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Article

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Introduction

Our daily lives are being increasingly affected by climate change and government policies to cut greenhouse gas emissions. What level of warming can be considered likely and what actions are countries [1] around the world taking to avoid severe climate change ?

Climate change is defined as long-term shifts in temperatures and weather patterns. Climate science has conclusively established that climate change since preindustrial times is first and foremost caused by humans. In other words, what humans do now will determine how much warming the world will experience (IPCC, 2021). Scientific evidence has proven that the primary cause of global warming is the burning of fossil fuels, such as coal, oil and gas. These processes emit gases that trap heat in the atmosphere, commonly referred to as the “greenhouse effect” and “greenhouse gases” (GHGs). The main GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases, while the main sources of these emissions are power generation, manufacturing, transport, buildings, agriculture and land use.

The consequences of climate change are far-reaching and encompass more than higher temperatures ; other important repercussions include changes in precipitation patterns, leading to severe droughts, fires, water scarcity and flooding, as well as the melting of polar ice, higher chances of catastrophic storms, rising sea levels and declining biodiversity. Climate change will therefore have a significant impact on human flourishing and our ability to grow food, find shelter and, ultimately, thrive.

Avoiding dangerous human interference with the climate system has been on the agendas of governments since the early 1990s, starting with the UN Framework Convention on Climate Change (UNFCCC). Reports by the UN’s climate assessment group, the Intergovernmental Panel on Climate Change (IPCC), indicate that limiting the rise in global temperatures to 1.5 °C would help to avoid the worst outcomes. To achieve this goal, climate science has shown that emissions need to peak as soon as possible, decline quickly and decisively thereafter, and reach net zero (meaning GHG removals and emissions are balanced) by around the middle of this century.

* The authors would like to thank Paul Butzen and Carine Swartenbroekx for their valuable comments and various staff members of the IMF and Capital Economics for the helpful discussions and sharing their data.
1 In this article, the word “countries” should be construed as including blocs of countries such as the EU.

Nevertheless, global GHG emissions have continued to rise (aside from a brief decline during the COVID-19 pandemic in 2020). One problem is that climate change is a global issue, requiring international cooperation and coordinated solutions. It is also one that is typically prone to free-riding, complicating negotiations and undermining trust among countries, each of which wishes to minimise its costs in the hope that others will take action to slow climate change. Despite these difficulties, a majority of governments and societies have, as the consequences of climate change become ever more apparent, understood that urgent action is required to help humanity avoid the most devastating effects. In recent years, climate change has consequently been at the forefront of – an increasingly complex array of – policy discussions and actions. There is no lack of information on this subject, but the sheer quantity makes it difficult to get a clear view at times.

The purpose of this article is therefore to provide an overview of the international context in which climate change mitigation policies are being adopted and summarise the current status of these policies in the world's largest emitters – China, the United States (US), India, the EU, and Japan – as well as the United Kingdom (UK), which is considered a frontrunner in terms of climate policy. Even though all countries should be prepared to tackle climate change and move towards a net-zero world, those discussed in this article are responsible for almost 60 % of global GHG emissions and consequently have a disproportionate influence on the outcome.

This article consists of four sections. In the first section, we lay out the Paris Agreement, which constitutes the most important framework for international climate negotiations and creates incentives for countries to become more ambitious in their climate policies. We also show where the world stands in terms of reaching the temperature goals of the Paris Agreement. We then turn to the policies and mix of policy instruments countries are using to meet their domestic targets, as well as the gap between current policies and climate goals. In the third section, we suggest several ways in which global climate policy ambitions could be strengthened to avoid the worst effects of climate change. We conclude with key takeaways.

1. Paris Agreement: set-up, goals and progress

1.1 What is the Paris Agreement?

The Paris Agreement is an international treaty on climate change adopted at the 2015 Conference of the Parties (COP) to the UNFCCC.[1] The latter was adopted in 1992 and entered into force in 1994. Its main goal is the stabilisation of GHG concentrations at a level that will prevent dangerous human-caused interference with the climate system. The main goal of the Paris Agreement is more concrete, namely to hold "the increase in the global average temperature to well below 2 °C above pre-industrial levels"[2] and pursue efforts "to limit the increase to 1.5 °C". These temperature goals are derived from climate science, as set out in the IPCC's reports. The Paris Agreement currently has near-universal coverage, as it has been ratified, approved or accepted by 195 parties (excluding Eritrea, Yemen and Iran). In addition to climate mitigation goals, the Paris Agreement provides a framework for adaptation policies to deal with climate consequences and for climate finance to support developing countries through climate-resilient development policies, technology transfers and the financing of emission-reduction projects. Although important, these topics fall outside the scope of this article.

The Paris Agreement has transformed international climate policy and provided a framework for countries to increase their climate policy ambitions, one that was especially welcome after many years of deadlock following the failure to conclude a global treaty in Copenhagen in 2009. Nevertheless, due to its lack of enforcement mechanisms, the Paris Agreement is based on soft law, which has led some experts to conclude that it is unlikely

1 Details on the practical implementation of the Paris Agreement (the so-called "Paris Rulebook") were only agreed at COP24, held in Katowice in 2018, and finalised at COP26, held in Glasgow in 2021.

2 The Paris Agreement does not specify what is meant by "pre-industrial", meaning this could in principle be any period before the Industrial Revolution. However, the IPCC has interpreted this term to refer to the period 1850-1900, as this is the earliest period for which almost global, reliable temperature measurements exist. Accordingly, this period is used as a proxy for pre-industrial temperatures (see IPCC, 2018).

to trigger the ambitious emission reductions needed in the coming decade (see below). If countries are to reach the most ambitious goal of the Paris Agreement, namely limiting global warming to 1.5 °C by the end of this century, they must (nearly) halve greenhouse gas emissions by 2030 (IPCC, 2021) and reach net zero by 2050. Even to meet the 2 °C target by the end of this century, GHG emissions will need to be lowered by around 30 % by 2030.

1.2 How does the Paris Agreement work in practice?

Under the Paris Agreement, countries commit to submitting national emission reduction targets in order to meet the goal of limiting the rise in global temperatures to 2 °C and ideally 1.5 °C by the end of this century. These domestic targets are communicated to the UNFCCC secretariat and then made available to the public in an online registry. The near-term targets are called nationally determined contributions (or NDCs) and are expected to be updated every five years. With each update, a country's commitments should become more ambitious (i.e., be ratcheted up). It is important to emphasise that this is a bottom-up process in which each country decides on its own targets. There are no top-down legally binding emission reduction standards to be met (in contrast to those applicable to developed nations under the Kyoto Protocol). Currently, the time horizon for NDCs is 2030. Countries are also asked to formulate and communicate long-term strategies (typically on emissions targets for 2050 or shortly thereafter) to the UNFCCC secretariat. However, they are not required to do so. The bottom-up approach of the Paris Agreement means there are a plethora of ways of formulating goals and measuring reductions (see below), which reflect different policy approaches (e.g. technology or R&D subsidies, carbon pricing applied to most or only a limited share of a country's GHG emissions, etc.) and different base years from which emissions reductions are measured (discussed in more detail below).

The first global stocktake will conclude this year at COP28. The purpose of this exercise is to assess the collective progress made towards achieving the Paris Agreement's near-term ambitions and long-term objectives. Countries are expected to report on where they stand compared to their NDC goals in accordance with specific criteria (an enhanced transparency framework). The submission of a mandatory transparency report and a national GHG inventory report will be biennial[1] from 2024 onwards, except for developed nations which are expected to report annually on their progress.

Given the absence of enforcement mechanisms at the international level, the Paris Agreement constitutes soft law only. Nevertheless, particularly in large and developed countries, NDCs have been transposed into legally binding national legislation.

Like the UNFCCC, the Paris Agreement is based on the principle of common but differentiated responsibilities and respective capabilities. This means that all countries are responsible for the protection of the global environment but are not expected to make the same efforts to reduce GHG emissions, as they have not made the same (historical) contribution to current global environmental degradation. Moreover, countries have different technologies and financial resources at their disposal and are not at the same stage of development. This partly explains why the Paris Agreement adopts a bottom-up approach. However, there is no consensus on the interpretation of common but differentiated responsibilities, as the economic development of some of the world's emerging countries (most notably China) has led to calls for a gradual alignment of their climate obligations to those of more developed nations.

1.3 Will the world as a whole achieve the temperature goals of the Paris Agreement?

In this subsection, we aim to show where the world stands in terms of reaching the temperature goals of the Paris Agreement (on a global level). Despite the progress made thus far and the significant long-term climate neutrality

1 Many countries already have comprehensive GHG emissions inventories. Progress can still be made, however, for countries that rely on proxy inventories and for subsectors for which better measurement technology is becoming available.

ambitions of many countries, GHG emissions still need to be cut, and quickly. The latest IPCC report estimates global mean surface temperature change to be around 1.1 °C above the 1850-1900 average (IPCC, 2023), with larger increases over land than oceans. Other institutions, such as the IMF, UNEP and Climate Action Tracker, have released similar assessments. Chart 1 compares current warming to possible future warming trajectories, as calculated by Climate Action Tracker. Of course, future estimates are always subject to uncertainty, particularly as they cover long periods of time. Nevertheless, the scientific literature agrees that there is a near-linear relationship between cumulative GHG emissions and climate change. Th global mean surface temperature is likely to rise by around 0.45 °C per 1000 Gt of CO_2 emitted, with a range of uncertainty of 0.27 °C to 0.63 °C (IPCC, 2023). Despite scientific uncertainty as to the precise magnitude of warming, it is clear that the window of opportunity to limit the global rise in temperatures to 1.5 °C by the end of this century is rapidly closing.

Considering all currently implemented policies, we end up with a median estimated temperature increase of 2.7-2.8 °C by 2100 (UNEP and CAT) or even 3.2 °C (IPCC). Even if all targets (all current NDCs) were to be fully realised by 2030, temperatures would still be expected to increase by 2.4-2.6 °C (UNEP and CAT). Even in the most optimistic scenario, which takes into account all *announced* climate pledges and all long-term strategies communicated to the UNFCCC as of November 2022, the expected median temperature increase is still around 1.8 °C (UNEP and CAT).

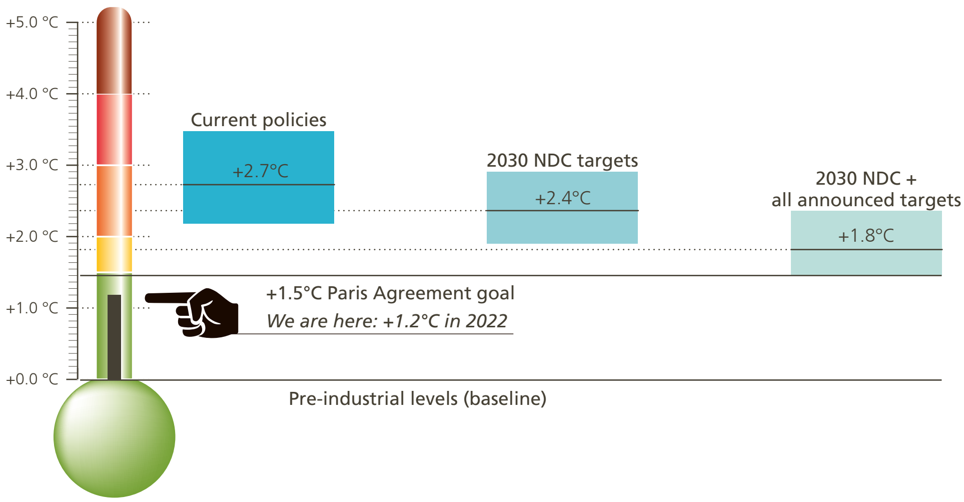
Consequently, all estimates clearly point to an urgent need for more ambitious climate policies. It would be unwise to take the most optimistic scenario as a starting point and refrain from additional action, especially since the gaps between policy ambitions and implementation also loom large (see below). From an economic cost-benefit and efficiency perspective, the first-best solution is to steer market behaviour by putting a price on GHGs (Pigou, 1920). As carbon pricing tends to be a politically sensitive issue, Hassler *et al.* (2021) studied the cost of policy errors (i.e., putting an incorrect tax on carbon in various ways). Their work clearly demonstrates that it is better to adopt climate policies that are too strict (i.e., to set a carbon price that is too high) than a price that is too low, as the latter entails a larger welfare cost for society due to tail risks. From this perspective, climate policy can be seen as an insurance policy against the most disastrous consequences of climate change. On the investment side, the good news is that the cost of renewables has plummeted over the last decade and they are now competitive with fossil fuels: the levelised cost of electricity from offshore wind is globally within the price

Chart 1

Gap between the Paris Agreement goals and climate policy ambitions worldwide

Global temperature increase by 2100

(as of November 2022, various scenarios and estimated ranges, median outcome mentioned)



Source: Climate Action Tracker.

range of electricity from fossil fuels, with the cost of hydropower, onshore wind and solar photovoltaics (PV) even lower.[1] A further decline is expected according to projections. Although the estimated global investment ratio needed to reach net zero by 2050 is substantial (around 3 % of GDP over 2020-2050) with a peak of around 4 % in 2030 (IEA, 2022a), it remains feasible, as such investment ratios were seen in 1970-1999. A rapid increase will particularly be needed in the electricity, infrastructure and end-use sectors, with growth primarily driven by investment in clean energy technologies.

2. Largest emitters: climate ambitions, policy mix and policy gaps

2.1 Which countries are the largest emitters of greenhouse gases?

The latest comprehensive data on GHG emissions date from 2021 (EU Edgar database; see Crippa *et al.*, 2022). After a significant dip in 2020 caused by the pandemic, during which emissions fell by around 5 % due to strict lockdowns and other measures that impacted economic activity, the level and growth rate of emissions climbed back in 2021, to around 53 Gt of CO_2 equivalent[2] at year's end.

In 2021, the world's largest emitter was China, responsible for almost 30 % of global GHG emissions, significantly more than the first runner-up, the US, which produced 11 % of global emissions. The top three was rounded out by India, which was responsible for 7.3 % of worldwide emissions. The EU27 came in fourth place, with 6.9 % of emissions. The fifth largest emitter was Russia, followed by Brazil, Indonesia, Japan and Iran. The last country is noteworthy as it is the largest emitter that is not a party to the Paris Agreement. The UK was responsible for only 0.8 % of worldwide emissions. Nevertheless, we include it in our overview due to its reputation as a frontrunner in climate policy. The top three emitters, the EU and Japan, which are analysed more closely in this article, collectively account for almost 60 % of global GHG emissions. Consequently, if these countries are able to reduce their GHG emissions to net zero by 2050, this would represent significant progress in terms of slowing dangerous climate change and decreasing climate risk.

The data also clearly illustrate why developing and emerging countries must implement ambitious climate policies as well if the world is to reach the Paris Agreement's temperature goals. Without their contribution and cooperation, it will be virtually impossible to cut global GHG emissions at the required pace and, in any case, significantly more costly to do so.

In terms of CO_2 emissions *per capita*, computed as the ratio of a country's CO_2 emissions to its population, the picture looks very different. The US has some of the highest per capita emissions in the world, although these have been steadily falling since the 1970s. Per capita emissions are still strongly increasing in several emerging and developing countries, while they are stabilising or even decreasing in most developed countries. Since 2000, China has recorded a very strong increase in per capita emissions, which are now higher than in the UK and the EU27 and similar to those of Japan.

The carbon intensity of GDP reflects the efficiency of a country's production technologies and industrial practices, as well as its economic structure. This indicator tends to be higher in developing economies, for reasons of technology, economic structure and comparative advantage (sometimes leading to the offshoring of carbon-intense industries to such economies). Significant improvements in energy efficiency have resulted in a marked decline in the carbon intensity of GDP in developed countries – and even more so in developing countries – since 2000.

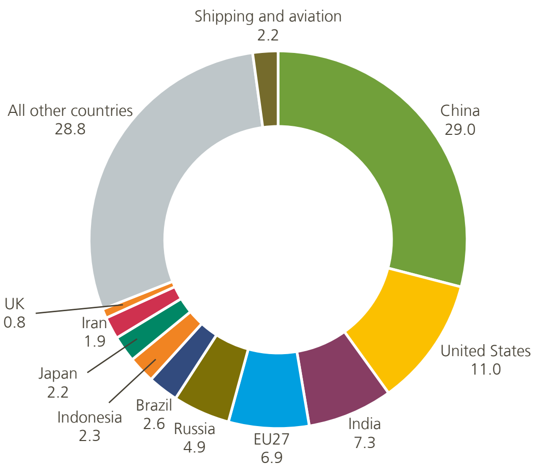
1 The levelised cost of electricity is the average net present cost of electricity generated by a particular technology over the life span of a typical project, including installation, capital, operating and maintenance costs.

2 Carbon dioxide equivalent or CO_2 equivalent is a metric used to compare emissions from various GHGs based on their global warming potential, by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential over a given period of time (typically 100 years).

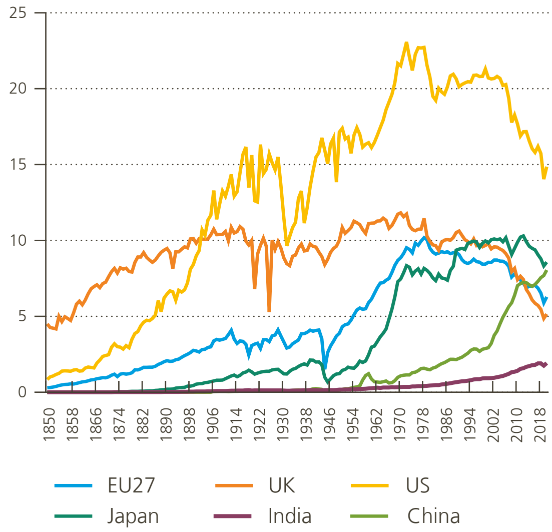
Chart 2

Efforts by emerging economies will be vital to achieve the Paris Agreement temperature goals

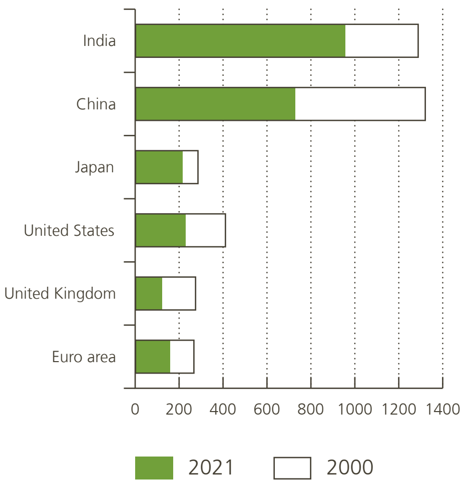
Global GHG emissions[1] in 2021
(million tonnes of CO_2 equivalent, % of total)



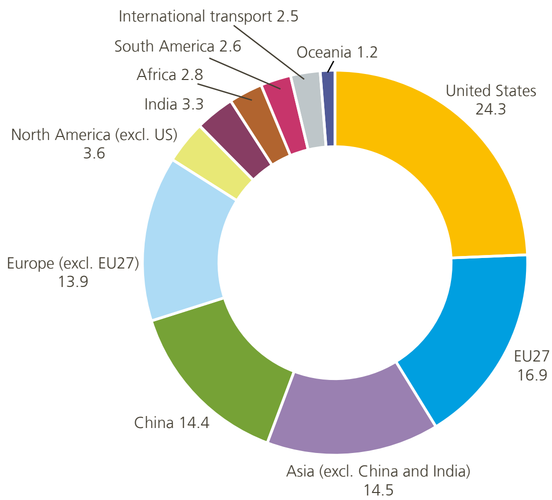
Annual CO_2 emissions per capita, 1850-2021
(tonnes)



Annual CO_2 emissions per million $ of GDP, 2021 versus 2000
(tonnes)



Cumulative CO_2 emissions by region, 1850-2021
(% of total)



Sources: Capital Economics, EU Edgar, Global Carbon Project, Our World in Data.
1 Excluding large-scale biomass burning, forest fires, and sources and sinks from land-use, land-use change and forestry (LULUCF).

From a historical perspective, advanced economies bear more responsibility for emissions. Since the nineteenth century, when human-caused climate change was not yet an issue, these economies have developed through increasing their GHG emissions. Developing economies often use this argument to defend their stance that they need to continue to increase emissions and to justify the position that developed nations should make the bulk of the efforts. This fairness perspective also explains why the Paris Agreement explicitly leaves room for common but differentiated responsibilities and respective capabilities. Nevertheless, looking at current levels of cumulative historical emissions, China and the rest of Asia are quickly catching up with more developed economies. The continuously increasing carbon footprint of China – and Asia at large – makes it increasingly less obvious to justify a smaller contribution to global GHG mitigation efforts. The historical fairness argument remains valid, however, for certain other developing economies.

2.2 National climate policies

We now turn to national climate mitigation policies. What pledges have countries made to reduce GHG emissions? Where do they stand in reaching their targets? What instruments are they using to accomplish their goals and how do these efforts relate to the global goals of the Paris Agreement, more specifically to the objective of keeping global warming well below 2 °C by the end of this century?

Table 1

Main climate mitigation targets included in NDCs and long-term strategies[1]

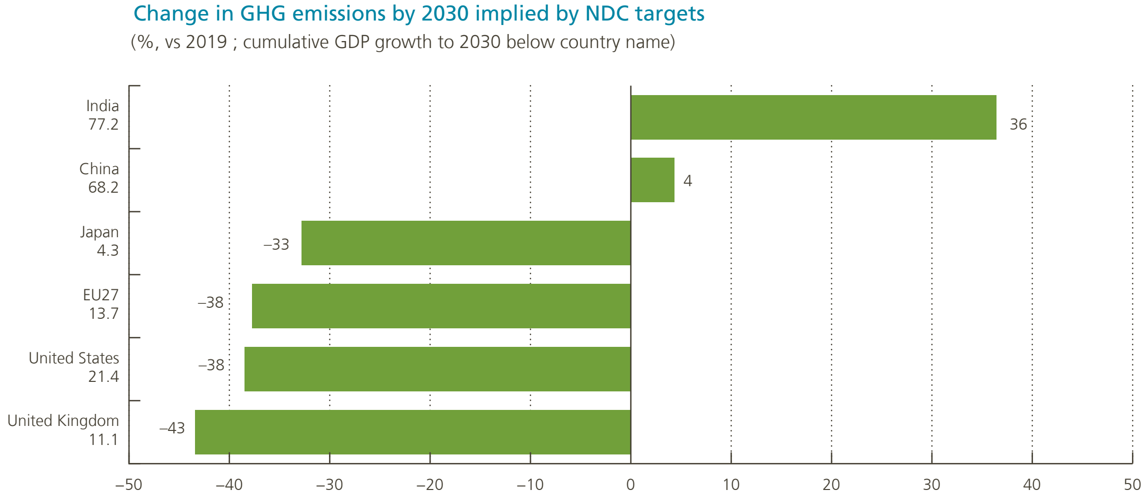
Share of global GHG emissions in 2021 (in %)	Country	Official (main) NDC target	Net zero target year
29.0		Reduce carbon **intensity** (CO_2/GDP) by over 65 % from 2005 levels by 2030 and peak CO_2 emissions before 2030	Before 2060
11.0		Reduce net GHG emissions by 50 % to 52 % from 2005 levels by 2030	2050 at the latest
7.3		Reduce emission **intensity** (GHG/GDP) by 45 % from 2005 levels by 2030	2070
6.9		Reduce GHG emissions by 55 % from 1990 levels by 2030	2050
2.2		Reduce GHG emissions by 46 % from 2013 levels by 2030, with strenuous efforts to cut by 50 %	2050
0.8		Reduce GHG emissions by at least 68 % from 1990 levels by 2030 and by at least 78 % by 2035	2050

Sources: Climate Action Tracker, UNFCCC NDC Registry, EU Edgar and national sources.
1 The share of global GHG emissions includes non-CO_2 GHGs.

Table 1 provides an overview of the main objective of each country's NDC, as well as the year by which it aims to reach net-zero emissions. As mentioned above, all main NDC goals are supposed to be reached by 2030. Other than that, there is no harmonisation in the formulation of the goals: each country can freely determine its own commitments. The targeted percentage reductions, as well as the base year to which they refer, differ from country to country. Moreover, some countries formulate their goals in absolute terms while others, most importantly China and India, do so in relative terms, namely the emissions intensity of GDP. When an economy is growing, this type of formulation is compatible with a rise in emissions by 2030. This relative approach contrasts sharply with the absolute GHG emission reductions pledged by the developed countries under consideration.

Chart 3

NDC-implied changes in emissions over the next decade vary widely



Sources: Climate Action Tracker, EC and IMF.

Chart 3 illustrates the NDC objectives set out in Table 1, using the same base year (2019) for all emission reduction goals and showing the implied absolute reduction in emissions needed for the period 2019-2030. It clearly demonstrates the heterogeneity between countries in terms of current climate ambitions. While the EU and the US will need to decrease their emissions by around 38 % from 2019 levels by 2030 according to their NDC goals, the UK is even more ambitious, with an intended decline of 43 %. Japan will need to reduce its emissions by about one-third. Extrapolating from the IMF's latest medium-term GDP growth projections, China's and India's NDCs still imply larger emissions in 2030 than in 2019, which directly follows from their relative rather than absolute NDC goals. India's and China's GDP is expected to grow strongly, by 77.2 % and 68.2 % cumulatively over the period 2019-2030, meaning an emissions increase of 4 % and 36 % still entails a relative emissions reduction effort. The exact numbers for China and India will of course depend on ex post economic growth and climate mitigation figures. As the Chinese and especially the Indian economies are still in full development, more readily available and cheaper renewables and energy storage will help to shift their energy supply towards decarbonised technologies, leading to a stronger emissions reduction pathway. China and India have also allotted more time to reach net-zero emissions so as not to harm their economic development.

2.3 The role of policy mix in achieving climate goals

Before discussing each country's climate policies, it is important to point out that in order to reach the Paris Agreement temperature goals, both price and non-price instruments will likely be needed. We define "price instruments" as all policy measures directly putting a price on emissions of carbon dioxide or other GHGs, while "non-price instruments" are all other policy instruments to cut GHG emissions. Most economists agree that pricing carbon or other GHGs is the most efficient and effective way of cutting emissions[1] since it internalises climate externalities, meaning climate polluters need to take their cost into account. This shift in relative

1 A 2019 US-focused statement in support of carbon pricing, for instance, gathered the support of a large number of economists, among which 28 Nobel Laureate Economists, four former Chairs of the US Federal Reserve, and 15 former Chairs of the US Council of Economic Advisers. For more information, see: https://www.econstatement.org.

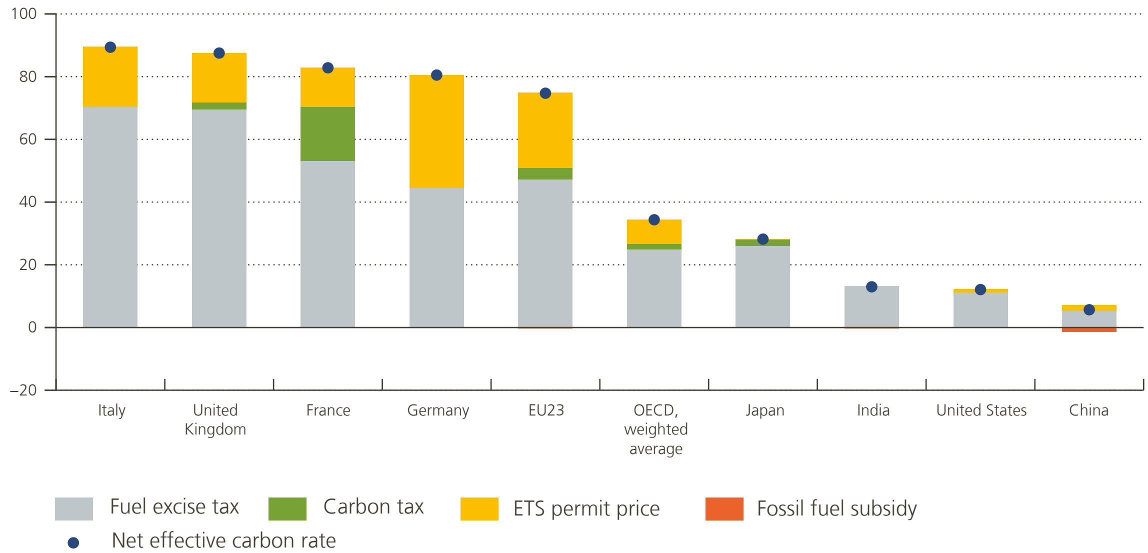
prices, in turn, will affect asset allocation and investment flows. In many cases, however, other complementary measures may be needed or even essential, due to additional externalities (such as strong learning-by-doing effects) or public acceptability concerns. For example, public investment, subsidies for R&D and support for the rollout of decarbonised technologies may be required, given that the timelines to reach the Paris Agreement temperature targets are rapidly collapsing and that the public is unlikely to accept an increase in the carbon price large enough to cut emissions quickly enough. Non-price policy instruments are often used when political opposition to a carbon tax is high. For example, the failure of the American Clean Energy and Security Act (or Waxman-Markey Bill) in 2009 led the US to move towards a non-price climate policy mix at the federal level: the Inflation Reduction Act focuses on subsidies for decarbonised technologies rather than carbon pricing. According to the World Bank (2023), only around 23 % of global GHG emissions are currently priced through an emissions trading system or a carbon tax, and even those that are subject to a carbon price are generally priced at levels deemed too low to be compatible with the Paris Agreement goals.

A recent IMF (2020) study used simulation exercises to assess the emission-reducing effect of different climate policy instrument mixes at the global level. The IMF's stylised, illustrative scenario, assuming an initial green infrastructure push (a 10-year green public investment programme starting at 1 % of GDP and linearly declining to zero over 10 years) combined with subsidies for renewables production (80 % subsidy rate for hydropower and solar energy) would lead to lower – but still steadily rising – carbon emissions by mid-century. The only scenario that would lead to a tangible and significant decline in carbon emissions is one that includes all of the above plus a gradually increasing carbon tax (growing at an annual rate of 7 %). Combined with carbon capture and storage technologies, this could effectively lead to net zero emissions by 2050, keeping the global temperature increase within 2 °C. Moreover, the simulated policy package has a net positive effect on global growth in the initial years and would have only a small negative effect on global real GDP of around –1 % by 2050. The IMF's analysis also confirms that action needs to be taken by all countries and that policies only involving industrialised economies will not suffice to reach the Paris Agreement goals.

Chart 4

Current carbon pricing of energy use varies greatly between countries

Net effective carbon rates [1]
(average in EUR per tonne of CO_2 equivalent, 2021)



Source: OECD.

1 Data were only available for 23 EU countries (thus Bulgaria, Croatia, Malta and Romania are excluded). EU23 represents the weighted average for these countries.

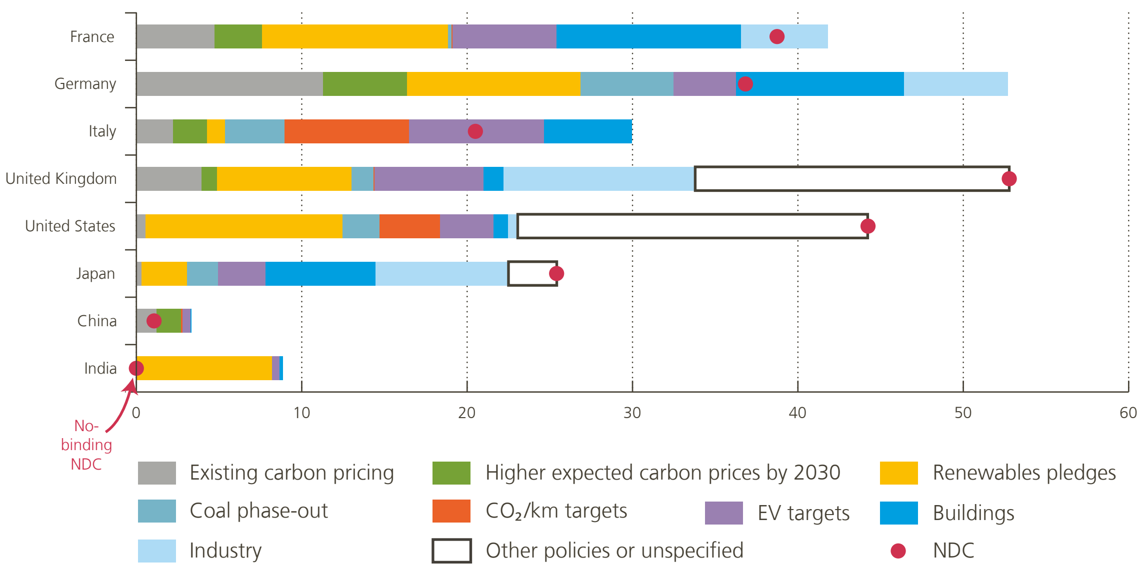
Looking at the current state of carbon pricing, it is clear that there are substantial differences between countries. Chart 4 displays net effective carbon rates, expressed in euro per tonne of CO_2 equivalent (tCO_2e) for 2021 as calculated by the OECD (2021). This measure is the sum of tradeable emission permit prices, carbon taxes and fuel excise duties, less fuel subsidies, and takes into account both the scope and level of each charge. Based on the effective carbon rates, research suggests that an increase in the rate by one euro per tCO_2e leads to an emissions reduction of 0.73 % in the long run, making once again the case for carbon pricing (Sen and Vollebergh, 2018). The latest figures show that net effective carbon rates are markedly higher in the EU and the UK than in the other OECD countries, India and China. Nevertheless, the bulk of carbon tax revenue (on average almost 90 %) comes from fuel excise duties, which were originally not – or at least not mainly – put in place for environmental reasons but rather to provide a steady stream of revenue to governments. In the EU and the UK, permit revenue plays an important role in the emissions trading system. Other carbon taxes are rare and often very low when they do exist, explaining the low global carbon price level overall. However, according to the World Bank (2023), improvement is on the way, as several countries plan to introduce an emissions trading system or a carbon tax in the near future. On the other hand, several fiscal policy measures adopted to protect households from the impact of the energy crisis in the aftermath of Russia's invasion of Ukraine led to temporarily lower net effective carbon rates, at least when the measures were tied to the consumption of fossil fuels rather than implemented as lump-sum transfers. It is therefore of the utmost importance to scale back untargeted, consumption-based price support measures in order not to disrupt the price signal. Targeted measures are moreover better suited to support the neediest households and preserve countries' fiscal space.

Looking beyond carbon pricing, similarly large heterogeneity between countries exists in the area of non-price instruments. Recently, the IMF attempted to map such instruments, which are often defined at sector level, into carbon-price equivalents for the G20 (see IMF and OECD, 2022). Chart 5 shows per country the combined impact of both types of measures on emissions between 2022 and 2030 compared to a no-carbon (equivalent)

Chart 5

The scale of various non-price instruments also varies from country to country

Combined emission-reducing effect of specified policies [1]
(% reduction in CO_2 emissions below no-carbon pricing counterfactual between 2022 and 2030)



Source: IMF.
1 The IRA is only partially captured in the analysis for the US, as it had not been officially approved by Congress at the time of assessment.

pricing counterfactual. The graph combines the effects of existing carbon pricing, higher expected 2030 carbon prices, renewables pledges, the phase-out of coal, carbon emissions targets for vehicles, electric vehicle targets, measures regarding energy use and efficiency for existing and new buildings, and industry-specific emission / energy-use targets. It is important to keep in mind that this exercise is far from exhaustive, not in the least given that climate policies are changing rapidly. Moreover, modelling emissions to determine the level of different reduction drivers remains sensitive to input assumptions. For example, the important measures introduced by the US Inflation Reduction Act, which is discussed in more detail below, are only partially captured by the exercise, as the legislation was in draft form at the cut-off date of the IMF's analysis. The black diamonds indicate the percentage carbon emissions reduction to be achieved according to each country's NDC target. A large white bar in the chart thus indicates a substantial gap between policy objectives and enacted measures. This can be due to a lack of policy implementation or to the fact that certain policy measures were insufficiently specified to be included in the exercise.

Countries differ quite strongly with regard to the policy mix they have opted for to attain their NDC targets. The US and India, for example, rely more on renewable energy targets, while Japan is focusing more on energy efficiency measures. France, Germany, the UK and Japan all have significant targets for the reduction of emissions in the industrial sector. Moreover, it is important to note that not all countries have adopted sufficient policies to reach their NDCs, meaning their policy mix is liable to change substantially. The following subsections provide more information on the country-specific policies of the largest emitters, in descending order based on the share of global GHG emissions they represent.

2.3.1 China

China is by far the world's largest GHG emitter. Without ambitious climate action in China, it will not be possible to meet the temperature goals of the Paris Agreement. Unfortunately, according to experts, China's latest NDC is not compatible with a global warming scenario of 2 °C, i.e., if all countries adopted China's climate mitigation targets, it would not be possible to limit global warming to 2 °C in this century. That being said, China has an elaborate and firmly established climate policy framework, called the "1+N" framework, to reach its climate goals. The "1" refers to its long-term goal of achieving net zero by 2060, whereas the "N" refers to implementation plans for specific areas and sectors to ensure that CO_2 emissions peak by 2030. China's national targets and plans have also been translated into measures at the provincial level (Sandalow *et al.*, 2022).

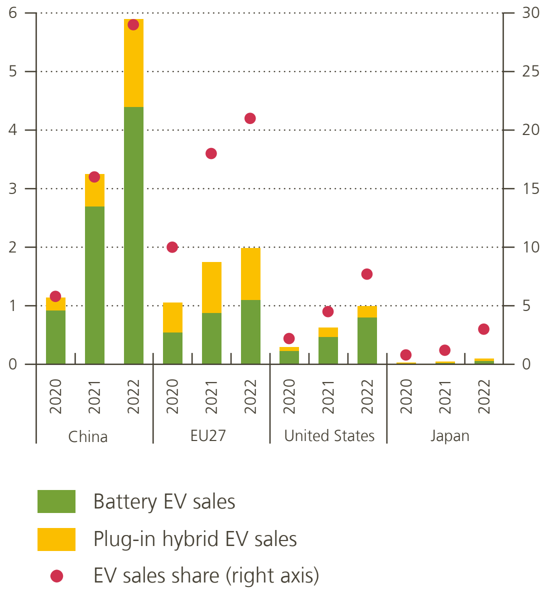
China has taken climate policy initiatives in many areas. Traditionally, China's climate policy has relied heavily on top-down regulation and energy efficiency standards. More recently, however, Chinese policymakers have tried to gradually introduce more market forces into the energy sector, which was above all designed to power China's rapid growth. These efforts include the development of pilot emissions trading schemes (ETS) to price carbon, the creation of a national emissions trading platform in the power sector, the integration of regional grids, and the development of spot and derivative markets for electricity (Chen, 2023).

Following earlier pilot programmes in several cities and provinces, the country's national ETS became officially operational in 2021, after repeated delays. China's national ETS covers only energy producers but is already the world's largest carbon pricing scheme in terms of the volume of emissions covered (an estimated 9 % of the world's total or more than double the coverage of the EU ETS). Although its carbon price has hovered around the relatively low level of USD 8 per tCO_2 since the system became operational and its impact to date is deemed minimal, China's ETS has great potential to become a centrepiece of global climate policy (Sandalow *et al.*, 2022). Unlike Europe's cap-and-trade scheme (see below), the Chinese ETS is currently set up as a system of tradable performance standards, allocated (for free during the first compliance cycle) based on output-dependent emission intensity benchmarks, without a cap on absolute total emissions (Stoerk, Dudek and Yang, 2019 ; World Bank, 2023). However, plans exist to tighten the benchmarks and to gradually extend the scope to other sectors, such as petrochemicals, chemicals, building materials, steel, nonferrous metals, paper and domestic aviation. The possibility of moving towards an absolute cap is also being considered (Liu, 2021 ; ICAP, 2023).

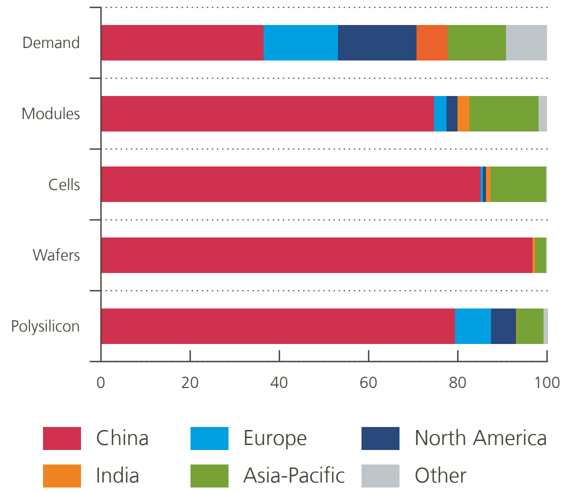
Chart 6

China is the world leader in electric vehicles and a dominant player in solar power value chains

EV sales
(left axis : millions, right axis : % of total car sales)



Solar PV demand and manufacturing capacity in 2021
(% of world total)



Sources : Capital Economics and IEA.

It could be argued that there are two faces to China's climate credentials, a bit like Dr Jekyll and Mr Hyde (Yue and Oxley, 2023). On the one hand, thanks to a strategic focus coupled with massive investment, substantial subsidies, economies of scale and targeted protectionist measures, China now occupies a dominant role in certain green value chains, most notably for solar panels and electric vehicles (EVs), the manufacture of EV batteries, and the refining of the raw materials used to make these batteries.

According to recent figures, China represented almost 70 % and 90 % of the global production capacity for the cathodes and anodes, respectively, used in EV batteries and 75 % of the production capacity for battery cells (IEA, 2022b). Leading Chinese companies moreover continue to invest in battery factories, including in the US and Europe.

Aided by generous government subsidies to EV buyers as early as 2009 and public procurement, the share of EVs in total Chinese car sales has grown very strongly, reaching 29 % in 2022, corresponding to almost 60 % of the world's total EV production. Chart 6 (left panel) shows that this compares very favourably to the US (where EVs account for only 8 % of car sales), Japan (3 %) and Europe (21 %). In Europe, the EV share is moreover inflated by plug-in hybrid EVs, which still emit carbon dioxide, particularly since most real-world driving is done with internal combustion engines. The choice of Chinese consumers in favour of full EVs is facilitated by the extensive network of public charging stations rolled out by the government. China is also the global leader in high-speed trains and could serve as a model for many other countries in the area of transport infrastructure.

Moreover, Chinese companies dominate global solar power value chains, from the production of high-purity silicon (polycrystalline silicon or polysilicon), the key raw material, wafers and solar cells to the manufacture of complete solar PV modules (Chart 6, right panel). A substantial share of Chinese solar PV systems is absorbed by the domestic market, but many are exported. Indeed, in Europe the vast majority of imported solar PV systems originate from China.

China has also taken a clear lead in the installation of renewable energy capacity, currently accounting for almost half of global renewable capacity deployment. It is projected that by 2024 China will be home to almost 70 % of all new offshore wind farms globally as well as over 60 % of onshore wind farms and 50 % of solar PV projects, even as feed-in tariffs (i.e., guaranteed energy price schemes) for such projects are being phased out (IEA, 2023a). Renewables have become competitive in China, which makes power sector decarbonisation easier to achieve, thereby potentially enabling a higher carbon price in the national ETS.

Unfortunately, however, China's green value chain dominance and impressive rollout of renewable energy capacity in recent years have not yet translated into record shares of renewables in power generation at home. Coal, the most polluting fossil fuel by far, still makes up around 60 % of China's energy mix, a true Mr Hyde side (Yue and Oxley, 2023 ; see the Annex). China consumes more coal than all other countries combined, has the world's fourth largest coal reserves and continues to build new coal mines and coal-fired power plants (Sandalow *et al.*, 2022). This continued reliance on domestic coal can be attributed in part to energy security and reliability concerns, reinforced by the energy crisis in the wake of Russia's invasion of Ukraine. It has also been linked to promotion criteria for local government officials, which emphasise short-term output growth, as well as the vested interests of state-owned industrial companies (Heerma van Voss and Rafaty, 2022). China has, however, recognised the large air quality trade-offs associated with the use of coal, making improvements in air quality a salient co-benefit of climate action in the country.

China's abundant use of coal also helps explain why it is the world's largest emitter of methane, a short-lived but potent greenhouse gas (see also below). In addition, China emits the largest quantity of so-called F-gases (hydrofluorocarbons), many of which have even greater heat-trapping potential than methane. These gases are found in appliances such as refrigerators, air conditioning units and heat pumps, products for which China is a dominant producer. In June 2021, China ratified the Kigali Amendment to the Montreal Protocol, which prescribes deep reductions in the production and consumption of F-gases.

According to independent analysis, China is expected to easily achieve and even exceed most of its NDC targets, even without introducing additional climate policies (Climate Action Tracker, 2023). There is more uncertainty about its long-term net-zero goal, which appears to cover only CO_2 emissions rather than all GHGs and for which the anticipated pathway lacks detail. Overall, observers agree that China's current ambitions fall short of 2 °C, with many experts expecting China to continue to underpromise and overdeliver.

2.3.2 United States

The United States is the world's second largest GHG emitter after China. Federal climate policy in the US has a turbulent history. The US signed the Kyoto Protocol but never ratified it. Under President Trump, the US withdrew from the Paris Agreement but re-joined when President Biden took office in 2021.

The US submitted its latest NDC to the UNFCCC in April 2021. Its economy-wide NDC target is a reduction in net GHG by 50 % to 52 % below 2005 levels by 2030. This goal is compatible with limiting global warming to 2 °C and almost consistent with the 1.5 °C target. Nevertheless, current US policies fall decisively short of achieving this target without additional actions (Climate Action Tracker, 2023).

The US relies on a diverse policy mix to tackle emissions but currently has no federal carbon pricing scheme. Following the failure of the Waxman-Markey Bill in 2009, which would have established a federal cap-and-trade system, the US has increasingly moved away from carbon pricing. The Obama administration pursued state-level GHG emissions targets for the power sector, primarily targeting coal. US power-sector GHG emissions have declined faster than foreseen by the Clean Power Plan, through a combination of market forces and renewables expansion (Mohlin *et al.*, 2019). Federal climate policy ambitions during the Trump administration were limited.

Despite the lack of carbon pricing initiatives at the federal level, parts of the US economy are covered by implicit and explicit carbon prices. The former take the form of limited fuel excise duties and the latter the form of state-level emissions trading systems, i.e. California's AB 32 cap-and-trade program and the Regional Greenhouse Gas Initiative (RGGI) which extends to 12 Eastern states. California's ETS covers a large portion of the state's economy, while the RGGI is limited to the power sector.

Under the Biden administration, federal US climate policy has gravitated towards the use of subsidies and tax incentives, leading to the landmark Inflation Reduction Act (IRA), which is expected to produce significant GHG emission cuts, even though it is not exclusively focused on climate mitigation (US DOE, 2022). Experts predict that the IRA will put the US on track to reduce its net GHG emissions by 32 % to 42 % below 2005 levels by 2030, which is six to 11 percentage points lower than in a no-IRA scenario (Larsen *et al.*, 2022 ; Bistline *et al.*, 2023). The IRA, which was signed into law on 16 August 2022, contains the largest climate policy and clean energy package in US history. It includes an estimated $ 392 billion in tax credits, grants and loan guarantees to lower energy costs, accelerate private investment in clean energy solutions (from a relatively low base, see the chart in the Annex) and strengthen green supply chains. [1] It builds on the foundations laid by the 2021 Build Back Better Act, which stranded in the US Senate, and complements the climate and clean energy actions in the Infrastructure Investment and Jobs Act, signed in November 2021. The bulk of the emissions decline will be ensured through the clean energy provisions of these two acts. The most important in the IRA are the production tax credit for (renewable) energy generation, the advanced manufacturing production tax credit for the production of selected components of renewable energy equipment, and the investment tax credit amounting to 30 % of the investment in renewable energy generation equipment. On the consumption side, the electric vehicle tax credit of up to $ 7 500 for certain vehicles depending on the date of purchase, the price of the car and the buyer's income, is expected to significantly encourage the uptake of electric vehicles. The electric vehicle tax credit is contingent on local content criteria that appear to be at odds with WTO rules. For instance, it is only available for cars assembled in North America (i.e. the US, Canada or Mexico), and in order to qualify for the full credit, a minimum percentage of battery components and critical raw materials used in those components must come from the US or a country with which the US has concluded a free trade agreement. These minimum shares are raised by around 10 ppt per year, to reach 100 % for components by 2029 and 80 % for raw materials by 2027. Moreover, as from 2024 or 2025, it will no longer be possible to source batteries or raw materials from foreign entities of concern, meaning companies from China, Russia or Iran. In December 2022, the US Treasury clarified that no local content requirements or price or income caps would be applied to private leased vehicles (Bown, 2023). The European Commission responded to the IRA by launching its Green Deal Industrial Plan.

The US has committed to reaching net zero by 2050. However, this goal is not legally binding, and the scope, architecture and transparency of the net-zero target can be improved (Climate Action Tracker, 2023). Whether a policy mix based purely on subsidies for decarbonised technologies will be sufficient without an explicit federal carbon price remains to be seen. Most experts agree that the IRA in its current state is insufficient to reach the US NDC target.

2.3.3 India

India is currently the third largest GHG emitter in the world. Due to its still high economic catch-up potential and the size of its population, per capita emissions are less than half the global average. Fuelled by strong economic and population growth, India's GHG emissions are rising rapidly though (see Chart 3). Energy consumption has more than doubled since 2000 and will continue to increase strongly as India further industrialises and urbanises.

1 The final amount of support could be much larger (even a multiple of the original estimate of nearly $ 400 billion) depending on actual uptake, as many tax credits are uncapped (Bistline *et al.*,2023).

Moreover, although near-universal household access to electricity was achieved in 2019, there are still substantial differences in energy use and the quality of service across states and between urban and rural areas. As a result of these factors, India is expected to account for nearly 25 % of the growth in global energy demand between 2019-2040, the largest country increase modelled by the IEA (2021a). The growth in its renewable energy share is expected to be the second largest in the world after China. It also plays a key role in global fossil fuel markets, due to the sheer size of its demand and potential demand growth in the coming years. As such, India's policy choices and its influence on energy affairs and emissions will be felt globally, making it an important force to be reckoned with (IEA, 2021a).

Almost 90 % of India's energy needs are met by three fuels : coal, oil and solid biomass (see the Annex). As a result, the air quality co-benefits of phasing out fossil fuels in electricity production are substantial and politically salient. India's renewable energy deployment has picked up recently, spurred by large-scale auctions for wind and solar PVs. Utility-scale solar PVs have particularly grown in recent years, but India's push to expand domestic manufacturing through its production-linked incentives (PLI) subsidy scheme could create some supply-demand mismatches in the short-term, slowing deployment in 2023-2024 (IEA, 2023a). Renewables are projected to account for 35 % of electricity generation by 2030 (more than 15 % of which will be provided by solar power alone), thus absorbing 60 % of the growth in demand for power (IEA, 2022a). Coal demand is expected to continue to grow and to peak only in the early 2030s based on current policies, when the deployment of renewables in the power sector accelerates further. If India were to fully meet its announced pledges, coal demand would peak in the late 2020s. India is also making progress in the area of effective energy efficiency policies, but the magnitude of its energy needs still implies large requirements for fossil fuel imports in the coming decades, with oil being the most important source (IEA, 2021a).

India's latest NDC targets (from August 2022) are still far from consistent with the goal of limiting global warming to 2 °C (if all countries were to adopt targets similar to India's, global warming would tend towards 4 °C or more). Even taking into account Prime Minister Modi's additional plans, which have been publicly announced but not included in an official NDC, India's ambitions still fall short. A projected 1.5 °C or 2 °C rise is only possible if India firmly cuts its use of fossil fuels (especially coal and gas) which will require international financial and technological support. India's NDC plays it safe : under current policies, the country will easily meet its target. While it is commendable that India has set a net-zero target, the long deadline to do so (by 2070) means the world will continue to struggle to meet the temperature goals of the Paris Agreement. Moreover, there is substantial room for improvement in the formulation and implementation of the long-term target, which lacks transparency as to the path India will take beyond the short term as well as clarity on whether it includes all GHGs or only CO_2 (Climate Action Tracker, 2023).

India does not yet have a binding domestic carbon pricing mechanism. However, it does impose excise duties on fuel and has a market for renewable energy and energy saving certificates. Further, a pilot carbon credit trading scheme – building on the state's experience with a particulate matter emissions market – is being planned in the state of Gujarat. In addition, India has updated its legislation so as to be able to set up a nation-wide carbon market. This market would at first function on a voluntary basis and later give way to a binding cap-and-trade system. India also applies carrots, such as renewable energy subsidies (which are unfortunately lower than coal subsidies) and support for green hydrogen producers, and sticks (e.g. fines for companies that do not meet the minimum required level of renewable energy in their production processes). It makes use of standards and labelling to incentivise energy-efficient consumption choices. Overall, the direction of travel is positive in India, but the pace is insufficient and incompatible with the Paris Agreement's temperature goals.

2.3.4 European Union

The EU is currently the world's fourth largest GHG emitter. Nevertheless, of the larger jurisdictions studied, it is the best in class in terms of both climate policy ambitions and implementation, as it has adopted comprehensive legislation to meet the Paris Agreement's temperature goals. According to Climate Action Tracker (2023), its NDC is consistent with a 2 °C increase and is almost sufficient for a 1.5 °C increase. EU climate policy has started to walk the talk and is now firmly in the implementation stage.[1]

The European Green Deal is the EU's roadmap to tackle climate change and reach climate neutrality, defined as net zero GHG emissions, by 2050. This climate neutrality target is enshrined in the European Climate Law. The European Climate Law contains a legal objective for the Union to reach climate neutrality by 2050, as well as an ambitious 2030 target of an emissions reduction of at least 55 % compared to 1990 plus provisions to ensure a process to further finetune legislation on the path to climate neutrality. As a result, the EU is one of the few jurisdictions that has understood the need for credible, long-term commitments to help firms and citizens make long-term investments in line with climate ambitions. Earlier this year, the EU wound up negotiations on its Fit for 55 package. Fit for 55 is the most ambitious climate policy package ever adopted by a major emitter : it sets declining limits per tonne of GHG emitted anywhere in the EU, strengthens carbon pricing and adopts a host of other mitigation policies including provisions to incentivise third countries to strengthen their own climate policy ambitions (through the carbon border adjustment mechanism or CBAM).

Given the large quantity of climate policy instruments used in Fit for 55, it is worth taking a closer look at the details. The EU is betting on a diverse policy mix to reach its goals, using both price and non-price instruments. Fit for 55 strengthens all existing instruments and introduces new ones. Regarding carbon pricing, the existing EU emissions trading system, covering the power sector, domestic aviation and industry (EU ETS 1) which account for around 40 % of EU GHG emissions, will be tightened, with the cap set to decline substantially faster. By 2039, no new allowances will be generated in the EU ETS 1. Moreover, the free allocation of emission allowances to industrial firms will be phased out at the same time as the CBAM is introduced, which will set a carbon price for imports in selected sectors upon entry to the single market. The carbon price will be the EU ETS 1 carbon price, less any carbon price already paid on the product in its country of origin. In this way, the EU hopes to incentivise third countries to adopt carbon pricing of their own. Finally, carbon pricing will be extended to buildings and road transport with the creation of EU ETS 2 as of 2027. This extension will be flanked by the European Social Climate Fund, which will use carbon pricing revenue from EU ETS 2 to directly support poorer households and microenterprises.

Climate policy entered core economic policy in the EU with the adoption of the Recovery and Resilience Facility (RRF) following the pandemic, as well as the European Central Bank's action plan to include climate change considerations in its monetary policy strategy, announced in July 2021. Under the RRF, 37 % of spending is earmarked for climate action and is being used across the EU to help member states meet their GHG mitigation targets.[2]

The EU is widely seen as a trailblazer on the path to climate neutrality, with legislation sufficient to meet its NDC and a firm commitment to the trajectory towards climate neutrality, thereby encouraging investment that targets cuts in GHG emissions. Policy debates in the EU tend to focus on practical questions of implementation. Of the major emitters discussed above, the EU is the only one to have successfully adopted not only targets compatible with the Paris Agreement but also the necessary policies to sufficiently cut GHG emissions and meet these targets.

2.3.5 Japan

Japan is the world's eighth largest GHG emitter. Historically, it has played a key role in climate negotiations and, in 1997, brokered the adoption of the Kyoto Protocol, the predecessor to the Paris Agreement. The Fukushima nuclear disaster in 2011 set Japan's climate ambitions back, however, as the country's nuclear facilities were

1 The breadth of the challenges posed by the transition to climate neutrality varies across EU member states, due to different starting points. For example, countries such as Germany, France and Italy have very different energy supply mixes (see the chart in the Annex).

2 The EU's climate policies include instruments other than those mentioned above, such as support for low-carbon innovation. For more information, please visit the website of the European Council, https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/.

completely turned off and fossil fuels substituted to make up for the drop in nuclear power (see the Annex). Consequently, Japan's GHG emissions temporarily rose but started to decline again in 2013, mainly due to improvements in energy efficiency.

In May 2016, Japan adopted the Plan for Global Warming Countermeasures (updated in 2021) which contains measures in a broad range of areas to reduce GHG emissions. The plan also converts the Japanese NDC and long-term net-zero plans into legally binding targets. In addition, the government has formulated a National Energy and Environment Strategy for Technological Innovation for 2050 (NESTI 2050), identifying technological priorities aimed at reducing emissions. Other important policy measures are the Energy Conservation Law and the recent Green Transformation Basic Policy, adopted in February 2023. The aim of the Green Transformation (GX) initiative is to drive economic growth and development through emissions mitigation. However, the GX policy does not stipulate concrete emission reduction targets. Japan's NDC provides for a reduction in GHG emissions by 46 % below 2013 levels by 2030. This is consistent with a 2 °C rise in global temperatures, but not a 1.5 °C increase (Climate Action Tracker, 2023).

Japan has introduced limited forms of carbon pricing. Its petroleum and coal tax (in place since the oil crises of the 1970s) has been complemented by a revenue-neutral carbon tax since 2012 (implemented as part of a broader tax reform). Nevertheless, its carbon tax rate remains low, including in the industrial and electricity sectors (Gokhale, 2021) mainly due to several exemptions and rebates for fossil fuels used in particularly energy-intensive industries. Starting in 2028, fossil fuel importers will be charged a carbon fee, the scope and coverage of which will be determined based on current regulations, such as the existing carbon tax. There are regional emissions trading schemes in place, in Saitama and Tokyo, but no national mandatory scheme. Japan's GX policy introduced a voluntary carbon credit scheme (the so-called "GX League") for the largest industrial polluters (with full operation foreseen for 2026). The auctioning of carbon allowances (as from 2033), as in the EU ETS, will be introduced in the future for power companies. The government also plans to raise US $ 144 billion for the green transition through a new type of sovereign debt, GX transition bonds, to be repaid using carbon tax revenue (by 2028).

Japan has set targets for shares of renewables and mineral resources and plans to reinstall and restart nuclear capacity, despite the fact that public distrust remains high following the Fukushima disaster. A 2021 poll by NHK magazine, conducted ahead of the 10th anniversary of the disaster, revealed that 67 % of respondents believe nuclear power plants should be reduced or even abolished, with only 3 % stating that nuclear power should be increased and 29 % that it should be maintained as is (NHK, 2021). According to the government's sixth Strategic Energy Plan (METI, 2021), however, nuclear energy will account for 20 % to 22 % of the country's electricity supply in 2030, up from only 5 % in 2020. Only 36 % to 38 % of supply is set to be provided by renewables in 2030, with the rest coming from gas (20 %), coal (19 %), oil (2 %), hydrogen and ammonia (1 %). Japan is the only G7 country still planning to build new coal-fired power plants and is not preparing to phase out coal use. Instead, it promotes "clean coal technologies" such as coal plants combined with carbon capture and storage (CCS). Although CCS technologies are not yet commercially viable, the Japanese government expects them to play an important role in the country's decarbonisation strategy. Japan is also betting on ammonia becoming a low-carbon energy source, alongside gas and coal, to reduce emissions from existing thermal power plants. Although this could be the case in the future, ammonia is not yet commercially viable in a climate-neutral way, and its production still relies on fossil fuels (Hasegawa, 2022). Similarly, there are questions regarding Japan's enthusiasm for green hydrogen, of which the country produces little.

In addition, Japan has ambitious energy-efficiency standards for buildings and is focusing on international development, including through expansion of the joint crediting mechanism (JCM). The JCM aims to facilitate the diffusion of leading decarbonisation technologies and infrastructure through investment by Japanese entities in partner countries, thereby contributing to GHG emission reductions and removals as well as sustainable development in other countries. At the same time, the JCM contributes to the achievement of NDCs as Japan evaluates its own contributions in a quantitative manner and acquires the share of the credit obtained through investment. In this way, Japan seeks to play a central role in financing the shift to clean energy in other

– mainly Asian – countries in a cost-efficient way. It envisages the creation of an Asia Zero Emissions Community, a platform to help partner countries achieve decarbonisation and make the transition to clean energy through policy coordination and direct assistance. The government will also implement measures to stimulate domestic public-private investment, particularly to frontload existing technologies and support the commercialisation of new technologies. Nevertheless, without additional measures, Japan will not reach its NDC goals (Climate Action Tracker, 2023).

Japan adopted a legally binding net-zero target (to be achieved by 2050) when amending the Act on the Promotion of Global Warming Countermeasures in May 2021. In June 2021, it presented its Green Growth Strategy, which includes sector-level roadmaps to reach net zero. Nevertheless, key parts of its net-zero strategy remain unclear (Climate Action Tracker, 2023). Japan reserves the right to use international offset credits to meet its net-zero target but the extent to which this will be allowed cannot be assessed based on currently available documents. The absolute reductions as well as removal targets have not been clearly communicated, and its pathway to net zero after 2030 remains particularly unclear.

2.3.6 United Kingdom

In absolute terms, the United Kingdom was responsible for only 0.8 % of global emissions in 2021. Nevertheless, we included it in our international comparison of climate policies for three main reasons. First, the UK is one of Europe's key trading partners and, since Brexit, has no longer been subject to the same climate policies as the EU. Second, despite its low level of absolute emissions today, it has historically been responsible for around 3 % of emissions since 1850 (not including former colonies), due to its importance in the Industrial Revolution. Third and most importantly, it was the first major economy to approve a legally binding net-zero emissions target. In the Climate Change Act 2008, the UK made an initial commitment to reduce its GHG emissions by at least 80 % by 2050, at a time when most countries where not even discussing legally binding emission reductions and the Paris Agreement was not yet in place. This commitment was strengthened in 2019, by an amendment providing for a reduction in GHG emissions by at least 100 % compared to 1990 levels (net zero) by 2050, and by the Environment Act 2021, which serves as the UK's new environmental protection framework.

Currently, the UK is the most ambitious country of those discussed in this paper, as its NDC targets are already compatible with the goal of limiting the rise in global temperatures to 1.5 °C by the end of this century (Climate Action Tracker, 2023 ; UK CCC, 2022). Its climate targets have been concretely translated into five-year "carbon budgets", which are set 12 years in advance. This provides transparency to the private sector, which often needs to decide on large-scale investments many years ahead of time. The UK's example of laying out a clear trajectory has been copied by several other countries in their own climate strategies (see Nigeria, for example). A clear timeline also makes it easier to track progress towards net zero.

A pathway to net zero is laid out in the UK's Net Zero Strategy, published in 2021, which sets out the trajectory until 2037, i.e. the end of the sixth carbon budget period. The strategy includes a clear and credible range for emissions reductions in all economic sectors and highlights choices on how to achieve the needed reductions. Nevertheless, the UK still needs to enhance its efforts to meet its NDC targets by 2030. Based on the latest implemented climate policies and expected policies under the Net Zero Strategy, Climate Action Tracker, the UK government and the UK Climate Change Committee (an independent advisory committee on climate policy) have indicated that the UK will not reach its goals. In particular, measures on land use, agricultural decarbonisation and energy efficiency for buildings and small industrial operations outside the UK ETS are lacking (UK CCC, 2022). For this reason, the UK government was taken to court by Friends of the Earth, Client Earth and the Good Law (international NGOs) in 2022 and was ordered by the High Court to provide an update to its climate plans by 31 March 2023. The update, called "Powering Up Britain", still contains gaps though and reveals that the country is expected to meet only 92 % of its target by 2030. Hence it remains to be seen whether further legal action will be taken or whether the UK government will continue to strengthen its climate policies to reach its ambitious goals.

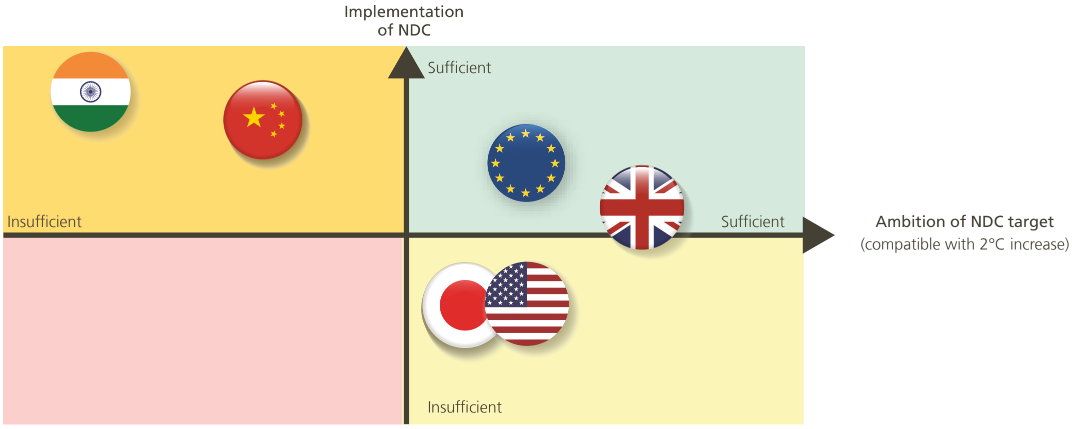
The UK government uses both price and non-price instruments to reach its climate goals. It replaced the EU ETS with its own ETS in 2021, covering the same sectors as the EU ETS and putting a price on about 30% of UK emissions. It also has a domestic power tax. The UK government has decided to ban the sale of new petrol and diesel cars from 2030. It has been successful in reducing the share of coal in the country's total energy supply, while boosting the shares of wind and solar (see the Annex). Nuclear capacity is expected to be ramped up to 24 GW by 2050, while offshore wind will reach 50 GW by 2030 and solar power will be quintupled by 2035. The government intends to reduce energy demand by increasing the energy efficiency of homes and businesses. Overall, this sets the UK on a clear path to climate neutrality which, if scaled up to the world level, would allow the temperature target of the Paris Agreement to be reached.

2.4 Countries score differently in terms of climate policy ambitions and implementation

Chart 7 provides a qualitative summary of the state of play of climate policy ambitions and implementation on the part of the major GHG emitters. It illustrates the foregoing discussion, with the important reservation that the assessment of sufficient or insufficient is based solely on GHG emissions rather than any fairness arguments. It is good news that none of the largest emitters are still in the red quadrant on the left, indicating both NDC ambitions and implementation insufficient to reach the global target of keeping warming below 2 °C. Nevertheless, China and India are both relatively unambitious, meaning the implementation of their policies is expected to be easily achieved. This lack of ambition could be partly strategic, as countries know they will need to progressively scale up their ambitions in a five-year cycle in accordance with the process provided for by the Paris Agreement. The UK and the EU are the only ones that can be situated in the green quadrant. Both their NDC ambitions and the implementation thereof appear compatible with the goal of keeping global warming to 2 °C. Japan and the US, on the other hand, need to step up their policies in order to ensure GHG emissions are cut in line with their climate policy ambitions. In both countries, climate mitigation policies are compatible with limiting global warming to 2 °C by the end of this century, but concrete measures and actions are lacking.

Chart 7

Qualitative assessment of country-specific climate policies



Source: Own illustration based on Climate Action Tracker.

3. Ways forward for global climate policy

3.1 Harmonisation in the formulation and measurement of the effects of climate policies

The previous sections illustrate where the world stands on the trajectory to reach the Paris Agreement temperature goals. Despite substantial progress since 2015, there are still several avenues policymakers can explore to develop and improve climate policies.

First, there could be greater harmonisation in the formulation of climate policy goals. At present, a lack of harmonisation in the formulation of NDC goals (including which GHGs to take into account) and selection of the base year makes it difficult to compare national climate policies and monitor overall progress towards achieving targets.

Second, methodological difficulties related to measurement of the effects of climate policies could be resolved. These include difficulties in converting non-price climate policy instruments into expected or realised emission reductions, as well as difficulties in assessing the broader economic effects of climate policies (taking cross-country spillovers into account, for example). The lack of a methodological consensus on how to estimate the effects of certain climate policy measures on emissions hampers the assessment and comparison of climate policies across countries and opens the door to distrust, free-riding and beggar-thy-neighbour behaviour. Lack of comparability gives rise to concerns about competitiveness losses and carbon leakage, thereby discouraging countries from taking more ambitious climate policy measures (IMF and OECD, 2022). Given the urgency of addressing climate change and implementing ambitious mitigation policies, a more globally coherent formulation of policy goals and progress in the area of measurement and methodology are needed as soon as possible.

Several initiatives have recently been taken to remedy these problems or at least to encourage discussion on these matters, e.g. the Inclusive Forum on Carbon Mitigation Approaches launched by the OECD in 2022, as well as a joint initiative by the IMF and the OECD (2022) in the context of Germany's G7 Presidency in 2022. The UNFCCC's enhanced transparency framework may also lead to progress. In the long run, all countries will ideally also formulate their policy goals along the same lines; together with an accepted measurement methodology, this would increase transparency and make international comparisons easier.

3.2 Pushing policy ambitions and implementation further

3.2.1 An international price on carbon

As mentioned in Section 1, climate mitigation policies need to be strengthened at the global level in order to achieve net-zero emissions by 2050. Recently, several proposals have been made to push ambitions further. The IMF has advocated the introduction of an international carbon price floor, as putting a price on carbon is the most economically efficient way of reducing emissions. This could also facilitate transparent negotiations, as the main focus would be on the level of the shared price floor (Weitzman, 2017), and help to scale up policy ambitions and actions by addressing key obstacles such as competitiveness issues and concerns of countries lowballing or reneging on their commitments (Black *et al.*, 2021).

Black *et al.* (2021) have proposed a global carbon price floor of $ 50 per tCO_2e, based on the price required to reach the goals of the Paris Agreement indicated in the Stern-Stiglitz report (High-Level Commission on Carbon Prices, 2017). According to several more recent simulations, however, a price of $ 50 per tCO_2e is in the low range of that required to achieve net zero by 2050 (Black *et al.*, 2022; IEA, 2021b; NGFS, 2021). As a concession for emerging and developing economies which still need room for economic development, Black *et al.* (2021) also advance a modified version of this proposal, in which they suggest a carbon price of $ 25 per tCO2e emitted in low-income countries, $ 50 per tCO2e in middle-income economies and $ 75 per tCO2e in high-income countries. Although the second proposal implies a certain efficiency cost according to Chateau *et al.* (2022) in that it shifts emission reduction and GDP costs from low-income to high-income countries, it gives more weight to fairness and equity considerations. Moreover, Black *et al.* (2021) have proposed a version of the international carbon price floor that would be applied, at first, only to a smaller number of large emitters responsible for the bulk of global emissions, with the possibility to complement the price floor with financial and technological assistance to low-income countries, thus addressing the climate finance dimension of the Paris Agreement. Needless to say, this proposal would still leave the door open for more ambitious climate policy by certain countries as international negotiations would concern only the price floor. Chateau *et al.* (2022) show in their models that an international carbon price floor would be an effective means of scaling up global mitigation efforts towards what is needed to reach the Paris Agreement temperature goals. They point out that while the concept of a global minimum price is key this could be achieved either *explicitly* by way of a carbon price or *implicitly* through equivalent policies, at least in part. In short, the IMF's proposal would lead to effective carbon tax rates as mentioned above, but some of the policy tools needed may be non-price instruments. The global GDP costs associated with an international carbon price floor would be modest (an estimated GDP reduction of 1.5 % by 2030, compared to the baseline), and decarbonisation is compatible with continued robust growth, provided it is supported by the right investments in low-carbon energy.

Overall though, the proposal for an international carbon price floor has received relatively little attention and is unlikely to gather enough diplomatic weight on its own. Knowing that actions taken in the next five to ten years will determine whether global warming can be limited to 1.5 °C or 2 °C (IMF and OECD, 2022), the lack of attention paid to carbon pricing by certain countries and the dearth of coordinated international efforts on this point are particularly worrisome.

Politicians are sometimes also reluctant or downright opposed to introducing carbon pricing, partly because they are worried about the electoral consequences and the possibility of disruptive mass protests such as the *gilets jaunes* movement that shook France in 2018-2019. Recent research has nevertheless shown that the public is often more willing to accept climate policies than politicians think. The 2021 Eurobarometer, for example, revealed that 90 % of respondents – and at least 75 % in each Member State – agree that GHG emissions should be reduced to a minimum while offsetting remaining emissions, in order to make the EU economy climate-neutral by 2050 (EC, 2021). A recent IMF survey of almost 30 000 people in 28 countries (Dabla-Norris *et al.*, 2023) shows that most respondents in both advanced and emerging countries believe all countries should pay to reduce carbon emissions. There is some heterogeneity between countries in terms of the percentages though, and across countries the baseline level of support is higher for subsidies for low-carbon technologies and renewables than for carbon pricing (Dabla-Norris *et al.*, 2023). Support for carbon pricing ranges from 29 % (Germany and Poland) to 74 % (Vietnam) of respondents. According to Dechezleprêtre *et al.* (2022) and Dabla-Norris *et al.* (2023), support for climate policies hinges on three key factors:

- perceived effectiveness of policies in reducing emissions (also with respect to co-benefits such as air quality);
- perceived distributional impacts on lower-income households (inequality concerns);
- expected gains and losses for one's own household (self-interest).

This means that support for climate policy depends not only on the specificities of the policy design but also on how well informed the population is of the specifics. Informing households on these points substantially increases support for climate policies in many countries. Dabla-Norris *et al.* (2023) and Klenert *et al.* (2018) also show that public acceptability of carbon pricing increases if revenue is reallocated to address distributional concerns or to subsidise climate-friendly infrastructure and low-carbon technologies. The survey evidence further suggests that securing cooperation among countries could induce more robust political support for climate action.

Another concern that is often cited to oppose carbon pricing policies relates to a loss of international competitiveness, especially in hard-to-abate sectors such as steel and cement. In the absence of a global agreement, the EU and several other jurisdictions plan to impose a carbon price on imports that are not subject to stringent GHG rules. The EU's CBAM, for instance, is explicitly not a trade policy measure but rather one put in place to protect the environmental integrity of the EU's climate policy by ensuring that goods sold in the single market are subject to similar levels of carbon pricing. For that reason, the CBAM explicitly deducts any carbon price already paid in the country of origin from that to be paid upon import into the EU. Given the EU's importance as an export market for many countries, it is likely that the CBAM will induce third countries to consider carbon pricing in affected sectors. The extent to which this will occur will of course depend mainly on the possibilities of those countries to divert trade away from the EU to other places. The CBAM remains, however, an auxiliary tool on the path towards global climate ambitions in line with 1.5 °C. As shown in a modelling study by Chateau *et al.* (2022), the CBAM alone will not induce GHG emission reductions sufficient to achieve the Paris Agreement temperature goals. Nonetheless, the CBAM has a clear role to play in preventing leakage (Böhringer *et al.*, 2022), potentially at a lower fiscal cost than the existing free allocation rules on energy-intensive and trade-exposed industries (Martin *et al.*, 2014).

3.2.2 Moving forward on methane mitigation

Aside from carbon dioxide, methane is the most important GHG, likely responsible for about one-third of global warming (IPCC, 2023). Two main characteristics determine the effect of a GHG on global warming: its ability to absorb energy and the length of time it remains in the atmosphere. Methane is 28 times as powerful as carbon dioxide when it comes to holding warmth in the atmosphere (global warming potential) over a time horizon of a century. However, methane stays in the atmosphere for significantly less time than CO_2 (about 12 years compared to several hundreds of years for CO_2). Methane also contributes to the formation of ozone, an air pollutant which poses a serious health risk.

Taking action on methane could therefore have a faster impact on limiting near-term warming than acting on CO_2 alone. Rapid methane action could mitigate the global temperature increase by around 0.1 °C by 2050 (Ocko *et al.*, 2021), a noticeable contribution towards keeping the increase below 2 °C. Around 40 % of methane emissions come from natural sources, with the other 60 % due to human activity. The largest source of anthropogenic emissions is agriculture (mainly livestock and rice cultivation), which accounts for around 25 % of emissions, closely followed by the energy sector (including oil, natural gas, coal and bioenergy). Landfills and waste also generate significant methane emissions (IEA, 2023b).[1] It is estimated that around 40 % of the emissions from oil and gas operations can be avoided at no net cost, given that methane is a saleable product in the form of natural gas. If the record gas prices seen around the world in 2022 are used as a basis, this figure rises to 80 %. There are large differences between the possibility to mitigate methane emissions in other sectors though due to differences in access to capital, knowledge and technical and regulatory solutions and in the degree of agency among participants (UNEP, 2022).

One of the most important initiatives in recent years is the Global Methane Pledge, by which countries commit to reducing global methane emissions by 30 % by 2030 (compared to 2020 levels). More than 150 countries have already signed the pledge since it was launched by the US government and the European Commission at COP26 in November 2021. At the time of COP27, more than 50 countries had concrete action plans to curb their methane emissions. Unfortunately, some of the largest methane emitters (particularly China, India and Russia) have not signed the pledge. Moreover, it is unclear whether the Global Methane Pledge will generate *additional* methane emission reductions or whether it merely serves as a tool for countries to publicise existing methane reduction plans which would have been implemented anyway. In the EU, for instance, comprehensive legislation on waste methane predates the Global Methane Pledge. China promised to take action on its own by 2023, and the EU is looking to expand legislation to reduce methane emissions from its energy imports, which

1 There is still a great deal of uncertainty regarding the magnitude and location of methane emissions for several reasons, including the challenge of quantifying diffuse methane and the fact that attention to methane as a GHG is relatively recent. The availability of measurement-based estimates at different scales is therefore limited and most emission estimates at national level still rely on standard emission factors (UNEP, 2022). The mission of the International Methane Emissions Observatory (IMEO) of the United Nations Environment Programme (UNEP) is to rapidly evolve from default emission factors to state-of-the-art, multi-scale, measurement-based reporting of methane emissions. Better and more transparent data will help facilitate more targeted action (IEA, 2023b), which is seen as key to methane abatement, in particular in the energy sector where a small number of very large emitters in some parts of the world offer cheap mitigation opportunities once measurements occur. There are already substantial opportunities to cut methane emissions in the energy sector, where methane abatement is often cost effective (IEA, 2023b).

could encourage methane action around the world. Cutting methane is important for near-term warming, but it is important that such steps not undermine action on long-lived greenhouse gases, in particular CO_2. While the phase-out of fossil fuel combustion on the path to climate neutrality will reduce energy-related methane emissions by definition, the same is not true of cutting energy-related methane emissions in the up- and mid-stream segments of the fossil fuel industries. Methane action should, therefore, be embedded in a wider climate-neutrality context that fits in with the Paris Agreement's long-term strategy and NDC approach.

3.2.3 Enhanced international cooperation on other climate-related issued

To push climate policy ambitions (and implementation) further, more international cooperation would be welcome so as to share experiences, foster trust and minimise the cost of initial investment and the deployment of certain technologies (more fully exploiting economies of scale). One example is the recent launch of a "climate club" by Germany. The club is intended to foster the sharing of best practices, the advancement of international partnerships and the conclusion of cooperation agreements with the goal of supporting countries in the transition to a decarbonised industrial sector. It aims to bring climate-friendly commodities, such as decarbonised steel, onto the market more quickly and improve opportunities worldwide.

The concept of a climate club also ties in with adaptation and climate finance for developing countries, a subject which falls outside the scope of this article but one that is crucial if the world is to reach the Paris Agreement goals. After all, a tonne of CO_2 avoided has the same effect anywhere in the world, but the cost of doing so may be very different depending on the location, economic development and financing possibilities of a country. Therefore, emerging and developing countries that join the club will receive support to push ahead with the transformation of their industries with a view to reaching climate neutrality.

4. Main takeaways

Global GHG emissions are still rising, and the time to act is quickly running out.

This article summarises the current state of climate change mitigation policies, with a particular focus on the largest emitters, which account for almost 60 % of global GHG emissions. The Paris Agreement provides a framework for climate policies and negotiations and sets a temperature target of well below 2 °C, with efforts to limit warming to 1.5 °C. Although meeting this target will not reduce the likelihood of damage from climate change to zero, limiting global warming in this way will help to mitigate the damage significantly (Hänsel *et al.*, 2020) and provide insurance value by reining in climate risk from adverse effects such as tipping points in the climate system (Dietz *et al.*, 2021). Indeed, as economic research has shown, climate policy mistakes are not symmetrical ; Hassler *et al.* (2021) find that "policy errors based on over-pessimistic views on climate change are much less costly than those made based on over-optimism". Economists thus, by and large, agree that ambitious climate policy is advantageous economic policy.

The questions that remain to be answered mainly concern how GHG emissions can be cut more cheaply, faster and at scale. As this article has shown, different countries provide different answers to these questions through their policy choices. In Europe, for instance, the focus is on changing relative prices, so that climate polluters pay. This shifts consumption away from carbon-intense production methods, which in turn incentivises investment in decarbonised production. The US, by contrast, takes the opposite approach. Instead of taxing emissions, it has decided, at present, to focus on making decarbonised technology available at scale. Such a complementary approach could deliver tangible global benefits that foster climate cooperation.

By changing relative prices in the world's second-largest consumer market, the EU creates certainty for domestic and foreign companies which may be hesitant to invest in decarbonisation. In the meantime, decarbonised innovation in the US could pave the way for making such investments cheaper. Similar developments in China and India are likely to lead to much larger economies of scale, thus lowering unit costs. Such developments are not new : through renewables subsidies in the early 2000s, several EU Member States incentivised the expansion of solar PV and wind energy, both of which are now cost-competitive with incumbent fossil fuel-generation in a wide variety of locations around the world. Comparable developments are likely to occur in the coming years with other technologies.

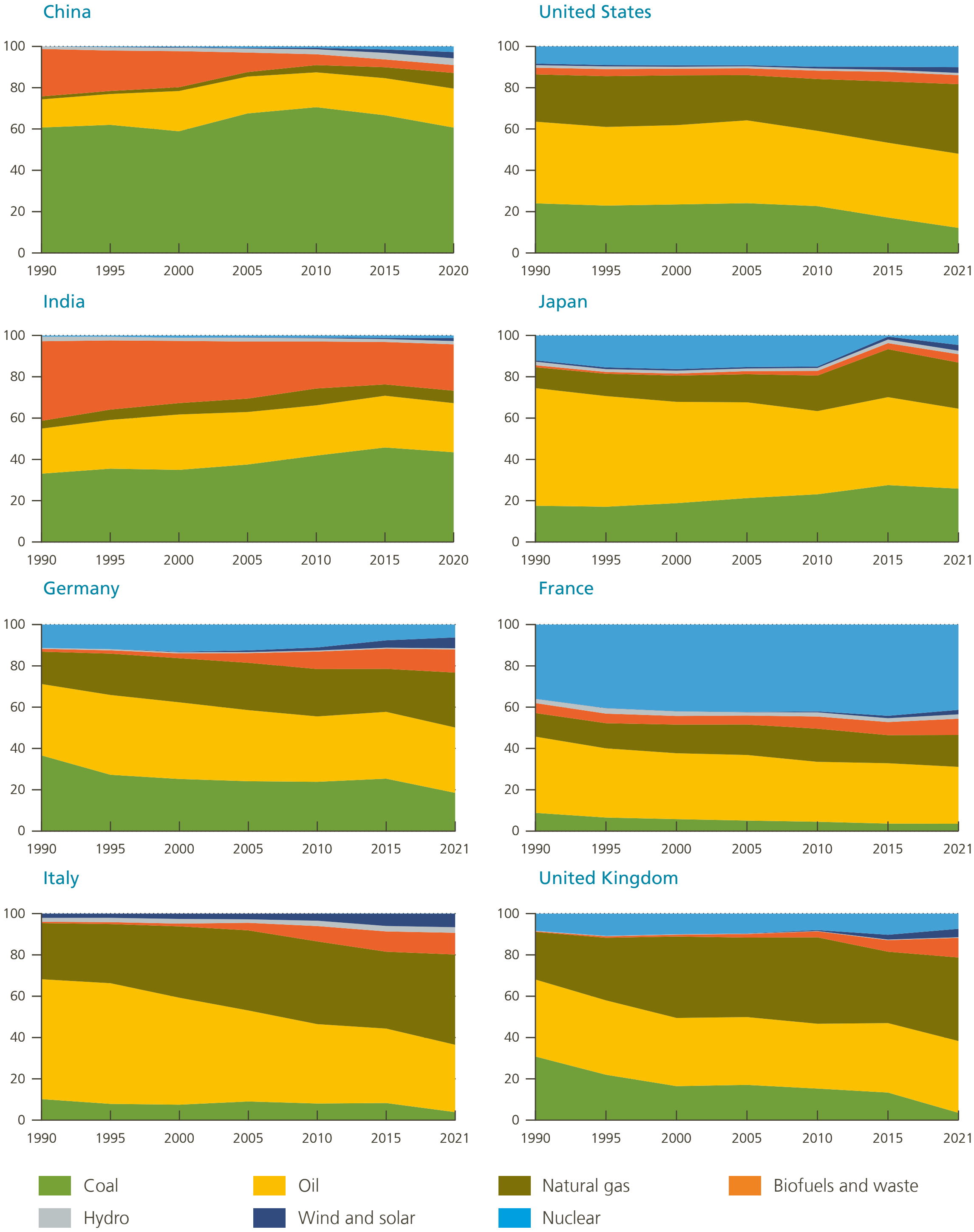
Currently, there are significant gaps in the climate policies of the largest GHG emitters (with the notable exception of the EU and UK), in terms of either policy ambitions (India and China) or implementation (Japan and the US). It remains to be seen whether the world will be able to mobilise sufficient political capital to act decisively and quickly enough to close these gaps.

In order to move forward and limit warming to 1.5 °C by the end of this century, urgent action and closer international cooperation on several levels are needed, but geopolitics and issues of political economy often stand in the way. As actions taken in the current decade will determine whether the world reaches the goals of the Paris Agreement, there is no time to waste.

Annex

Sources of energy supply vary significantly across countries[1]

(in %, five-year intervals)



Sources: Capital Economics and IEA.

1 Energy supply excludes electricity and heat trade. Coal also includes peat and oil shale where relevant. The latest year for which data are available is 2021, except for China and India, for which it is 2020.

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Conventional signs

%	per cent
$	US dollar
e.g.	*exempli gratia* (for example)
et al.	*et alia* (and others)
etc.	*et cetera*
i.e.	*id est* (that is)
ppt	percentage point

List of abbreviations

Countries or regions

EU	European Union
EU27	European Union of 27 countries
UK	United Kingdom
US	United States

Abbreviations

CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon capture and storage
CH_4	Methane
CO_2	Carbon dioxide
COP	Conference of the Parties
EC	European Commission
ETS	Emissions Trading System
EUR	Euro
EV	Electric vehicle
G7	Group of Seven
GDP	Gross domestic product
GHG	Greenhouse gas
Gt	Gigatonnes
GW	Gigawatt
GX	Green Transformation
ICAP	International Carbon Action Partnership
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRA	Inflation Reduction Act
JCM	Joint crediting mechanism
LULUCF	Land use, land-use change and forestry
METI	Ministry of Economy, Trade and Industry (Japan)

NBB	National Bank of Belgium
N_2O	Nitrous oxide
NDC	Nationally Determined Contribution
NESTI 2050	National energy and environment strategy for technological innovation for 2050
NGFS	Network for Greening the Financial System
OECD	Organisation for Economic Co-operation and Development
PLI	Production-linked incentives
PV	Photovoltaic
R&D	Research and development
UN	United Nations
UK CCC	United Kingdom Climate Change Committee
UNEP	United Nations Environment Programme
UNFCCC	UN Framework Convention on Climate Change
US DOE	United States Department of Energy

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