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Executive summary

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Executive summary

This is the ninth edition of the UN Environment Emissions Gap Report. It assesses the latest scientific studies on current and estimated future greenhouse gas emissions and compares these with the emission levels permissible for the world to progress on a least-cost pathway to achieve the goals of the Paris Agreement. This difference between "where we are likely to be and where we need to be" is known as the 'emissions gap'. As in previous years, the report explores some of the most important options available for countries to bridge the gap.

The political context this year is provided by several processes and events:

- The Talanoa Dialogue—an inclusive, participatory and transparent dialogue about ambitions and actions, conducted under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) and designed to help build momentum for new or updated Nationally Determined Contributions (NDCs) to be submitted by 2020.
- The Global Climate Action Summit in September 2018—bringing together many non-state and subnational actors (NSAs) that are actively involved in climate issues.
- The Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C—focusing on "the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty". The Emissions Gap Report has benefited significantly from the IPCC Special Report and its underlying studies.

This Emissions Gap Report has been prepared by an international team of leading scientists, assessing all available information, including that published in the context of the IPCC Special Report, as well as in other recent scientific studies. The assessment production process has been transparent and participatory. The assessment methodology and preliminary findings were made available to the governments of the countries specifically mentioned in the report to provide them with the opportunity to comment on the findings.

1. Current commitments expressed in the NDCs are inadequate to bridge the emissions gap in 2030. Technically, it is still possible to bridge the gap to ensure global warming stays well below 2°C and 1.5°C, but if NDC ambitions are not increased before 2030, exceeding the 1.5oC goal can no longer be avoided. Now more than ever, unprecedented and urgent action is required by all nations. The assessment of actions by the G20 countries indicates that this is yet to happen; in fact, global CO2 emissions increased in 2017 after three years of stagnation.

This year's report presents the newest assessment of the emissions gap in 2030 between emission levels under full implementation of the unconditional and conditional NDCs and those consistent with least-cost pathways to stay below 2°C and 1.5°C respectively.

- With the results of the new global studies prepared for the IPCC report, the emissions gap— especially to stay below 1.5°C warming—has increased significantly in comparison with previous estimates, as new studies explore more variations and make more cautious assumptions about the possibility of global carbon dioxide-removal deployment.
- Pathways reflecting current NDCs imply global warming of about 3°C by 2100, with warming continuing afterwards. If the emissions gap is not closed by 2030, it is very plausible that the goal of a well-below 2°C temperature increase is also out of reach.
- The assessment of country action for this Emissions Gap Report concludes that while most G20 countries are on track to meet their Cancun pledges for 2020, the majority are not yet on a path that will lead them to fulfilling their NDCs for 2030.
- Concerns about the current level of both ambition and action are thus amplified compared to previous Emissions Gap Reports. According to the current policy and NDC scenarios, global emissions are not estimated to peak by 2030, let alone by 2020. The current NDCs are estimated to lower global emissions in 2030 by up to 6 $GtCO_2e$ compared to a continuation of current policies. As the emissions gap assessment shows, this original level of ambition needs to be roughly tripled for the 2°C scenario and increased around fivefold for the 1.5°C scenario.
- Action by non-state and subnational actors (NSAs), including regional and local governments and businesses, is key to implementing the NDCs. The strong engagement by NSAs demonstrated at the recent Global Climate Action Summit is promising and can help governments deliver on their NDCs, but the impact of current individual NSA pledges on reducing the gap is extremely limited. Chapter 5 of this Emissions Gap Report was pre-released at the Summit, and documents that if international cooperative initiatives succeed in increasing their membership and ambition, substantially greater potential can be realized. The chapter emphasizes that enhanced monitoring and reporting of actions and resulting emissions reductions will be essential for the credibility of NSA action.
- Countries therefore need to move rapidly on the implementation of their current NDCs; at the same time, more ambitious NDCs are necessary by 2020 to meet the jointly agreed goals. This report summarizes the different approaches countries can take to build enhanced ambition and enhance the scale, scope and effectiveness of their domestic policy.
- The policies and measures chapters in this year's report address two key aspects for the longer-term transition to a zero-emission economy and society. Fiscal policies provide a key opportunity for reducing future emissions, and there are options to design them in such a way that they deliver the desired results without creating

economic and social problems. Several countries have demonstrated that it is possible to overcome social resistance, but few have gone far enough to have the necessary emissions reduction impact. Innovation policy and market creation also offer significant mitigation potential and governments should play a key role in ensuring the development and market introduction of new and emerging low-carbon technologies and practices.

The key messages from the 2018 Emissions Gap Report send strong signals to national governments and to the political part of the Talanoa Dialogue at the 24th session of the Conference of the Parties (COP 24). Along with the recent IPCC Special Report, these messages provide the scientific underpinning for the UN 2019 Climate Summit, which will convene on the theme of 'A Race We Can Win. A Race We Must Win'. By way of the summit, the United Nations Secretary-General will seek to challenge States, regions, cities, companies, investors and citizens to step up action in six key areas: energy transition, climate finance and carbon pricing, industry transition, nature-based solutions, cities and local action, and resilience.

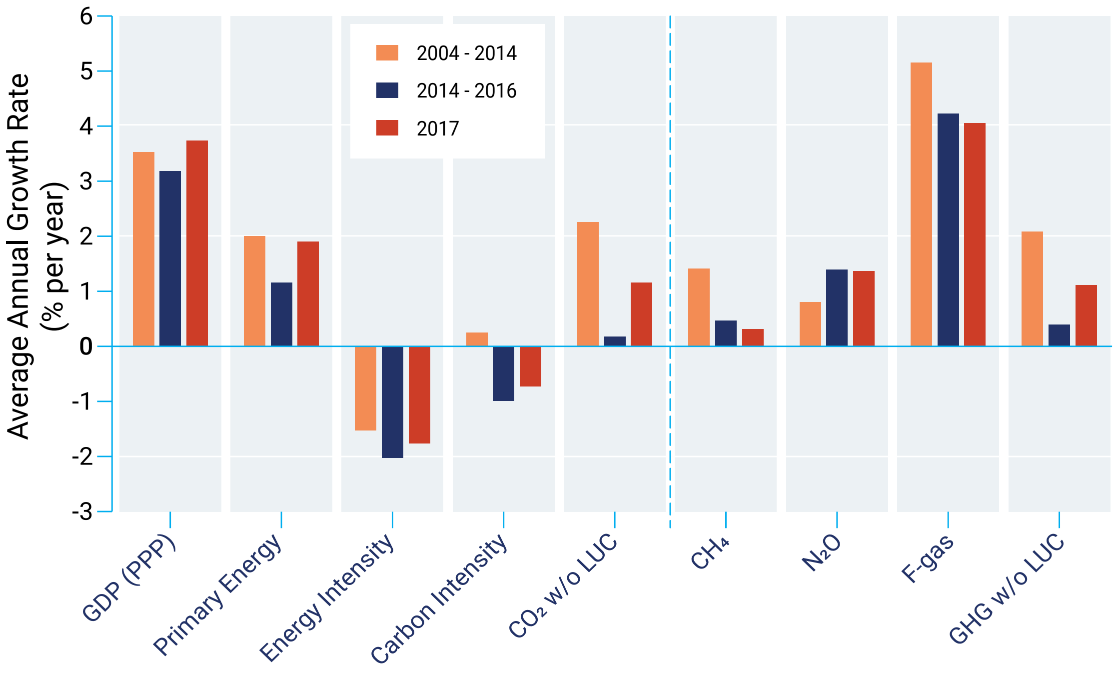
2. Global greenhouse gas emissions show no signs of peaking. Global CO_2 emissions from energy and industry increased in 2017, following a three-year period of stabilization. Total annual greenhouse gases emissions, including from land-use change, reached a record high of 53.5 $GtCO_2e$ in 2017, an increase of 0.7 $GtCO_2e$ compared with 2016. In contrast, global GHG emissions in 2030 need to be approximately 25 percent and 55 percent lower than in 2017 to put the world on a least-cost pathway to limiting global warming to 2°C and 1.5°C respectively.

In 2017 greenhouse gas emissions (GHG) - excluding emissions from land-use change - reached a record 49.2 $GtCO_2e$. This is an increase of 1.1 percent on the previous year. Emissions from land-use change, which vary from year to year because of weather conditions, added another 4.2 $GtCO_2$, bringing the total to 53.5 $GtCO_2e$.

Despite modest growth in the world economy, CO_2 emissions from fossil fuel combustion, cement production and other industrial processes remained relatively stable from 2014 to 2016. This brought optimism to climate policy discussions, indicating that global GHG emissions might show signs of peaking. However, preliminary estimates of global CO_2 emissions from fossil fuels, industry and cement for 2017 suggest an increase of 1.2 percent (Figure ES.1). The main drivers of the increase are higher gross domestic product (GDP) growth (about 3.7 percent) and slower declines in energy, and especially carbon, intensity, compared with the 2014–2016 period. The 2017 increase leaves considerable uncertainty as to whether the 2014–2016 slowdown was driven primarily by short-term economic factors.

Since CO_2 emissions from fossil fuels, industry and cement dominate total GHG emissions, the changes in CO_2 emissions had the largest influence on GHG emissions from 2014 to 2017. Land-use change emissions have remained relatively flat, despite large annual variations driven by weather patterns and uncertainty in input data.

Figure ES.1: Average annual growth rates of key drivers of global CO2 emissions (left of dotted line) and components of GHG emissions (right of dotted line)



Note: Land-use change emissions are not included due to large inter-annual variability. Leap-year adjustments are not included in the growth rates.

Global peaking of emissions by 2020 is crucial for achieving the temperature targets of the Paris Agreement, but the scale and pace of current mitigation action remains insufficient. Following on from the Talanoa Dialogue, which has raised confidence in implementation efforts and has shown that increased ambition is possible, national governments have the opportunity to strengthen their current policies and their NDCs by 2020.

Global peaking of GHG emissions is determined by the aggregate emissions from all countries. While there has been steady progress in the number of countries that have peaked their GHG emissions or have pledged to do so in the future (Figure ES.2), the 49 countries that have so far done so, and the 36 percent share of global emissions they represent, is not large enough to enable the world's emissions to peak in the near term. By 2030, up to 57 countries, representing 60 percent of global emissions, will have peaked, if commitments are fulfilled.

Countries that have already peaked have a critical role to play in determining the timing and level of global emissions peaking, as each country's decarbonization rate after peaking will be a defining factor in global cumulative emissions. However, it is clear that countries that have peaked their GHG emissions have not reduced their emissions at a fast-enough rate since the peak year.

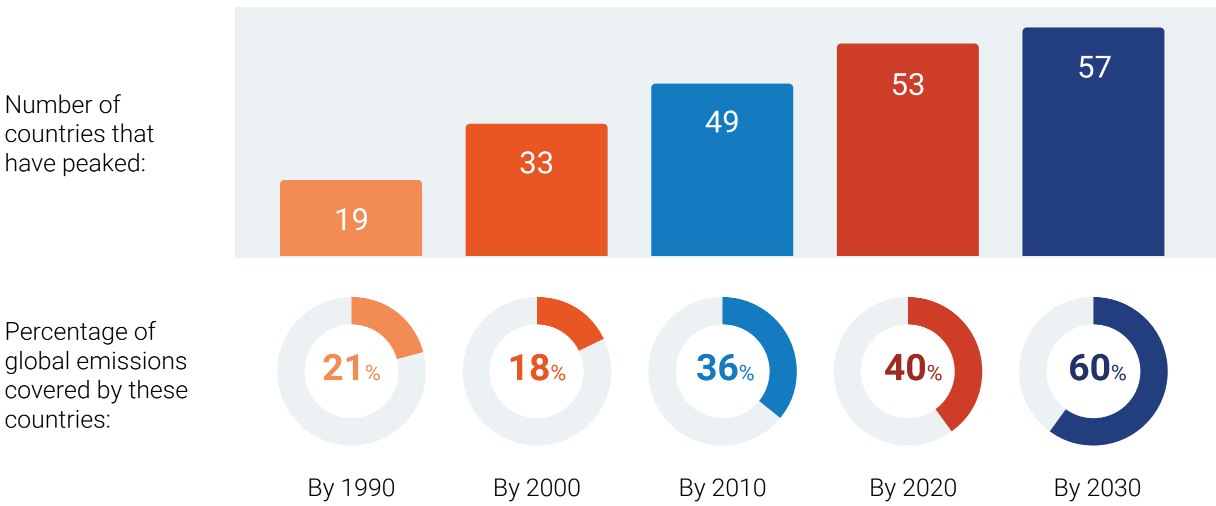
Collectively, G20 members are projected to achieve the Cancun pledges by 2020, but they are not yet on track to realize their NDCs for 2030. Consistent with past Emissions Gap Reports, this report finds that the GHG emissions of the G20 countries, as a group, will not have peaked by 2030 unless there is a rapid increase in ambition and action within the next few years.

While G20 members collectively are on track to achieving the target emission levels in 2020 implied by the Cancun pledges, some countries (Canada, Indonesia, Mexico, the Republic of Korea, South Africa and the United States) are either not projected to achieve their Cancun pledges, or there is uncertainty on whether they will achieve them.

At present, the G20 countries are collectively not on track to meet their unconditional NDCs for 2030. Around half of the G20 members' GHG emissions trajectories fall short of achieving their unconditional NDCs (Argentina, Australia, Canada, EU28, the Republic of Korea, Saudi Arabia, South Africa and the United States). Three G20 members (Brazil, China and Japan) are on track to meeting their NDC targets under current policies, while emissions under current policies of three additional countries (India, Russia and Turkey) are projected to be more than 10 percent below their unconditional NDC targets. This may, in some cases, reflect relatively low ambition in the NDCs. It is uncertain whether two countries (Indonesia and Mexico) are on track to meeting their NDC targets in 2030 under current policies.

G20 members will need to implement additional policies to reduce their annual GHG emissions further by about 2.5 $GtCO_2e$ to achieve their unconditional NDCs and by about 3.5 $GtCO_2e$ to achieve their conditional NDCs by 2030. These additional reductions needed have gone down by approximately 1 $GtCO_2e$ compared with 2017, due to lower projections of emissions under current policies in China, the EU28 and the United States.

Figure ES.2: Number of countries that have peaked or are committed to peaking their emissions, by decade (aggregate) and percentage of global emissions covered (aggregate)



Source: Levin and Rich (2017)

3. The gap in 2030 between emission levels under full implementation of conditional NDCs and those consistent with least-cost pathways to the 2°C target is 13 $GtCO_2e$. If only the unconditional NDCs are implemented, the gap increases to 15 $GtCO_2e$. The gap in the case of the 1.5°C target is 29 $GtCO_2e$ and 32 $GtCO_2e$ respectively. This gap has increased compared with 2017 as a result of the expanded and more diverse literature on 1.5°C and 2°C pathways prepared for the IPCC Special Report.

The 2018 Emissions Gap Report draws on a substantial number of new, least-cost scenarios for meeting the 2°C and 1.5°C warming limits. Last year 16 scenarios were available for both the 1.5°C and 2°C pathway categories; this year, there are a total of 85. These new scenarios are more diverse and often set a lower maximum potential for carbon dioxide removal, which in turn results in deeper emissions reductions over the coming decades to stay within the same overall carbon budget. Each of the scenarios considers least-cost climate change mitigation pathways that start reductions from 2020 and is based on the climate model and set-up used in the IPCC Fifth Assessment Report.

Three temperature levels—2°C, 1.8°C and 1.5°C—are chosen to provide a more nuanced overview of pathways that keep warming in the range of 2°C to 1.5°C, including providing an overview of the peak and 2100 temperature outcomes associated with different likelihoods (Table ES.1). The inclusion of the 1.8°C level allows a more nuanced interpretation and discussion of the Paris Agreement's temperature targets.

Table ES.1: Total global greenhouse gas emissions in 2030 under different scenarios (median and tenth to ninetieth percentile range), temperature implications and the resulting emissions gap

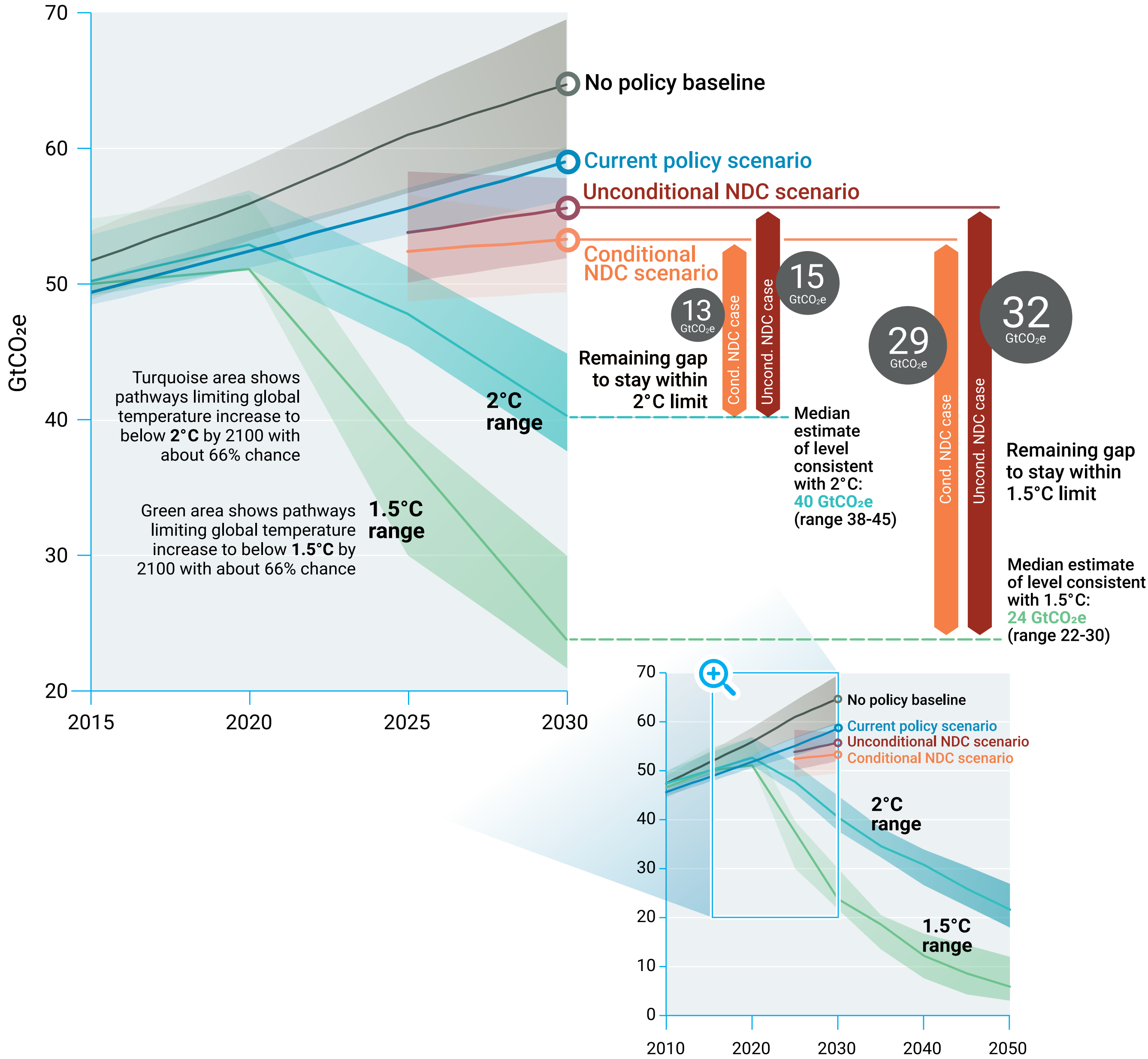
Scenario (rounded to the nearest gigatonne)	Number of scenarios in set	Global total emissions in 2030 [GtCO2e]	Estimated temperature outcomes			Emissions Gap in 2030 [GtCO2e]		
			50% chance	66% chance	90% chance	Below 2°C	Below 1.8°C	Below 1.5°C in 2100
No-policy baseline	179	65 (60–70)						
Current policy	4	59 (56–60)				18 (16–20)	24 (22–25)	35 (32–36)
Unconditional NDCs	12	56 (52–58)				15 (12–17)	21 (17–23)	32 (28–34)
Conditional NDCs	10	53 (49–55)				13 (9–15)	19 (15–20)	29 (26–31)
Below 2.0°C (66% chance)	29	40 (38–45)	Peak: 1.7–1.8°C In 2100: 1.6–1.7°C	Peak: 1.9–2.0°C In 2100: 1.8–1.9°C	Peak: 2.4–2.6°C In 2100: 2.3–2.5°C			
Below 1.8°C (66% chance)	43	34 (30–40)	Peak: 1.6–1.7°C In 2100: 1.3–1.6°C	Peak: 1.7–1.8°C In 2100: 1.5–1.7°C	Peak: 2.1–2.3°C In 2100: 1.9–2.2°C			
Below 1.5°C in 2100 (66% chance)	13	24 (22–30)	Peak: 1.5–1.6°C In 2100: 1.2–1.3°C	Peak: 1.6–1.7°C In 2100: 1.4–1.5°C	Peak: 2.0-–2.1°C In 2100: 1.8–1.9°C			

Note: The gap numbers and ranges are calculated based on the original numbers (without rounding), which may differ from the rounded numbers (third column) in the table. Numbers are rounded to full $GtCO_2e$. GHG emissions have been aggregated with 100-year global warming potential (GWP) values of the IPCC Second Assessment Report. The NDC and current policy emission projections may differ slightly from the presented numbers in Cross-Chapter Box 11 of the IPCC special report (Bertoldi *et al*., 2018) due to the inclusion of new studies after the literature cut-off date set by the IPCC. Pathways were grouped in three categories depending on whether their maximum cumulative CO_2 emissions were less than 600 $GtCO_2$, between 600 and 900 $GtCO_2$, or between 900 and 1,300 $GtCO_2$ from 2018 onwards until net zero CO_2 emissions are reached, or until the end of the century if net zero is not reached before. Pathways assume limited action until 2020 and cost-optimal mitigation thereafter. Estimated temperature outcomes are based on the method used in the IPCC Fifth Assessment Report.

Current policies are estimated to reduce global emissions in 2030 by around 6 $GtCO_2e$ compared with the no-policy scenario (Table ES.1). This is in line with the 2017 assessment, implying that studies have not identified significant and unambiguous progress in the implementation of policies that would enable the NDCs to be achieved by 2030.

The updates to this year's assessment result in changes of the GHG emission levels in 2030, compared with the 2017 Emissions Gap Report, consistent with limiting global warming to 2°C and lower. According to the new scenario estimates, emissions of all GHGs should not exceed 40 (range 38–45) $GtCO_2e$ in 2030, if the 2°C target is to be attained with about 66 percent chance. To keep global warming to 1.8°C with about 66 percent chance, global GHG emissions in 2030 should not exceed 34 (range 30–40) $GtCO_2e$. For a 66 percent chance of keeping temperature increase below 1.5°C in 2100 (associated with no or a low overshoot), global GHG emissions in 2030 should not exceed 24 (range 22–30) $GtCO_2e$.

Figure ES.3: Global greenhouse gas emissions under different scenarios and the emissions gap in 2030 (median estimate and tenth to ninetieth percentile range)



The full implementation of the unconditional NDCs is estimated to result in a gap of 15 $GtCO_2e$ (range 12–17) in 2030 compared with the 2°C scenario. This is about 2 $GtCO_2e$ higher than the gap assessed in the previous report because the most recent 2°C scenarios indicate a lower benchmark. If, in addition, the conditional NDCs are fully implemented, the gap is reduced by about 2 $GtCO_2e$. The emissions gap between unconditional NDCs and 1.5°C pathways is about 32 $GtCO_2e$ (range 28–34). This is about 13 $GtCO_2e$ higher than the assessment in the 2017 report, due to the much larger number of available scenario studies that rely less on large volumes of carbon dioxide removal and thus show lower 2030 benchmark values. Considering the full implementation of both unconditional and conditional NDCs would reduce this gap by about 3 $GtCO_2e$.

Implementing unconditional NDCs, and assuming that climate action continues consistently throughout the 21st Century, would lead to a global mean temperature rise of about 3.2°C (with a range of 2.9–3.4°C) by 2100 relative to pre-industrial levels, and continuing thereafter. Implementation of the conditional NDCs would reduce these estimates by 0.2°C in 2100. These projections are similar to the 2017 estimates.

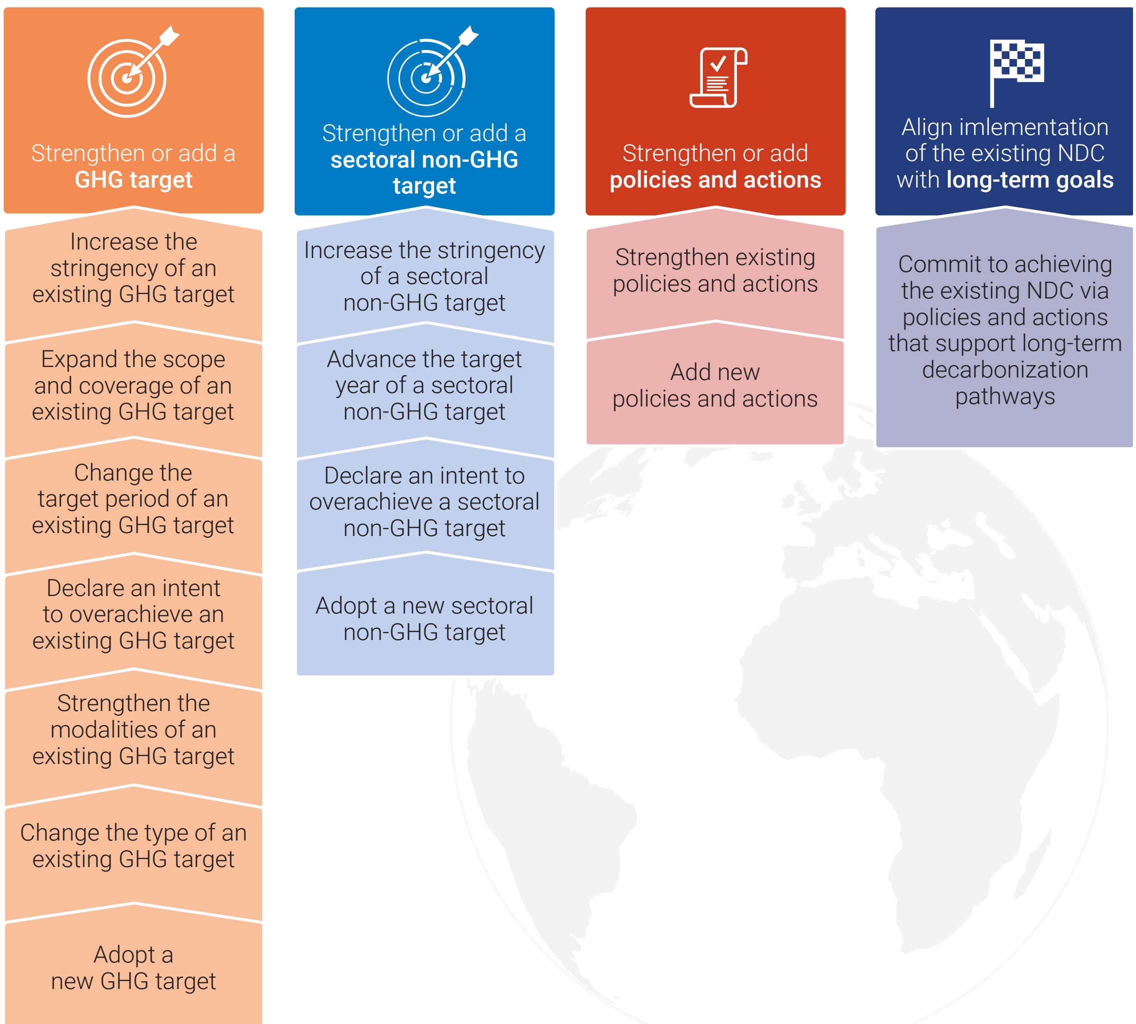
4. Countries need to strengthen the ambition of NDCs and scale up and increase effectiveness of domestic policy to achieve the temperature goals of the Paris Agreement. To bridge the 2030 emissions gap and ensure long-term decarbonization consistent with the Paris Agreement goals, countries must enhance their mitigation ambition. Enhanced ambition in the NDCs sends an important signal regarding mitigation commitment, both internationally and domestically. However, domestic policies are crucial to translate mitigation ambition into action.

Ambition can, in this context, be viewed as a combination of target-setting, preparedness to implement and a capacity to sustain further reductions over time.

There are various ways in which a country could reflect enhanced mitigation ambition in its NDCs (Figure ES.4).

These options are not mutually exclusive, and whether an NDC revision results in enhanced ambition depends on the scale of the revision rather than its form. It is important for countries to consider a wide range of options to identify those that are most meaningful and practical in their unique circumstances, and to bring about the deep emission reductions required to bridge the gap.

Figure ES.4: Typology of strengthening mitigation ambition of NDCs



Source: Adapted from Franzen et al., (2017) Major gaps in coverage and stringency of domestic policies remain, including among G20 members, in, for example, fossil fuel subsidy reduction, material efficiency measures in industry, oil and gas methane, support schemes for renewables heating and cooling, emission standards for heavy-duty vehicles, and e-mobility programmes. Even in areas where policy coverage is high, stringency can be improved. For example, while all G20 countries have policies to support renewables in the electricity sector, stringency of these policies can still be enhanced.

The technical potential for reducing GHG emissions is significant and could be sufficient to bridge the emissions gap in 2030. A substantial part of this potential can be realized through scaling up and replicating existing, well-proven policies that simultaneously contribute to key sustainable development goals.

The 2017 Emissions Gap Report provided an updated assessment of the sectoral emission reduction potentials that are technically and economically feasible in 2030, considering prices up to US$100/t$CO_2$e. It found that global emissions could be reduced by 33 (range 30–36) GtCO_2e per year in 2030, compared with the current policy scenario of 59 GtCO_2e per year (Chapter 3). If, in addition, a number of newer and less certain mitigation options were included, the mitigation potential would increase to 38 (range 35–41) GtCO_2e. The emissions reduction potential is thus sufficient to bridge the gap in 2030. As the 2017 Emissions Gap Report showed, a large part of the technical potential lies in three broad areas: renewable energy from wind and solar, energy-efficient appliances and cars, and afforestation and stopping deforestation.

In these and many other areas—and across all countries—there is significant potential to realize a substantive part of the technical mitigation potential through the replication of proven good-practice policies that can simultaneously contribute to key sustainable development goals. Realizing this potential would significantly narrow the gap by 2030, beyond current NDCs.

5. Non-state and subnational action plays an important role in delivering national pledges. Emission reduction potential from non-state and subnational action could ultimately be significant, allowing countries to raise ambition, but the current impacts are extremely limited and poorly documented.

NSAs provide important contributions to climate action beyond their quantified emission reductions. They build confidence in governments concerning climate policy and push for more ambitious national goals. They provide space for experimentation or act as orchestrators, coordinating with national governments on climate policy implementation. Initiatives and actors also incentivize, support and inspire additional climate action by exchanging knowledge and good practices, engaging in advocacy and policy dialogue, assisting in formulating action plans, and rewarding and recognizing climate actions.

The number of actors participating is rising fast: more than 7,000 cities from 133 countries and 245 regions from 42 countries, along with more than 6,000 companies with at least US$36 trillion in revenue, have pledged mitigation action. Commitments cover large parts of the economy and are gradually expanding in regional coverage. Many of the actors are engaging in so-called 'international cooperative initiatives', which are characterized by multi-country and multi-actor engagement.

The numbers seem impressive, but there is still huge potential for expansion. Based on available data, not even 20 percent of the world population is represented in current national and international initiatives, and many more of the over 500,000 publicly traded companies worldwide still can, and must, act. On the financial side, a record of just over US$74 billion of Green Bonds were issued in the first half of 2018, but this still represents only a very small fraction of the capital markets around the world.

The emission reduction potential from NSAs is large, but estimates vary considerably across studies (Figure ES.5). If international cooperative initiatives are scaled up to their fullest potential, the impact could be considerable compared with current policy: up to 19 $GtCO_2e$ per year by 2030 (range 15–23 $GtCO_2e$) according to one study. If realized, this would be instrumental in bridging the emissions gap to 2°C pathways.

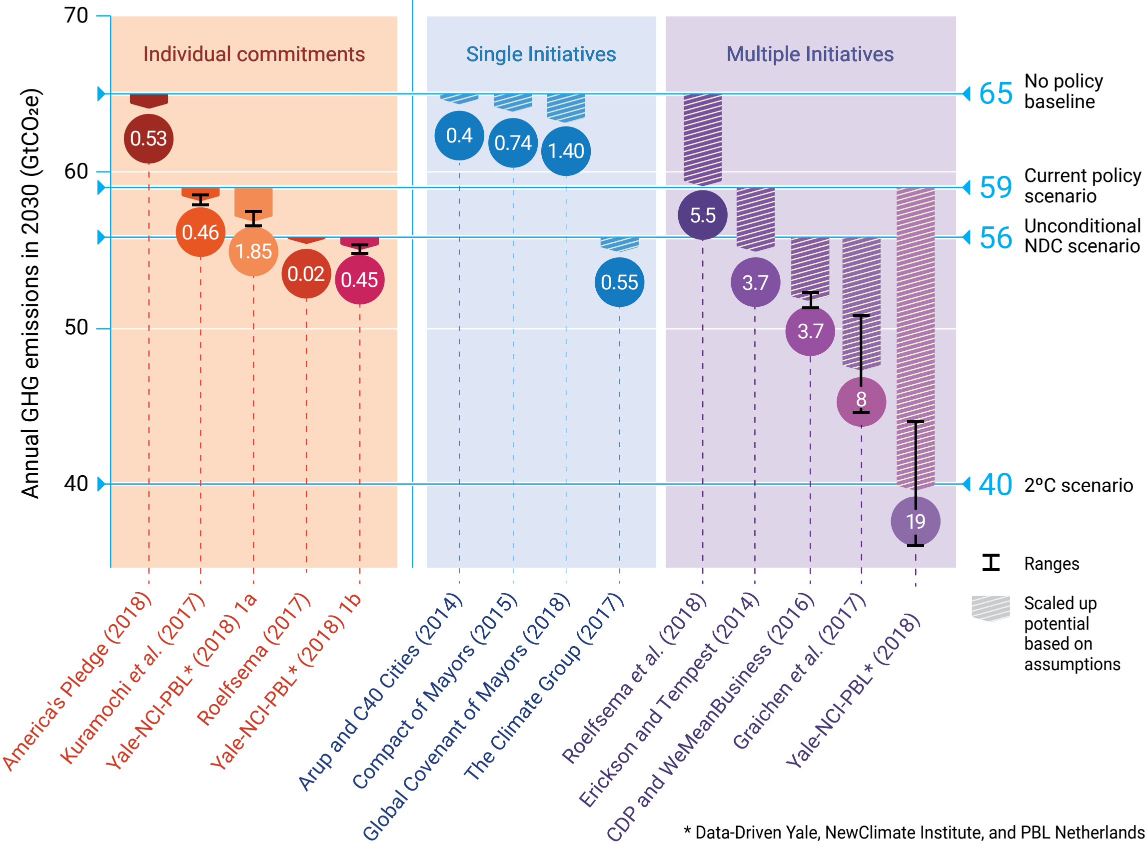
However, the additional emission reductions under full implementation of pledged commitments made so far by individual non-state actors are still quite limited: up to 0.45 $GtCO_2e$ (range 0.2–0.7 $GtCO_2e$) per year by 2030 compared with full unconditional NDC implementation, and up to 1.85 $GtCO_2e$ per year (range 1.5–2.2 $GtCO_2e$) compared with current policy. A more comprehensive assessment of all non-state and subnational climate action occurring globally is limited by the current low level of available data and lack of consistent reporting on non-state and subnational climate action.

Non-state actors need to adopt common principles when formulating their actions. Such principles should include clear and quantifiable targets based on relevant benchmarks, technical capacity of the actors, availability of financial incentives and the presence of regulatory support.

Figure ES.5: The range of estimated potential emission reductions in various NSA studies

Figure ES.5a: Emission reduction potential of pledged commitments by NSAs

Figure ES.5b: Scaled up potential emission reductions based on single and multiple initiatives



Source: Based on data in table 5.2.

Note: a) For studies that include ranges, median estimates are provided with ranges indicated in figures ES.5a and ES.5b.
b) Studies that are cross-hatched evaluate single and multiple ICI goals rather than individual actors' recorded and quantified pledges. They rely on assumptions of future scaled-up impact and therefore represent potential rather than a quantified analysis of individual actors' NSA pledges.
c) Extrapolation of 2025 estimates has been made.

6. Fiscal policy reform can play a key role in creating strong incentives for low-carbon investments and reducing GHG emissions. Revenues from carbon pricing can be used for reducing other taxes, increase spending on social issues and/or compensating low-income households. Well-designed fiscal reform packages can reduce the costs of mitigating emissions, thereby making these fiscal reforms more socially acceptable. The use of carbon pricing to reduce GHG emissions is still only emerging in many countries and generally not applied at a sufficient level to facilitate a real shift towards low-carbon societies.

Fiscal policy is a key government tool for managing and influencing the national economy and can be used to tax fossil fuels or subsidize low-emission alternatives as a way of influencing carbon emissions and ultimately investments in the energy sector.

Pricing of carbon emissions through taxes or domestic emissions trading systems is, in many countries, part of the national climate policy and is referenced in many NDCs as one of the possible policy tools to be used. Before 2005, when the Kyoto Protocol entered into force, hardly any emissions were covered by carbon taxes or trading systems. Coverage of explicit carbon pricing policies increased to about 5 percent of global GHG emissions between 2005 and 2010, primarily because of the introduction of the European Union's Emissions Trading System. Between 2010 and 2018, coverage rose to about 15 percent of global emissions, with 51 carbon pricing initiatives now in place or scheduled. If China implements carbon pricing as announced, coverage would rise to about 20 percent of global GHG emissions.

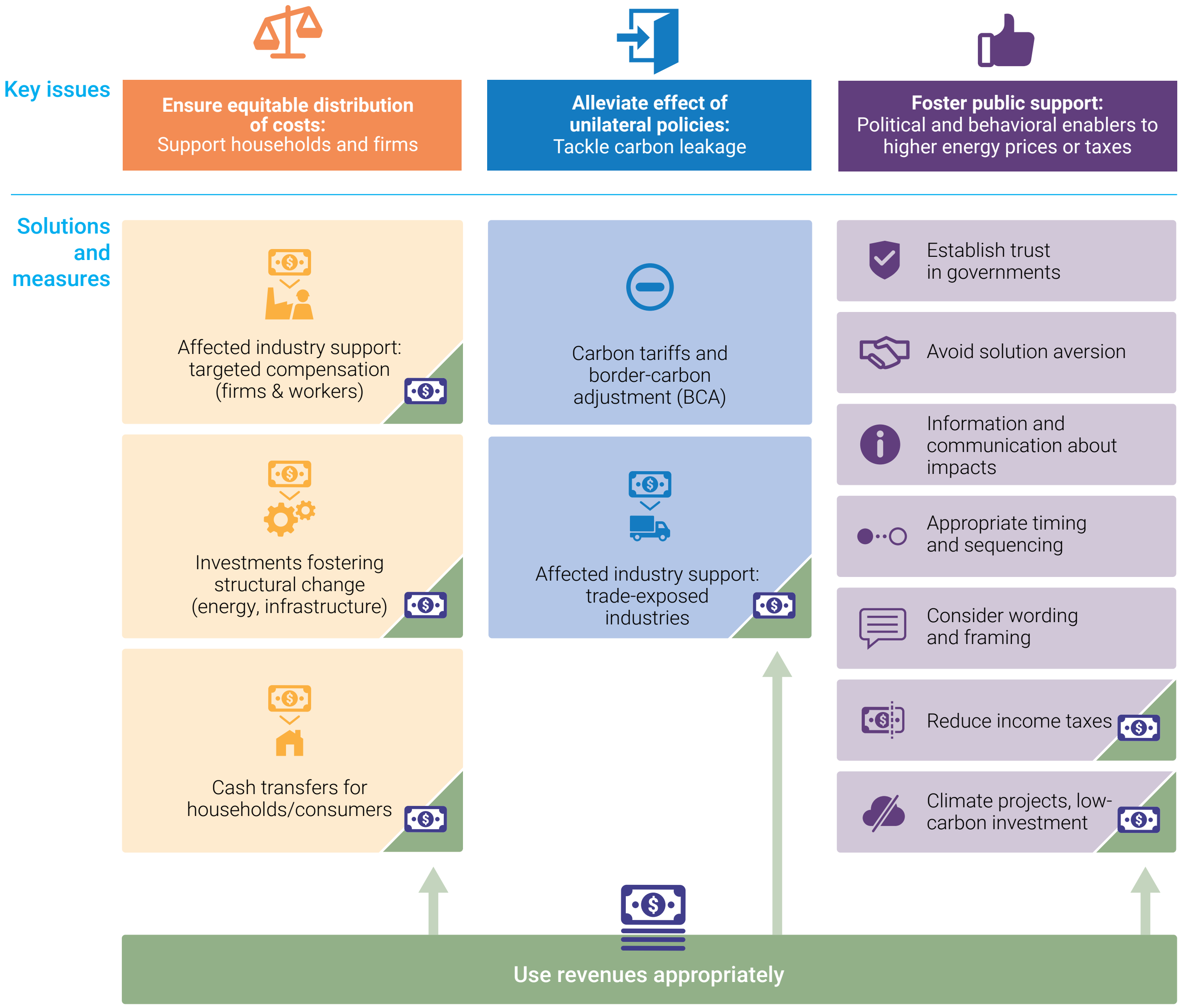
However, in most countries, fiscal policy is currently not yet geared towards delivering the required transition to a low-carbon economy. Effective carbon prices are too low and inconsistent, and the broader fiscal policy framework is often poorly aligned with climate policy goals. Besides carbon pricing, many governments levy specific taxes on energy use—partly to collect additional revenues. Even when considering energy-specific taxes together with explicit carbon pricing policies, half of the emissions from fossil fuels are not priced at all, and only 10 percent of global emissions from fossil fuels are estimated to be priced at a level consistent with limiting global warming to 2°C.

Studies show that a carbon tax of US$70/t$CO_2$ in addition to existing measures could reduce emissions from just above 10 percent in some countries to more than 40 percent in other countries. Furthermore, in developing and emerging economies, an additional carbon tax of this order could raise the equivalent of 2 percent of GDP in public revenue.

Fiscal policies are used for different purposes and many countries actually subsidize fossil fuels for various economic and social reasons. If all fossil fuel subsidies were phased out, it would lead to a reduction of global carbon emissions of up to about 10 percent by 2030.

Several key issues need to be considered when introducing carbon pricing and phasing out fossil energy subsidies with the aim of reducing carbon emissions. These issues, along with possible ways of addressing them, are illustrated in Figure ES.6 below. Embedding carbon pricing in fiscal reform packages that are progressive, equitable and socially acceptable, and incentivizing investment in new and job-creating industries is essential. It is instructive for policymakers to reflect on experience with other environmental fiscal reforms, where positively worded narratives, transparent communication, engagement with stakeholders and appropriate compensation have often helped overcome political and popular resistance to policies that increase fossil energy prices.

Figure ES.6: Key issues for making fiscal reforms politically viable (upper part) and solutions and measures to address them (lower part)



Note: The green arrows show different ways to use revenues from carbon pricing. Measures that are related to financial flows have a green mark

7. Accelerating innovation is a key component of any attempt to bridge the emissions gap, but it will not happen by itself. Combining innovation in the use of existing technologies and in behaviour with the promotion of investment in new technologies and market creation has the potential to radically transform societies and reduce their GHG emissions.

Based on an assessment of existing studies of what works, there are five key principles or 'success factors' that policymakers should consider when designing policies and programmes to accelerate low-carbon innovation:

1. Public organizations must be willing to take on the high, early-stage risk that private organizations shy away from.
2. At the mid-stage of the innovation chain, public organizations must be able to nurture feedback effects among different parts of the innovation landscape and help de-risk private investment in commercial-scale projects.
3. Green policies must set a direction for the whole economy, not for each sector separately.
4. Mission-oriented innovation is useful for stimulating investment and innovation across different parts of the economy to reach concrete, target-specific goals, such as X percent cost reduction in a specific low-carbon technology, by a specific date.
5. Policy instruments need to be structured to mobilize actors through bottom-up exploration and participation. All these policies benefit from a long-term design horizon that creates certainty for private finance to be crowded in.

While these principles apply to countries at any stage of economic development, a country's financial resources and technological capacity determine what types of concrete policies are most appropriate.

In order to illustrate these rather abstract concepts, the global solar photovoltaic (PV) technology development is presented as a case example of how application of the various innovation policy components has been driving and shaping PV technology and market development, with different countries in the lead during different periods.

Innovation in solar photovoltaic (PV) technology illustrates both the nonlinear nature of innovation and how the various innovation policies reviewed drive and shape it. PV was deployed with a compound annual growth rate of about 38 percent from 1998 to 2015, continually defying forecasts. PV diffusion spurred cost reductions through 'learning by doing', scale economies and R&D, and also lower profit margins through increasing competition, which in turn stimulated further deployment of ever-cheaper systems. From 1975 to 2016, PV module prices fell by about 99.5 percent, and every doubling of installed capacity coincided with a 20 percent drop in costs. Public innovation policies were, and continue to be, crucial for this process across the innovation chain.

The PV experience cannot be applied as a universal model, but it illustrates the various innovation success factors and the vision, patience and long-term thinking often required. Indeed, it is useful to reflect on how commercially viable, low-carbon technologies, such as PV and on-shore wind turbines, achieved their present status, when thinking about what is needed to reach new goals. For example, how can we deliver on the need for commercially viable and sustainable batteries and other power-storage technologies to rapidly reduce global transport-sector emissions by 2030? What kind of political vision and combination of public and private resources, at what scale, should be agreed upon and committed to in order to make this happen?

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