



# Transitioning towards a zero-carbon society: science-based emissions reduction pathways for South Korea under the Paris Agreement

May 2020

## **Transitioning towards a zero-carbon society: science-based emissions reduction pathways for South Korea under the Paris Agreement**

May 2020

### **Authors**

Ursula Fuentes Hutfilter, Ryan Wilson, Matthew Gidden, Gaurav Ganti, Deborah Ramalope, Bill Hare

### **Acknowledgements**

We would like to thank collaborators, who have made this report possible. In particular Dr. Andreas Geiges and Matt Beer for their efforts related to data science and graphic design, respectively. We would also like to express our gratitude to the team of Solutions for Our Climate for their extensive comments and suggestions. Nonetheless we would like to emphasise that the sole responsibility for the content of the study and any areas therein, lies with the authors.

We would also like to thank the IAM modelling groups that have contributed their data to the IPCC scenario database, which has significantly enabled and facilitated our work.

This publication may be reproduced in whole or in part and in any form for educational or non-profit purposes without special permission from Climate Analytics, provided acknowledgment and/or proper referencing of the source is made.

This publication may not be sold or used for any commercial purpose without prior written permission from Climate Analytics.

This document may be cited as: Climate Analytics (2020). Transitioning towards a zero-carbon society: science-based emissions reduction pathways for South Korea under the Paris Agreement.

A digital copy of this report is available at:  
[www.climateanalytics.org/publications](http://www.climateanalytics.org/publications)

This report was funded by the European Climate Foundation (ECF).

**In collaboration with:**



**TABLE OF CONTENTS**

---

**SUMMARY ..... 1**

**INTRODUCTION ..... 2**

**NATIONAL CLIMATE TARGETS ..... 3**

**CURRENT POLICY PROJECTION ..... 4**

**PARIS AGREEMENT COMPATIBLE EMISSIONS PATHWAYS for South Korea..... 6**

**ADEQUACY OF NATIONAL DOMESTIC TARGETS .....10**

**ADEQUACY OF NATIONAL NDC TARGET – COMPARISON WITH FAIR SHARE RANGE.....10**

**CONCLUSION AND POLICY RECOMMENDATIONS .....12**

**ANNEX I — SIAMESE.....15**

**ANNEX II – METHODOLOGY FOR DERIVING LEAST-COST PARIS AGREEMENT COMPATIBLE EMISSIONS PATHWAYS FOR SOUTH KOREA.....16**

**ANNEX III – METHODOLOGY FOR DERIVING A FAIR SHARE RANGE FOR SOUTH KOREA.....18**

**REFERENCES.....19**

## SUMMARY

---

2020 is a critical year for more ambitious emissions reductions: Governments are expected to bring forward enhanced emission reduction commitments (Nationally Determined Contributions, or 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.

South Korea's current NDC is rated as "highly insufficient" by the Climate Action Tracker, and if all governments' climate targets were in the same range, the world would warm by 3 to 4°C, more than double the limit in the Paris Agreement. Like all other nations that signed the Paris Agreement, South Korea is obligated to **update its NDC in 2020** in order to play its part in reducing global emissions sufficiently by 2030 to keep the 1.5°C limit in the Agreement within reach, and close the gap identified by the world's peak climate science body, the Intergovernmental Panel on Climate Change (IPCC).

The intended Green New Deal legislation aiming for a net zero emissions target in 2050 is an opportunity to link it with an enhanced NDC target to ramp up climate ambition and action. Here are the key considerations for South Korea in strengthening its NDC:

- **Transformational ramping up of ambition** - not just incremental change - is needed. Dynamic technological and social developments and innovation make this possible.
- The **overall NDC, which incorporates both domestic reductions and its fair share contribution to the international effort**, needs to be scaled up to 70-94% below 2017 emission levels by 2030. At present its NDC target is only 24.4% below 2017 levels.
- A **fair share contribution to international efforts needs to complement an adequate domestic target** and lead to **real and additional emission reductions**. It cannot replace this domestic contribution to deep decarbonisation in line with the Paris Agreement. The recent announcement to account for management of existing forest as a large part of this non-domestic contribution would reduce this additional contribution to international effort and risk reducing the overall level of ambition without real and additional reductions.
- In line with good practice, **South Korea's NDC needs to be expressed as reduction against a base year in absolute emission terms, rather than against a Business-as-Usual (BAU) projection**. At present the NDC is described as a reduction of 37% below BAU. The new NDC target would need a reduction of at least 74% below BAU (corresponding to **70% below 2017 emission levels**) to constitute a **fair share to achieving the Paris Agreement Long-Term Temperature Goal**.
- The **domestic reduction component of the NDC** would need to be scaled to up to **59% below 2017 emission levels by 2030**. At present its domestic reduction target is only 19% below 2017 levels. Expressed as change from BAU, the domestic target would need to be increased from the current 32.5% to a 66% reduction below BAU (59% reduction below 2017 levels). This would be consistent with a global least-cost pathway in line with the Paris Agreement, which minimises reliance on large-scale carbon dioxide removal (CDR) technologies and mitigation options in the future.
- A strategy to achieve this reduction would need to address transformational contributions by all sectors, building on the current approach of sectoral targets. In particular, it would need to **accelerate the transition away from coal and other fossil fuels towards renewable energy**. South Korea's power mix has a low share of renewable energy but the country has significant potential for expanding solar photovoltaics and wind. It can then also build on its aim to develop a hydrogen economy, focusing it on green hydrogen.
- Fast action to fully decarbonise the electricity generation is a fundamental step in reducing emissions in all other sectors, where electrification plays an important role. **South Korea needs to phase out coal for power generation by 2029**, which entails developing a clear roadmap. A fast and orderly phase-out of coal from power generation brings many additional economic, environmental, and health co-benefits which builds the foundations for a just and well-managed energy transition.

## INTRODUCTION

---

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, recognising that this would significantly reduce the risks and impacts of climate change (UNFCCC, 2015a). 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 from getting global emissions on a pathway in line with the Long-term Temperature Goal of the Paris Agreement (PA LTTG) (Climate Action Tracker, 2019c; 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.

Current collective efforts committed to by countries under the Paris Agreement are projected to lead to warming of 2.8°C (Climate Action Tracker, 2019b), a dangerous level of warming with potentially catastrophic impacts. Even with these low levels of ambition, countries' planned policies are inadequate to achieve their current NDC targets. This calls for urgent and ambitious action by everyone to close the emissions gap. 2020 provides an important milestone for countries to ramp up ambition and action and to align their NDCs with the Paris Agreement. Transformational, not incremental change is needed to scale up NDC targets and collectively bring pathways in line with the Paris Agreement (Climate Analytics, 2019b).

Like many countries' NDCs, South Korea's current NDC is also not PA compatible. Its NDC has a target of reducing greenhouse gas emissions by 37% below business as usual (BAU) by 2030, which translates into a 24.4% reduction below 2017 levels.

In its latest 2030 GHG roadmap (July 2018), South Korea increased the domestic emission reduction component of its NDC from 27.5% to 32.5% reduction below BAU by 2030 with the remaining 4.5% to be achieved through international market mechanisms and forestry (Ministry of Environment, 2018). The Climate Action Tracker has rated the NDC target as "highly insufficient", while the domestic component of the NDC is currently projected to be missed without much stronger climate action (Climate Action Tracker, 2019a).

The recent landslide victory of the ruling Democratic party gives it a strong mandate to implement the intended Green New Deal aiming at net zero emissions by 2050. This needs to be linked with a clear roadmap for phasing out coal and enhance the 2030 NDC target.

The single most important step to significantly reducing emissions is phasing out coal for power generation. In February we released a report detailing what is required from South Korea to ensure its power sector emissions are in line with limiting warming to 1.5°C as per the Paris Agreement (Climate Analytics, 2020). This report showed that South Korea must phase out coal, the most polluting source of electricity generation, by 2029, while rapidly scaling up its use of renewable energy technologies.

With this follow up report, we analyse how much improvement is needed in South Korea's economy-wide emission reduction target for it to be consistent with Paris Agreement. We establish economy-wide benchmarks for domestic emission reductions in 2030 consistent with the PA 1.5 limit, based on downscaling of least-cost PA mitigation pathways to South Korea.

We then compare a fair-share based range of emissions reductions for South Korea, building on the analysis of the Climate Action Tracker (2019) with the overall NDC Target, which can include both domestic action and additional contributions through international support.

This analysis provides an indication of the share of domestic and international action that South Korea would need to aim for by 2030 in order to be compatible with the Paris Agreement.

This report is structured as follows:

1. South Korea's national climate targets will be outlined and put into context with both their current and planned climate policies;
2. A range of Paris Agreement compatible economy-wide emission reduction pathways will be derived and explained;
3. The resulting emissions reductions by 2030 will be compared with South Korea's domestic reduction target;
4. The adequacy of current national targets will be discussed comparing a "fair share" range derived from scientific literature based on the Climate Action Tracker's analysis of the NDC target,
5. Conclusions will be drawn regarding the need to enhance the current NDC this year to comply with the decisions implementing the Paris Agreement and the need to close the 2030 ambition and action gap as highlighted by the UNSG and the UNFCCC.

## NATIONAL 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. According to government calculations, this amounts to an emissions level of 536 MtCO<sub>2</sub>e in 2030, however, this is using the global warming potentials (GWP) from the Second Assessment Report (SAR) of the IPCC published in 1995. The independent assessment Climate Action Tracker estimates that the NDC target corresponds to a level of 539 MtCO<sub>2</sub>e based on GWP values from the Fourth Assessment Report (AR4) of the IPCC, and corresponds to a reduction of 19% below 2010 emissions levels by 2030 (Climate Action Tracker, 2019a). The Climate Action Tracker assumes that the target excludes the Land Use and Land Use Change and Forestry (LULUCF) sector (Climate Action Tracker, 2019a), which is consistent with the NDC and subsequent Government reports (Government of the Republic of Korea, 2019a, 2019b). The Climate Action Tracker rates the NDC target as "highly insufficient" compared to the levels that would be required to achieve the Long-term temperature goal of the Paris Agreement.

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). The NDC currently excludes the Land use, land-use change and forestry (LULUCF) sector, but refers to a decision to be taken later regarding a possible inclusion of LULUCF.

In December 2019, the South Korean government updated its Enforcement Decree for the Framework Act on Low Carbon Green Growth to formalise its 2030 emissions reduction target as a 24.4% reduction in nationwide GHG emissions below 2017 levels (Ministry of Environment, 2018). This equates to an emissions level of 536 MtCO<sub>2</sub>e, in line with the current NDC target for a 37% emissions reduction below business as usual (BAU) by 2030. If South Korea were to update the NDC based on this new framing, the updated target utilising a reduction against a base year (2017), increases transparency by clearly presenting the absolute emissions reductions implied by the target, instead of against a BAU pathway, but it would not increase the level of ambition which is what is needed for an updated NDC pursuant to Article 4.3 of the Paris Agreement.

The South Korean government has confirmed in its latest Biennial Update Report (BUR) and in the amendment to the 2030 Roadmap that as part of the non-domestic component of its NDC, it aims to use accounting of forest sinks to achieve part of the additional reductions beyond the domestic target. In its Roadmap update, it specifies that it wants to achieve 22 MtCO<sub>2</sub> in annual reductions by 2030 through accounting of forest sinks mainly through accounting of management and enhancement of existing forest, with only the remaining 16 MtCO<sub>2</sub> of targeted non-domestic reductions to come from international carbon credits (Government of the Republic of Korea, 2019a; Ministry of Environment, 2018). This breakdown is not provided in the latest National Communication and BUR provided to the UNFCCC. It would in fact reduce the contribution to international efforts, without

increasing the domestic target. Accounting of management of existing forests would not contribute to the necessary transformation to achieve real emission reductions.

South Korea's ruling party recently won the April 15 legislative election with a landslide victory, giving it a mandate to implement an ambitious Green New Deal based on its intention to legislate policies (Farand, 2020). Their proposed policy package for a Green New Deal includes a carbon tax, a phase-out of domestic and international coal project financing, and a scaling-up of renewable energy investment. This does not yet include a commitment to increase the ambition level of the 2030 NDC target.

## CURRENT POLICY PROJECTION

---

As South Korea is projected to miss its “highly insufficient” NDC by a wide margin, their 2030 projected emissions level under current policies falls in the “critically insufficient” category of the Climate Action Tracker (Climate Action Tracker, 2019a). This represents a trajectory towards warming of over 4°C assuming similarly insufficient actions from other countries.

**Figure 1** shows the rapid growth in South Korean GHG emissions in particular over the two decades to 2010, with the energy sector (electricity generation, oil refining, and solid fuel manufacturing) being the largest, contributing 38% to total emissions in 2017. **Figure 1** also demonstrates that under current policy projections, emissions are not expected to fall over the coming decade, rather showing a continued steady increase to 2030. The domestic emission reduction component of South Korea's NDC is also shown in **Figure 1**, demonstrating that a sharp increase in efforts would be needed simply to achieve the existing, insufficient emissions target.

The South Korean government has included a “current policy” projection of GHG emissions to 2030 in their Fourth National Communication released in November 2019 (Government of the Republic of Korea, 2019b). The projected 2030 emissions level under this scenario (850.6 MtCO<sub>2e</sub>) is the same as the Business as Usual (BAU) scenario used in 2015 to derive their current 37% below BAU emissions reduction target. This would imply no relevant emissions reductions policies implemented between 2015 and 2019, despite adopting the 8<sup>th</sup> Basic Plan for Long-Term for Electricity Supply and Demand in 2017 which contained a 20% renewable energy generation target, and indicates a 26.4% reduction in GHG emissions below the 2030 BAU scenario (MOTIE, 2017).



## South Korea Greenhouse Gas Emissions

Historical breakdown and current policy projections to 2030

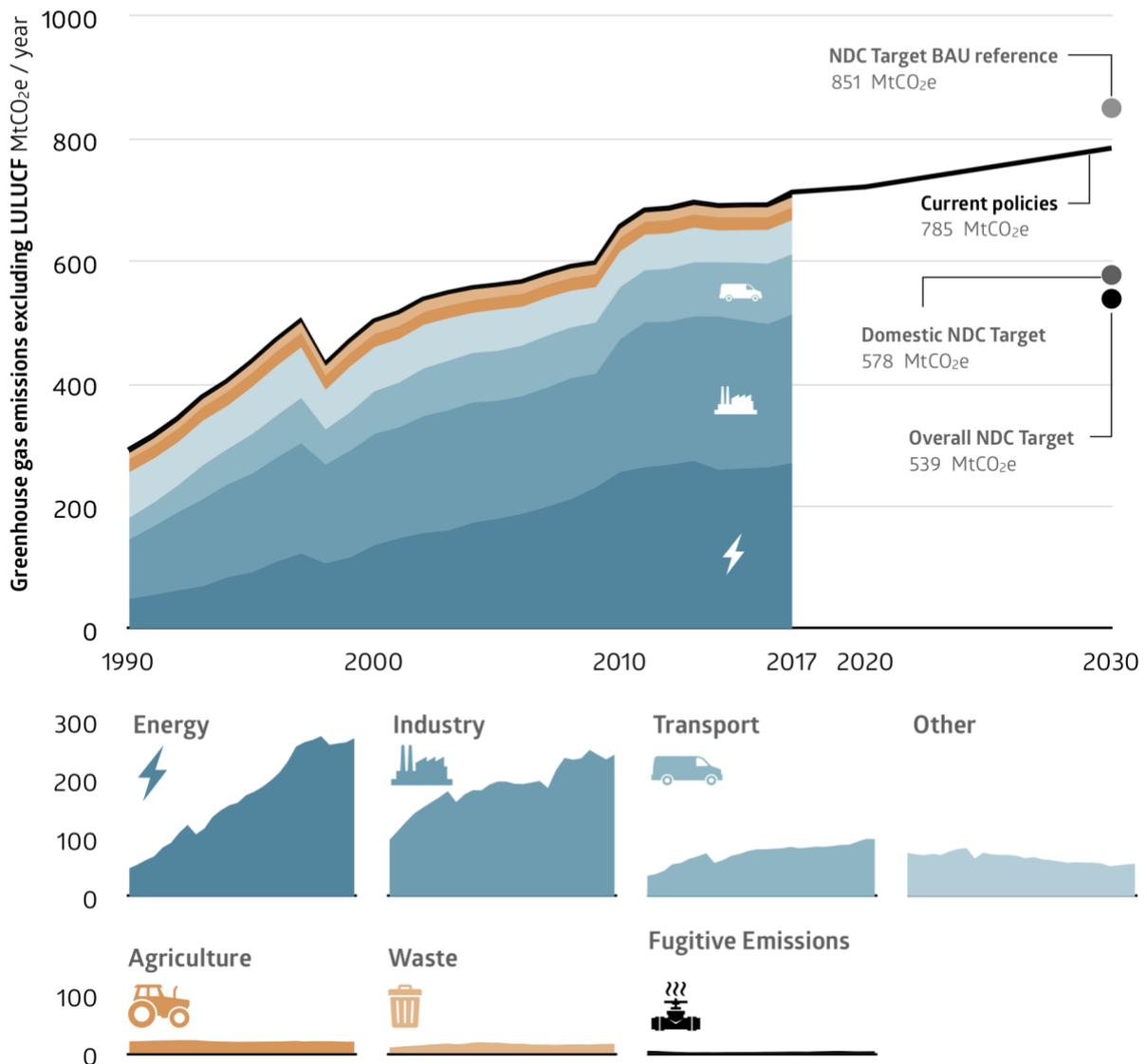


Figure 1. Sectoral breakdown of historical emissions and projection to 2030<sup>1</sup>

(Sources: SK National Greenhouse Inventory 2019, projection based on Climate Action Tracker, with data from US EPA 2019, APERC 2019) (not corrected to AR4 GWP)<sup>2</sup>

Two key cross-sectoral policies currently in place are the Korea Emissions Trading Scheme (ETS) launched in 2015, and the GHG Energy Target Management System (TMS) launched in 2012, which covers emitters not covered by the ETS. The ETS covers 68% of national GHG emissions and nearly 600 companies from 23 sub-sectors including all installations in the industrial and power sectors with annual emissions higher than 25 ktCO<sub>2</sub>e (ICAP, 2019b), and includes both direct and indirect emissions.

The emissions cap has increased by 110 MtCO<sub>2</sub>e between Phase I over 2015-2017 (1,686 MtCO<sub>2</sub>e), to Phase II over 2018-2020 (1,796 MtCO<sub>2</sub>e), wherein 97% of permits will be allocated for free, with just 3% to be auctioned. The auctioned fraction is to be increased to 10% in Phase III (2021-2025), a markedly smaller proportion than in

<sup>1</sup> Historical emissions are taken from National Greenhouse Inventory 2019; emission projections are derived by combining projections of energy-related CO<sub>2</sub> emissions (APERC, 2019), and non-CO<sub>2</sub> emissions based on (US EPA, 2019) data.

<sup>2</sup> The South Korean government uses global warming potentials (GWP) from the IPCC's Second Assessment Report (SAR) to calculate its GHG emissions inventory. As a result, the GHG emissions values reported here are in SAR GWP, rather than GWPs from the Fourth Assessment Report (AR4)

the current phase of the EU ETS (2013-2020), where, by comparison, 57% of permits will be auctioned (ICAP, 2019a).

The 2030 GHG Roadmap, adopted in 2018, provides details on sector-specific reduction targets as well as policy measures to be further encouraged. This includes stricter building standards, industrial energy efficiency and process improvement measures and the promotion of eco-friendly raw materials and fuels (Ministry of Environment, 2018).

With regards to the power sector, which produced 54% of national CO<sub>2</sub> emissions from fuel combustion in 2017, the current President, Moon Jae-In, has indicated an intention to reduce reliance on nuclear and coal-fired power and increase the share of renewable energy. However, current targets are not ambitious enough - with 36% of electricity in 2030 to be generated from coal powered plants, and 18.8% of generation is targeted to come from natural gas (MOTIE, 2017). Our previous report that produced a science-based coal phase-out pathway for South Korea, released in February 2020, stipulated a phase-out date of 2029 that would bring South Korea's power sector in line with the long-term temperature goal of the Paris Agreement (Climate Analytics, 2020).

The ruling party's recently announced Green New Deal policy suite proposes an ambitious net-zero 2050 emissions target, but does not provide details as to how it would get there, or to what extent emissions would be reduced over the near-term.

## **PARIS AGREEMENT COMPATIBLE EMISSIONS PATHWAYS FOR SOUTH KOREA**

---

The IPCC Special Report on 1.5°C (SR15) adopted and published in October 2018 outlines pathways for limiting global warming to 1.5°C and assesses global, regional, and sectoral transformations in the near-, mid-, and long-term, as well as synergies and trade-offs for sustainable development. With this, the SR15 currently provides the best available science for operationalising the LTTG. It provides the most comprehensive and up-to-date assessment of mitigation pathways consistent with the PA LTTG. The IPCC SR15 clearly shows that rapidly reducing emissions by 2030 – by around 45% compared to 2010 globally – is an important strategy in achieving the Paris Agreement 1.5°C target and to avoid the risk of institutional and economic lock-ins with carbon intensive infrastructure, which will then be costly or more difficult to phase out later. Delaying emissions reductions would reduce the flexibility of future response options and increase the reliance on Carbon Dioxide Removal (CDR). All pathways require a rapid decarbonisation of energy systems by 2050.

The long-term temperature goal in the PA is stronger (well below 2°C, pursue efforts towards 1.5°C) than the previous target established under the Cancun Agreements (below 2°C). This means that emissions pathways compatible with the PA must increase substantially both the margin and likelihood by which warming is kept below 2°C when compared with these former “below 2°C” emissions pathways, and simultaneously be consistent with the 1.5°C limit of the PA. This is reflected in the SR15 Summary for Policymakers (SPM) establishing 1.5°C compatible mitigation pathways as being pathways with no or limited overshoot. More specifically, this includes mitigation pathways that limit median global warming to 1.5°C throughout the 21<sup>st</sup> century without exceeding that level (“no-overshoot”), or that allow warming to drop below 1.5°C by the end of the century (around 1.3°C warming by 2100) after a brief and limited overshoot (less than 0.1°C) of median peak warming below 1.6°C around the 2060s (“low-overshoot”).

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. This is reflected in the Integrated Assessment Model (IAM) pathways assessed by the IPCC through two main options: either as large-scale afforestation and reforestation (AR) or the use of bio-energy and carbon dioxide storage (BECCS).

The IPCC finds limits for a sustainable use of both CDR options globally by 2050 to be below 5 GtCO<sub>2</sub> p.a. for BECCS and below 3.6 GtCO<sub>2</sub> p.a. for sequestration through AR while noting uncertainty in the assessment of sustainable use and economic and technical potential in the latter half of the century (Climate Analytics, 2019c). Integrated Assessment Models (IAMs) are used to develop mitigation pathways as described above. They provide an estimate of domestic mitigation contributions across geographic regions, as well as for all sectors, aiming at minimising overall global mitigation costs whilst meeting a climate or carbon budget target. By doing so, IAMs take into account the interactions between economic development, energy consumption and climate change emissions, under “idealised” conditions (for example a global carbon price or emissions trading scheme). The outcome is an estimate of “economically optimal” domestic contributions.

IAMs have clear limitations; the way most of the models are set up assumes that mitigation of climate change is always more expensive than non-action. This results from assessing least-cost pathway mitigation costs compared to a business-as-usual (BAU) scenario, and starting from the assumption that the BAU scenario is already economically optimal (Climate Analytics, 2019a). These models represent past technologies and trends much better than newer technologies such as energy storage, electrolysers, and green hydrogen whose future costs and deployment pathways are harder to predict, while recent and significant cost reductions in existing technologies such as solar photovoltaics (PV) are not captured. As a consequence, experience shows most IAMs tend to have a conservative view of the potential for transformational change. However, despite their limitations, IAMs still provide reasonable, but conservative, guideposts for whole-of-economy pathways consistent with the Paris Agreement.

We therefore estimate PA compatible cost-effective pathways for domestic emissions reduction in South Korea by making use of Climate Analytics’ SIAMESE (Simplified Integrated Assessment Model with Energy System Emulator) model (Sferra et al., 2019) (see Annex I). This approach is consistent with other studies looking at national implications of results from global and regional energy models (Climate Analytics, 2019a). We calculate these trajectories by first estimating emissions from energy supply and consumption resulting from a variety of IAM results with consistent assumptions of socioeconomic and technological progress in addition to a scenario from the IEA that was also used for our earlier report (Climate Analytics, 2020). These pathways are harmonised to the latest year of available emissions inventories (2017) and supplemented with non-energy use pathways from the IMAGE model (Government of the Republic of Korea, 2019c) which resolved directly for Korea, creating a whole-of-economy estimate for a Paris Agreement compatible target.

A full description of the assessment methodology is provided in Annex II. The IEA Energy Technology Perspectives (ETP) Beyond 2°C Scenario (B2DS) (International Energy Agency, 2017) explores how much available technologies and those in the innovation pipeline could be pushed to put the energy sector on a trajectory that would limit warming to well below 2°C. The B2DS scenario can be used as a proxy for Paris Agreement 1.5°C compatible pathways (see also Climate Analytics 2019a, CAT, 2018). The IPCC Special Report on 1.5°C assessed the B2DS and found that characteristics of the energy system in this scenario are comparable to the range of mitigation pathways that achieve the 1.5°C limit with no- or limited overshoot.<sup>3</sup> The B2DS was used in our previous report which used this scenario to derive a PA compatible coal phase-out pathway for South Korea’s electricity sector because it is the only 1.5°C compatible IAM scenario that situates South Korea in the OECD, a suitably homogeneous region. Here, we have downscaled TPED (Total Primary Energy Demand) from the OECD region in the IEA B2DS using historical data for South Korea from 2014, the starting year for the B2DS. The downscaled IEA B2DS pathway was further adjusted to take into account the projected emissions increase until 2020, but keeping the same cumulative emissions. Steeper emissions reductions are therefore necessary to compensate for lack of action over the past five or so years.

---

<sup>3</sup> The warming impact of the IEA B2DS depends on the assumptions made for non-energy-related and non-CO<sub>2</sub> emissions. The IEA estimated a peak global warming of 1.75°C. However, if the average assumptions are applied as in comparable mitigation scenarios as analysed by the IPCC, and if the pathway is extended beyond 2060 (the final year in B2DS) allowing for net negative emissions in the energy sector, at a level similar to that in other scenarios assessed by the IPCC, then we find that the B2DS reaches peak warming of 1.6°C and warming drops below 1.5°C before 2100. With these additional assumptions B2DS would therefore fully classify as what IPCC SR15 calls a no- or limited overshoot pathway. Indeed, IPCC SR15 in Chapter 2 notes “... this [B2DS] scenario can give information related to a 1.5°C overshoot pathway up to 2050.” (CAT, 2018)

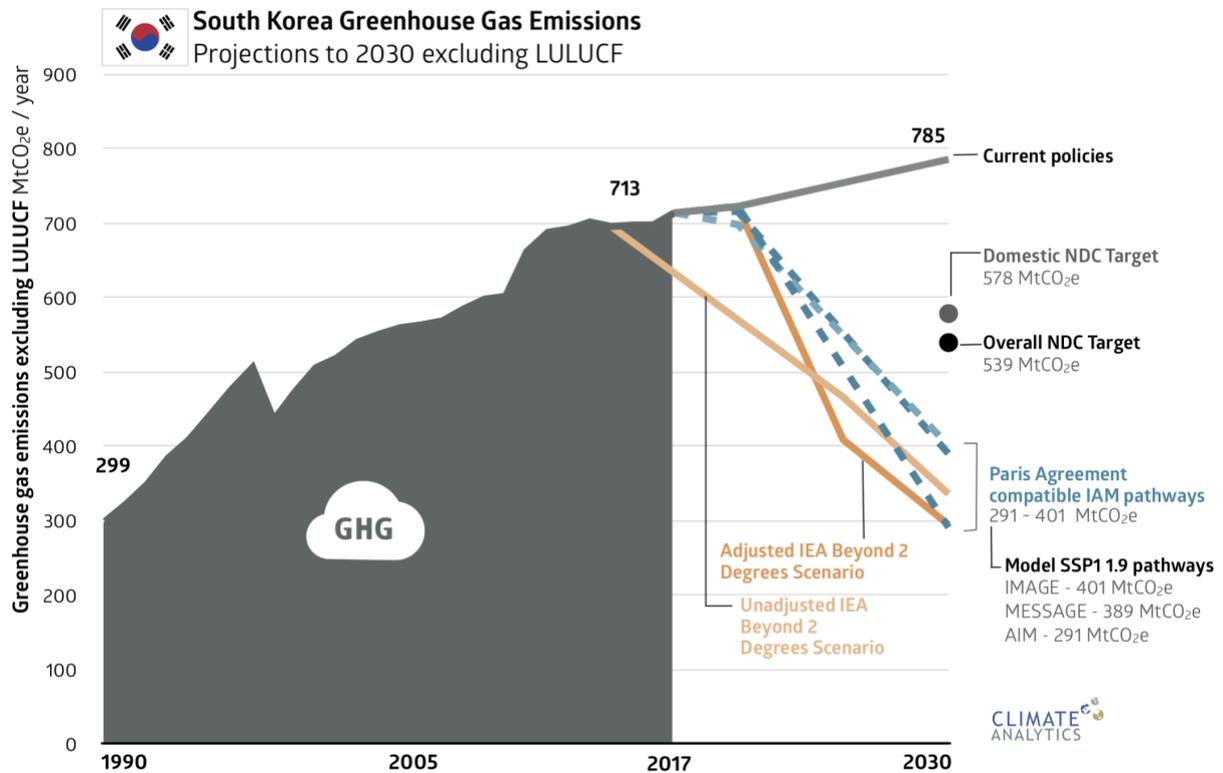


Figure 2. Current policy projection and PA compatible pathways to 2030 excl. LULUCF

Figure 2 shows the resulting Paris Agreement compatible GHG emissions pathways for South Korea. While the emissions levels implied by the downscaled IAM pathways track fairly closely to those projected under current policies until 2020, this is due to the design of the latest iteration of IAMs, which assume strong mitigation efforts do not begin prior to 2020. A sharp deviation from emissions projected under current policies occurs post-2020, however, whereby the emissions range stipulates a much higher level of policy ambition to bring about a steep reduction in total emissions to 2050.

The 2030 upper and lower values of the range of emissions of PA compatible pathways analysed here are 401 and 291 MtCO<sub>2</sub>e respectively, with all values falling within this range representing a significantly deeper emission cut than South Korea’s current domestic NDC, which at 578 MtCO<sub>2</sub>e by 2030, sits well outside this range. This range represents absolute emissions reductions below 2017 levels of between 44-59%, whereas the domestic NDC represents an emissions reduction of 19% below 2017 levels. These steep reductions are driven by a combination of declining overall energy demand, as well as replacement of coal and natural gas demand primarily with increased renewable energy generation.

Phasing out coal-fire power generation is the single most important step to achieve these steep emissions reductions in line with the Paris Agreement, as we have shown in our previous report (Climate Analytics, 2020). Fast action to fully decarbonise the electricity generation is a fundamental step in reducing emission 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 GHG emissions (Climate Analytics, 2020).

It is notable that the most ambitious pathway of the three IAMs analysed here is from the AIM (Asia-Pacific Integrated Model), developed by a collaboration of the Japanese National Institute of Environmental Studies and Kyoto University. With a specific focus on the Asia-Pacific region and having been developed in the region, this model embodies a high degree of local expertise, providing a high degree of confidence in the achievability of the level of ambition implied by this emissions pathway. The IEA B2DS adjusted to reflect a later start of mitigation confirms this more ambitious end of the range in 2030.

The two IAMs analysed that reflect a higher 2030 level of emissions (IMAGE, MESSAGE) imply the need for a greater degree of carbon dioxide removal (CDR) in later years<sup>4</sup>. The downscaled scenarios, while consistent with the PA 1.5 limit and sustainability limits to CDR use around 2050, lead to less reductions compared to 2010 by 2030 (39-41%) for Korea than what is needed globally (45%) in line with the Paris Agreement, and rely more on CDR than the pathways with higher reductions by 2030, with a share of BECCS factor 2-3 higher than in the downscaled AIM scenario for Korea.

In contrast to well-proven mitigation options such as expansion of renewable energy in particular solar PV and wind energy, there are considerable challenges related to CDR options. While they are considered necessary to a certain extent in most mitigation pathway studies, there are some important challenges that need to be addressed through increased research and development and careful assessment of synergies and trade-offs with sustainable development in relation to sustainable use of CDR options (Climate Analytics, 2019c).

Significant recent cost reductions of existing renewable energy technologies such as solar PV and battery storage and increasing prospects of others such as green hydrogen, suggest that investing more heavily in these to reduce emissions further over the short to medium term is a less risky approach than relying on CDR technologies in the long term while allowing relatively higher short to medium term emissions.

We therefore conclude that the lower end of the range should be aimed for in an updated NDC as a robust strategy to reduce the risk of relying on CDR technologies and options through this and next century.

---

<sup>4</sup> BECCS is factor 2.8 and 1.8 higher than in AIM for IMAGE and MESSAGE, respectively. (The IEA B2DS scenario has a much smaller share of BECCS than the IAM pathways).

## ADEQUACY OF NATIONAL DOMESTIC TARGETS

The domestic emission reduction component of South Korea’s NDC is for a 32.5% reduction below BAU by 2030. This corresponds to a 2030 emissions level of 578 MtCO<sub>2e</sub><sup>5</sup>, which is significantly less ambitious than any value within the PA compatible range of emissions reductions derived by our downscaled IAM scenarios. **Table 1** summarises this below.

The domestic reduction component of the NDC would need to be scaled up from the current 32.5% to 66% below BAU, and from the current 19% below 2017 levels to a 59% reduction below 2017 levels. This would be a level consistent with a global least cost pathway in line with the Paris Agreement and minimising reliance on large-scale CDR technologies and mitigation options in the future.

*Table 1. South Korea’s domestic emissions reduction target and least-cost PA compatible emissions range and recommendation for an updated Paris Agreement compatible NDC target level*

	Emissions MtCO <sub>2e</sub>	% reduction below BAU	% reduction below 2017 levels	% reduction below 2010 levels
<b>SK Domestic GHG Emission Reduction Target 2030 (SAR GWP)</b>	574	32.5%	19%	13%
<b>SK Domestic GHG Emission Reduction Target 2030 (AR4 GWP)</b>	578	32.5%	19%	13%
<b>Emissions Range in 2030 for three Least-cost PA Compatible pathways</b>	291 – 401	66-53%	59-44%	56-39%
<b>PA compatible domestic NDC target</b>	291	66%	59%	56%

## ADEQUACY OF NATIONAL NDC TARGET – COMPARISON WITH FAIR SHARE RANGE

In contrast to IAMs, equity approaches try to answer a very different question: what is a “fair share” for a country or region in the global mitigation effort? There is no globally agreed equity framework and a range of criteria for defining a “fair share” has been proposed and published in the literature, such as (historical) responsibility, capability and equality, and used to implement different quantitative equity approaches. In general, these approaches do not assume that mitigation occurs fully where the effort is being allocated based on equity approaches. If the equity consideration leads to larger reductions than the least-cost approach outlined in the previous section, this provides an indication of the expectation for a country to contribute to financing and/or supporting mitigation efforts in other countries (Climate Analytics, 2019a).

A clear definition of how to operationalise the notion of “equitable sharing” of the remaining emissions to hold warming to 1.5°C has proved elusive, and often reflects differing interests of the concerned governments. However, several proposals have been put forward. These include, for example, effort-sharing regimes based on the premise of “historic responsibility” (those who have contributed more emissions historically also take up a larger share burden for mitigation). The approaches can be categorised in the following manner (based on definitions used in Chapter 6 of WGIII of the 5<sup>th</sup> Assessment Report of the IPCC):

<sup>5</sup> The South Korean government uses global warming potentials (GWP) from the IPCC’s Second Assessment Report (SAR) to calculate their emission reduction targets in absolute emissions levels. We convert these values using GWP from the Fourth Assessment Report (AR4)

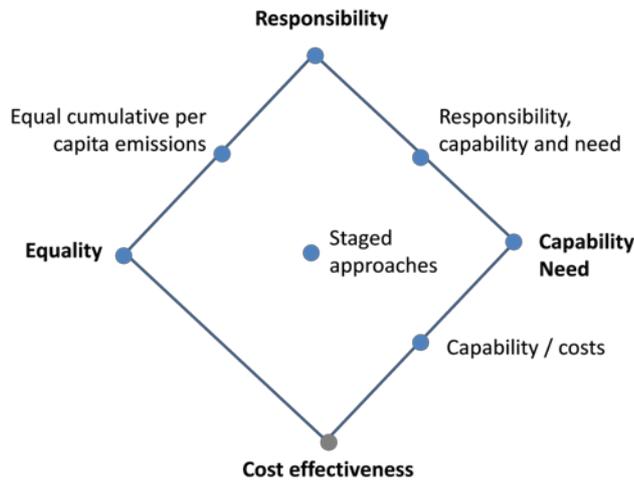


Figure 3. Categories of "effort-sharing" regimes (Höhne, den Elzen, & Escalante, 2014)

The Climate Action Tracker provides a range of GHG emissions for selected countries that incorporates considerations of historical responsibility, capability, and equality from the relevant literature. This is referred to as a country's "Fair Share" range of GHG emissions, and is a representation of that country's fair contribution towards limiting warming to 1.5°C. We compare the emissions consistent with the 1.5°C Paris Agreement compatible Fair Share range for South Korea to the 2030 NDC target.

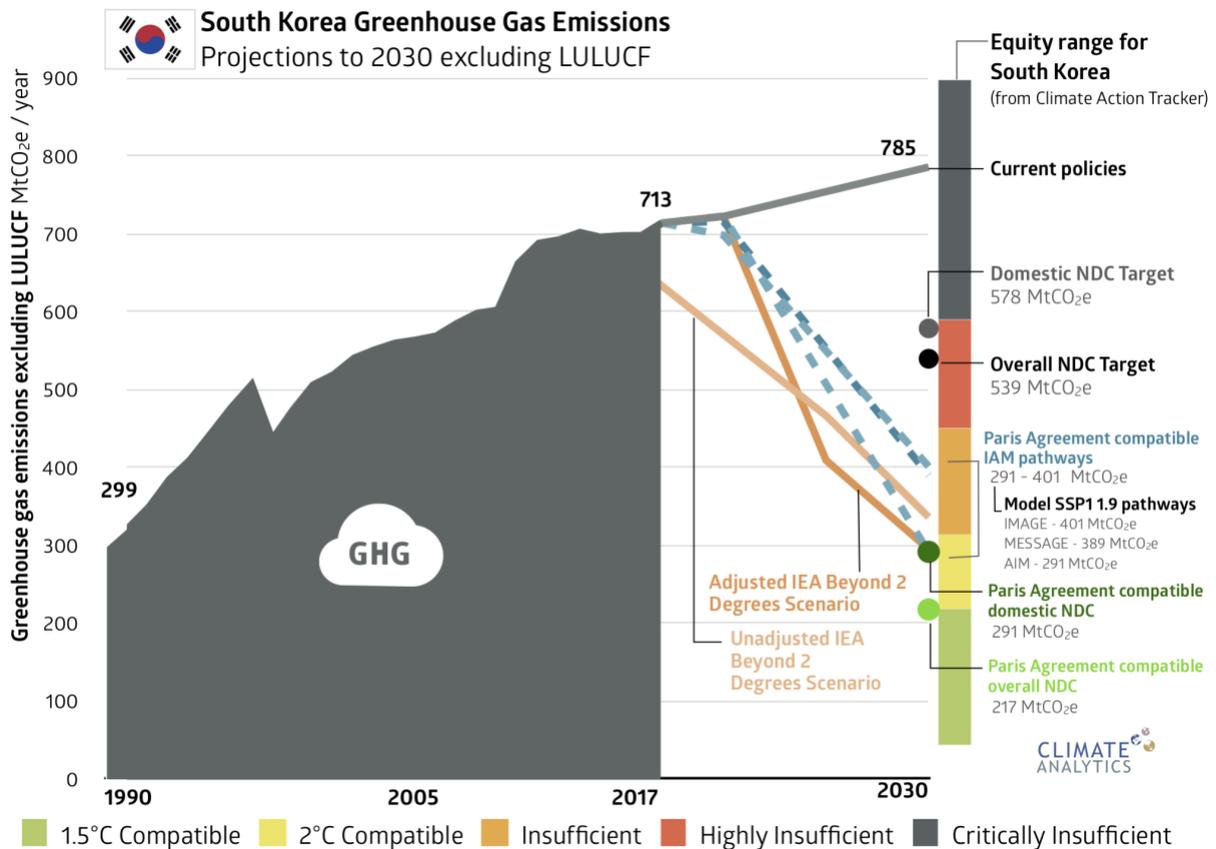


Figure 4. South Korea's "highly insufficient" NDC and "fair share" 2030 emissions range as per the CAT methodology including PA compatible domestic and overall NDC. Source: own calculation, based on Equity ranges from the Climate Action Tracker. The "Fair Share Range" is comprised of the three categories "1.5 C PA compatible", "2°C compatible", and "Insufficient". See Annex II for detailed explanation of methodology.

The Climate Action Tracker rates South Korea's NDC as "highly insufficient", meaning that if all other countries made similarly unambitious commitments, warming of between 3°C and 4°C would occur (Climate Action Tracker,

2019a). The full 2030 CAT equity range for South Korea can be seen in **Figure 4**. The “insufficient” range represents 2°C–3°C of warming, while the “critically insufficient” range corresponds to >4°C of warming.

The fair share range implies deeper reductions in 2030 for South Korea than the Paris Agreement consistent least-cost domestic emission reductions pathway range.

This implies that while representing a range of least-cost emissions pathways that would constitute a PA compatible domestic emissions reduction, South Korea must commit to do more overall. Consistent with the approach for South Korea to achieve an NDC target through a combination of domestic reductions and international finance, the NDC target consistent with the Paris Agreement 1.5°C limit would need to be set to a level of not more than 217 MtCO<sub>2</sub>e in 2030, that is at least a reduction of 70% below 2017 levels (74% below BAU). We also show the results for a reduction consistent with the former “hold below 2°C” goal agreed 2010 in Cancun. This falls within the Fair Share range, but is not fully consistent with the Paris Agreement.

**Table 2.** South Korea’s NDC vs. 1.5°C compatible “fair share” range of emissions

	Emissions MtCO <sub>2</sub> e	% reduction below BAU	% reduction below 2017 levels	% reduction below 2010 levels
<b>SK Overall GHG NDC Emission Reduction Target 2030 (SAR GWP)</b>	536	37%	24.4%	19%
<b>SK Overall GHG Emission Reduction Target 2030 (AR4 GWP)</b>	539	37%	24.4%	19%
<b>Paris Agreement 1.5° compatible “fair share” range (AR4 GWP)</b>	42 – 217	95-74%	94-70%	94-67%
<b>“Stay below 2°C” (old Cancun target) compatible range (AR4 GWP)</b>	217 – 313	74- 63%	70-56%	67-53%

## CONCLUSION AND POLICY RECOMMENDATIONS

### 2020 REMAINS A CRITICAL YEAR FOR ENHANCED CLIMATE ACTION

We have shown that the current 2030 NDC target is not consistent with the PA’s 1.5°C limit. South Korea needs to update its NDC to bring it in line with the Paris Agreement Long-Term Temperature Goal.

South Korea, like other Parties to the Paris Agreement, need to update their NDC in 2020, in line with the Paris Agreement decision and the urgent need to close the 2030 ambition and action gap identified by the IPCC and reiterated by Parties to the Paris Agreement. Transformational ramping up of ambition, and not just incremental change is needed, and also possible building on the dynamic technological and social developments and innovation.

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 Long-Term Temperature Goal.

Given the urgency of the climate threat, making bold steps for climate mitigation are necessary. Further delays of bold action imply higher cost and more risks in the future, by locking in emissions intensive infrastructure and

reliance on large-scale carbon dioxide removal technologies with potential risks for sustainable development. Collectively, failing to scale up climate action substantially by 2030 would put the PA LTTG to get out of reach.

In line with the recommendation in article 4.4 of the Paris Agreement, that developed countries undertake “economy-wide absolute emission reduction targets” (UNFCCC, 2015b) the South Korean NDC should be expressed as a reduction against a base year in absolute emission terms, rather than against a “Business as Usual” (BAU) projection. At present the NDC is described as a reduction of 37% below BAU.

## **BOLD SCALING UP OF DOMESTIC ACTION NEEDED**

The domestic reduction component of the NDC would need to be scaled up from the current 19% below 2017 levels to a 59% reduction below 2017 levels. Expressed in reduction below BAU as in current NDC, it would need scaling up from the current 32.5% to 66% reduction below Business as Usual. This would be a level consistent with a global least cost pathway in line with the Paris Agreement avoiding reliance on large-scale CDR technologies and mitigation options in the future.

We also conclude that a PA consistent pathway does not allow for any further delay in comprehensive mitigation action and get on a pathway towards net zero emissions.

A strategy to achieve this reduction would need to address transformational contributions by all sectors, building on the current approach of sectoral targets, and in particular would need to accelerate the transition away from coal and other fossil fuels towards renewable energy. Recent technology developments, in particular vast reductions in renewable energy and energy storage costs, advances in battery-electric vehicles (as well as fuel-cell vehicles, particularly for freight transport) and green hydrogen options for industry and heavy transport offer opportunities for faster emissions reductions than envisaged in scenarios that were developed even just a few years ago. South Korea can build on its aim to develop a hydrogen economy but needs to focus on green hydrogen and expand its currently low share of wind and solar energy in the power mix (Climate Analytics, 2020).

Fast action to fully decarbonise the electricity generation is a fundamental step in reducing emission 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 GHG emissions. We have shown that South Korea needs to phase out coal for power generation by 2029, and needs to develop a clear plan and roadmap to achieve this. A fast and orderly phase-out of coal for power generation entails many additional economic, environmental, and health co-benefits which builds the foundations for a just and well-managed energy transition in South Korea (Climate Analytics, 2020).

This would be an important step for a strategy to achieve net zero emissions by mid-century in line with the Paris Agreement as intended to be legislated with the Green New Deal by the ruling party that recently won a landslide victory on 15 April (Farand, 2020). An orderly and fast phase-out of coal for power generation would also be consistent with the policy goals outlined in the most recent Plan for National Environment approved by the State Council in December 2019, in particular the need to scale up emissions mitigation measures and targets to respond to the global climate emergency. Additional benefits for health and green growth need to be taken into account when defining targets and a strategy in line with the Paris Agreement.

A necessary step towards a net zero emissions strategy is the development of Paris Agreement and sustainable development consistent pathways and the translation of a broad legislative framework toward net zero emissions, as has been proposed, into a detailed roadmap and action plan, and use its elements in the development of the Long-Term Strategies due in 2020 under the framework of the Paris Agreement. These, together with the planned development of a roadmap for phasing out coal use by 2029, would form a solid policy foundation that would effectuate the required transformation changes required to align with the Paris Agreement 1.5°C limit.

## A FAIR NDC TARGET FOR SOUTH KOREA IN LINE WITH THE PARIS AGREEMENT

The overall NDC target for South Korea needs to be scaled up from a reduction of 24.4% below 2017 levels to at least a reduction of 70% below 2017 level for South Korea to contribute its fair share to achieving the Paris Agreement Long-Term Temperature Goal. Expressed as reduction below BAU as in current NDC, it would need scaling up from the current 37% below BAU to at least a reduction of 74% below BAU. This would go beyond the domestic emissions reduction of 59% below 2017 levels (66% reduction below BAU) in line with the Paris Agreement. This is consistent with the approach by South Korea to aim for additional reductions through international finance that would complement domestic emissions reductions in line with the Paris Agreement.

The recent announcement to account for management of existing forest as a large part of this non-domestic contribution would reduce this additional contribution to international effort and risk reducing the overall level of ambition without real and additional reductions. A fair share contribution to international efforts needs to complement an adequate domestic target and lead to real and additional emission reductions abroad.

This international finance and support for mitigation in developing countries needs to be consistent with the pathways that collectively achieve the Paris Agreement Long Term Temperature Goal. In particular, South Korea's continuing investment in carbon intensive projects in the Southeast Asian countries, particularly in coal fired power generation in Indonesia, Vietnam, and the Philippines are inconsistent with the Paris Agreement and Sustainable Development Goals and would undermine the necessary support for climate mitigation action and emission reductions in developing countries. Cooperation initiatives in the Asia-Pacific countries, including the "New Southern Policy" is a prime opportunity for South Korea to re-focus its international cooperation efforts and finance flows on facilitating acceleration of the global energy transition, promoting sustainable development in partner countries and thus contributing to the achievement of the Paris Agreement objectives (Climate Analytics, 2020). The commitment of the ruling party to phase out both domestic and overseas coal financing by public institutions is a promising step in this direction.

The Simplified Integrated Assessment Model with System Emulator (SIAMESE) is a reduced complexity IAM (Integrated Assessment Model), which provides cost-effective emission pathways at the country, or state level, taking into account the complex interaction between economic growth, energy consumption and climate change. For example, higher economic growth entails higher energy consumption leading to higher emissions (also depending on low carbon technology developments, costs and climate change targets). While downscaling results from a given model (e.g. IMAGE, MESSAGE, AIM etc.), SIAMESE takes into account a coherent set of assumptions in line with a Shared Socioeconomic Pathway (SSP) (Fricko, Havlik, Rogelj, Klimont, & Gusti, 2017; Riahi et al., 2017) associated with the scenario being assessed. At the same time, SIAMESE has a cost optimisation perspective when allocating how much a country or a region would need to contribute to global emissions reductions in line with the Paris Agreement long term goal.

The SIAMESE approach can be applied to the overall economy (e.g. scaling down the overall primary energy consumption and emissions), or adapted to individual sectors (e.g. transport, power etc.). SIAMESE takes as its input the original IAM pathways (e.g. of the R5ASIA region) and the observed energy consumption of a specific country. Based on the SIAMESE simulation we calculate the Paris compatible energy projection for a specific country. In terms of the equations underpinning the model, SIAMESE mimics the structure of Integrated Assessment Models, where the economic output (GDP) is a function of capital, labour and energy consumption by using a CES (Constant Elasticity of Substitution) production function.

## ANNEX II – METHODOLOGY FOR DERIVING LEAST-COST PARIS AGREEMENT COMPATIBLE EMISSIONS PATHWAYS FOR SOUTH KOREA

---

Using both IAM results downscaled using SIAMESE from the R5ASIA region (the Asia region defined by the IPCC in its 5<sup>th</sup> Assessment Report which includes South Korea) and the IMAGE SSP1 (see Annex I) 1.9 W/m<sup>2</sup> scenario for South Korea<sup>6</sup>, a least-cost, Paris Agreement compatible emissions range for South Korea's total GHG emissions is derived in three core steps. These are:

1. Deriving a non-CO<sub>2</sub> emissions pathway from IMAGE's SSP1-19 scenario;
  2. Deriving a pathway for non-energy CO<sub>2</sub> emissions pathway from IMAGE's SSP1-19 scenario;
  3. Downscaling regional IAM scenarios for TPED and deriving CO<sub>2</sub> emissions for each pathway.
- These steps are explained in detail below:

### 1. Deriving a non-CO<sub>2</sub> emissions pathway

The IMAGE SSP1 1.9 scenario for South Korea includes a pathway for non-CO<sub>2</sub> emissions. This scenario is the only 1.5°C compatible IAM scenario created at the national level specifically for South Korea, and hence has been chosen as the basis to derive the calibrated non-CO<sub>2</sub> emissions pathway for this project. This pathway is calibrated to historical total non-CO<sub>2</sub> emissions from the most recent available data (2017) from South Korea's 2019 National GHG Inventory Report (Government of the Republic of Korea, 2019c).

### 2. Deriving a pathway for non-energy CO<sub>2</sub> emissions

The IMAGE SSP1 1.9 scenario for South Korea includes CO<sub>2</sub> emissions pathways for each sector of the economy including the energy sector and the industry sector. Historically, industrial activity constitutes the vast majority of the contributions to non-energy CO<sub>2</sub> emissions (85-93% between 1990 and 2016) – the remaining resulting almost entirely from waste incineration. We therefore assume that the evolution of industrial emissions intensity and resulting activity in the IMAGE SSP1-1.9 is a reasonable proxy for PA emissions of CO<sub>2</sub> from non-energy processes. We use the rate of decline in industry emissions in the IMAGE SSP1-1.9 scenario to create the trajectory of non-energy CO<sub>2</sub> emissions calibrated to the most recent available data (2017) from South Korea's 2019 National GHG Inventory Report (Government of the Republic of Korea, 2019c).

### 3. Downscaling regional IAM scenarios for TPED and deriving CO<sub>2</sub> emissions for each pathway

Of the many IAM scenarios that model future energy demand and associated GHG emissions, only a fraction can be considered to be both compatible with limiting warming to 1.5°C and to satisfy the sustainability criteria of the IPCC which includes limitations on the projected utilisation of CDR technology. Climate Analytics has determined that only 19 IAM scenarios fit this description (Climate Analytics, 2019c), and these are the IAM scenarios from which this report has selected those to be used to derive the PA compatible GHG emissions range for South Korea. Of these 19 scenarios there are three that share common socioeconomic assumptions consistent with the pathway chosen for non-CO<sub>2</sub> emissions; those produced by the IMAGE, AIM, and MESSAGE models.

Total primary energy demand (TPED) for the R5ASIA region is downscaled for the SSP1 1.9 IMAGE, AIM, and MESSAGE scenarios to South Korea starting with 2017 as the base year. Emission factors for oil, coal, and natural gas are calculated for South Korea and used to derive emission pathways associated with the IMAGE, AIM, and MESSAGE TPED scenarios downscaled to South Korea. The values in each interval year of the non-CO<sub>2</sub> and non-energy CO<sub>2</sub> emissions pathways derived in steps 1 and 2 are added to each of the three downscaled SSP1 1.9 scenarios and these form the pathways used to derive the Paris Agreement compatible total GHG emissions range for South Korea.

---

<sup>6</sup> This refers to the Shared Socioeconomic Pathway 1 (SSP1 - low challenges to mitigation and adaptation) scenario for South Korea produced by the IMAGE model as part of the Coupled Model Intercomparison Project Phase 6 (CMIP6)

In our previous report released in February 2020, we downscaled the IEA's Energy Technology Perspectives (ETP) Beyond 2 Degrees Scenario (B2DS) power sector energy demand of the OECD region to provide a Paris Agreement compatible coal phase-out pathway for South Korea. That pathway was chosen as it is the only 1.5°C compatible IAM scenario that situates South Korea in the OECD, a suitably homogeneous region. We include an emission pathway associated with the ETP B2DS for TPED of the OECD, downscaled with SIAMESE to South Korea.

As the ETP uses 2014 as its base year, we have created an alternative emissions pathway that maintains the original carbon budget but reflects the historical and projected increase in emissions between 2015 and 2020. We have used historical GHG emissions between 2015-2018 and assumed emissions in 2018-2020 are in line with current policy projections. We then adjust the remaining projected emissions levels in each subsequent interval year by a common factor (0.88) that produces the same level of total emissions as the original carbon budget. We compare the estimation from the B2DS scenario for South Korea with the other scenarios considered in our report (see Figure 2), and find that it lies at the lower bound of the range in 2030 resulting from estimations across the three SSP1 1.9 models considered.

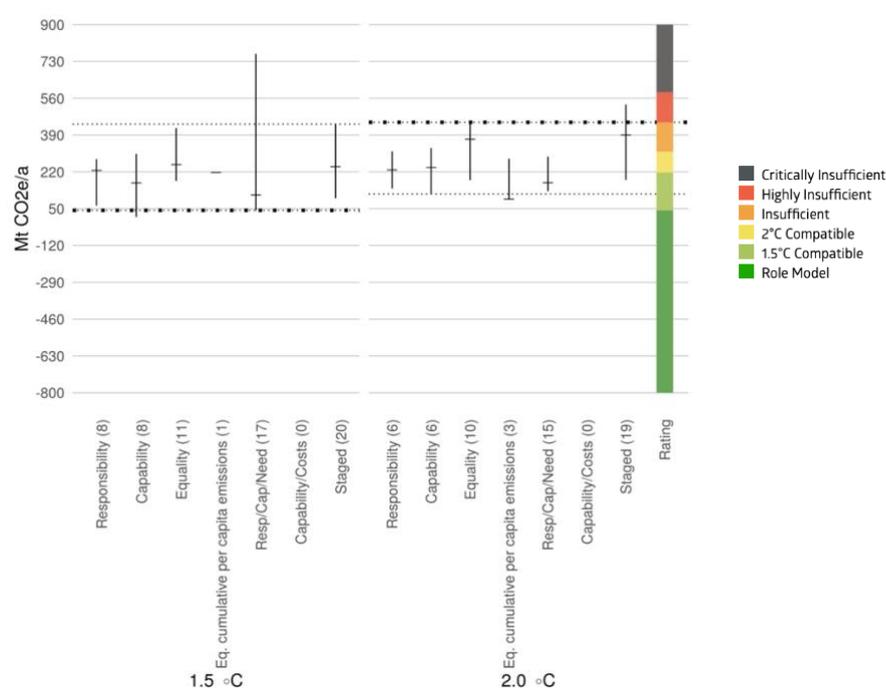
## ANNEX III – METHODOLOGY FOR DERIVING A FAIR SHARE RANGE FOR SOUTH KOREA

The Climate Action Tracker (CAT) provides a transparent way of comparing NDCs with the many interpretations of what is “fair.” This approach takes into account results from studies that are compatible with the former 2°C goal, as well as the 1.5°C limit in the Paris Agreement, to cover the full range of perspectives and historical developments of the long-term temperature goals.

Instead of deciding what is fair, a Fair Share range is constructed for each country from the range of fairness estimates from the literature, and then divided into three sections:

- Insufficient,
- 2°C compatible<sup>7</sup>
- 1.5°C Paris Agreement<sup>8</sup> compatible (see **Figure 1**)

Each section corresponds to the temperature outcomes that would result if all other governments were to put forward emissions reduction commitments with the same relative ambition level (Climate Action Tracker, 2020).



**Figure 1** Detailed results of effort sharing categories and how they are used to construct the Fair Share range for South Korea in 2030. The left hand part of the graph shows the range of emission levels expected for South Korea under each of the seven different sharing categories (number of data points included for each category in brackets) for both the 2°C and 1.5°C temperature limits. The coloured bar shows the translation into the six rating categories used by CAT (critically insufficient, highly insufficient, insufficient, 2°C compatible, 1.5°C Paris Agreement compatible, and role model). The “Insufficient” to “1.5°C Paris Agreement compatible” range represents the full fair share range of a country, excluding outliers (the categories with the least ambitious and the most ambitious approaches). (Climate Action Tracker, 2019a)

If all governments were to put forward commitments within the “2°C compatible” category, warming could be held below 2°C with a likely probability (66% or greater), but not “well below 2°C” or below 1.5°C. If all governments put forward “1.5°C Paris Agreement compatible” commitments at the most ambitious of their Fair Share range (minimum fair emissions), warming would be held well below 2°C and limited to 1.5°C.

<sup>7</sup> The 2°C compatible limit refers to scenarios that hold warming below a 2°C increase above the global mean pre-industrial climate with a likely (66%) or greater probability over the entire 21st century.

<sup>8</sup> The 1.5°C Paris Agreement compatible refers to scenarios that hold the global mean increase in warming well below 2°C and limit this warming to 1.5°C. This means that peak 21st century warming is significantly lower than in the 2°C compatible scenarios, with warming by the end of the 21st century is 1.5°C or below with about 50% probability.

## REFERENCES

- CAT. *Scaling up climate action: Key opportunities for transitioning to a zero emissions society - European Union.*, (2018).
- Climate Action Tracker. (2019a). Climate Action Tracker - South Korea. Retrieved from <https://climateactiontracker.org/countries/south-korea/>
- Climate Action Tracker. (2019b). Climate Action Tracker Update, December 2019.
- Climate Action Tracker. (2019c). *Governments still showing little sign of acting on climate crisis (December 2019 Update)*. Retrieved from [https://climateactiontracker.org/documents/698/CAT\\_2019-12-10\\_BriefingCOP25\\_WarmingProjectionsGlobalUpdate\\_Dec2019.pdf](https://climateactiontracker.org/documents/698/CAT_2019-12-10_BriefingCOP25_WarmingProjectionsGlobalUpdate_Dec2019.pdf)
- Climate Action Tracker. (2020). CAT - Comparability of Effort. Retrieved from <https://climateactiontracker.org/methodology/comparability-of-effort/>
- Climate Analytics. (2019a). *En route to Paris? Implications of the Paris Agreement for the German transport sector*. Retrieved from [https://climateanalytics.org/media/31\\_co2\\_budget\\_studie\\_en\\_web.pdf](https://climateanalytics.org/media/31_co2_budget_studie_en_web.pdf)
- Climate Analytics. (2019b). *How can Paris Agreement commitments be improved now to close the gap to 1.5°C*. Retrieved from [https://climateanalytics.org/media/ndc\\_closing\\_the\\_gap\\_to\\_1p5c.pdf](https://climateanalytics.org/media/ndc_closing_the_gap_to_1p5c.pdf)
- Climate Analytics. (2019c). *Insights from the IPCC Special Report on 1.5°C for preparation of long-term strategies*. Retrieved from [https://climateanalytics.org/media/climateanalytics\\_ipcc-1t-leds\\_report\\_april\\_2019.pdf](https://climateanalytics.org/media/climateanalytics_ipcc-1t-leds_report_april_2019.pdf)
- Climate Analytics. (2020). *Transitioning towards a coal-free society : science based coal-phase out pathway for South Korea under the Paris Agreement*. (February).
- Farand, C. (2020). South Korea to implement Green New Deal after ruling party election win. Retrieved from Climate Home News website: <https://www.climatechangenews.com/2020/04/16/south-korea-implement-green-new-deal-ruling-party-election-win/>
- Fricko, O., Havlik, P., Rogelj, J., Klimont, Z., & Gusti, M. (2017). The marker quantification of the Shared Socioeconomic Pathway 2: A middle-of-the-road scenario for the 21st century. *Global Environmental Change*, 42, 251–267. <https://doi.org/10.1016/J.GLOENVCHA.2016.06.004>
- Government of the Republic of Korea. (2019a). *3rd Biennial Update Report of the Republic of Korea Under the UNFCCC*. <https://doi.org/10.1017/CBO9781107415324.004>
- Government of the Republic of Korea. (2019b). *Fourth National Communication of the ROK under the UNFCCC*. <https://doi.org/10.1017/CBO9781107415324.004>
- Government of the Republic of Korea. (2019c). National GHG Inventory Report Republic of Korea 2019. In *Journal of Chemical Information and Modeling*. <https://doi.org/10.1017/CBO9781107415324.004>
- Höhne, N., den Elzen, M., & Escalante, D. (2014). Regional GHG reduction targets based on effort sharing: a comparison of studies. *Climate Policy*, 14(1), 122–147. <https://doi.org/10.1080/14693062.2014.849452>
- ICAP. (2019a). *ETS Detailed Information: EU Emissions Trading System (EU ETS)*. Last update: 29 October 2019. Retrieved from International Carbon Action Partnership website: [https://icapcarbonaction.com/en/?option=com\\_etsmap&task=export&format=pdf&layout=list&systems\[\]=43](https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems[]=43)
- ICAP. (2019b). *Korea Emissions Trading Scheme*. Retrieved from [https://icapcarbonaction.com/en/?option=com\\_etsmap&task=export&format=pdf&layout=list&systems\[\]=47](https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems[]=47)
- International Energy Agency. (2017). *Energy Technology Perspectives 2017*. [https://doi.org/10.1787/energy\\_tech-2017-en](https://doi.org/10.1787/energy_tech-2017-en)
- 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%28%29.pdf>
- 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/announce>

- 2/bbs/bbsView.do?bbs\_cd\_n=6&biz\_anc\_yn\_c=Y&bbs\_seq\_n=64603
- 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>
- Riahi, K., van Vuuren, D. P., Kriegler, E., Edmonds, J., O’Neill, B. C., Fujimori, S., ... Tavoni, M. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change*, 42, 153–168. <https://doi.org/10.1016/j.gloenvcha.2016.05.009>
- Sferra, F., Krapp, M., Roming, N., Schaeffer, M., Malik, A., Hare, B., & Brecha, R. (2019). Towards optimal 1.5° and 2 °C emission pathways for individual countries: A Finland case study. *Energy Policy*, 133. Retrieved from <https://doi.org/10.1016/j.enpol.2019.04.020>
- UNEP. (2019). *Emissions gap report 2019*. <https://doi.org/10.18356/ff6d1a84-en>
- UNFCCC. (2015a). Paris Agreement. *Conference of the Parties on Its Twenty-First Session*, Vol. 21932, p. 32. <https://doi.org/FCCC/CP/2015/L.9/Rev.1>
- UNFCCC. (2015b). *Paris Agreement*. 1–16. Retrieved from [https://unfccc.int/sites/default/files/english\\_paris\\_agreement.pdf](https://unfccc.int/sites/default/files/english_paris_agreement.pdf)

**Climate Analytics gGmbH**

Ritterstraße 3  
10969 Berlin, Germany

E / [contact@climateanalytics.org](mailto:contact@climateanalytics.org)  
W / [www.climateanalytics.org](http://www.climateanalytics.org)

