UN environment

Executive Summary:
The Emissions Gap Report 2017

A UN Environment Synthesis Report

Input to the Talanoa Dialogue:
Where are we?
Where do we want to go?
How do we get there?

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Executive summary

The Paris Agreement adopted in 2015 set the specific goal of holding global warming to well below 2 degrees Celsius (°C) compared to pre-industrial levels, and of pursuing efforts to limit warming to 1.5°C. This report, which is the eighth Emissions Gap Report produced by UN Environment, focuses on the "gap" between the emissions reductions necessary to achieve these agreed targets at lowest cost and the likely emissions reductions from full implementation of the Nationally Determined Contributions (NDCs) forming the foundation of the Paris Agreement. It also explores potential for enhanced mitigation efforts in a number of key sectors, presenting cost-effective options for enhanced action to close the emissions gap.

The report has been prepared by an international team of leading scientists, assessing all available information, including that reviewed by the Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report (AR5), as well as more recent scientific studies. The assessment production process has been transparent and participatory. The assessment methodology and preliminary findings were made available to the governments and stakeholders concerned during relevant international forums, as well as on the UNEP Live website. The governments of the countries with specific mention in the report have, throughout the process, been invited to comment on the specific assessment findings.

1. The overarching conclusions of the report are that there is an urgent need for accelerated short-term action and enhanced longer-term national ambition, if the goals of the Paris Agreement are to remain achievable — and that practical and cost-effective options are available to make this possible.

- The successful Paris Agreement has generated and incentivized action at scale by both governments and the private sector. Nevertheless, it marks only a beginning. **The NDCs that form the foundation of the Paris Agreement cover only approximately one third of the emissions reductions needed to be on a least-cost pathway for the goal of staying well below 2°C. The gap between the reductions needed and the national pledges made in Paris is alarmingly high.**

- Looking beyond 2030, it is clear that if the emissions gap is not closed by 2030, it is extremely unlikely that the goal of holding global warming to well below 2°C can still be reached. Even if the current NDCs are fully implemented, the carbon budget for limiting global warming to below 2°C will be about 80 percent depleted by 2030. Given currently available carbon budget estimates, the available global carbon budget for 1.5°C will already be well depleted by 2030.

- Action by subnational and non-state actors, including regional and local governments and businesses, is key to enhancing future ambition. There is still limited evidence that non-state action will fill a significant part of the emissions gap, although there is significant potential for it to do so. Enhanced monitoring and reporting of non-state actions and the resulting emissions reductions be will be essential to making pledged actions transparent and credible.

- **More ambitious NDCs will be necessary by 2020 and should build on the existing, extensive knowledge about the cost-effective policies and measures that can be taken.** A systematic assessment of sectoral mitigation options presented in the report shows that the gap can be closed before 2030 by adopting already known and cost-effective technologies, often by simply adopting or adapting best practice examples already deployed in the most innovative country contexts. The assessment in Chapter 4 shows that emissions could be reduced by up to 30 to 40 $GtCO_2e$ per annum, with costs below US$100/$tCO_2e$. It is remarkable that a large part of this potential comes from just six relatively standardized categories: solar and wind energy, efficient appliances, efficient passenger cars, afforestation and stopping deforestation. These six present a combined potential of up to 22 $GtCO_2e$ per annum.

- This eighth Emissions Gap Report assesses in more detail some specific options that may contribute to closing the gap. These include addressing the possibilities and risks associated with technologies and practices to remove carbon dioxide from the atmosphere via enhanced land-use sinks and advanced storage technologies. The land-use related options offer an annual reduction potential in 2030 of the order of between 4 and 12 $GtCO_2e$, forming part of the sectoral potential mentioned above. It is still too early to judge the potential for the emerging technology options.

- The report also covers an assessment of the potential contribution from reductions in short-lived climate pollutants (SLCPs), although they are not directly comparable with reductions in long-lived greenhouse gases. Reductions of SLCPs limit the rate of short-term warming, and when sustained and combined with CO_2 reductions, these reductions also help to limit long-term warming, which is the ultimate aim of closing the emissions gap.

- Finally, the report presents an assessment of recent developments in the coal sector, and discusses how a transition away from coal could be incentivized. The assessment shows that a transition could take place remarkably quickly, if political will and market signals provide adequate incentives, but it also shows that a just transition requires careful consideration of the social and energy system impacts and additional policies to cope with such impacts. If these effects are not addressed from the beginning of a transition process, they very often prevent or hamper the process significantly. Government policy is essential not only to incentivize innovation, but also to mitigate adverse effects and to ensure social and political acceptability. It is essential to do everything possible to ensure that the benefits stemming from a transition are shared.

2. The Facilitative Dialogue and the 2020 revision of the NDCs are the last opportunity to close the 2030 emissions gap.

These key messages send a set of strong signals to the Facilitative Dialogue process scheduled to take place under the aegis of the United Nations Framework Convention on Climate Change (UNFCCC) during 2018, and suggest that ambition should be significantly enhanced in the new and updated NDCs that will be submitted in 2020.

If the climate targets in the Paris Agreement are to remain credible and achievable, all countries will need to contribute to significantly enhancing their national ambitions, augmenting their national policy efforts in accordance with respective capabilities and different circumstances, and ensuring full accounting of subnational action. Furthermore, a strong commitment to facilitating and stimulating widespread, equitable and accountable innovation will be needed, to ensure that the best the world can offer in terms of cost-effective technology, policy and business models is available wherever needed. Non-state actors need to adhere to high standards of accountability in this respect.

Missing the 2020 option of revising the NDCs would make closing the 2030 emissions gap practically impossible.

3. Global CO_2 emissions from energy and industry have remained stable since 2014, but overall greenhouse gas emissions continue to rise slowly.

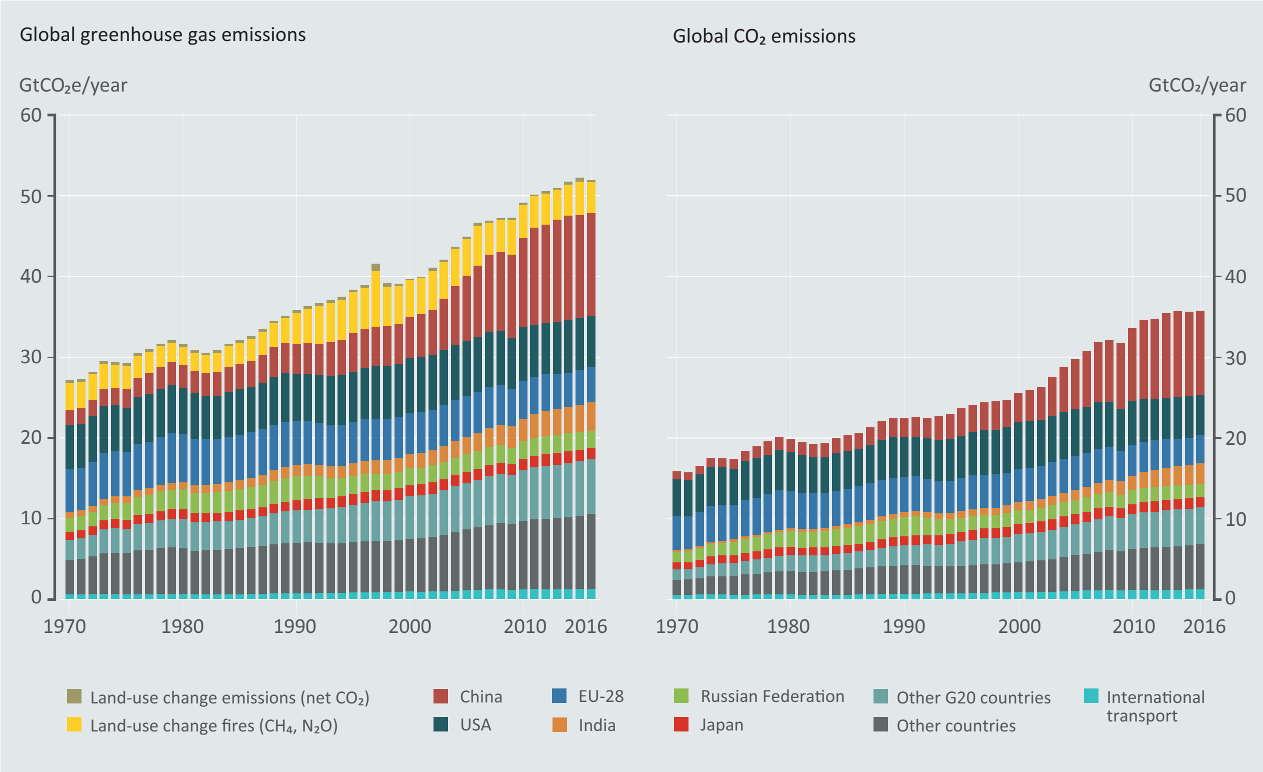
Global carbon dioxide (CO_2) emissions from fossil fuel combustion, cement production and other industrial processes account for about 70 percent of total global greenhouse gas emissions, and were estimated at a total of 35.8 $GtCO_2$ for 2016, as shown in figure ES.1. There is increasing evidence that these emissions have remained more or less stable for the past three years, reversing the previous tendency of increases each year. This may indicate a decoupling of energy- and industry-related CO_2 emissions from economic growth during these years, in which global Gross Domestic Product increased by between 2 and 3 percent annually. The main drivers have been reduced growth in coal use since 2011, primarily in China and secondarily in the United States, growing renewable power capacity and generation, especially in China and India, combined with enhanced energy efficiency and structural changes in the global economy.

However, the trend is still over a relatively short period, and could potentially be reversed if growth in the world economy accelerates. Furthermore, continued investment in more traditional technologies, especially coal-fired power stations, implies significant technological lock-in and long-term commitment to continued emissions. The assessment shows that between 80 and 90 percent of coal reserves worldwide will need to remain in the ground, if climate targets are to be reached. This compares with approximately 35 percent for oil reserves and 50 percent for gas reserves.

Total global greenhouse gas emissions, including emissions from land use, land-use change and forestry (LULUCF), are estimated at about 51.9 $GtCO_2e$/year in 2016. The time series data for global total CO_2 and greenhouse gas emissions used for the Emissions Gap Reports have been updated since the 2016 report, with the estimate for global total greenhouse gas emissions in 2014 now updated to 51.7 $GtCO_2e$, and the estimate for global total CO_2 emissions in 2015 updated to 35.6 $GtCO_2$. Emissions still show a slowdown in growth in the past two years, with calculated increases of 0.9 percent, 0.2 percent and 0.5 percent in 2014, 2015 and 2016 respectively, as shown in figure ES.1.

Figure ES.1.a: Global greenhouse gas emissions for top six emitting countries and regions (excluding land use, land-use change and forestry), international transport emissions, and land use, land-use change and forestry emissions.

Figure ES.1.b: Global carbon dioxide emissions per region from fossil fuel use, cement production and other processes, and from international transport.



Note: Other G20 countries include Argentina, Australia, Brazil, Canada, Indonesia, Mexico, Republic of Korea, Saudi Arabia, South Africa and Turkey. The greenhouse gas total are expressed in terms of billions of tonnes of global annual CO_2 equivalent emissions ($GtCO_2e$/year). CO_2 equivalent is calculated using the Global Warming Potentials (GWP-100) metric of UNFCCC as reported in the IPCC Second Assessment Report, similar as has been done in the IPCC Fifth Assessment Report.
Source: EDGAR v4.3.2 FT2016 (Olivier *et al.,* 2017).

4. Global greenhouse gas emissions in 2020 are likely to be at the high end of the range of the scenarios consistent with the 2°C and 1.5°C goals respectively, making it increasingly difficult to be on track to meet the 2030 emission goals.

G20 countries are collectively on track to meet the middle range of their Cancun Pledges for 2020, but for some countries further action is needed and there are still many opportunities to further reduce emissions in the short term, as documented in Chapter 4. While praise for meeting a target is merited, it should be remembered that it does not give any indication of how ambitious the target was.

The assessment shows that according to all available estimates, four of the G20 members – China, the EU28, India and Japan – are on track to meet their 2020 pledges without purchasing offsets. A further three – Australia, Brazil and Russia – are on track according to most estimates.

According to both government and independent estimates, Canada, Mexico, the Republic of Korea, South Africa and the United States are likely to require further action, possibly supplemented by purchased offsets, in order to meet their 2020 pledges. Mexico's 2020 pledge is conditional on the provision of adequate financial and technological support from developed countries as part of a global agreement, and the fulfilment of this condition has not been assessed.

Independent estimates of the Republic of Korea's 2020 emissions are well above the level implied by its pledge. The country's amended Green Growth Basic Act, however, replaced the 2020 pledge with the NDC target for 2030, implying there no longer is a 2020 target.

Insufficient information is currently available to determine whether Indonesia is on track to meet its pledge. Independent projections span a wide range, and official projections reflecting current policies are unavailable.

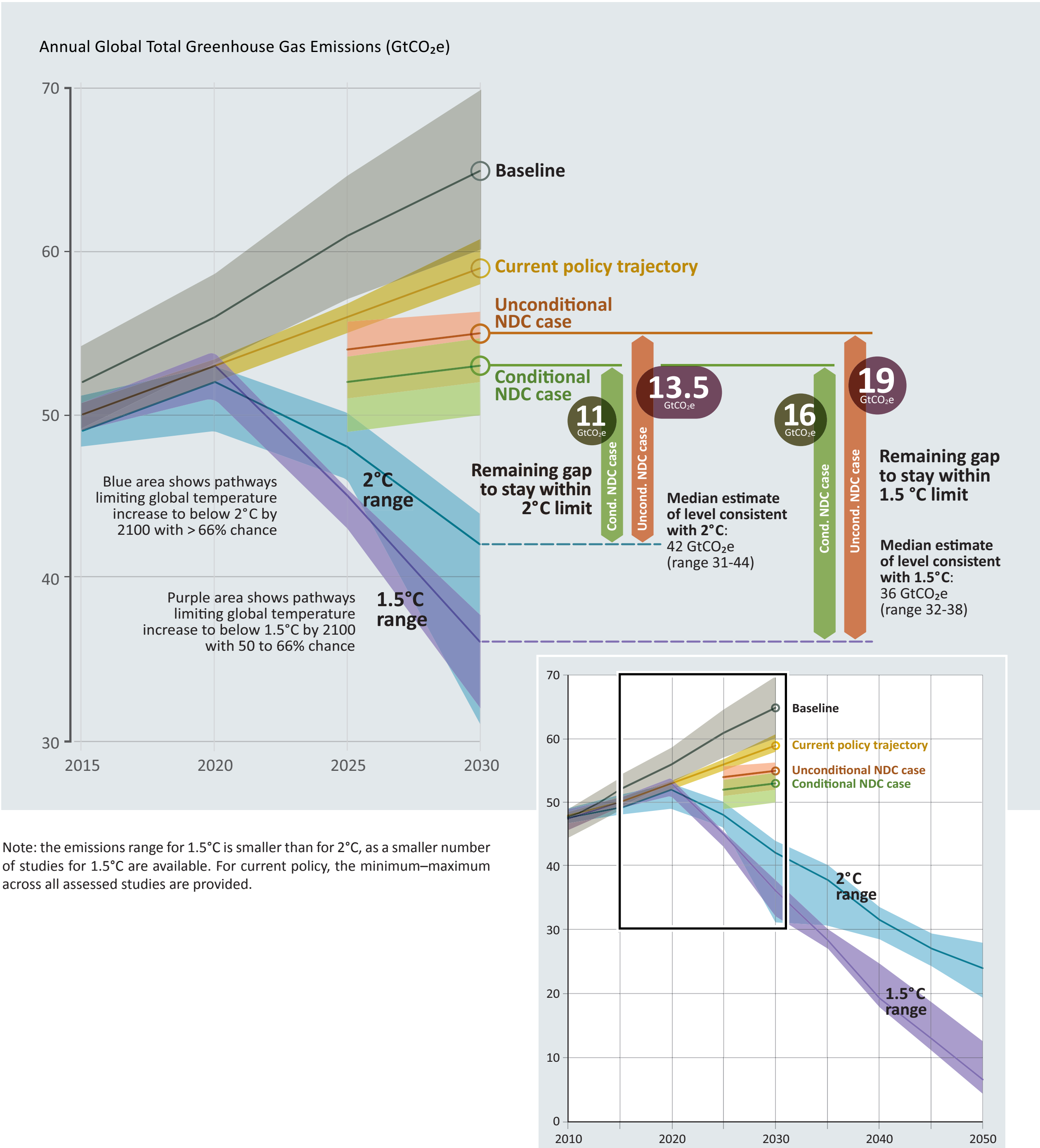
Finally, Argentina, Saudi Arabia and Turkey have not made greenhouse gas reduction pledges for 2020. All three countries submitted post-2020 pledges to the UNFCCC as part of their Intended Nationally Determined Contributions (INDCs).

The limited collective ambition of the Cancun Pledges means, however, that the global greenhouse gas emissions in 2020 are likely to be at the high end of the range of the scenarios consistent with the 2°C and 1.5°C targets respectively. This increases the challenge of meeting the necessary 2030 emission goals. With the limited time to 2020, it will be difficult to realize any significant additional emission reductions, but many actions can still be initiated that both lead to short-term reductions and facilitate pathway changes for the next decade.

5. A large gap exists between 2030 emission levels and those consistent with least-cost pathways to the 2°C and 1.5°C goals respectively. The 2°C emissions gap for the full implementation of both the conditional and unconditional NDCs for 2030 is 11 to 13.5 $GtCO_2e$. The gap in the case of the 1.5°C target is 16 to 19 $GtCO_2e$.

The assessed global scenarios show that if least-cost trajectories are followed, then emissions of all greenhouse gases should not exceed 42 $GtCO_2e$ in 2030, if the 2°C target is to be attained with higher than 66 percent chance. The level for 1.5°C has in earlier reports been reported with higher than 50 percent probability and is about 5 $GtCO_2e$ lower than the central estimate for the 2°C pathways. New studies are, however, becoming available that present least-cost pathways starting from 2020 that could return global warming to below 1.5°C by 2100 with higher than 66 percent probability. These studies indicate a much lower required level of around 24 $GtCO_2e$, which would imply a need for significantly faster and deeper reductions than previously anticipated. The number of published studies on this topic is considered too low to allow for inclusion in the gap assessment with a high level of confidence in 2017, but it is expected that further analysis of these 1.5°C pathways with higher than 66 percent probability will be included in the 2018 report.

Figure ES.2: Global greenhouse gas emissions under different scenarios and the emissions gap in 2030 (median estimate and 10th to 90th percentile range).



Note: the emissions range for 1.5°C is smaller than for 2°C, as a smaller number of studies for 1.5°C are available. For current policy, the minimum–maximum across all assessed studies are provided.

The emissions gap related to the 2°C goal for the full implementation of NDCs for 2030 is 11 to 13.5 $GtCO_2e$, for conditional and unconditional pledges respectively. These estimates are slightly lower than the 12 to 14 $GtCO_2e$ estimates in the 2016 report, due to updated information from five global studies with lower emission projections resulting from the NDCs. The emissions gap in the case of 1.5°C with higher than 50 percent probability is found to be 16 to 19 $GtCO_2e$ for conditional and unconditional NDCs respectively, which is higher than the 15 to 17 $GtCO_2e$ estimates in the 2016 report, due to new studies on 1.5°C pathways and the harmonization of 2010 emission levels across scenarios. As indicated above, there are not enough studies available to give a reliable estimate for a gap in the case of higher than 66 percent probability, but it is clear the gap will be larger.

The alarming number and intensity of extreme weather events in 2017, such as hurricanes, droughts and floods, adds to the urgency of early action. These events underline the importance of the Paris Agreement, which seeks to limit warming to "well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels". The particular class of models referred to in this Emissions Gap Report looks at meeting the Paris Agreement goals at the lowest possible costs, and therefore results do not change even when the risks of climate change become more apparent.

Implications for the carbon budget: If the current NDCs are fully implemented, the carbon budget for limiting global warming to below 2°C with higher than 66 percent probability will be about 80 percent depleted by 2030. Given currently available carbon budget estimates, the available global carbon budget for 1.5°C with at least 50 percent probability will already be well depleted by 2030.

Implications for temperature levels in 2100: Full implementation of the unconditional NDCs and comparable action afterwards is consistent with a temperature increase of about 3.2°C by 2100 relative to pre-industrial levels. Full implementation of the conditional NDCs would lower the projection by about 0.2°C.

6. Most G20 countries require new policies and actions to achieve their NDC pledges.

This 2017 report includes an updated assessment of the emissions associated with the NDC pledges and current policies of each of the G20 countries, including the EU. As these countries collectively generate around three quarters of global greenhouse gas emissions, their success in implementing (or exceeding) their NDC pledges will have a major impact on the achievement of the global temperature goals.

The assessment shows that for many countries, implementing their NDC would lead to lower emissions than the current policies scenario, or in other words that additional policies will have to be implemented to meet the NDC target. The level of ambition embedded in NDCs varies considerably: for some countries the NDC target is actually above current projected policy case emissions.

With this caveat, recent studies assessed suggest that Brazil, China, India and Russia are likely to – or are roughly on track to – achieve their 2030 NDC targets with currently implemented policies. Conversely, Argentina, Australia, Canada, the European Union, Indonesia, Japan, Mexico, South Africa, the Republic of Korea and the United States are likely to require further action in order to meet their NDCs, according to government and independent estimates.

7. Subnational and non-state action has the potential to reduce the emissions gap by a few gigatonnes CO_2e/year by 2030. Improved information about the impact of subnational and non-state action is urgently required.

Subnational and other non-state actors, such as private companies, make a considerable contribution to global greenhouse gas emissions. For example, the world's 100 largest emitting publicly traded companies account for around a quarter of global greenhouse gas emissions. State and non-state actions can both overlap and mutually reinforce each other, but it is currently unclear how many of the actions by non-state actors are included in the national pledges. The assessment provided here suggests that the aggregated additional impact of the various non-state initiatives is of the order of a few $GtCO_2e$ in 2030, over and above current NDCs. This is potentially a significant contribution to closing the gap, if the initiatives reach their stated goals, and if these reductions do not displace actions elsewhere. Coordinated, comparable and transparent reporting and verification of actions by all actors is essential to clarify effects and possible overlaps. This would also help in gaining recognition of ambitious action and would facilitate replication.

8. The Kigali Amendment and the ICAO Offsetting Scheme provide some welcome additional momentum and may contribute just under 1 $GtCO_2e$ to closing the gap in 2030.

The Kigali Amendment, signed in December 2016, aims to phase out the use and production of hydrofluorocarbons, and the agreement is expected to accelerate this process, which some countries have already included in their NDCs. The impact compared to a no-action baseline would globally be of the order of 0.7 $GtCO_2e$/year in 2030. Since some countries already include hydrofluorocarbons phase-down in their NDCs, the additional impact compared to the NDCs will be smaller. UN Environment will in 2018 undertake a new specific assessment to shed more light on the impacts of implementing the Kigali Amendment.

International aviation emissions are expected to grow from 0.5 $GtCO_2e$ in 2017 to around 1.1 $GtCO_2e$ in 2030, with increasing traffic demand over the coming decades. Domestic aviation is included in many countries' NDCs and related national actions, but international aviation is not. The ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) established to reduce emissions from international aviation is estimated to have an impact of 0 to 0.3 $GtCO_2$ per year on global emissions in 2030. The wide range implies that the result will depend on the way the offsetting rules will be set. The long-term impact will likely be larger.

9. The assessment of the emissions gap and the mixed progress on implementation of both the Cancun Pledges and the NDCs show that there is a significant distance between the current collective ambitions and commitments and what is required to meet the temperature goals of the Paris Agreement. It is therefore absolutely crucial that the Facilitative Dialogue in 2018 addresses the need and the opportunities for significantly enhanced action pre-2030, including by assisting and informing countries in urgently strengthening their NDCs.

In order to inspire the process of strengthening NDCs, this 2017 Emissions Gap Report addresses a number of key opportunities for closing the 2030 emissions gap, including:

- A systematic review of the mitigation potential of a large number of sector actions. The results here are unambiguous: technologies and institutional innovations are available to bridge the emissions gap, and at reasonable cost.
- A detailed assessment of global developments in the coal sector that also examines the options and barriers for a gradual coal phase-out.
- Opportunities offered by limiting emissions of SLCPs. Reducing these pollutants will limit the rate of short-term warming, and when sustained and combined with CO_2 reductions, help limit long-term warming, which is the ultimate aim of closing the emissions gap.
- Options for both biological and technological carbon dioxide removal: some of the former come with decades of experience, while many of the latter are still in their infancy.

10. The emissions reduction potential by 2030 at costs <US$100/$tCO_2$e, compared to the current policy trajectory, is sufficient to close the emissions gap in 2030 under all cases assessed. It could in addition provide many benefits for other important environmental, social and economic goals.

The systematic review presents estimates of the global emission reduction potentials that could be achieved in 2030 in six key sectors: agriculture, forestry, buildings, energy, industry and transport. For all sectors, the main categories of emissions reduction for 2030 are identified.

The focus is on the socio-economic potential, meaning that the numbers presented refer to the total emissions reductions that can be achieved using all technologies available in a given future year. The potential is defined by all reductions that can be achieved at a cost of no more than US$100/$tCO_2$e, using social, not private, payback times. Most of the potential, however, can be achieved at a cost significantly below US$100/$tCO_2$e.

There are important uncertainties related to technology development assumptions and implementation rates, such as how rapidly solar photovoltaic energy production can be scaled up, or the rate at which buildings can be retrofitted. Most of the underlying analysis introduces some degree of 'realism' to the assessment and its respective assumptions. In general, the potentials can be achieved if countries around the globe are willing to establish necessary policies that enable the available solutions to be implemented and barriers to be addressed.

The total of all emission reduction potentials in the assessment amounts to 35–41 $GtCO_2$e/year in 2030, with details shown in table ES.1. However, there are some areas where estimates of potentials are fairly new, and it is uncertain whether it is indeed feasible to realize them by 2030. Leaving out these areas will reduce the emission reduction potential to 30–36 $GtCO_2$e, which is still more than double the 2030 emissions gap for the 2°C goal.

An important question is of course what are the policies, measures and costs required to implement a substantial part of these emission reduction options? Although answering in full is beyond the scope of the current assessment, some first comments are made in Chapter 4. It is remarkable that a large part of the potential consists of just six relatively standardized categories: solar and wind energy, efficient appliances, efficient passenger cars, afforestation and stopping deforestation. These six measures sum up a potential of 15–22 $GtCO_2$e, making up over 40 percent of the total potential. All these measures can be realized at modest or even net-negative incremental costs, and in most of the cases there are proven policies that can be replicated.

For both current and evolving technologies, the assessment reported here are at the global level. Further work will be needed to disaggregate by region and design appropriate mitigation plans for each country. Countries will need to undertake more specific assessment of the key options relevant to their own circumstances as part of the collective effort to boost the global mitigation ambitions. It will be important to ensure that international technical and financial support is available to facilitate action in developing countries.

Table ES.1: Overview of emission reduction potentials in 2030 ($GtCO_2e$ per year).

Sector	Category	Emission reduction potential in 2030 ($GtCO_2e$)	Category	Sectoral aggregate potential ($GtCO_2e$)
Agriculture	Cropland management	0.74	Basic	3 (2.3 - 3.7)
	Rice management	0.18		
	Livestock management	0.23		
	Grazing land management	0.75		
	Restoration of degraded agricultural land	0.5 - 1.7		
	Peatland degradation and peat fires	1.6	Additional	3.7 (2.6 - 4.8)
	Biochar	0.2		
	Shifting dietary patterns	0.37 - 1.37		
	Decreasing food loss and waste	0.97 - 2		
Buildings	New buildings	0.68 - 0.85	Basic	1.9 (1.6 - 2.1)
	Existing buildings	0.52 - 0.93		
	Renewable heat - bio	0.39		
	Renewable heat - solar	0.21		
	Lighting	0.67	Basic (indirect emissions)	See energy sector potential
	Appliances	3.3		
Energy sector	Solar energy	3 - 6	Basic	10 (9.3 – 10.6)
	Wind energy	2.6 - 4.1		
	Hydropower	0.32		
	Nuclear energy	0.87		
	Bioenergy	0.85		
	Geothermal	0.73		
	CCS	0.53		
	Bioenergy with CCS	0.31	Additional	0.3 (0.2 - 0.4)
	Methane from coal	0.41	Basic	2.2 (1.7 - 2.6)
	Methane from oil and gas	1.78		
Forestry	Restoration of degraded forest	1.6 - 3.4	Basic	5.3 (4.1 - 6.5)
	Reducing deforestation	3		
Industry	Energy efficiency - indirect	1.9	Basic (indirect emissions)	See energy sector potential
	Energy efficiency - direct	2.2	Basic	5.4 (4.2 - 6.6)
	Renewable heat	0.5		
	Non-CO_2 greenhouse gases	1.5		
	CCS	1.22		
Transport	Heavy Duty Vehicles potential (efficiency, mode shift)	0.88	Basic	4.7 (4.1 - 5.3)
	Light Duty Vehicles potential (efficiency, mode shift, electric vehicles)	2.0		
	Shipping efficiency	0.7		
	Aviation efficiency	0.32 - 0.42		
	Biofuels	0.63 - 0.81		
Other	Landfill gas recovery	0.4	Basic	0.4 (0.3 - 0.5)
	Enhanced weathering measures	0.73 - 1.22	Additional	1 (0.7 - 1.2)
Total basic emission reduction potential				**33 (30 - 36)**
Total emissions reduction potential including additional measures				**38 (35 - 41)**

Note: Although for many emission reduction categories a single point estimate is given, there are always uncertainties, assumed to be ±25 percent. For the categories peatland degradation and peat fires, biochar and energy efficiency, the potential in 2030 is more uncertain. Therefore, a higher uncertainty range of 50 percent is applied to these categories. In the final column, the categories are aggregated to the sectoral level. The numbers in the third column are not corrected for overlap between measures. The numbers in the final column are corrected for overlap, and this is also reflected in the total potential. Therefore, the total is smaller than the sum of the individual potentials in the third column. The aggregate potentials for indirect emission reductions in buildings and industry are reflected in the electricity sector potential.

11. Avoiding building new coal-fired power plants and phasing out existing ones is crucial to closing the emissions gap. This will require careful handling of issues such as employment impacts, investor interests, grid stability and energy access to achieve a just transition.

Many of the sectoral mitigation options presented above will, if implemented at scale, bring significant changes to the global energy sector, especially in growing but quickly decarbonizing electricity capacity. For this to happen, it will be important to also reduce the fossil-based electricity capacity already in place and under construction and avoid planning new coal plants. A gradual phase-out of coal is needed, recognizing that coal-based power generation will remain significant for a number of both developing and industrialized countries until at least 2030.

Today, there are an estimated 6,683 operating coal-fired power plants in the world, with a combined installed capacity of 1,964 GW. If these plants were operated until the end of their lifetime and not retrofitted with carbon capture and storage (CCS), the stock of operating power plants would emit an accumulated amount of around 190 $GtCO_2$.

Without additional policy interventions, the number of coal-fired power plants will continue to increase. As of early 2017, across the globe there were additional 273 GW of coal-fired capacity in construction and 570 GW at the planning stage. Ten countries make up approximately 85 percent of the entire coal pipeline, with 700 GW being built or planned in China, India, Turkey, Indonesia, Vietnam, Japan, Egypt, Bangladesh, Pakistan and the Republic of Korea alone. As shown in table ES.2, these new plants, if operated until the end of their assumed lifetime of 40 years, would lead to additional accumulated emissions of approximately 150 $GtCO_2$. In comparison, the total remaining carbon budget is approximately 1,000 $GtCO_2$ for staying below 2°C and less than 600 $GtCO_2$ for staying below 1.5°C. On a positive note, in 2016 a large number of planned coal-fired power plants— particularly in China and India — were shelved or cancelled, and globally there was a slower rate of coal expansion generally.

Large-scale phase-out of coal will pose very different challenges and solutions for individual countries, and with respect to existing plants, recently built plants and those in the pipeline.

Chapter 5 discusses experiences with possible market and non-market-based policy instruments and how these could be used to incentivize a transition away from coal. A set of country assessments presents the challenges a transition would have for the largest coal-using and exporting countries. One example, from India, illustrates some of these challenges by showing that coal production, transport, usage and ash disposal employ almost one million people. Coal mining is the second largest employer in India — the largest being the railroads, which again has coal transporting as its number one product and revenue source.

The country examples show that if a transition is to succeed, it will need to be carefully managed, ensuring that impacts on workers, coal owners, industry and energy users are, as far as possible, addressed up front and that compensation measures are developed in consultation with these key stakeholders. Failing to address the interests of the potential "losers" in any transition process has made many societal or industrial transitions fail or created political and social unrest.

Table ES.2: Committed carbon dioxide emissions for coal-fired power plants, in $GtCO_2$, by status and region.

Region	Announced	Pre-permitted	Permitted	Construction	Operating	Total
East Asia	12.19	12.34	6.30	30.41	126.41	187.66
South Asia	6.21	9.87	5.89	8.28	27.42	57.67
South-East Asia	7.00	5.78	2.63	5.21	8.95	29.60
European Union	0.60	0.66	0.17	1.14	7.22	9.79
Non-EU Europe	4.86	5.30	1.70	0.44	3.56	15.87
Middle East and Africa	5.83	1.16	1.94	2.14	2.46	13.52
Latin America	0.61	0.17	0.28	0.37	1.74	3.18
Eurasia	1.65	0.00	0.00	0.20	2.69	4.54
North America	0.00	0.00	0.15	0.00	8.85	9.01
Australia and New Zealand	0.00	0.00	0.00	0.00	1.14	1.14
Total	38.97	35.28	19.08	48.20	190.44	331.97

Note:
- The figures take into account the remaining lifetimes of existing plants.
- A lifetime of 40 years is assumed for newly constructed power plants.
- European Union data refers to the current 28 Member States. North America refers to both Canada and the United States.
- It is assumed that not all permitted, pre-permitted and announced power plants come online.

Source: Edenhofer *et al.* (2017) and Shearer *et al.* (2017)

12. Reductions in SLCP emissions can be an important part of global mitigation efforts and contribute to the achievement of a number of Sustainable Development Goals. Significant potential, beyond existing commitments, is achievable with proven technologies, but dedicated policy action to establish legal frameworks and institutional capacity is required to unlock it.

SLCPs are agents that have a relatively short lifetime in the atmosphere — from a few days to a few decades — and a warming influence on climate. The main SLCPs are black carbon, methane and tropospheric ozone, and some hydrofluorocarbons are also included. Although some SLCPs, particularly black carbon, are not greenhouse gases and not included under the UNFCCC and its Paris Agreement, most SLCPs are considered in evaluations of pathways towards the temperature targets. Reducing these pollutants will limit the rate of short-term warming and, when sustained and combined with CO_2 reductions, will help limit long-term warming, which is the ultimate aim of closing the emissions gap.

A complete separation between these pollutants and CO_2 reductions is also not possible, as decarbonization strategies will lead to reductions in some SLCPs, including black carbon, about a third of which originates from fossil fuel sources, and energy efficiency improvements can reduce all types of emissions. SLCP reductions have the potential to decrease the rate and degree of warming in the next few decades, due to the rapid effect of their mitigation on temperature.

Studies have estimated that mitigation of SLCPs has the potential to avoid up to 0.6°C of warming by mid-century and in this way, to reduce impacts that are related to cumulative heat uptake, helping ensure a steady and lower temperature trajectory towards the temperature goals of the Paris Agreement. In addition, there will be a number of other benefits associated with a reduced emissions pathway, notably improved air quality.

Successful cooperation on the individual building blocks of the international climate regime, such as the Climate and Clean Air Coalition or the Montreal Protocol, will build the trust and confidence required to help accelerate progress on some of the bigger elements of the Paris Agreement.

In many NDCs it is usually difficult or impossible to identify particular compounds, as targets are given in CO_2e often without specific targets for methane, hydrofluorocarbons or black carbon. Instead the NDCs provide a broad list of sectors and actions where mitigation action is planned. Four countries specifically address black carbon in their NDCs—Mexico, Chile, Nigeria and Canada—with Mexico specifying a target.

13. Carbon dioxide removal from the atmosphere can provide an additional mitigation element to conventional emission abatement strategies. Biological CO_2 removal through afforestation, reforestation, forest management, restoration of degraded lands, soil carbon enhancement and biochar application in agriculture can play an immediate role, and can also significantly contribute to achieving several other Sustainable Development Goals.

Carbon dioxide removal refers to a cluster of technologies, practices and approaches that remove and sequester carbon dioxide from the atmosphere. Despite the common feature of removing CO_2, these technologies and approaches are very different. In generic terms, they can be distinguished as biological or engineered options. For biological options such as afforestation, reforestation or soil carbon management, experience has been accumulated over decades. On the other hand, engineered options such as bioenergy combined with carbon capture and storage, or certainly direct air capture, have large potential but are still in the early stages of development.

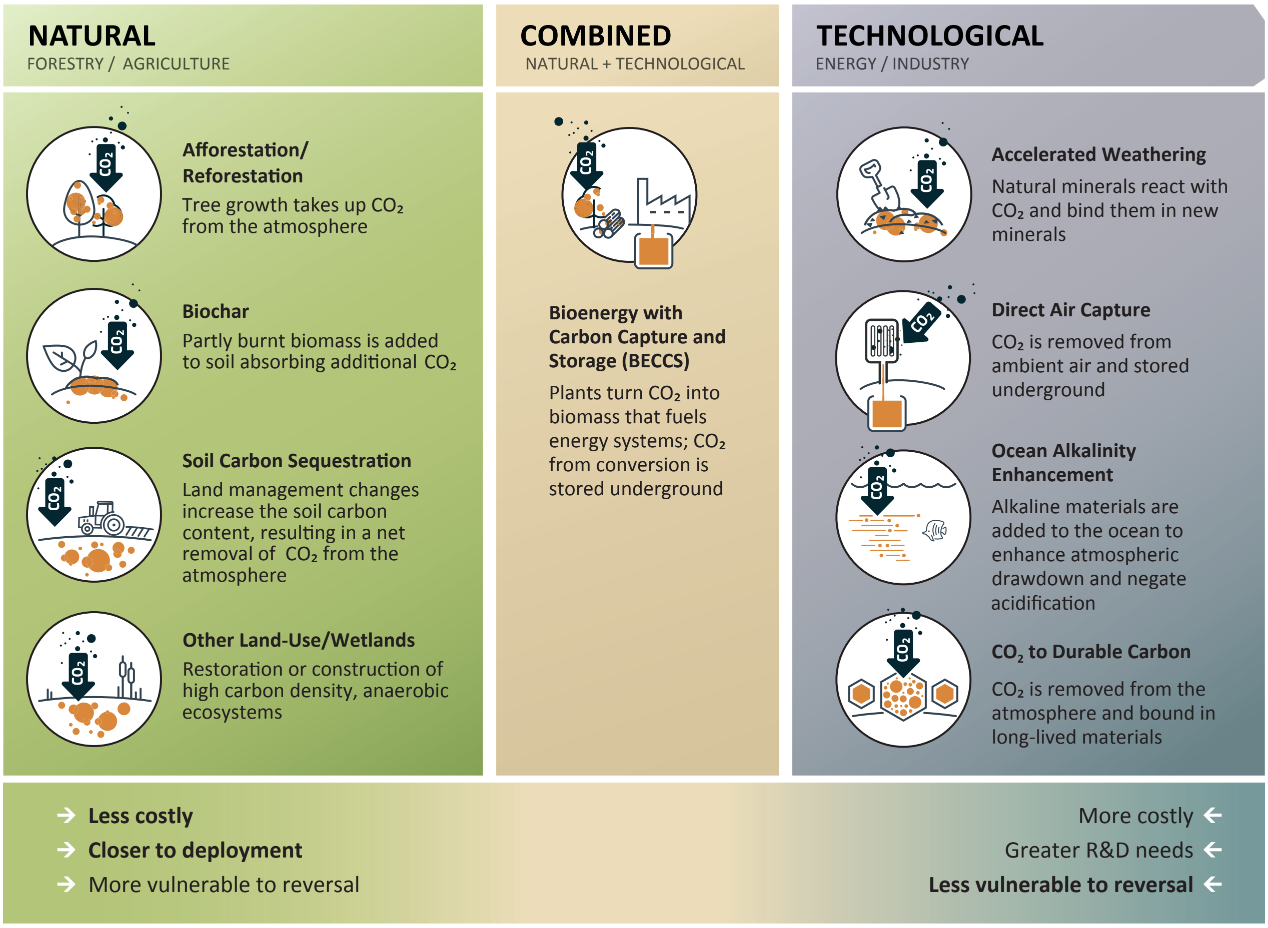
As indicated in the sectoral mitigation options presented in table ES.1, the potential for significant contributions to close the gap exists in the agricultural and forestry sectors. Chapter 7 presents a more detailed assessment of some of these options, along with some of the more recent technological approaches to capturing and storing CO_2.

Land-based carbon removal options, including forests, wetlands and soils have been managed by humans for many years and as such, there is a wealth of knowledge that can be readily applied today with confidence. In addition, these approaches present opportunities to meet other global sustainability goals, such as improved water quality, ecosystem restoration, biodiversity preservation and improved crop yields. The total annual reduction potential is in the order of 4 to 12 $GtCO_2e$, with relatively wide ranges for the various options; some studies indicate a significantly higher potential.

For these land-based options to contribute to carbon removal at the gigatonne scale, large land areas and ecosystems may need to be engaged in new ways. There are substantial uncertainties regarding effective carbon removal rates, possible volumes and duration of effective sequestration, and implications for ecosystem services and food production currently associated with these land areas.

The chapter presents a detailed assessment of one specific set of options that has briefly been addressed in previous Emissions Gap Reports—bioenergy with carbon capture and storage. This option warrants a specific focus, because it forms an integral part of the solutions considered within many integrated assessment models, and its components are already applied at a large scale. Most scenarios that aim to

Figure ES.3: Major strategies for negative emission technologies.



Note: This figure includes the major strategies that have been discussed in the literature so far (Minx *et al.,* 2017).

keep global warming below 2°C, and especially those aiming for below 1.5°C, include contributions from this option at the gigatonne scale. Achieving these reductions, however, would entail significant land-use and water-resource requirements and substantial investment; the question of whether the model assumptions are realistic is therefore a relevant one. In addition, while bioenergy and carbon capture and storage are relatively mature technologies individually, there is very little deployment of them in combination, especially at a large scale. Whether the combined option can thus be scaled up promptly to help achieve the ambitious climate targets remains uncertain. Mitigation action in other sectors should therefore not be delayed.

As for engineering options, the chapter provides an assessment of emerging options, such as direct air capture combined with carbon storage, accelerated weathering of materials, ocean alkalinity enhancement and conversion of CO_2 into long-lived products. Most of these options are at early piloting stage, so it is hard to judge the technical and economic potential in the short term, and the chance of these technologies making a real contribution to closing the 2030 gap seems unrealistic. Beyond 2030, these technologies may show additional important reduction potential. When global emissions need to move towards net zero by around 2050, CO_2 removal may offer some welcome flexibility and, as with other technologies, cost and performance will likely improve with increased deployment.

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