



# Transitioning towards a coal-free society: science based coal-phase out pathway for South Korea under the Paris Agreement

February 2020

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### **Cover image**

Hadong Coal Plant, South Korea. Copyright SFOC.

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## FOREWORD

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This report explores the implications of the Paris Agreement for coal-fired power generation in South Korea and compares Paris Agreement compatible emissions scenarios with the current national climate and energy plans and targets.

Our studies show that coal needs to be phased out from power generation by 2040 globally and by 2030 in Organisation for Economic Co-operation and Development (OECD) countries to be in line with the Paris Agreement. South Korea, an OECD member, needs to be releasing zero carbon emissions from coal by 2030, if it is to play its part in meeting the Paris Agreement's goal of keeping warming within 1.5°C above pre-industrial levels.

In September 2019, Climate Analytics released a report unpacking for the first time the implications for coal power of 1.5°C Paris Agreement compatible energy transformation pathways assessed in the IPCC Special Report on Global Warming of 1.5°C (IPCC SR1.5) and providing regional benchmarks for coal-based electricity production for the five regions considered by the IPCC SR1.5 (Climate Analytics, 2019c).

Similar to previous publications (Climate Analytics, 2017a, 2018b, 2018a, 2019a), this report seeks to translate these global and regional benchmarks into meaningful policy recommendations and analysis at national level. Our main aim is to provide science-based input into the ongoing discussions in South Korea about the future of coal in the energy mix and the most effective strategies to mitigate emissions as required to be in line with the Paris Agreement.

These include creating detailed roadmaps to implement the directive on the 5th Comprehensive Plan for National Environment (2020-2040), as well as the national process to revise and update South Korea's Nationally Determined Contribution (NDC) to the Paris Agreement and present a long-term Low Emissions Development Strategy, all due in 2020.

The full version of this report is planned for April 2020. However, given the discussion on new measures related to fine dust emissions, including measures for reducing coal use in the electricity sector, is currently ongoing, and that the government plans to announce its new policy in the first half of 2020, we have decided to release this interim report, focusing on coal use in power generation.

The full version of the report will also include analysis related to the economy wide reductions that South Korea would have to make to be consistent with the Paris Agreement and reflect on the implications of these emissions pathways in the context of the NDC revision and update process.

## KEY MESSAGES

- A fast phase-out of coal from power generation is essential to get South Korea on track to meet its national emissions reduction targets, which need to be revised and enhanced in 2020 under the Paris Agreement framework. This will not be possible unless an orderly and ambitious plan to phase out coal and scale up renewable energy generation is clearly defined. This plan should be a primary focus for South Korea's climate and energy policy.
- Despite the encouraging signs that a transition to a coal-free electricity mix may be starting, South Korea has no concrete national commitment, roadmap, or policy instrument to accelerate phasing out coal, and no systematic framework to ease the transition.
- Under a Paris Agreement compatible emissions pathway for power generation, South Korea's coal power plant emissions need to decrease steeply in the coming years, falling by 58% below 2017 levels by 2025 with phase-out by 2029, while renewable energy generation needs to increase rapidly to reach more than half of power generation by 2030.
- If retirement of South Korea's coal plants continues at its current pace, they would release more than twice (247%) the amount of carbon emissions allowed under South Korea's remaining Paris Agreement compatible power sector budget for coal. If the planned coal units come online, the difference between committed emissions and pathways consistent with the Paris Agreement would increase to 317%.

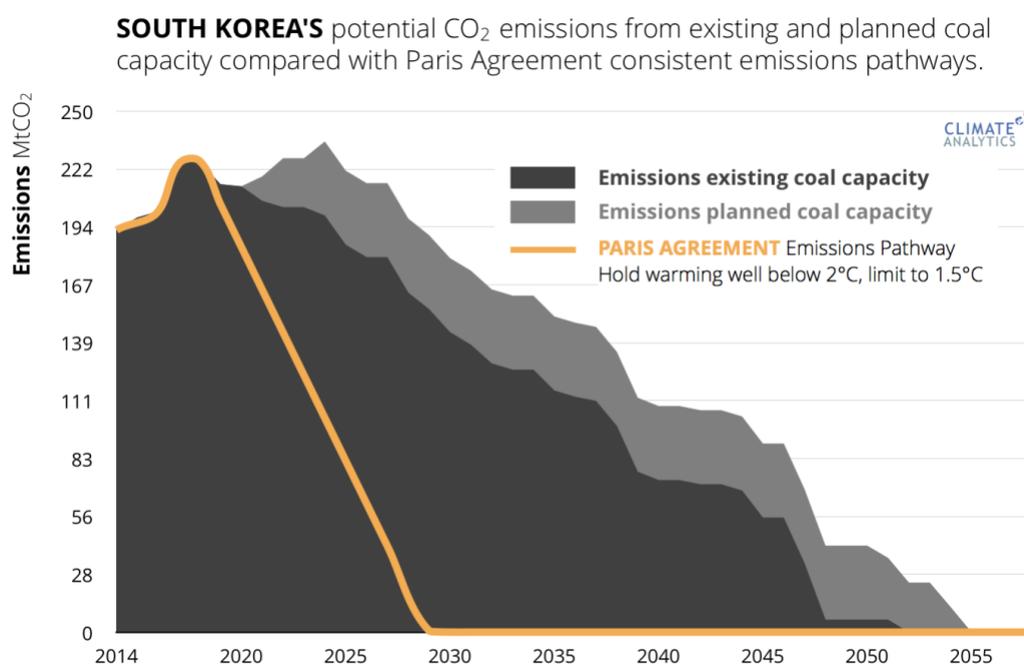


Figure 1 - Coal power plant emissions pathways for South Korea. Emissions from operating coal capacity are calculated based on proposed retirement age (30 years) and historical utilisation rates (81%), and reported emissions intensities per combustion technology and coal type. Paris Agreement compatible pathway for South Korea is a result of the downscaling of the results for the OECD from the IEA ETP B2DS scenario to South Korea with the SIAMESE model.

- In order to be in line with the Paris Agreement, South Korea will need to retire its operating power plants much earlier than the currently proposed age of 30 years and/or dramatically reduce their utilisation rate. Every new coal unit that comes online will only increase the already large gap between Korea's emissions and its Paris Agreement compatible pathway, lock-in emissions for decades and increase the risk of stranded assets.

- A clear policy signal and structured phase-out plan would bring multiple benefits for South Korea's population, industrial and electricity sector. It would also provide an opportunity for the country to come up with plans to support and create opportunities for coal related businesses, workers, owners and investors, to be better placed to transition to a coal-free society. South Korea would be better placed to make a sound and just transition away from coal, while reaping a multitude of additional benefits and opportunities that go beyond climate change mitigation. These include substantial improvements in air quality, job opportunities from higher investments in renewable energy and a reduction in energy import dependency.
- Fast action to fully decarbonise electricity generation is a fundamental step in achieving emissions reductions in all other sectors, where electrification plays an important role. The longer the world and South Korea continue to use coal, the higher the cost and the lower the feasibility of limiting global warming to the safer level set out in the Paris Agreement. Further investment in fossil fuel infrastructure, including natural gas, risks leaving stranded assets and locking the country into a pathway inconsistent with the Paris Agreement.
- Little attention has been paid to South Korea's role in extending coal dependency in other countries through financing coal power generation projects abroad and the absence of clear expectations about the future of coal use on countries exporting coal to South Korea. Playing its part in facilitating the global energy transition and achieving the Paris Agreement objectives through its international engagements, as well as sending a clear signal for change in its international strategy around coal, should form an integral part of South Korea's transition to a coal-free society.

## INTRODUCTION

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The Paris Agreement aims to strengthen the global response to the threat of climate change by holding global temperature rise to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change (UNFCCC, 2015). Most countries presented individual contributions to this goal in 2015 in their first Nationally Determined Contributions (NDCs). Given that the aggregation of these individual contributions is still far away from getting global emissions on a pathway in line with the Long-term temperature goal of the Paris Agreement (Climate Action Tracker, 2019b; UNEP, 2019), a substantial scaling-up of climate action and ambition is required in 2020, when enhanced NDCs and new long-term low emissions sustainable development strategies (LT-LEDS) are due.

Staying within the 1.5°C limit of the Paris Agreement requires a rapid transformation of our energy system. This transformation is unprecedented in terms of scale of change needed across the world and in all sectors (IPCC, 2018a).

Due to the huge contribution of coal to climate change, phasing it out and supplanting it with renewable energy has been identified as one of the single most important measures to bring down emissions at the pace and scale needed to curb dangerous climate change (Climate Analytics, 2016b, 2019c; Kuramochi et al., 2018; Steckel et al., 2017). Emissions pathways derived from the latest science, assessed in the IPCC Special Report on Global Warming of 1.5°C, show that unabated coal-based power generation globally should be reduced to 80% below 2010 levels by 2030 and phased out before 2040 (and much earlier in many countries) to keep the door open for achieving the Paris Agreement goal (Climate Analytics, 2019c).

The reality of coal power generation is very different across countries, with some being already coal-free, some pursuing the reduction of their dependency on this fuel, and others planning to build new coal power plants. Therefore, to understand the national policy implications of this important global milestone, it is necessary to translate global and regional pathways to national pathways that take into consideration the different starting points of each country.

With this aim, in this report we explore the implications of the Paris Agreement for coal-fired power generation in South Korea by comparing the emissions of current and planned coal capacity, as well as national electricity mix targets, with benchmark emissions pathways from energy-economy models. The report focuses on coal-fired power generation for three reasons:

1. South Korea needs to implement the Paris Agreement. However, with current policies, it is still far from meeting its nationally determined target of reducing emissions 24.4% below 2017 level by 2030 (or reducing emissions 37% below business-as-usual by 2030).<sup>1</sup> Moreover, this nationally determined target is still far from being a 1.5°C compatible pathway and needs to be enhanced in 2020 under the first revision cycle on national contributions under the Paris Agreement.

Energy and emissions modeling results show that coal power generation phase-out is the most important step to achieve steep emissions reductions in line with the Paris Agreement. These models show that fast action to fully decarbonise electricity generation is a fundamental step in reducing emissions in all other sectors, where electrification plays an important role. Failing to quickly phase out coal from the electricity mix has far reaching implications in terms of feasibility and the cost of reducing greenhouse gas (GHG) emissions.

A fast phase-out of coal for power generation therefore plays an essential role in getting South Korea on track to meet its national emissions reduction targets, which need to be revised and updated in 2020, and get into an

<sup>1</sup> South Korean government revised its national emissions reduction target to 24.4% reduction from 2017 emissions in December 2019, which corresponds to 37% reduction from 2030 BAU.

emissions trajectory that is in line with the long-term temperature goal of the Paris Agreement, taking advantage of the dynamic technology development and decreasing costs of renewable energy and storage technologies to accelerate a transition to renewable energy.

2. The most recent Plan for National Environment, approved by the State Council in December 2019, has identified three key national strategies that will guide government action in the period 2020-2040:

- The transition to a coal-free society that benefits from improved air quality;
- The scaling up of emissions mitigation measures and targets to respond to the global climate emergency;
- The establishment of inclusive and just environmental policy.

Phasing out coal from power generation plays a critical role in achieving these policy goals considering its share in the national electricity mix and the damages it causes to health and environment, which are not captured by the financial costs of electricity production. Coal-fired power plants produce 42% of South Korea's electricity, and due to its high carbon-intensity, they are a leading contributor to climate change and air pollution, representing 30% of national CO<sub>2</sub> emissions and 11% of the fine dust (PM<sub>2.5</sub>) pollution (National Council on Climate and Air Quality, 2019)(Government of South Korea, 2018)

Beyond GHG emissions reductions, fast and orderly phase-out of coal for power generation entails many additional economic, environmental and health co-benefits which lays the foundations for a just and well-managed energy transition in South Korea.

3. A Paris Agreement compatible plan for phasing out coal from power generation is a key measure to close the existing gap between South Korea's climate policy directives and objectives, and its policy implementation actions.

The current government has identified coal use reduction as a priority since the beginning of its term in 2017, with the development of a roadmap for the reduction of the use of coal in Korea being planned for 2020. Temporary measures the government put in place to restrict coal power generation in order to tackle dangerous air pollution levels have proven the sector's huge potential to contribute to multiple policy objectives. This should be motivation enough for government to want to pursue a Paris Agreement compatible pathway, which not only results in the reduction of greenhouse gases but comes with many other co-benefits.

However, national plans and policies are not yet in line with these overarching policy goals: coal is still expected to have the largest share (36%) in the electricity generation mix in 2030 under the Basic Plan for Electricity Supply and Demand (BPE8). Seven new coal power generation units are still to come online in the next couple of years, increasing the risk of stranded assets. Additionally, South Korea is among the top financiers of coal power expansion around the world.

By providing a Paris Agreement compatible trajectory for coal in the power sector, we propose concrete policy recommendations for coal use that could be implemented in the short term to increase policy coherence and close the implementation gap for national climate policy. Current national discussions on policy measures, as well as the societal pressure to reduce coal use is a critical opportunity for the government to set up strategies in 2020 that are transformational and result in policies appropriate for the scale and speed required to achieve Paris Agreement objectives.

## **MOMENTUM FOR CHANGE IN THE ROLE OF COAL IN SOUTH KOREA'S ELECTRICITY MIX**

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South Korea's electricity system is dominated by centralised, carbon-intensive coal-fired generation, fuelled almost entirely by imported black coal. However, there are signs of momentum towards a transition to a coal-free electricity mix. Societal and political perceptions of the role of coal in the future energy mix are changing. President Moon Jae-In stated that one of the goals of his administration was to reduce the country's dependence on coal-fired power

generation. New regulation of coal power generation was put in place in response to concerns about dangerous levels of air pollution. Subnational and non-state actors are introducing progressive measures to end dependency on coal: for example, the Chungnam province, which hosts almost half of the entire coal fleet, has joined an international alliance vowing to eliminate unabated coal power generation by 2030 in OECD countries.

Coal accounted for approximately 42% of South Korea’s electricity generation in 2018. There are 12 grid-connected coal power stations consisting of 60 generation units with an average capacity weighted age of 15 years. The large majority of electricity generation, including coal power plants, is operated by the state-run utility Korea Electric Power Corporation (KEPCO) and its subsidiaries.

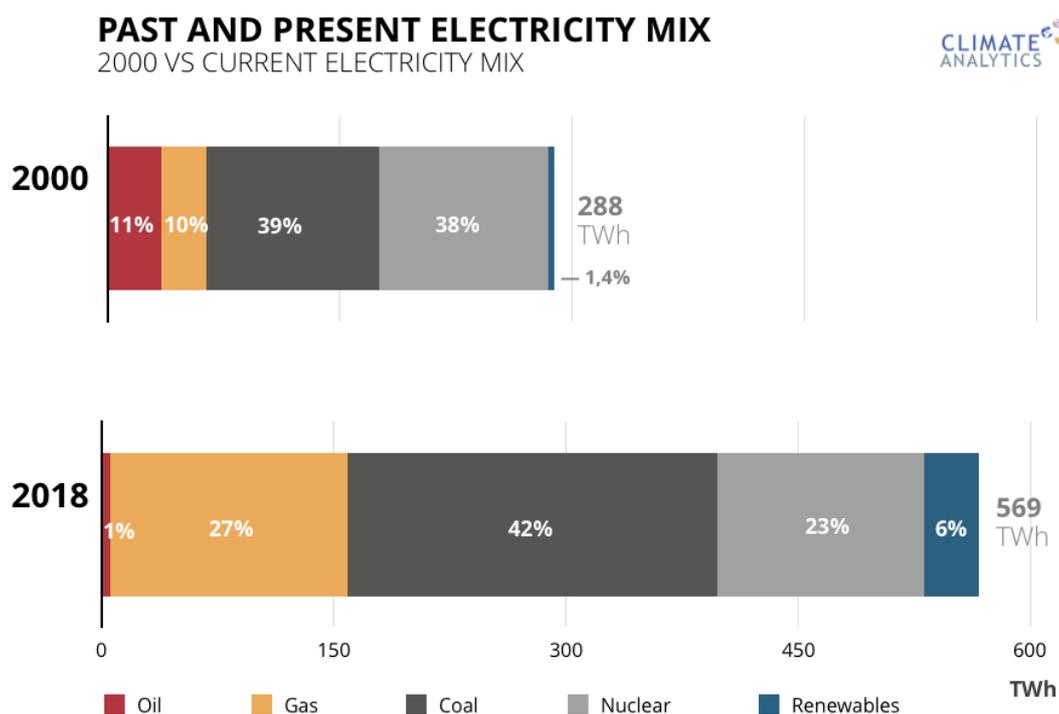


Figure 2 – Electricity generation by fuel type in 2000 and 2018. Source: Own elaboration based on APERC Energy Outlook and KEPCO Statistics 2019

Coal power generation is responsible for around 30% of South Korea’s carbon dioxide (CO<sub>2</sub>) emissions and has been the main driver of emissions increases over the past two decades. The share of coal in power generation increased from 39% in 2000 to 42% in 2018, resulting in more than doubling of generation in the same period (see Figures 2 and 3).

2 Smaller Combined Heat and Power (CHPs) generation plants, with a combined capacity of 1,563 MW, have also been taken into account on our emissions estimates to provide a complete overview of emissions from coal-based power generation.

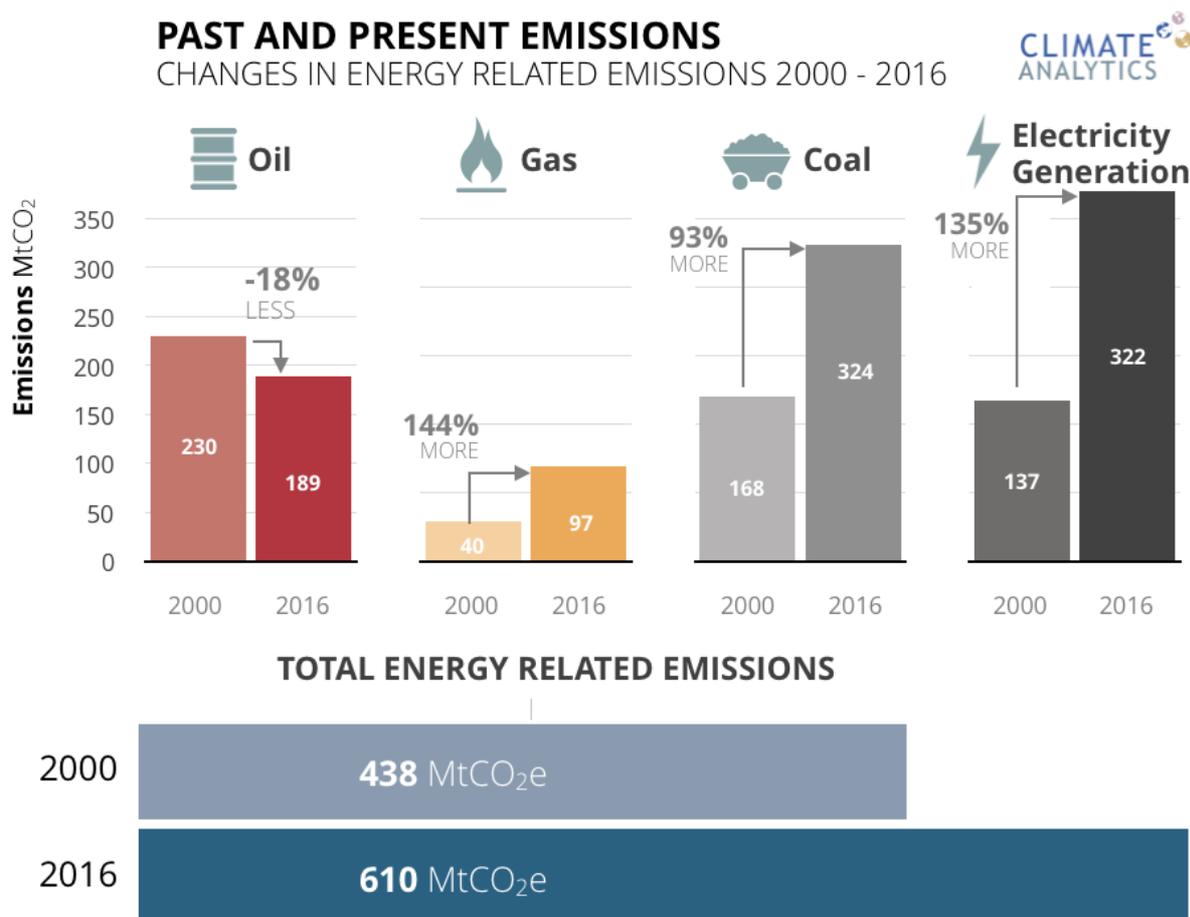


Figure 3 – Energy related emissions by fuel 2000 and 2016. Source: Own elaboration based on APERC Energy Outlook 2019. Officially reported energy related emissions in national inventories are slightly lower (411 MtCO<sub>2</sub>e in 2000 and 605 MtCO<sub>2</sub>e in 2016) due to differences in classification between the two sources.

While South Korea has one of the highest shares of ultra-super critical (best technology available) coal power plants in the world, the sector's contribution to air pollution is very significant, representing 11% of fine dust pollution in 2018.

Under the previous Lee administration, the government announced the sixth Basic Plan for Long-term Electricity Supply and Demand (BPE6), which planned to double the capacity of coal power generation between 2013 and by 2027 by adding 27 new coal units to the national grid (MOTIE, 2013). Since May 2017, the new administration under President Moon Jae-In announced a change in the approach towards energy in South Korea, declaring reducing the share of coal and nuclear power and increasing the contribution of renewable energy a priority.

Sub-national governments in South Korea are also taking progressive steps towards reducing coal use for power generation. The Chungnam province, home to roughly half of South Korea's coal-fired power plants, joined the Powering Past Coal Alliance (PPCA) in 2017, becoming the first South Korean and East Asian member of the Alliance. This alliance is a coalition of national and sub-national governments, businesses and organizations working to advance the transition from unabated coal power generation to clean energy, and recognizes the need to phase out coal in OECD countries by 2030 to meet global climate goals (Powering past coal Alliance, 2017).

Besides climate change mitigation, one of the key drivers of the renewed approach toward coal power generation is the increasing awareness and need to tackle air pollution and its dangerous public health consequences.

South Korea enforces regulatory limits on sulfur oxides (SO<sub>x</sub>), carbon monoxide (CO), nitrogen oxide (NO<sub>x</sub>), ground level ozone (O<sub>3</sub>), particulate matter (PM-10 and PM-2.5), lead, and benzene. Nonetheless, air pollution is still a serious problem and multiple cities register dangerous levels of air pollutants. In March 2019, the government

declared air pollution a “social disaster” after seven cities experienced record-high concentrations PM-2.5 (Reuters, 2019)

To reduce air pollution, the government has implemented multiple measures in recent years that affect coal power generation<sup>3</sup>.

- In June 2017, the government announced that it would close 10 existing coal-fired power generation units, and would not add any additional coal plants to the existing pipeline. President Moon also pledged to permanently close all coal plants aged 30 years or more during his presidential term (2017–2022).
- In 2018, government tightened air quality standards for fine dust (PM-2.5) to a daily average of 35 micrograms per square meters ( $\mu\text{g}/\text{m}^3$ ) and a yearly average to  $15 \mu\text{g}/\text{m}^3$  – from previous  $50 \mu\text{g}/\text{m}^3$  and  $25 \mu\text{g}/\text{m}^3$  respectively.

In May 2019, the Clean Air Conservation Act was revised to impose stricter emissions standards for all facilities including thermal power plants and industries.

- In September 2019, the National Council on Climate and Air Quality proposed a seasonal dust management system, which included tougher emissions standards, and restrictions for coal power plant operation, as well as aged diesel vehicles circulation during the high-pollution season (typically from December to March).
- In November 2019, the government moved the maximal planned closure date of the six older coal-fired power generation units to 2021, a year earlier than in previous plans, which will result in emissions savings of between 6-12MtCO<sub>2</sub>.

These temporary measures to restrict coal power generation to tackle dangerous air pollution levels have already shown the huge potential of the sector to contribute to multiple policy objectives. For instance, particulate matter emissions from coal power plants decreased 36% in December 2019 compared to the same period in the previous year (MOTIE, 2019b). The government is currently preparing the next set of new measures to cope with fine dust emissions, including measures related to the reduction of coal use in the electricity sector.

**Despite the encouraging signs of momentum towards a transition to a coal-free electricity mix, South Korea has no concrete national commitment, roadmap, or policy instrument to accelerate coal phase-out, and no systematic framework to ease the transition to a coal-free society.**

#### *Box 1 – South Korea’s international coal footprint*

South Korea’s approach to coal power generation has international and global implications that should be considered when discussing the need and responsibility for climate action, as well as the potential to contribute to the global energy transition and the achievement of the Paris Agreement goals.

South Korea continues to be one of the top financiers of coal power generation expansion around the world. It is the third biggest public investor in coal-fired power plant projects abroad among the G20 countries, investing more than \$1 billion per year through its public finance agencies (PFAs); Korea Trade Insurance Corporation (K-SURE), Export-Import Bank of Korea (KEXIM) and Korea Development Bank (KDB) (Farrow, Anhäuser, Myllyvirta, & Son, 2019).

Between January 2013 and August 2019, South Korea’s PFAs financed 22 coal-fired power plants abroad, amounting to 5.7 billion USD, for a capacity of 7 GW. New coal plants with the capacity of 4.5 GW are under review for possible investment (Farrow et al., 2019). The majority of public financing during this period was in Southeast Asia, particularly Vietnam (72%), Indonesia (22%), with smaller shares in countries like Bangladesh

<sup>3</sup> Stricter air quality standards affect coal power plants in two ways: retrofitting and refurbishing required in older units increases their operation cost and can strongly influence closure decisions, and even for units that meet emission standards, limits to absolute air pollution ultimately imply a reduction in the utilization rate of the generation units, affecting the utilities’ profitability.

and Chile. Many projects under consideration consist of sub-critical and super-critical coal power generation units, meaning not the best available technology with far lower emissions standards than those applied domestically (idem).

South Korea's coal power generation industry is fueled largely with imported coal, including from countries where fossil fuels extractive industries have an influential role in national politics to delay climate action despite how vulnerable their countries are to climate change (e.g. Indonesia and Australia), and where the coal mining has high local social and environmental impacts (e.g. South Africa and Colombia)(Statista, 2018). The lack of a clear policy signal about the future of coal imports in South Korea is indirectly contributing to industry demand projections that are used to continue and expand coal extraction in these countries, complicating and increasing the cost of their energy transition.

While there is increasing awareness and political momentum towards a transition to a coal-free society, not nearly enough attention has been given to the role that South Korea is playing in extending other countries' coal dependency and the role it could play in facilitating the global energy transition and achieving Paris Agreement objectives by changing its international strategy around coal.

Current national discussions on policy measures, as well as and the societal pressure to reduce coal use, make 2020 a critical opportunity for the government to announce bold commitments and targets and roadmaps for climate and energy policy. A clear policy signal and a structured phase-out plan would provide multiple benefits for South Korea's population and the electricity sector. It would also provide an opportunity to come up with plans aimed at supporting and creating opportunities for coal-related businesses, workers and investors to be better placed to make a sound transition away from coal.

In the following sections we analyze how a Paris Agreement compatible trajectory for coal in the power sector would look for South Korea, calculate the emissions gap between this trajectory and emissions projections under current policies, and reflect on the adequacy of national energy and electricity targets. Finally, we derive concrete policy recommendations for reducing coal use that could be implemented in the short term to increase policy coherence and closing the implementation gap for national climate policy.

## PARIS AGREEMENT COMPATIBLE PATHWAY FOR COAL IN THE POWER SECTOR

In 2016, Climate Analytics concluded that to meet the Paris Agreement 1.5°C temperature goal, emissions of unabated coal<sup>4</sup> would have to be phased out globally by 2050, in China by 2040, and in the OECD and the European Union by 2030 (Climate Analytics, 2016a)<sup>5</sup>. The study was based on an evaluation of energy-economic scenarios from Integrated Assessment Models (IAMs) available at the time. On this basis, Climate Analytics also developed coal phase-out studies for different countries including the European Union, Japan, Germany, and Australia (Climate Analytics, 2017b) (Climate Analytics, 2018a) (Climate Analytics, 2018b)(Climate Analytics, 2019b).

More recently, the much larger number and range of 1.5°C compatible scenarios assessed in the IPCC 1.5°C Special Report (SR1.5) greatly extended the scientific basis (IPCC, 2018b). **Climate Analytics has analysed the scenarios in the IPCC SR1.5 and found that coal needs to be phased out from electricity generation globally by 2040, to get the world on a trajectory compatible with the Paris Agreement** (Climate Analytics, 2019c), which is roughly a decade earlier than previously estimated.

The scenarios underpinning IPCC SR1.5 do not provide data at the national level but focus instead on different regions (e.g. the OECD). To draw conclusions on South Korea's emissions and energy scenarios, we have selected the International Energy Agency's (IEA) Energy Technology Perspectives (ETP) Beyond 2°C scenario (B2DS)<sup>6</sup> (IEA, 2017).

<sup>4</sup> Coal plants without carbon capture and storage.

<sup>5</sup> In this study we assume that a phase-out of coal-fired power plants is achieved whenever emissions are reduced by more than 90% below 2010 levels.

<sup>6</sup> The IEA report includes two additional scenarios that are not relevant here: the Reference Technology Scenario (RTS) or baseline scenario, assuming the implementation of present day climate change mitigation commitments (NDCs and other); and the 2°C scenario (2DS) that

This is consistent with our previous work looking at national level Paris Agreement benchmarks for coal phase-out in Germany and Australia (Climate Analytics, 2018a) (Climate Analytics, 2019b).

The ETP B2DS scenario provides a close analogue to a typical 1.5°C compatible pathway at the global level for the power sector from the IPCC SR1.5 scenario set. This scenario also contains energy system data on some key countries and regions, including the OECD.

One advantage of using the IEA ETP instead of the other pathways in the IPCC database for downscaling regional results is that it is the only pathway that includes South Korea in OECD, of which it has been a member since 1996, rather than in the non-OECD Asia region.

For the OECD, the B2DS scenario has a coal phase-out date in the power sector some five years later (2035) than the median of the IPCC SR1.5 scenarios (2030). The IEA B2DS OECD trajectory on the use of coal in electricity (without CCS) lies above the median of 1.5°C pathways assessed in SR1.5. Given this context, the 2035 phase-out date for coal in the power sector in the OECD in the B2DS scenario appears to be a conservative estimate for a 1.5°C consistent pathway for this region.

To draw conclusions on South Korean emissions and energy scenarios, the OECD coal use pathways need to be downscaled to the national level. For this report, we have downscaled the OECD results to South Korea by making use of Climate Analytics' SIAMESE model (Simplified Integrated Assessment Model with Energy System Emulator) (Sferra, Krapp, et al., 2018), consistent with other reports looking at national implications of global and regional energy models (Climate Analytics, 2016c, 2017b, 2018b, 2018a; Sferra, Schaeffer, & Torres, 2018).

SIAMESE is able to downscale the results of aggregated regions (OECD in this case) to the national level by determining the optimal electricity mix and emission pathways for all countries in a given region, using a welfare maximisation approach that ensures emissions reductions that add up to the required regional emissions reductions. For more details on the downscaling methodology and model assumptions see Annex 1 – SIAMESE Model.

There are two main advantages of using SIAMESE over other downscaling methodologies, such as applying regional reduction rates to national historical data. Firstly, SIAMESE mimics the structure of energy-economy models like the IEA ETP model, from which the B2DS scenario is derived, and is able to distribute mitigation efforts across countries and sectors under a scenario which takes into account observed energy consumption, energy mix composition, GDP and population data across different countries in the region. In addition, SIAMESE can take into account specific policies that are in place (e.g. renewable energy target) and expected energy trends (e.g. nuclear phase-out dates) at the national level, making the results more relevant for national policy discussions.

For instance, for this report to be robust and relevant for current policy discussions in South Korea, we have constrained the ability of the model to allocate amounts of specific fuels above what is implied by government targets. For example, we have limited the amount of nuclear and gas power generation to shares of 23.9% and 18.8% in 2030 respectively, in line with targets found in the government's 8th Basic Plan for Long-Term Electricity Supply and Demand. We have also assumed a gradual nuclear phase-out over time, with no further nuclear plants built beyond those currently under construction, in line with the government's stated goal. We assume a 40-year lifetime of nuclear plants in line with the expected lifetime of plants with scheduled closure dates in the early 2020s.

These 2030 government targets for gas and nuclear power generation also reflect the economic and political realities of potential future increases in these generation technologies. Any major build out of gas capacity over the short-term would create a substantial risk of widespread stranded assets, as the GHG emissions implied by such long-term and sustained reliance on gas power generation are not compatible with emission reductions required by the Paris Agreement. With regards to nuclear, given a majority of the population is committed to seeing a decreased reliance on nuclear power in the future (Lim, 2019), and the government's commitment to a gradual phase-out after plants currently under construction are finished, further construction of additional nuclear capacity is considered unrealistic.

includes assumptions on additional mitigation action that would result in a 50% chance of keeping anthropogenic global warming below 2°C above pre-industrial levels by 2100.

Given that the IEA B2DS uses 2014 as the last historical year in calibrating its results, we need a two-stage approach to derive a Paris Agreement compatible pathway for coal power generation in South Korea that reflects accurately the most recent emissions trends:

- First, we use the SIAMESE model to downscale the regional energy mix from the OECD region to South Korea, calibrating the model with the officially reported historical electricity generation records from the South Korean Electric Power Corporation (KEPCO) until the last historical year of the B2DS scenario (2014)<sup>7</sup>. Based on emissions factors calculated using emissions data reported by the South Korean government we then derive a Paris Agreement compatible emissions pathways consistent with this energy mix and calculate an emissions budget for coal-based power generation (cumulative emissions 2014 to 2050) based on this pathway.
- Second, historical coal power generation as reported by the official sources for the years 2015-2018 is higher than the levels that South Korea would have reached had it followed the Paris Agreement consistent pathway from 2014 (last historical year in the B2DS derived pathway). We modify the emission trajectory so that South Korea does not exceed the total emissions budget derived from the original pathway (starting in 2014). Under this approach, to compensate for emissions exceeding the original pathway between 2014-2018, it would have to speed-up emissions reductions in coal power generation after 2018, reaching a full phase-out of these emissions by 2029, which is earlier than the median coal phase out pathway of the range of IPCC scenarios consistent with the 1.5 °C limit for the OECD region.

**The SIAMESE Paris Agreement compatible pathway shows that coal power plant emissions need to decrease steeply in the coming years, falling by 58% below 2017 levels by 2025 with phase-out by 2029<sup>9</sup>.** In the next section, we compare the emissions projections under current plans for coal power plants with this Paris Agreement emissions benchmark pathway.

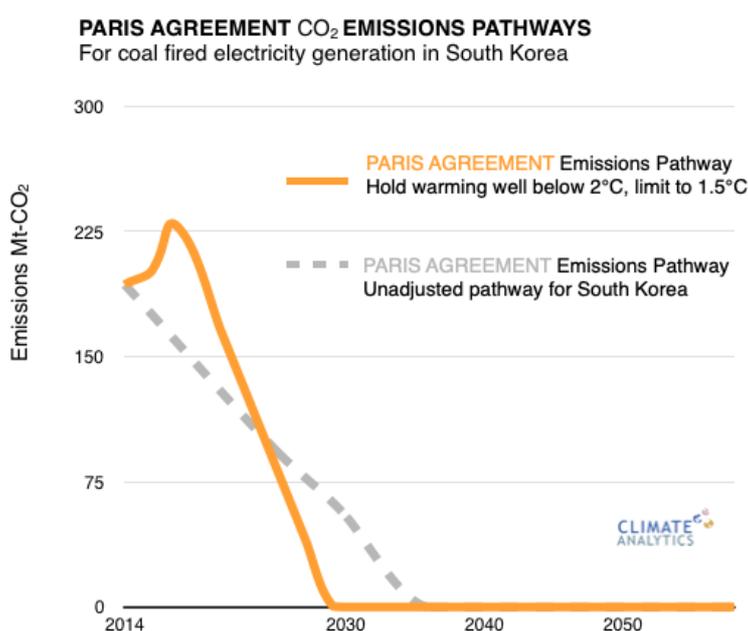


Figure 4 – Paris Agreement compatible coal power plants emissions pathways for South Korea. The unadjusted Paris Agreement compatible pathway for South Korea is a result of the downscaling of the results for the OECD from the IEA ETP B2D scenario to South Korea with the SIAMESE model. The adjusted pathway keeps the same carbon budget, while taking into account historical emissions until 2018.

<sup>7</sup> We assume the 2014 energy mix of non-utility generation as reported by KEPCO to be proportional to the electricity generation of auto-producers outlined in the IEA World Energy Balances. We also use the fuel split for “group energy” generation reported in the KEPCO Statistics.  
<sup>8</sup> The IEA and SIAMESE models have 2014 as a starting date and provide results for 2025 and 2030. Values between the starting point and these data points are linearly interpolated.  
<sup>9</sup> As we interpret “coal phase-out” to relate to emissions from coal reaching below 90% of their 2010 level, this leaves a modelled residual value of 14MtCO<sub>2</sub> at the time of phase-out.

## THE COAL POWER PLANTS EMISSIONS GAP

Contrary to what is needed to achieve the Paris Agreement’s long-term temperature goal and its own objective to become a carbon-free society, South Korea is still planning to start operation of seven additional coal power generation units with combined capacity of 7.27 GW in the next four years. By 2025, 11 units with a combined capacity of 5.24 GW are expected to retire or be converted to another fuel, meaning that there will be an operating capacity net increase of around 1 GW. Considering the new units planned, and the age profile of the operating fleet, if all plants were to operate until the proposed retirement age of 30 years, coal would continue to be a part of the electricity mix for many decades and only be phased out by 2055.

Here, we calculate the emissions that would result from South Korea’s current and planned coal power plants in order to estimate the emissions gap between current and planned infrastructure, national targets, and emissions pathways compatible with the Paris Agreement. Our key assumptions to estimate future emissions are lifetime and utilisation factors, which are very uncertain in the future.

For plants without a planned retirement date, we have assumed a lifetime of 30 years, which is consistent with the announcement of President Moon, to aim to retire all power plants older than 30 years during his presidential term, and the average retirement age for plants with a planned retirement/conversion year. It is worth noting that this lifetime assumption is much below the global average retirement age of 40 years and the historical retirement age of South Korean coal power plants (38 years), which means our cumulative emissions estimates are conservative, and observed emissions could be higher if power plants stay online longer than 30 years.

We have also assumed an average utilisation factor of 81%, which is equal to the 2017 average, according to national reported generation values at the unit level. Finally, emissions intensities are estimated based on standard reported values per combustion technology and coal type, around which there is very little uncertainty. We assume no further additions beyond what is currently planned for our estimates.

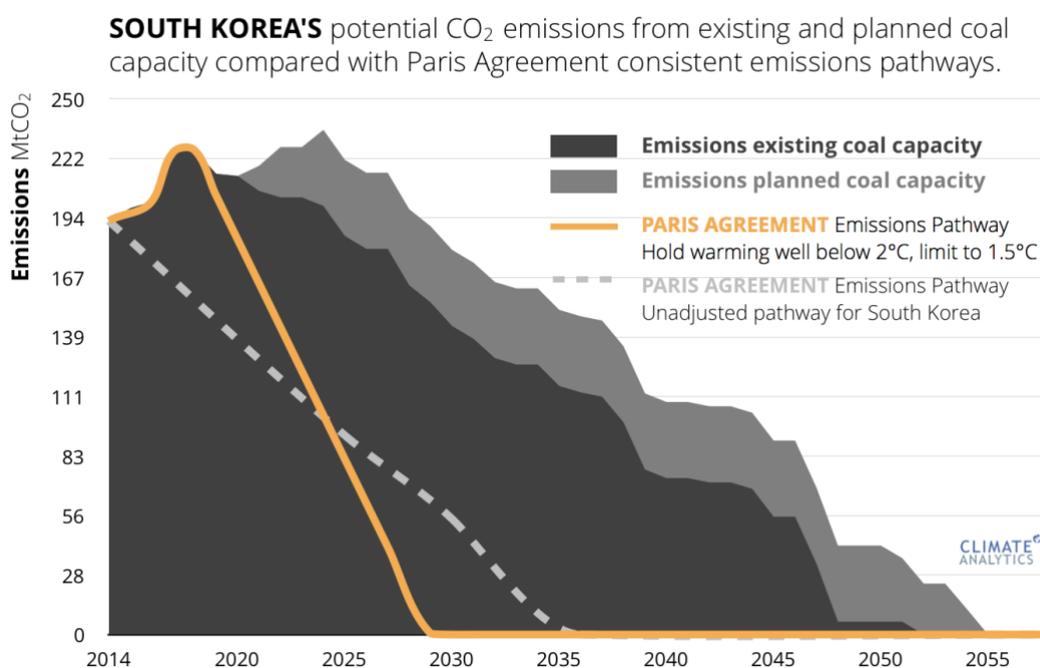


Figure 5 – Coal power plant emissions pathways for South Korea. Emissions are calculated based on proposed retirement age (30 years) and historical utilisation rates (average 81%), and reported emissions intensities per combustion technology and coal type. The Paris Agreement compatible pathway for South Korea is a result of the downscaling of the results for the OECD from the IEA ETP B2D scenario to South Korea with the SIAMESE model, and taking into account historical emissions until 2018.

Our methodology is described in detail in Annex II – Estimating CO<sub>2</sub> emissions from coal plants.

Our estimates show that, without additional policies, coal-related CO<sub>2</sub> electricity emissions are projected to increase in the short term, as new units come online, peak around 2025, and fall continuously in the following decades due to aging of the coal fleet, planned retirements and conversions to other fuels. However, if the speed of coal retirements continues at its currently planned pace, South Korea’s operating plants would emit two and a half times (247%) the remaining power sector budgets for coal in line with the Paris Agreement, which we estimate by calculating the cumulative emissions consistent with the downscaled emissions pathway in Figure 5. If the planned coal units come online, the difference between committed emissions and pathways consistent with the Paris Agreement would increase to 317%. If the lifetime of existing power plants is extended beyond the assumptions made in this report, this carbon budget will be exceeded by a much larger margin.

In order to achieve the Paris Agreement long-term temperature goal, our results show that **South Korea will need to retire its operating power plants much earlier than the currently proposed age (30 years) and/or dramatically reduce their utilisation rate. Every new coal unit that comes online will only increase the already large gap between South Korea’s emissions and its Paris Agreement pathway.** Given the urgency of the emissions reductions needed in the power sector, a clear policy signal and structured phase-out plan is needed.

The longer the world and South Korea continue to use coal as currently planned, the higher the cost and the smaller the feasibility of keeping the door open to achieve the Paris Agreement’s long-temperature goal, and prevent dangerous climate change.

## ADEQUACY OF NATIONAL TARGETS

### ENERGY AND ELECTRICITY TARGETS

The main directives for energy and electricity in South Korea are the 2017 8<sup>th</sup> Basic Plan for Electricity Supply and Demand (BPE8), and the 2019 Third Energy Master Plan (EMP3) up to 2040 (MOTIE, 2017, 2019a, 2019c). In the BPE8, it committed not to allow further additions to the coal power plants pipeline and to gradually reduce the use of coal power. However, the targets for the 2030 electricity generation mix in these Plans foresee maintaining coal’s dominant role in the electricity mix, which would consist of 23.9% nuclear, 36.1% coal, 18.8% natural gas and 20% renewable energy.

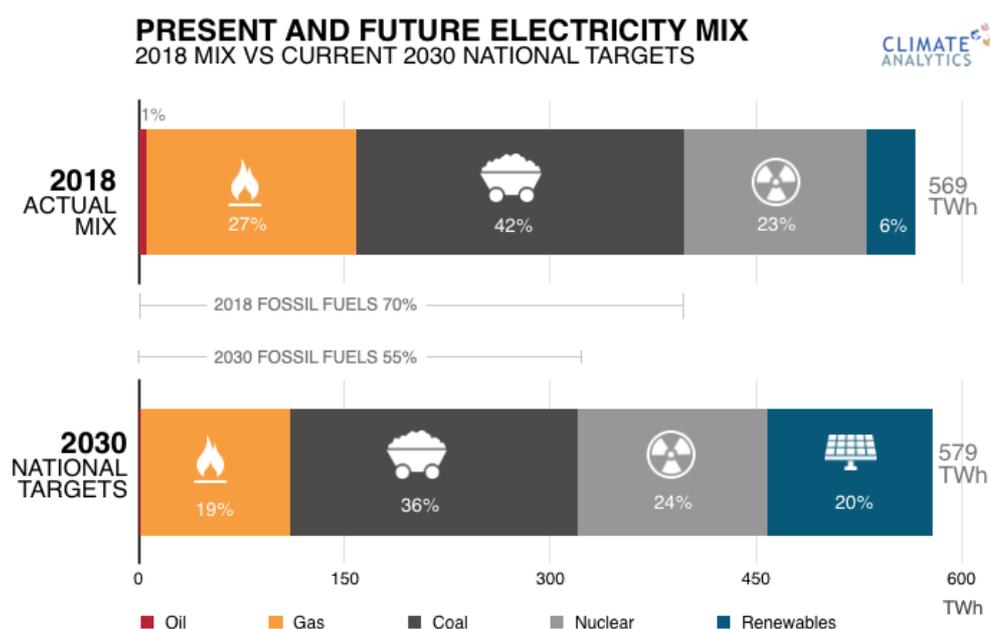


Figure 6 - Electricity generation by fuel type in 2018 and national targets for 2030. Source: Own elaboration KEPCO Statistics 2019 and 8<sup>th</sup> Basic Plan for Electricity Supply and Demand

The EMP3 also aims to increase the renewable electricity share to 30–35% by 2040 – up from 3% in 2017, but doesn't provide clear targets for this timeframe for other fuels. These plans do not include any commitment regarding phase-out of coal power generation, and suggest the government will continue with the construction of the seven coal generation units currently in the pipeline, which could lock in emissions for decades and increase the risk of stranded assets.

Table 1- South Korea's electricity mix by fuel in 2030 under different scenarios

| Fuel          | 2018     | 2030   |  |   |
|---------------|----------|--|--|---|
|               | Observed | 8 <sup>th</sup> Basic Plan for Electricity Supply and Demand | APEREC's Energy Outlook 2019-Current Policy Scenario | Paris Agreement SIAMESE electricity mix <sup>10</sup> |
| Nuclear       | 23%      | 24%  | 24%  | 24%   |
| Renewables**  | 6%       | 20%  | 7%   | 48%   |
| Unabated Coal | 42%      | 36%  | 38%  | 0%  |
| Coal with CCS | NA       | NA   | 0%   | 7.6%  |
| Oil           | >1%      | >1%  | >1%  | 1%  |
| Unabated Gas  | 27%      | 19%  | 30%  | 19%   |
| Gas with CCS  | NA       | NA   | 0%   | 0.3%  |

\* Shares might not add up to 100% due to rounding to closest unit; \*\*Includes Bioenergy.

When the national targets and current policies are compared against the results derived from the Paris Agreement-compatible pathway for South Korea, **it is clear that the 2030 targets are not yet aligned with a strategy to limit warming to 1.5°C, as they allow for continuation of coal use much beyond 2030, and have a very conservative renewable energy target.**

While the model assumes an increase in the share of nuclear energy (1%) as well as a role for fossil fuels with CCS (7.9%), it is unlikely that these options will be more feasible than a further increase in renewable energy. This is due to the cost reductions in renewable energy and storage technologies, and the fact that neither nuclear energy nor CCS have become less expensive. What is more, incomplete capture would need to be compensated with additional, and likely expensive, efforts to remove carbon dioxide from the atmosphere (see text box 2 below).

It is also important to note that the total electricity generation for 2030 resulting from the downscaling exercise is 645.6 TWh, which lies between the baseline and target generation projections in the BPE8 (667 TWh and 579.5 TWh respectively). Total generation is endogenous to the energy model, and largely driven by GDP per capita growth assumptions which reflect UN population projections (0.25% between 2014-2035 and decreasing afterwards) and GDP growth consistent with Shared Socioeconomic Pathways (SSP2) in the model included in the IPCC database (2.9% on average for 2014-2040). If electricity demand was closer to government scenarios, which assume lower population growth of (0.1% until 2031 and decreasing afterwards) and lower economic growth (2% yearly between 2017-2040), higher shares of renewable energy generation would be easier to achieve, or the increased share of nuclear and gas (compared to the BPE8) is more likely to be unnecessary.

Considering these two important caveats to the model results, South Korea should aim for a renewable energy share of more than 50% in 2030, particularly given that there are a number of studies highlighting the achievability of high shares of renewable energy for South Korea, including reaching close to 100% by 2050 (Jacobson et al., 2017; Teske, Meinshausen, & Dooley, 2019). This shows there is a huge ambition gap in the nationally determined targets for electricity generation.

<sup>10</sup> To account for the earlier coal phase-out (2029) implied when accounting for historical emissions from 2015-2018, we run SIAMESE with a 2030 constraint limiting unabated coal demand to zero and report the resultant fuel mix.

**South Korea should urgently revise its national electricity generation targets for 2030 and improve the alignment of these targets with the stated priorities of the government**, and with multiple policy goals including climate change mitigation, air pollution control, and energy independence. Adjusted targets are the first step to provide the correct signals to utilities, investors, and consumers, which play a key role in the implementation of the energy transition.

Moreover, as shown in APEC Energy Demand and Supply Outlook (APERC, 2013), under current policy projections, as estimated by the Asia Pacific Energy Research Centre (APERC), South Korea is still far from meeting its insufficient national targets for its electricity mix as outlined in the 8<sup>th</sup> Basic Plan for Electricity Supply and Demand, in particular when it comes to renewable energy generation. To gain credibility about the achievement of self-imposed national targets and increase policy and investment coherence, South Korea needs to urgently implement policies to enable a quick coal phase-out from the electricity mix and substantially speed up the deployment of low carbon and carbon neutral technologies for electricity production.

Beyond 2030, results from the scenario analysis by Climate Analytics show that, like coal, other unabated fossil fuels (i.e. oil and gas without carbon capture and storage) will also need to decrease rapidly in South Korea's electricity mix, while renewable energy sources will need to be phased in quickly. These results call into question South Korea's perception of the role of gas to in the transition to a coal-free society (e.g. some coal units are scheduled to convert to gas as main fuel). The role of gas as a bridge fuel is very limited under a Paris Agreement compatible pathway, where unabated gas is reduced steadily after 2030, and needs to reach below 5% by 2050. The government intends to have an energy mix where gas "will continue to play a greater role in the future" (MOTIE, 2019c) but over-expansion of gas infrastructure could substantially increase the risk of stranded assets and divert valuable financial flows from clean energy sources. Instead, Korea could build on its hydrogen economy strategy (IPHE, 2019) and explore focusing on importing green hydrogen from countries with high renewable energy potential, and taking advantage of the reduction in cost expected (IRENA, 2019).

#### *Box 2 - Use of carbon capture and storage (CCS) technologies*

The energy models that produce the underlying pathways presented in the IPCC SR1.5 incorporate a number of technologies to achieve emissions reductions. Among these technologies most models include the use of carbon capture and storage (CCS) in power plants. The IEA ETP model, from which the B2DS scenario is derived, includes use of CCS technologies for coal, gas, and biomass power plants, and therefore the resulting downscaled pathway for South Korea also includes the use of this technology.

A key metric of our analysis is the comparison between committed emissions from current and planned coal power plants and a Paris Agreement compatible emissions pathway for this fuel and sector. To estimate this metric and provide policy recommendations, in this report we focus on coal generation without carbon capture and storage (CCS). The main reasons to exclude coal use with CCS from core analysis are the following:

- In most energy models, including the ETP model, fossil fuel power plants with CCS are assumed to emit little or no CO<sub>2</sub> and are not relevant for emission budget considerations within the model. In reality, coal power plants with CCS are very likely to emit at the very least a tenth of the average emissions compared with an installation without CCS (World Nuclear Association, 2018) (Wuppertal Institute for Climate Environment and Energy, 2008)(MIT, 2016)and therefore cannot be considered a zero carbon alternative to coal in the power sector.
- Deployment at scale (i.e. excluding the handful of demonstration and pilot projects across the globe) of CCS for fossil fuel power plants is unlikely given the reduction in electric output efficiency and high costs, especially with the rapidly declining costs of zero-carbon alternatives. The economic and technical performance results of CCS demonstration projects in power plants to the date provides evidence to support this assumption.
- There are physical and geological constraints for large-scale deployment of CCS at the national level, which cannot be accounted for within our downscaling framework. While CCS might be viable for a certain share of the global fossil fuel fired power plants fleet, this technology should chosen on a case-by-case basis, with consideration of the national circumstances (e.g. cost, social acceptance, geotechnical constraints, etc).

For South Korea, we think that even if the use of CCS were to be considered viable and desirable, from an emissions accounting perspective and considering the geological limits, it is much more likely that this technology would be used for biomass power plants than for fossil fuel power plants. Therefore, the results from the Paris Agreement compatible pathway for coal and gas with CCS should be interpreted with extreme caution: in the likely scenario of limited deployment of CCS in fossil fuel power plants, the electricity generation assumed by the model under these technologies should be replaced by zero carbon generation from renewable energy sources.

## CLIMATE TARGETS

South Korea's Paris Agreement commitment (Nationally Determined Contribution or NDC) includes a target of reducing GHG emissions by 37% below business-as-usual emissions by 2030. South Korea's NDC is an economy-wide target covering all greenhouse gases (GHG) and is planned to be met with a combination of domestic emissions reductions and carbon credits from international market mechanisms (Republic of Korea, 2015). In July 2018, the government announced updated national targets for emissions including the objective to peak national emissions around 2020 and increase the target for domestic emissions reductions to 32.5% emissions in 2030, compared to the 25.7% previously established in the NDC (ICAP, 2018; Ministry of Environment, 2018).

The independent assessment Climate Action Tracker estimates that the NDC target corresponds to a reduction of 20% below 2010 emissions levels by 2030 excluding the Land Use and Land Use Change and Forestry (LULUCF) sector<sup>11</sup> (Climate Action Tracker, 2019a). The Climate Action Tracker rates the NDC target as "highly insufficient" compared to the levels that would be required to achieve the goals of the Paris Agreement (*idem*).

The increased targets for domestic emissions reductions are a step in the right direction and a positive sign that the government is willing to take stronger climate action. However, with currently implemented policies, South Korea is still far from meeting its target emissions reductions and under its most recent plan for the power generation mix will continue to rely heavily on coal in the future (APEREC, 2019).

Enhanced NDCs, as well as Long Term Strategies are due in 2020 under the framework of the Paris Agreement. This, together with the planned development of a roadmap for reducing coal use in South Korea during 2020, means that this year offers a critical window of opportunity to develop a coal phase-out roadmap as well as an updated NDC target and an economy-wide Long Term Strategy in line with the Paris Agreement 1.5°C limit.

## CONCLUSION AND POLICY RECOMMENDATIONS

The South Korean government has identified as its key priorities the transition to a coal-free society that benefits from high air quality; the scaling up of emissions mitigation measures and targets to respond to the global climate emergency, and the establishment of inclusive and just environmental policy. The Paris Agreement sets a clear pathway for coal-fired power plants in South Korea, which has the potential to address all these priorities simultaneously.

The South Korean government should put in place a national plan for an orderly coal phase-out as soon as possible. This plan should consider cancelling or fuel conversion for the seven new coal generation units planned to be added to the system and an orderly retirement of the remaining operating coal power stations by 2029 as shown by the Paris Agreement compatible pathway presented in this report.

Such a plan would provide stakeholders with certainty, facilitating the transition to a coal-free society. It would also help to give clear signals for investments into fast uptake of renewable energy capacity needed to go beyond national targets and replace coal power generation, and avoid a continued flow of investment into unsustainable assets and fossil fuels related infrastructure (e.g. planned coal power plants, LNG terminals, gas power plants). It would prevent South Korea from becoming locked into a carbon intensive pathway and reduce the risk of stranded

<sup>11</sup> The NDC states that a decision on the inclusion of the Land Use and Land Use Change and Forestry (LULUCF) sector, and the accounting rules to use for it, will be made at "a later stage", more details on the accounting approach for this sector could change the target emissions estimate for 2030.

assets, while also reducing the cost and complexity of achieving national mitigation targets. Instead, its long-term strategy needs to aim at fully decarbonizing electricity generation before 2050 as a fundamental step for achieving emissions reductions in all other sectors, where electrification plays an important role. South Korea can build on its aim to develop a hydrogen economy by focusing on green hydrogen.

In addition to its contribution to climate change, coal use for electricity production comes with multiple associated negative effects, including air and water pollution. This is particularly relevant for South Korea given its air pollution problems. A fast phase-out of coal would therefore not only be a critical component of the most cost-efficient means to get on a Paris Agreement compatible emissions pathway but would also offer a range of benefits and opportunities that go beyond emissions reductions, including health co-benefits and job opportunities from higher investments into renewable energy and reduced energy import dependency. A planned coal phase-out can be the basis for a just transition to ensure enough employment is created, for example through increased investment in renewable energy to replace employment in fossil fuel industry.

In addition to creating and implementing a domestic plan for a transition to a coal-free society, as one of the main coal financiers overseas and a significant coal importer, South Korea should reconsider its international strategy around coal. Instead of playing a central role in the extension of other countries' coal dependency, it could focus its international cooperation efforts and finance flows on facilitating the global energy transition towards decarbonization based on renewable energy and the achievement of the Paris Agreement objectives.

The longer South Korea and the world continue to use coal for power generation, the higher the cost and lower the feasibility of achieving the Paris Agreement's long-term temperature goal. Failure to phase-out fossil fuels from the energy system, including coal, at the speed needed, increases substantially the likelihood of South Korea and the world experiencing the unprecedented environmental, social and economic damage that the scientific literature has associated with increases in temperature beyond 1.5°C.

#### OPPORTUNITIES FOR ACTION

- 2020 is a critical year for more ambitious emissions reductions: governments are expected to bring forward enhanced NDCs with more ambitious 2030 targets, and new long-term low emissions sustainable development strategies (LT-LEDS) that bring collective action in line with the Paris Agreement's long-term temperature goal. Under its current energy and electricity plans, South Korea's power generation mix will remain heavily dependent on fossil fuels, which is inconsistent with Paris Agreement compatible pathways. National targets need to be revised and enhanced substantially in 2020, and a LT-LEDS needs to address the need to fully decarbonize electricity generation as well as end use sectors through electrification. South Korea can build on its leadership in developing a hydrogen economy by focusing on green hydrogen.
- Climate change mitigation – and the considerable air pollution benefits it would deliver - could gain significant attention in the next general election in April 2020. Given the urgency of the climate threat, making bold steps for climate mitigation around the election will stimulate meaningful discussion in the political forum. The new set of measures to cope with fine dust emissions, including measures related the reduction of coal use in the electricity sector, planned to be released in February 2020, is a prime opportunity for a giving a first step in this direction. Ideally, this plan should include a unit-by-unit retirement schedule, which would allow for an assessment of the related health and climate implications and the investment support measures required to replace the units, ensuring clean and reliable electricity supply.
- The Chungnam province, the location of around half of the country's coal power generation capacity, became the first member of the Powering Past Coal Alliance in South Korea and the East Asia region in 2017. The national government could send a very strong signal both at home and internationally on its commitment to support the bold leadership of its sub-national actors and its focus on implementing climate policy by stepping-up its international leadership to the level of this province and joining the Alliance before COP26. Membership of the Alliance would also benefit the country by providing a platform for exchange and knowledge sharing on key issues related to coal phase-out implementation strategies, including just

transition measures and processes, alignment of investment and financial flows with the Paris Agreement, and best practices for scaling up renewable energy power generation.

- Recently, the South Korean government has put considerable effort towards building strong cooperation with the Association of Southeast Asian Nations (ASEAN) through its New Southern Policy, which is promising to support ASEAN countries with infrastructure and economic development. However, South Korea's investment in carbon intensive projects in the Southeast Asian countries, in particular the investments in coal power plants in Indonesia and Vietnam, is inconsistent with the Paris Agreement and the Sustainable Development Goals. Investing in carbon-intensive projects abroad contributes to dependency on fossil fuels in those countries, puts at risk the achievement of national and international climate targets, and increases the risk of stranded assets, both in South Korea and the recipient countries. The cooperation initiatives with Asia-Pacific countries, including the Southern Policy, is a prime opportunity for South Korea to re-focus its international cooperation efforts and finance flows on facilitating the acceleration of the global energy transition, promoting sustainable development in partner countries, and the achievement of the Paris Agreement objectives.

## ANNEX I - SIAMESE

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The Simplified Integrated Assessment Model with Energy System Emulator (SIAMESE) is able to downscale the energy-system characteristics of a particular IAM at the country level, by providing cost-effective scenario in line with a global temperature target. At the same time, SIAMESE can take into account specific policies in place and expected energy trends (e.g. limited nuclear developments) at the country level. Therefore, it can provide insights to policy makers on how to realistically improve current policies and pledges in line with the Paris Agreement long-term target.

In this study we downscale the OECD electricity generation results of the IEA's Energy Technology Perspectives (ETP) model to South Korea. At the base year (2014), the model is calibrated based on observed electricity generation, GDP and population data. In a way, this calibration process sets some preferences regarding the energy mix composition. More precisely, SIAMESE allocates electricity generation in the regions by equalising the marginal utility of energy, under a welfare maximisation approach. Energy prices are endogenous in the model<sup>12</sup> and coincide with the marginal utility of energy.

In terms of the equations underpinning the model, SIAMESE mimics the structure of Integrated Assessment Model, where the economic output (GDP) is a function of capital, labour and energy consumption by using a CES (Constant Elasticity of Substitution) production function.

This version of SIAMESE focuses on downscaling electricity generation from the OECD region of the IEA ETP model. In terms of gases, SIAMESE focuses on CO<sub>2</sub> emissions only (excluding LULUCF) and does not cover other GHG such (e.g. CH<sub>4</sub>, N<sub>2</sub>O etc.). Other gases' emissions can be downscaled by using a simple (proportional) downscaling technique or via several other methods, such as using marginal abatement cost curves.

<sup>12</sup> SIAMESE determines the energy prices for each fuel, based on energy consumption levels from the IEA's ETP model.

## ANNEX II - ESTIMATING CO<sub>2</sub> EMISSIONS FROM COAL PLANTS

To estimate emissions resulting from currently operating and planned coal power plants in South Korea we used the Global Coal Plant Tracker (GCPT) database, which provides information on every known coal-fired power generation unit, including its location, status, investor, capacity, combustion technology<sup>13</sup> and fuel, year of opening and planned retirement. For this analysis we use the information provided in the July 2019 version of the GCPT. For an up-to-date list of status of plants under development or assessment, as well as additional characteristics of the units like the observed historical load factors and fuel use, which allow for a more accurate estimation of the emissions produced by each plant, we merged the GCPT data with information provided by a national database for coal power plants hosted by KEPCO, which reflects status of coal power units as of December 2019.

The data used in this report comprise of detailed information per plant concerning the country, its capacity, status and combustion technology, which allows to estimate CO<sub>2</sub> from these plants, using the following formula:

**Yearly emissions:**

$$Emi_{it} = Cap_i * \frac{1}{eff_i} * lf_{it} * ef_i * \phi$$

with:

***Emi<sub>it</sub>*** are the yearly emissions of plant unit *i* in Mt CO<sub>2</sub> in a particular year *t*

***Cap<sub>i</sub>*** is the Capacity of plant unit *i* in MW<sub>el</sub>. MW<sub>el</sub> describes the electrical output of a power plant (unit). About two thirds (actual value depending on the combustion technology) of the energy contained in a coal power plant's fuel is lost while converting it into electricity. The thermal energy released during the conversion is usually not used anymore but gotten rid of via cooling towers or rivers.

***eff<sub>i</sub>*** is the conversion efficiency of a power plant unit: How much of the energy contained in the fuel (coal) is converted to electricity. In general, this is higher for modern plants, which dominate Korea's coal power generation.

***lf<sub>it</sub>*** is the load factor of the power plant in a particular year *t*. The load factor is the ratio of the actual power plant output over its theoretical maximum output and is usually calculated over the course of a year. The theoretical maximum output can be calculated by assuming that a power plant runs at its nameplate capacity 24 hours a day, 365 days a year. I.e. a power plant unit with a capacity of 100 MW has a theoretical maximum output of

$$100 \text{ MW}_{el} * 10 \frac{\text{hours}}{\text{day}} * \text{ayr} \frac{\text{days}}{\text{year}} = 876.000 \text{ MWh.}$$

Actual output over a given year is lower since the plant will NOT always operate at full output – e.g. due to demand fluctuations – and has to be taken offline completely for maintenance. There is uncertainty around future utilisation rates of coal power plants in South Korea, but under our baseline scenario we assume the reported capacity factor at the unit level for 2017 for our projection period (81%).

***ef<sub>i</sub>*** is the emissions factor, which contains information on how much CO<sub>2</sub> is released for a given amount of coal burned. Unit is kg CO<sub>2</sub>/TJ. Higher-grade coal contains a higher share of carbon, which is converted to CO<sub>2</sub> during combustion. We use emission factors from (IPCC, 2006). Since this source contains only emission factors for pure types of coal, we assumed a 50/50 share for plants that use two different coal grades, e.g. bituminous and sub-bituminous coal.

***φ*** is a conversion factor to end up with the correct units (Mt CO<sub>2</sub>/yr).

**Calculating lifetime emissions:**

$$\text{Lifetime } Emi = \sum_{2017}^T Emi_{it}$$

<sup>13</sup> The database distinguishes between different combustion technologies in the following categories: subcritical, supercritical and ultra-supercritical without or with CCS, ranking from least to most efficient respectively. We do not consider coal fired power plants retrofitted with CCS technology further in our analysis.

with T being the last year the plant unit is in operation.

For simplicity, we assume that the shutdown of a given unit happens on 31 December of the respective year. T is calculated as Opening year + lifetime. This is because The decisive assumption here is the lifetime, and for plants that are not yet in operation, the opening year. We assume an average lifetime of 30 years, which is consistent with the announcement of President Moon, to aim to retire all power plants older than 30 years during his presidential term, and the average retirement age for plants with a planned retirement/conversion year. For unit not yet in operation, we assume the planned opening dates according to the KEPCO database.

## REFERENCES

- APERC. (2013). *APEC Energy Demand and Supply Outlook-5th Edition*. Retrieved from [https://aperc.iecej.or.jp/publications/reports/outlook/5th/volume2/EDSO5\\_V2\\_Philippines.pdf](https://aperc.iecej.or.jp/publications/reports/outlook/5th/volume2/EDSO5_V2_Philippines.pdf)
- APERC. (2019). *APEC Energy Demand and Supply Outlook – 7th edition (Vol II)*. Retrieved from [http://aperc.iecej.or.jp/file/2010/9/24/Outlook\\_Volume\\_II\\_4E.pdf](http://aperc.iecej.or.jp/file/2010/9/24/Outlook_Volume_II_4E.pdf)
- Climate Action Tracker. (2019a). Country Assessment - South Korea.
- Climate Action Tracker. (2019b). *Governments still showing little sign of acting on climate crisis*.
- Climate Analytics. (2016a). *Implications of the Paris Agreement for coal use in the power sector*. Retrieved from Climate Analytics website: [http://climateanalytics.org/files/climateanalytics-coalreport\\_nov2016\\_1.pdf](http://climateanalytics.org/files/climateanalytics-coalreport_nov2016_1.pdf)
- Climate Analytics. (2016b). *Implications of the Paris Agreement for Coal Use in the Power Sector*. Retrieved from [https://climateanalytics.org/media/climateanalytics-coalreport\\_nov2016\\_1.pdf](https://climateanalytics.org/media/climateanalytics-coalreport_nov2016_1.pdf)
- Climate Analytics. (2016c). *Implications of the Paris Agreement for Coal Use in the Power Sector*. Retrieved from <http://climateanalytics.org/publications/2016/implications-of-the-paris-agreement-for-coal-use-in-the-power-sector.html>
- Climate Analytics. (2017a). *A stress test for coal in Europe under the Paris Agreement*. Retrieved from [http://climateanalytics.org/files/eu\\_coal\\_stress\\_test\\_report\\_2017.pdf](http://climateanalytics.org/files/eu_coal_stress_test_report_2017.pdf)
- Climate Analytics. (2017b). *A Stress Test for Coal in Europe under the Paris Agreement*.
- Climate Analytics. (2018a). *Science based coal phase-out pathway for Germany in line with the Paris Agreement 1.5°C warming limit*. (October). Retrieved from [https://climateanalytics.org/media/germany\\_coalphaseout\\_report\\_climateanalytics\\_final.pdf](https://climateanalytics.org/media/germany_coalphaseout_report_climateanalytics_final.pdf)
- Climate Analytics. (2018b). *Science Based Coal Phase - Out Timeline for Japan Implications for Policymakers and Investors*. (May).
- Climate Analytics. (2019a). *Decarbonising South and South East Asia*. (May).
- Climate Analytics. (2019b). *FOR CLIMATE 'S SAKE : COAL-FREE BY 2030 Rationale and timing of coal phase-out in Australia under the Paris Agreement*. (November).
- Climate Analytics. (2019c). *Global and regional coal phase-out requirements of the Paris Agreement: Insights from the IPCC Special Report on 1.5°C*. Retrieved from [https://climateanalytics.org/media/report\\_coal\\_phase\\_out\\_2019.pdf](https://climateanalytics.org/media/report_coal_phase_out_2019.pdf)
- Farrow, A., Anhäuser, A., Myllyvirta, L., & Son, M. A. *DEADLY DOUBLE STANDARD: South Korea's Financing of Highly Polluting Overseas Coal Plants Endangers Public Health*. , (2019).
- Government of South Korea. (2018). *National GHG Inventory of South Korea*.
- ICAP. (2018). Republic of Korea approves 2030 GHG roadmap and 2nd phase ETS allocation plan. Retrieved November 3, 2019, from <https://icapcarbonaction.com/ko/news-archive/567-republic-of-korea-approves-2030-ghg-roadmap-and-2nd-phase-ets-allocation-plan>
- IPCC. (2006). Stationary Combustion. In H. S. Eggleston, L. Buendia, K. Miwa, T. Ngara, & K. Tanabe (Eds.), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.
- IPCC. (2018a). *Global Warming of 1.5°C: Summary for Policymakers*. Retrieved from [http://report.ipcc.ch/sr15/pdf/sr15\\_spm\\_final.pdf](http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf)
- IPCC. (2018b). *Global Warming of 1.5°C. Summary for Policymakers*. (October 2018).
- IPHE. (2019). *International Partnership for Hydrogen and Fuel Cells in the Economy - South Korea*.
- IRENA. (2019). Hydrogen: A renewable energy perspective. In [/publications/2019/Sep/Hydrogen-A-renewable-energy-perspective](https://publications/2019/Sep/Hydrogen-A-renewable-energy-perspective).
- Jacobson, M. Z., Delucchi, M. A., Bauer, Z. A. F., Goodman, S. C., Chapman, W. E., Cameron, M. A., ... Yachanin, A. S. (2017). 100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World. *Joule*, 1–14. <https://doi.org/10.1016/j.joule.2017.07.005>
- Kuramochi, T., Höhne, N., Schaeffer, M., Cantzler, J., Hare, B., Deng, Y., ... Blok, K. (2018). Ten key short-term sectoral benchmarks to limit warming to 1.5°C. *Climate Policy*, 18(3), 287–305. <https://doi.org/10.1080/14693062.2017.1397495>
- Lim, E. (2019). South Korea's Nuclear Dilemmas. *Journal for Peace and Nuclear Disarmament*, 2(1), 297–318. <https://doi.org/10.1080/25751654.2019.1585585>
- Ministry of Environment. (2018). *National Greenhouse Gas Reduction Target by 2030:*

*Amended baseline roadmap roadmap for achieving achievement.* Retrieved from Ministry of Environment, Republic of Korea website:  
<http://energytransitionkorea.org/sites/default/files/2018-11/18.072030-%EC%A0%9C%BC%20%28%29.pdf>

MIT. (2016). *Carbon Capture and Sequestration Technologies Program at MIT.*

MOTIE. (2013). *Sixth Basic Plan for Long-term Electricity Supply and Demand.*

MOTIE. (2017). Announcement of the 8th Basic Electricity Supply and Demand Plan (2017-2031). Ministry of Trade, Industry and Energy Announcement 2017-611. In Korean. Retrieved April 12, 2018, from [http://www.motie.go.kr/motie/ne/announce2/bbs/bbsView.do?bbs\\_cd\\_n=6&biz\\_anc\\_yn\\_c=Y&bbs\\_seq\\_n=64603](http://www.motie.go.kr/motie/ne/announce2/bbs/bbsView.do?bbs_cd_n=6&biz_anc_yn_c=Y&bbs_seq_n=64603)

MOTIE. (2019a). *3rd Energy Master Plan (“제3차 에너지기본계획”).* In Korean. Retrieved from Ministry of Trade, Energy and Industry, Republic of Korea website: [http://www.motie.go.kr/common/download.do?fid=bbs&bbs\\_cd\\_n=81&bbs\\_seq\\_n=161753&file\\_seq\\_n=1](http://www.motie.go.kr/common/download.do?fid=bbs&bbs_cd_n=81&bbs_seq_n=161753&file_seq_n=1)

MOTIE. (2019b). *Press release from the morning of December 31, 2019 on the comparison of Fine Dust Emissions of Coal Power Generation in December.* 2019.

MOTIE. (2019c). *Third Energy Master Plan.*

National Council on Climate and Air Quality. (2019). *National policy proposal to solve the fine dust problem.*

Powering past coal Alliance. (2017). *POWERING PAST COAL ALLIANCE: DECLARATION.* Retrieved from [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/660041/powering-past-coal-alliance.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/660041/powering-past-coal-alliance.pdf)

Republic of Korea. (2015). *Submission by the Republic of Korea Intended Nationally Determined Contribution* (pp. 1–4). pp. 1–4. Retrieved from <http://www4.unfccc.int/submissions/INDC/Published Documents/Republic of Korea/1/INDC Submission by the Republic of Korea on June 30.pdf>

Reuters. (2019). *South Korea steps up fight against pollution, says problem is “social disaster.”*

Sferra, F., Krapp, M., Roming, N., Schaeffer, M., Malik, A., & Hare, W. (2018). Towards optimal 1.5°and 2°C emission pathways for individual countries: a Finland case study. *Energy Policy in Review, submitted.*

Sferra, F., Schaeffer, M., & Torres, M. (2018). *Report on Implications of 1.5°C Versus 2°C for Global Transformation Pathways.* Retrieved from [https://www.cop21ripples.eu/wp-content/uploads/2018/06/RIPPLES-Deliverable-2-3\\_2018\\_06\\_04\\_FINALc.pdf](https://www.cop21ripples.eu/wp-content/uploads/2018/06/RIPPLES-Deliverable-2-3_2018_06_04_FINALc.pdf)

Statista. (2018). Distribution of coals imported into South Korea in 2017, by country of origin.

Steckel, J. C., Garg, A., Burton, J., Friedmann, J., Jotzo, F., Luderer, G., ... Yanguas Parra, P. (2017). *UNEP Emissions GAP Report 2017-Chapter 5.*

Teske, S., Meinshausen, M., & Dooley, K. (2019). *Achieving the Paris Climate Agreement Goals.*

UN DESA. (2019). *World Population Prospects 2019.* Retrieved August 13, 2019, from <https://population.un.org/wpp/Download/Standard/Population/>

UNEP. (2019). *Emissions gap report 2019.* <https://doi.org/10.18356/ff6d1a84-en>

UNFCCC. (2015). Paris Agreement. *Conference of the Parties on Its Twenty-First Session*, Vol. 21932, p. 32. <https://doi.org/FC/CP/2015/L.9/Rev.1>

World Nuclear Association. (2018). *“Clean Coal” Technologies, Carbon Capture & Sequestration.* 1–12.

Wuppertal Institute for Climate Environment and Energy. (2008). *Ecological, Economic and Structural Comparison of Renewable Energy Technologies with Carbon Capture and Storage.*

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