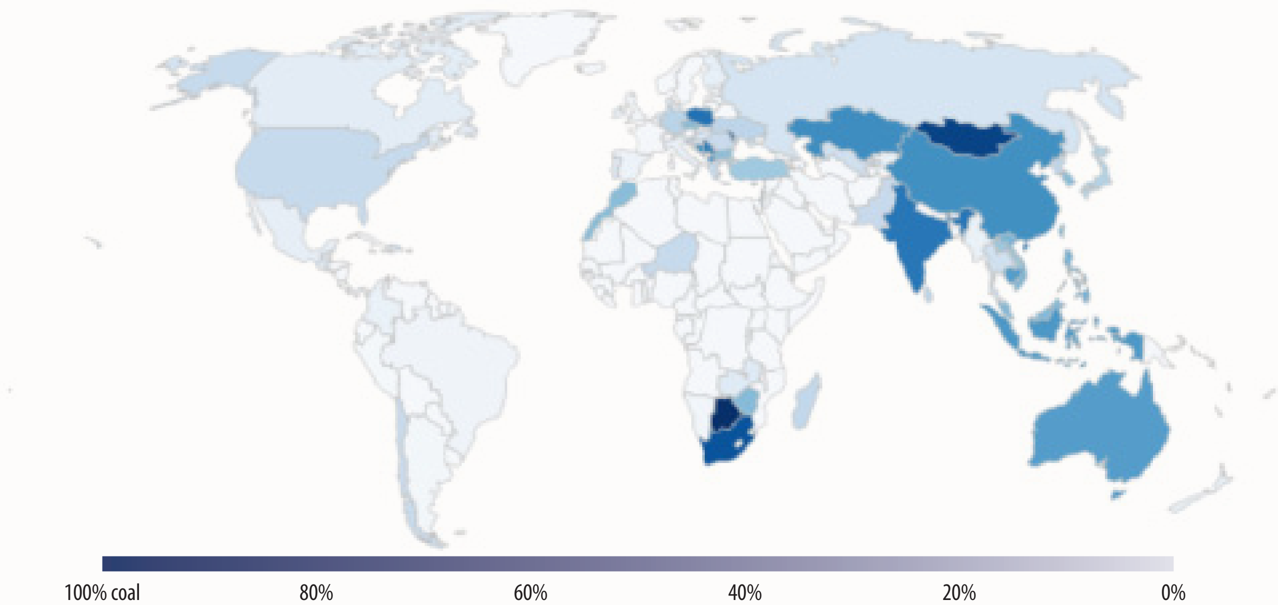
A profound shift in the source of global iron and steel production occurred during recent decades, with 83 per cent of global production coming from non-OECD countries, compared with 45 per cent in 1978. This is primarily due to a steep rise in Chinese production, with China accounting for more than half of total global steel production in 2018 compared with just 15 per cent in 2000 (World Steel Association, 2020).

A large proportion of the remaining global coal consumption is by the cement industry, with approximately 60 per cent of non-electricity, non-iron/steel-based demand coming from cement production in 2017 (International Energy Agency, 2019; and World Coal Association, 2020). China dwarfed all other countries in cement production in 2019, producing an estimated seven times more cement than second-placed India, and again accounted for more than half of total global production (Curry, 2020). Viet Nam, a country with a considerable network of coal-fired power stations, was estimated to be the world's third-largest producer of cement in 2019.

While these trends point to a need for discussion on transition away from coal use across the energy system, it is important to note that phasing out coal use in the power sector is a relatively low-hanging fruit. The technological alternatives to fossil fuels in the electricity sector are mature and ready to deploy if there is an enabling policy environment, and it is for this reason this report focuses on coal use in the Asia-Pacific electricity sector.

Figure 2

Coal generation as percentage of national electricity generation in 2019



Source: Ember, 2020
Note: The boundaries shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

The Asia-Pacific region holds a very large share of current global coal capacity and power generation as well as expansion plans. A total of 27 countries in the region have coal capacity larger than 30 MW (Global Energy Monitor, 2020) and account for about 75 per cent of current global coal generation capacity (approximately 1,500 GW). Many ESCAP member States hold a high share of coal-fired power generation. The Asia-Pacific region is out of step with the trend of decreasing coal use that is seen elsewhere, particularly in the European Union and the United States. Efforts to reduce coal use elsewhere are being offset by an expansion of coal consumption in the Asia-Pacific region, and the rapidly increasing share of global coal use correspondingly implies the growing importance of local efforts to phase out its use.

There is great diversity regarding socioeconomic development, access to electricity and other factors driving electricity demand in the Asia-Pacific region. The region includes many countries that are still working on providing access to electricity, which together with economic and population growth, and urbanization, is one of the driving factors for the high growth in electricity demand. Figure 2 shows the percentage of coal generation in electricity production globally.

Table 1 shows the share of coal in both power generation and capacity for the Asia-Pacific countries arranged in order of highest to lowest coal capacity. The top eight (China, India, Japan, Russian Federation, Republic of Korea, Indonesia, Australia, Viet Nam) account for about 70 per cent per cent of global coal capacity – China and India account for 61 per cent. The Asia-Pacific region, as a whole, accounts for 76 per cent of global coal capacity.

Table 1

Share of coal in power generation and capacity in the Asia-Pacific region by economy

Economy	Share of coal fired power in national power generation (%) (2018)	Total current coal capacity (MW)	Share of global coal capacity (%)	Net Capacity Change: Jan 2020 to July 2020	Retired
China	66.8%	1,022,877	50.0%	9 671	27,684
India	73.5%	228,157	11.1%	-300	7,514
Japan	32.3%	48,309	2.4%	1,245	960
Russian Federation	15.9%	44,562	2.2%	-1,080	2,535
Republic of Korea	44.1%	36,436	1.8%	-1,120	1,845
Indonesia	56.4%	33,135	1.6%	250	0
Australia	60.5%	25,107	1.2%	0	1,840
Viet Nam	47.4%	19,717	1.0%	688	0
Taiwan Province of China	47.5%	18,873	0.9%	0	362
Turkey	37.2%	17,717	0.9%	57	0
Malaysia	45.3%	13,529	0.7%	0	0
Kazakhstan	69.6%	12,704	0.6%	0	0
Philippines	52.4%	9,954	0.5%	0	0
Hong Kong, China	66.5%	6,110	0.3%	0	500
Thailand	20.0%	5,933	0.3%	0	600
Pakistan	7.7%	5,090	0.2%	0	0

Economy	Share of coal fired power in national power generation (%) (2018)	Total current coal capacity (MW)	Share of global coal capacity (%)	Net Capacity Change: Jan 2020 to July 2020	Retired
Democratic Peoples' Republic of Korea	12.0%	3,700	0.2%	0	0
Uzbekistan	3.4%	2,522	0.1%	0	0
Lao Peoples' Democratic Republic	34.9%	1,878	0.1%	0	0
Bangladesh	1.9%	1,185	0.1%	660	0
Kyrgyzstan	7.0%	910	0.04%	0	195
Sri Lanka	30.9%	900	0.04%	0	0
Mongolia	88.5%	816	0.04%	0	0
Cambodia	37.4%	505	0.02%	0	0
New Zealand	3.6%	500	0.02%	0	0
Tajikistan	6.8%	400	0.02%	0	0
Brunei Darussalam	0%	220	0.01%	0	0
Myanmar	6.3%	160	0.01%	0	0
Papua New Guinea	-	0	0	0	0
Total Asia-Pacific		1,561,906	76.3%	10,071	44,036
Global	39% (2019)	2,047,046	100%	-2,930	

Source: IEA, 2020d and authors' calculations based on Global Energy Monitor, 2020.
Note: Note: Countries are listed here in descending order based on their current coal capacity. Countries not included in the table do not have coal power plants bigger than 30 MW and are not planning new ones.

1.2 Planned coal fired power generation

The Asia-Pacific region accounts for almost the entire global coal-fired power development pipeline, and a 94 per cent share of all coal-fired power plants in construction, planned or announced[3] (a total of about 500 GW).

Table 2 shows the coal pipeline in countries in the Asia-Pacific region, in different stages of development. For most countries, it confirms the tendency of shrinking expansion plans, in particular over the first half of 2020; however, China, the Philippines and the Russian Federation show a net increase in the coal pipeline. The top 10 countries account for 91 per cent of the total global coal pipeline – China (48 per cent), India (12 per cent), Turkey (6 per cent), Indonesia (6 per cent), Viet Nam (6 per cent), Bangladesh (4 per cent), the Philippines (2 per cent), Japan (2 per cent), Mongolia (1 per cent) and Pakistan (1 per cent). Just five countries – China, India, Turkey, Indonesia and Viet Nam account for 80 per cent of the global coal pipeline.

Figure 3 shows the cumulative capacities in the different stages of development by technology, which is relevant to the impact on greenhouse gas emissions. Subcritical, supercritical and ultra-super critical power plants can be differentiated by the pressure of the boiler used in coal power plants; the pressure is the lowest in subcritical power plants and the highest in the ultra-supercritical power plants, with efficiency increasing with the boiler pressure.[4] However, the likelihood of the pipeline ever being completed is shrinking. For example, the Philippines recently announced a moratorium, which could take out up to 8 GW to 10 GW of their pipeline (Ahmed and Brown, 2020; and Department of Energy, 2020).

3 "Announced" refers to proposed plants that have been described in corporate or government plans but have not yet taken concrete steps such as applying for permits or acquiring land.

4 For a more detailed overview see https://www.gem.wiki/Coal_power_technologies

**Table 2 **

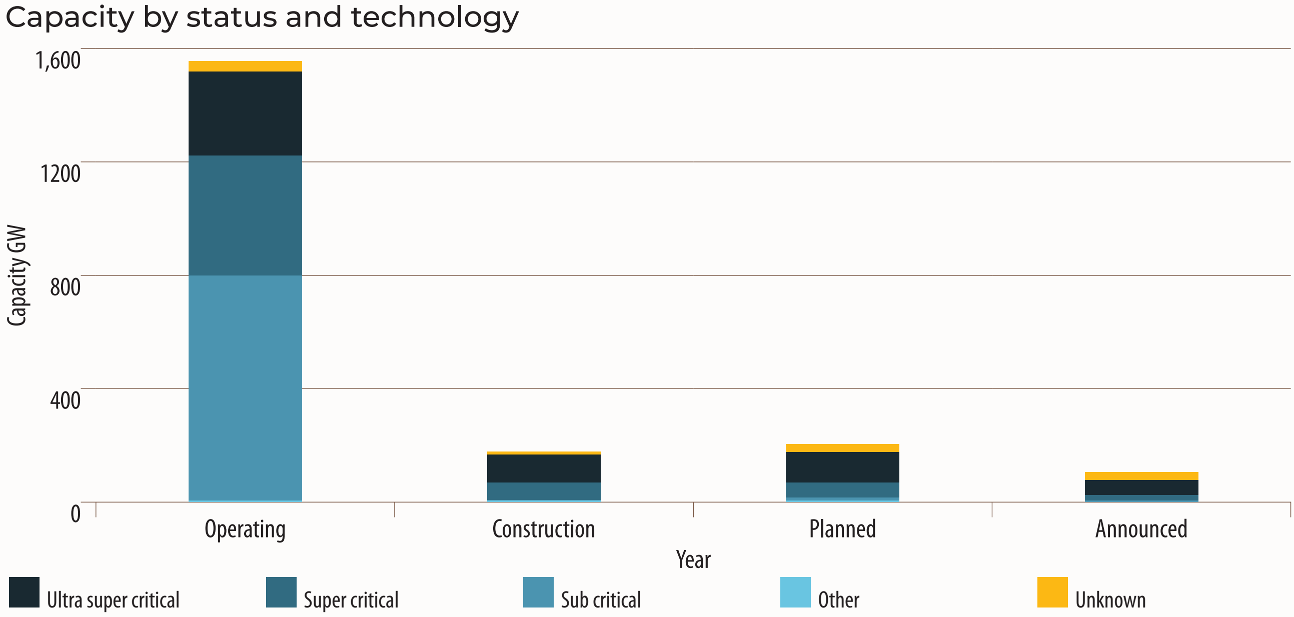
The coal pipeline in the Asia-Pacific region: Current expansion plans and recent changes

Economy	Total coal capacity in construction (MW)	Currently Planned coal capacity (MW)	Announced coal capacity (MW)	Total coal pipeline: in construction, planned, announced (MW)	Share of global pipeline (in %)	Change in coal pipeline (construction, planned, announced minus cancelled) Jan 2020 to July 2020
China	98,520	105,162	48,564	252,246	48.35	45 275
India	35,205	23,518	6,030	64,753	12.41	-22 998
Japan	7,424	2500	0	9,924	1.9	-247
Russian Federation	656	1000	786	2,442	0.47	195
Republic of Korea	7,260	0	0	7,260	1.39	0
Indonesia	11,290	10,370	9,660	31,320	6	-5,700
Australia	0	0	2,320	2,320	0.44	-660
Viet Nam	7,420	19,480	2,840	29,740	5.7	-540
Taiwan Province of China	0	0	0	0	0	0
Turkey	1,610	18,605	13,460	33,675	6.46	-550
Malaysia	0	0	0	0	0	0
Kazakhstan	636	0	0	636	0.12	0
Philippines	1,941	9,240	900	12,081	2.32	1,328
Hong Kong, China	0	0	0	0	0	0
Thailand	0	56	1,255	1,311	0.25	-1,000
Pakistan	1,650	4,260	1,538	7,448	1.43	-220
Democratic People's Republic of Korea	0	0	0	0	0	0
Uzbekistan	0	0	150	150	0.03	0
Lao People's Democratic Republic	0	0	2,800	2,800	0.54	-700
Bangladesh	4,754	3,960	12,290	21,004	4.03	-120
Kyrgyzstan	0	0	0	0	0	0
Sri Lanka	0	0	1,200	1,200	0.23	0
Mongolia	850	5,280	1,400	7,530	1.44	0
Cambodia	150	1,400	265	1,815	0.35	0
New Zealand	0	0	0	0	0	0
Tajikistan	0	0	0	0	0	0
Brunei Darussalam	0	0	0	0	0	0
Myanmar	0	0	0	0	0	-1,090
Papua New Guinea	0	60	0	60	0.01	0
Total Asia-Pacific	179,366	204,891	105,428	489,715	93.9%	12,973
Total global	189,817	217,803	114,698	521,688	100%	2,955
Asia-Pacific share of global	94.5%	94.1%	91.9%	93.9%	93.9%	-

Source: Authors' calculations based on Global Coal Plant Tracker (information as of July 2020) (Global Energy Monitor, 2020).
Note: The economies are listed here in a descending order based on their current coal capacity. Countries not included in the table do not have coal power plants bigger than 30 MW and are not planning new ones. Coal capacity in pipeline: In different phases ranging from construction to planned or announced. Currently planned coal capacity includes plants that are in different stages of pre-permit development or have received all necessary approvals but not yet begun construction. Announced refers to proposed plants that have been described in corporate or government plans but have not yet taken concrete steps such as applying for permits or acquiring land.

**Figure 3 **

Current coal fleet and pipeline in **Asia-Pacific** region by status and technology



Source: Authors' calculations based on data from Global Energy Monitor, 2020.

It is also unlikely that the announced or proposed coal-fired power plants in Australia will ever be built.[5]

Of the total of about 490 GW of coal capacity in the pipeline, a large share is planned for ultra-super critical or super critical (best available) technology, whereas about half of the currently planned 1,500 GW project pipeline is subcritical. The shift to more modern technology is motivated by efficiency gains. However, even with a high share of super critical or ultra-super critical units, impacts on air pollution and greenhouse gas emissions would remain high. For example, the Republic of Korea has one of the highest shares of ultra-super critical coal power plants in the world, and still the sector's contribution to air pollution is very significant, representing 11 per cent of fine dust pollution in 2018 (*Climate Analytics*, 2020b).

As could be expected, such a large region is highly differentiated across subregions. Here we look more closely into Asia-Pacific subregions with the highest expansion plans and group countries regarding the significance of their expansion plans in relation to currently operating capacity. We group countries in the Asia-Pacific subregions into categories, distinguishing between countries with relatively stable or contracting coal capacities (where there are no major expansion plans or expansion plans are smaller than retired capacity); and countries with expanding coal capacities. For the latter, we distinguish between those with high expansion plans in comparison to current capacity from those with higher current capacity than

5 Two new coal-fired power plants have been proposed in Australia by two owners/developers who have sought federal government funding. For one of them, in Collinsville, NSW, a feasibility study is being funded by the federal Government. A new plant at Hazelwood (Victoria) has not been shortlisted for a government underwriting programme.

**Table 3 **

Country groupings by Asia-Pacific subregion and coal capacity expansion categories

Category		Asia-Pacific subregion				
		North and Central Asia	East and Northeast Asia	South and Southwest Asia	South-East Asia	Pacific
Stable/contracting	Small or no net expansion; expansion smaller than retired capacity	Kazakhstan[6] Kyrgyzstan Russian Federation Tajikistan Uzbekistan	Democratic People's Republic of Korea Hong Kong , China, Japan Republic of Korea[7] Taiwan Province of China		Brunei Darussalam Malaysia Myanmar	Australia, New Zealand
Continuing expansion from high-current capacity	Current capacity larger than pipeline	--	China	India	Indonesia Thailand	--
Accelerating expansion compared to current capacity	Pipeline larger than current capacity	--	Mongolia	Bangladesh Pakistan Sri Lanka Turkey	Philippines Viet Nam Cambodia Lao People's Democratic Republic	--
New Player	No current capacity, but planning new capacity	--	--	--	--	PNG
Share of current coal capacity within Asia-Pacific region		3.9%	72.8% China: 65% Without China: 7.3%	16.2% India: 14.6% Without India: 1.6%	5.5%	1.6%
Share of coal pipeline within Asia-Pacific region		0.7%	56.6% China: 51.5% Without China: 5%	26.2% India: 13.2% Without India: 12.9%	16.2%	0.5%

Source: Authors' calculations, based on data from Global Energy Monitor, 2020.

expansion plans, which typically have not relied or relied substantially on coal until recently. Only one country in the region (Papua New Guinea) does not have any current coal capacity but is planning new capacity ("new player") (table 3). The subregions show very different characteristics concerning the age distribution of their coal fleet.

6 Kazakhstan would currently fall into the "expanding" category, as it has 636 MW under construction, but has no further pipeline.

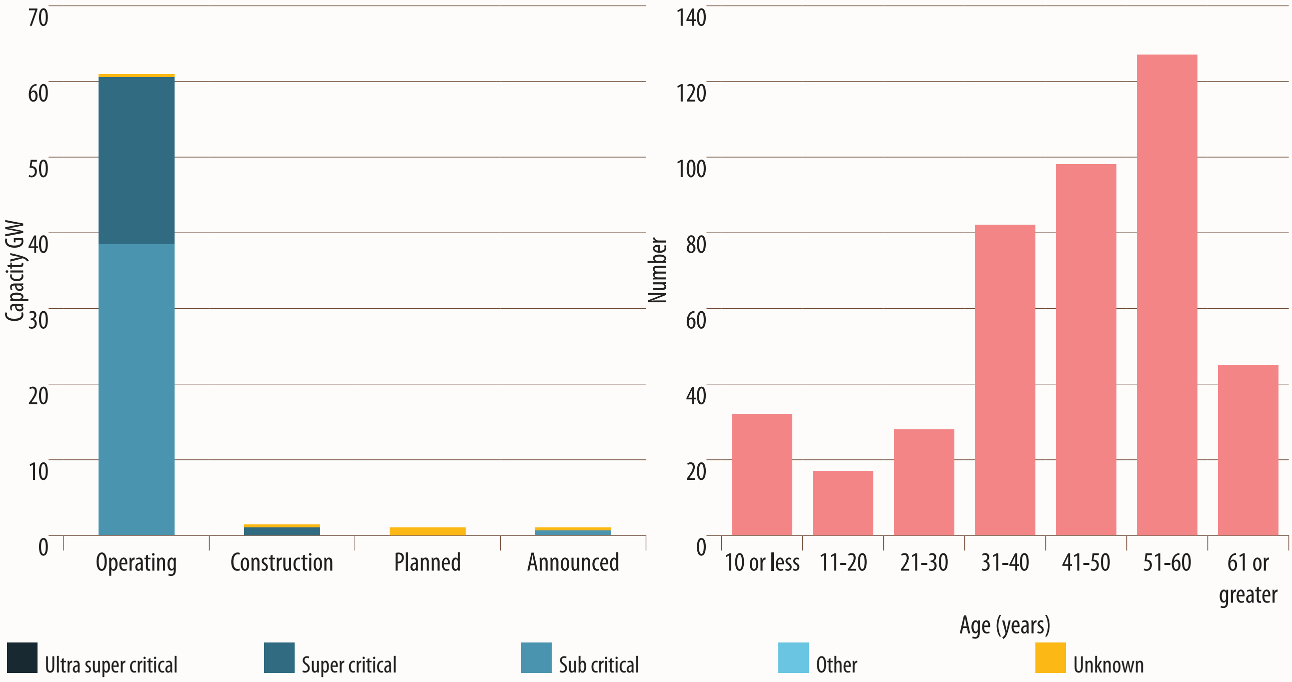
7 Japan and the Republic of Korea are still expanding, as they both have capacity in construction and, in the case of Japan, in permitted state.

Of the five countries in the North and Central Asia subregion with coal capacity above 30 MW, none has meaningful expansion plans. They have largely unchanged or slightly contracting total capacity with ageing coal fleets (figure 4). This subregion includes 4 per cent of current coal capacity within the Asia-Pacific, but only

**Figure 4 **

Current coal fleet and pipeline (left) and age distribution (right) in the **North and Central Asia** (**NCA**) **subregion** by status and technology

Capacity by status and technology



Source: Authors' calculations, based on data from Global Energy Monitor, 2020.
Note: This region is characterised by an ageing coal fleet and a high share of subcritical technology.

0.7 per cent of the coal expansion pipeline and a large share of sub-critical technology.

This is similar in the Pacific countries with coal capacity, mainly Australia, and with some capacity in New Zealand. One country in the Pacific, Papua New Guinea, has no current coal capacity but is planning new capacity ("new player").

The coal fleets in the East and North-East Asia subregion are typically stable or contracting, but younger compared to the coal fleet in the North and Central Asia or Pacific subregions. They have a much higher share of more modern, more efficient technology (super critical, ultra-super critical) (figure 4). Japan and the Republic of Korea are currently still expanding their capacity but are actively discussing policies to reduce coal use.

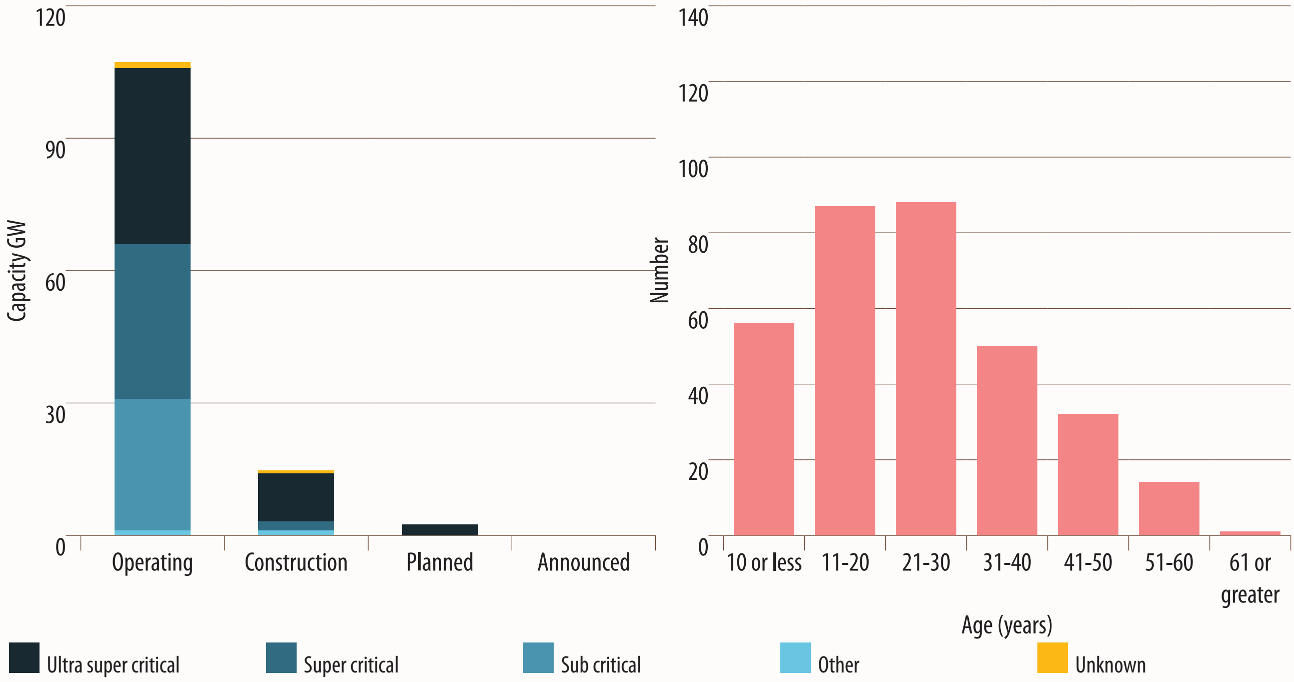
Two countries in the East and North-East Asia region, China and Mongolia, are currently expanding and continuing to plan expansion of their coal capacity. In Mongolia, the capacity growth expansion plans are larger than the current capacity. For China, the capacity growth expansion plans are smaller than the current capacity. This is partly influenced by the policies of control over coal consumption and its share in the energy mix in the thirteenth Five-Year Plan (2016-2020) (Wang *et al.*, 2020), which is reinforced by actions against air pollution and climate change in China (Hang *et al.*, 2019)this paper decomposes industrial SO_2 emissions into six specific driving factors in three whole process treatment dimensions (i.e. source prevention, process control, and end-of-pipe treatment.

China alone is home to about half of all operating coal power and almost half the global coal

**Figure 5 **

Current coal fleet and pipeline in countries in the **East-/North-East subregion** (**ENEA**) with stable or contracting coal capacity, by status and combustion technology

Capacity by status and technology



Source: Authors' calculations, based on data from Global Energy Monitor, 2020.
Note: Economies included: the Democratic People's Republic of Korea; Hong Kong, China; Japan; Republic of Korea; and Taiwan Province of China. Most are OECD countries, with a relatively high share of super critical and ultra-super critical technology.

pipeline (Global Energy Monitor, 2020) (see tables 1 and 2, and Figure 6). However, with the strong growth in renewable energy, the recently announced long-term target of carbon neutrality by 2060, strengthening the NDC target by 2030 to aim for peaking CO_2 emissions earlier than 2030, and existing policies to reduce overall coal use in primary energy and capping coal, there is expectation for change in relation to coal-fired power generation.

Countries in the South and South-West Asia subregion with coal capacity are all expanding their capacity, most with very high expansion plans compared to their current capacity. This reflects their fast-growing energy output, particularly electricity demand. This group of countries include only 2 per cent of current coal capacity within the Asia-Pacific region, but 13 per cent of the expansion pipeline within the region.

While India also still relies strongly on coal-fired power generation, this has decreased and the pipeline is shrinking. With strong policies to enhance renewable energy uptake, there is potential for India to move away faster from coal (figure 8).

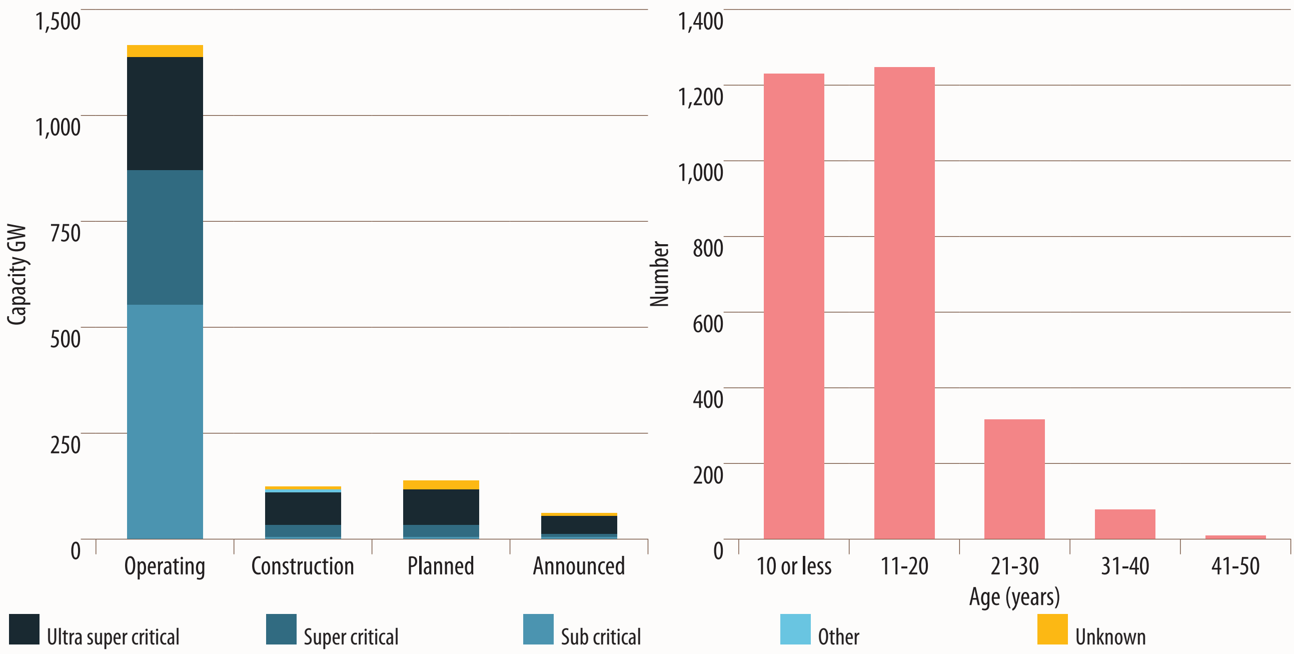
Turkey stands out as the only OECD country with such a high coal expansion pipeline. The other OECD countries, e.g., the Republic of Korea and Japan, are developing policies to move away from dependency on coal.

The South-East Asian subregion is dominated by countries with expansion plans, mostly from an already high current capacity – Indonesia, the

**Figure 6 **

Current coal fleet and pipeline in **China**, by status and combustion technology

Capacity by status and technology

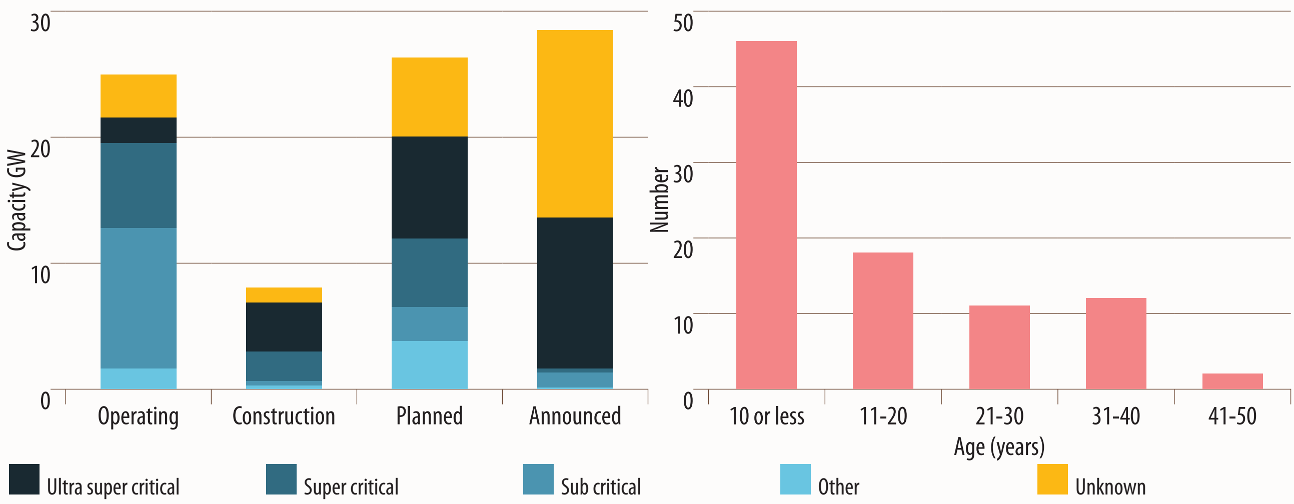


Source: Authors' calculation, based on data from Global Energy Monitor, 2020.

**Figure 7 **

Coal capacity by status and technology, in countries in the **South and South-West Asia (SSWA) subregion** with high expansion plans compared to current capacity

Capacity by status and technology

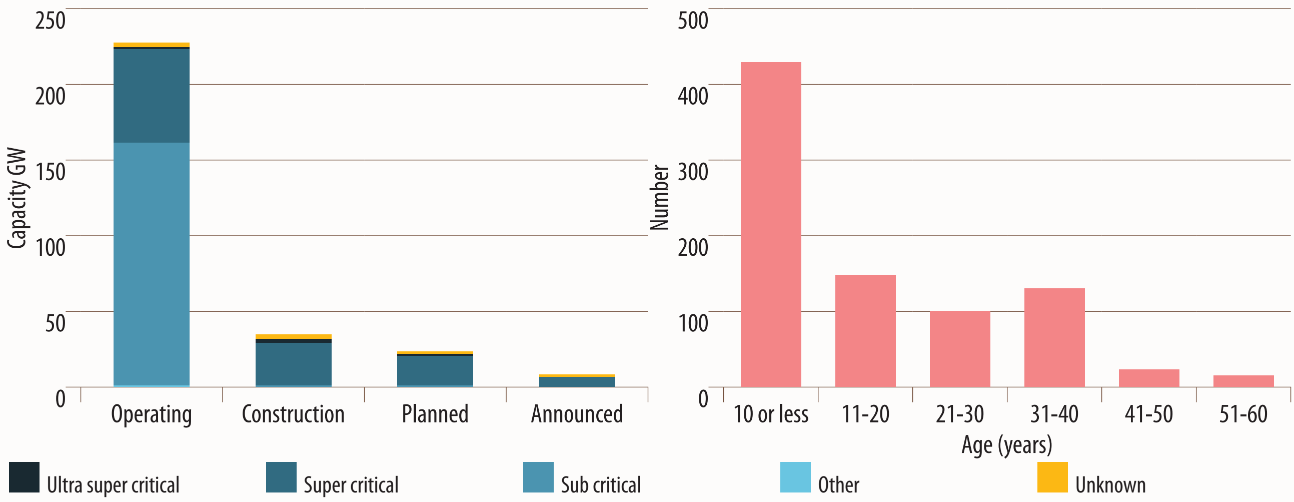


Source: Authors' calculation, based on data from Global Energy Monitor,2020.
Note: This group includes Bangladesh, Pakistan, Sri Lanka and Turkey.

**Figure 8 **

Current coal fleet and pipeline in **India** by status and technology

Capacity by status and technology

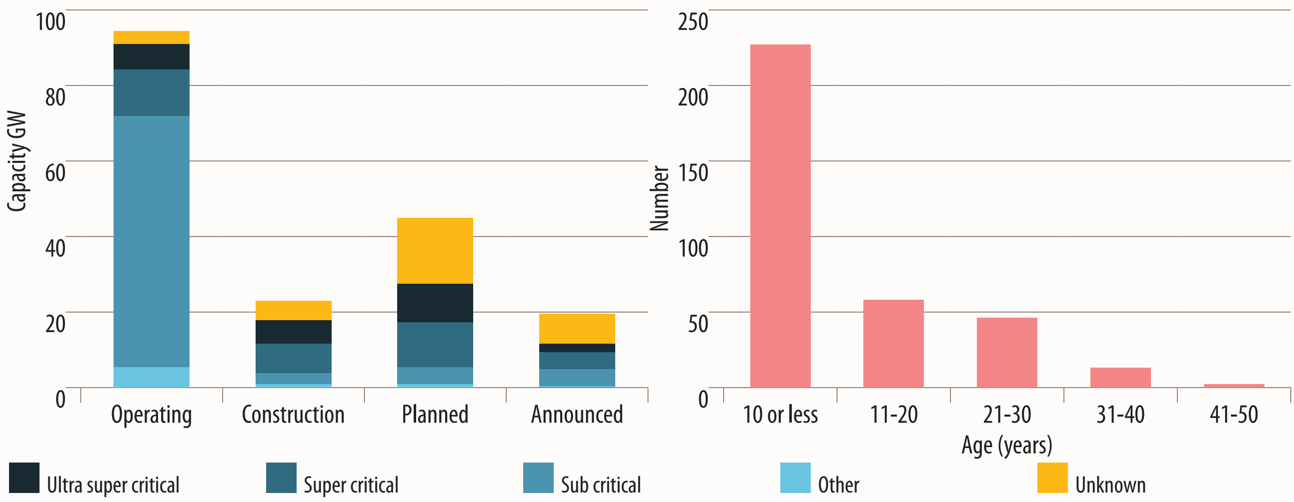


Source: Authors' calculation, based on data from Global Energy Monitor, 2020.

**Figure 9 **

Coal capacity by status and technology, (left) and age distribution (right) for countries in the **South-East Asian** (**SEA**) **subregion** (all categories)

Capacity by status and technology



Note: Authors' calculation, based on data from Global Energy Monitor, 2020

Philippines, Thailand and Viet Nam – with the Philippines and Viet Nam still having expansion pipelines larger than the current capacity. Cambodia and the Lao People's Democratic Republic currently have low capacity but large expansion plans. This subregion, which is characterised by high growth in demand for energy, particularly electricity, includes 5 per cent of the Asian-Pacific region's coal capacity, but 16 per cent of its coal pipeline.

In contrast to the rest of the world, where coal-fired power generation dropped during 2019, some South-East Asian countries have shown a strong increase in coal-fired power generation, with Indonesia, Malaysia and the Philippines meeting higher electricity demand almost exclusively with coal (Buckley, 2020b).

However, there are also signs of movement away from plans to increase coal capacity and generation; in Thailand, for example, a new power development plan was approved in 2019 that reduced the goal for coal and increased the goal for renewable energy for 2027 (The Diplomat, 2019). Viet Nam saw a record increase in solar capacity in 2019 and the first half of 2020, and is moving towards plans to limit the use of coal and enhance the development of renewable energy (Chaturvedi, 2020). Recently, the Philippines announced a moratorium on new coal power generation, which could take out a total of 10 GW of planned coal capacity of the current pipeline. However, given the large number of relatively new coal-fired power plants in the Philippines, the challenge will be to plan for a transition that will phase out existing plants before the end of their lifetime (figure 9).

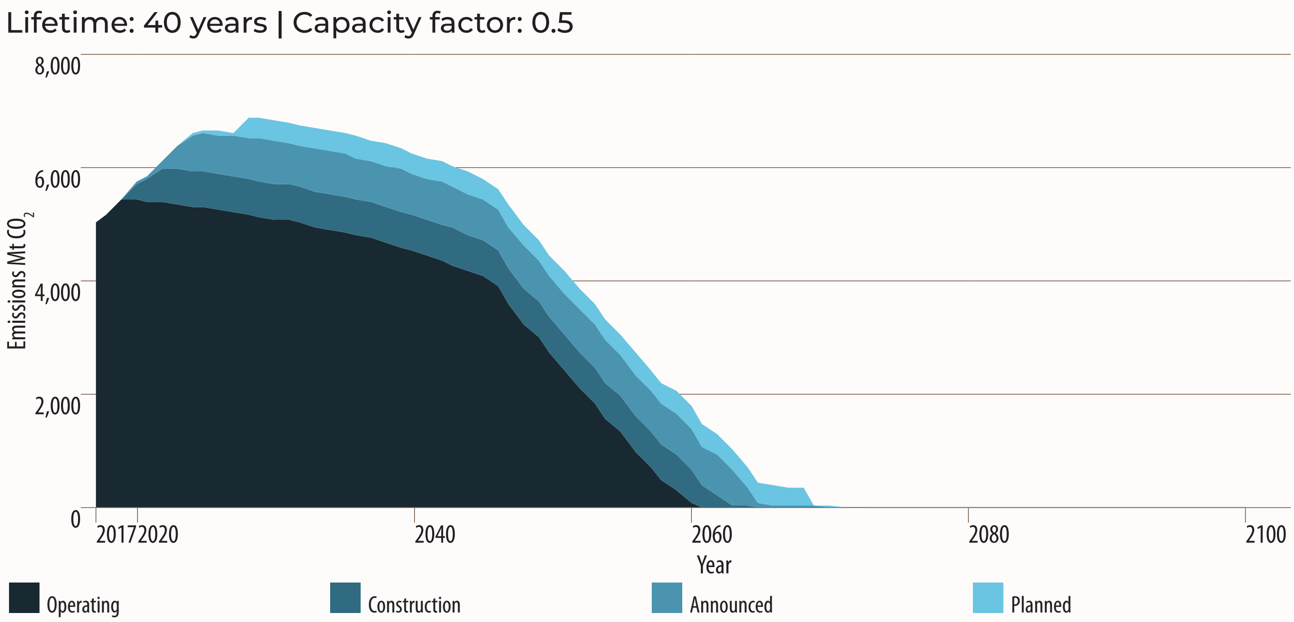
Energy security concerns over increasing fuel import dependency are an important factor in addition to the reduced cost of renewable energy and the benefits of access to clean energy (see chapter 4).

1.3 Emissions from coal power generation not consistent with the Paris Agreement

Figure 10 shows the resulting carbon dioxide emissions over time from the current coal capacity in the Asia-Pacific region. This emissions profile depends on the age profile, combustion technology and fuel type, as well as on assumed lifetime (here a lifetime of 40 years is assumed, based on the global average of retirements from historical observations) and the capacity factor (here a capacity factor of 50 per cent is assumed, consistent with *Climate Analytics*, 2019c"

**Figure 10 **

Estimated emissions over time resulting from current coal-fired power generation capacity in the **Asia-Pacific region**



Source: Authors' calculation, based on Global Energy Monitor, 2020.
Note: Assuming a plant lifetime of 40 years, as well as added capacity as included in the current coal pipeline.

Even without adding the additional capacity in the pipeline, emissions would continue at an unsustainable level until after 2040 and would only be phased out by around 2060. If all the currently planned and announced capacity were realised, emissions would rise from 4.2 GtCO_2 per annum in 2017 to 6.9 GtCO_2 per annum, and only peak around 2028.

This is in stark contrast to the need to phase out unabated coal power generation by 2040 globally, in order to be consistent with the Paris Agreement, and to reach peak coal-fired power generation by 2020 and decline quickly afterwards to 80 per cent below 2010 levels by 2030 (*Climate Analytics*, 2019c). In the OECD and Reforming Economies (such as the North and Central Asia subregion) coal would need to be phased out earlier, i.e., before 2030.

To be consistent with the Paris Agreement, a large part of the current coal capacity in the Asia-Pacific region would need to be retired early, well before the assumed plant lifetime of 40 years, and/or utilise less than the assumed 50 per cent. In addition, countries would need to refrain from building new coal capacity. Any additional capacity increases the risk of stranding assets that already exist, thus threatening to unnecessarily increase the cost of energy transition and place a higher burden on the emerging economies that are less able to afford it.

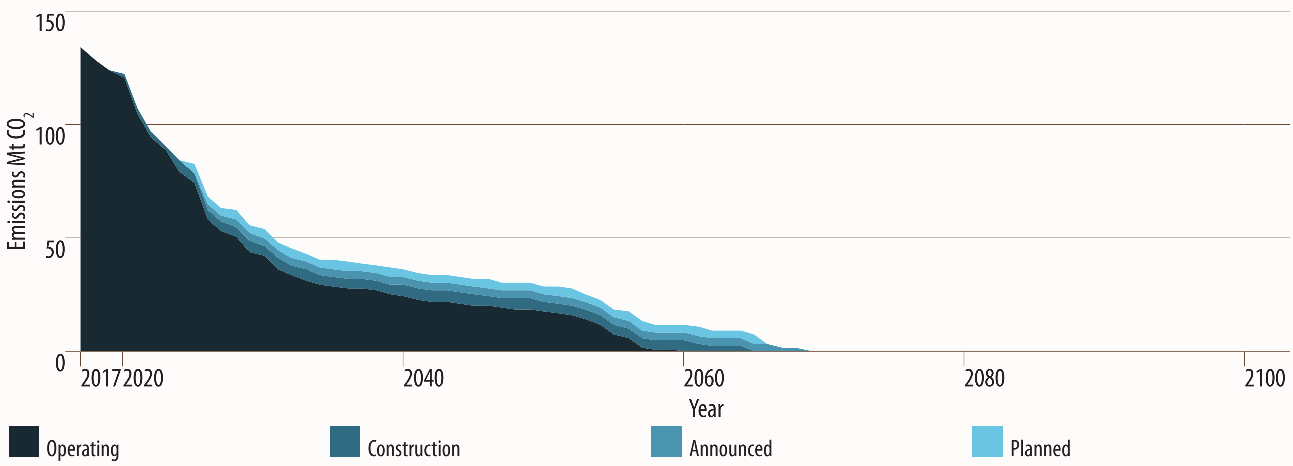
At the regional level, this risk is particularly high in those subregions with relatively new coal capacity and large expansion plans, such as South and South-West Asia and the South-East Asia. Expansion plans would also have a large impact on greenhouse gas emissions; emissions in the South and South-West Asia countries with high expansion plans would more than triple compared to current levels () while in South-East Asia they would more than double (Source: Authors' calculation, based on Global Energy Monitor, 2020).), if all the planned added coal capacity were to come into operation.

However, for the regions where coal capacity is stable or contracting, such as the North and Central Asia subregion as well as the OECD countries in the East and North-East Asia subregion, the current operating capacity would need to reach lower utilisation and be phased out by 2031 to be compatible with the Paris Agreement (*Climate Analytics*, 2019c).

**Figure 11 **

Estimated emissions over time resulting from current coal-fired power generation capacity in the **North and Central Asia subregion**

Lifetime: 40 years | Capacity factor: 0.5

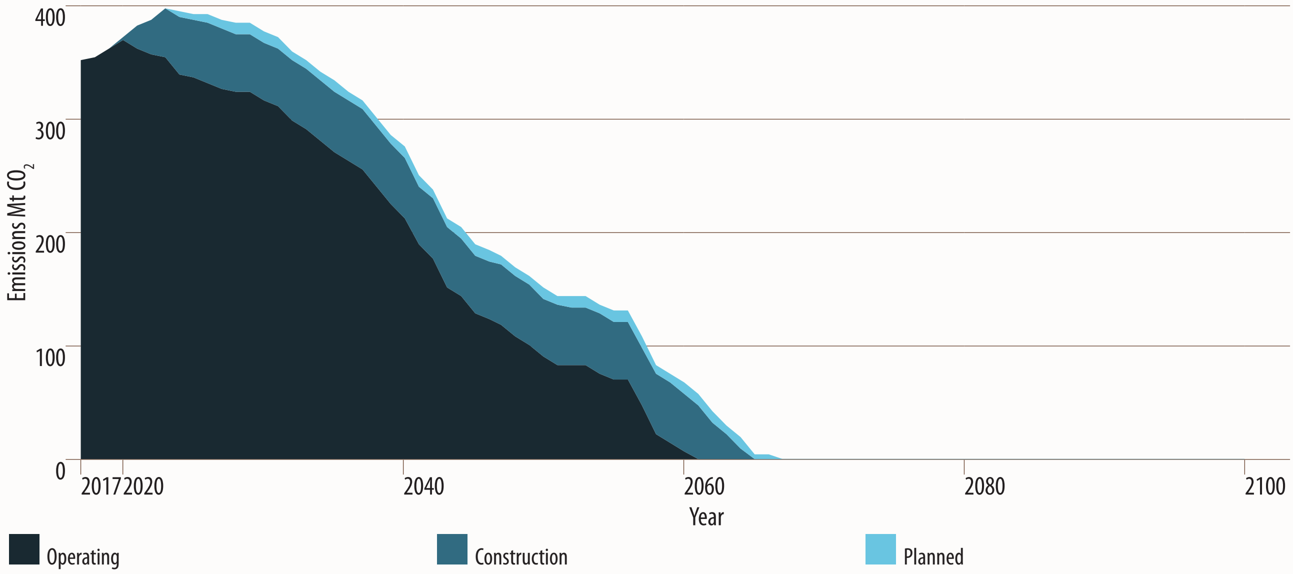


Source: Authors' calculation, based on Global Energy Monitor, 2020.
Note: Assuming a plant lifetime of 40 years as well as added capacity as included in the current coal pipeline.

**Figure 12 **

Estimated emissions over time resulting from current coal-fired power generation capacity in the countries of the **East and North-East Asia subregion** with stable or contracting coal capacity

Lifetime: 40 years | Capacity factor: 0.5

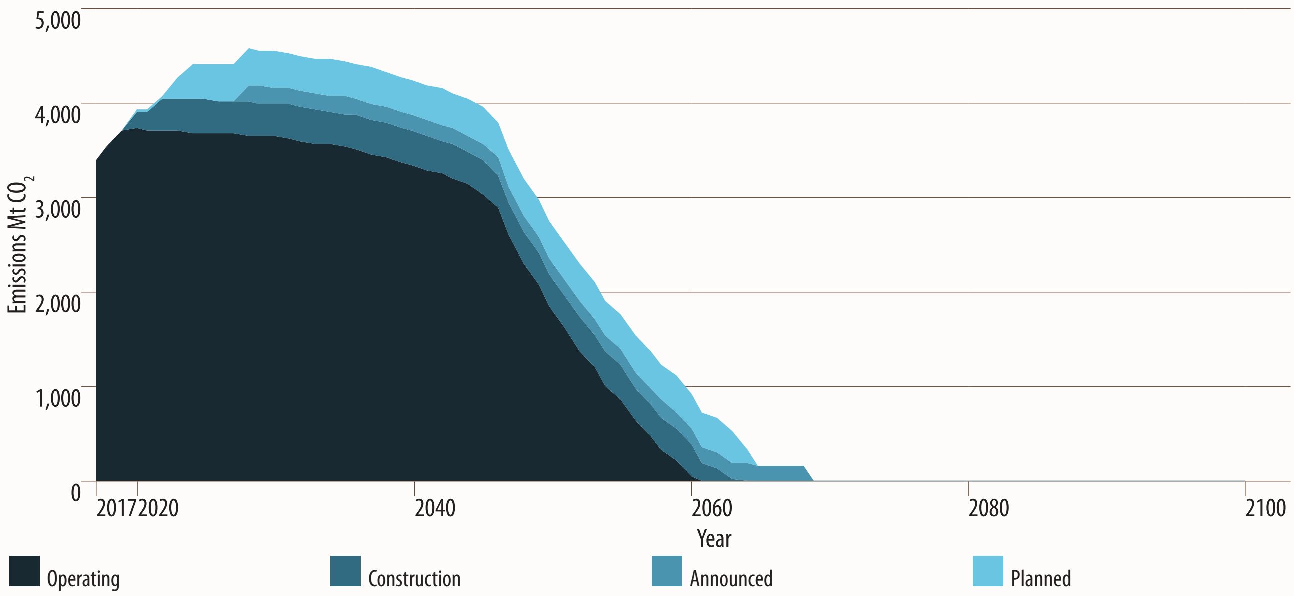


Source: Authors' calculation, based on Global Energy Monitor, 2020.
Note: Assuming a plant lifetime of 40 years as well as added capacity as included in the current coal pipeline

**Figure 13 **

Estimated emissions over time resulting from current coal-fired power generation capacity in the **China**

Lifetime: 40 years | Capacity factor: 0.5

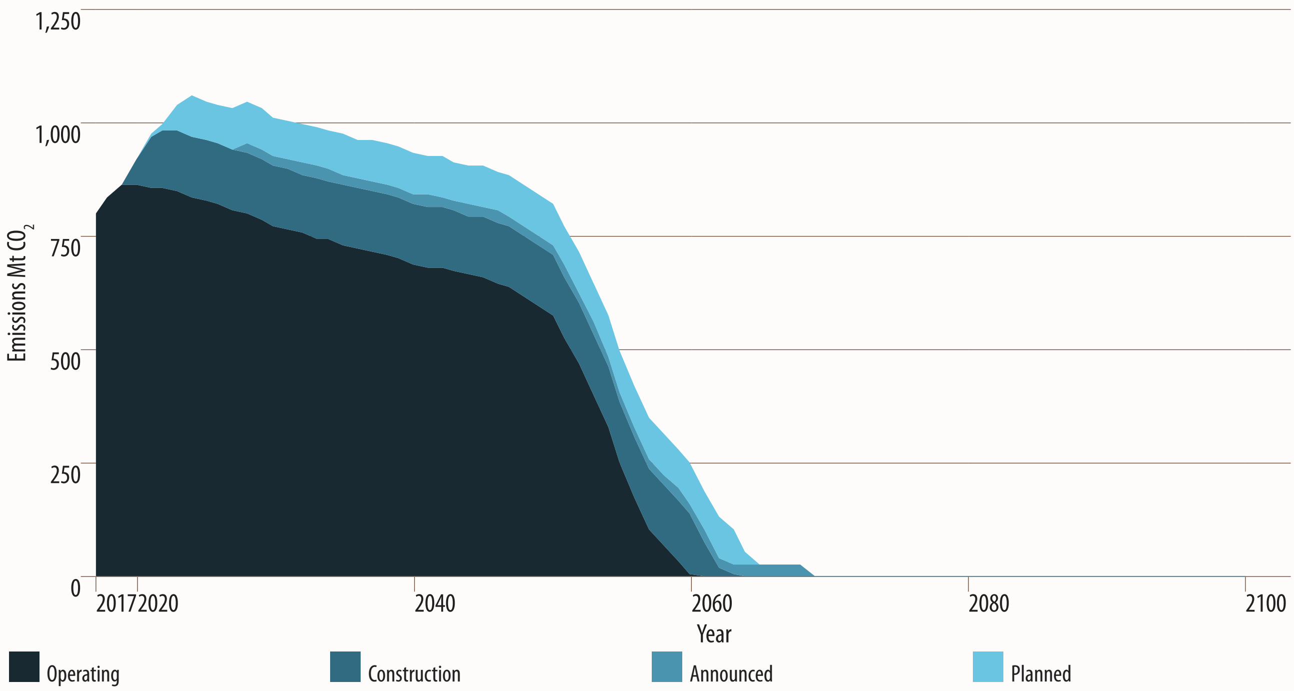


Source: Authors' calculation, based on Global Energy Monitor, 2020.
Note: Assuming a plant lifetime of 40 years as well as added capacity as included in the current coal pipeline.

**Figure 14 **

Estimated emissions over time resulting from current coal-fired power generation capacity in **India**

Lifetime: 40 years | Capacity factor: 0.5

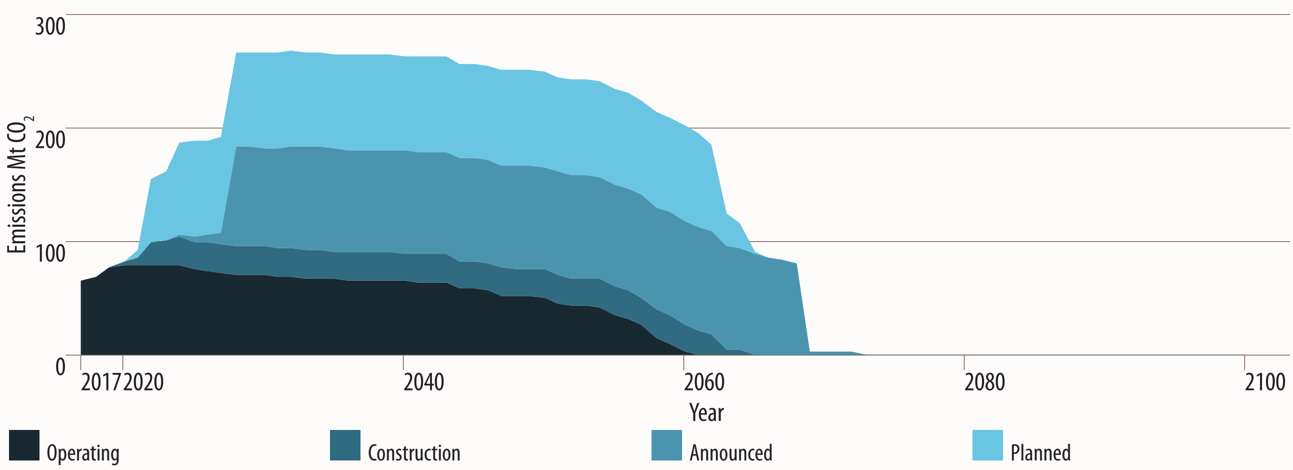


Source: Authors calculation, based on Global Energy Monitor, 2020.
Note: Assuming a plant lifetime of 40 years as well as added capacity as included in the current coal pipeline.

**Figure 15 **

Estimated emissions over time resulting from current coal-fired power generation capacity in the countries of the **South and South-West Asia subregion** with high capacity expansion plans

Lifetime: 40 years | Capacity factor: 0.5

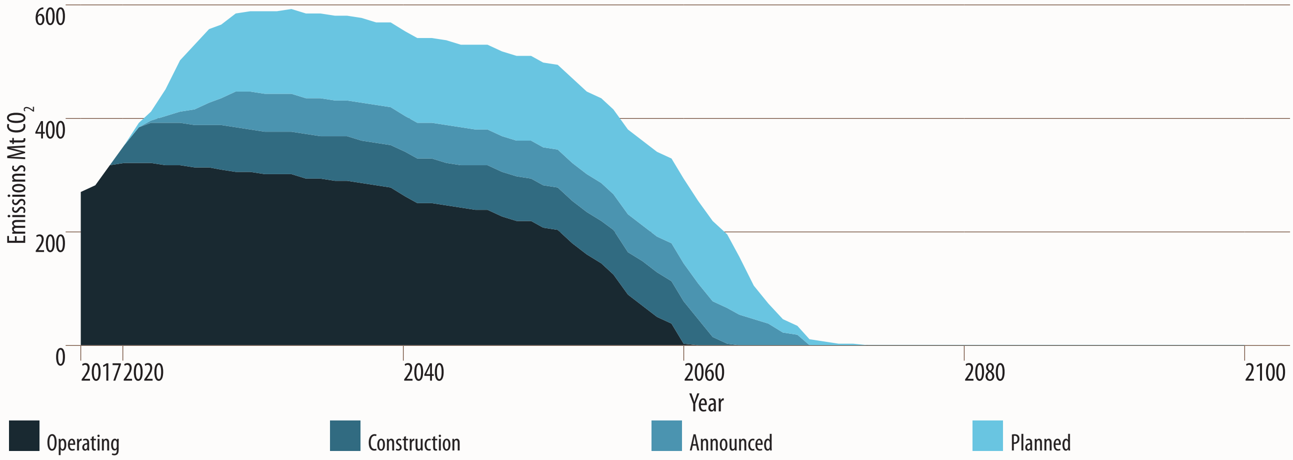


(Turkey, Pakistan, Bangladesh, and Sri Lanka)
Source: Authors' calculation, based on Global Energy Monitor, 2020.
Note: Assuming a lifetime of 40 years as well as added capacity as included in the current coal pipeline.

**Figure 16 **

Estimated emissions over time resulting from current coal-fired power generation capacity in the countries of the **South-East Asia subregion**

Lifetime: 40 years | Capacity factor: 0.5



Source: Authors' calculation, based on Global Energy Monitor, 2020.
Note: Assuming a plant lifetime of 40 years as well as added capacity as included in the current coal pipeline.

1.4 Impact of COVID-19 crisis on policies for the phase out of coal in the region

The COVID-19 crisis and resulting energy demand reduction due to the immediate public health measures as well as the economic downturn have led to reduced demand for coal. For coal being used in electricity generation, the reduction has been stronger than the overall demand reduction for electricity; the high marginal cost of coal generation is resulting in coal generators being ramped down first in line with the merit order effect. Existing renewable energy sources operate at zero marginal cost and therefore have experienced less impact than coal by the overall demand drop (IEA, 2020a).

The IEA (2020d) projected a 7 per cent decline in global coal demand in 2020. This was confirmed by an analysis (Jones *et al.*, 2020) that found global coal generation fell 8.3 per cent in the first half of 2020, compared with the first half of 2019, following a year-on-year fall of 3 per cent in 2019. This fall is much larger than the 3 per cent fall in electricity demand globally, and is largely attributable to the COVID-19 pandemic. In fact, 30 per cent of the coal fall was attributable to increased wind and solar generation, with the world's coal fleet running for the first time at less than half of its capacity in 2020 (Jones *et al.*, 2020).

It is important to distinguish this immediate impact from the impact on investment and new capacity development, where supply chain and construction delays caused by the COVID-19 pandemic have also affected renewable energy projects (IEA, 2020a). COVID-19 has also had an impact on the rate of new wind and solar installed in 2020, and IEA (2020a) projected a 13 per cent fall in 2020. This fall will have a time-lag impact on renewable energy generation. This indicates the importance of making a concerted effort to enhance investment in renewable energy through a green recovery in order to sustain, and even accelerate, the rate of investment in renewable energy capacity.

Within the Asia-Pacific region, the picture is not uniform. India showed a very large decrease in coal-fired power generation, due to a high impact of COVID-19 on electricity demand as well as a slowdown of the economy that had already started in 2019. Coal generation was reduced by 14 per cent between the first half of 2019 and first half of 2020. By contrast, coal-fired power generation in China only was reduced by 2 per cent due to an early recovery of the economy in the second quarter of 2020. Both China and India are experiencing a reduction in usage and large over-capacities. In India, the coal plant capacity factor fell to a level as low as 42 per cent in April and May, averaging 51 per cent so far this year (Jones *et al*., 2020). A large fall in generation in the Russian Federation (13 per cent) was due to a decrease in electricity demand and a record high hydropower generation (early and aggressive snowmelt season) (Jones *et al*., 2020).

In relation to coal capacity, the global coal fleet contracted for the first time on record in 2020, with more capacity retired in the first half of 2020 than commissioned. This led to a decline of 2.9 GW in global coal capacity in the first half of 2020 (Shearer, 2020).

This trend of declining coal capacity is dominated by trends outside of the Asia-Pacific region, in particular record retirements in the European Union and the United States. The picture in the Asia-Pacific region is different, with an overall net increase of coal capacity by 10 GW in the first half of 2020 that was mainly driven by China (9.6 GW). Outside of China, net retirements in the Republic of Korea, the Russian Federation and India have been almost cancelled out by a net increase in capacity in Japan, Viet Nam, Bangladesh and Indonesia (authors' calculation based on Global Energy Monitor, 2020; see Table 1).

All starts of new construction of coal-fired power plants globally in the first half of 2020 were in the Asia-Pacific region (China, the Philippines, Bangladesh and the Russian Federation). These countries (with the exception of Bangladesh) have shown an increase in their pipeline, with almost all other countries globally showing a contracting pipeline.[8] Following a short-term slowing down of construction due to the pandemic, China stands out with a surge in new permits and a large increase in the pipeline (Shearer, 2020).

Beyond these short-term impacts, it is an open question as to how strongly coal-fired power generation will resurge within the next few years. This will depend on the success of the recovery from the pandemic, and on how Governments address economic stimulus programmes for recovery from the economic downturn caused by the pandemic as well as the implementation of public health measures necessary to contain it.

The latest World Energy Outlook by the IEA (2020d) forecasts that overall coal demand will not to return to pre-crisis levels, even with a fast recovery from the pandemic in 2021. In fact, the IEA expects the share of coal in the overall global energy mix to fall below 20 per cent for the first time since the Industrial Revolution. Projected increases in coal demand in developing economies in Asia are markedly lower than in previous World Energy Outlooks, and global coal demand is expected to decline based on current policies and a fast recovery from the pandemic (Stated Policy Scenario – STEPS). In that scenario, the share of coal in the global power generation mix falls from 37 per cent in 2019 to 28 per cent in 2030, and to 15 per cent by then in the Sustainable Development Scenario (SDS). The expectation that coal will not return to pre-crisis levels is shared by other projections (DNVGL, 2020). However, coal is not expected to peak before 2030 (DNVGL) or 2040 (IEA, 2020d) in South and South-East Asia.

There are moves to focus on green recovery – for example, in the European Union and the Republic of Korea, where the momentum to move away from coal-fired power generation is increasing. However, other countries are still not sending clear signals towards a shift in investment to clean energy through stimulus packages.

8 Brazil is the only exception.

Chapter 2

Drivers of coal expansion in the region

2.1 Asian countries are joining the global trend away from coal

Globally, there are a combination of drivers that are leading to a move away from coal (Buckley, 2020a). These drivers are also relevant to varying degrees within the Asia-Pacific region. The sharp reduction in the cost of solar and wind as well as storage technologies (see chapter 3), particularly solar PV, is now the most cost-effective new source of electricity, consistently cheaper than new coal- or gas-fired power plants in most countries of the world (IEA, 2020c). This, together with policies against air pollution (e.g., India, the Republic of Korea and Japan) and the increasing adoption of climate change policies (e.g., European Union countries) due to awareness of the need to phase out coal in order to implement the Paris Agreement, is leading to an increasing move to phase out coal for power generation at the national or subnational level.

There are clear signs of an increasing aversion to financing new coal-fired power plants among many Governments and investors, given the above trends and the increasing awareness of the risk of stranded assets. Financial institutions are increasingly moving away from coal and explicitly committing to divest from, restrict or ban financing of thermal coal. This includes Asian financial institutions that have lately joined an initiative by more than 100 significant financial institutions to strengthen policies to move away from thermal coal, including major Chinese and Japanese financial institutions (Buckley, 2019). Some Governments in Asia have also started making moves in the same direction. For example, the government of Japan has committed to cutting support for coal-fired power plants, although this commitment has been assessed as not tight enough (Nikkei Asia, 2020). Such governmental commitment is useful, as a recent study revealed that banks were reluctant to leave involvement in electricity generation with fossil fuels due to the considerable returns (Xie *et al.*, 2021)Russia, India, China and South Africa (BRICS countries.

The Powering Past Coal Alliance (PPCA) reflects the increasing global momentum against coal. Launched in 2017 by Canada and the United Kingdom, it has grown to a total of 110 members, with 34 national Governments now members of the alliance, in addition to 33 subnational governments, signing up to goals in line with the Paris Agreement's long-term temperature goal. This translates into a specific goal of phasing out coal by 2030 in the OECD as well as to globally reduce unabated coal-fired power generation by two-thirds by 2030 and phase it out by 2050. The alliance also calls for a moratorium on new unabated coal-fired power generation. In addition, a total of 44 business organisations have joined PPCA. All members commit to supporting clean energy investment and restricting financing for unabated coal power.

Only four of the 34 national Governments in PPCA are in the Asia-Pacific region (New Zealand, Marshall Islands, Tuvalu, Vanuatu), all of which are in the Pacific subregion and all are countries with no or minimal shares of coal-fired power. However, at the subnational level, there is more momentum within countries in the Asia-Pacific region, including countries with high coal dependency: Three subnational governments from Australia and three Republic of Korean provinces have so far joined the PPCA.

Overall, despite these global and regional trends, a continuation of high reliance on coal as well as coal expansion plans are still prevalent in the Asia-Pacific region, particularly in South and South-East Asia (see chapter 1).

2.2 Drivers of coal expansion in Asia and the Pacific

Contrary to the strong global drivers counteracting reliance on coal, there are factors still driving support for coal and the expansion of coal-fired power generation within many ESCAP member States. This report analyses why the global drivers against coal are generally not as strong in the Asia-Pacific region, especially in South and South-East Asia which have large coal expansion plans. Even though on purely economic grounds, there is a clear case in those countries for a faster transition to renewable energy (see chapter 3), particularly when the large benefits of a transition to renewable energy are also factored in (see chapter 4).

One of the key factors that has been driving coal expansion in South and South-East Asia is the very high growth rate in energy generation. This is especially due to electricity demand, which is driven by rapid economic growth and development efforts to increase access to modern energy, together with urbanisation. This has led to increasing reliance on fossil fuels, particularly coal, in addition to other sources such as hydro energy or biomass.

In addition, the Asia-Pacific region has a large share of global coal reserves, and countries with their own coal resources have historically relied, and continue to rely, heavily on this domestic resource for power generation. Sixty per cent of global coal reserves are located in ESCAP member States, led by the Russian Federation (15 per cent), Australia (14 per cent), China (13 per cent), India (10 per cent) and Indonesia (4 per cent). Other countries in the region with coal reserves are Kazakhstan (2 per cent) and Turkey (1 per cent) together with New Zealand, Pakistan, Viet Nam, Thailand and Mongolia shares below 1 per cent of global reserves (BP, 2020). Viet Nam is one example of a country that has recently turned from being a net exporter to a net importer of coal, given the country's large increase in demand for electricity.

Correspondingly, 80 per cent of global coal production as well as global consumption is in ESCAP member States, with the largest share in both cases (about 50 per cent) in China. However, consumption and production are generally not evenly distributed, leading to large trade movements mostly within the region (Zhao *et al.*, 2021).[9] Some of the largest producers and exporters as well as some of the largest importing countries are located in the Asia-Pacific region. A total of 78 per cent of global imported coal is imported by countries in the Asia-Pacific region. Four of the largest coal importing countries by volume globally are also located in the Asia-Pacific region (China, India, Japan and the Republic of Korea), while a similar share (76 per cent) of coal exports are supplied by the three largest exporting countries globally (Australia, Indonesia and the Russian Federation) (BP, 2020)).

This leads to some of the economies in the region being highly dependent on income from coal exports, such as Australia, Indonesia and, to a lesser extent, the Russian Federation. This

9 South Africa is an important source for coking coal in India, while the Russian Federation exports mainly to Europe.

influences the political economy in relation to support for coal consumption and coal-fired power generation, with strong government support for coal mining and coal fired power generation.

In the case of Indonesia, another important element explaining the political economy supporting coal is the importance of revenue from coal mining not only for the state's budget, but also for regions and municipalities as well as a push towards more domestic use of coal in the light of expected downward trends in China and other export destinations (Fuentes *et al*., 2018, 2019).

An important driver to continue support for coal, most notably in coal producing countries, is the need to maintain employment in regions where coal production is concentrated. This can be a large barrier against a transition away from coal, unless it is addressed specifically through targeted national support for regions affected, for which there is an increasing body of experience in countries embarking on transition in particular in Europe (e.g., Spain and Germany).

The Governments of key coal producing countries are actively supporting coal production in many ways, including through subsidies and public finance. As China's case shows, since the coal mining industry provides jobs and revenue, local governments often protect coal mines even against the national policy (Wang *et al*., 2020; and Zhang *et al*., 2017). The UNEP Production Gap Report 2019 highlights this for seven top fossil fuel producers, all G20 members, with the top six located within the Asia-Pacific region – China, the United States, the Russian Federation, India, Australia and Indonesia (SEI *et al*., 2019).

India and Indonesia are the main supporters of coal mining within the G20, even though the largest part of that government support is given to coal-fired power generation (Gençşü *et al*., 2019).

Beyond the influence of key coal producing and exporting countries, support for coal in the Asia-Pacific region is driven by the geopolitical influence of four countries that have historically relied on coal and are large coal importers – China, Japan, the Republic of Korea and India. Governments or government-owned financial institutions or utilities in those four countries strongly support coal expansion in the Asia-Pacific region. The main recipients of this support are countries in South and South-East Asia – Bangladesh, Indonesia, Pakistan and Viet Nam(End Coal, 2020; Gençşü *et al*., 2019). These are countries with either small or no coal resources (with the exception of Indonesia) and high development needs, and therefore high increases in energy demand, especially for electricity.

The Global Coal Public Finance Tracker shows that the countries providing the highest levels of public finance of coal to be China, Japan, the Republic of Korea and India (End Coal, 2020). The recipients receiving the largest levels of funding are Indonesia, Viet Nam, Bangladesh and Pakistan (End Coal, 2020). In a study of the support for coal in G20 countries, Gençşü *et al.* (2019) identified the following sources and volumes for public financing for coal internationally:

- China and Japan are the largest sources of funding ($9.5 billion and $5.2 billion of financing per year, respectively), with all of the public financing in those two countries going to international projects;

- The other two countries that provide public financing for coal internationally are the Republic of Korea ($1.1 billion per year) and India ($800 million per year).

Most of the public finance identified in China and Japan, and all of the international public finance identified in the Republic of Korea and India, was for coal-fired power. The international public finance from India was for a single coal-fired power project in Bangladesh(End Coal, 2020; Gençşü *et al*., 2019).

However, there are increasing signs of change, particularly from the Governments of the Republic of Korea and Japan as well as from financial institutions in the four countries. Some multilateral development banks (MDBs) and

**Table 4 **

Providers and recipients of the highest amount of G20 international public finance for coal, 2016-2017, annual average (million United States dollars)

	Country providing the highest amount of public finance for coal		
Recipient country	China	Japan	Republic of Korea
Bangladesh	1,650	1,207	None identified
Indonesia	1,370	1,271	562
Pakistan	3,975	None identified	None identified
Viet Nam	880	1,230	495

Source: Gençsü et al., 2019.

national development banks are moving away from coal, also driven by public pressure.

The influence of the coal industry on national policies and decision-making is linked to the prevalence of some policies that have supported the drive to keep expanding coal, in particular fossil fuel, or coal subsidies.

Gençsü *et al*. (2019) identified a large amount of public finance (approximately $10.1 billion annually) was provided for domestic coal-fired power in India. This was partly as a result of the dominance of a publicly-owned banking system, reflecting the continuation of reliance on coal for energy generation in economic planning despite the push for expansion of renewable energy.

Indonesia provides significant fiscal support for domestic coal use in the generation of electricity at below-market levels for households. Other countries with significant fiscal support (including through differentiated taxing favouring coal over other fuels) within the G20 are Australia, China, Turkey and India. In Australia and Indonesia, fiscal support was identified as the main source of financing for coal.

Direct coal subsidies supporting coal consumption or production can take the form of fiscal, income or price support, public finance as well as state-owned enterprise investment. They can be non-transparent (IRENA, 2020c) and need analysing at country level, for example in relation to provision of below market prices for consumption (see, for example, IISD, 2017) for Indonesia, or the provision of below-market tariffs for coal transportation by rail to support the mining industry.

The strong international support in the region and the strong influence of the coal industry on national policy and decision-making has supported the continuing prevalence of the narrative of supposedly cheap coal and the need to provide "baseload power" to address growing energy demand. This narrative is kept alive by vested interests largely favouring coal (see Steckel and Jakob, 2018 for Indonesia and Viet Nam) despite the economic evidence of the cost effectiveness of renewable energy and the benefits of decreasing fuel import dependency. The prevalence of the perception of cheap coal versus expensive renewable energy has been studied for a number countries, particularly in South-East Asia, as a key factor in slowing down transition to renewable energy that is happening rapidly in other parts of the world (Fuentes *et al*., 2020; and Marquardt and Delina, 2019).

An often-repeated argument that is also prevalent and supported by vested interests in the region is that coal helps to lift millions of people out of poverty. This argument has historically been used by international public finance agencies and by Governments such as India, Indonesia and Australia to justify support for coal (Blondeel and Van de Graaf, 2018). However, an analysis by Granoff *et al*. (2016) showed that coal does not end energy poverty; it has been given too much credit for extreme poverty reduction – the low carbon option can lift people out of income poverty, while coal will further entrench poverty. Fuel subsidies have been shown to often increase inequality, benefiting the richer parts of society (Couharde and Mouhoud, 2020). Given the need for central generation and transmission, coal-fired power generation expansion has often helped urban centres but bypassed the poor and excluded rural areas. In contrast, renewable energy provides the opportunity for affordable access to clean energy in rural areas through decentralised power generation, while the negative impacts of coal-fired power generation such as air pollution and climate change hit the poorest and most vulnerable harder (see chapter 4).

Another related claim that is supported by vested interests, and adopted by some Governments, is that coal-fired power generation can continue to be viable in a carbon-constrained economy by retrofitting, for example, with the use of carbon capture and storage (CCS). This claim is made despite the evidence that this has not yet materialised at scale, even though substantial political and financial support has been provided for developing CCS (see Chapter 3).

An important aspect of political economy and links to support coal is the role of state-owned enterprises (SOEs) and the level of government involvement in SOEs. According to Gençsü *et al*. (2019), investments by state-owned coal mining and coal-fired power companies, particularly in China and India SOEs, provided $8.8 billion, and $6.4 billion, respectively. Significant investment by SOEs was also identified in the Russian Federation ($0.7 billion per year). SOE investments were also identified in Indonesia, the Republic of Korea and Turkey. Gençsü *et al*. (2019) found that the highest amounts of investment in coal-fired power by state-owned power companies among G20 countries were in China ($7.6 billion per year) and India ($5.3 billion per year).

Together with inconsistent policy signals and uncertainty regarding long-term goals as well as complex energy policy responsibilities within Governments with the strong influence of state-owned enterprises (see Fuentes *et al*., 2019, for Indonesia) has led to investors holding back more than in other regions. This delays the development of policies and energy plans needed to overcome barriers to faster expansion and the integration of larger shares of renewable energy, particularly wind and solar. For example, the need to develop transmission grids accordingly needs consistent long-term planning and policy support (Fuentes *et al*., 2018, 2019)

Again, there are some recent signs of change. As SOEs become increasingly aware of the need to diversify their business, they are starting to increase investment in renewables and plan for the longer-term full transition away from coal mining and coal-fired power. Examples are efforts to diversify and invest in renewables by the China Energy Investment Corporation (CEIC) and Coal India Limited, the world's largest coal mine operator (IISD, 2018). There are also signs of change in policy direction, with energy and electricity planning moving away from high reliance on coal, such as in Viet Nam and Thailand. However, these changes are currently too slow compared to the transformation needed to implement the Paris Agreement's long-term temperature goal and the Sustainable Development Goals (*Climate Analytics*, 2019b) (see chapter 3).

Key players in the region with regard to investment and financial flows are MDBs. A recent study of six banks active in the region shows that they are not making enough progress with their pledge to align with the Paris Agreement (Dunlop *et al*., 2019). Fossil fuel exclusion policies is one area of work highlighted as still needing improvement.

Chapter 3

How can trends be reversed – pathways for a transition to clean energy

3.1 Paris Agreement compatible energy transition

In its *Special Report on 1.5°C* (IPCC SR1.5), the IPCC comprehensively analysed socioeconomic mitigation paths that allow global warming to be limited to 1.5°C compared with pre-industrial levels by using complex energy-economic/land-use models (Integrated Assessment Models) (IPCC, 2018a). In the *Summary for Policymakers*, the IPCC defines the group of mitigation pathways that are compatible with the 1.5°C limit in the Paris Agreement's long-term temperature goal as those that either keep warming below 1.5°C ("no overshoot"), or those that temporarily exceed the 1.5°C limit only minimally (below 0.1°C) and then return to a value below the limit before 2100 ("low overshoot" pathways) (IPCC, 2018b).

Due to the high historical and thus cumulative emissions, and because some emissions cannot be completely reduced to zero (e.g., emissions from agriculture), a certain degree of carbon dioxide removal (CDR) from the atmosphere is required to limit warming to 1.5°C. This is reflected in the Integrated Assessment Model pathways assessed by the IPCC SR1.5 through two main options – large-scale afforestation and reforestation or the use of bioenergy and carbon dioxide capture and storage. The IPCC SR1.5 identified limits for a sustainable use of both CDR options globally by 2050 to be below 5 $GtCO_2$ p.a. for bioenergy and carbon dioxide capture and storage and below 3.6 $GtCO_2$ p.a. for sequestration through afforestation and reforestation, while noting uncertainty in the assessment of sustainable use, and economic and technical potential in the latter half of the century (*Climate Analytics*, 2019b).

By using the 1.5ºC compatible pathways identified in the IPCC SR1.5 that also comply with these sustainability limits, key milestones for Paris Agreement consistent mitigation pathways can be identified. One such crucial milestone is the need to peak the total GHG and CO_2 emissions by 2020 and then reduce it rapidly by about 45 per cent by 2030 compared to 2010. In these pathways, total GHG emissions need to reach net zero around 2070, while CO_2 emissions need to reach net zero by 2050 and then become negative.

The following key characteristics and global benchmarks for sectoral transformations can be derived for the energy system, based on these Paris Agreement-consistent pathways (*Climate Analytics*, 2019b):

- Large reductions in energy demand across all end-use sectors by 2030;

- Fully decarbonised primary energy supply by mid-century;
- Fully decarbonised electricity generation by 2050, mainly through increased use of renewable energy;
- Electrification of end-use sectors and decarbonisation of final energy other than electricity;
- A rapid increase in use of renewable energy.

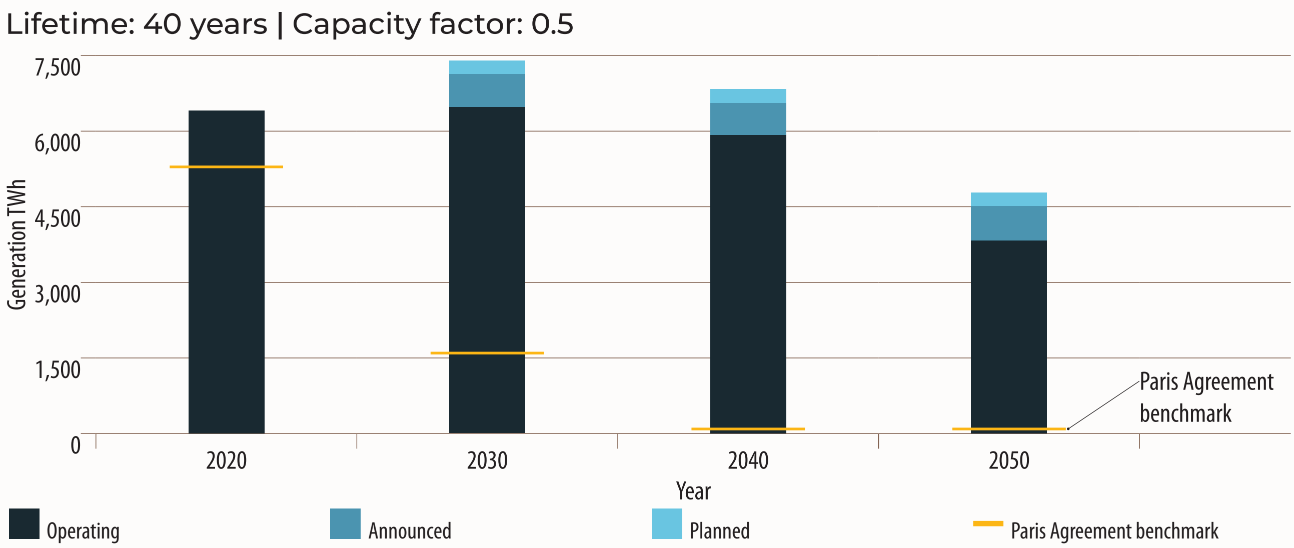
Coal phase-out requirements of the Paris Agreement

The Paris Agreement consistent pathways outlined in the previous section have been used to identify the benchmarks for the single most important step to achieve the necessary steep emission reduction, i.e., phasing out coal for power generation (*Climate Analytics*, 2019c). Benchmarks have been derived based on the use of unabated coal. While the pathways often include an uptake of coal with CCS in the power sector, this report judges it as very unlikely to be implemented given the high costs and environmental footprint as well as the fact that renewables are now often cheaper than coal without CCS fitted. This trend will only accelerate. It is also of critical significance that CCS is globally absent in the current coal pipeline after several decades of research and development efforts. This is a key indicator that deployment of CCS at scale in the power sector is increasingly unlikely.

Integrated Assessment Models generally assume that coal power plants with CCS do not produce any, or only minimal, carbon dioxide emissions, whereas they are in fact likely to emit at the very least a tenth of the average emissions compared with an installation without CCS. As CO_2 capture rates of 80-90 per cent from thermal stations are considered most likely, CCS cannot be considered a zero carbon alternative to the use of unabated coal in the power sector (*Climate Analytics*, 2019c). To reach net zero CO_2 emissions there would need to be compensating CDR deployed to capture the remaining 10-20 per cent of coal power plant CO_2 emissions. Deployment of CCS over conventional coal would imply a high carbon price, which in turn would give renewable energy

**Figure 17 **

Potential coal generation in **Non-OECD Asia** against Paris Agreement benchmarks



Source: Climate Analytics, 2019c, based on GCPT database in 2019.
Note: This region includes all countries in the following ESCAP subregions: East and North-East Asia, except Japan; South and South-East Asia; South and South-West Asia, except Turkey. The Republic of Korea is included as it was not a member of OECD in 1990.

an advantage over CCS and would widen the cost gap between renewable energy and CCS even further, given the significant remaining emissions from CCS.

Based on the analysis of the Paris Agreement 1.5°C compatible pathways outlined above, the following key benchmarks have been identified for coal use in power generation (*Climate Analytics*, 2019c):

- Coal use for power generation needs to peak by 2020 and be reduced quickly afterwards, regardless of the region;
- Unabated coal-fired power generation needs to be reduced by 80 per cent from 2010 levels by 2030 and phased out globally before 2040;
- Between 2030 and 2040, all regions need to phase out coal;
- OECD, eastern Europe and former Soviet Union countries need to phase out coal by 2031. This holds for the OECD countries in ESCAP (Japan, the Republic of Korea and Turkey) as well as for the countries in the North and Central Asia subregion;
- Non-OECD Asia needs to reach a reduction of coal generation of 63 per cent, compared to 2010, by 2030 and phase out coal by 2037, completing a global coal phase-out before 2040.

Non-OECD Asia faces the most challenging gap between potential generation from coal and the Paris Agreement benchmarks, with generation from currently operating coal-fired power generation already largely exceeding the Paris Agreement benchmarks ( ).

Power generation: Models underestimate renewable energy, overestimate CCS and nuclear

Integrated Assessment Model (IAM) scenarios evaluated in the IPCC as well as energy system scenarios such as those published by the IEA typically underestimate the political, economic, social and technical feasibility of solar energy, wind energy, and electricity storage technologies. These renewable and storage technologies have improved dramatically over the past few years, with costs dropping rapidly and corresponding much faster growth trajectories than expected (IRENA, 2020b). These trends are expected to continue.

The IPCC SR1.5 has shown that nuclear energy and CCS in the electricity sector have not registered similar improvements. The costs of nuclear power have generally not decreased, and have even increased over time in some developed countries, and construction times are long. Nuclear energy is assumed in some models to contribute to reducing emissions, playing a larger or smaller role depending on modelling assumptions; however, some pathways show a decline in both capacity and energy share.

Nuclear energy plays a smaller role in power generation in the Asia-Pacific region compared with Europe. A share of about 30 per cent of global nuclear generation is located in this region, almost half of which (12 percentage points) is in China (BP, 2020). Nuclear energy requires significant regulation domestically and internationally (through International Atomic Energy Agency inspections), thereby adding to the cost of deployment of this technology. More than 70 per cent of global nuclear power generation is located in OECD countries (BP, 2020). Within the Asia-Pacific region, apart from China (5 per cent of power generation), only the Republic of Korea (25 per cent of power generation), Russian Federation (19 per cent of power generation), Japan (9 per cent of power generation in 2019), Pakistan (7.5 per cent of generation in 2017-2018) (Din, 2020) and India (3 per cent of power generation) have nuclear energy. Japan and the Republic of Korea, are moving away from nuclear power generation (data for shares of power generation all for 2019: Climate Transparency 2020 report, based on Enerdata).

The costs of CCS have not come down during the past decade despite large funding efforts by some Governments.

The present generation of IAM pathways and other energy system scenarios often assume an increased share of fossil fuel-based power generation, with CCS contributing to the reduction of emissions in the power sector. CCS is typically deployed in IAM pathways beyond 2030, reflecting the fact that they are currently not a commercially viable option. Despite strong support for CCS by some Governments, there are currently only 21 large-scale CCS facilities in operation (Global CCS Institute, 2020) around the world, and only three under construction. Only two of the currently operating facilities are linked to power stations, one of which was recently mothballed, the Petra Nova plant in the United States (Wamsted and Schlissel, 2020). There is one CCS facility under construction that is linked to power generation (ZEROS Project, United States). However, fossil fuel power plants with CCS have so far been used for enhanced oil recovery and therefore have not stored carbon dioxide in a secure geological reservoir.

The adverse economics of CCS power plants require them to operate at a capacity factor close to 90 per cent which is increasingly unlikely, given the cost-effective renewable energy options. Together with the large co-benefits of renewable energy, this adverse cost trend makes CCS technologies increasingly unlikely to be able to compete with renewable energy and storage, a fundamental economic dynamic which is not reflected in many energy-economy models (Schaeffer *et al*., 2019).

In the Asia-Pacific region, there are currently no CCS projects linked to power generation that are operational or under construction. Four CCS projects linked to power generation are in the early stage of development or evaluation – three in China (one for EOR[10,11,12]) and one in the Republic of Korea.[13] None of them are expected to be operational before the middle of the next decade (Global CCS Institute, 2020).

Carbon capture and use (CCU) in the chemical industry is increasingly being promoted as a solution to overcome the challenges to long-term storage. However, the contribution by CCU, through chemical conversion, to mitigation is questionable and its potential has been assessed as less than 1 per cent (Mac Dowell *et al*., 2017) there is growing interest in finding commercially viable end-use opportunities for the captured CO_2. In this Perspective, we discuss the potential contribution of carbon capture and utilization (CCU. While it can be an option to substitute feedstock and produce material with less carbon content, it is not an option for mitigation of emissions from the use of fossil fuels in power generation, as it does not provide for long-term storage. To the contrary, Kätelhön *et al*. (2018) showed that a substantial contribution by CCU to mitigation can only be achieved through substitution and decoupling chemical production from fossil sources through involving the production of hydrogen from renewably generated electricity.

Switching to gas – risk of stranded assets

Continued use of natural gas for power generation would only be consistent with the Paris Agreement if used with CCS, given the need to decarbonise power generation before mid-century in order to achieve the Paris Agreement temperature goal. Even then, it would play only a small role in electricity generation by 2050 at around 8 per cent of global electricity generation (IPCC, 2018). Due to incomplete CO_2 capture rates, the use of gas with CCS would have to be balanced out with additional CDR. With renewable energy – often with storage – already cheaper than constructing new natural gas power plants in many economies (IEA, 2020d), new investments

10 Sinopec – Shengli Power Plant, Shandong Province, for enhanced oil recovery in the Shengli oilfield.

11 The GreenGen programme proposed the development of a large-scale integrated gasification combined cycle IGCC CCS demonstration project in Tianjin, near Beijing. The third and last phase of the programme would involve the construction and operation of a 400 MW IGCC power plant with associated carbon capture facilities capable of capturing up to 2 Mtpa of CO_2. Storage locations and transportation methods are currently under evaluation.

12 As Stage II of a planned programme of CCS activities, China Resources Power is examining the possibility of adding large-scale carbon capture facilities to its Haifeng power plant development in Guangdong province. The proposed capture facilities would be designed to capture around 1 Mtpa of CO_2 emissions. Storage site options are under investigation. Planned operation would begin in the 2020s.

13 Korea CCS 1&2 is evaluating the development of 1 Mtpa CCS facilities with CO_2 either sourced from a power plant in north-eastern Gangwon Province or in western Chungnam Province of the Republic of Korea, or an oxy-fuel power plant or in a 300 MW integrated gasification combined cycle IGCC power plant. Capture and storage operations could begin around the middle of the next decade.

in gas-fired power plants are increasingly at risk of becoming stranded assets both in developed and developing countries.

Increasing evidence for feasibility of 100 per cent renewable energy systems

The potential of direct and indirect electrification (green hydrogen and energy carriers (based on green hydrogen from renewable electricity) highlights the crucial role of decarbonising power generation in leading to increased electricity demand to electrify end-use sectors, directly or indirectly. This increase in demand needs to be factored into planning for renewable energy expansion (UBA, 2020).

Other sectoral analyses, including an increasing number of 100 per cent renewable energy scenarios (Creutzig *et al*., 2017; Hansen *et al*., 2019; and Jacobson *et al*., 2017)but it does not identify solar energy as a strategically important technology option. That is surprising given the strong growth, large resource, and low environmental footprint of photovoltaics (PV, show that fossil fuels can be completely phased out faster, including through faster electrification of end-use sectors (transport, buildings and industry) and replacement of fossil fuels with biofuels or green hydrogen, for some industrial processes such as steel production.

The integration of variable renewable energies (VRE) into energy networks, however, requires stable backup power. This is increasingly possible with large-scale battery installations or pumped hydropower as well as the use of smart devices and information technologies to precisely manage localised demand and distributed supply (IRENA, 2019). Sector coupling, such as power to hydrogen, will also help to manage VRE integration and, in doing so, will reduce emissions from sectors that are currently difficult to decarbonise (IRENA, 2018a)low-carbon electricity from renewables may become the preferred energy carrier. The share of electricity in all of the energy consumed by end users worldwide would need to increase to 40 % in 2050 (from about half that amount in 2015. Few countries have systematically adopted targets including sector coupling, but some countries and regions are far advanced in high uptake of VRE (Denmark and South Australia) (*Climate Analytics*, 2020a; and IEA, 2019).

Hansen *et al*. (2019) summarized the existing research and the growing number of studies, but they also highlighted the fact that gaps exist for studies in South and South-East Asia, in comparison to the large number of studies for Europe, the United States and Australia. These studies have shown the feasibility of 100 per cent renewable energy power systems and, more recently, fully renewable energy systems at the global, regional and national levels.

An early study of ASEAN by Greenpeace (2014) was used to develop a 100 per cent renewable-based power sector by 2050 in the whole of South-East Asia connected to Australia. This compared pathways relying on the use of storage technologies with other pathways relying on imported electricity by transmission of renewable energy through a High Voltage Direct Current cable connection (Gulagi, Choudhary, *et al*., 2017b). This integrated scenario includes desalination and industrial gas demand, with wind and solar dominating renewable electricity generation (Gulagi, Choudhary, *et al*., 2017b). However, another study found that ASEAN energy policy has inconsistency between its political vision of being green and action plans leading to fossil fuel dominated outlooks (Shi, 2016)highlighting the paradox of its fossil fuel-dominated outlooks when contrasted with its aspirations to move toward a green energy mix, and reviews green energy strategies using the strengths, weaknesses, opportunities, and threats (SWOT.

The LUT Energy System Model has also been used to develop a 100 per cent renewables-based power sector by 2050 in three countries of the region – Indonesia, Papua New Guinea and Viet Nam. In all three cases, solar PV is the major source of energy providing 81 per cent of electricity to Viet Nam and 88 per cent to Indonesia and Papua New Guinea. This increase would take place despite a significant increase in electricity consumption resulting from electrification of end-use sectors (Ram and Bogdanov, 2017; and Ram *et al*., 2017).

For South Asia, a more recent modelling exercise confirms that a 100 per cent renewable energy system is possible with regional grid interconnection at a lower total system levelized cost of electricity (LCOE), when compared to a scenario where each individual country attempts to make such a transition individually (Gulagi, Choudhary, *et al.*, 2017).

Another recent global study by Teske (2019) developed global long-term energy pathway scenarios, with regional analysis. It defines a 1.5°C scenario based on a global energy related CO_2 budget of 450 Gt for 2015 to 2050. The pathway does not consider societal or political barriers, but outlines what is technically possible. Most notable in this scenario is the accelerated deployment of renewables, representing 92 per cent of the final energy demand by 2050. In addition, the total energy demand would be significantly lower by 2050 compared to current policies. By 2030, 74 per cent of electricity generation would be renewable with some natural gas remaining in the electricity generation mix, and reaching 100 per cent renewables by 2050.

There are multiple barriers to overcome for a 100 per cent renewable energy transition in the Asia-Pacific region, and the barriers vary between countries and subregions. Barriers to renewable energy has been widely covered in academic literature. Barriers range from market failures, financial barriers, information and awareness barriers, capacity-building needs and sociocultural barriers (Ghimire and Kim, 2018; Kardooni *et al.*, 2018; Lucas *et al.*, 2017; Sen and Ganguly, 2017; Shah and Solangi, 2019; and Weir, 2018). For example, the structure of the power sector, state-owned buyer monopolies and power purchasing agreements reduce perceived risks for fossil fuel investment such as stranded asset risks in some countries in South-East Asia (Johnson *et al.*, 2020). The Pacific Islands face a lack of energy data, lack of human resources, and scarcity of financial opportunities resulting in mixed progress to date (Lucas *et al.*, 2017; and Weir, 2018). These obstacles can be overcome by introducing or expanding policies and programmes discussed in chapter 5.

Key benchmarks for the power sector – global and regional

Based on these multiple lines of evidence, a range of benchmarks for the power sector has been derived through an in-depth analysis of the IAM pathways outlined above as well as an additional analysis using results from bottom-up models in the literature, 100 per cent renewable studies and information from existing literature (Climate Action Tracker, 2020). This report builds on this analysis to derive further regional benchmarks relevant to the Asia-Pacific region, particularly for South and South-East Asia as well as South and South-West Asia, which are the most relevant ones for coal expansion (see Chapter 1. Current situation, trends and expansion plans).

The benchmarks are derived considering the objective of decarbonising the sector as quickly as possible, minimizing the reliance on CDR and considering the status of the regions or individual countries.

Table 5 show the results of this benchmark analysis of the share of unabated coal-fired power generation and the share of renewable energy for power generation at the global and regional levels. It shows the analysis of the 1.5o C compatible IAM pathways from the IPCC as well as the IEA's ETP Below 2 Degree Scenario (B2DS) also analysed in (*Climate Analytics*, 2019b) for South and South-East Asia, and the Energy Watch Group (EWG)/LUT, 2017) scenario study for a high degree of renewable energy penetration across every region of the world.

This joint modelling initiative between the Energy Watch Group and LUT University simulates a total global energy transition across multiple sectors, including electricity and transport, and shows that a transition to 100 per cent renewable energy is economically competitive with the current fossil-fuel and nuclear-based system (Ram *et al.*, 2019). It finds that every region can reach a 100 per cent renewable electricity system or very close to it by 2050. The levelized cost of energy for global 100 per cent renewable system reduces costs from 54 €/MWh (in 2015) to 53 €/MWh by 2050, and when accounting for negative externalities, a renewable system is substantially

**Table 5 **

Share of unabated coal-fired power in the electricity sector for 1.5°C compatible pathways at global, regional and national levels

Country	Year	IAM pathways median	IAM pathways p25	ETP B2DS	EWG and LUT	PA Benchmark
Global	2030	7%	2%	11%	1%	0-2.5%
	2040	1%	0%	0%	0%	0%
	2050	0%	0%	0%	0%	0%
OECD90	2030	4%	1%	8%		0%
	2040	1%	0%	0%		0%
	2050	0%	0%	0%		0%
REF	2030	2%	0%	5%		0%
	2040	0%	0%	2%		0%
	2050	0%	0%	0%		0%
Asia non-OECD	2030	12%	6%	20%		5-10%
	2040	0%	0%	0%		0%
	2050	0%	0%	0%		0%
North-East Asia	2030				6%	
	2040				1%	
	2050				0%	
South-East Asia	2030			8%	7%	5-10%
	2040			0%	0%	0%
	2050			0%	0%	0%
South Asia	2030			24%	12%	5-10%
	2040			0%	0%	0%
	2050			0%	0%	0%
India	2030	19%	11%	11%	7%	5-10%
	2040	1%	1%	0%	0%	0%
	2050	0%	0%	0%	0%	0%
China	2030	17%	8%	26%	7%	5-10%
	2040	1%	0%	0%	0%	0%
	2050	0%	0%	0%	0%	0%
Indonesia	2030	13%	8%	11%	6%	5-10%
	2040	1%	0%		0%	0%
	2050	0%	0%	0%	0%	0%

Source: Authors evaluation, based on (Climate Action Tracker, 2020). IAM for India, China, Indonesia, downscaled with SIAMESE (see Climate Action Tracker, 2020 for details). PA final benchmarks for global, India, China and Indonesia from Climate Action Tracker 2020. Benchmarks for OECD, REF, ASIA; based on Climate Analytics, 2019c.

cheaper (Ram *et al.*, 2019). This is supported by an increasing body of literature at the regional and national levels (Hansen *et al.*, 2019).

This includes studies for Japan (e.g., Ishihara *et al.*, 2018) shows feasibility of 100 per cent renewable energy with wind, solar and tidal energy; Renewable Energy Institute and Agora Energiewende (2018) showed that an RE share of 40 per cent can be achieved by 2030. For the Republic of Korea (Hong *et al.*, 2019), it has been argued that a transition to renewable energy

**Table 6 **

Benchmarks for the share of renewable energy for power generation for 1.5°C Paris Agreement compatible pathways at the global, regional and national levels

Country/ region	Year	IAM pathways median	IAM pathways p75	ETP B2DS	EWG and LUT	PA Final Benchmark
Global	2030	52%	56%	47%	89%	55-90%
	2040	73%	76%	63%	98%	75-100%
	2050	71%	82%	74%	100%	98-100%
OECD90	2030	44%	48%	41%		
	2040	65%	71%	57%		
	2050	72%	82%	69%		
REF	2030	29%	64%	34%		
	2040	56%	80%	48%		
	2050	67%	74%	61%		
Asia non-OECD	2030	55%	61%	47% (60%)[14]		60-80%[15]
	2040	76%	80%	62% (87%)		85-90%
	2050	71%	81%	73% (97%)		98-100%[16]
North-East Asia	2030	--	--		89%	
	2040	--	--		96%	
	2050	--	--		99%	
South-East Asia	2030	--	--	43%	85%	50-85%[17]
	2040	--	--	65%	99%	80-98%
	2050	--	--	81%	100%	98-100%
South Asia	2030	--	--	39%	81%	50-80%
	2040	--	--	55%	89%	80-90%
	2050	--	--	62%	100%	98-100%
India	2030	65%	66%	42%	81%	65-80%
	2040	86%	88%	62%	98%	90-100%
	2050	84%	88%	75%	98%	98-100%
China	2030	70%	76%	49%	89%	75-90%
	2040	89%	91%	61%	96%	90-95%
	2050	90%	94%	70%	99%	98-100%
Indonesia	2030	45%	50%		84%	50-85%
	2040	68%	79%		99%	80-100%
	2050	74%	79%		99%	98-100%

Note: Share of renewables (including biomass) per cent of total generation (same countries/regions and sources as in Table 5)

14 In parentheses – total share of decarbonised electricity generation.
15 Sixty per cent from ETP decarbonised share and 80 per cent from range for Asian subregions from EWG (conservative). See also Teske et al., 2019
16 See results for IEA and ETP and IAM for decarbonised electricity, and the wide range of scenario literature. See also Teske et al., 2019, chapter 8, Asia non-OECD results
17 See (Climate Analytics, 2019b) – defined benchmark of 50 per cent based on decarbonised electricity in IEA ETP. Similar to Indonesia. Greenpeace, 2013 – 60 per cent RE in 2030 in ASEAN.

is not as easy as for other countries due to the lower renewable energy potential and less grid integration with other countries.

IEA, IRENA, ACE and APERC not ambitious enough and incompatible with the Paris Agreement

Scenarios developed in the region with intergovernmental agencies are typically not as ambitious as seen in the literature. This is not only the case for IEA, but also for IRENA.

IRENA developed a global pathway including South-East Asia that is centred on renewable resources and improved energy efficiency (IRENA, 2020a). It is less ambitious than the recent 100 per cent RE scenarios described above, as it suggests modern renewables could represent 41 per cent of the Total Primary Energy Supply (TPES) in 2030 and 75 per cent in 2050 under the transforming energy scenario for South-East Asia. The renewable energy penetration into power generation would grow from 20 per cent in 2017 to 53 per cent in 2030 and 85 per cent in 2050 in South-East Asia in the IRENA scenario. This is at the low end (for 2030) and below (for 2050) what has been identified as Paris Agreement consistent benchmarks for this sector in the Asia-Pacific region. The pathway for the "Rest of Asia", including South Asia, Central Asia and West Asia, has a similar development of renewable energy share in power generation that increases from 18 per cent in 2017 to 52 per cent in 2030 and 81 per cent in 2050, and a higher share in East Asia from 23 per cent in 2017 to 60 per cent in 2030 and 90 per cent in 2050.

The most ambitious scenario developed for South-East Asia by the ASEAN Centre for Sustainable Energy (ACE) is the "ASEAN Progressive Scenario" (APS). It represents ambitions of the subregion's countries that reach beyond their renewable or energy efficiency targets (ACE, 2017). APS presents a pathway for renewables to reach 34 per cent of the total primary energy supply by 2030 and 37 per cent by 2040. This is compared to 21 per cent in 2030 and 20 per cent in 2040 in a business-as-usual (BAU) scenario based on past policy practises. Total primary energy supply increases to 131 per cent in the BAU scenario and only 79 per cent in the APS scenario, due to energy savings and energy efficiency. However, fossil fuels retain the majority share of the TPES mix, representing 63 per cent in 2040 (17 per cent coal, 28 per cent oil and 18 per cent gas).

In the electricity generation mix, renewables represent 52 per cent in the APS scenario in 2040 compared to 26 per cent in the BAU scenario (ACE, 2017).[18] This is not in line with the Paris Agreement benchmarks identified above and less ambitious than the IRENA TES (73 per cent in 2040). Similarly, even the most ambitious scenario of the APERC model for the Asia-Pacific is not in line with these benchmarks.

APERC models scenarios for Asia and the Pacific, with the most ambitious scenario being the 2°C scenario (2DC) (APERC, 2019). The 2DC shows a pathway to scale up renewables and decrease energy intensity and CO_2 emissions, in order to reach an average global temperature of 2°C below pre-industrial temperatures by 2050. APERC compares the scenario with a BAU scenario representing current policies and trends. The 2DC scenario shows a pathway where renewables can represent 30 per cent of TPES in 2030 and 38 per cent in 2050 in the Asia-Pacific region. In this scenario renewable energy represents only 58 per cent of power generation by 2050, compared to 32 per cent in the business-as-usual pathway. APERC also provides scenario data for South-East Asia. Under the 2DC scenario, renewables represent 44 per cent of electricity generation in 2030 and 63 per cent in 2050.

3.2 Renewable energy potential

Untapped renewable energy potential in South Asia and South East Asia

Renewable energy, particularly solar and wind energy, have large and largely untapped potential in South and South-East Asia. Utilization of solar and wind could satisfy the needs of almost all South and South-East Asian countries many times over, with generally high solar irradiance

18 Hydro represents the largest share of installed renewable capacity in all scenarios, followed by solar PV.

potential across the regions, especially in South Asia and mainland South East Asia, and less in Malaysia ,the Philippines and Indonesia due to seasonal cloudiness (*Climate Analytics*, 2019a). Compared with solar, wind resources are more unevenly distributed, with large potential in the Philippines and Viet Nam (onshore and offshore), as well as Thailand (onshore); however, the mountainous areas make utilization a challenge (*Climate Analytics*, 2019a).

The availability of hydropower, geothermal and bioenergy is much more unequally distributed, but it can contribute to grid flexibility as well as complement wind and solar technologies. Indonesia has particularly large geothermal potential, followed by the Philippines, where it is often in protected areas or national parks, and therefore may not be feasible (Fuentes *et al*., 2019e). The latter also have the advantage of providing electricity in areas without a well-functioning electricity grid (*Climate Analytics*, 2019b).

A recent study of the technical potential for renewable energy in ASEAN members confirms a high potential, particularly for solar and wind (Vidinopoulos *et al*., 2020). For the region as a whole, the study showed that the total primary energy supply (TPES) projected for 2040 could be covered with renewable energy based on solar, wind, hydro and geothermal resources. This projection takes into account land-use needs for urban and transport areas (including expansion needs), agriculture as well as protection of natural habitat. However, not all countries would be self-sufficient (Vidinopoulos *et al*., 2020). This points to the need for larger regional cooperation in cross-border power interconnection because of the uneven distribution of renewable energy resources. The study identified 90 per cent of the potential coming from solar PV, in particular from rural areas, 8 per cent from wind, 2 per cent from hydro and 1 per cent from geothermal (Vidinopoulos *et al*., 2020).[19] Three countries – Cambodia, the Lao People's Democratic Republic and Myanmar – cover more than 30 per cent of the technical potential, and collectively more than 30 times the estimated demand by 2040. This underscores the benefits of regional integration as shown by some of the regional modelling studies (Gulagi, Bogdanov, *et al*., 2017)a cost optimal 100% renewable energy based system is obtained for Southeast Asia and the Pacific Rim region for the year 2030 on an hourly resolution for the whole year. For the optimization, the region was divided into 15 sub-regions and three different scenarios were set up based on the level of high voltage direct current grid connections. The results obtained for a total system levelized cost of electricity showed a decrease from 66.7 €/MWh in a decentralized scenario to 63.5 €/MWh for a centralized grid connected scenario. An integrated scenario was simulated to show the benefit of integrating additional demand of industrial gas and desalinated water which provided the system the required flexibility and increased the efficiency of the usage of storage technologies. This was reflected in the decrease of system cost by 9.5% and the total electricity generation by 5.1%. According to the results, grid integration on a larger scale decreases the total system cost and levelized cost of electricity by reducing the need for storage technologies due to seasonal variations in weather and demand profiles. The intermittency of renewable technologies can be effectively stabilized to satisfy hourly demand at a low cost level. A 100% renewable energy based system could be a reality economically and technically in Southeast Asia and the Pacific Rim with the cost assumptions used in this research and it may be more cost competitive than the nuclear and fossil carbon capture and storage (CCS).

South-East Asia has many hydro projects and has large potential, especially for the lower Mekong countries. Indonesia has the largest potential for hydro, with up to 402 TWh (Vidinopoulos *et al*., 2020). However, the potential for hydro also needs to be assessed in the context of socioeconomic and environmental impacts.

Indonesia and the Philippines could have the technical potential for ocean energy (240 GW and 170 GW, respectively). However, as an emerging technology, ocean energy should be considered

19 The percentages do not add up to 100 per cent because of rounding off.

as an option in the future with further research and development (Ölz and Beerepoot, 2010).

Bioenergy plays a large role in renewable energy in the Asia-Pacific region. However, there is transition away from traditional biomass with electrification as well as due to adverse health effects (APERC, 2019). There are also concerns regarding the sustainability of bioenergy in South-East Asia, particularly with palm oil plantations (APERC, 2019). Bioenergy needs to be considered carefully when planning a low carbon future, together with other options such as carbon capture and storage.

Since South-East Asia is rich in renewable energy resources and a significant disparity between production and demand centres, the regional energy connectivity that is being promoted by ASEAN and ESCAP is a valuable institutional asset in more cost-effectively decarbonizing the energy systems (Li *et al*., 2020).

Renewable energy potential in East Asia

Large and untapped renewable energy potential has also been identified in East Asian countries. Cheng *et al*., (2019) provides an estimate of available wind and solar resources in China, Japan, the Republic of Korea and Mongolia, and demonstrates that sufficient land is available to supply current East Asian electricity consumption from PV and wind. That report identifies the potential for storage capacity in the form of pumped hydro electrical storage to support high levels of variable wind and PV energy supply in East Asia. It estimates the storage requirements to support 100 per cent renewable electricity in East Asia, finding that this requirement is a small fraction of the available pumped hydro electrical storage in the region. East Asia has abundant wind resources compared to the rest of the world, and China is already leading global wind power generation with continued growth (Zhao *et al*., 2020). Japan and the Republic of Korea recently started planning significant investments in offshore wind energy to utilize the abundant coastline wind resources. Solar and wind potential is high, particularly in western China and Mongolia, but Japan and the Republic of Korea also have yet-untapped solar energy potential.

Estimates of the percentage of land are needed to achieve 100 per cent renewable energy are 0.3 per cent for the whole of East Asia, with the largest share in the Republic of Korea (2.6 per cent) and Japan (1.4 per cent). This study does not account for the additional option of importing green hydrogen from areas with higher renewable energy potential, e.g., Australia, by countries with less potential such as Japan or the Republic of Korea.

3.3 Comparison of costs for renewable energy and storage vs. fossil fuel technologies

Renewable energy costs have rapidly fallen during the past 10 years, due to technology improvements, economies of scale, competition in renewable energy supply chains and advancing industry experience (IRENA, 2020b). Solar and wind projects costs can be more economical than the cheapest existing coal-fired generation options (IRENA, 2020b). The IEA's World Energy Outlook for 2020 reports that solar PV is now "the cheapest source of new electricity generation in most parts of the world" (IEA, 2020d). This trend can be seen clearly in **figure 18,º** which shows the LCOE of key solar and wind technologies trending at or below the lowest costs for a range of fossil fuel power generation technologies.

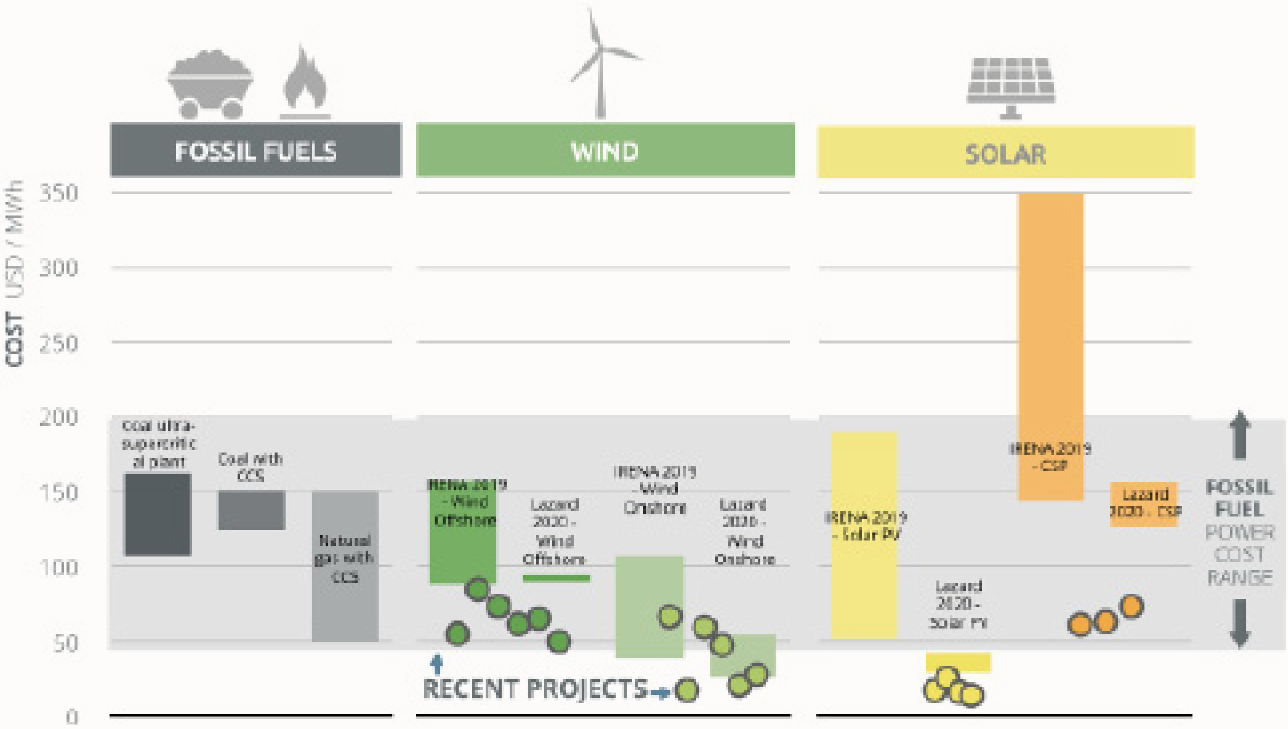
China and India have the lowest costs for solar and onshore wind, and recently in China offshore wind. Other Asian countries typically have higher costs than the global average (Table 7) as well as any other region.

Growth in solar PV in 2019 was driven by continued new capacity additions in Asia, with the region contributing about 60 per cent of the new installations during that year. Developments in Asia were driven by China, India, Japan and the Republic of Korea, which together installed 47.5 GW of new PV capacity during 2019. Viet Nam has emerged as a new, important PV market in the region, after installing about 5.6 GW last year – another example of newer markets gaining maturity (IRENA, 2020b).

The rapid decline in total installed costs, increasing capacity factors and falling O&M costs

**Figure 18 **

Levelized cost of electricity – a comparison between fossil fuels and renewable sources, 2019



Source: Authors' elaboration based on Lazard, 2020 and IRENA, 2020.

have contributed to the remarkable reduction in the cost of electricity from solar PV and the improvement of its economic competitiveness.

Utility-scale Solar PV

Solar PV has experienced a huge fall in prices over the past decade. Globally, the weighted-average LCOE of new utility-scale solar PV fell 82 per cent from 2010 to 2019, to $0.068/kWh (IRENA, 2020b). IRENA (2020b) found 40 per cent of new utility solar PV installations in 2019 had lower costs than the cheapest new fossil fuel capacity alternatives. Between 2010 and 2019, the LCOE of utility-scale solar PV fell 85 per cent in India, 82 per cent in China and in the Republic of Korea, 78 per cent in Australia and 62 per cent in Japan (IRENA, 2020b). IRENA also found that the range of LCOE costs was continuing to narrow. India showed the highest reduction in utility-scale solar PV between 2010 and 2019, with costs declining by 85 per cent to reach $0.045/kWh – a value of 34 per cent lower than the global weighted average for that year. China also achieved one of the most competitive LCOEs globally with $0.056/kWh for 2019. However, in Japan, the LCOE of utility-scale PV was about two times higher than in India and declined only 4 per cent (the lowest decline among markets evaluated by IRENA).

Solar PV is also now within the coal power LCOE range, particularly in Thailand, with a benchmark LCOE a little below $90/MWh, and at similar level as in the Philippines, where coal is more affordable than in Thailand. The most competitive solar PV projects in the first half of 2019 in the region had LCOEs of $S60-65/MWh. (The world record was reached in Portugal in the summer of 2019, at $16/MWh).

Residential solar PV

For rooftop solar PV, IRENA identifies India, China, Australia and Malaysia as low-cost markets (together with Spain, outside of the Asia-Pacific

**Table 7 **

Global and regional Weighted Average LCOE (2019 $/MWh): Selected countries and regions

	Utility solar PV		Residential solar PV		Commercial sector solar PV		Onshore wind		Offshore wind	
Year	2010	2019	2010	2019	2010	2019	2010	2019	2010	2019
Global	378 (188-514)	68 (52-190)					86 (58-117)	53 (38-107)	161 (114-204)	115 (88-157)
Asia									214	117 (115-189)
Other Asia (excl. India and China)							117 (90-129)	99 (57-131)		
China	301	54		67		64	72 (51-101)	46 (37-64)	177 (116-189)	112 (94-119)
India	30	4		63		62	83 (50-120)	49 (36-70)		
Japan	No data	144	455	163		147	157	113	214	198
Republic of Korea	502	91		125		115				
Viet Nam	No data	82								
Malaysia				95		80				
Thailand				106						
Oceania							117 (101-155)	54 (43-71)		
Australia	376	84	319	75		78				
Turkey		78								

Source: IRENA ,2020b.
Note: LCOE (2019 $/kWh), weighted average. In brackets: Range (5-95 Per centile).

region), with good irradiation conditions. Those countries have experienced increasingly competitive total installed costs, achieving very low LCOEs and declining between 2013 and 2019, from between $0.156/kWh and $0.220/kWh to between $0.071/kWh and $0.121/kWh – a decline of between 46 per cent and 57 per cent.

South-East Asia has had a significantly higher LCOE of solar PV compared to the rest of Asia (90 per cent higher in 2016) due to the huge capacity added by projects in India and China, but also highlighting the potential for huge cost reductions (IRENA, 2018b). Viet Nam is an emerging market player and its LCOE of solar PV electricity fell 55 per cent in just three years from 2016 (IRENA, 2020b).

Wind

The global weighted average cost of onshore wind has dropped 39 per cent since 2010, and projects in 2019 had a weighted average LCOE of $0.053/kWh (IRENA, 2020b). Onshore wind is cheaper than fossil fuel-generated new electricity (IRENA, 2020b). Total installed costs declined 9 per cent in India, and 5 per cent in China from 2018 to 2019 (IRENA, 2020b). Similar to solar PV, South-East Asia experienced a higher LCOE, at around 42 per cent higher than the rest of Asia in 2016 (IRENA, 2018b).

Onshore wind has shown a benchmark LCOE in the range of coal in Viet Nam (around $90/MWh), but projects in Indonesia and Thailand showed higher costs.

The global weighted average cost of offshore wind dropped from $0.161/kWh in 2010 to $0.115/kWh in 2019 (IRENA, 2020b). China represents 95 per cent of Asia's wind power installations (IRENA, 2020b).

Focus on trends in South-East Asia

The costs of renewables in South-East Asia have fallen significantly, in line with global trends; however, the LCOE for renewables is not as low as the rest of Asia (IRENA, 2018b). Cost reduction can be achieved through the right policy support for renewable deployment, and reduction of costs associated with licences and permits, connection to the grid, land acquisition, improving supply change efficiency, local installation services, offering risk mitigation options and low-cost capital (IRENA, 2018b).

An analysis of recent development costs of renewable energy in South-East Asia (Zissler, 2019) showed that geothermal energy, which has a large potential in Indonesia and the Philippines, may already be competitive with coal, especially in Indonesia. It may also be on par with, or cheaper than coal under optimal conditions in Malaysia, the Philippines and Viet Nam. Biomass also appears to be least-cost competitive among conventional renewable energy technologies in all those South-East Asian countries.

With cost reductions of 40-50 per cent since 2010 for solar PV in Indonesia, Thailand and Viet Nam and 15-45 per cent for onshore wind, resulting mainly from industrial learning curves throughout the world, shows that there is potential for a continuing reduction of cost. Bloomberg New Energy Finance (BNEF) expects new solar PV LCOE to be cost-competitive with new coal in 2021-2022 in Indonesia, Malaysia, the Philippines and Thailand, and for onshore wind from the second half of the 2020s to before 2030 (Zissler, 2019)). Unsubsidised solar PV is already cheaper than unsubsidised coal and gas power in Thailand, the Philippines and Viet Nam, according to BNEF, but still more expensive in Malaysia and Indonesia (Greenpeace, 2020), with cost reductions expected to make it competitive with coal in the near future.

Up to certain levels, variable renewable energy can be integrated into local grids without the need for storage through flexibility in the network or demand management and complementary market reform. Beyond certain levels of integration, and depending on the size and other parameters of the grid, battery storage or other forms of storage such as pumped hydro need to be deployed (IEA, 2020b). With the rapidly declining cost of battery storage, these alternatives are being deployed on an increasing scale in more and more grids (large-scale and distributed).

3.4 Integration to maximise benefits from renewable energy potential

Regional integration of renewable energy offers numerous advantages for resource sharing and cost reduction, with larger grid integration and transmission providing more flexibility and less need for additional storage.

While solar and wind resources can meet the needs of South and South-East Asia four times over (*Climate Analytics*, 2019b), the resources are unevenly distributed. However, countries that are not rich in renewable resources, such as Brunei Darussalam or Singapore, would have the option of importing clean energy rather than relying on fossil fuels. Hydropower, geothermal and bioenergy are not equally distributed, but they still present opportunities for grid flexibility in some locations (*Climate Analytics*, 2019b). The unequal distribution of renewables across the region opens possibilities for energy trading, as countries with excess renewable energy have the option of new export opportunities.

Regional integration can build on existing initiatives and discussions, e.g., South Asia (SAARC and SASEC) and for South-East Asia (ASEAN grid and the recent IRENA initiative with ACE) (*Climate Analytics*, 2019b; and ESCAP, 2019a). It is also feasible for a larger area covering East Asia (Asia Super Grid; see Renewable Energy Institute, 2019).

An emerging option in addition to larger regional grid integration is trade of green hydrogen produced from renewable electricity, where countries with strong renewable full load hours provide cost-efficient green hydrogen. Countries with smaller renewable full load hours could then rely on a global market to decarbonise hard-to-abate sectors in a cost-efficient way. An increasing number of countries are developing hydrogen strategies, including some with explicit focus on green hydrogen. Renewable (green) hydrogen production will likely compete with large-scale fossil hydrogen supply within this decade (Henze, 2020; and Hydrogen Council, 2020). Renewable production pathways for already existing hydrogen demand will become cost-competitive and able to contribute to the decarbonisation of hard-to-abate sectors in a cost-effective way (BNEF, 2020; and Glenk and Reichelstein, 2019). Renewable hydrogen production has the potential to become cost-competitive with natural gas in industry but also in the power generation sector by 2050 (BNEF, 2020).

Chapter 4

Benefits of a transition from coal towards renewable-based efficient energy system

This chapter explores the benefits of transitioning to a renewable-based efficient system. The benefits are both social and economic, and are in the form of reduced risk of climate change impacts on a region poised to be heavily affected by climate change. A sustainable energy transition will bring the region closer to meeting the SDGs. The chapter considers data that has not been explicitly shown elsewhere to provide new insights of the regional economic impacts of global warming. Despite the benefits of a renewables transition, particularly the lower costs of a renewables- based efficient energy system, the drivers of fossil fuels and the continuation of coal investment are a barrier to an accelerated transition, as outlined in Chapter 2. Drivers of coal expansion in the region.

4.1 Access to clean and affordable energy

There has been substantial progress in expanding modern energy access, with more than 95 per cent of the population in the Asia-Pacific region having access to electricity in 2018, yet still around 200 million people have been without access to electricity, most of them (more than 180 million) in rural areas, and most of them in South and South-West Asia (153 million, mostly in India, Pakistan and Bangladesh) followed by South-East Asia (29 million) (ESCAP, 2020).

Most of the populations without access to electricity in South-East Asia are located in emerging economies, such as Cambodia and Myanmar, and rural areas and countries with many islands, such as Indonesia and the Philippines. Due to challenging locations, like remote islands or deep forest areas, decentralised (household or community level) energy solutions based on renewable energy provide advantages over ‘conventional’ grid-based electricity forms.

There is a wide variety of options for renewable energy, both on conventional grids and decentralised micro-grid or off grid, allowing for access to all populations (*Climate Analytics*, 2019b). Renewable energy can be deployed rapidly and in areas that are not connected to the grid, important for a region where not all of the population has access to electricity. Renewables in remote communities provide electricity, and reduce poverty and inequality for these areas, allowing for educational opportunities and extended study hours with access to light (*Climate Analytics*, 2019b). Electricity provides the possibility for accessing the economic benefits of digital technology and can help combat poverty.

4.2 Employment

Renewable energy provides employment opportunities; and employment is crucial for post-COVID-19 recovery, although renewable energy transition strategies must account for the negative impact on those who are affected by such a transition.

Renewable energy offers economic and employment opportunities, and the construction and maintenance can be labour-intensive, thus providing local jobs (*Climate Analytics*, 2019b). Renewable energy projects should leverage local capacity; the employment gains from renewable energy are greater than the jobs lost in the transition from fossil fuels. One study found that $1 million in investments creates 7.49 jobs in renewables or 7.72 in energy efficiency, whereas the same amount creates 2.65 jobs in fossil fuels (Garrett-Peltier, 2017)and transforming the energy sector by increasing efficiency and use of renewables is one of the primary strategies to reduce emissions. Policy makers need to understand both the environmental and economic impacts of fiscal and regulatory policies regarding the energy sector. Transitioning to lower-carbon energy will entail a contraction of the fossil fuel sector, along with a loss of jobs. An important question is whether clean energy will create more jobs than will be lost in fossil fuels. This article presents a method of using Input-Output (I-O).

In the context of COVID-19, it is financially beneficial for policymakers to aim economic recovery packages towards energy industries in order to provide more jobs while encouraging infrastructure development that will support ongoing economic growth. It is also financially prudent for Governments to shift current investments from fossil fuels to renewable energy or energy efficiency to assist economic recovery, as each $1 million moved from conventional energy generates a net increase of five jobs. IRENA found that the employment intensity of renewables varied regionally. In the ASEAN region, every $1 million invested creates 30 jobs, compared to as low as five or ten jobs in other regions (IRENA, 2020d)

IRENA compares the Planned Energy Scenario with a Transforming Energy Scenario in which new investment is focused on sustainable energy (IRENA, 2020a). The study found that, under the Transforming Energy Scenario, South-East Asia would lose less than half a million jobs in fossil fuels by 2050, but gain five million jobs, mainly in renewables but also in energy efficiency and power grids and energy flexibility. East Asia would lose three million existing jobs but gain more than four million jobs.

4.3 Health, reduced air and water pollution, and impact on water scarcity

Phasing out coal reduces air, water and soil pollution. Outdoor air pollution is an increasing issue in the Asia-Pacific region, as it has a negative impact on health and creates mounting costs in urban areas (*Climate Analytics*, 2019b). All forms of pollution have adverse health impacts and can cause non-communicable diseases, and phasing out coal has large benefits gained from avoided air pollution (*Climate Analytics*, 2019b).

Coal is one of the most water-intensive forms of electricity generation, as during the lifecycle of coal it uses and pollutes vast amounts of water used for coal mining, coal processing and combustion in power plants as well as being related to the disposal of coal ash. In its different lifecycle stages – mining, processing, combustion and waste storage – coal use can have multiple negative impacts on water quality. These include water contamination due to acid mine drainage, due to toxic wastewater from processing and disposal of ash after combustion.

Water contamination caused by heavy metals (such as lead, mercury, nickel, tin, cadmium, antimony and arsenic) contained in coal processing and post-combustion wastes also cause a range of serious diseases, such as skin and lung cancer, cardiovascular diseases and gene mutation (*Climate Analytics*, 2019b).

The need for cooling water in thermal power plants such as coal-fired power can contribute to water scarcity. Almost 40 per cent of India's freshwater-cooled thermal power generation capacities are located in areas that are already water-stressed, i.e., with a high level of competition over available water affecting residents, other industries as well as agriculture. The competition for water is expected to increase further. As 79 per cent of India's new energy capacity is expected to be installed in areas that already suffer from water scarcity or water stress (IRENA, 2017b). Beyond the direct impact of increased competition for water on the people's lives, water shortages have negatively affected the reliability of electricity supply, forcing thermal power plants to shut down and causing power outages (*Climate Analytics*, 2019b).

4.4 Avoided risk of stranded investments

The large gap between potential power generation from coal and currently operating capacity in the Asia-Pacific region, particularly in East, South and South-East Asia, highlights the stranded asset risk of continuing investments into coal-fired power generation. The market development for renewable energy technologies, particularly solar PV and wind (onshore and offshore) in the region (see chapter 3), together with the increasing awareness of Governments and the private sector of the need to shift investments in a transformational way, highlights the fact that this risk is increasing with the growing competitiveness of renewable energy.

It is not just climate change policy that is driving this shift. As outlined in chapter 3, market analyses – including those published by Lazard (2020), BNEF (2020) and IRENA (2020b) – consistently indicate that unsubsidised renewable sources are already more competitive than new fossil fuel generation on a levelized cost of energy basis, and are challenging even the marginal cost of existing coal generators. Furthermore, renewable energy costs are decreasing more rapidly. A report by Wood Mackenzie (2020) estimates that, by 2030, new renewable generation in Asia Pacific will have, on average, a 23 per cent lower levelized cost of energy than coal.

Carbon Tracker has analysed the stranded asset risk for coal plant owners in Thailand, the Philippines and Viet Nam, where the average coal unit would need to be retired at just 15 years old, far earlier than the 40 years often associated with coal plant lifetimes (The Carbon Tracker Initiative, 2018). As long as investors do not consider climate-related risks as a significant factor, they are at risk of stranded assets (Johnson *et al.*, 2020). This risk extends beyond investors to banks, and investment or pension funds with large exposure to this asset class, leading to high financial stability risk.

Factors that support this entrenchment or shielding of investors against recognising the risks are the lack of climate regulations – such as carbon pricing or restrictions on fossil fuel plans, existing support and funding through state subsidies and export credit guarantees for coal – as well as the control of access to the grid by incumbent state-owned utilities, and power purchase agreements being used to shield these utilities from policy and regulatory risk (Johnson *et al.*, 2020).

4.5 Energy security and independence

Many countries within the region rely on fossil fuel imports as their domestic supply of fossil fuels does not meet demand. Installation of renewable energy can replace fossil imports, thereby creating security and avoiding the price fluctuations of fossil fuel imports (*Climate Analytics*, 2019b).

While some countries in the region have traditionally been self-sufficient, increasing demand has led to net exporting countries becoming net importing countries, such as Viet Nam. Historically a coal exporting country, Viet Nam has already become a net importer of coal.

4.6 Environmental degradation

Coal use can also have implications for land-use and soil quality. Soil contamination can be a result of different coal-related processes releasing pollutants and toxic substances into the air and water or directly into the soil. Coal ash is usually transported to large disposal spaces, either in dry form or using water to transport it in pipelines. Fugitive dust of untreated dry coal ash can lead to soil contamination, while transportation in pipelines contaminates the water used for the process as well as natural water sources and soils that come into contact with the contaminated water. Moreover, the land under and around the disposal spaces for coal ash is contaminated and there are high risks of leakages, e.g., into ground water. Soil degradation may not only be caused by contamination, but also by soil erosion. The reduction of tree coverage, as forests are cut down to make room for mines, can increase soil erosion in surrounding areas, which can result in a loss of the fertile layer and subsequently a reduction of agricultural productivity (*Climate Analytics*, 2019b).

4.7 Land use

In direct competition for land, coal mining as well as the construction of new coal power plants requires land to be rededicated. This can lead to increasing deforestation and decreasing cultivation of land for agriculture and food production as well as the resettlement of whole villages (Greenpeace, 2014). It is estimated, that the area needed to dispose of the amount of coal ash that would have resulted from Viet Nam's original Power Development Plan VII would have been about 2800 ha, a toxic dump site the size of almost 40 per cent of the area of Singapore (*Climate Analytics*, 2019b).

While renewable energy technologies also require large areas of land, which has been identified by IRENA (IRENA, 2017a) to be one of the barriers to renewable energy in Indonesia (IRENA, 2017a), the land around wind turbines or solar panels can in parallel be used for agriculture or livestock and is not subject to contamination by toxic substances (*Climate Analytics*, 2019b). In addition, new renewable applications are being pioneered to avoid use of otherwise productive land, in particular offshore wind and floating solar arrays on reservoirs, fish farms and wastewater treatment ponds. Degraded land such as landfill sites and even the Fukushima irradiated area are being used for large-scale renewable energy.

4.8 Shifting investment – opportunities for a green COVID-19 recovery

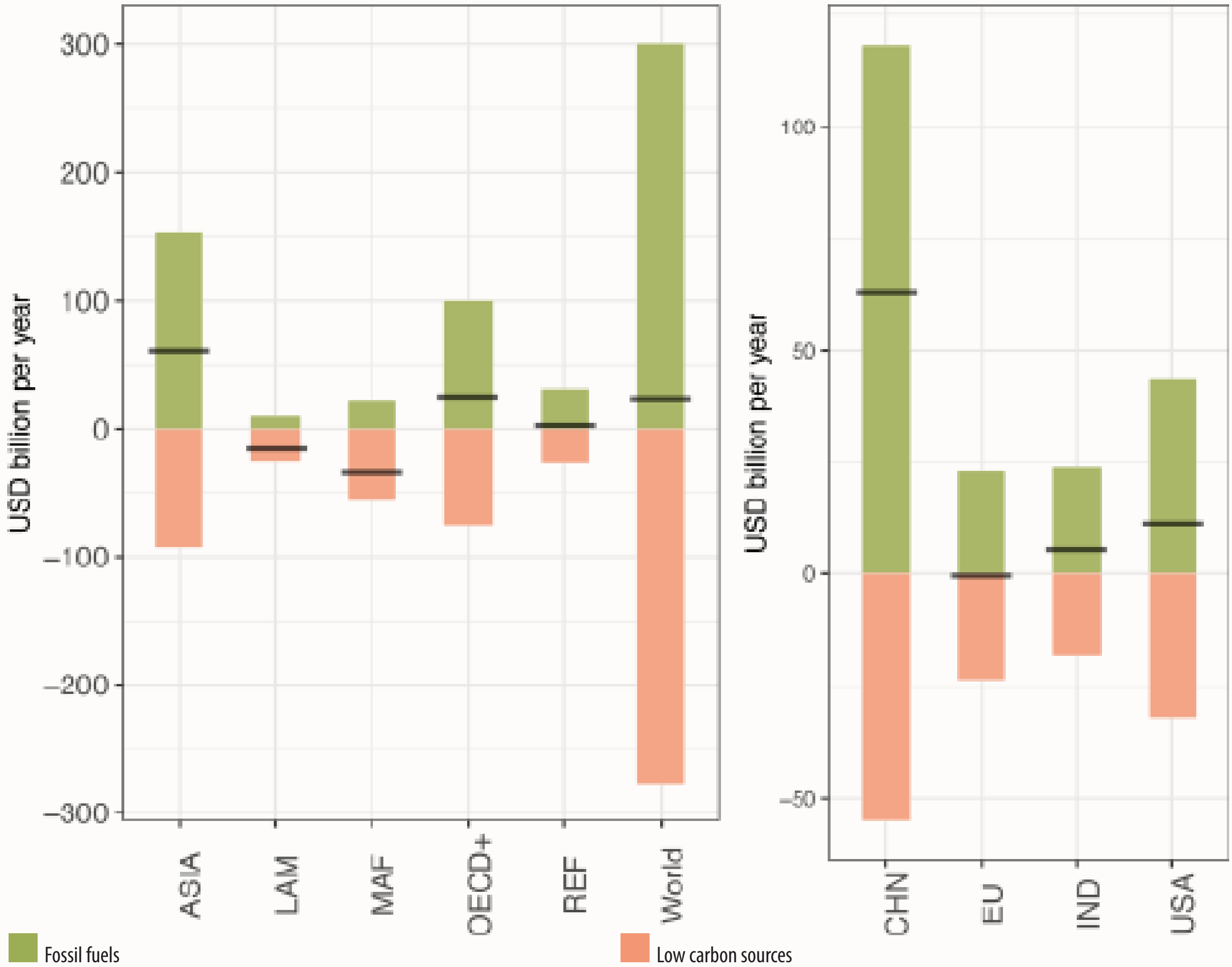
An average annual low-carbon energy and end-use energy efficiency investment needs under a Paris Agreement-compatible pathway have been estimated at about US$ 1.4 trillion per year globally over the near term between 2020 and 2024. This yearly estimate of low-carbon energy investments amounts to some 10 per cent of the total pledged COVID-19 stimulus to-date (Andrijevic *et al*., 2020)

Importantly, the comparison of current policies and Paris Agreement pathways shows that rather than an overall increase in investment, what is mostly needed is a shift in investment away from fossil fuels. Increases in low-carbon investments have to be accompanied by divestments from high-carbon fossil fuels in the range of US$ 280 billion per year over the same near-term period. Subtracting divestments from investments indicates that the overall increase in net annual investments to achieve an ambitious low-carbon transformation in the energy sector are notably small (Andrijevic *et al*., 2020). However, notably for the countries in the OECD and non-OECD Asia, there is a higher need for additional investment, see Figure 19.

The analysis supports the call for green recovery supported by international organisations such as IEA (2020c) and IMF (2020). Andrijevic *et al.* (2020) also pointed to a potential to increase the synergy of green recovery and energy transition. They highlighted the regional differences and the opportunities for international collaboration through institutionalised international support within intergovernmental frameworks such as the Green Climate Fund or multilateral development banks to enable a global climate positive recovery. They also pointed to targeted financial instruments such as blended finance using government, multilateral and philanthropic money to lower the risk for private investors and mobilise private investment in developing countries. Figure 19 shows the annual shift in energy investments from the current policy baseline scenario to a pathway compatible with the 1.5°C limit of global mean temperature for

**Figure 19 **

Shift in energy investments from current policy to a 1.5 pathway



Source: Andrijevic *et al.*, 2020, supplementary material, figure S5. For definition of regions see chapter 1.

five macro regions and the world (left) and four large economies (right).

4.9 Economic impacts of climate change

The Paris Agreement long-term temperature goal (LTTG) is defined as "holding the increase in the global average temperature to well below the 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognising that this would significantly reduce the risks and impacts of climate change" (UNFCCC, 2015, Art. 2.1). The current scientific understanding of the risks of global warming of 1.5°C outlined in the IPCC SR1.5 report (IPCC, 2018a) finds climate change presents a severe threat, and limiting the global mean temperature increase to 1.5°C above pre-industrial levels poses less risk than a warming of 2°C or higher.

The Asia-Pacific region has countries that are extremely vulnerable to climate change, making it the most disaster-prone region globally (ESCAP, 2018).

The authors' detailed analysis of differentiated impacts of climate extremes at different levels of global warming over the five Asia-Pacific subregions is presented in annex 2 of this

Box 1 \ The additional burden of COVID-19

The World Bank estimates that GDP in 2020 contracted by 0.5 per cent in East Asia and the Pacific, and 2.7 per cent in South Asia due to a combination of a collapse in oil prices and the impacts of COVID-19, which have constrained private consumption and investment. Developing countries are likely to suffer increased losses due to weak health-care systems, losses in trade and tourism, reduced capital and financial inflows, leading to higher debts (World Bank, 2020a and 2020b).

According to the World Travel and Tourism Council (WTTC), the biggest loss in employment is expected in the Asia-Pacific region, due to restrictions in tourism. From 2014 to 2019, the region created 21.5 million new jobs in travel and tourism, which accounted for 56 per cent of all new jobs globally.* In a worst-case scenario where travel restrictions are eased from September domestically and from November internationally, the WTTC projects that job losses in Asia-Pacific would amount to 115 million (58 per cent) of all job losses globally (World Travel and Tourism Council, 2020).

The COVID-19 induced economic contraction will likely undo years of progress towards development goals and put millions back into poverty, making it more difficult for countries to cope and recover from damage imposed by climate-related disasters. For example, in April 2020, four Pacific islands (the Solomon Islands, Vanuatu, Fiji and Tonga) were hit by a category 5 cyclone; COVID-19 restrictions locally and globally have made it extremely difficult for the Governments and private organisations to provide immediate relief and recovery support, both financially and physically. Relief in the form of food aid and medical supplies have been delayed, limited and unevenly distributed, while conditions in evacuation centres are complicated by social distancing requirements.

* Including those outside the travel and tourism sector.

report. The results are presented as a gauge of how global temperature increases affect key climate change indicators related to extreme weather events such as extreme precipitation and flooding, drought and heat waves.

The impacts of climate change on the economy are transmitted through different channels and are unevenly distributed among countries. The magnitude of economic impact depends not only on the magnitude of the change in climatic variables, but also on the resilience of each country to climate-related hazards. Asia-Pacific countries are particularly at risk of higher impacts due to increased intensity and frequency of extreme events as well as development hurdles and the current COVID-19 situation that make coping from extreme events more challenging. This section presents the future impacts on the Asia-Pacific countries of a stronger global mitigation action in reaching a 1.5°C world, compared with the current NDC path of close to 3°C, compared to the pre-industrial period.

Disaster risk profile of Asia-Pacific countries

The Asia-Pacific region is the most disaster-prone region in the world (UNDP, 2019). Due to its location and geographic conditions, the Asia-Pacific region is experiencing a variety of natural disasters, i.e., cyclones, earthquakes, tsunamis, flooding, drought, dust storms and heat waves. Four disaster hotspots are discernible (ESCAP, 2019b) in which a combination of socioeconomic vulnerabilities and climate risks often entails devastating impacts:

1. Transboundary river basins, which are particularly prone to risk of flooding;

2. The Pacific ‘Ring of Fire’ with its high typhoon risk;

3. Small Island Developing States (SIDS) in which tropical cyclones often affect a large share of

those countries' population and infrastructure; and

4. The countries in South, Central and South-West Asia that are at risk from drought, sand and dust storms.

With climate change, the frequency and intensity of climate-related natural disaster as well as the complexity and the uncertainty of such disasters have been increasing. Countries are experiencing unprecedented extreme events for which they are often not sufficiently prepared. For example, unprecedented flooding occurred in the Islamic Republic of Iran in 2019 and in Kerala, India in 2018. A combination of flooding and heatwaves hit Japan in July 2018, resulting in more than 300 fatalities. Cyclone Ockhi developed near the equator in 2017, affecting areas without prior cyclone experience (ESCAP, 2019b).

In the recent past, the Asia-Pacific region has seen heavier rainfall and higher maximum wind speeds during storms, resulting in an increased risk of large-scale floods.

The Asia-Pacific region is home to 10 out of the 15 countries in the world in which most of the people are exposed to annual river floods (ESCAP, 2019b). Similarly, greater extreme temperatures aggravate the risk of heatwaves and drought (IPCC, 2012). The Pacific typhoon season seems to be setting up new negative records each year. The resulting increases in rainfall pose an additional risk for countries with major river basins.

In 2019, more than 40 per cent of the 440 natural disasters worldwide occurred in the Asia-Pacific region, causing total damage of more than $66 billion and affecting a disproportionally high number of people. Three-quarters of all people affected by natural disasters worldwide live in the Asia-Pacific region (CRED, 2020).

In 2018, Cyclone Gita, the most intense cyclone to hit Tonga, affected 80 per cent of Tonga's population. Typhoon Mangkhut severely hit many countries in the region, including the Philippines, Guam, southern China, Viet Nam and Thailand. It claimed more than 100 lives and affected more than two million people in the Philippines alone, due to cascading impacts such as landslides and flooding (ESCAP, 2019b). Since 1970, more than one million people have lost their lives due to natural disasters in the region with floods taking an increasingly large share of fatalities.

While the number of fatalities from natural disasters has decreased over time, the number of people affected as well as the economic costs have increased over the recent past decades. The average annual economic loss from natural disasters is estimated at present to be equal to 2.4 per cent of GDP, with an expected clear upward trend when temperatures continue to rise (ESCAP, 2019b). Importantly, slow-onset disasters should not be neglected in the analysis as they have been recently found to account for almost two-thirds of all disaster losses in the region (ESCAP, 2019b).

Given the sheer size of the Asia-Pacific region and its geographic disparities, there are important regional differences in disaster risk and vulnerability. Regardless of the disaster type, however, it is almost always the poor and most marginalized parts of the population who are hardest hit. In turn, disasters are likely to transmit poverty, marginalization and disempowerment across generations, often implying a significant setback in development outcomes.

Future economic impacts due to climate change

This section provides estimates of projected medium- and long-term changes in GDP per capita for the countries in the Asia-Pacific region with under close to 1.5°C warming – Representative Concentration Pathway (RCP) 2.6 – and close to 3°C warming (RCP 6.0). The analysis takes pre-industrial climate as a basis, and evaluates the future impacts due to climate change compared to a "no change" scenario. The estimates are based on the methodology developed by Burke, Davis and Diffenbaugh (2018), which is estimating growth effects based on annual mean temperature change. The method does not account for economic damages by other climate perils, such as extreme weather events. This limitation needs to be kept in mind when interpreting the results.

The RCP2.6 scenario used here results in 1.67°C global mean warming above pre-industrial temperatures by mid-century and remains at about this level until at least the end of this century. Warming under RCP2.6 exceeds the 1.5°C limit in the Paris Agreement, but is used here as proxy for the most optimistic scenario in the CMIP5 archive. RCP 6.0 results in a 1.87°C global mean warming by mid-century and close to 3°C (2.92°C) by the end of the century, again compared to pre-industrial levels.

Increased global warming is projected to lead to substantial changes in GDP per capita compared to a scenario in which future temperatures would be similar to the average annual temperature between 1986 and 2005. There are, however, important regional differences. While some of the former Soviet Union countries, notably Mongolia and the Russian Federation, are projected to experience GDP gains as their mean temperatures increase from very cold levels, all other countries in the region are expected to experience GDP losses. Potential GDP gains projected by this methodology need to be interpreted with great caution as they are based on only mean temperature changes, not extreme event impacts. The Russian Federation, for example, has experienced annual average damages by extreme events of more than 2 billion US$ PPP per year over the 1998-2017 period that are not accounted for in this approach . With ever intensifying extreme weather events, increasing economic damages need to be expected. These additional damages may well counteract any potential gains projected for more northern and cold countries and add to the losses of all others. The projected number of losses to be incurred depends both on the time horizon considered as well as the assumed amount of global warming. The regional pattern of the countries that are expected to experience the highest (and lowest) losses in GDP per capita, however, remains remarkably stable over the different warming trajectories and time horizons.

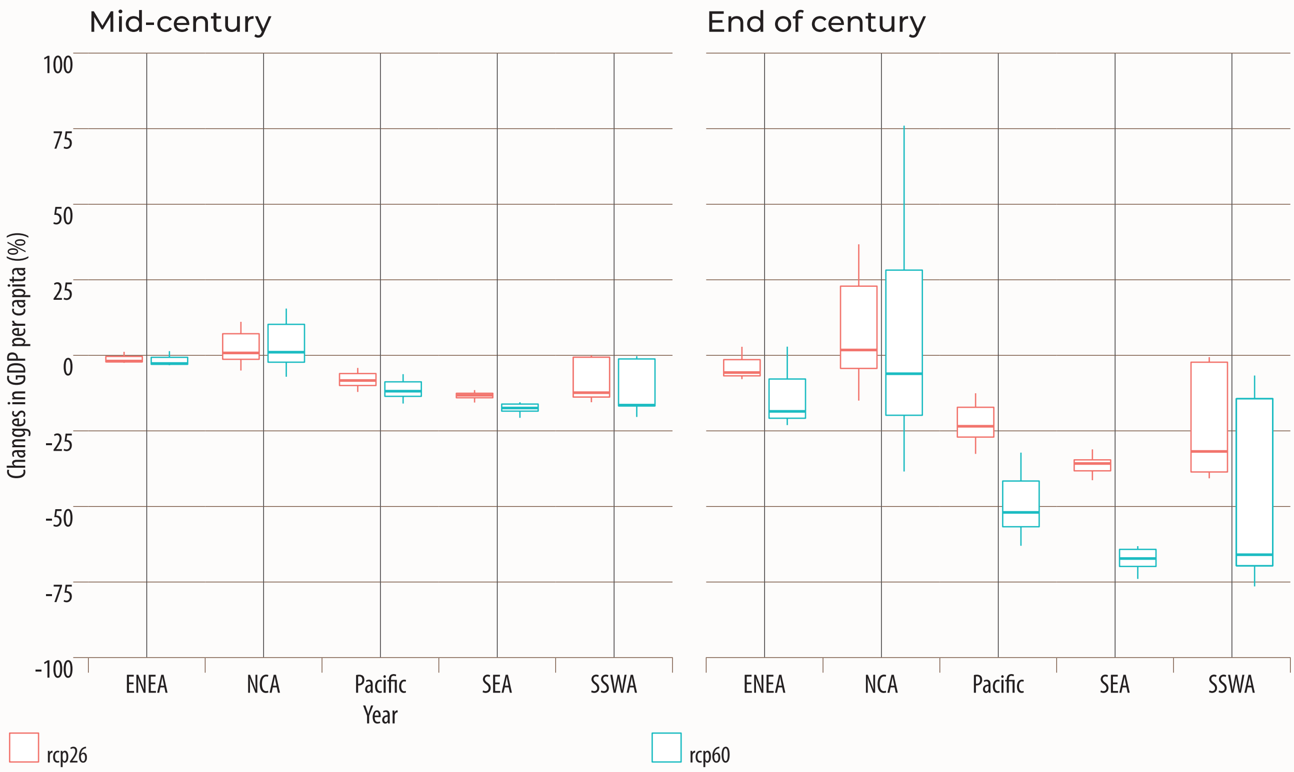
In particular, under RCP 2.6, countries in South and South-East Asia as well as SIDS are projected to incur the largest economic losses. Their GDP per capita is expected to be 10 to 15 per cent lower compared to the baseline scenario. Australia or the Islamic Republic of Iran, for example, are projected to incur moderate losses of about 5 per cent of their GDP per capita. A few countries (New Zealand, the Republic of Korea and Turkey) are projected to see no change in their GDP.

When considering the impacts of RCP 2.6 at the end of this century, the exact numbers for projected GDP losses and gains are uncertain, but the picture for the most- and least-affected countries remains the same. Countries in South and South-East Asia as well as SIDS are again projected to experience the highest GDP per capita reductions, with the losses projected to more than double compared to mid-century. Almost half of the Asia-Pacific countries considered in this analysis are projected to experience GDP losses between 30 per cent and 41 per cent (compared to the baseline scenario).

Under a ~2° global warming by mid-century (RCP6.0) projected losses in GDP per capita change only slightly compared with ~1.7° global warming) at mid-century (RCP. 2.6). The highest losses amount to 21 per cent compared to the baseline scenario with this 0.3°C difference in global mean warming. GDP per losses per capita increase dramatically with a further 1°C-plus warming to ~3° at the end of the century (RCP 6.0). The highest projected losses at 3°C global warming amount to around three-quarters of total GDP per capita in Pakistan, India and Cambodia. Losses will be at least 50 per cent of GDP per capita for half of the Asia-Pacific countries considered in this analysis.

**Figure 20 **

Projected changes in GDP per capita in subregions due to changes in global mean annual temperature



Source: Results from Burke *et al.*, 2018.
Note: Close to 1.5°C (RCP 2.6), 2°C and 3°C scenarios (RCP 6.0) compared to a no climate change scenario by mid-century (left) and end-of-century (right). The box-plots represent the median values of GDP per capita changes of each country belonging to the regions. The boxes represent the 25th-75th percentile, the horizontal line in the middle represents the median, the vertical lines extending from the boxes represent 0-25th per centile and 75th-100th per centile.

Future economic gains from half-a-degree cooler world: A comparison of 1.5°C and 2°C scenarios

This section provides projected GDP per capita impact estimates of a half-degree increment in global warming – i.e., 1.5°C vs 2°C – for the countries in the Asia-Pacific region. The estimates are based on the methodology developed by Burke, Davis and Diffenbaugh (2018).[20]

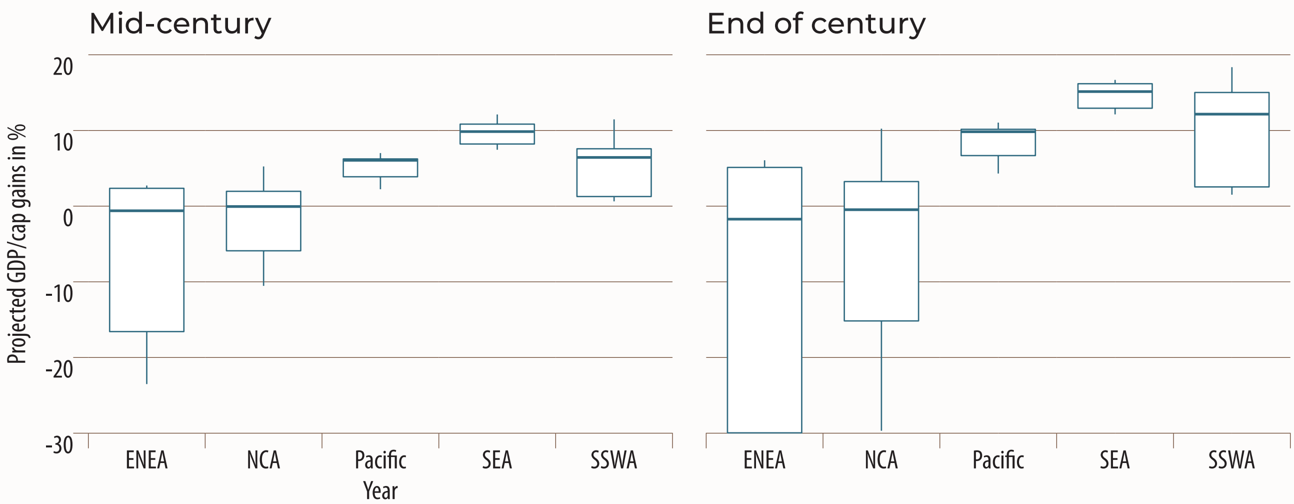
Clear gains in GDP per capita of up to 12 per cent in mid-century and up to 18.3 per cent by the end of this century are expected for countries in the Pacific, South-East Asia, and South and South West Asia in achieving 1.5°C instead of 2°C. The largest gains are expected in Thailand, Cambodia, Bangladesh, the Lao People's Democratic Republic and Viet Nam.

There are larger within-region differences for East and North-East Asia and North and Central Asia ( ). Countries with relatively colder climates in these regions are projected to incur losses from half-a-degree-less warming by mid-century and the end of the century. Gains are expected for China, Japan, Turkmenistan, Uzbekistan, Azerbaijan and Tajikistan in mid-century and at the end of the century.

20 The resulting estimates from the model in the previous section are fitted into a linear model to obtain a per-degree-Celsius impact of global temperature to changes in GDP per capita in each country. The resulting per-degree-impact is halved to obtain the half-a-degree-Celsius impact.

**Figure 21 **

Projected GDP per capita gains from limiting 1.5°C versus 2°C warming by subregion



Source: Results from Burke *et al.* (2018).

Chapter 5

Conclusion and recommendations

This chapter reviews policy options, including best practice examples from other regions, to derive insights into how the Asia-Pacific region can transition away from coal to a renewable-based, efficient energy system that is compatible with the Paris Agreement SDGs. It offers recommendations for key actors in the region to accelerate phasing out coal in line with the Paris Agreement benchmarks, and to harness and maximize the benefits available through the transition.

1. National Governments: Adopt best practice policies – a green recovery from COVID-19, phase out fossil fuel subsidies, carbon pricing, renewable energy support, and encourage and push for a shift in investment.

There is ample evidence at the international, regional, national, and subnational levels that demonstrates how existing technologies and proven, easily-replicated policies can close the gap between current policies and a Paris Agreement consistent pathway (*Climate Analytics*, 2020a). This is particularly the case in the power sector, where the energy transition is advancing rapidly, given the increasing economic competitiveness of renewable energy and storage technologies as well as energy efficiency measures and the many benefits these provide for sustainable development.

At the national level, Governments can benefit from a wealth of evidence including from experiences in countries and regions with carbon pricing and higher integration of renewable energy. This understanding of appropriate policy interventions can support working towards the adoption of best practices, particularly the adjustment and alignment of climate and energy targets toward long-term goals and a pathway that is consistent with the Paris Agreement.

One of the first steps for Governments in the Asia-Pacific region should be to focus on phasing out fossil fuel subsidies combined with the development of carbon pricing, both of which have been highlighted as best practice policies in the IPCC SR15 and UNEP Gap reports (IPCC, 2018; UNEP, 2019 and 2017). In the context of this report, coal subsidies warrant particularly targeted intervention (chapter 2). Coal subsidies are prevalent in the Asia-Pacific region, presenting a financial burden and a challenge to any change in direction. Carbon pricing is not yet widely applied; therefore, the ability to externalise the cost of damage caused by carbon emissions is one of the key drivers for continued investment in coal, even though these investments are inconsistent with the Paris Agreement and the SDGs (chapter 4). Both have already been implemented in a number of countries and subnational legislations in the region including in China, Japan and the Republic of Korea.

A moratorium on new coal power permits, such as that decided recently by the Philippines, is an important short-term step for Governments in the region to take to avoid building up further stranded assets as well as future costs from locking in high-emitting fossil fuel infrastructure.

Another step is to accelerate the adoption of best practice policies to enhance the share of variable renewable energy and accelerate investment, particularly in wind and solar, through market design, demand-side management, transmission and distribution system enhancements, grid interconnections and support for energy storage. Despite the financial competitiveness on the basis of the cost of energy, renewable energy faces market failures including information asymmetry and monopolistic control of the energy market by incumbents, as well as some technical challenges such as issues of integration into the region's power grids. Policy support needs to be cost-efficient and adapted to stages of development for individual technologies. Renewable energy targets, support policies, feed-in tariffs and auctioning, and investments in grid and market regulation to enable uptake of variable renewable energy are some of the key proven and broadly applied policies identified for expediting the electrification of non-power sectors and the transition towards 100 per cent renewables.

An increasingly important area of policy support for renewable energy is support for distributed renewable energy, both in urban and remote areas. Policy support is effective, especially during the initial development period of renewable energy; however, its cost efficiency needs to be considered carefully (Ding *et al.*, 2020).

There is increasing interest in engagement from the private sector as well as in joining efforts to support the required acceleration of investment into renewable energy and the need to shift in investment away from fossil fuels. This is in addition to innovation policies for accelerating deployment of key renewable energy and storage technologies. This can also include specific research and development efforts for emerging technologies such as electrolysers, novel renewable energy technologies or process changes in hard-to-abate sectors. Clear national policies, roadmaps and targets provide important signals to the private sector to accelerate the shift of investments.

While the COVID-19 pandemic has led to some delays in policy processes, the need to develop economic stimulus programmes to boost investment and recover from economic slowdown provides an additional opportunity to focus economic recovery and stimulus policies on investment into accelerated energy transition. Green recovery needs to be at the heart of economic stimulus packages developed by Governments. This needs to focus in particular on directing public funding and incentivising private investments in (a) renewable energy as well as related technology and infrastructure development such as storage and transmission grids, and (b) electrification of end-use sectors and further measures to improve energy efficiency across end-use sectors.

The International Monetary Fund (IMF, 2020) has suggested focusing public investment in the context of COVID-19 stimulus packages on "climate smart" infrastructure – including renewable energy, modernising the electricity grid, public transport, digital infrastructure – and the development of "climate-smart" technologies (battery, hydrogen and carbon capture), and avoiding carbon intensive investments such as fossil fuel power. In addition, the IMF has proposed the requirement for commitments to emission reduction targets and a transition to low-carbon economy when providing "crisis support" for carbon-intensive industries or businesses as well as the disclosure of carbon footprints.

An important area of policy that needs to be focused on by national Governments is changing public financing flows and adopting policies to mobilise green investment from the private sector through, for example, targeted and transparent guarantees (Intenational Monetary Fund, 2020), green bonds. In addition, banks and investors should be required to disclose climate risk and climate readiness, especially when they receive public support, for example, in the context of the COVID-19 economic response measures. This is particularly important because of the urgent need to increase investment in renewable energy and energy efficiency while shifting investment away from fossil fuels during the next decade.

2. National Governments: Move to transformational policies, set targets and commence long-term planning.

The scale of the necessary transformation requires long-term planning in order to avoid locking in high-emissions pathways (e.g., through switching from coal to gas instead of directly to renewable energy) as well as good practice governance ensuring participation and transparency, and transition management to ensure social cohesion particularly for regions and sectors most affected by a transition.

While renewable energy targets are being set by a large number of countries, and frequently adjusted upwards with lowering costs, they are currently still often below the level of benchmarks consistent with the Paris Agreement. A key strategy to decarbonise the whole energy system is electrifying end-use sectors, either directly or indirectly, through the production of green hydrogen or other energy carriers of renewable energy. This has implications for planning and policies in the electricity sector, as increased demand and sector integration need to be factored in.

In addition, targets that are defined in terms of capacity must also consider the additional need for capacity increase arising from the electrification of end-use sectors (IRENA, 2020a). This is linked to the integration of increasing shares of variable renewable energy towards achievement of 100 per cent renewable energy systems, requiring that technical barriers to integration be addressed as well as solutions be provided to financial challenges. This should be complemented with strategies to increase the share of renewable energy for heating and cooling in the residential and industrial sectors

(IRENA, 2020a) where policies are much scarcer than in the power sector (Adib *et al.*, 2020).

Long-term strategies and enhanced climate targets for 2030 were both due in 2020 under the Paris Agreement, but this development has been delayed in many countries due to the COVID-19 pandemic. They are now expected before the next UNFCCC climate conference (COP26) in Glasgow in 2021. The urgent need to close the ambition and action gap for 2030 requires a strong focus on using this opportunity to align energy and climate policy by taking advantage of:

1. The increasing competitiveness of renewable energy and storage technologies; and

2. The increasing wealth of evidence and experience with integration of high shares of renewable energy to substantially ratchet up climate and renewable energy targets in particular in the context of ratcheting up NDC targets for 2030 during 2020/2021.

This requires an increased effort in the economy approach and participation by all relevant stakeholders to maximise synergies between a range of objectives in order to achieve sustainable development and help shift the narrative towards the benefits of an accelerated energy transition. This is necessary in overcoming an outdated mindset that is still prevalent and which includes the influence of vested interests that are not in line with the interest of the whole society. This can also include consideration of best practice and learning from experiences in the area of climate governance and by institutions to ensure effective coordination across departments and across levels of government.

Developing coal phase-out plans by 2040 is the single most important step that needs to be included in these plans to ensure consistency with the Paris Agreement and SDGs. This needs to be combined with a process for planning and management of the transition that is developed with stakeholders from regions affected, particularly those stakeholders that currently depend on employment and income from coal mining and coal-fired power generation. An increasing number of countries, especially in Europe, are planning or legislating the phasing out of coal for power generation and linking it to transition policies in order to provide certainty for investors and stakeholders as well as to enable management of a smooth transition (Andrijevic *et al.*, 2020).

Focusing on nationally appropriate "just transitions" for fossil fuel-dependent regions is critical to ensuring the political viability of rapid fossil fuel phase-outs (UNEP, 2019). This holds true particularly for countries and regions with high dependency on revenue from fossil fuel/coal production and exports. This emerging area of policy practices is particularly interesting for countries in the Asia-Pacific region to tap into, for example, through joining initiatives such as the Powering Past Coal Alliance. An increasing number of countries are moving towards establishing phase-out targets and pathways, some with legislation. This is, however, not the case in the Asia-Pacific region (chapter 2).

3. Clear pathways to enable anticipation of change and avoid more stranded assets

Important elements in developing NDC targets and long-term strategies in line with the Paris Agreement is the advancement of scenarios and analysis as well as involving and informing stakeholders and supporting a dialogue about benefits at the sectoral level. There is increasing awareness for the need to ensure that investors are aware of climate-related risks, including the risk of stranded assets, through appropriate regulation of energy and electricity markets as well as policies to enhance transparency in relation to climate risks. This is particularly important because of the need to increase investment in clean energy, particularly renewable energy and energy efficiency, and substantially doing so by shifting investment flows away from fossil fuels towards renewable energy.

A key gap in the development of both national and regional strategies, plans and policies is the need to develop a range of scenarios for the energy system that are in line with the Paris Agreement and SDGs, and which aim for 100 per cent renewable energy. While number of studies are increasing, they are much more abundant for European countries or Europe as a region as well as the United States and the Pacific subregion. These studies need to be developed within countries and with engagement and active participation of stakeholders, as they can be a key element for the development of strategies and alignment of climate and energy targets. This is important to enable making informed decisions and avoiding locking in new fossil fuel stranded assets, for example, through investment in natural gas infrastructure that is not in line with Paris Agreement benchmarks.

Stakeholder engagement and participatory approaches are important for achieving successful development and endorsement of long-term strategies and plans, particularly with a view to the need for transformational change across all sectors (IPCC, 2018a; and Schaeffer *et al.*, 2019). Several countries in the Asia-Pacific region are being supported by ESCAP in developing national roadmaps to support the achievement of SDG 7 and the NDCs. This process allows integrated planning and uses an optimisation approach to determine the mix of policies and technologies needed for integrated achievement of energy access, efficiency and renewable energy targets.

Compared with policies addressing the need to expand renewable energy demand and reduce fossil fuel demand, currently much less political attention is being given to addressing the "production gap", as highlighted by the UNEP Production Gap report (SEI *et al.*, 2019) as the gap between planned fossil fuel production and the level of production consistent with the Paris Agreement. Globally planned fossil fuel production by 2030 is projected to lead to emissions of 39 $GtCO_2$, which is 21 $GtCO_2$ higher than levels compatible with limiting warming to 1.5°C. This production gap is largest for coal.

The Governments of key fossil fuel-producing countries are actively supporting production in many ways, including through subsidies and public finance; this is one of the drivers of the continued expansion of coal-fired power generation in the Asia-Pacific region (see chapter 2). Several countries (Belize, Costa Rica, Denmark, New Zealand and France) are partially or totally banning oil and gas exploration and extraction. While other countries are in the process of phasing out coal extraction, it is partly based on economic considerations (Germany and Spain).

Exploration, production and export bans or quotas, prohibition of key infrastructure or technologies, and ensuring comprehensive emissions assessments for new supply projects are among the regulatory approaches suggested for limiting fossil fuel production, but have largely not yet been implemented. These can be combined with fiscal approaches such as removing fossil fuel producer subsidies and increasing royalties or introducing fees for production or export of fossil fuels (*Climate Analytics*, 2020a).

4. Financial support and capacity-building

Wealthy countries should focus their financial and other development support on the need to shift investments, thereby leveraging the private sector to support transformation of the energy system towards clean energy. This holds true particularly for Australia, Japan, the Republic of Korea, China and India, which currently play a strong role in cementing dependency on fossil fuels in poorer countries in the Asia-Pacific region, and especially in South and South-East Asia. The cost efficiency of financial support may play a significant role (Ding *et al.*, 2020).

Coordination of government and philanthropic donors with the private sector can be an important strategy. It has started with a focus on South-East Asia, but needs to also apply to other countries in the Asia-Pacific region, especially where investment in new coal or gas projects is only just starting.

5. Regional and international cooperation – alignment with the Paris Agreement goals, and engaging stakeholders, the private sector and civil society

Regional and international cooperation in the Asia-Pacific region can play an important role. International collaboration and coordination can help in speeding up the adoption of best practice policies and collective achievement of key benchmark targets. Many initiatives are aimed at the policies listed above, and include national and subnational level governments joining with efforts by civil society, research and the private sector.

International cooperation and coordination can build on experiences in relation to facilitation of joint market creation – for example, for green hydrogen (*Climate Analytics*, 2020a). Initiatives such as the Hydrogen Council are examples of coalitions of non-state actors that can support national efforts to accelerate a clean energy transition and the adoption of key technologies. In addition, coordination of the phasing out of fossil fuel production is an area that has been proposed but not yet implemented. The Powering Past Coal Alliance (see chapter 2) and other recent initiatives in the area of energy system transformation are often successful when they include both national and subnational level governments as well as the private sector, civil society and research organisations. This is important to creating effectiveness in mobilising stakeholder engagement as well as supporting a shift in narrative and perception.

Existing regional cooperation structures and agreements such as ASEAN, APEC and the recently created RCEP trade agreement can be utilized to explore options for alignment of targets and initiatives with the Paris Agreement consistent energy system transformation. This needs to include the assessment and increased awareness of risks from climate change and the importance of the benefits to actually achieve the global goal of limiting global temperature rise to 1.5 degrees. This is the case for some of the most vulnerable countries in the world as well as some of the largest GHG emitters that are located in the Asia-Pacific.

ESCAP could, on the behest of its member States, scan and review existing initiatives and agreements, their relevance to the transformation away from coal to renewable energy, and the gaps in engagement of countries in the region. This can be the basis for the development of specific recommendations for engaging with existing initiatives or initialising new initiatives tailored to the needs and opportunities of the region. This includes linking to existing trade agreements and developing specific agreements to facilitate trade of renewable energy, green hydrogen or e-fuels based on green hydrogen. This can also include likeminded coalitions, learning platforms such as the United Nations Issues Based Coalition on Air Pollution and Climate Change, which coordinates the work of multiple United Nations organizations on these issues, including coal phase-out.

Given the Asia-Pacific region's high share of coal production, an initiative at the regional level could also focus on joining efforts and overcoming barriers to shifting away from coal production and dependency on coal exports by countries or in subnational legislation in the region.

6. Cross border power system connectivity

An important area for enhanced regional cooperation is cross-border power system connectivity (Shi *et al.*, 2019). This can build on existing examples and initiatives, with the objective of moving to 100 per cent renewable energy systems. With an increasing realisation of the benefits from pushing for up to 100 per cent renewable energy for power generation and for the whole energy system – and the integration challenges that this entails – regional cooperation for grid interconnection is an increasingly important policy area. Existing multilateral initiatives seeking to facilitate transnational grid connections include the Asia Super Grid (Renewable Energy Institute, 2019), and the IRENA Greening ASEAN Power Grid Initiative, building on the ASEAN Power Grid (APG). While the APG originally was not focused on increasing renewable energy integration (*Climate Analytics*, 2019b), the framework has enabled significant development of hydro power in the Lao People's Democratic Republic which is now supplying electricity to Malaysia with Thailand as a wheeler. Further opportunities abound to support renewable energy development.

Existing subregional initiatives can be adapted and applied elsewhere. Parts of the Asia-Pacific region are endowed with some of the worlds' best renewable energy potentials, with examples including solar resources in the Pacific (Australia), hydro power potential in parts of South and South-East Asia, and wind and solar potential in Central and East Asia. Cooperation provides meaningful opportunities for a faster transition to 100 per cent renewable energy, including by countries that have lower potential or higher demand – for example, with high population density.

7. Financial institutions: Cooperation on sustainable finance, clear policies and transparency

More countries in the Asia-Pacific region are joining Initiatives such as the Climate Investment Platform (CiP) or the recently launched International Platform of Sustainable Finance now with 14 members including China, India, Indonesia and New Zealand. These forums provide an opportunity to benefit from scaling-up the mobilisation of private capital towards environmentally sustainable investments through dialogue between policymakers in charge of developing sustainable finance regulatory measures, and potentially moving towards alignment of best practices.

Development banks play an important role in investment flows in the Asia-Pacific region. They are crucial to leveraging private sector finance and opening new market opportunities, particularly in policy environments where investments are still perceived as high risk due to policy uncertainty and other barriers. Their policies should include clear targets for phasing out lending to unabated coal-fired power generation and ramping up their focus on assistance to financial regulators to promote green national financial strategies. More than 110 financial institutions have already adopted policies restricting coal power, including some Asian financial institutions.

8. Private sector engagement

The private sector can play an important role in accelerating investment in renewable energy as well as joining private-public partnerships and joining initiatives to finance large-scale renewable energy projects.

Initiatives in the private sector have also started to develop benchmarks for decisions at the sectoral level. Incorporating climate risk and following the recommendations of the Taskforce on Climate-Related Financial Disclosure is an important element in providing the right information to the private sector; public finance institutions should set an example in this regard. ESCAP could support this by encouraging the development of clear benchmarks at the regional level.

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Annexes

Annex 1 Asia-Pacific coal fleet pipeline

**Table 8 **

Coal fleet capacity pipeline in Asia-Pacific by combustion technology and fuel type

Country	Share of total capacity and pipeline (construction, planned, announced)				
	Subcritical coal plants	Supercritical coal	Ultra-supercritical coal plants	Hard coal	Lignite plants
China	41.5	23.5	32.4	95.5	4.5
India	57.2	38.0	1.6	95.1	4.9
Japan	22.6	25.4	47.6	100.0	0.0
Russian Federation	66.2	28.8	1.2	65.2	34.8
Republic of Korea	14.7	38.6	44.0	100.0	0.0
Indonesia	53.5	12.6	12.6	97.2	2.8
Australia	84.3	8.9	0.0	76.5	23.5
Viet Nam	24.3	37.0	13.3	99.8	0.2
Turkey	20.4	16.5	16.1	50.6	49.4
Malaysia	58.6	7.4	29.6	95.6	4.4
Kazakhstan	40.1	59.9	0.0	100.0	0.0
Philippines	42.2	21.1	10.0	94.6	5.4
Hong Kong, China	100.0	0.0	0.0	100.0	0.0
Thailand	71.1	8.2	16.2	51.2	48.8
Pakistan	19.7	34.2	5.3	60.5	39.5
DPRK	94.6	0.0	0.0	44.6	55.4
Uzbekistan	27.2	72.8	0.0	0.0	100.0
Lao People's Democratic Republic	40.1	0.0	0.0	59.9	40.1
Bangladesh	2.4	9.1	77.1	100.0	0.0
Sri Lanka	100.0	0.0	0.0	100.0	0.0
Mongolia	15.8	15.6	0.0	96.4	3.6
Cambodia	33.2	0.0	0.0	100.0	0.0
New Zealand	100.0	0.0	0.0	100.0	0.0
Tajikistan	100.0	0.0	0.0	100.0	0.0
Brunei Darussalam	0.0	0.0	0.0	100.0	0.0
Myanmar	100.0	0.0	0.0	100.0	0.0
Papua New Guinea	0.0	0.0	0.0	100.0	0.0

Source: Global Energy Monitor, 2020.
Note: When percentages do not add to 100 per cent, the residuals correspond to plants with unknown fuel type or combustions technology. Countries not included in the table do not have coal power plants bigger than 30 MW and are not planning new coal power plants.

Annex 2 Climate change impacts

The Paris Agreement long-term temperature goal (LTTG) is defined as "holding the increase in the global average temperature to well below a 2°C level above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognising that this would significantly reduce the risks and impacts of climate change" (UNFCCC, 2015; Art. 2.1). The current scientific understanding of the risks of global warming of 1.5°C outlined in the IPCC SR1.5 report (IPCC, 2018a) finds climate change presents a severe threat, and limiting the global mean temperature increase to 1.5°C above pre-industrial levels, poses less risk than a warming of 2°C or higher.

The Asia-Pacific region has countries that are extremely vulnerable to climate change, making it the most disaster-prone region globally (ESCAP, 2018). The Climate Risk Index assesses countries on the direct impacts of climate change. Direct impacts include, for example, drought and precipitation deficits, heavy precipitation events (particularly eastern Asia), typhoons, flooding, biodiversity and ecosystem impacts such as species loss (*Climate Analytics*, 2019b; and IPCC, 2018a). In 2018, the Asia-Pacific region had five countries in the top 10 countries most affected by climate change in the Global Climate Risk Index 2020. Japan and the Philippines are ranked first and second place, respectively, while India is fifth, Sri Lanka is sixth, and Fiji is ranked tenth (Germanwatch, 2019). Based on the long-term index from 1999 to 2018, the top 10 list of most affected countries contain six countries from Asia and the Pacific, as Myanmar was placed second, the Philippines (fourth), Pakistan (fifth), Viet Nam (sixth), Bangladesh (seventh) and Nepal (ninth) (Germanwatch, 2019).

The IPCC found that Asia has large numbers of people exposed to climate-related risks, making the region particularly susceptible to poverty (IPCC, 2018a). The Asia-Pacific region is experiencing increasingly frequent climate-related disasters, intensifying conflicts, poverty and inequality (ESCAP, 2018).

A compounding factor is that relief efforts in response to extreme weather events in 2020 have been hindered by the COVID-19 pandemic. Forecasts for 2020 anticipate a high probability of extreme weather affecting food supply and availability, creating a dual threat of economic recession, especially for poorer countries (FAO, 2020).

The average global temperature increases of approximately 1°C since pre-industrial times (1850-1900) have resulted in an increased intensity and frequency of extreme weather events across all parts of the world. The trajectory of current policies globally will keep greenhouse gas emissions increasing and will maintain this warming trend in future, resulting in an increase in the severity of associated hazards.

This annex presents the authors' analysis of differentiated impacts of climate extremes at different levels of global warming over the five Asia-Pacific subregions, defined by ESCAP as East and North-East Asia (ENEA), North and Central Asia (NCA), the Pacific (PACIFIC), South-East Asia (SEA), South and South-West Asia (SSWA).[21] The present analysis was carried out at the Paris Agreement's temperature limit of 1.5°C as well as for 2°C and 3°C global mean warming above pre-industrial levels. The 3°C warming level is the anticipated temperature rise associated with the NDCs (Nationally Determined Contributions) thus far submitted to UNFCCC by the Parties to the Paris Agreement.

The results are presented as an indicator of how global temperature increases of 1.5°C, 2°C and 3°C over the pre-industrial period (1851-1900) affects the four key climate change indicators outlined. These indicators were selected on the basis of their direct or indirect links to the most important climate change impacts in the region, related to extreme weather events such as extreme precipitation and flooding, drought and heatwaves.

21 http://data.unescap.org/dataviz/methodology/list-of-countries-in-the-asia-pacific-region-and-subregions.html

Based on the data from the most advanced CMIP6 generation of GCMs recently made available, all the indicators analysed in this study point towards an increase in all five subregions of the severity of three of the four climate extremes examined, which scale almost linearly with the global temperature increase. The proxy for drought (CDD) shows a decrease in two subregions (ENEA and NCA), an increase in two subregions (Pacific and SSWA), while it remains almost constant in SEA with increasing levels of global warming.

Table 9 presents projections of extreme indicators for the list of ESCAP member States having high coal capacity, as shown in table 1. Heat extremes of TXx and HWFI are directly proportional to the increase in

**Table 9 **

Climate impact indicators

Indicator	Relevance	Definition	Results
Extreme precipitation/ flooding: maximum 5-day precipitation (RX5day)	RX5day is an important index for the region because any future change in this index will increase (or decrease) the intensity of the hazards such as Floods, landslides, debris flows, Glacial Lake outburst floods (GLOFs), hydropower production etc.	To calculate the maximum five-day precipitation sum, the maximum sum of precipitation falling during five consecutive days for each year is calculated. A 20-year average of the reference as well as future temperature thresholds are taken for further analysis.	A large variation among all the Asia-Pacific subregions, with the tropical subregion of SEA and high-latitude subregion of NCA showing highest and lowest increases, respectively. RX5day related hazards are likely to already get severe in 1.5°C warmer world compared to the reference period. A greater severity is likely to be added to these hazards at 3°C global warming for all the Asia-Pacific subregions.
Drought: Consecutive dry days (CDD)	Changes in CDD will likely increase or decrease different hazards which include droughts, agriculture production, hydropower production, environmental flows etc.	To calculate consecutive dry days, the number of consecutive days with precipitation < 1 mm per day for each year is calculated followed by 20-year averages around each threshold as well as reference period. Counted are the number of dry day periods of more than five days.	The SSWA subregion, which is characterized by an arid to semi-arid climate with a strong seasonal cycle, has the largest CDD value among all the subregions, while NCA and SEA indicate the lowest value among all Asia-Pacific subregions in the reference period. Unlike RX5day, which projects an increase for all the subregions, CDD projects a light decrease in ENEA, NCA and SSWA) while an increase SEA and the Pacific regions.
Heat: Maximum value of daily Maximum Temperature (TXx)	Any changes in the values of TXx will impact agriculture production, cryosphere degradation, disease transmissivity, health etc.	TXx represent the temperature of hottest days and is defined as the yearly maximum value of the maximum daily temperature	Increase in the TXx is higher than the corresponding global average values in all the Asia-Pacific subregions. The NCA, ENEA and SSWA subregions once again show much more aggressive warming than the Pacific and SEA subregions, which is very similar to what is seen earlier for the case of RX5day. TXx related hazards are likely to get worse in 1.5°C warmer world as compared to the reference period; however, a far more severity is likely to be added to these hazards at the level of 3°C global warming for all the Asia-Pacific subregions.
Heatwaves (HWFI):	Besides having an impact on sectors such as tourism, cryosphere degradations, agriculture production etc., HWs directly affects the health sector and have caused multiple events which lead to mortality and morbidity across the globe.	HWs are calculated by counting the number of events per year when daily maximum temperature remains higher than the 95th per centile of the reference period continuously for at least six days.	HWs increases with the increase in global temperature in all the Asia-Pacific subregions. The Pacific and SEA subregions show higher values of HWs in the reference period than the rest which is attributed to the lower amplitude in the annual temperature. These two regions show an aggressive increase in HWs than the rest of the regions, with NCA and SSWA showing a lower increase. Although equatorial/tropical regions show higher increase, HWs in SSWA arid regions could be much more severe due to a higher regional temperature which sometimes go beyond the limit of human tolerance.

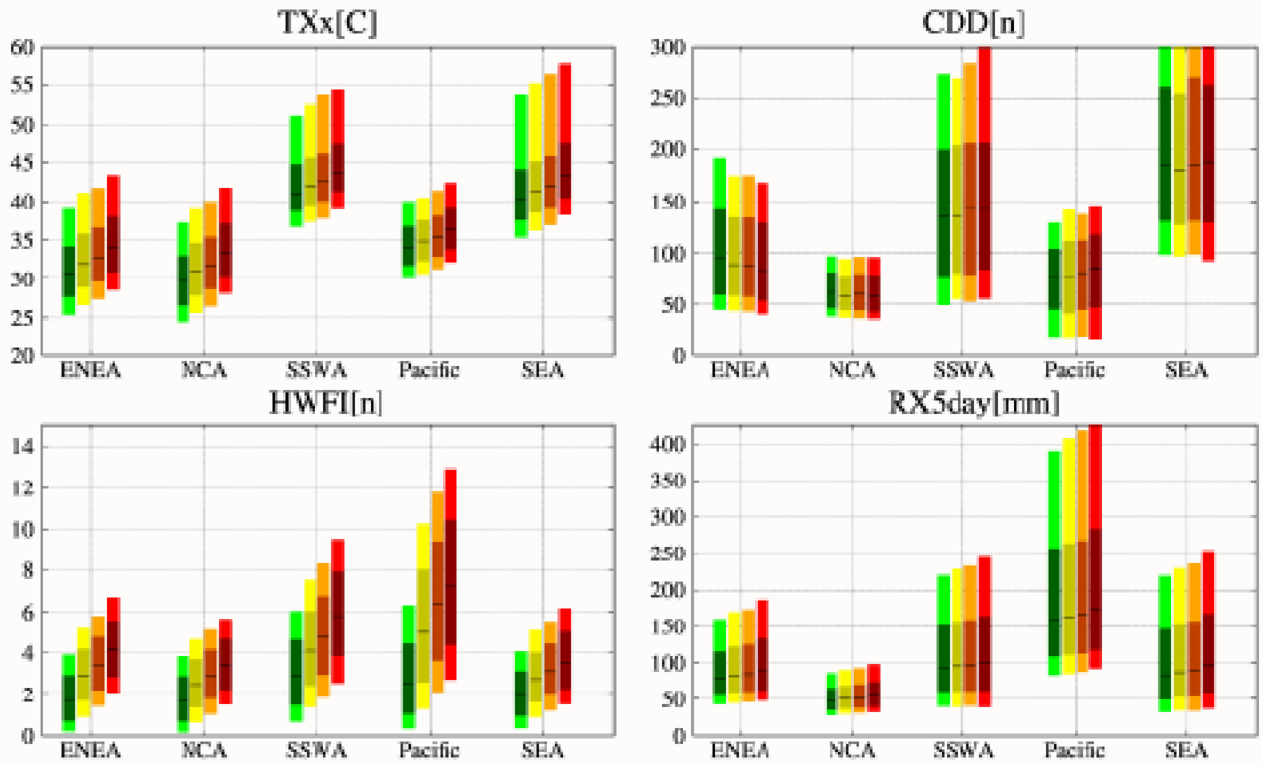
global temperature for all countries. In terms of magnitude, the highest increase in HWFI is seen in the near equatorial countries such as Malaysia, Indonesia, the Philippines, Papua New Guinea etc. However, countries which regularly experience heat-related mortality and morbidity in the present climate, such as Australia, India, Pakistan and Bangladesh, are also projected to experience a higher number of HWFI events at 3°C than at 1.5°C in a warmer world.

Almost all the countries show an increase in the RX5day which also proportionate directly to the global temperature (table 9). The countries which show a higher difference between 3°C, relative to the reference period, than 1.5°C include Bangladesh, India, Indonesia, Malaysia, Myanmar, the Republic of Korea and Viet Nam. Many countries in the Pacific and South-East Asia (SEA) subregions, including Australia, Indonesia, Malaysia, the Philippines, Thailand and Viet Nam, show an increase in CDD with an increase in global temperature thresholds, whereas other countries of NCA and SSWA, including China, the Russian Federation, India and Pakistan, do not show any substantive change in CDD.

The results of the analysis indicate that substantial avoidance in the severity of future climate extremes can be achieved if the global temperature increase is kept to the Paris Agreement 1.5°C limit, compared with either 2°C warming or an increase of 3°C that is likely to result from the NDC base. This emphasizes the need for early and substantive efforts to curb the greenhouse gas emissions and reinforces the urgency of transformative change in the energy system at the country, regional and global level.

**Figure 22 **

Projected changes in climate extremes over five **Asia-Pacific subregions**



Note: Projected changes in the four climate extreme variables in five Asia-Pacific subregions. Green, yellow, orange and red bars represent the values for reference (1991-2010), 1.5°C, 2°C and 3°C thresholds, respectively. The black line in each bar shows the median values. The length of the bars shows the full ranges (results from all the models), while the darker shades in each bar show the 66 per cent likely ranges (17th - 83rd percentiles).

It is important to highlight a few limitations of the study – large ranges of uncertainty, especially in the precipitation-related variables of extreme precipitation/flooding (RX5day) and drought (CDD), imply that care must be taken in interpreting the results as the resolution of the GCMs employed is rather coarse. Moreover, spatial averaging has been carried out on the large spatial ESCAP subregional level, which is likely to hide the heterogeneity of the climate change signal within each region. Country-level results are presented in table 10.

**Table 10 **

Extreme indicator for specific ESCAP member States

Indicator	CDD			Rx5day			TXx			HWFI		
Economy	Ref	1.5°C	3°C	Ref	1.5°C	3°C	Ref	1.5°C	3°C	Ref	1.5°C	3°C
Australia	148	143	160	100	107	109	42.7	43.2	45	3	4	6
Bangladesh	116	132	133	167	166	207	41.4	41.5	43.2	2.3	2.3	3.6
Brunei Darussalam	18	20.5	23.6	149	165	155	30.8	31.4	33.2	3.3	7.2	10.6
Cambodia	111	115	112	145	151	158	37.1	38.2	39.7	2	2.8	4.1
China	106	98	98	91	94	101	30	31	33	1.9	3	4.4
Hong Kong, China	60	61	66	167	171	198	32.6	33.6	35.3	2.6	4.8	5
India	190	186	190	129	136	152	41.4	42	44	2	2.5	3.6
Indonesia	47	53	62	154	158	171	31.6	32.3	34	2.9	6.9	10
Kazakhstan	89	87	94	33	35.4	37.3	40	40.7	43.6	2.1	3	4
Kyrgyzstan	72	68	72	52	54	59	29	30	32.3	1.7	2.9	3.6
Lao People's Democratic Republic	106	105	111	163	169	188.6	38	39	41.2	2.3	2.7	4
Malaysia	27	28	36	163	168	179	31.6	32	34	3.2	6.2	9.6
Mongolia	120	111	100	40	42.6	44.1	33.3	35.3	38	1.5	2.6	3.7
Myanmar	133	140	145	197.9	203	245	37	37.5	39	2.2	2.7	3.8
New Zealand	23	22	22	103	107	113	23.5	24.1	25.5	1.9	2.8	4.8
Democratic People's Republic of Korea	50	47	49	135	152	154	30	30.5	32.8	1.5	2.4	3.5
Pakistan	255	252	260	47	50	56	42.3	43.2	45	2.1	3	4
Papua New Guinea	40	40	42	163	165	180	30.4	31	32.6	3.6	7.8	10
Philippines	49	51	55	189	202	202	31	32	33.5	2.5	5	6.6
Russian Federation	53	49	48	54	58	61	27.3	28.6	31	1.7	2.4	3.4
Republic of Korea	44	44	49	153	154	172	29.8	30.5	32.5	1.4	2.3	2.8
Sri Lanka	93	90	99	145	142	166	33.4	34	35.5	2	2.9	4.7
Tajikistan	102	107	111	68	71	75	28	28.7	31	1.6	2.8	3.2
Thailand	135	129	151	170	176	178	38.3	39	41	2.3	2.7	3.8
Turkey	92	87	100	70.6	70	71	35.7	37	39.6	1.9	3	3.4
Uzbekistan	176	167	179	33	34.1	37.3	42.8	44.2	46.5	1.9	2.9	3.9
Viet Nam	78	81	88	173	181	194	36.1	37	38.9	2.4	3.5	5

Source: Based on authors analysis of CMIP6 data.

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