The COP27 Net Zero Atlas

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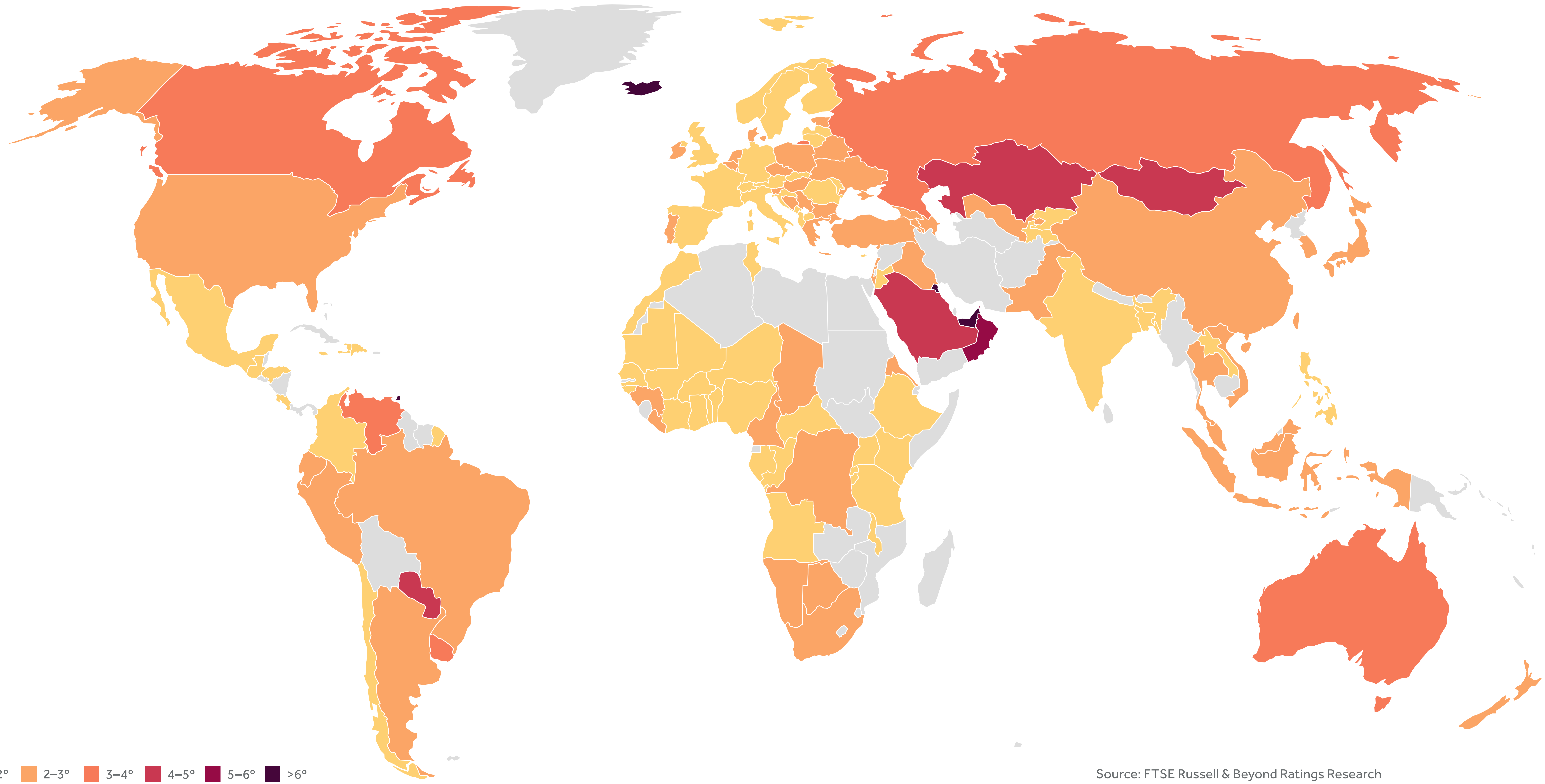
World Atlas

Figure 01: Implied Temperature Rise of every country with a quantifiable NDC target



Source: FTSE Russell & Beyond Ratings Research

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Foreword

Last year's inaugural FTSE Russell *Net Zero Atlas* warned that while much progress has been made since Paris, national commitments in aggregate could still fall short of the scale and pace of change required, with countries' current policies aligning with a 3°C global warming trajectory, double that of the Paris Agreement.

As world leaders gather in Sharm-el-Sheikh, the *COP27 Net Zero Atlas* builds on our previous report to systematically assess climate targets, mitigation strategies and physical risk exposures for G20 countries. We refresh last year's evaluation of the 'temperature alignment' of national climate commitments and actions for G20 countries, taking account of new pledges from some of the largest emitters. Crucially, this year's report also adds a baseline analysis of the physical risks affecting these nations, and the associated impacts on livelihoods, infrastructure, and the economy.

Our analysis shows that time is short. The physical effects of climate change are already material today, are escalating rapidly, and will pose significant economic and policy challenges for G20 economies by the middle of the century or earlier. Whilst countries' current climate policies are gradually aligning with their 2030 commitments, they currently still imply a 2.8°C level of warming on average, well short of the ambition needed to reach the goals of the Paris Agreement by 2050.

The findings have important implications for financial markets now and in the years ahead. The transition and physical risks arising from climate change are already beginning to reshape economic growth trajectories and asset valuations and investors need to adapt both analytical tools and investment strategies to respond to these challenges.

Arne Staal
Group Head of Benchmarks & Indices,
CEO FTSE Russell

Executive Summary

One year on from our first *COP26 Net Zero Atlas*, as world leaders begin to gather in Sharm el-Sheikh for COP27, we provide a comprehensive update of our analysis of G20 climate targets.

Transition Risk

We find incremental progress, with all G20 countries now having set a mid-century target and all but Mexico now targeting to achieve net zero emissions. Brazil has formally brought forward its net zero goal from 2060 to 2050 (the only country to enhance its long-term goal since Glasgow) and eight G20 countries have enhanced their 2030 Nationally Determined Contributions (NDCs) since our last analysis.

G20 countries' current climate policies have also seen some enhancements (evaluation based on our collaboration with IIASA and the New Climate Institute). This notably includes the Inflation Reduction Act (IRA), which we estimate to align US current policies to a 3.5°C pathway compared to 4.1°C without its implementation. For both NDCs and current policies, some of the largest improvements since COP26 have been made by some of the most carbon intensive G20 members, including Saudi Arabia and Australia.

Despite this, both G20 countries' transition commitments and current policies are not yet ambitious enough to achieve the goals of the Paris Agreement. On average, G20 long-term commitments now align with a global temperature rise of 2.1°C. But the 'ambition gap' we highlighted last year remains intact, with more ambitious long-term targets often contrasting with notably weaker 2030 NDC commitments.

Indeed, G20 NDCs on average now align with 2.7°C compared to 2.9°C last year. Only seven G20 members' NDCs align with the Paris Agreement's goal of keeping the global temperature rise below 2°C. Nine others, including the US and China, have above 2°C trajectories; Canada and Australia have NDCs that imply temperature increases in excess of 3°C; and Russia and Saudi Arabia's current targets align with a 4°C warming pathway.

We also continue to observe inconsistencies between current policies and NDCs. For many emerging economies, NDC commitments imply significantly lower ambitions than their current policies are on track to deliver. While enhanced NDCs have reduced this gap in some cases (notably for China), they remain pronounced for others including Turkey (0.3°C gap) and Russia (0.6°C gap).

In contrast, the current policies of several advanced economies are significantly off track when measured against their more ambitious NDCs. In Canada, current policies are tracking towards a 4°C trajectory while its 2030 NDC commitment aligns to a much lower 3°C trajectory. Sizable gaps remain for others, including the United States, Germany and South Korea.

Physical Risk

We expanded the scope of this year's *Net Zero Atlas* to include a survey of physical risks facing G20 countries based on an extensive literature review and in-house processing of publicly available climate data from the CMIP6 climate modelling initiative. We highlight the main risks and adaptation priorities for G20 countries, providing a fresh lens on the urgency for governments to step up transition efforts to avoid the worst effects of climate change.

G20 countries are not immune to physical climate risks. Our results show that climate change already has a material impact on G20 countries today, and risks will continue to escalate without rapid emissions reductions, with annual losses from disasters rising by 5% per annum for the last 30 years.

Executive Summary

By 2050, unmitigated climate change would result in a range of new or intensified risks, posing a significant economic and policy challenge for G20 economies. However, our analysis shows that both acute hazards and chronic risks will be diverse and highly regionalized in scope, confronting the G20 with complex adaptation challenges. These challenges are surveyed in detail in each of the G20 country profiles in the report, but, for example, include:

- The rapid deterioration of ecosystems and infrastructure in the northern parts of Canada and Russia, the two economies that will experience the largest temperature shifts among G20 (up to 6°C+ in parts of Northern Canada)

- Smaller temperature increases in hotter G20 countries, such as India and Saudi Arabia, but climate change may jeopardize the viability of livelihoods in the worst affected regions where temperatures are already close to harmful thresholds and are threatening to regularly reach 50°C+ by 2050

- Expected increases in water scarcity, impacts on crop yields and forest fires in dry regions of many G20 countries, such as Turkey, Italy and Australia

- An increase in extreme precipitation events, leading to more frequent and intense riverine and coastal flooding. Low-lying, densely populated coastal urban centres, including in China, Japan, Indonesia and the Southeastern US, are at risk of catastrophic flood damages through a combination of more intense cyclones and hurricanes and rising sea levels.

Introduction

Tracking national climate mitigation efforts will once again be central as world leaders gather for the 27th Conference of the Parties (COP) to the United Framework Convention on Climate Change (UNFCCC), held in Sharm El-Sheikh in Egypt this year.

The first cycle of 'Nationally Determined Contribution' (NDC) updates, launched prior to COP26 and extended for one year, will be closing at COP27. Ahead of the conference, some large emitters have already revised their NDCs (e.g., China, India, and Australia) and others have pledged new or enhanced mid-century net zero targets (e.g., Brazil, Australia, and Russia). A global stocktake of progress towards implementing the Paris Agreement will take place a year later at COP28, launching the next cycle of NDC revisions.

This 'pledge and review' process is a key feature of the Paris Agreement. Following on from the first edition of our Net Zero Atlas ahead of COP26 at Glasgow last year, this report updates our calculations of the Implied Temperature Rise (ITR) associated with countries' pledges and policies. ITR provides a consistent (if highly stylized) metric to assess alignment with different global warming trajectories and to systematically compare climate commitments across countries and over time. It also provides valuable context to investors considering the climate alignment of sovereign issuers within their portfolios.

Billed as the 'African COP', Sharm El-Sheikh will also focus closely on the challenges of climate adaptation for the world's most highly climate vulnerable countries, as well as pledges on climate finance and 'loss and damage' by developed countries. In this context, the evermore apparent physical effects of climate change take centre stage. In 2022 alone, droughts in Europe, record temperatures in India and extreme rainfall in Pakistan have all been linked to rising global temperatures.

We address this in two ways. First, by expanding the scope of our analysis to include a survey of the main physical risks facing G20 countries. We consider both acute hazards and chronic impacts and their effects on livelihoods, infrastructure, and economic activity to highlight the main risks and adaptation priorities for G20 countries. Second, we also present a survey of the specific and differentiated climate risks, both transition and physical, facing Africa in the coming decades.

Chapter 1

Transition Risk

Methodology

Implied Temperature Rise (ITR) estimates for national carbon commitments

Our country-level temperature metrics (denoted in °C) indicate the global "Implied Temperature Rise" that would result from every country having a commitment or set of policies with the same level of ambition as the studied country. However, they do not imply that those countries alone can have such an influence on global temperature.

In interpreting these temperature metrics, it is also worth keeping in mind that, while the focus is on annual per capita emissions at a specific moment in time, a 1.5°C or 2.0°C aligned trajectory results from the extent of cumulative anthropogenic emissions over time. Therefore, a country with very high per capita emissions that has set a 2050 net zero target could, for example, have a 2°C+ ITR. Effectively, such a country would have consumed much of its carbon budget already and would need to decarbonize faster than 2050 to remain aligned with the goals of the Paris Agreement.

We calculate the Implied Temperature Rise (ITR) for each country and three scenarios (net zero targets, NDCs and current policies) in four steps[1]:

1. **We first estimate the annual greenhouse gas (GHG) emissions per capita and population[2] of each country for 2030 (separately for NDCs and current policies) and 2045/2050/2060/2070 (depending on the net zero target of the country considered).** We calculate this based on the reductions implied by the announced NDCs and net zero targets, assuming countries meet their goals. For current policies, this is based on detailed projections developed by IIASA and NewClimate researchers that assume no additional mitigation action would be taken beyond the currently implemented policies (further detail on these calculations can be found in the Annex).[3]

2. **We then assign the percentage shares of the global annual carbon budget in 2030 and 2045/2050/2060/2070 to individual countries, based on the CLAIM model.**[4] This "share of the burden" calculation, based on a proprietary model, uses a statistical approach to simulate millions of possible "country shares" according to their climate and economic profile (historical emissions, energy intensity, GDP/capita, etc.). The model provides likely carbon budgets allocations, consistent with a 2°C scenario, whose global budget comes from the MESSAGE-GLOBIOM model used in the assessment reports of the IPCC.[5]

3. **We then calculate the implied global emissions for each country's net zero target, NDCs and current policies.**[6] This is based on the emissions projections and their percentage share of global emissions budget, i.e., the level of global emissions that would result from all other countries which have the same implied level of effort as the country in question.

4. **Finally, we calculate the Implied Temperature Rise (ITR) over pre-industrial levels, including the implied global emissions for each country and scenario respectively.** These calculations are based on an equation translating GHG emissions volume into a temperature increase. This equation is calibrated on the recommendations of Rogelj et al. (2019)[7], based on IPCC (2018).[8]

Transition Commitments

1.1 Transition commitments of G20 countries

One year on from our inaugural *COP26 Net Zero Atlas*, we have updated our analysis of G20 countries' climate targets for COP27. This includes net zero targets for Australia (by 2050),[9] Turkey (by 2053)[10] and Russia (by 2060),[11] which were only made directly before or at COP26 and were not covered in our first Atlas, as well as all updates to NDCs that have happened since. In collaboration with the New Climate Institute and IIASA, we have also updated our assessment of countries' current policies.

Box 1. Net Zero targets for the rest of the world

Beyond the G20, 89 countries globally (including the G20) now have net zero commitment heading into COP27 (See the 'Data & Methodologies' annex for more details). Notably, we also find that countries are increasingly moving to formalize their commitments. Around 65 national net zero targets are now formalized in laws or in official policy documents (rather than verbal political pledges). Ahead of COP26, only around 50 countries had made similarly formal commitments.

Mid-century net zero targets

All G20 countries, which collectively account for 80% of global emissions,[12] have now set a mid-century emissions reduction target. All also target net zero emissions, except for Mexico, which has so far only committed to a 50% reduction by 2050 from 2000 levels.[13] Thirteen G20 members have a 2050 net zero target (including Germany, which is targeting 2045), while the remaining seven have targets beyond 2050, including India, which is currently targeting net zero emissions in 2070. Brazil is the only G20 country that has meaningfully enhanced its mid-century target since COP26 by formally bringing its net zero pledge forward from 2060 to 2050.[14]

It is important to note that net zero targets do not automatically equate to a 1.5°C-aligned commitment. Indeed, we estimate that the ambitions of G20 countries' mid-century targets would on average align with a global temperature rise of 2.1°C. The targets of twelve members are aligned with the Paris Agreements' goal of limiting global warming to below 2°C (including the European members and Japan, as well as India, Indonesia, South Africa, Turkey, Brazil and Argentina); while those of eight others are aligned to above 2°C warming (including the North American members, China and Russia as well as Australia, South Korea, and Saudi Arabia).

Medium term 2030 NDC commitments

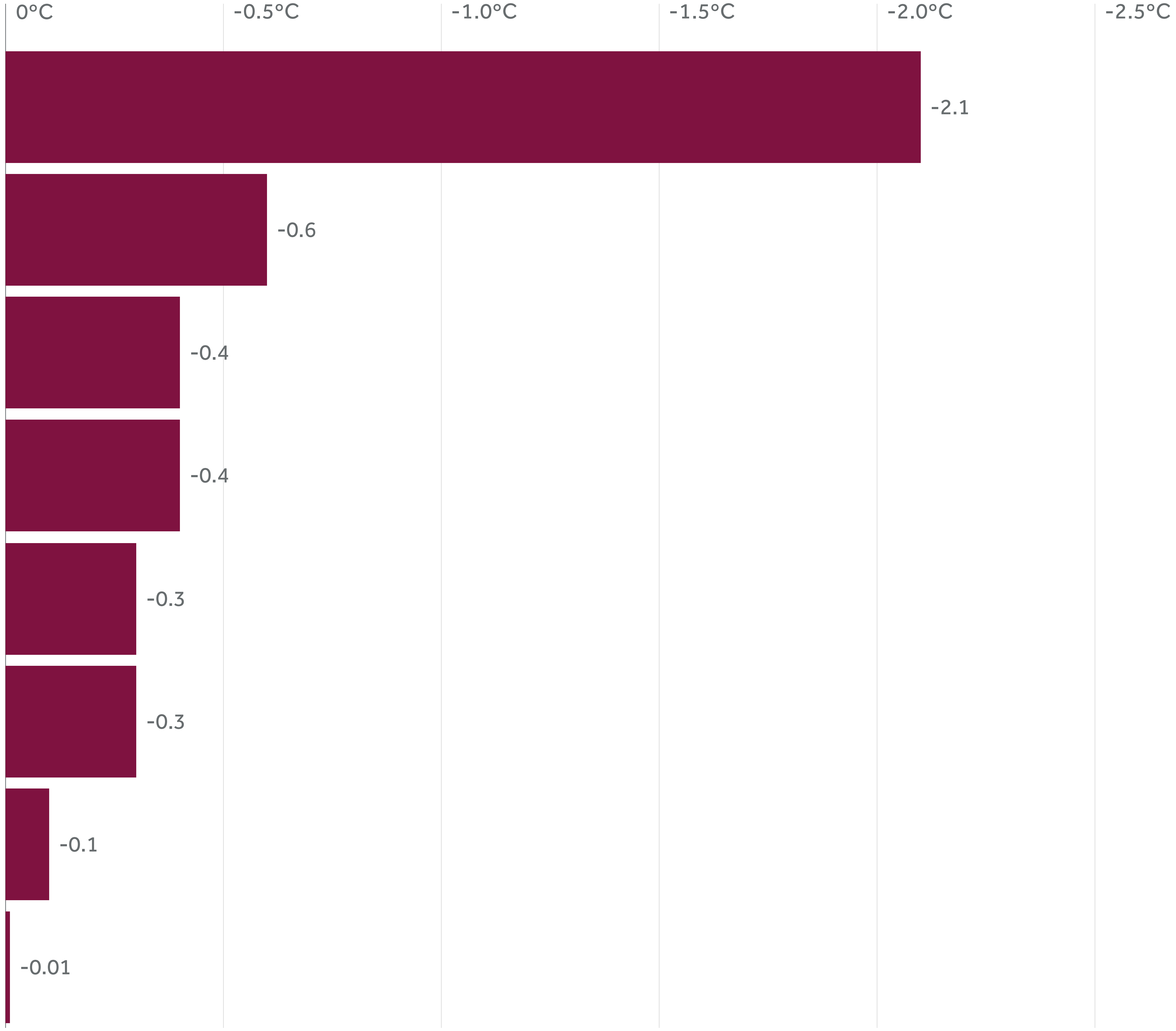
Core to the Paris Agreement is a mechanism through which countries increase their medium-term mitigation commitments, or Nationally Determined Contributions (NDCs) over time. Since last year, eight G20 countries (including five countries post COP26) have deployed this mechanism and updated their NDCs. These changes are summarized in Figure 2.[15]

These enhanced commitments are reflected in our updated calculations. The overall ITR implied by G20 NDC commitments declines from 2.9° C at the time of the Glasgow conference to 2.7° C as negotiators gather in Sharm el-Sheikh – with large reductions for Saudi Arabia (4.5°C from 6.6°C previously), Australia (3.5°C from 4.1°C), and China (2.9°C from 3.3°C), see Figure 2.

Nonetheless, the 'ambition gap' we identified in the last Net Zero Atlas remains pronounced, with 2030 NDC commitments continuing to be notably weaker than 2050 net zero targets (See Figure 2). Only seven G20 members' NDCs are aligned with the Paris Agreements' goal of limiting global warming to below 2° (including its European members, as well as India and Mexico). Meanwhile Canada and Australia have NDCs that imply temperature increases in excess of 3°C, and Russia and Saudi Arabia's current targets imply 4°C+ warming, see Figure 3.

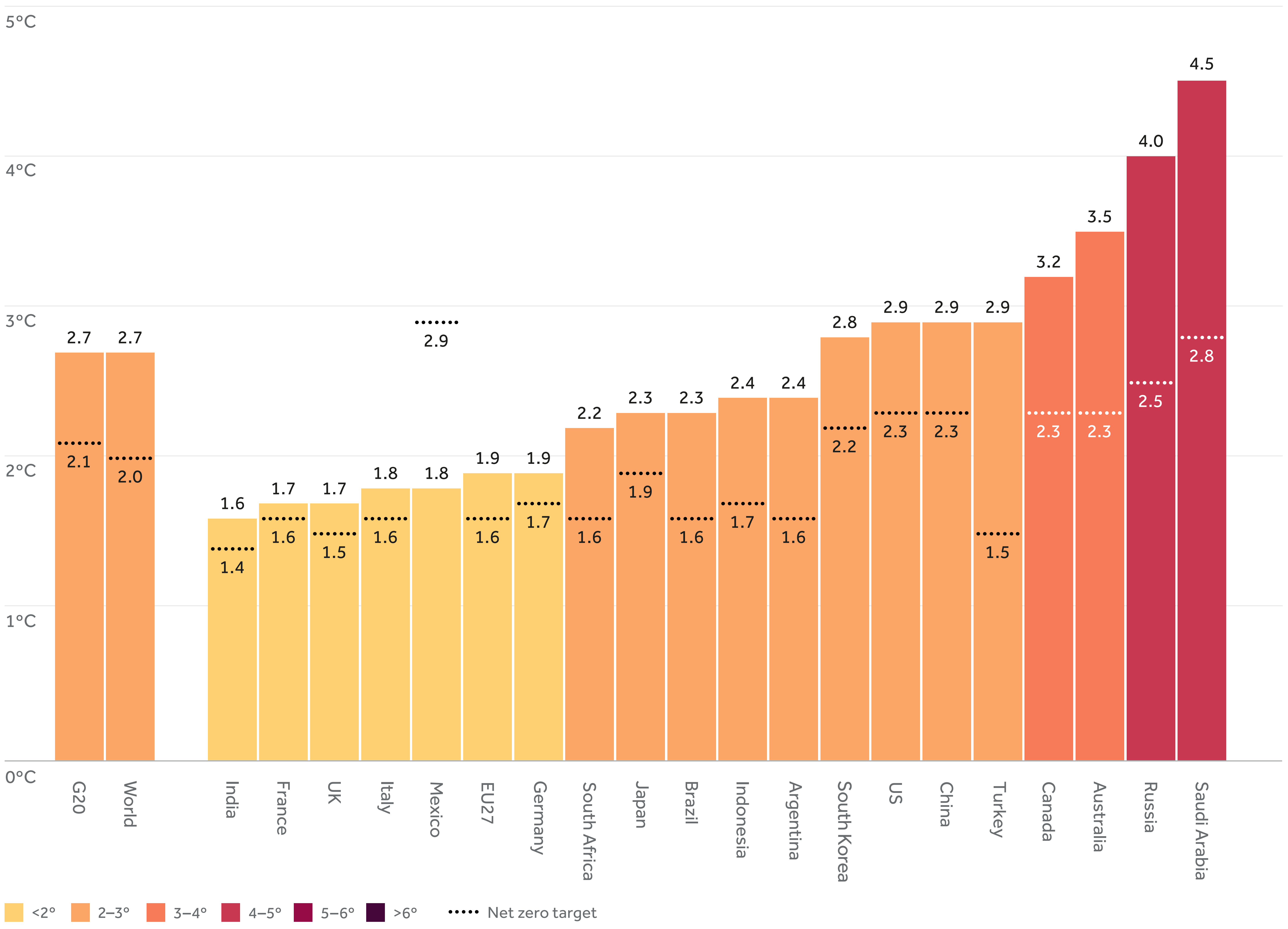
Figure 02: G20 Countries with updated NDCs in the last 12 months, with corresponding change in Implied Temperature Rise (in degree Celcius)

Country	Target update	ITR change
Saudi Arabia	Reduce annual emissions by 278 million tons of CO_2eq in 2030 relative to 2019; previously a 130 million tons reduction.[16]	-2.1
Australia	43% below 2005 levels by 2030; previously a 28% reduction.[17]	-0.6
China	65% less emissions per unit of GDP from the 2005 level by 2030; previously a 60-65% reduction.[18]	-0.4
South Korea	40% below 2018 level by 2030; previously 24.4% compared to the 2017 level.[19]	-0.4
Indonesia	31.89% below 2010 levels by 2030 against the BAU scenario; previously a 29% reduction.[20]	-0.3
Argentina	349 million tons of carbon dioxide equivalent ($MtCO_2e$) in 2030; previously a maximum of 359.[21]	-0.3
Brazil	50% below 2005 levels by 2030; previously a 43% reduction.[22]	-0.1
India	45% less emissions per unit of GDP from 2005 level by 2030; previously a 33-35% reduction.[23]	-0.01



Source: FTSE Russell & Beyond Ratings Research

Figure 03: Implied Temperature Rise for G20 countries for 2030 NDCs and mid-century targets (in degrees Celsius)



Source: FTSE Russell & Beyond Ratings Research

Note: Our assessment is based on the unconditional part of the NDCs. The ITR implied by the mid-century target is particularly high in Mexico relative to its peers because its commitment is to reduce its emissions by 50% in 2050 compared to 2000 level, rather than a net zero target.

1.2 Current Policies

We also examine the alignment of current policies, based on projections developed in collaboration with the New Climate Institute and IIASA. These projections capture the level of G20 countries' 2030 GHG emissions would track towards if their current climate-related policies remained in force unchanged.[24]

Collectively, G20 countries' current climate policies are still significantly off global climate targets, even if they have become gradually more aligned, with the ITR declining from 3.0°C at the time of COP26 to a 2.8°C trajectory at COP27 (See Figure 4).

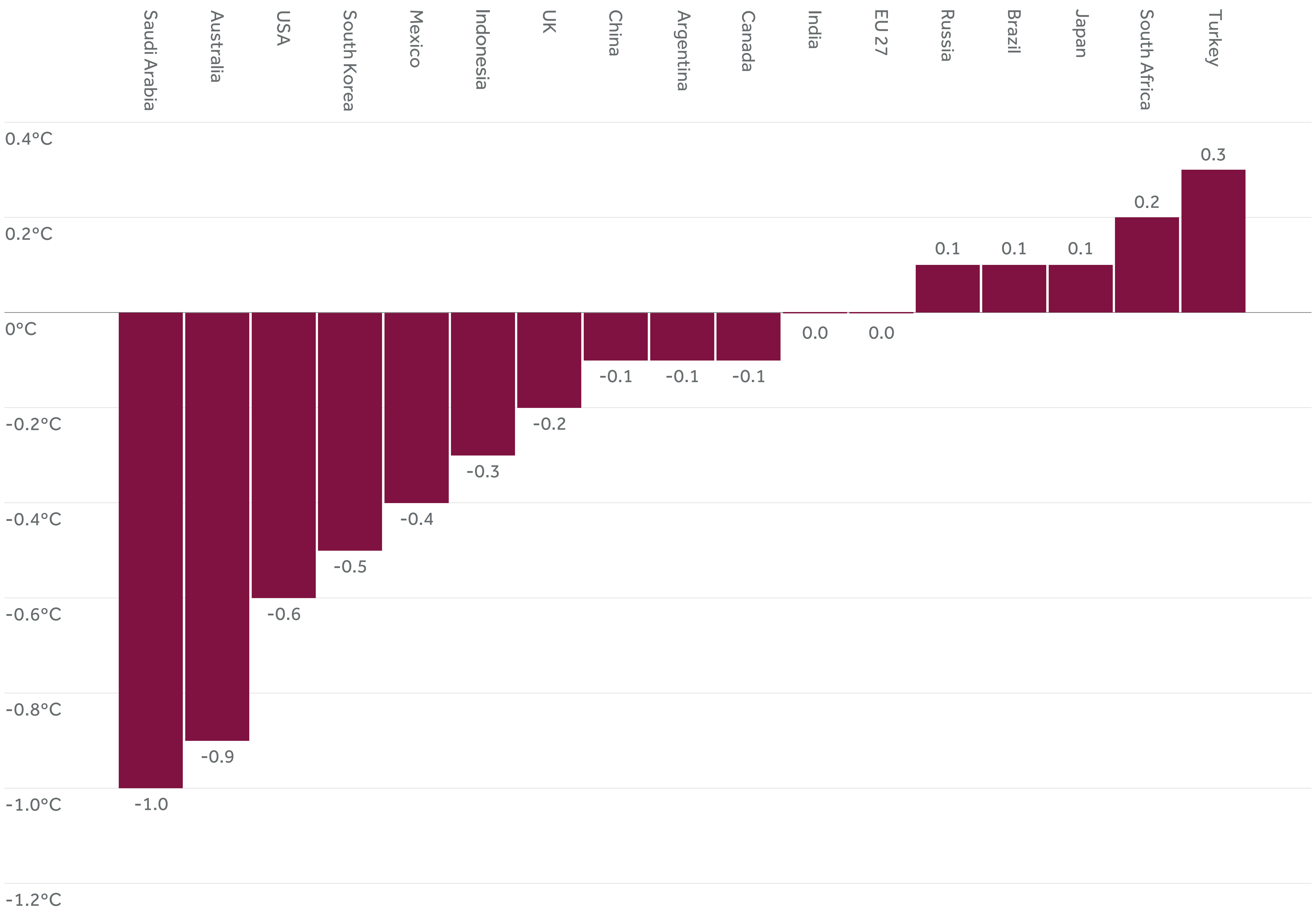
Perhaps the single most important climate policy development since Glasgow is the introduction of the Inflation Reduction Act (IRA) in the US, the world's second largest GHG emitter. The IRA provides US $369 billion of support to the development and deployment of clean energy technologies, such as electric vehicles, solar panels, and batteries in the form of tax credits, grants and loans. Overall, the IRA reduces our 2030 projection of US emissions under current policies by c. 1 $GtCO_2e$[25] and the corresponding ITR declines from 4.1°C at COP26 to 3.5°C at COP27.

Notable improvements are also apparent in other relatively carbon intensive economies. Saudi Arabia's current policies remain the least aligned among G20 countries. However, the introduction of the "Saudi Green Initiative"[26] and the complementary "Middle East Green Initiative" – including inter alia a target for 50% renewables in the electricity mix by 2030; the planting of '10 billion trees'; and measures for energy efficiency – have significantly reduced its ITR from 5.9°C to 4.8°C. Australia has also introduced several measures since COP26, including the reinforcement of the Emissions Reduction Fund[27] and the Future Fuel and Vehicle Strategy,[28] which boost solar and electric vehicle deployment. These measures have reduced Australia's ITR estimate from 4.4°C to 3.5°C under current policies.

While not signed into law yet, and hence not reflected in our ITR calculations, the EU's 2030 Climate and Energy Framework and its 'Fit for 55' package will also further increase the Bloc's climate transition efforts. This will enable the EU to reach its 2030 GHG emissions reductions target of 55% compared to 1990 level[29] (40% previously) through measures such as increasing the share of renewables in the electricity mix by 2030 to 40-45% from the current target of 32%.

We note that the war in Ukraine and the associated energy crisis are yet to have a material impact on our ITR projections. However, there are concerns that supply bottlenecks could impact the implementation of existing climate policies, particularly in the EU and China. In the former, some Member States have re-opened mothballed coal plants to deal with temporary energy shortages. In China, the government aims to "strictly control" coal consumption during the 14th Five Year Plan (2021-2025 FYP) and to a "phase down" during the 15th FYP (2026-2030).[30] But 2021 coal consumption reached record levels[31] and more than 8.5 GW of new coal-fired power plants have been approved in the first quarter of 2022[32] as part of efforts to address a challenging energy supply situation.[33] However, in the medium term, supply challenges may also increase the momentum around renewable deployment, illustrated for example by the REPowerEU plan proposed by the European Commission.[34]

Figure 04: Change in ITR for current policies between COP26 and COP27 (in degrees Celsius)



Box 2. Contextual factors for ITR calculation[35]

Observing those countries with a higher ITR compared to our previous assessment (Figure 4) is a reminder that 'Current Policies' emissions projections are also influenced by economic and political factors. Higher expected emissions for Turkey, and higher ITR projections as a result, are, for example, mainly the result of stronger post-covid GDP forecasts rather than policy changes.

Uncertainty around policy implementation can be another important driver. The slower than expected implementation of the Integrated Resource Plan (coal phase-out) in South Africa[36] and the non-enforcement of the Forest code[37] (the main law to reduce deforestation) in Brazil, for example, are key drivers for the upward revisions of our ITR projections for these countries.

Finally, changes to national GHG inventories also impact our ITR calculations. The UNFCCC reporting framework requires countries to regularly update historical GHG 'inventories', which can significantly impact ITR calculations by changing the base emissions level against which any percentage reduction is referenced.

For example, in 2022, an update to Mexico's historical GHG inventory reduced the base emissions level against which its NDC target is referenced (22% below a 'Business-as-usual' scenario by 2030). This effectively implies that if Mexico achieves its NDC target, it will achieve a lower emissions level in 2030 than previously projected, resulting in the ITR of Mexico's NDC being reduced by 0.4°C.

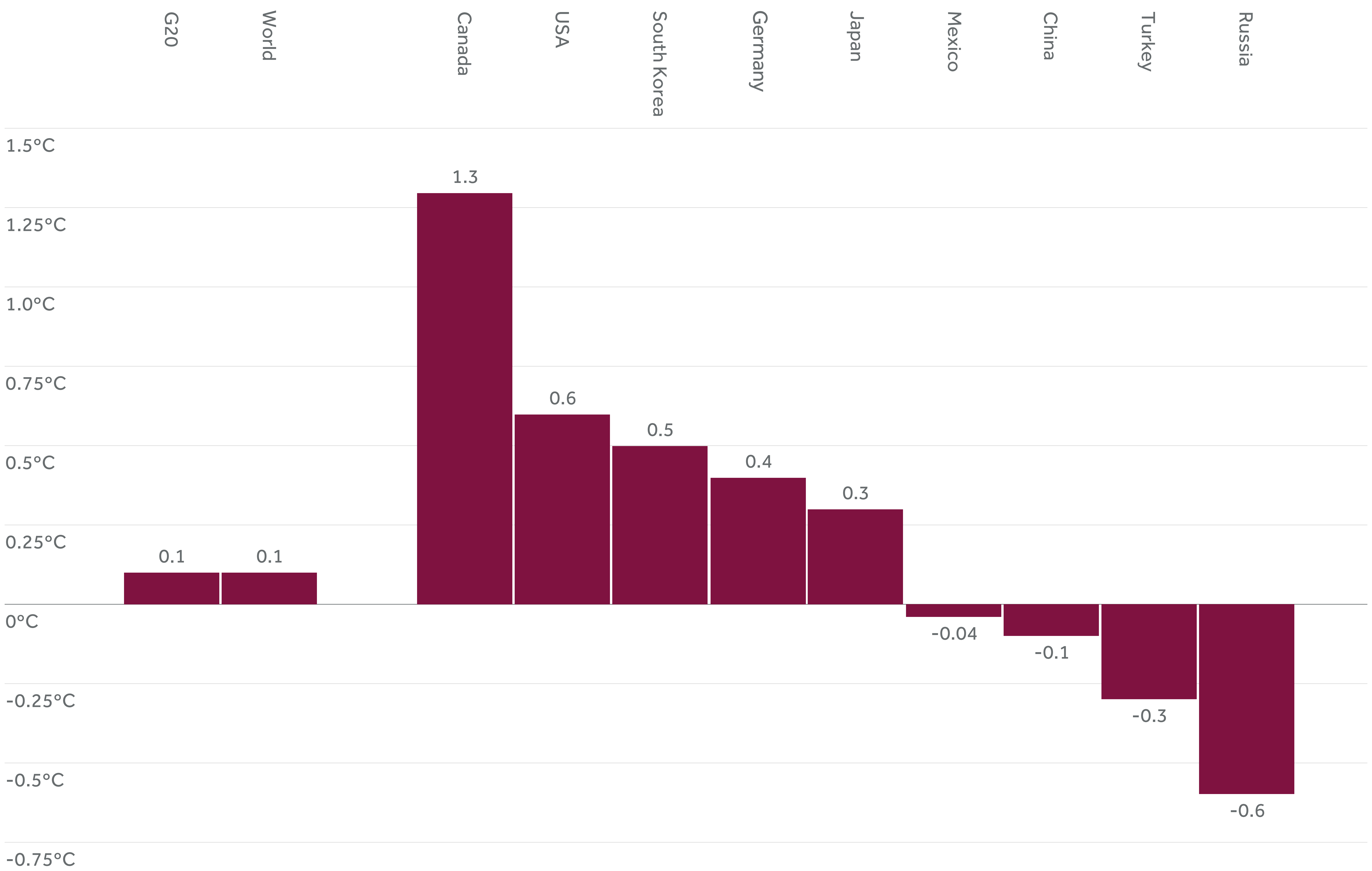
Source: FTSE Russell & Beyond Ratings Research

1.3 Current policies often out of sync with 2030 targets

While in aggregate the ambition level implied by G20 countries' NDC commitments and their current policies are quite similar (2.7°C vs 2.8°C respectively), one of the key findings from our inaugural *Net Zero Atlas* was that there are significant inconsistencies between both for several individual G20 countries. For many emerging economies, their NDCs implied a significantly lower ambition than their current policies were on track to deliver. While enhanced NDCs have reduced this gap in some cases (notably for China), they remain pronounced particularly for Turkey (0.3°C gap) and Russia (0.6°C gap) (See Figure 5).

In contrast, the current policies of several advanced economies are significantly off track when measured against their more ambitious NDCs. This is particularly apparent in the case of Canada, where current policies are tracking towards a 4°C+ trajectory, while its 2030 NDC commitment is aligned to a much lower 3°C+ trajectory. The implementation of new climate policies for Australia has aligned its current policies and NDCs (both now tracking towards 3.5°C). But sizable gaps remain for others, including the United States, Germany and South Korea, pointing to the need for these countries to further enhance current policy measures to achieve their 2030 targets.

Figure 05: Gap between Implied Temperature Rise from current policies and NDCs (in degrees Celsius)



Source: FTSE Russell & Beyond Ratings Research.

Chapter 2

Physical Risk

Methodology

Climate change is a global phenomenon, but the type and extent of physical risk exposure varies enormously from country to country and even region to region, based on:

- Location and environmental characteristics - for example, countries with a relatively large agricultural sector are more sensitive to droughts, whereas countries with high population densities in coastal areas will be more vulnerable to sea level rise
- The projected evolution of climate hazards in the territory - for example, water stress is projected to increase by 40% in the US, while decreasing by a third in the UK
- The countries' resilience, i.e., the ability to "anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner"[1]
- The countries' adaptive capacity, i.e., the ability to "design and implement effective adaptation strategies [...] to reduce the likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards"[2]

In this chapter (and in the country profiles), we survey the main evolution of climate in the G20 countries and the associated impacts on livelihoods, infrastructure, and activities to highlight the main risks and adaptation priorities for G20 countries. This includes an estimate of the evolution of the main climate hazards at the country level (e.g., the increase in average temperature or the additional number of very hot days). However, it is important to emphasize that this study does not attempt to provide a comprehensive quantification of climate change impacts, which is beyond the scope of this research.

Our analysis relies on a combination of an extensive literature review and in-house processing of publicly available climate data from the CMIP6 climate modelling initiative, as well as other public sources, such as the World Resources Institute. These models provide a statistical description (mean, variability) of weather conditions over a long period of time (typically 20-30 years) at a given location – in other words, a statistical description of potential future conditions. No climate model can predict an individual storm occurring in a few years, but it can statistically describe the frequency and intensity of future storms. These models are subject to the uncertainty of climate projections, both in terms of our understanding of the climate system and the transition pathway that the world will follow. Climate models are increasingly able to provide reliable information on future climate hazards, even though the reliability of climate information can vary among hazards and regions. To account for potential biases from the climate models, we provide mean climate values from an ensemble of climate models from the CMIP6 initiative.

Unless specified otherwise, we focus on the mid-century time horizon and the SSP585, high emissions scenario (leading to a global temperature increase of +4-5°C by 2100) to provide a higher-end estimate on the potential nearer term impacts. Emission pathways diverge strongly in the second half of the century, with exponential growth of impacts in the high emission scenario. Meanwhile, we note that climate change is already beginning to materialize and that even achieving the goals of the Paris Agreement would entail significant physical risk in the coming decades.

It is worth noting that global climate change is directly linked to cumulative, past and future greenhouse gases (GHG) emissions. However, the physical risks of a country are caused by global emissions, and not just by its own GHG emissions. Countries with low emissions, or those that are implementing strong mitigation efforts, can experience disproportionately large physical risks, and vice-versa. This is especially the case for developing countries,[3] whose contributions to global climate change are severely unbalanced with the physical risks they face.

Physical Risk

The G20 countries' emissions are the primary driver of anthropogenic climate change, and their mitigation efforts will be decisive in determining the extent of global warming the planet will experience over the course of the 21st century.

However, G20 members will also be subject to the consequences of climate change, i.e., the various manifestations of physical risks. These include acute effects (e.g., a change in the frequency and/or intensity of extreme meteorological or climate events like storms, droughts, and floods); chronic impacts (slow onset changes in climate conditions e.g., increasing average temperatures leading to increasing cooling needs), as well as their second- and third order knock-on effects.

While physical risk exposure varies widely across G20 countries, the typical characteristics of a G20 country – big, diversified, advanced or emerging economies with large populations and landmass – inherently imply that they are generally more resilient and have a higher adaptive capacity than most other countries. They are therefore more able to cope with adverse effects of climate change, particularly in comparison to smaller, developing countries.

However, this does not mean that physical risks do not matter for G20 members or that they pale in comparison with transition risks. First, the G20 is a highly diverse group, gathering advanced and emerging countries and characterized by heterogeneous economies (e.g., the nominal GDP per capita is 30 times higher for the US than for India[4]) Beyond these differences, our in-depth review in this report (and other similar studies[5,6,7]) clearly shows that in many cases these risks:

- **Are already material today:** The cost of extreme weather events that can be attributed to climate change has been estimated at US $2.9 trillion for the 2000-2019 period.[8]

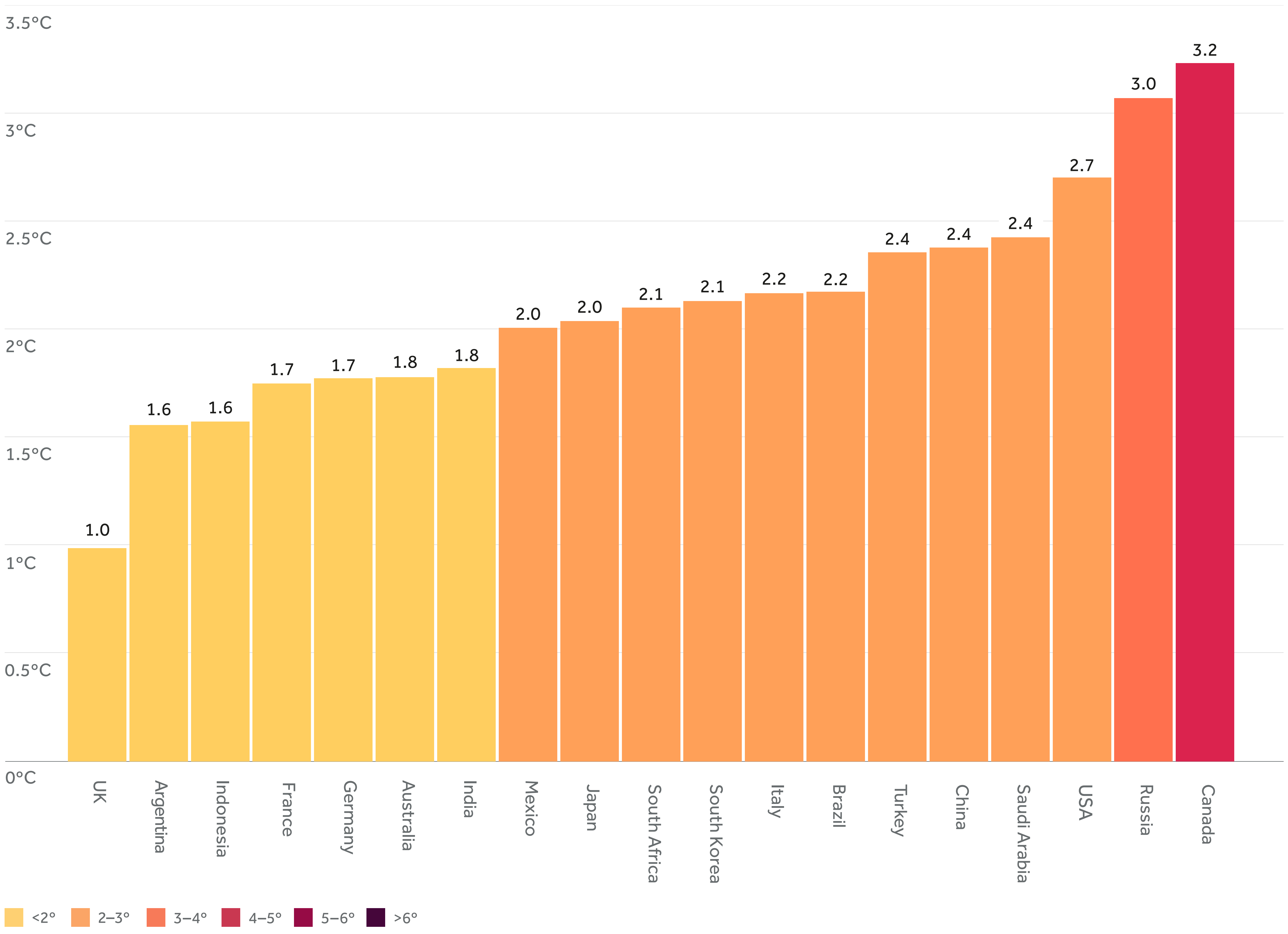
- **Are escalating rapidly:** Annual losses from catastrophic events have been rising for the last 30 years at around 5% per year, and the number of recorded events that have resulted in insured losses above US $1 billion has more than doubled in 20 years.[9]

- **Are likely to pose a significant economic and policy challenge to G20 economies by the middle of the century:** By 2050, the costs induced by sea level rise in Europe alone could reach hundreds of billion euros.[10]

- **Will, in many cases, be exceeded by the complex knock-on effects from physical risks materializing outside of their own territorial borders** (from political and financial instability to supply chain disruption and migration): Though estimates are highly uncertain, climate change might force up to one billion people to migrate.[11]

In the following section, we provide a summary of our main findings by hazard for G20 countries. The country profiles summarize the key physical risks facing each member and provide a short case study of how physical risks are already materializing.

Figure 06: Average temperature increase by 2050, following the SSP585, high emission scenario



Warmer temperatures and increasing droughts are threatening infrastructures and ecosystems

The first direct effect of increasing concentrations of GHG is the global warming of the atmosphere. This warming induces two impacts for population and human activities:

- A chronic, slow shift in temperatures that can lead to decreases in productivity, impacts on crop yields or shifts in energy consumption
- An increase in the frequency and intensity of extreme heat events that can contribute to droughts and have severe impacts on human health

G20 countries will be experiencing warming and be impacted by temperature increases to varying degrees. Counterintuitively, the largest increases in average temperature are projected to occur in the northernmost G20 countries: Canada and Russia (up to + 3.2°C and +3°C by 2050, respectively). These countries are likely to experience some benefits, such as less energy required for heating, a decreased risk of frost and greater access to ice free shipping routes (however, even the benefits can

Source: FTSE Russell – see annex for more details

remain uncertain; for instance, extreme cold events will not disappear, and could even be enhanced by climate change in some contexts.[12]). However, potential costs – particularly extensive damage to infrastructure and ecosystems – are likely to significantly outweigh the benefits, resulting in Canada and Russia being among the G20 countries that are likely to be the most adversely impacted by temperature increases.

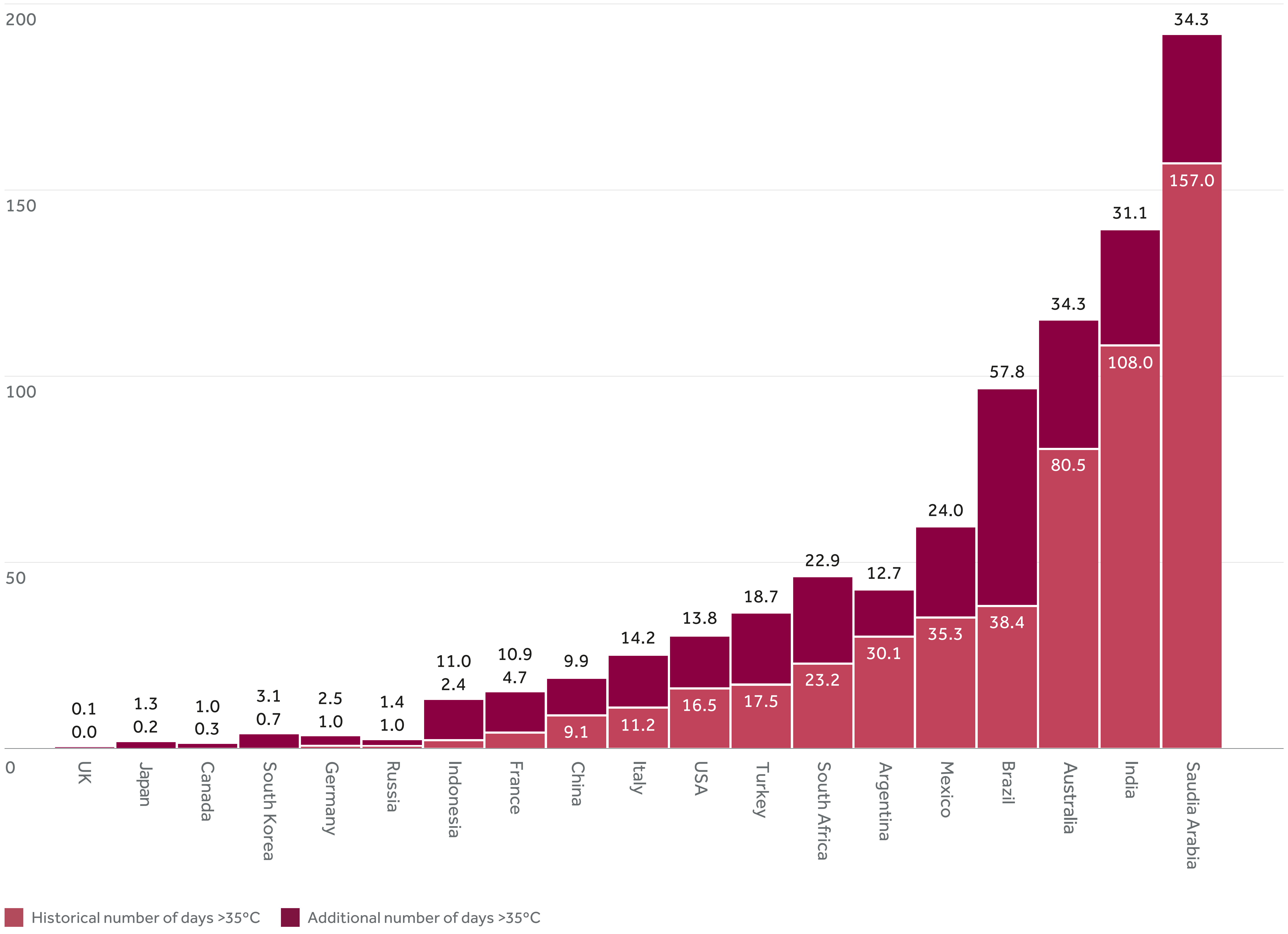
Other G20 countries that are likely to see large impacts from temperature increases include India, Saudi Arabia and Turkey. While the temperature increases are smaller (+1.8-2.4 °C), these countries are already experiencing very high temperatures. In the most exposed regions, like the Andhra Pradesh in southeastern India, further increases could seriously jeopardize the long-term viability of livelihoods and local economies.

A country's preparedness to cope with heat (such as via early warning systems) also shapes its vulnerability to rising temperature. For example, while the UK is projected to see the smallest temperature increase among G20 countries (c. +1°C), its infrastructure is less resilient than other countries. This creates additional adverse impacts, such as rail infrastructure 'buckling' as it expands under higher temperatures, potentially causing more disruption than in countries that have more resilient infrastructure but are also projected to experience higher temperature rises.

Temperature increases are also likely to increase the risk posed by tropical diseases to G20 countries. By mid-century, many G20 members will become suitable for dengue fever, malaria and zika virus.[13] In Italy for example, 70-90% of the population is projected to be potentially exposed to tropical diseases by 2050.[14]

Physical Risk

Figure 07: Historical frequency of very hot days (T>35°C) and additional days by 2050, following the SSP585 high emission scenario



Increasingly intense and frequent heatwaves are putting lives at risk

Extreme heatwaves can cause large numbers of casualties, with the 2003 heatwave in Europe causing an estimated 14,000 casualties in France alone.[15]

Demographics and socioeconomic characteristics are important factors in defining vulnerability to heat, with the elderly, the poor and densely populated cities that create urban heat island effects at particular risk. Widespread use of air conditioning can reduce such health impacts, seen in the steep decline in heat-related mortality in the US.[16] However, it is also a growing source of GHG emissions, creating the potential for a positive feedback loop, where rising temperatures and more frequent heatwaves become a driver for higher emissions.

Source: FTSE Russell – see annex for more details

Crop yield losses and wildfires

The combination of both higher average temperatures and more frequent, more extreme heatwaves will also cause several knock-on effects, including wildfires, increased water-stress and crop yield-losses.

Warmer temperatures and enhanced drought conditions will increase competition for water use. In parts of G20 countries that already experience high water stress today, this could lead to restrictions on water use and severely impact populations and economic activity (including utilities, agriculture, and the tourism industry). South Africa (where following a severe drought, Cape Town's water supply system came close to depletion in 2018) is at particular risk, but similar challenges also apply to a number of arid regions in G20 countries, including Turkey or Saudi Arabia.

Coupled with dry conditions, warmer temperatures also make many regions more prone to longer and more intense wildfire seasons, including in the US West Coast, the Mediterranean, Australia, Canada (where the forest carbon sink is turned into a carbon source) and Russia. By mid-century, the likelihood of catastrophic wildfire events is projected to increase by 22-33% globally.[17]

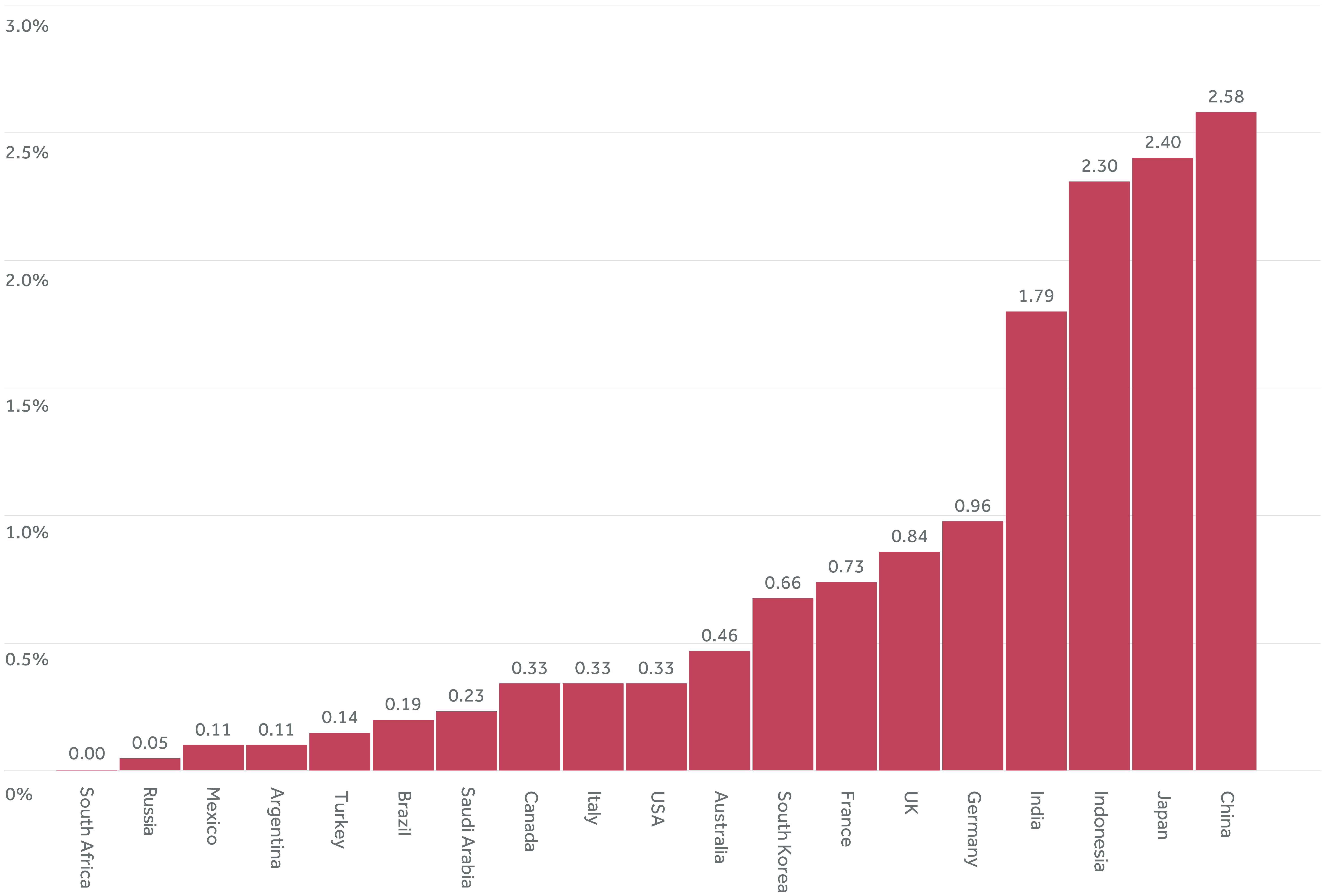
Figure 08: USA Projected change in exposure to heatwaves 2050

In most regions, warmer average temperatures, heatwaves and droughts particularly threaten the agriculture sector. The US Midwest, the Canadian Prairies, Northern India and Eastern China are among the key global production regions for staple crops including rice, wheat, corn and soy. Crop failures in any of these regions could be a significant threat to global food security, and there is increasing risk they could occur at the same time. A recent study[18] highlighted that the risk of simultaneous crop failure in all these regions under a 2°C warming scenario is nine times higher for maize and three times higher for wheat and soy.

While most G20 countries are net exporters of agricultural products and benefit from high levels of economic development, making many relatively food secure, the economic impacts of climate change for economies with large export-oriented agricultural sectors (including Brazil, Argentina, and to a lesser extent the US and the EU) could be sizable.

In the long term, growing conditions shifting to higher latitudes could change the relative importance of the main production regions and create new ones, but many non-climatic parameters influence the production capacity of a region (e.g., soil characteristics, topography, human knowledge). It is not certain that increases in regions that will become climatically suitable for cultivation will be able to balance production decreases in historical agricultural regions.

Figure 09: Proportion of the population exposed to a 1/100-year coastal flood in 2050, following the SSP585 high emission scenario



Increasing damages from heavy rainfall and storms, exacerbated by sea-level rise

Beyond temperature increases, the warming of the atmosphere has complex impacts on the entire global climate system, changing precipitation patterns all over the world.

Asia's G20 countries are home to a monsoon-influenced climate, and therefore generally experience extreme precipitation events. Monsoon rainfall in India, Indonesia or southern China is expected to be more variable, with more intense extreme rainfall and stronger floods. At the same time, rapid population growth and urbanization have created large, sealed urban areas, preventing rainwater infiltration and enhancing flooding risk. In Europe, the United Kingdom and Germany are exposed to the highest risk of increased riverine floods, with annual rainfall projected to rise by 5-20% by 2100,[19] raising the risk of flash floods and large-scale riverine inundations.

Source: FTSE Russell – see annex for more details

These impacts can sometimes be unintuitive, such as less water being available due to lower precipitation throughout the year, while rising instances of heavy rainfall leading to more flooding. For instance, even regions impacted by drier conditions, such as the Mediterranean Basin, are threatened by higher flood risks.

Climate change is also affecting oceanic storm systems. North and Central America are highly exposed to these increasingly intense storms and associated storm surges. While climate change is not expected to significantly change the frequency of hurricanes, it is expected to increase their intensity, bringing stronger winds, higher rainfall and ultimately causing more damage to property and infrastructure – particularly in Southeastern US and Mexico, which are threatened by North Atlantic hurricanes.

A similar evolution, with more intense tropical cyclones, is projected over the Asian coastal regions, where high population densities in urban environments concentrate vulnerabilities, especially in the coastal urban areas of eastern China or southern Japan. Increasingly intense tropical storms and cyclones, coupled with higher sea levels, are expected to cause more damages, with coastal areas particularly at risk as sea-level rise increases the likelihood of harmful storm surges linked to extreme events.

Local impacts, global consequences

In this report, we describe the main hazards that G20 members will experience and the potential consequences on their economies, infrastructures and populations. However, it would be naïve to believe that climate change is imposing only local and regional consequences on sovereign economies. In a globalized economy, impacts are cascading along the value chain from producers to consumers, and climate change is likely to have large knock-on effects.

This is one of the reasons why estimates of economic impacts are subject to such large margins of uncertainty. For example, the large-scale floods that affected Thailand in 2011 caused a doubling of the price of hard drives globally.[20] The droughts in Russia in 2010 caused a 70% decrease in wheat production in some regions, leading to an export ban that threatened food security and political stability in many developing countries.[21]

The disruption of supply chains is among the main global physical risks, especially where production is highly concentrated (e.g., semi-conductors). It is true that half of the G20 members are net exporters[22] but none are self-sufficient, meaning all might be impacted by the consequences of climate change elsewhere in the world. Negative effects are not unidirectional; strong economic impacts in importing countries can lead to financial instability and decreases in purchasing power, in turn impacting producing countries.

Climate change and environmental conditions are also becoming a key driving force for migration.[23] Most emigration is likely to occur in developing countries, given they are the most vulnerable to the destabilizing effects of climate change, with increasing food insecurity, decreasing productivity and the growing impacts of extreme events all acting as push factors for existing populations. In many contexts, G20 countries might be the destination.

As noted by a recent report, "more than one billion people live in countries that are unlikely to have the ability to mitigate and adapt to new ecological threats, creating conditions for mass displacement by 2050".[24] This has been illustrated by recent migration waves from Syria and Iraq to neighboring Turkey, but also to Germany and other EU countries. India, despite having high levels of exposure to physical climate risk itself, may face incoming refugees from Pakistan, the country with the largest number of people at risk of mass displacement. Similarly, declining agricultural productivity in Mexico could lead to millions being displaced, with neighboring North American G20 countries targeted as the destination.[25]

Finally, it is important to note that physical risks can also impede national and international GHG mitigation strategies. Warmer temperatures are, for example, leading to the thawing of permafrost, which will release large amounts of methane into the atmosphere, thus increasing the level of GHG and the pace of warming further. At the same time, increasingly frequent wildfires are also releasing large quantities of GHG into the atmosphere as well as decreasing the carbon-sink potential of forests around the world. Such impacts could jeopardize the mitigation strategies described in this report and increase the level of effort needed to limit climate change.

Chapter 3

Focus on Africa

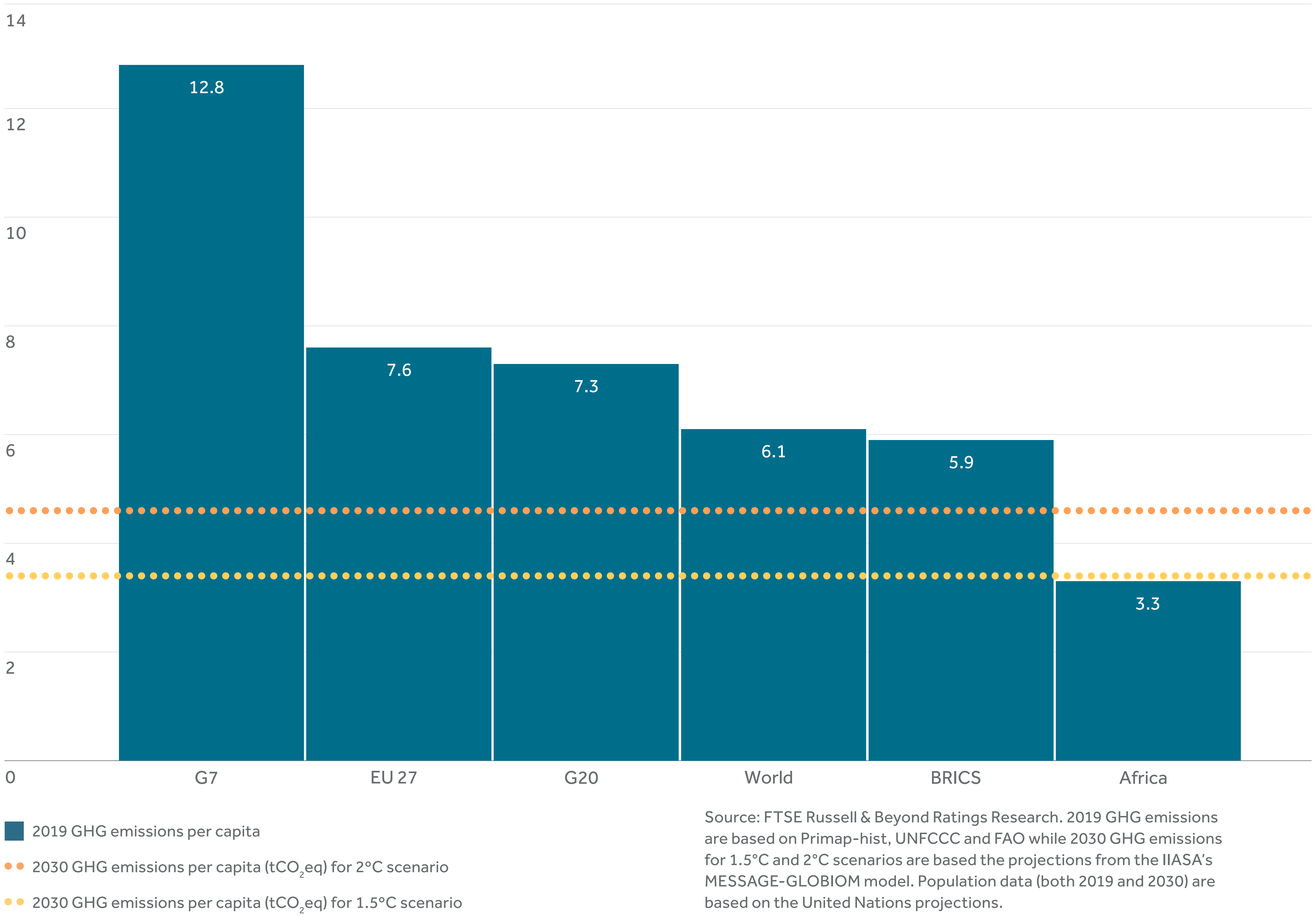
Focus on Africa

Hosted in Sharm El-Sheikh in Egypt, COP27 has been billed as the 'African COP'. This refers not only to the meeting's location, but to an expected focus on African countries' exposure to growing risks from climate change (both transition and physical).

Africa's transition risks profile differs fundamentally from that of most G20 countries. Historically, African countries have been comparatively low emitters. Despite rapid industrialization and urbanization in many parts of the continent, Africa's 54 countries still only account for c. 9% of global greenhouse gas emissions[1] (and contributed less than 3% of cumulative global CO_2 emissions between 1751 and 2017[2]), while making up 23% of the Earth's land area and housing 18% of the global population.[3]

Figure 10: In per capita terms, African nations have considerably lower emissions than other regions

GHG Emissions per capita for regional and international country groups (in tCO_2e per capita)

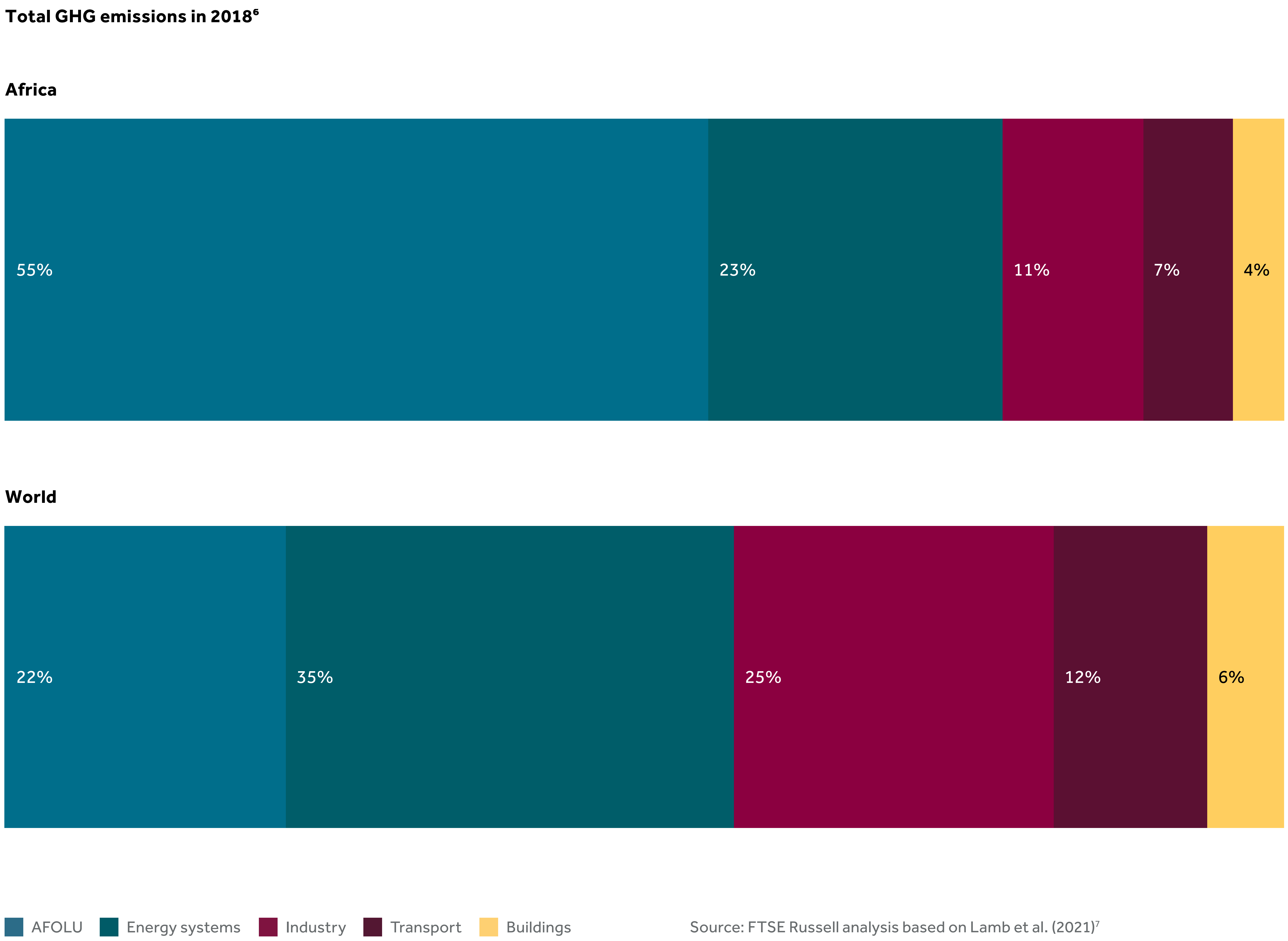


Source: FTSE Russell & Beyond Ratings Research. 2019 GHG emissions are based on Primap-hist, UNFCCC and FAO while 2030 GHG emissions for 1.5°C and 2°C scenarios are based the projections from the IIASA's MESSAGE-GLOBIOM model. Population data (both 2019 and 2030) are based on the United Nations projections.

As a result, Africa's current emissions, unlike for other regions, are compatible with the 2030 global emissions level required for alignment with the Paris objective. We estimate that, in aggregate, African countries could *increase* their per capita emissions by c. 0.4% per annum until 2030 and still remain below the average global emissions per capita required for 1.5°C. By contrast, the world as a whole needs to *reduce* per capita emissions by 5% annually to meet a similar level. To maintain a Paris-aligned trajectory post-2030, however, African countries would, on average, have to reverse emissions growth[4] and eventually converge towards net zero emissions by mid-century.

Africa's emissions profile is also unique – with Agriculture, Forestry and Other Land Use (AFOLU) change being by far the largest contributor to the continent's GHG emissions (55%), far higher than the global average (c. 22%) (See Figure 11).[5] By contrast, Energy Systems and Industry make up a much smaller proportion of Africa's emissions than elsewhere – c. 12% and 14% less than the global average respectively.

Figure 11: Africa's emissions profile differs from global trends



Source: FTSE Russell analysis based on Lamb et al. (2021)[7]

Focus on Africa

Both transition and physical risks are also shaped by rapidly expanding and urbanizing populations, which still often lack access to basic services. The population is expected to double in 26 African countries by 2050; Nigeria, for example, will become the third most populated country on Earth with 400 million inhabitants.[8] At the same time, today over 750 million Africans lack access to basic sanitation services, 600 million lack access to electricity, and more than 400 million lack access to a basic level of drinking water service.[9] Roughly half of the population is employed in farming[10] (often subsistence farming) and nearly half of its export revenue is generated by fossil fuels.[11]

The central challenge of transition strategies for African nations is how to rapidly expand energy access, while safeguarding the continent's ecosystems and avoiding 'carbon lock-in'. This includes avoiding investing heavily in the build-out of infrastructure for outdated, fossil-fuel based power generation, as well as transport technology and export sectors (from coal or gas-fired power stations to oil and gas pipelines or LNG terminals).

Africa has the potential to leapfrog increasingly obsolete fossil-fuel technologies by harnessing its significant renewables potential; the continent has, on average, greater long-term solar power potential than any other.[12] Stopping deforestation and expanding into carbon sequestration could also pose a potentially lucrative revenue stream.[13]

Transition planning in many African nations, however, is still in its early stages. Ten countries have so far made commitments to net zero emissions by mid-century,[14] which often serve as a first step in formal transition planning in terms of sectoral decarbonization pathways, timetables and investment requirements.

African countries are set to be disproportionately exposed to the impacts of climate change due to a combination of historically adverse climate conditions and a large share of agriculture and other weather-sensitive activities in its GDP. The African Development Bank recently estimated that Africa has been losing "5 to 15% of its GDP per capita growth because of climate change",[15] while one study estimated GDP per capita is 13.6% lower on average for African countries than it would be if human-caused global warming since 1991 had not occurred.[16]

Warming temperatures in a historically hot environment already impacts agricultural productivity. According to the WMO, yield growth rates have decreased by 34% since 1961[17] In addition, in central and western Africa, dry spells may become twice as frequent in the future.[18] Around 95% of fields are rain-fed in Sub-Saharan Africa, which could become highly problematic for a region that relies heavily on subsistence farming.[19] East Africa is, for example, already facing what has been identified as its longest and worst drought in more than 40 years.[20] Agriculture and food production has been defined as the number one priority for adaptation in Africa.[21]

Climate change is projected to further intensify strain on water supplies, which are already scarce and not readily available for a significant part of the population. Increase in water stress could also intensify existing conflicts or trigger new ones over water resources and their uses, such as hydroelectric power generation. The current tensions over the Nile river represent a striking example of the complexity of managing common water resources across borders.[22]

Focus on Africa

On the coastlines, sea level rise and the increase in frequency and severity of coastal flooding is also a serious issue. In the east and south of Africa, tropical cyclones are expected to become more intense and more costly. For example, cyclones Idai in 2019 and Eloise in 2021 affected millions of people in Mozambique, triggering massive population displacements and causing USD 2-3 billion in losses.[23,24] Coastal and inland floodings are projected to become more likely, causing catastrophic damages on urban centers and putting a rapidly growing urban population at risk.

Across the entire continent, a higher number of heatwaves are also expected, with increasing health impacts on the population, including exacerbation of heat-related morbidity and mortality.[25] This could also result in critical losses in labor productivity, as a significant proportion of the population works outdoors. A temperature rise of 3°C could lead to a 50% reduction in productivity (relative to a baseline from 1986-2005).[26] A recent study based on 150 large African cities estimates that exposure to harmful temperatures will be 20 to 52 times higher by 2100 than present-day, especially in Western and Central Africa.[27]

The spread of vector-borne diseases could also be significantly enhanced by a combination of flooding, higher temperatures and more variable rainfall patterns. With 2°C of warming, tens of millions more people are forecast to be exposed to vector-borne diseases, primarily malaria in East and Southern Africa; dengue and zika in North, East and Southern Africa; and cholera in East, Central and West Africa.[28]

To face these existing and upcoming challenges, the role of climate adaptation is paramount in Africa. So far, with only 25% of climate finance for adaptation globally and 10% for dual benefit actions, mitigation has been the prime focus of investments.[29] Current estimates determine that Africa requires US $259-407 billion for 2020-2030 to enhance adaptation to climate change.[30]

Despite the benefits and cost-effectiveness of adaptation, the financing gap still represents a major constraint. The key adaptation outcome from COP26 has been the commitment from developed countries to double the climate adaptation finance by 2025, but these new, improved pledges still fall short of needs. COP27 thus poses an opportunity to improve these commitments and mobilize private finance to help bridge the requirement gap, with 87% of climate finance in Africa so far provided through public sources.[31]

Chapter 4

Country Profiles

Argentina

Argentina's 2050 net zero target[1] is Paris-aligned. However, its latest 2030 nationally determined contribution, NDC[2], and current policies align with a 2°C+ trajectory.

Key climate-related policies

Carbon tax on energy (2017)[4] The tax targets emissions from transport fuels and coal at a rate of US $5/t$CO_2$ by 2020. It excludes natural gas consumption and shale gas production, and it is reviewed each trimester.

Renewable Energy Law (2016)[5] By 2023, 18% of Argentina's electricity must be supplied by renewable sources, rising to 20% by 2025.

Biofuels Law (2021)[6] From 2021, the law mandates blending 5% biodiesel and 12% ethanol with gasoline. This new regime allows authorities to adjust blending mandates based on input prices, with a floor of 3%.

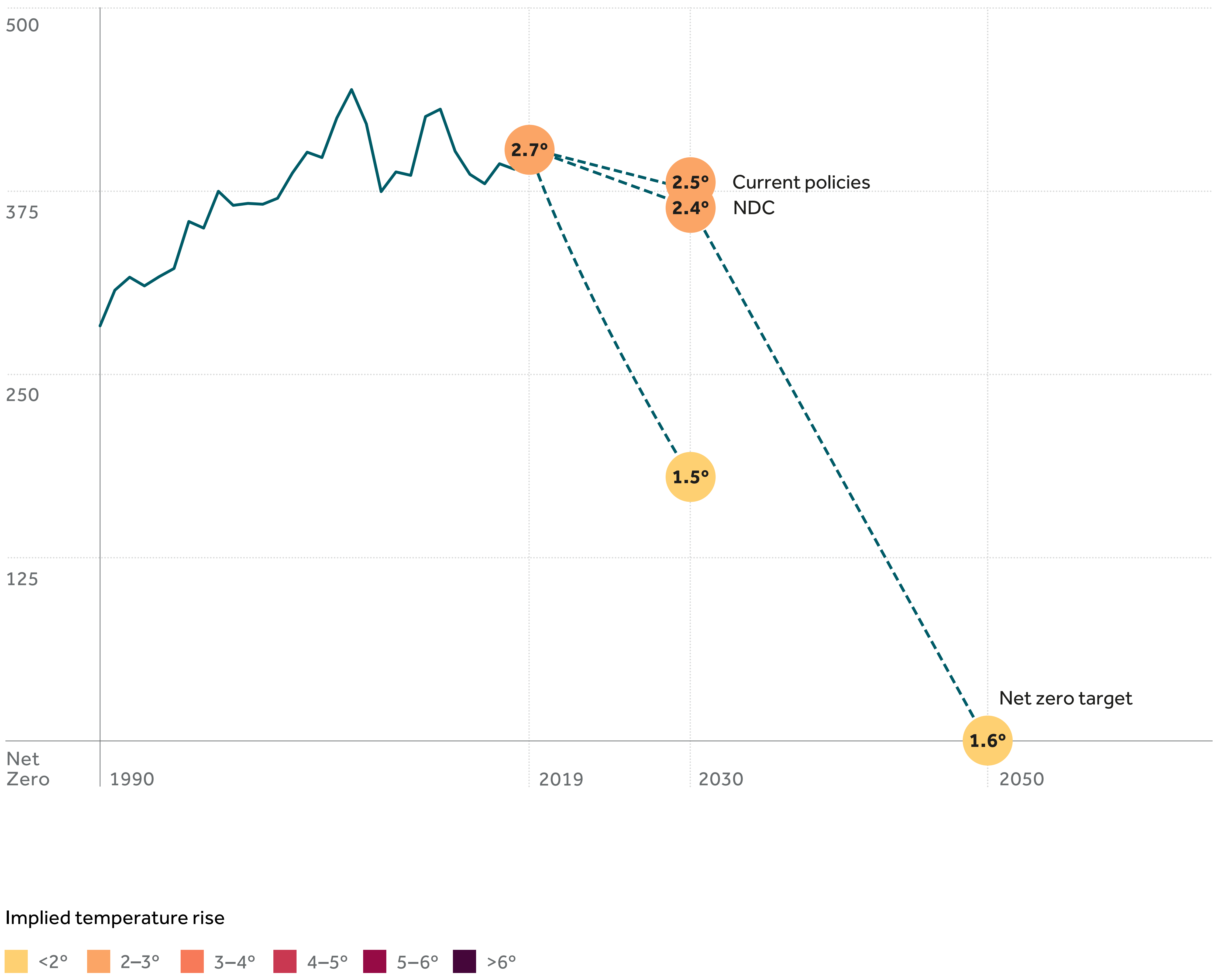
National plan for the restoration of native forests (2019)[7] By 2030, the plan aims to restore 20 million hectares of native forest.

GDP
US$491 billion

Population
45 million

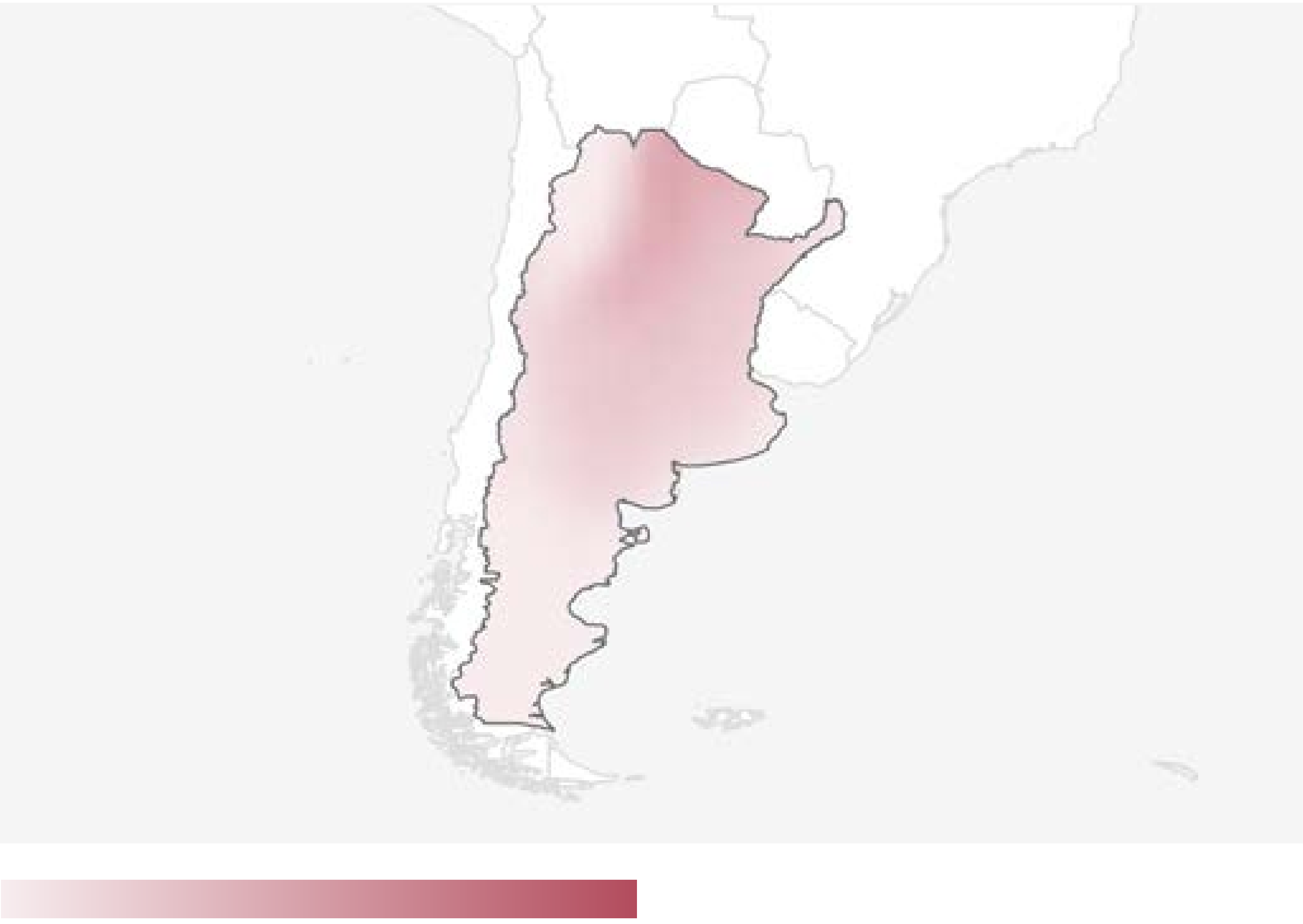
Under Argentina's latest NDC, we estimate greenhouse gas emissions per capita would fall from 9.0 tons of CO_2e in 2019 to 7.4 by 2030. Its current policies imply a reduction to 7.7 tons over the same period.[3]

GHG Emissions ($MtCO_2e$)



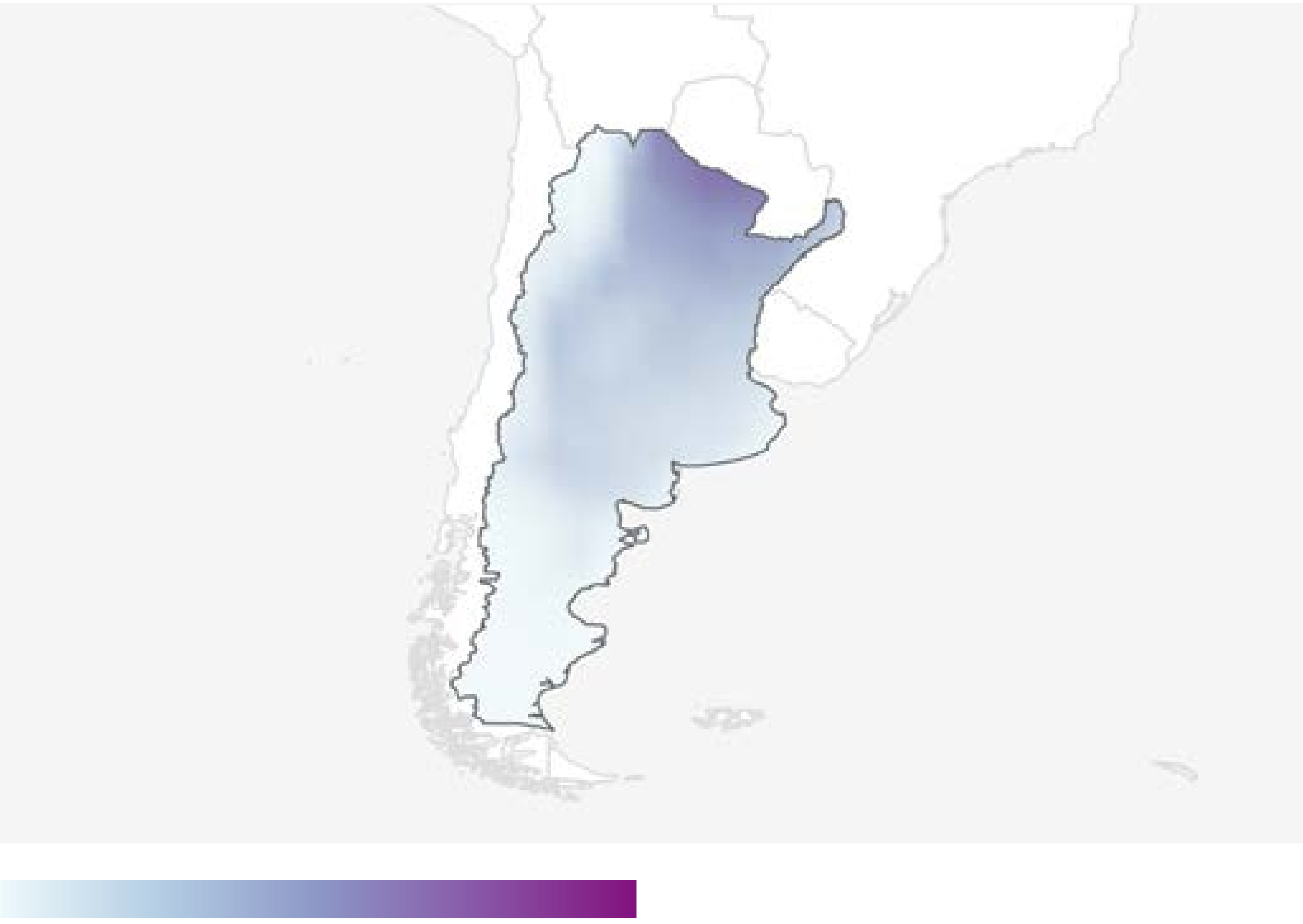
Argentina

Historical exposure to heatwaves



Frequency of days above 35°C, based on global climate projections from the CMIP6 initiative.

Projected change in exposure to heatwaves by 2050



Summary of physical risk exposure

Argentina's climate is shaped by its location and its highly specific topography, with the Andes running along its west and a significant portion of its east border facing the South Atlantic. This makes it prone to a wider range of weather extremes than most countries, with distinct physical risks facing different areas of the country.

The frequency of extreme rainfall and floods is expected to increase significantly by 2050, especially in the coastal east, likely generating significant losses in a country, where floods historically represent 58% of economic losses.[8] While sea-level rise and storm surges threaten the coast, particularly urban areas around the Plata River, including Buenos Aires, their impacts may be limited as the most populated shorelines are on higher ground.

Paradoxically, a higher incident of floods and extreme rainfall events is expected to be accompanied on average by warmer and drier conditions across the country. Argentina's agricultural sector is particularly vulnerable, with possible declines in livestock health (Argentina has some of world's largest cattle herds) and maize yields (Argentina's main crop).[9]

Increasingly frequent heatwaves could have significant health impacts on Argentina's population, particularly given its urbanization rate of 92% is among the highest among G20 countries.

Recent events

The 2017-2018 drought in the Argentine Pampas
During the summer of 2017, a major drought hit the agriculturally rich part of central-eastern Argentina. The event, linked to a mild La Niña phenomenon, severely reduced crop production – particularly for maize and soybean – with economy-wide losses exceeding US $4 billion,[10] mostly from lost farming output.

2050 projections

Change in average temperature
+1.6°C

Change in precipitation
+0.7%

Change in water stress
+161%

Australia

Australia's 2050 net zero target[11] aligns with a 2°C+ scenario. We estimate its latest 2030 NDC[12] and current policies to align with a 3.5°C trajectory.

Key climate-related policies

Emissions Reduction Fund (ERF) (updated in 2022)[14] The government purchases carbon credits generated by companies that voluntarily reduce their emissions. The fund was modified in 2022 to allow existing purchase contracts to be terminated and for companies to sell their credits in the market.

Future Fuels and Vehicle Strategy (2021)[15] This strategy sets out a technology-led approach to tackle emissions in the transport sector aimed at increasing the uptake of hybrid, hydrogen, electric and biofueled vehicles. It plans to reduce 8 $MtCO_2e$ by 2035.

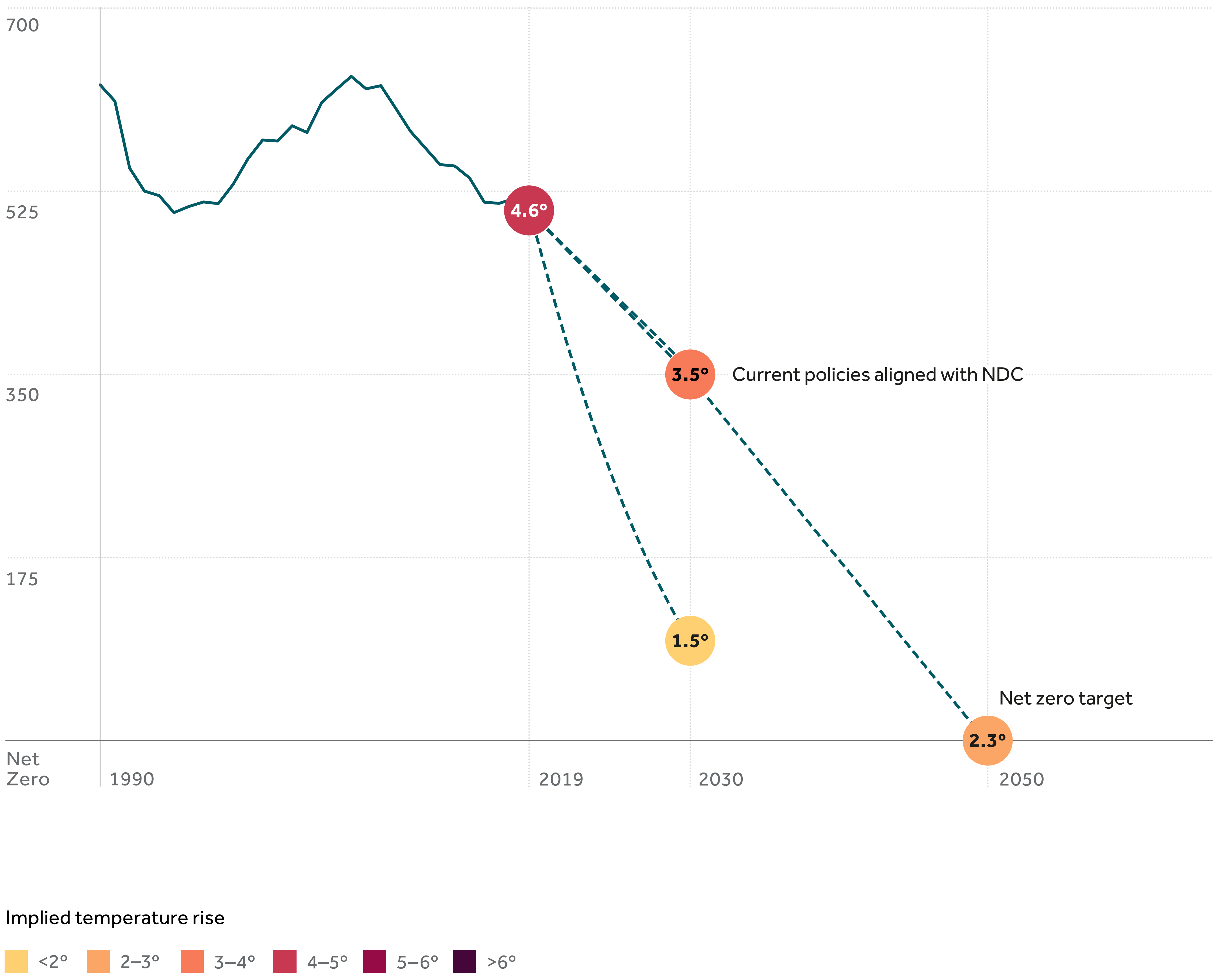
Australian Federal Budget 2021-22 (2021)[16] The budget includes inter alia the funding for hydrogen hubs and carbon capture storage, support for farmers to reduce emissions through the national soil carbon innovation challenge and trials for low-emission technologies, and investment to help Australian businesses and supply chains adopt energy efficiency measures.

GDP
US$1,543 billion

Population
26 million

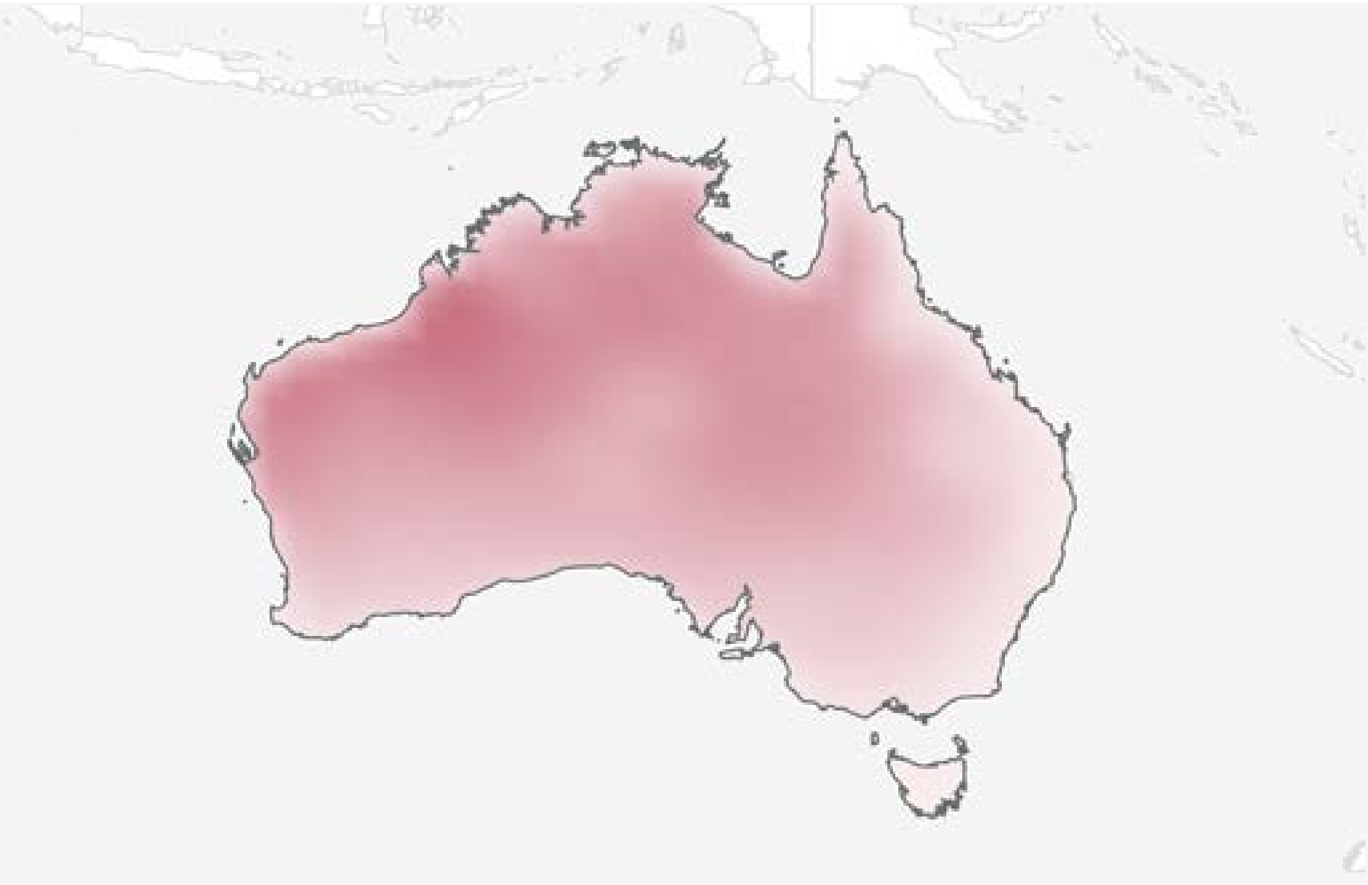
Under Australia's latest NDC, we estimate greenhouse gas emissions per capita would fall from 20.1 tons CO_2e in 2019 to 12.3 tons by 2030. Its current policies imply a reduction to 12.6 tons over the same period.[13]

GHG Emissions ($MtCO_2e$)



Australia

Historical exposure to heatwaves



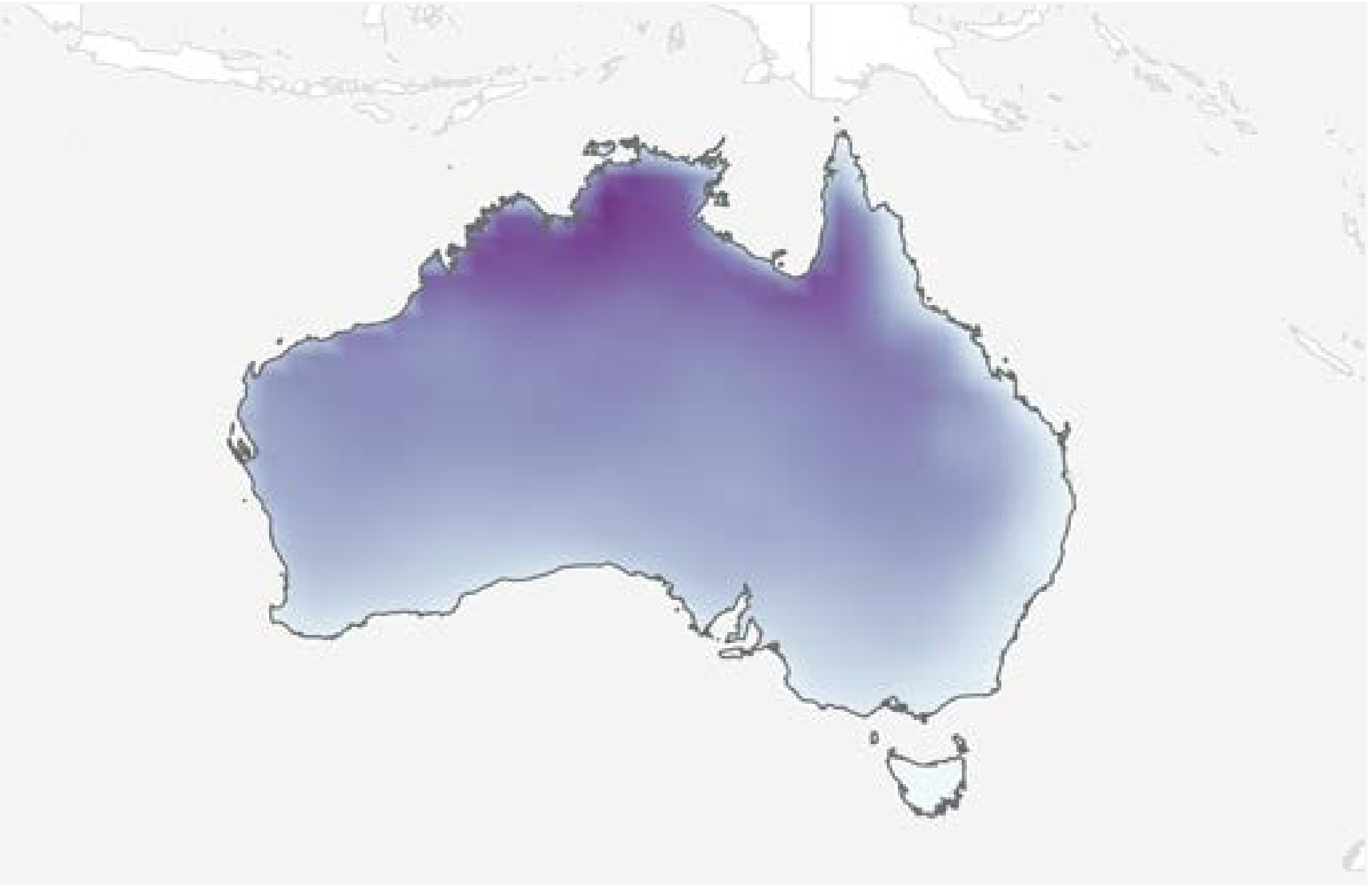
0 days 150 days

Frequency of days above 35°C, based on global climate projections from the CMIP6 initiative.

Recent events

The 2019-2020 bushfire season
The 2019-2020 Australian bushfire season was particularly intense and constituted a major disaster. Wildfires burned from July 2019 to March 2020, scorching 46 million acres, destroying thousands of buildings, killing 34 people and over a billion animals. A WWF report[20] estimated a loss of US $4-5 billion from damage to Australia's food system alone.

Projected change in exposure to heatwaves by 2050



0 days +80 days

2050 projections

Change in average temperature
+1.8°C

Change in precipitation
+0.1%

Change in water stress
+832%

Summary of physical risk exposure

Australia is home to a wide range of climates, with a large arid to semi-arid area in its center and sub-tropical conditions in the north. Population and activities are concentrated along the western and southern coasts, with more temperate and oceanic conditions.

Droughts are projected to occur more frequently, particularly in the southern parts of the country. This will further increase water stress and lead to a higher frequency of wildfires and intensity – with average annual burned area already having increased four times over the past two decades.[17]

Rising temperatures and associated droughts, heatwaves, and wildfires will also impact the economically important agricultural sector, with models indicating potential heat-related economic impacts could reach US $151 billion by 2050.[18]

Counterintuitively, drier conditions will also make Australia more vulnerable to more frequent extreme precipitation events and resultant flooding, as water infiltration is reduced on drier soils. This will lead to higher risk to property and populations, with the population at risk of river flooding expected to double by 2050.[19]

Brazil

Brazil's 2050 net zero target[21] is Paris-aligned. However, its latest 2030 NDC[22] and current policies align with a 2°C+ trajectory.

Key climate-related policies

10-Year National Energy Expansion Plan (PDE) (2011/2019)[24] By 2029, the plan targets 48% of total primary energy supply to come from renewables (36% excluding hydropower) and 22% of total electricity generation (excluding hydropower).

Biodiesel blending mandates (2020-2021)[25] In March 2020, the Brazilian government raised the biodiesel blending mandate from 11% to 12%. It plans to raise this further to reach 15% by 2023.

National Plan on Climate Change (2008)[26] and Forest Code (2012)[27] These plans aim to reduce illegal deforestation rates in all Brazilian biomes to zero as well as restore 12 million hectares of forests by 2030.

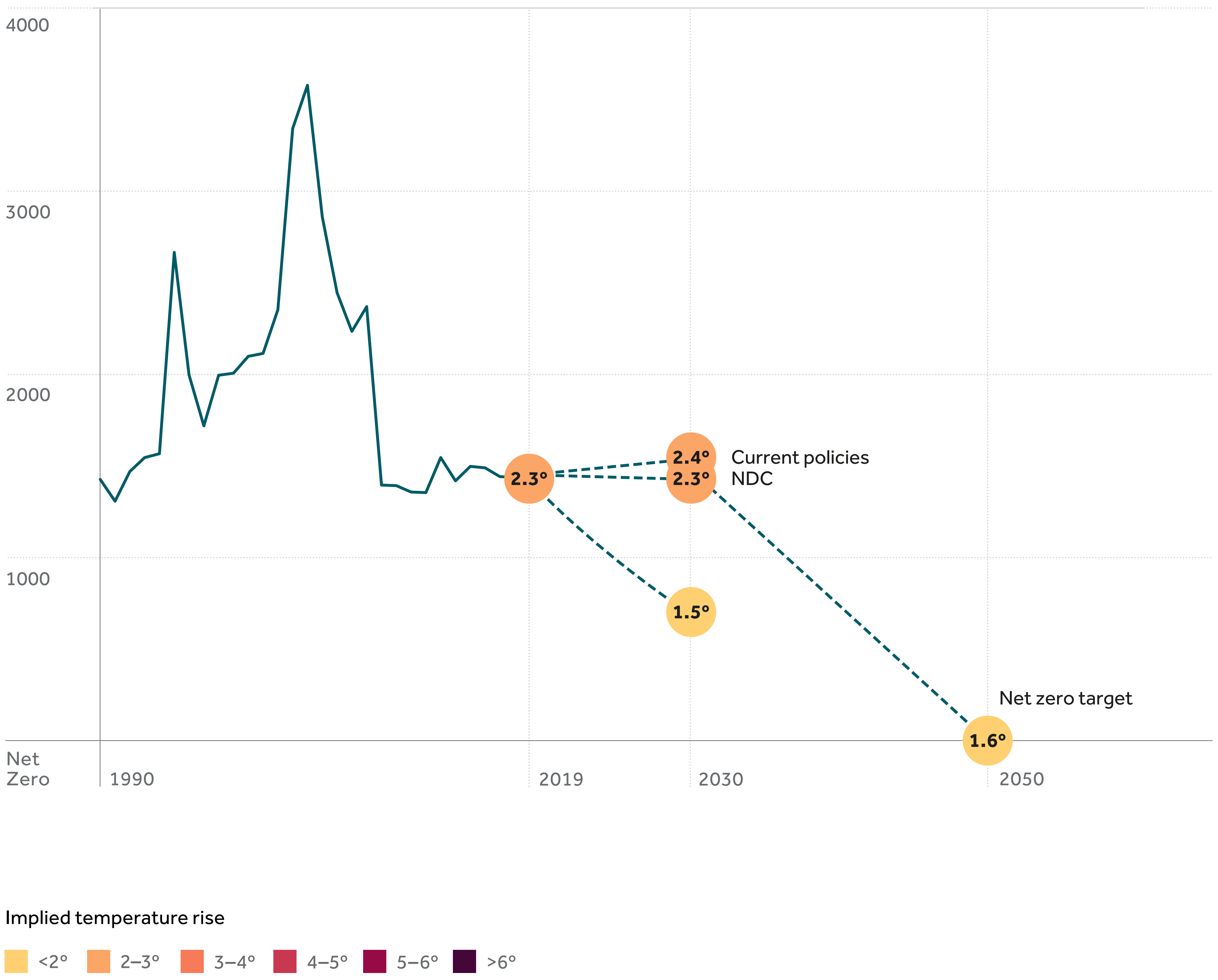
Green Rural Product Certificate - Decree 10,828/2021[28] The decree regulates the issue of Rural Product Certificates, related to the activities of conservation and recuperation of native forests and their biomes.

GDP
US$1,609 billion

Population
215 million

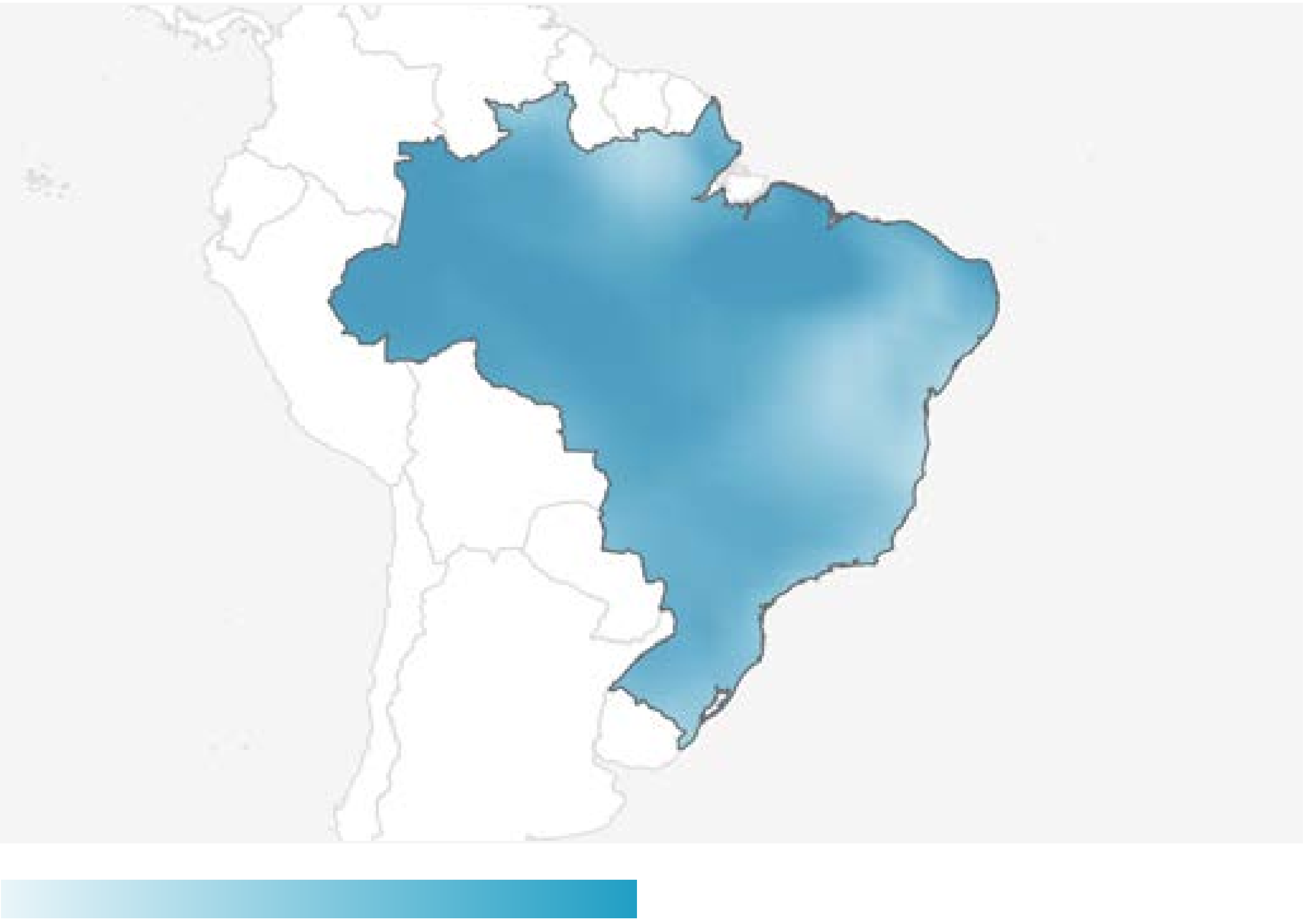
Under Brazil's latest NDC, we estimate greenhouse gas emissions per capita would decrease from 6.9 tons CO_2e in 2019 to 6.4 by 2030. Its current policies imply a constant level of 6.9 tons over the same period.[23]

GHG Emissions ($MtCO_2e$)



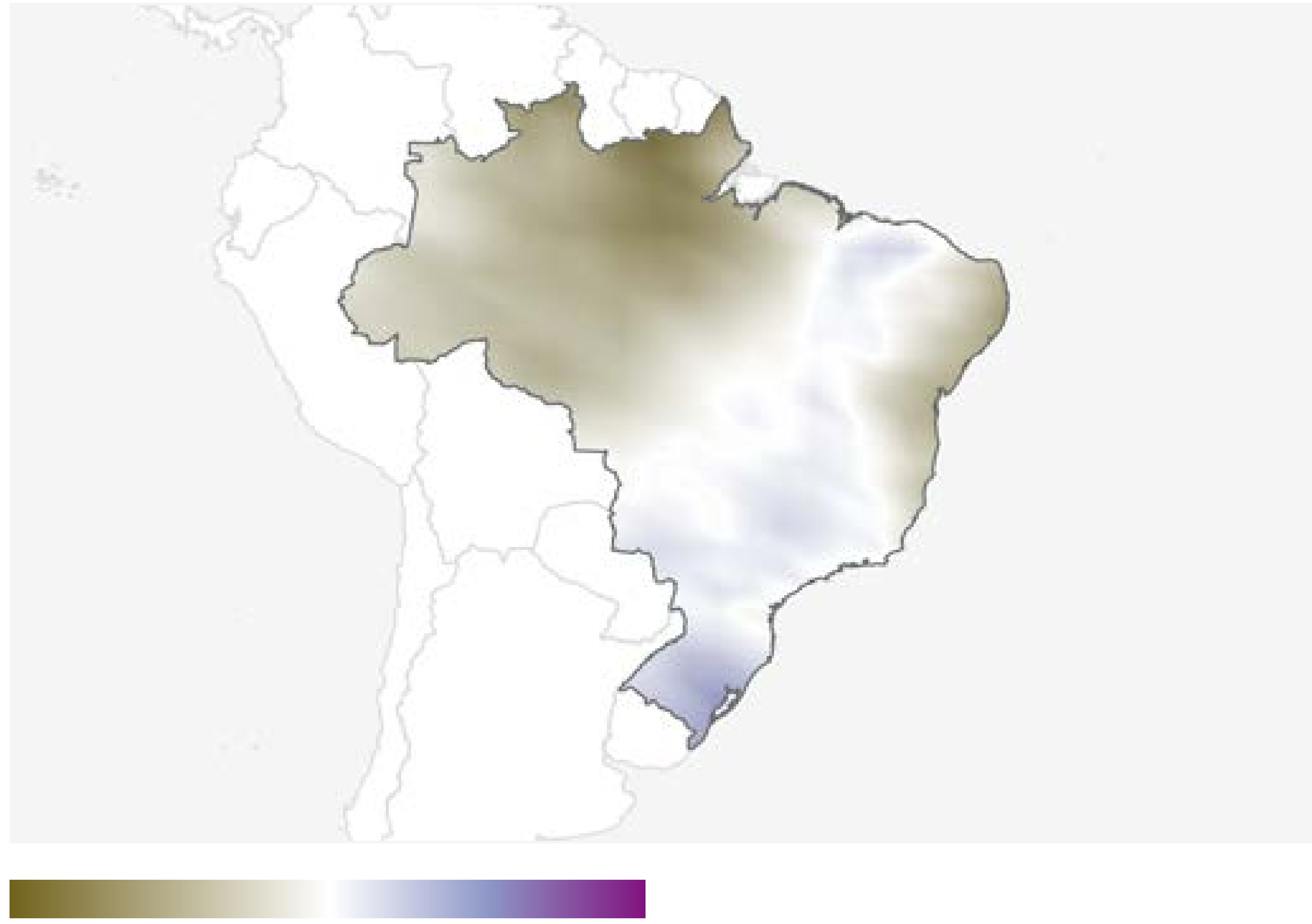
Brazil

Historical precipitation



Average annual precipitation based on global climate projections from the CMIP6 initiative.

Projected change in precipitation by 2050



Summary of physical risk exposure

Brazil has mostly a tropical climate and is home to the largest rainforest in the world, the Amazon. Variable rainfall patterns can be observed across the country, with overall moderate rainfall concentrated in the summer and drier conditions in the northeast.

More extreme precipitation events are expected, which could lead to severe flooding and landslides, and cause significant damage to urban areas. Coupled with increasing temperatures, this might result in the spread of climate-sensitive vector-borne diseases such as Zika or dengue fever to new regions, and higher transmissibility in urban centers.[29]

Higher temperatures, increased droughts and water stress will also put Brazil's large agricultural sector at risk, with sugarcane and maize particularly impacted (where the country is the world's largest and third largest producer respectively). Yield losses could also contribute to intensifying competition for arable land and further deforestation.

The lowlands of the Amazon delta are at risk from sea-level rise. Damages to coastal infrastructure, along with ecosystem degradation could also constitute a threat to Brazil's tourism industry, which currently represents more than 5% of the economy.

Recent events

The 2011 floods in the state of Rio de Janeiro
In January 2011, thunderstorms in the mountainous region of the Rio de Janeiro state set off a combination of major floods, landslides and mudslides, with local weather services recording almost as much rain in a day as the monthly average. The event caused more than 900 deaths, as well as US $1.2 billion in damages to public infrastructure, housing and farmlands.[30]

2050 projections

Change in average temperature
+2.2°C

Change in precipitation
-0.2%

Change in water stress
+24%

Canada

Canada's 2050 net zero target[31] aligns with a 2°C+ scenario. However, we estimate its latest 2030 NDC[32] and current policies to align with a 3°C+ trajectory and 4°C+ trajectory respectively.

GDP
US$1,991 billion

Population
38 million

Under Canada's latest NDC, we estimate greenhouse gas emissions per capita would fall from 19.2 tons of CO_2e in 2019 to 10.4 tons by 2030. Its current policies imply a lower reduction to 16.9 tons over the same period.[33]

Key climate-related policies

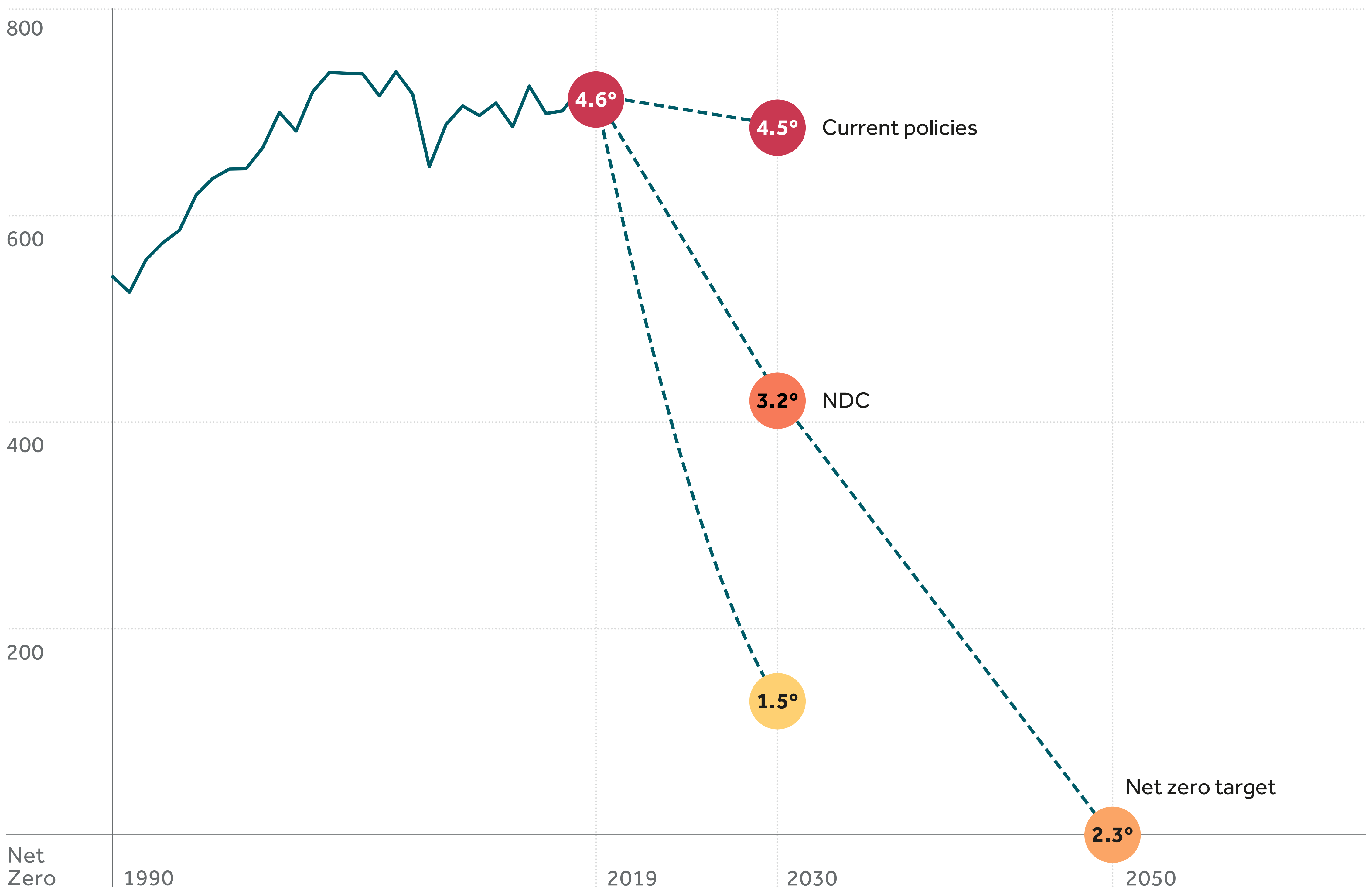
Zero Emission Vehicle Infrastructure Deployment (updated in 2021)[34] This policy aims to ensure low-emissions vehicles comprise 30% of new light-duty vehicle sales by 2030 and a long-term goal of 100% by 2040. Budget has been allocated for the 2019-2024 period, particularly for deploying charging and refuelling stations in localized areas.

Greenhouse Gas Pollution Pricing Act (2018)[35] The Act establishes a federal price on emissions, consisting of a carbon levy on small emitters (under 50 kt CO_2e/yr) and a cap-and-trade system/output-based pricing system on industrial facilities (over 50 kt CO_2e/yr).

Regulations to address methane in the oil and gas sector (2020)[36] Regulation aiming to reduce methane emissions from oil and gas by 40-45% by 2025, compared to 2012 levels. The government announced a CAD 750 million Emissions Reduction Fund helping to reach this target.

Regulation of HFCs (2020)[37] The Regulations Amending the Ozone-depleting Substances and Halocarbon Alternatives Regulations aim to reduce the supply of hydrofluorocarbons (HFCs) that enter Canada and the demand for HFCs in manufactured products.

GHG Emissions ($MtCO_2e$)

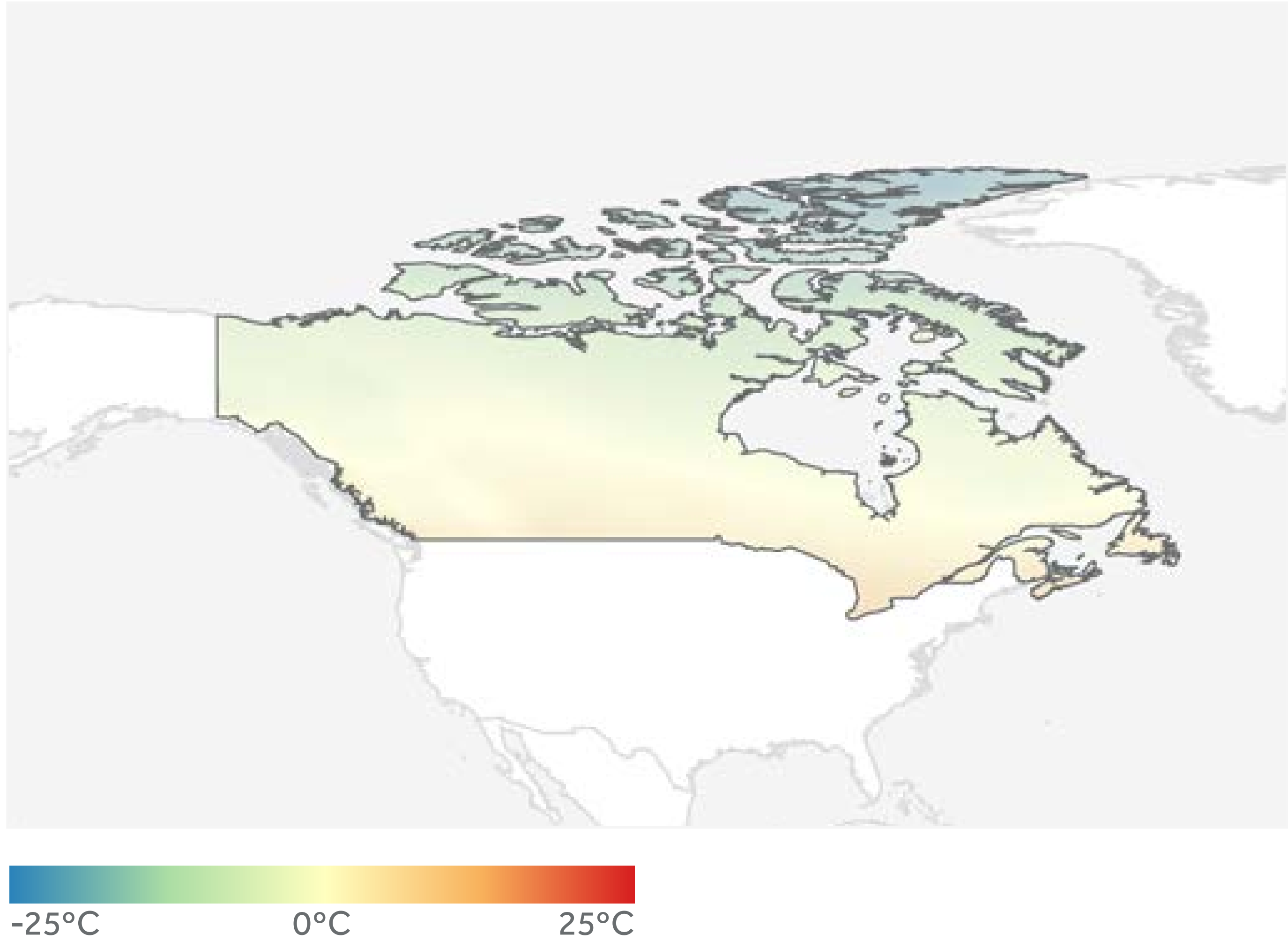


Implied temperature rise

<2° | 2–3° | 3–4° | 4–5° | 5–6° | >6°

Canada

Historical average temperature

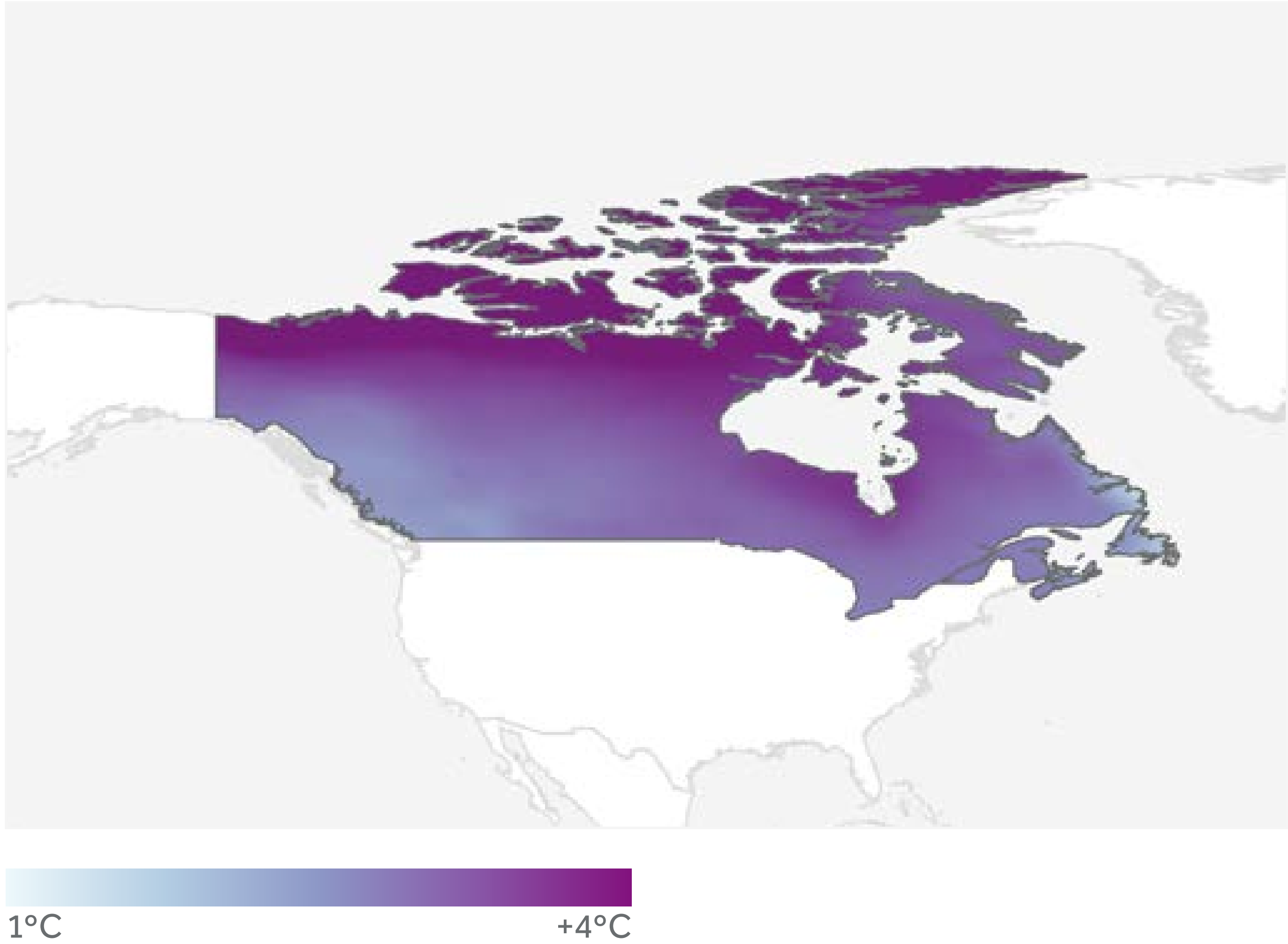


Average annual temperature based on global climate projections from the CMIP6 initiative.

Recent events

The 2016 Fort McMurray wildfire
In May 2016, a large wildfire started in northern Alberta and swept through the city of Fort McMurray. It grew rapidly, spreading in both north and east directions due to the dryness of the region and burning almost 6,000 square kilometers of forest. The wildfire led to the displacement of over 80,000 people, destroyed 2,400 homes and businesses, and halted oil sands production. Total costs have been estimated at US $7 billion.[42]

Projected change in average temperature by 2050



2050 projections

Change in average temperature
+3.2°C

Change in precipitation
+1.6%

Change in water stress
+10%

Summary of physical risk exposure

Canada is one of the coldest countries on Earth but is now warming twice as fast as the G20 average. Although the country will face milder winter conditions in the future, the economic impacts of climate change could be costly and disruptive.

Warmer temperatures (of up to 6°C in Northern Canada by 2050) will lead to shorter ice seasons. Thawing permafrost represents an increasing risk to infrastructure, including ice roads that are important winter transport routes in the northern parts of the country. Glacial cover is also projected to decrease, diminishing freshwater availability and impacting hydropower production, which currently accounts for almost 60% of Canada's electricity generation.[38]

More extreme precipitation events are expected with rising temperatures, as snowfall more readily transforms to rain, with damages from inland flooding alone over the past 10 years being estimated at more than US $7 billion.[39] These extreme events are expected to be more frequent, more widespread, and more harmful in nature, especially in coastal areas exposed to rising sea levels and storm surges. Overall, the potential economic impact from floods and storms has been projected to exceed US $50 billion by 2050.[40]

Increased wildfire risk from drier, warmer conditions threatens the role of Canada's boreal forest as a vital carbon sink, as well as negatively impacting biodiversity and timber production levels. Recent reports highlight that Canada's managed forest has in fact been a carbon net source since 2001.[41]

China

China's 2060 net zero target[43] aligns with a 2°C+ trajectory. We estimate its latest 2030 NDC[44] and current policies to align with a 2.5°C-3.0°C trajectory.

Key climate-related policies

14th Five-Year Plan [2021-2025] (2021)[46] The plan aims for 20% of total primary energy supply to come from sources other than fossil fuels by 2025, and to reduce energy intensity by 13.5% and carbon intensity by 18%.

Revision of Land Administration Law of the People's Republic of China (2019)[47] The law, which became effective in January 2020, re-affirms a commitment to maintain a supply of at least 120 million hectares of arable land designated as permanent basic farmland.

15-year plan [2021-2035] to protect ecosystems (2020)[48] Tasks include increasing forest cover to 26% by 2035, expanding the grassland vegetation cover to 60%, and increasing the nature reserve areas to 18% of total national area.

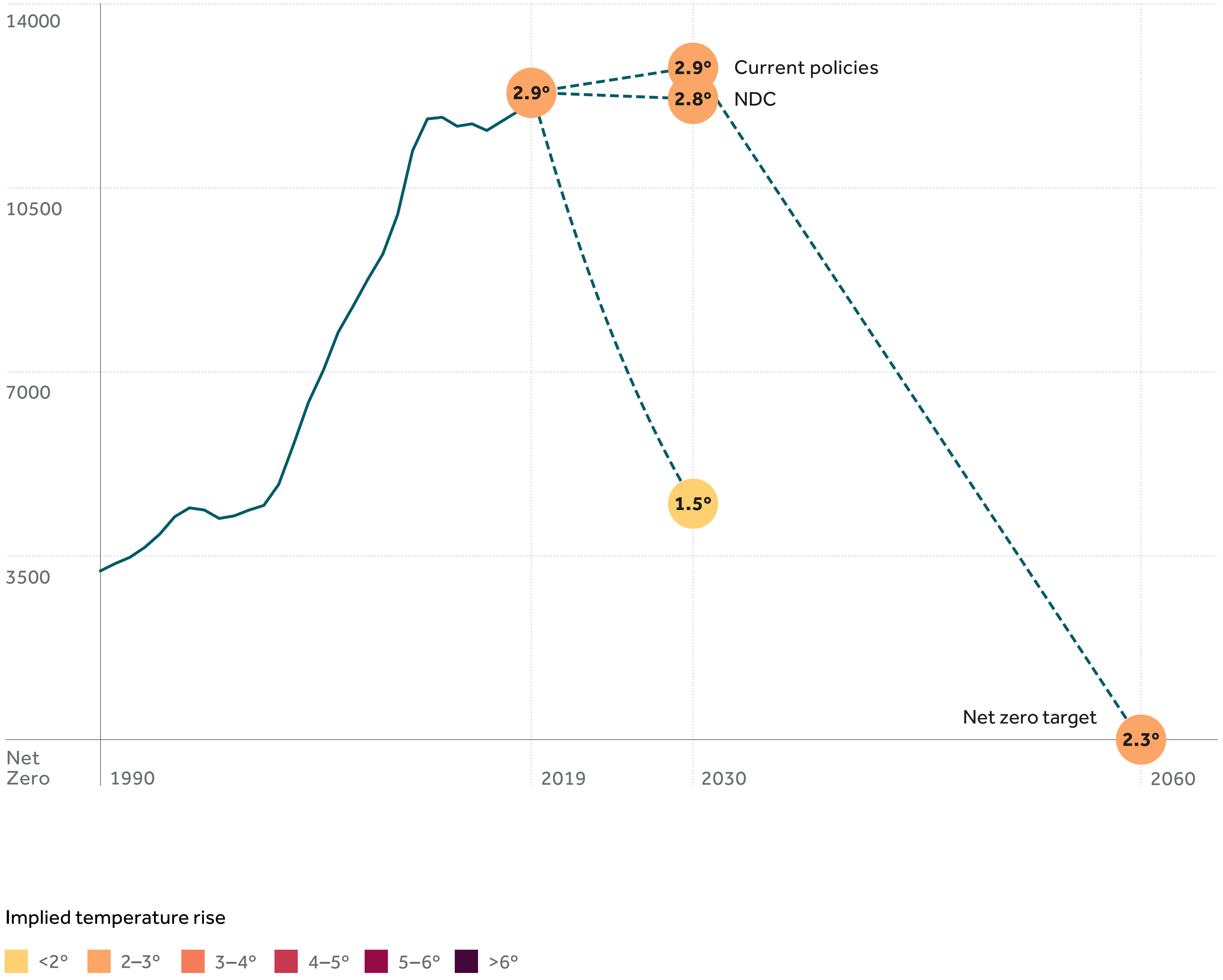
Plan for carbon peaking in the steel sector (2022)[49] The plan targets the peaking of carbon dioxide emissions from the steel sector in 2030.

GDP
US$17,734 billion

Population
1,425 million

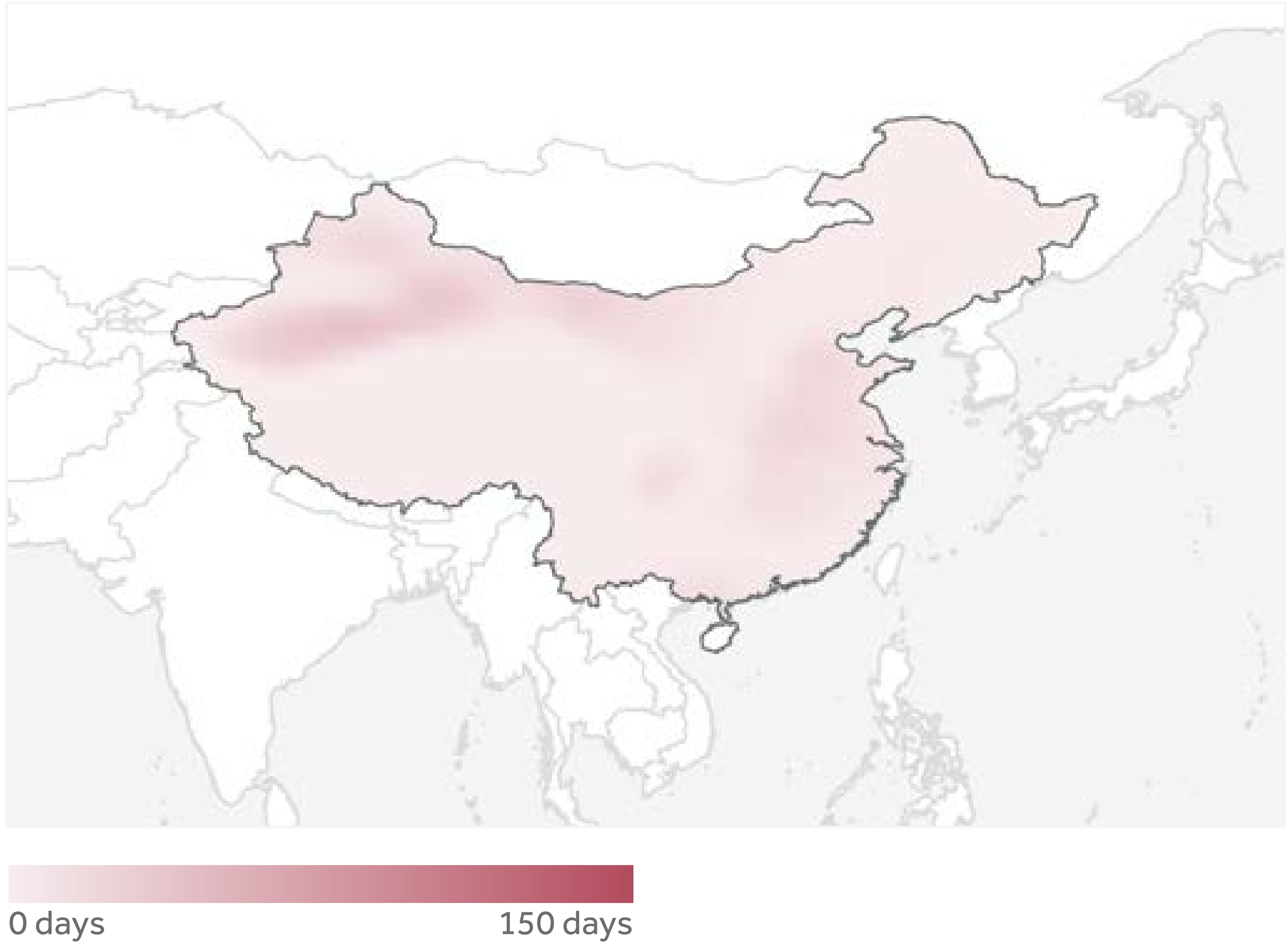
Under China's latest NDC, we estimate greenhouse gas emissions per capita would increase from 8.6 tons of CO_2e in 2019 to 8.7 tons by 2030. Its current policies imply a smaller increase to 8.3 tons over the same period.[45]

GHG Emissions ($MtCO_2e$)



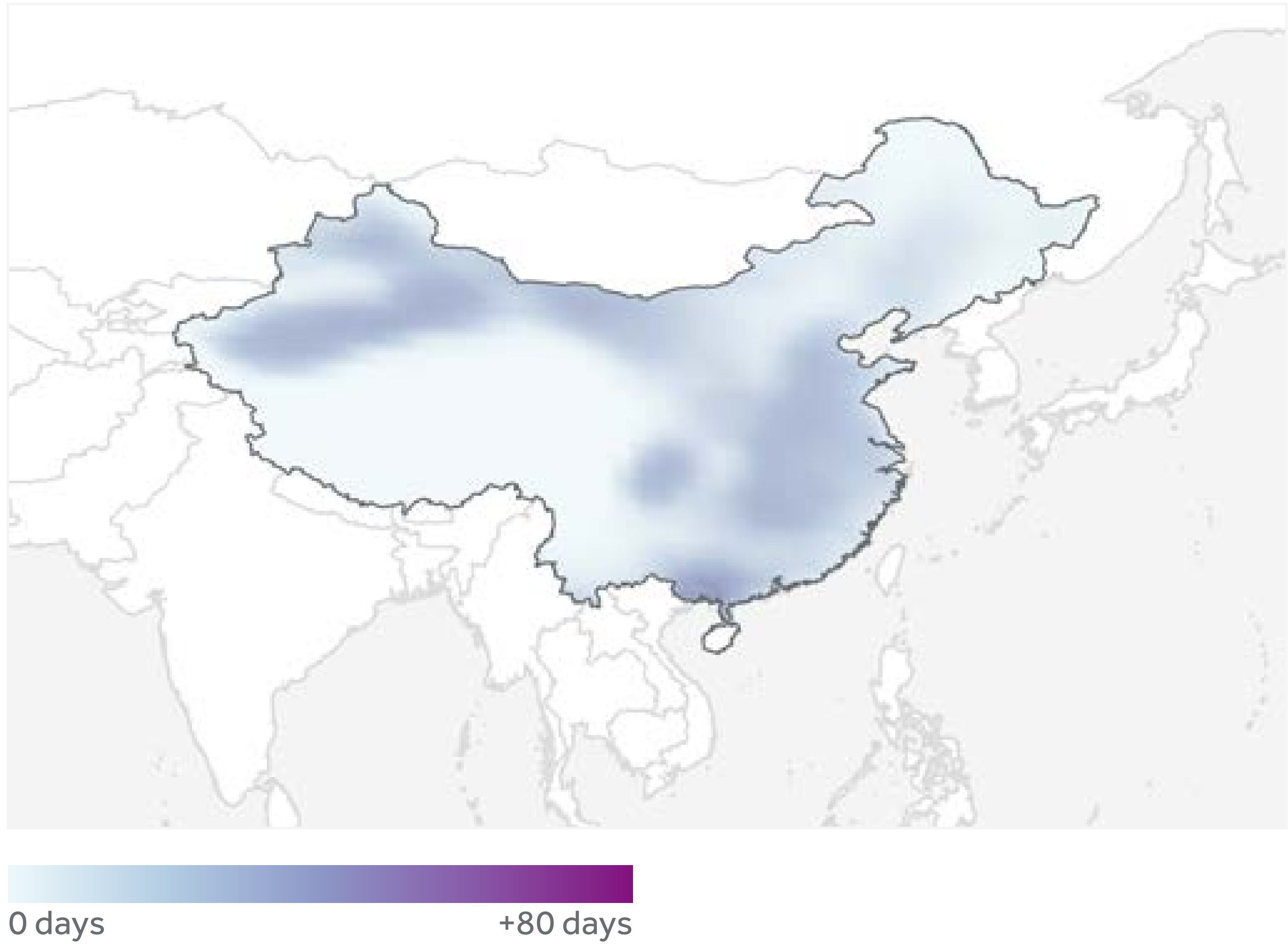
China

Historical exposure to heatwaves



Frequency of days above 35°C, based on global climate projections from the CMIP6 initiative.

Projected change in exposure to heatwaves by 2050



Recent events

The summer 2022 heatwave and drought
In 2022, nearly half of China was hit for more than two months by its worst heatwave in decades, affecting at least 900 million people. Simultaneously, severe drought reduced water levels in river basins and lakes to record lows. This caused the closing of shipping routes and blackouts due to reductions in hydropower production, impacting industrial production. China's Ministry of Energy Management estimated that the drought alone caused losses of RMB ¥2.73 billion (US $390 million).

2050 projections

Change in average temperature
+2.4°C

Change in precipitation
+1.0%

Change in water stress
+24%

Summary of physical risk exposure

China is the second largest country in the world and is therefore home to a large variety of climate conditions, from the temperate north to the subtropical south, strongly influenced by monsoons. This exposes China to the full range of physical risks.

Temperature averages and extremes are both expected to increase more rapidly than the global average, reaching up to +2.4°C by 2050. Warmer temperatures and associated heatwaves will reduce labor productivity and have significant negative health consequences, especially in China's nine megacities, which have over 10 million people each.

More frequent droughts are expected in the western and central regions, affecting agricultural production. In some provinces, the decrease in crop yield has already been estimated at 15% over the last decade, and this trend is expected to continue.[50] Potential crop failure in China will impact global food security, as the country is one of the world's largest breadbaskets.

Existing high flood risk – often triggered by the East Asian monsoon season – will increase further with higher intensity of rainfall events. Urbanization rates have tripled in the last 40 years,[51] making cities increasingly vulnerable to flash flooding, as urban surfaces prevent water infiltration. In urbanized coastal areas, rising sea levels are an additional contributor to this risk, with over 500 million coastal residents currently threatened.

While uncertainties remain, the intensity of tropical cyclones is generally expected to increase with higher sea temperatures and a warmer atmosphere. Western coastal regions (including Shanghai's 25 million inhabitants) are exposed to such events that can lead to devastating storm surges.

France

France's 2050 net zero target[52] is Paris-aligned. We estimate that its latest 2030 NDC[53] target and current policies broadly align with this trajectory.

Key climate-related policies

As an EU member state (see EU ambition profile) Relevant policies include the 'Fit for 55' package (2022), the European Green Deal (2019) and the EU Farm to Fork Strategy (2019).

'France Relance' plan[55] Plan which allocates 30 billion euros of public funds to building energy retrofitting, transport infrastructure and investment in low carbon innovation.

France's 2020 National Low-Carbon Strategy and Multiannual Energy Plan[56] The plan aims to phase out coal by 2022, reduce emissions from power generation by 33% before 2030 (compared to 2015), reduce energy consumption from the building sector by 28% in 2030 (compared to 2010) and achieve carbon neutrality for buildings by 2050 supported by mandatory building codes.

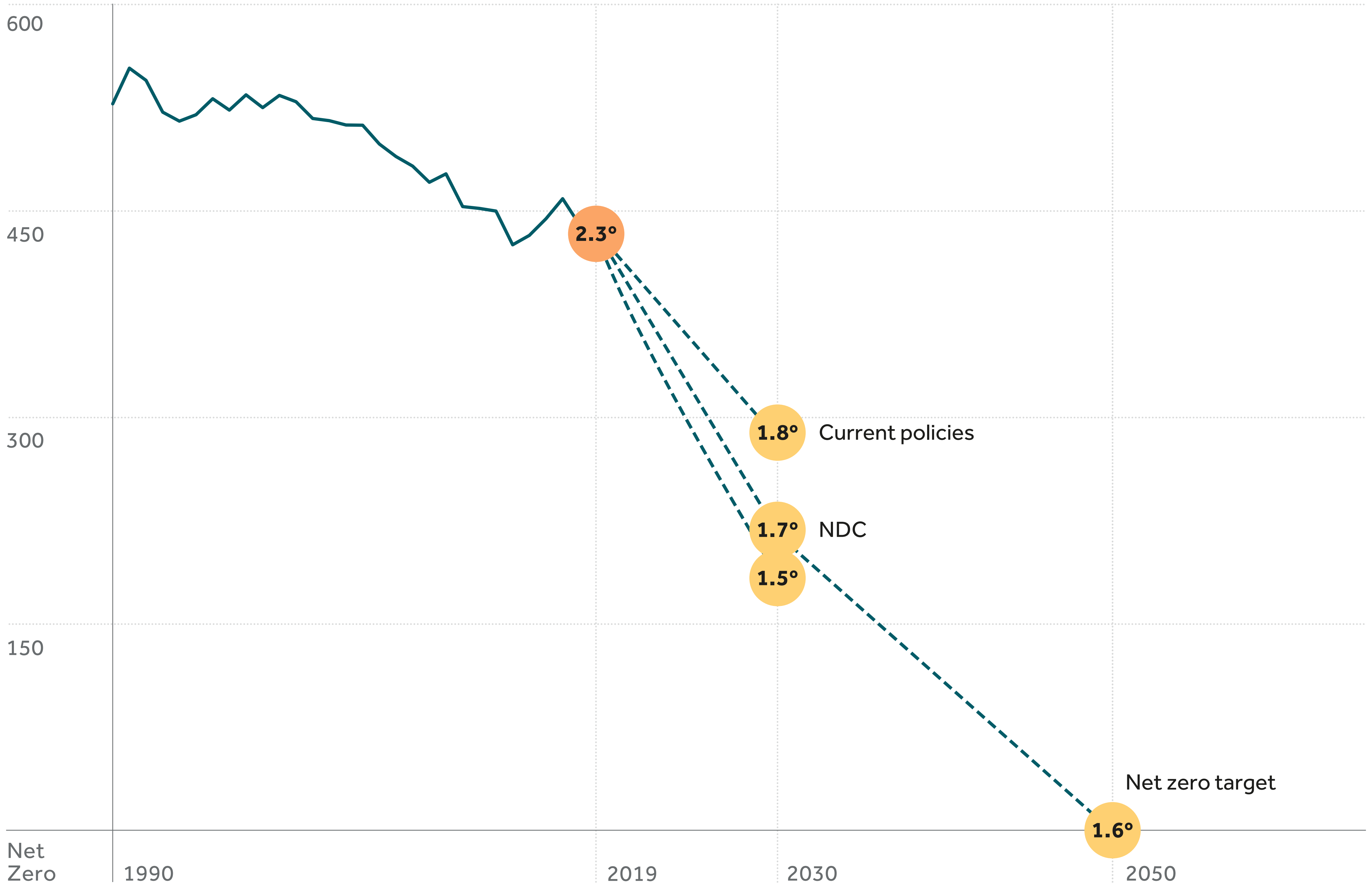
Carbon tax on energy products (2018)[57] The carbon tax was initially set at EUR €7/tCO_2 in 2014 and was intended to rise to EUR €100/tCO_2 by 2030. Since 2018 it has been frozen at EUR €44.6/tCO_2.

GDP
US$2,937 billion

Population
64 million

Under France's latest NDC, we estimate greenhouse gas emissions per capita would fall from 6.7 tons of CO_2e in 2019 to 3.2 tons by 2030.[54] Its current policies imply a reduction to 4.3 tons over the same period.

GHG Emissions ($MtCO_2e$)



Implied temperature rise

<2° | 2–3° | 3–4° | 4–5° | 5–6° | >6°

France

Historical drought

150 days — 300 days

Frequency of dry days based on global climate projections from the CMIP6 initiative.

Projected change in drought by 2050

0 days — +25 days

Recent events

The summer 2003 heatwave
The 2003 European heatwave particularly affected France, with an estimated 14,000 casualties (20% of the Europe-wide total), particularly among the elderly, caused by high temperatures that exceeded 40°C for 8 days in the north,[61] where most people are not used to extreme temperatures.

2050 projections

Change in average temperature
+1.8°C

Change in precipitation
-0.4%

Change in water stress
+12%

Summary of physical risk exposure

Despite having a temperate climate, France's diverse geography makes it prone to a large range of hazards, from Atlantic winter storms and floods to heatwaves and droughts.

Heatwaves are expected to become at least twice as frequent by 2050.[58] Coupled with increased incidence of drought, these changes significantly threaten France's agricultural production, including key products such as wine, champagne and cheese, and status as major tourist destination, particularly in the southwest.

Homes and infrastructure are already being damaged, with wildfire risks spreading in many regions and expected to triple by 2050. Shrinkage and swelling of soils, currently causing almost as much damage as flooding, is becoming more prevalent, with 10 million houses[59] already exposed and damages expected to increase with more frequent droughts.

Intensifying heatwaves[60] will also cause significant health impacts in large and densely populated cities and particularly in the Paris region, home to almost 20% of the French population.

Germany

Germany's 2045 net zero target[62] as well as its latest 2030 NDC[63] are Paris-aligned. However, we estimate its current policies to align with a 2°C+ trajectory.

GDP
US$4,223 billion

Population
83 million

Under Germany's latest NDC, we estimate greenhouse gas emissions per capita would fall from 9.5 tons of CO_2e in 2019 to 4.4 tons by 2030.[64] Its current policies imply a reduction to 6.8 tons over the same period.

Key climate-related policies

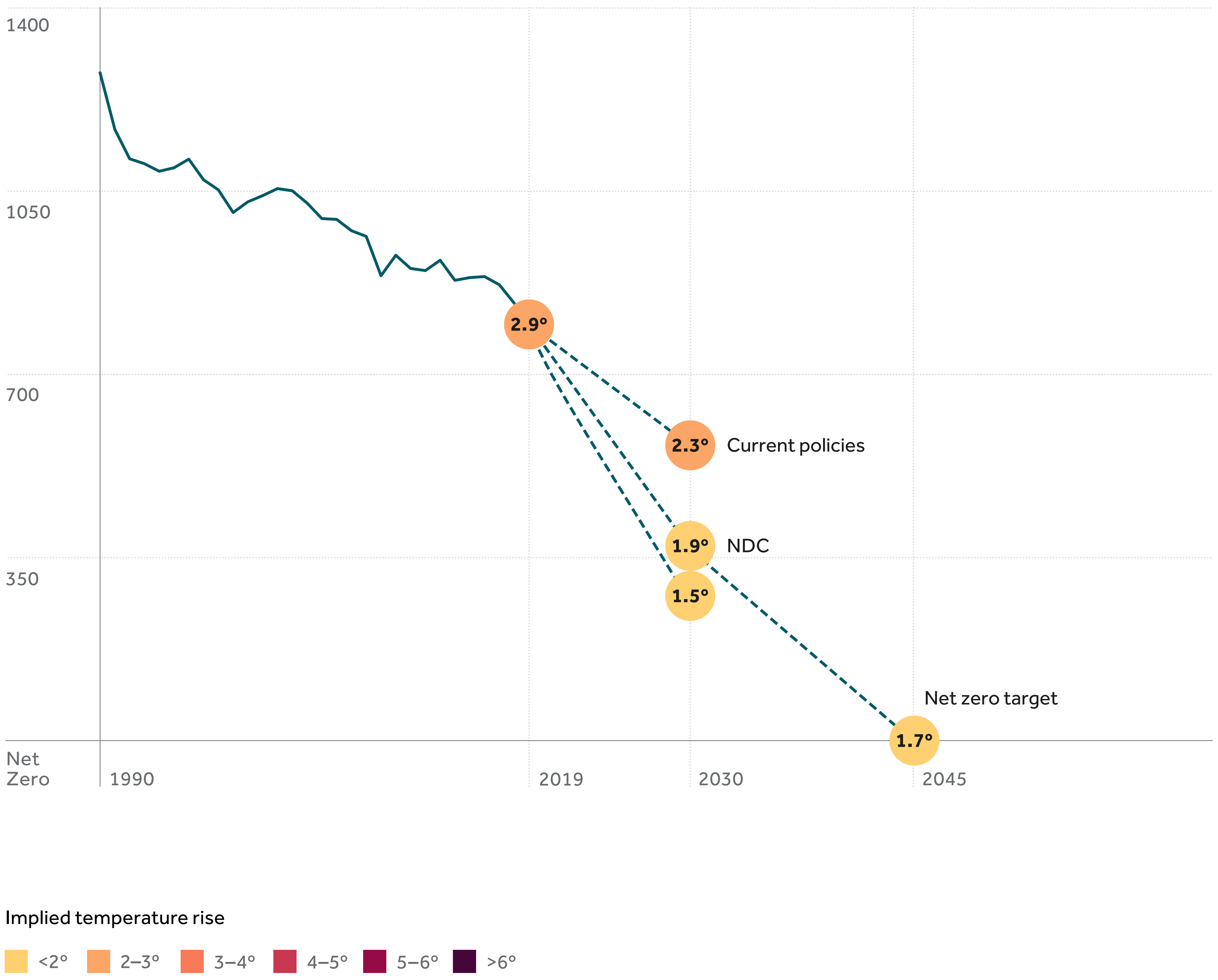
As an EU member state (see EU ambition profile) Relevant policies include the 'Fit for 55' package (2022), the European Green Deal (2019) and the EU Farm to Fork Strategy (2019).

National Energy and Climate Plan (NECP)[65] The plan is targeting 30% of gross final energy consumption to come from renewables by 2030, and a gradual phase-out of coal-fired power generation by 2038 at the latest.

Energy Efficiency Strategy 2050[66] Aims at a 30% reduction in primary energy consumption by 2030 (vs. 2008) and includes policies such as carbon pricing in the heating and transport sector, and an energy efficiency strategy for buildings.

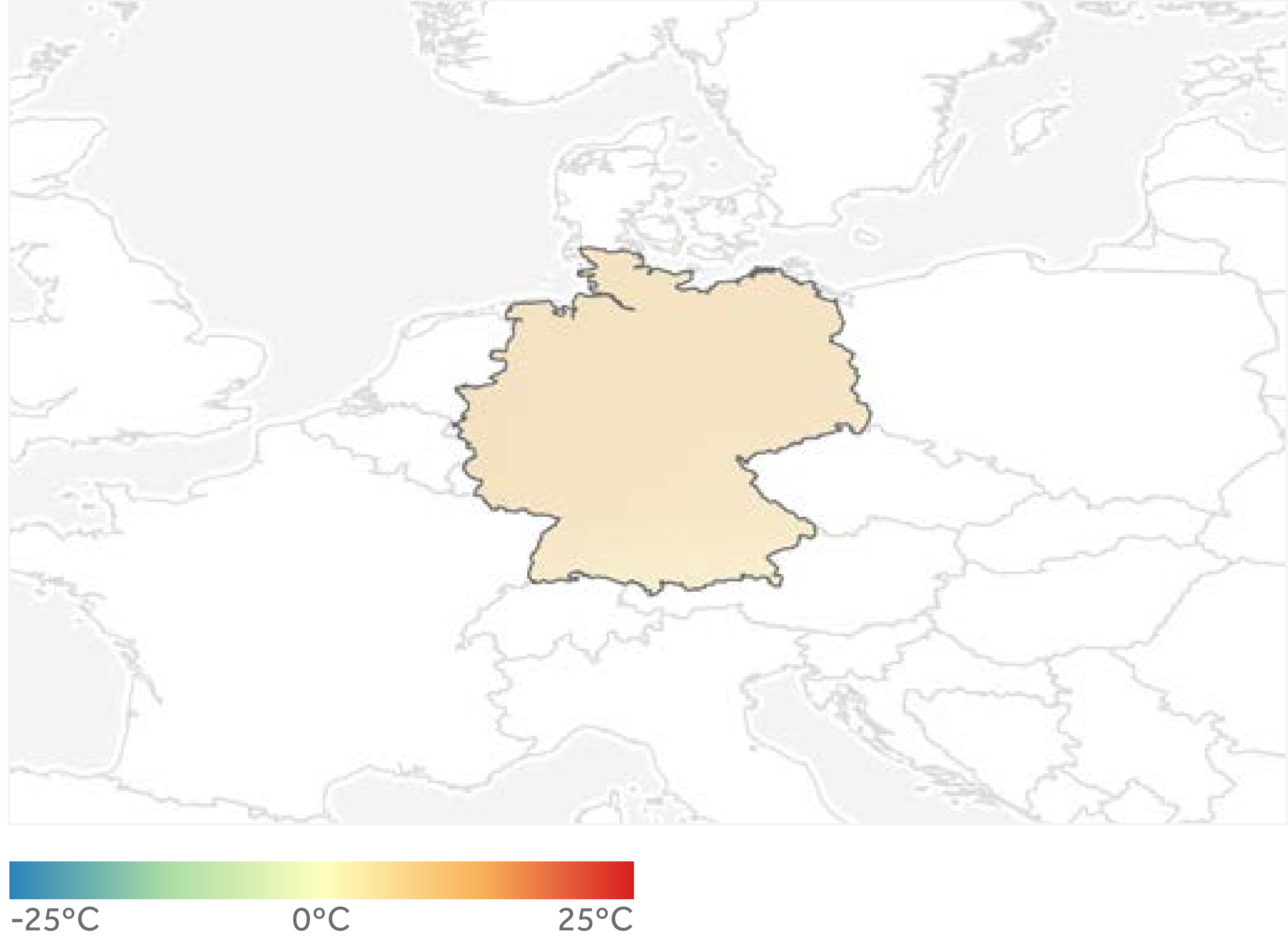
German Fertilizer Ordinance (2017)[67] Targets the reduction of nitrogen surpluses. This includes reducing ammonia emissions from agriculture, targeting a decrease in nitrous oxide emissions, improving nitrogen efficiency and expanding support for organic farming.

GHG Emissions ($MtCO_2e$)



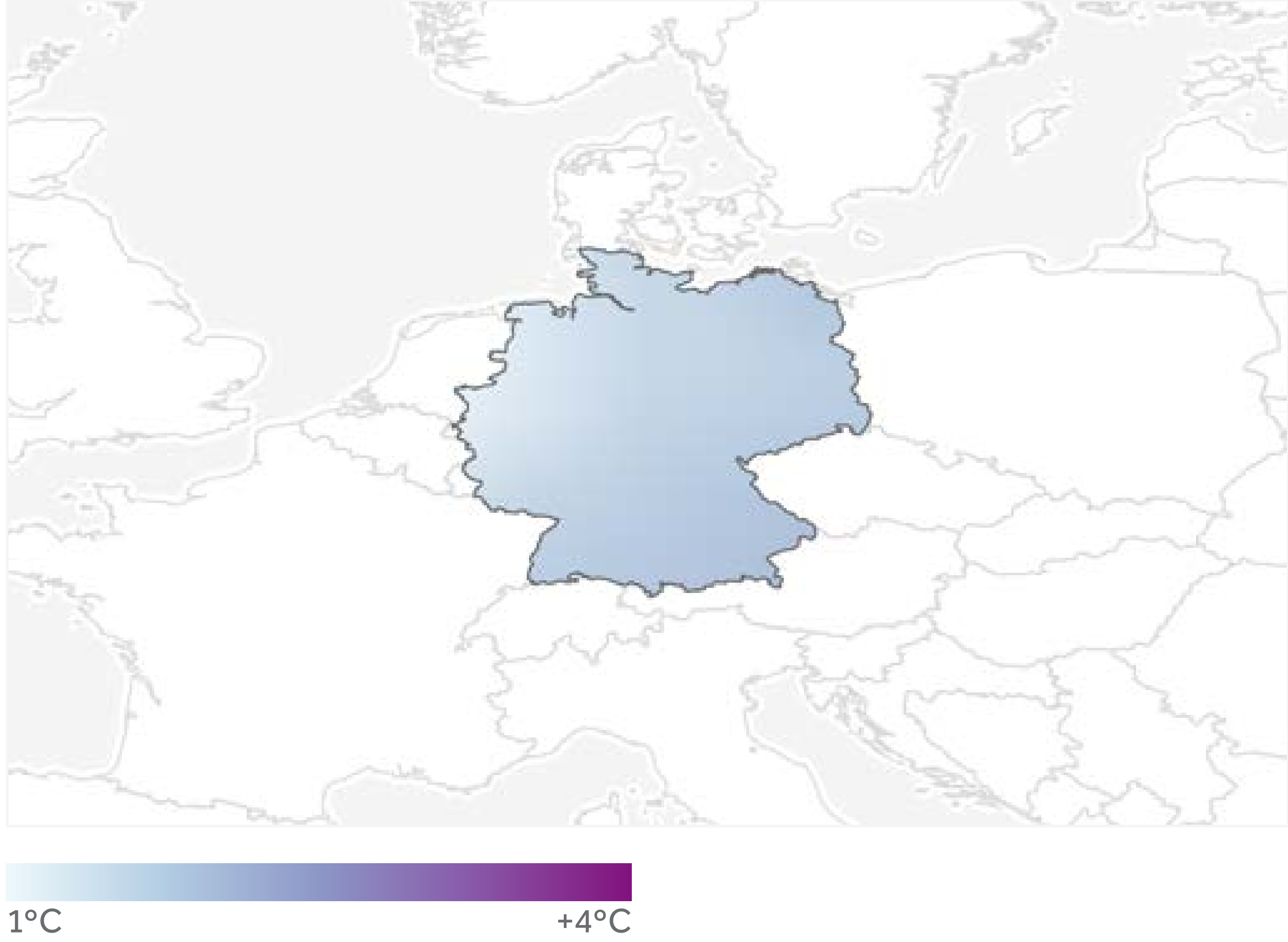
Germany

Historical average temperature



Average annual temperature based on global climate projections from the CMIP6 initiative.

Projected change in average temperature by 2050



Summary of physical risk exposure

Germany has a temperate climate with abundant precipitation. Already at risk from flooding events, especially in the west, the country will face increasing water-related challenges in the future.

Flood risks are expected to increase, due to more frequent and more intense precipitation events. Large-scale riverine floods will become more likely, with an up to five times larger share of Germany's population exposed to riverine floods by 2050[68] and the potential to disrupt and damage critical assets for the German industrial sectors, which represents 29% of Germany's GDP.

The northern coast of Germany is also exposed to rising sea levels, where increased coastal events threaten to damage property and infrastructure. Hamburg is particularly vulnerable, with an estimated 20% of its 2.5 million population at risk of long-term displacement.[69]

Although water stress may ease by up to 40% in the coming decades due to increased precipitation, severe summer droughts and subsequent disruption to economically important fluvial transport remain a threat, as seen in the Rhine Valley in 2018. Shrinking Alpine glaciers due to warming temperatures will further reduce river flows, with potential negative impacts on German agriculture and energy production.

Although exposure to heatwaves is expected to increase to a lesser extent than for many other G20 members, Germany's population is particularly vulnerable to strong heat episodes, given the country has the second highest median age globally.

Recent events

The summer 2021 floods

During the summer of 2021, Germany was affected by its most severe flood event in 100 years, due to intense rainfall turning streams into torrential currents. Flash floods led to more than 200 casualties and damage estimated at around US $40 billion.[70] Such events will become more likely in the future, as a warmer climate enables air to retain more moisture and thus produce more intense precipitation.

2050 projections

Change in average temperature
+1.8°C

Change in precipitation
-0.1%

Change in water stress
-6%

India

Due to low per capita emissions and a large carbon budget, we estimate that India's latest 2030 NDC[71], net zero target[72] and current policies are Paris-aligned.

GDP
US$3,173 billion

Population
1,417 million

Under India's latest NDC, we estimate greenhouse gas emissions per capita would rise from 2.1 tons of CO_2e in 2019 to 2.6 tons by 2030. Its current policies imply a slightly larger rise to 2.4 tons over the same period.[73]

Key climate-related policies

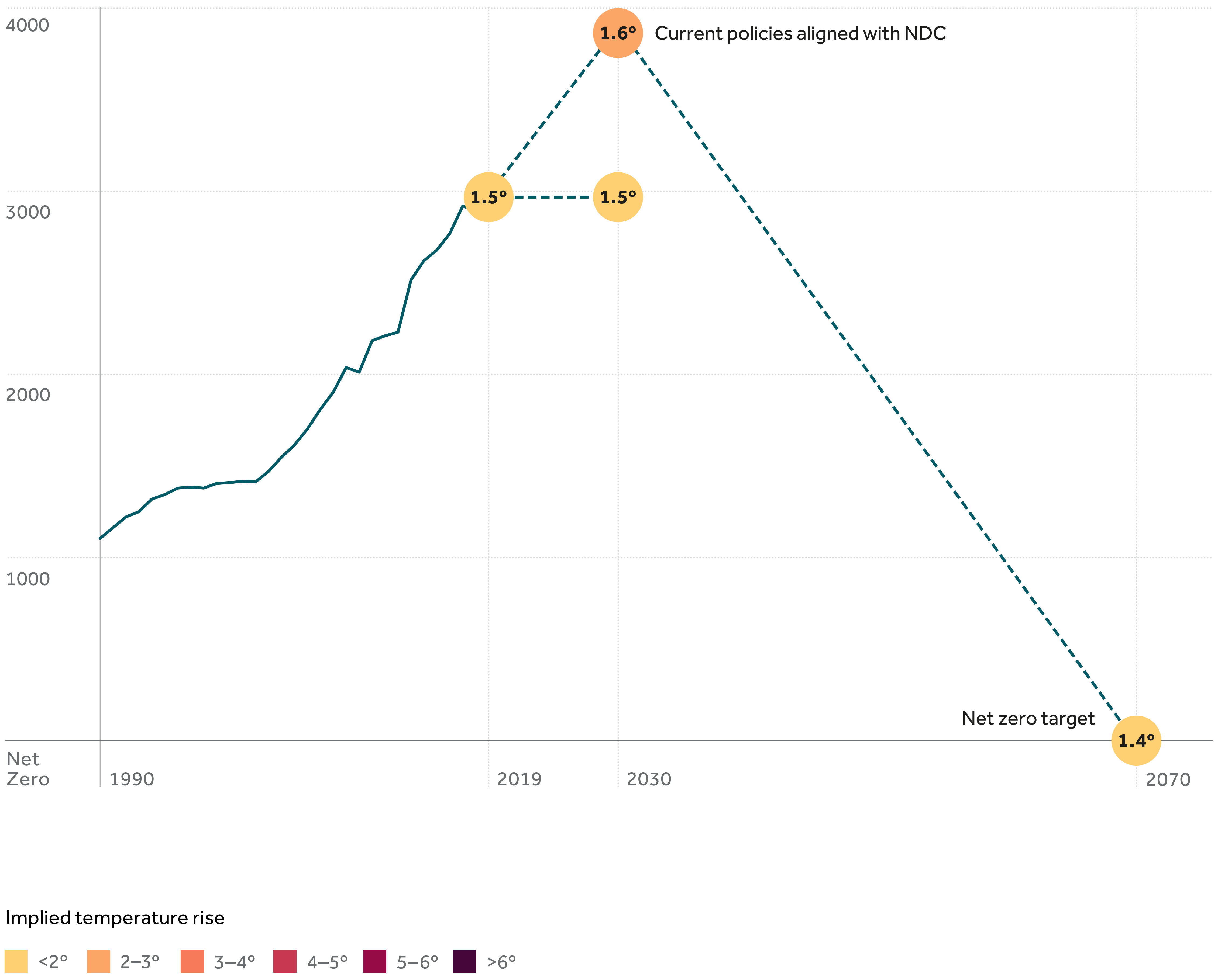
Clean energy cess (coal tax) (2010)[74] Currently a tax of US $ 3.2/tCO_2 is imposed on coal, lignite, and peat.

National Electricity Plan (2018)[75] The plan targets demand reductions and presents capacity additions for various energy technologies, including a slowdown in the installation of new coal fired power plants. It covers two five-year periods: 2017-2022 and 2022-2027.

Energy efficiency in industry (PAT scheme) (2011)[76] The main instrument to increase energy efficiency in industry is the Perform, Achieve and Trade (PAT) mechanism, which is implemented under the 'National Mission on Enhanced Energy Efficiency'. PAT resembles an emissions trading scheme (ETS).

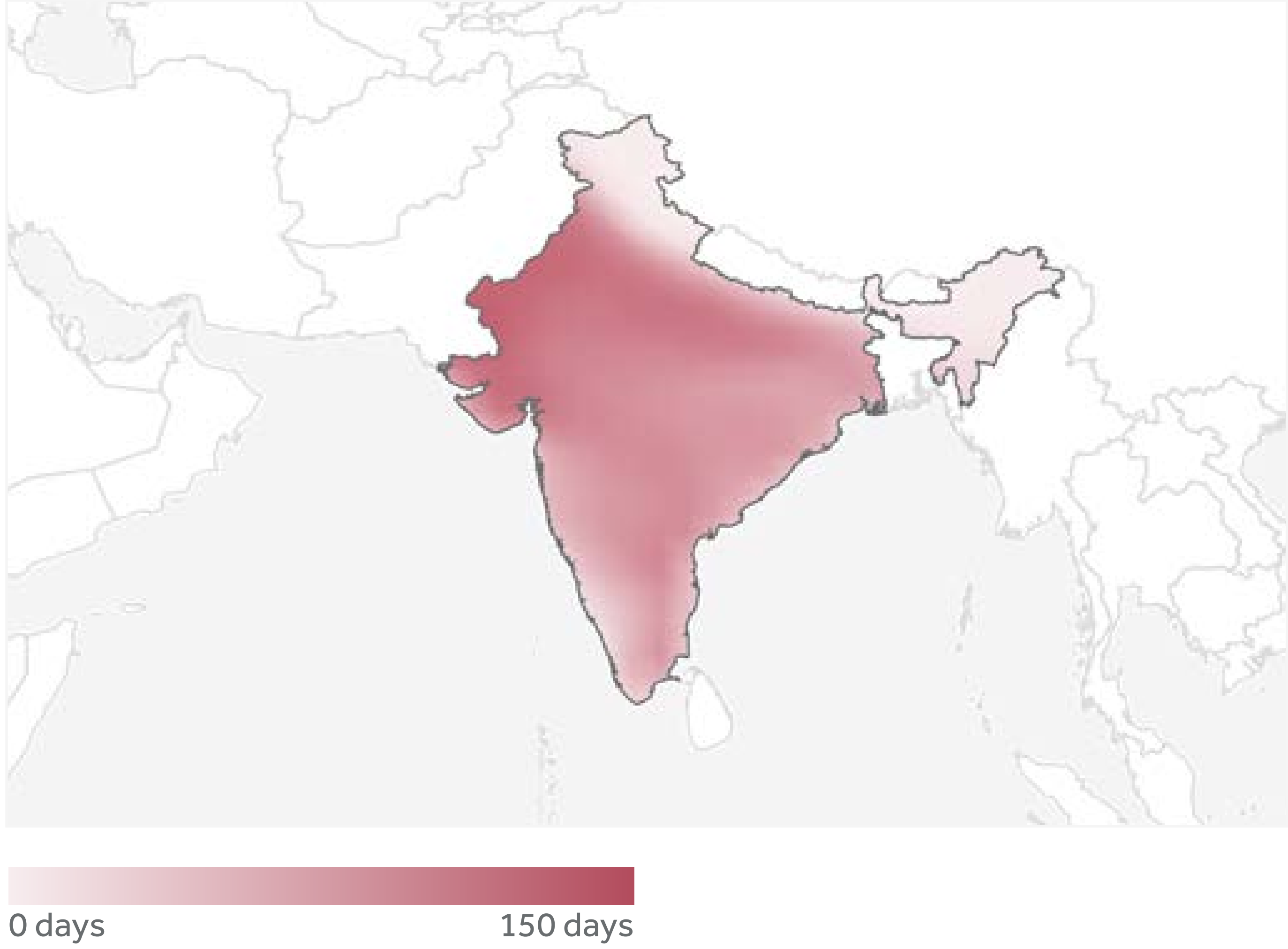
Scheme for Faster Adoption and Manufacturing of Hybrid and EV (FAME) (2019)[77] This is the second phase of the FAME scheme, which provides subsidies for the purchase of electric two-, three-wheelers, hybrid and electric cars and buses.

GHG Emissions ($MtCO_2e$)



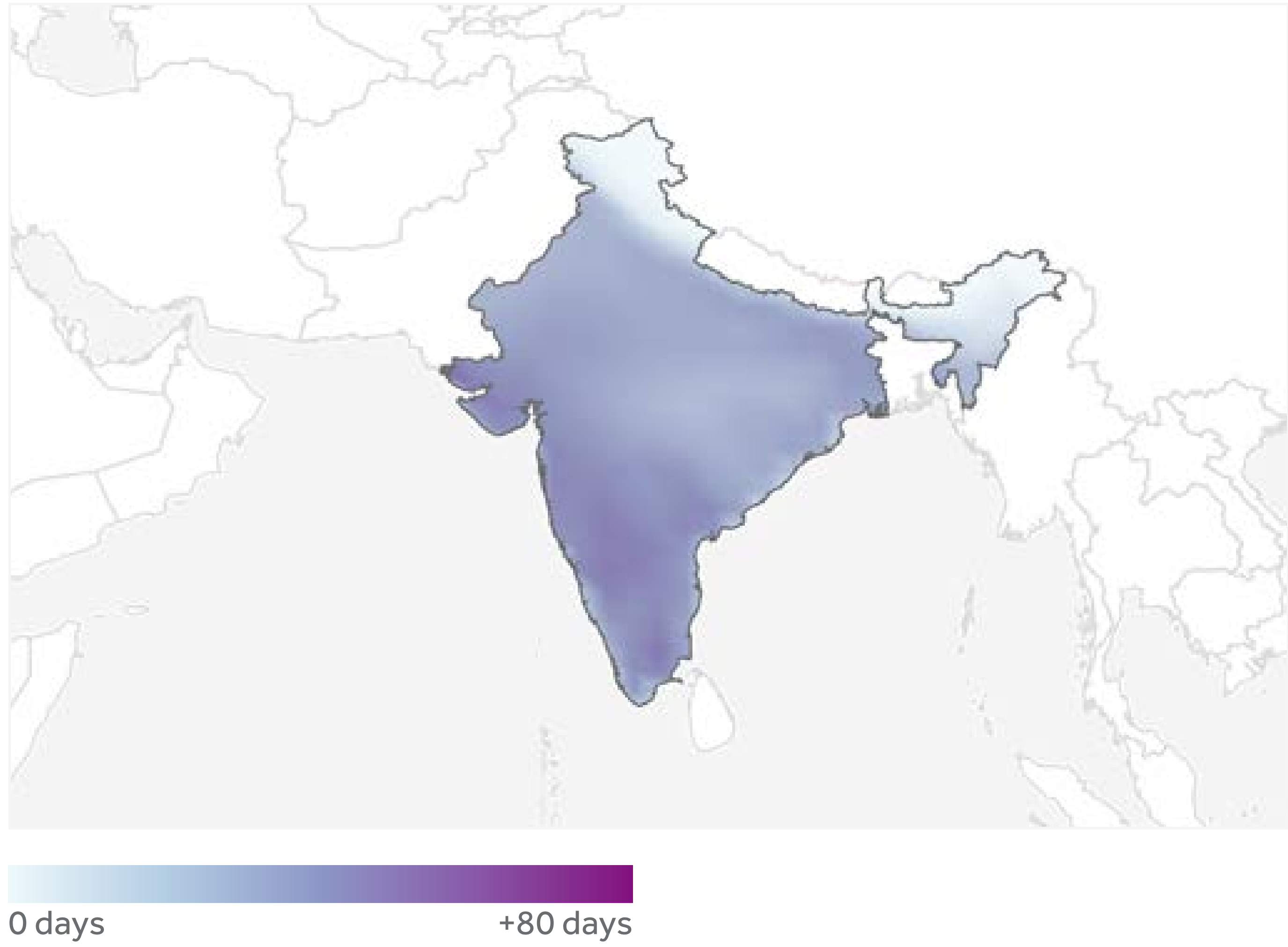
India

Historical exposure to heatwaves



Frequency of days above 35°C, based on global climate projections from the CMIP6 initiative.

Projected change in exposure to heatwaves by 2050



Recent events

The 2022 heatwave and drought
Since in March 2022, north-west India has experienced its worst heatwave in at least 120 years,[80] raising questions on whether some areas will remain habitable in the long term. In addition to heat-related labor productivity loss, hospitalizations and deaths, high energy demand for cooling has led to a major electricity shortage. A simultaneous drought due to 70% less rainfall than the monthly average accentuated the impact on agriculture, particularly on wheat production.

2050 projections

Change in average temperature
+1.8°C

Change in precipitation
+1.0%

Change in water stress
+32%

Summary of physical risk exposure

India's mainly tropical climate is strongly influenced by the monsoon season, with heavy rains and high temperatures between May and September. The northeastern part of the country has among the highest precipitation rates in the world. High poverty rates, population densities, and temperatures make India one of most vulnerable G20 countries to climate change.

India regularly experiences some of the world's highest temperatures, and heatwaves are expected to increase in magnitude and frequency, with several weeks of very hot days (35°C or more) expected each year by 2050. Recurrent episodes of potentially lethal temperatures will become very likely by 2050 in the northwest, putting 310–480 million people at risk. Heat could also significantly impact labor productivity, with some studies projecting a decrease by 10–40% by 2050.[78]

India is very exposed to floods due to intense precipitation during the summer monsoons and tropical cyclones on the coast, with on average circa five million people exposed to floods each year, already by far the highest number in the planet.[79] Flood-related damages could rise exponentially through a combination of increasingly intense monsoon precipitation events as well as rapid economic development.

Despite strong rainfall during the monsoon season, India is also increasingly at risk of drought and water scarcity. India has one of the highest water stress levels among the G20 and is largely dependent on Himalayan glaciers for freshwater supply. Warmer temperatures and the gradual retreat of glaciers will reduce the amount of freshwater available over the years. Among G20 countries, India's high agriculture share of GDP (20%) makes it particularly vulnerable to the impact of heat and drought on crop yields.

Indonesia

Indonesia's 2060 net zero target[81] is Paris-aligned. We estimate its latest 2030 NDC[82] and current policies to align with a 2°C+ trajectory.

Key climate-related policies

Electricity Supply Business Plan (RUPTL 2019–2028)[83] The plan aims to add new renewable electricity capacity between 2019 and 2028: 6,061 MW of hydropower, 4,607 MW of geothermal, 3,483 MW of solar and 2,563 MW of wind.

National Energy Policy (2014)[84] Aims to increase the share of new and renewable energy (including nuclear) to 23% of total primary energy supply by 2025.

New Carbon Law (2021)[85] Indonesia's sweeping new carbon regulations introduce a general carbon tax policy, a general carbon economic value, sector-based emission caps, and a carbon trading framework.

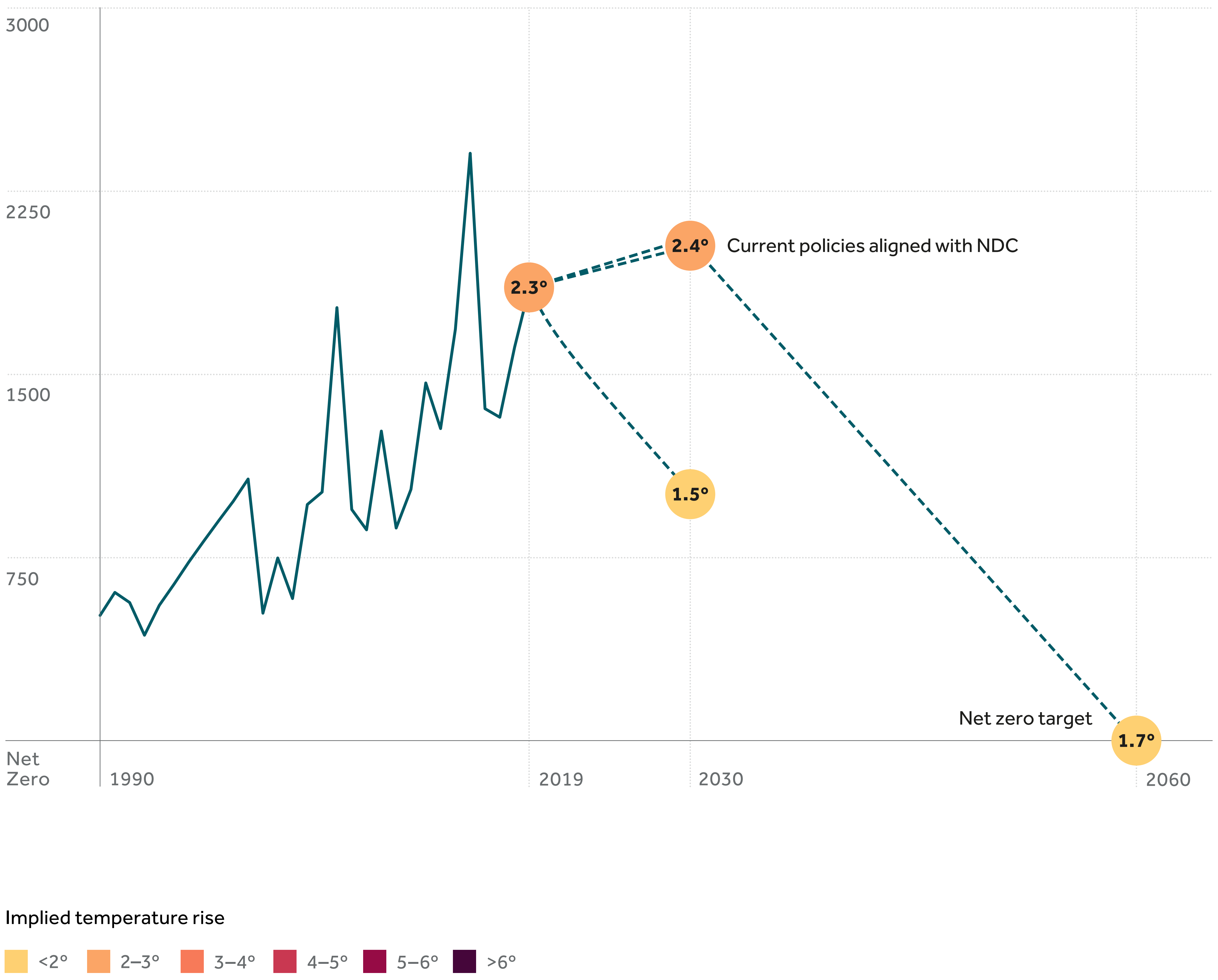
Indonesia's FOLU Net Sink 2030 (2022)[86] The plan is a 60% reduction in national Greenhouse Gas (GHG) emissions through GHG reduction in the forestry and other land use sectors.

GDP
US$1,186 billion

Population
275 million

Under Indonesia's latest NDC, we estimate greenhouse gas emissions per capita would fall from 6.9 tons of CO_2e in 2019 to 6.8 tons by 2030. Its current policies imply a stable level of 6.9 tons over the same period.

GHG Emissions ($MtCO_2e$)

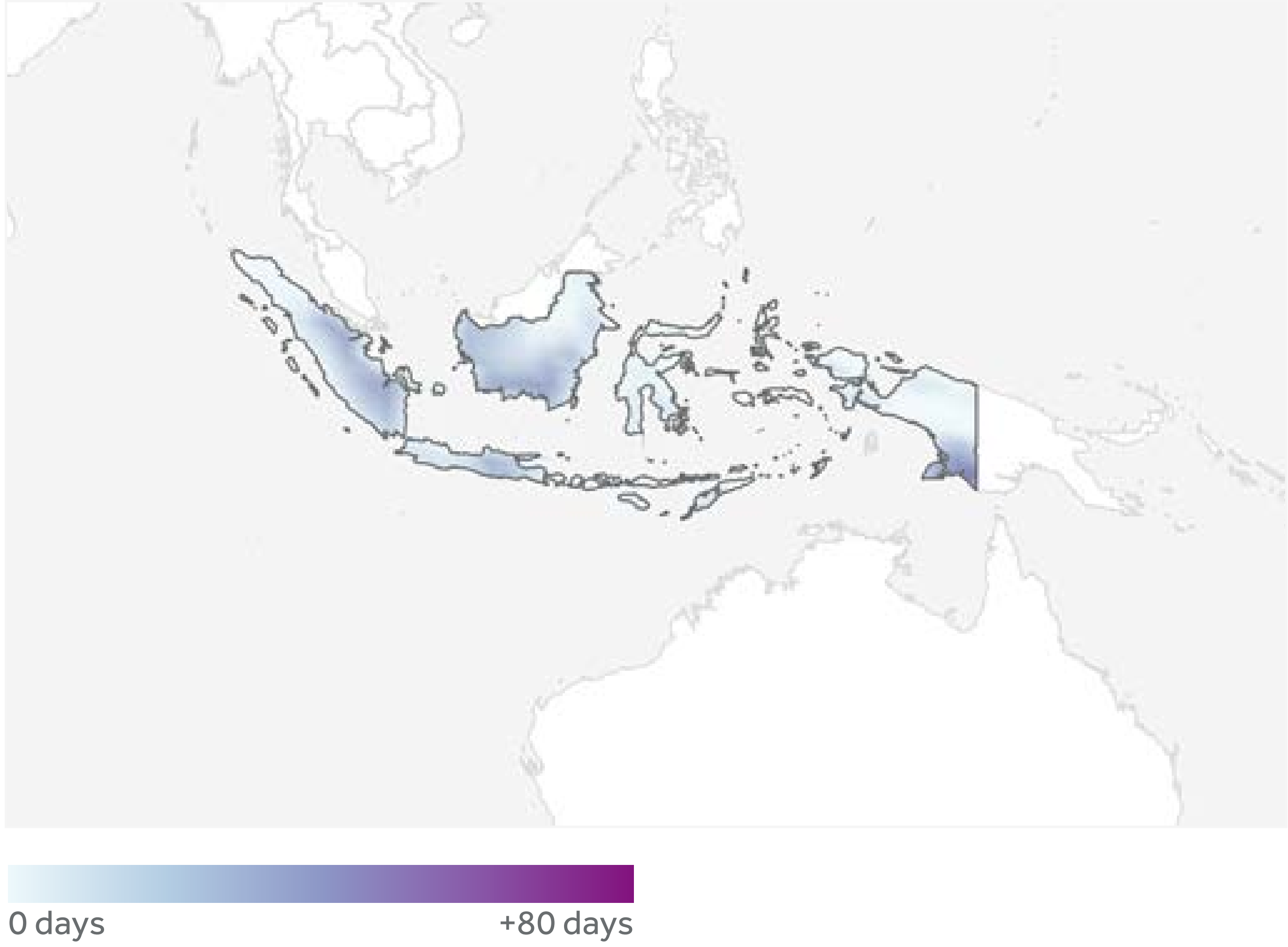


Indonesia

Historical exposure to heatwaves

Frequency of days above 35°C, based on global climate projections from the CMIP6 initiative.

Projected change in exposure to heatwaves by 2050



Summary of physical risk exposure

Indonesia's tropical climate is characterized by high rainfall and stable temperatures throughout the year. Changes in precipitation patterns and sea-level rise are the biggest threats for the island nation.

Floods are the main natural hazard in Indonesia. More frequent high rainfall events and more intense storms will increase the risks of inland flooding, while threats from sea-level rise are more pronounced for Indonesia than for many other G20 countries given 42 million people today are already living 10 meters or more below sea level.[87] The capital Jakarta is particularly at risk, as the region is sinking rapidly and, by 2050, its northern part could be submerged. Tourism, highly concentrated on shorelines and small islands, could also be severely impacted by accelerated coastal erosion and the loss of beaches.

A combination of warmer temperatures, enhanced evapotranspiration and changes in precipitation patterns, could severely impact Indonesia's agricultural output, which represents 13% of its GDP. One study estimated the impacts could be around US $7 billion per year, mainly driven by strong decreases in rice yields.[88]

Warmer temperatures also increase the risk of tropical diseases such as malaria and dengue fever. By 2050, this could cost around US $450 million, with 40% arising in the Jakarta region alone.[89]

Recent events

The 2021 Seroja tropical cyclone
In April 2021, a tropical cyclone hit a cluster of eastern Indonesian islands with heavy wind and rain causing historic levels of floods and landslides that destroyed thousands of properties and caused significant infrastructure damage. More than 22,000 people were evacuated and at least 200 died during the event. Initial estimates suggested losses of at least US $130 million to the Indonesian economy.[90]

2050 projections

Change in average temperature
+1.6°C

Change in precipitation
+0.1%

Change in water stress
+168%

Italy

Italy's 2050 net zero target[91] is Paris-aligned. While somewhat less ambitious, we estimate its latest 2030 NDC[92] target and current policies are aligned to a below 2.0°C trajectory.

GDP
US$2,100 billion

Population
59 million

Under Italy's latest NDC, we estimate greenhouse gas emissions per capita would fall from 6.2 tons of CO_2e in 2019 to 3.9 tons by 2030. Its current policies imply a fall to 4.5 tons over the same period.[93]

Key climate-related policies

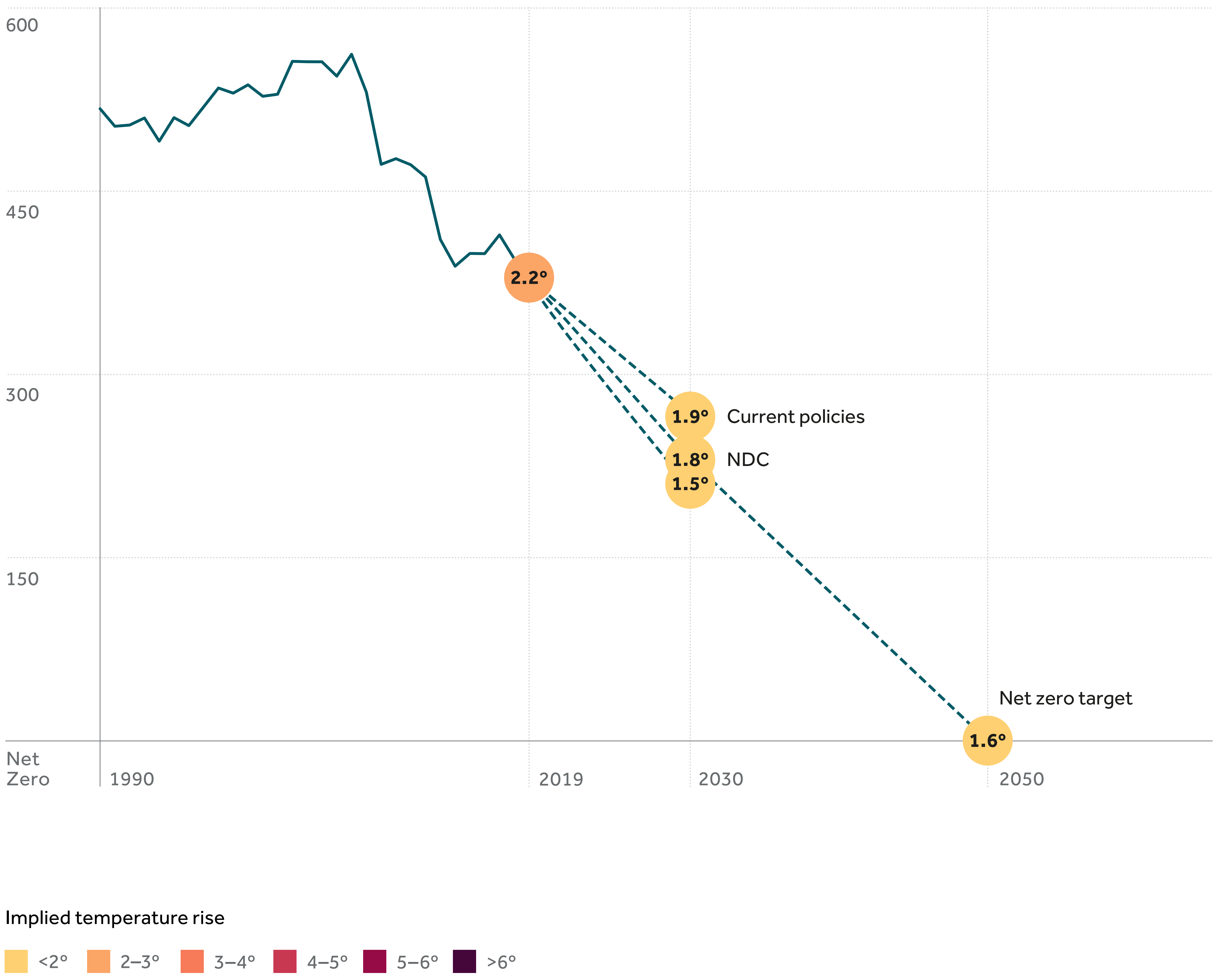
As an EU member state (see EU ambition profile) Relevant policies include the 'Fit for 55' package (2022), the European Green Deal (2019) and the EU Farm to Fork Strategy (2019).

Integrated National Energy and Climate Plan (2019)[94] The plan involves phasing out coal by 2025, with 30% of gross final energy consumption coming from renewables and a 43% reduction in primary energy consumption by 2030.

National Plan for Electric Vehicle Charging Infrastructure (PNIRE — approved in 2012, updated in 2016 and new update ongoing)[95] PNIRE has achieved its objectives to have 19,000 charging stations and 130,000 electric vehicles in circulation by 2020 and EV purchase subsidies have been increased in 2018 to support demand.

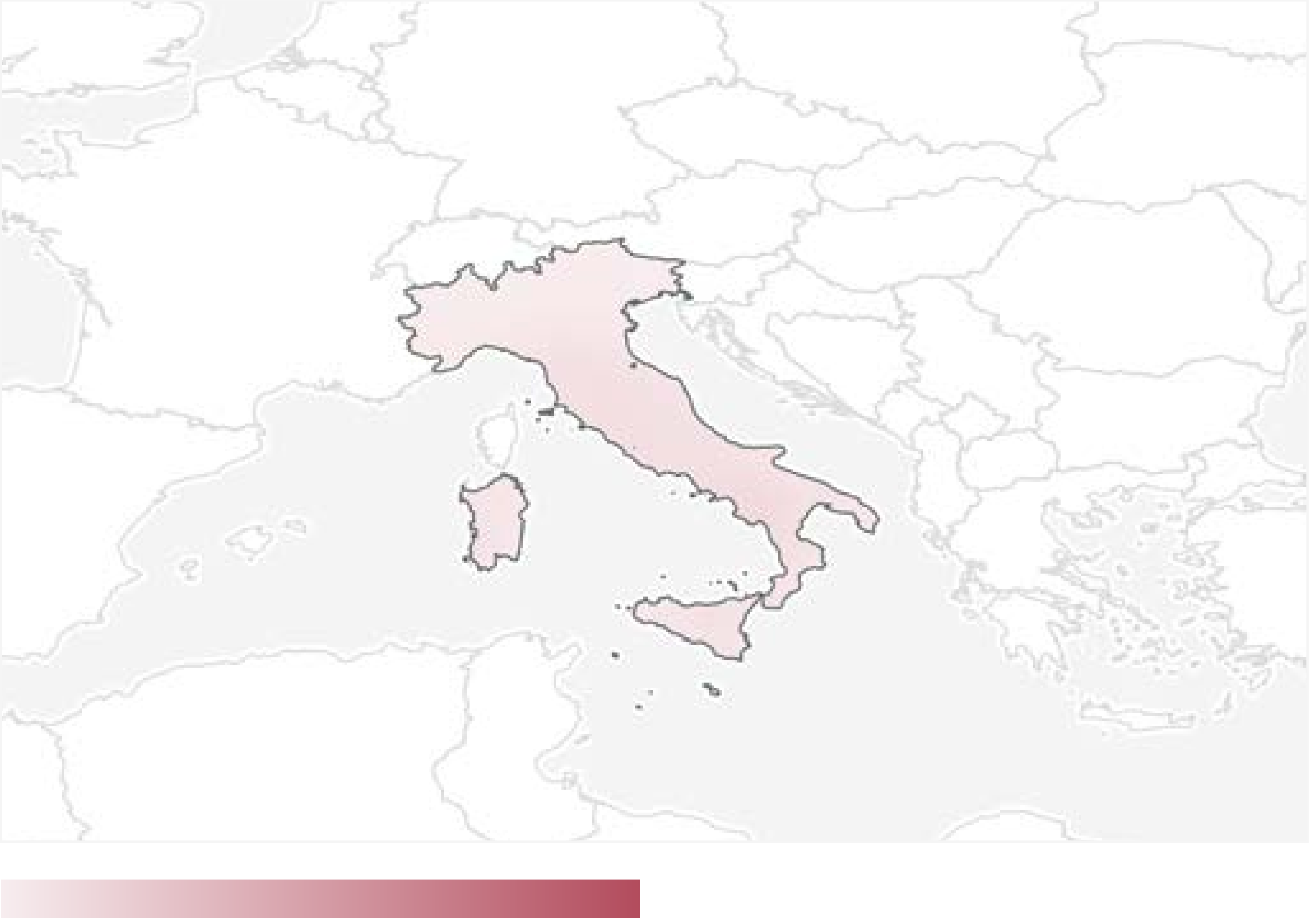
National Energy Efficiency Action Plan (2017)[96] The plan includes a 'white certificates' mechanism, which is designed to encourage energy efficiency gains via tradable certificates, as well as tax deductions for building renovations designed to improve energy efficiency.

GHG Emissions ($MtCO_2e$)



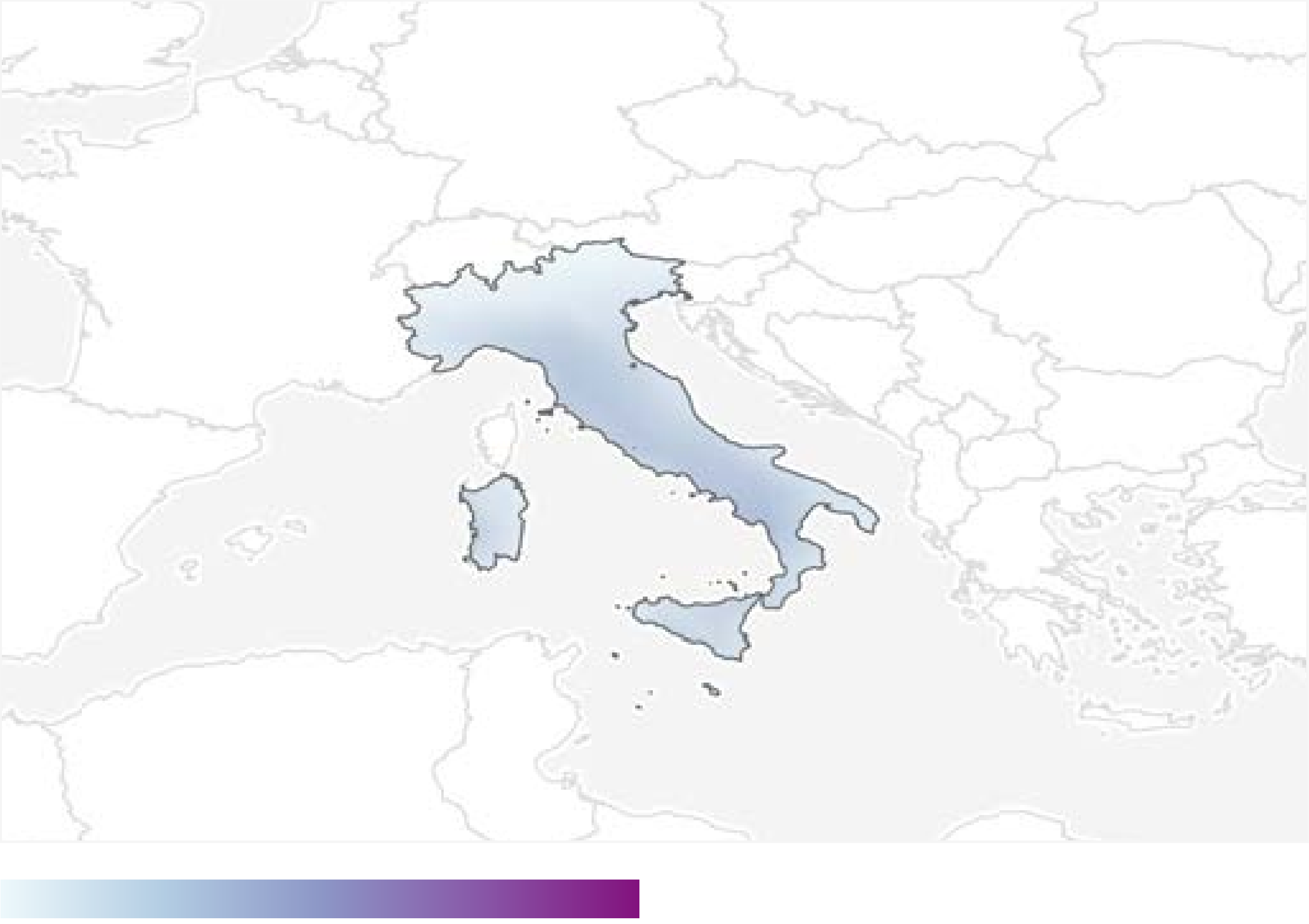
Italy

Historical exposure to heatwaves



Frequency of days above 35°C, based on global climate projections from the CMIP6 initiative.

Projected change in exposure to heatwaves by 2050



Summary of physical risk exposure

Located in the Mediterranean, Italy faces warm and dry conditions, especially in the southern part of the country, with higher rainfall in the Alps in the north, and the Apennines that run along the center of the country.

The frequency of droughts is expected to double by 2050,[97] leading to increased water stress and potential disruption of industrial production in the north. Agriculture may be strongly impacted in the south, which is already experiencing high levels of water stress.

More intense and frequent heatwaves will also impair agricultural yields, especially in the rural south. The strong economic discrepancies between the richer north and poorer south of the country may be further exacerbated by unequal exposures to climate hazards. Heat and recurrent droughts could also impact the tourism sector (representing 10% of Italy's GDP), as restrictions on water use may make the country a less attractive tourism destination. Tropical diseases such as malaria or dengue fever are already on the rise[98] due to warmer temperatures.

Flash floods and riverine inundations are already frequent, especially in the Po valley, where 40% of Italy's economic activities and 30% of its population are clustered.[99] More intense rainfall events are expected, which can trigger landslides in mountainous areas. The estimated cost of landslides and floods is about EUR 1 billion per year,[100] and is expected to continue to increase.

Sea-level rise poses a large threat to infrastructure, increasing the exposure of densely populated areas to coastal flooding, and could be further exacerbated by storms. A study estimated that annual expected damages from coastal floods alone could reach EUR 1.4 billion per year in 2050.[101]

Recent events

The summer 2022 heatwaves
In the summer of 2022, Italy was hit by persistent heatwaves and droughts with temperatures of over 40°C. There were serious health impacts for vulnerable populations as a result, and three times more wildfires than usual. In northeast Italy, a glacier collapsed causing an ice avalanche that killed 11 people. Predictions suggest that 2022 is a snapshot of what the European and Italian climates might look like by the mid-century.

2050 projections

Change in average temperature
+2.2°C

Change in precipitation
-1.2%

Change in water stress
+48%

Japan

Japan's 2050 net zero target[102] is Paris-aligned. However, we estimate its latest 2030 NDC[103] and current policies to align with a 2.0°C–3.0°C trajectory.

GDP
US$4,937 billion

Population
123 million

Under Japan's latest NDC, we estimate greenhouse gas emissions per capita would fall from 9.1 tons of CO_2e in 2019 to 6.3 tons by 2030. Its current policies imply a reduction to 7.9 tons over the same period.[104]

Key climate-related policies

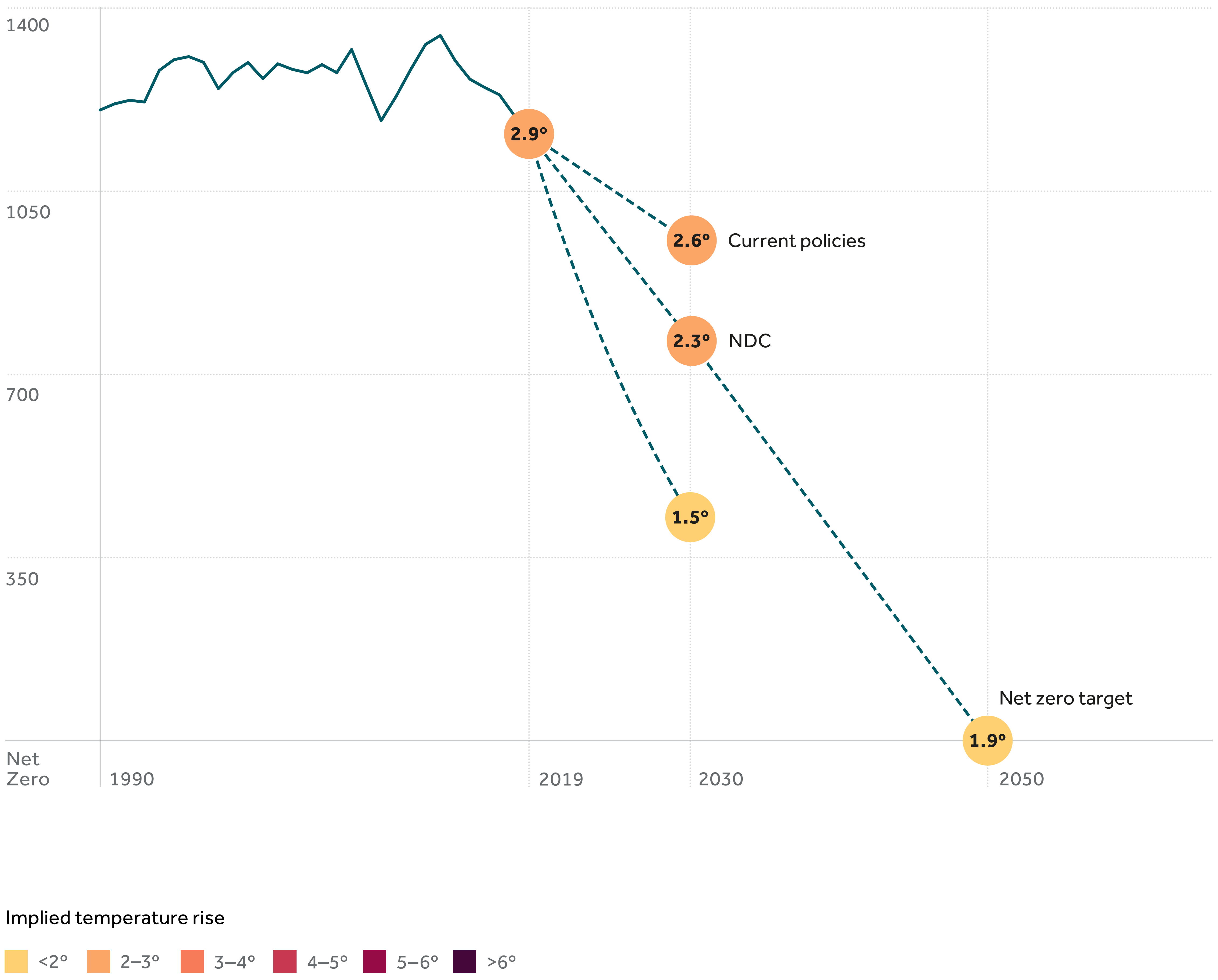
Green Growth Strategy (2021)[105] The strategy provides sector and technology-level roadmaps to achieve net zero by 2050. This includes a target for electrified vehicles (including fuel cell vehicles and non-plugin hybrids) to make up 100% of new passenger car sales by 2035.

Basic Energy Plan (2021)[106] The plan aims to diversify the energy mix by increasing the share of electricity from renewable sources to 36%-38% by 2030 (including large hydro).

Phase-out old and inefficient coal-fired power plants (2020)[107] The government is considering shutting down or mothballing about 100 out of total of 110 existing inefficient coal plants by 2030.

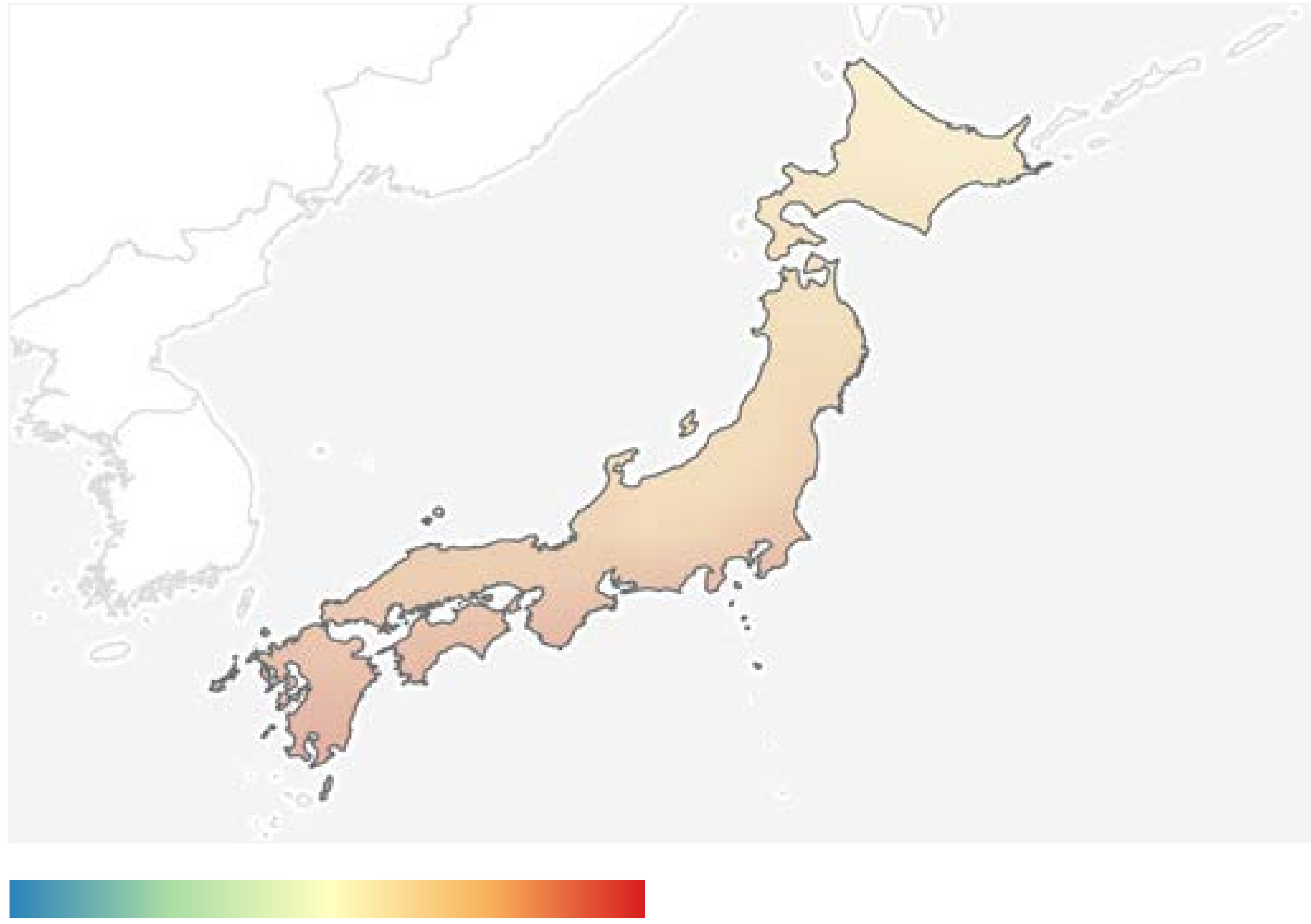
Fuel Efficiency Standards for Passenger Vehicles (2020)[108] The standards require manufacturers to improve the fuel efficiency of their vehicles by 32.4% (to reach 25.4 km/l compared to efficiency of 19.2 km/l in 2016) in 2030. The target vehicles are gasoline vehicles, diesel vehicles, LPG vehicles, electric vehicles and plug-in hybrid vehicles.

GHG Emissions ($MtCO_2e$)



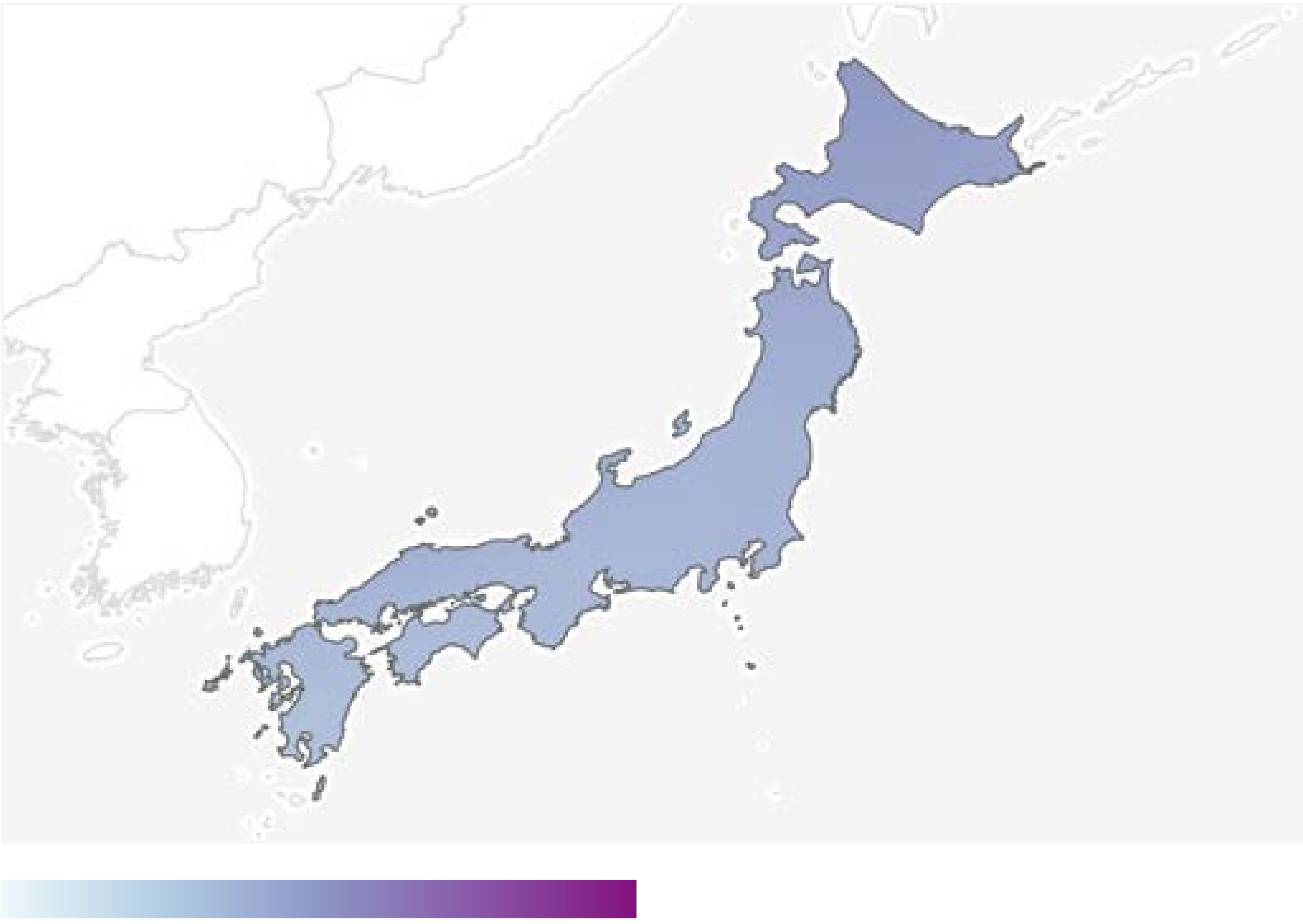
Japan

Historical average temperature



Average annual temperature based on global climate projections from the CMIP6 initiative.

Projected change in average temperature by 2050



Summary of physical risk exposure

Japan's climate is influenced by the East Asian monsoon season and the country is especially exposed to tropical cyclones as well as coastal or inland flooding, which can also impact its industrial sector, the second largest in the world.

Sea and air temperature rises cause conditions that both trigger and exacerbate tropical storms and cyclones. More intense storm systems coupled with higher sea levels are likely to cause more frequent and stronger storm surges, leading to large-scale coastal flooding damage. Japan is particularly exposed to such threats, as 80% of the population resides in high-density coastal communities, especially on the southern coast.

Frequency of extreme precipitation events is also expected to increase, causing major floods and landslides, with severe consequences to properties and transport infrastructure. Currently, 1,500 landslides occur every year, an increase of 50% from the previous decade.

Increasing temperatures are a significant threat to Japan's population. Almost 30% of the population are 65+ years old[109] (the highest proportion of any country in the world). This increases existing vulnerability to heat-related mortality, with current levels expected to worsen by two or three times by mid-century.[110]

Recent events

The 2020 floods in Kyushu

In July 2020, torrential rainfall hit the southern Japanese island of Kyushu, leading to a series of severe floods. Flooding and landslides killed 77 people and more than 15,000 buildings were reported as destroyed, damaged or flooded. Insurance market losses are estimated at US $855 million.[111] As an important manufacturing area, Kyushu also experienced business disruptions when companies (including Toyota, Canon and Panasonic) were compelled to temporarily halt their local production lines.

2050 projections

Change in average temperature
+2.0°C

Change in precipitation
+0.2%

Change in water stress
-15%

Republic of Korea

The Republic of Korea's 2050 net zero target[112] aligns with a 2°C+ trajectory. We estimate its latest 2030 NDC[113] and current policies to align with a 2°C + and 3°C+ trajectory, respectively.

Key climate-related policies

Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy (Renewable Energy Act) (2021)[115]
The revised Renewable Energy Act increases the minimum quota for renewables under the Renewable Portfolio Standard. Power producers with capacity over 500 MW must generate at least 25% of gross power from renewable sources by 2034.

2050 Carbon Neutral Forest Sector Promotion Strategy (2021)[116]
The strategy is to plant three billion trees over 30 years and thereby increase the annual LULUCF removals by 34 $MtCO_2e$.

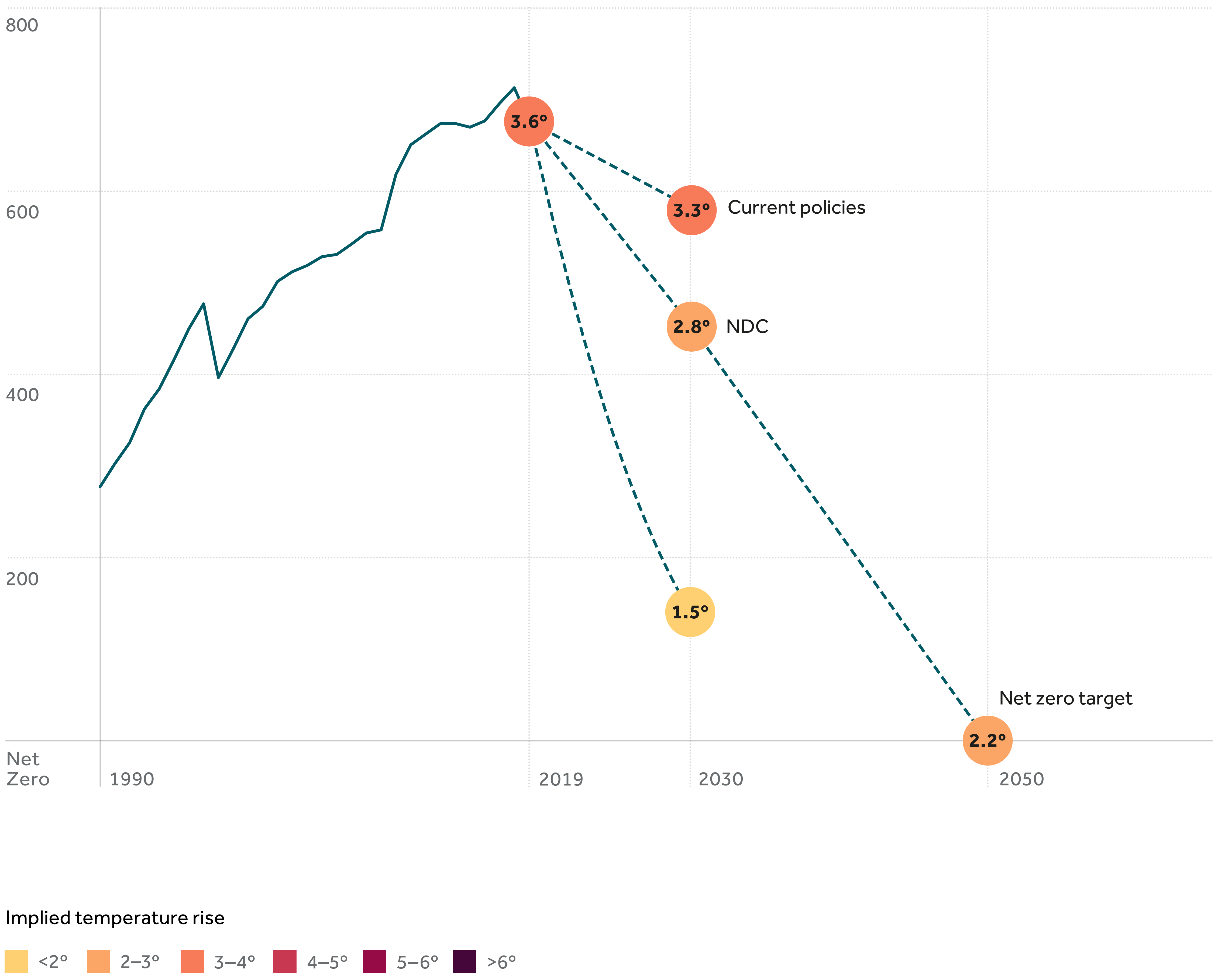
Framework Act on Carbon Neutrality and Green Growth (2021)[117]
This policy enshrined the Republic of Korea's 2050 climate-neutrality target into law. Emissions reductions targets will now be integrated into national budget planning through the climate-responsive budgeting program. The act also sets up a climate response fund, which will be used to support the structural transformation of carbon-intensive industries.

GDP
US$1,779 billion

Population
52 million

Under the Republic of Korea's latest NDC, we estimate greenhouse gas emissions per capita would fall from 13.1 tons CO_2e in 2019 to 8.8 tons by 2030. Its current policies would imply a smaller reduction to 11.3 tons over the same period.[114]

GHG Emissions ($MtCO_2e$)



Republic of Korea

Historical precipitation

500mm 2000mm

Average annual precipitation based on global climate projections from the CMIP6 initiative.

Projected change in precipitation by 2050

-20mm 0 +20mm

Recent events

The summer 2022 floods
In August 2022, the Republic of Korea was hit by its worst flooding in decades after three days of record-level rainfall. Around 800 buildings were damaged by floods and nine people lost their lives. The capital city Seoul was extensively flooded, leaving some transport infrastructure around the capital damaged or suspended.

2050 projections

Change in average temperature
+2.1°C

Change in precipitation
+0.9%

Change in water stress
-3%

Summary of physical risk exposure

The climate of the Republic of Korea is characterized by cold, dry winters and hot, humid summers with intense rainfall during the summer monsoon season.

More intense precipitation events, especially in the southern part of the country and during the monsoon season, will result in more frequent inland flooding, damaging property and infrastructure. Monsoon rains are expected to become more variable, and increased variability means that more frequent drought events cannot be ruled out. The country's water systems may be affected, with floods during the monsoon season and lower water availability for the rest of year.

Sea level rise and more intense storms and cyclones are also expected to impact densely populated coastal areas, with estimated losses amounting to EUR €41 billion to EUR €87 billion for coastal floods alone.[118]

The Republic of Korea's average temperature trend is rising faster than the global average, with a temperature increase of up to 2.1°C by mid-century. This increase could affect the supply of energy as demand for cooling grows, impacting electricity prices. Extreme heat events will harm the health of the country's aging population, because heatwave-related excess deaths could rise by two or three times by 2050.[119]

Mexico

Mexico's 2050 target[120] aligns with a 2.5°C-3.0°C trajectory. We estimate its latest 2030 NDC[121] and current policies to align with a below 2.0°C trajectory.

Key climate-related policies

Program for the development of the National Electric System 2020-2034 (PRODESEN) (2021)[123] This strategic policy document sets out electricity demand, consumption and generation projections until 2034, and plans for the country's electricity system to be able to meet expected demand. It also projects emissions from this sector until 2034. It is estimated that clean energy[124] will account for approximately 40% of final energy by 2034.

Support for sustainable forestry development (2021)[125] It supports the actions contributing to the protection, conservation, restoration, and incorporation of sustainable management of forest, which in turn contribute to the adaptation and mitigation of the effects of climate change.

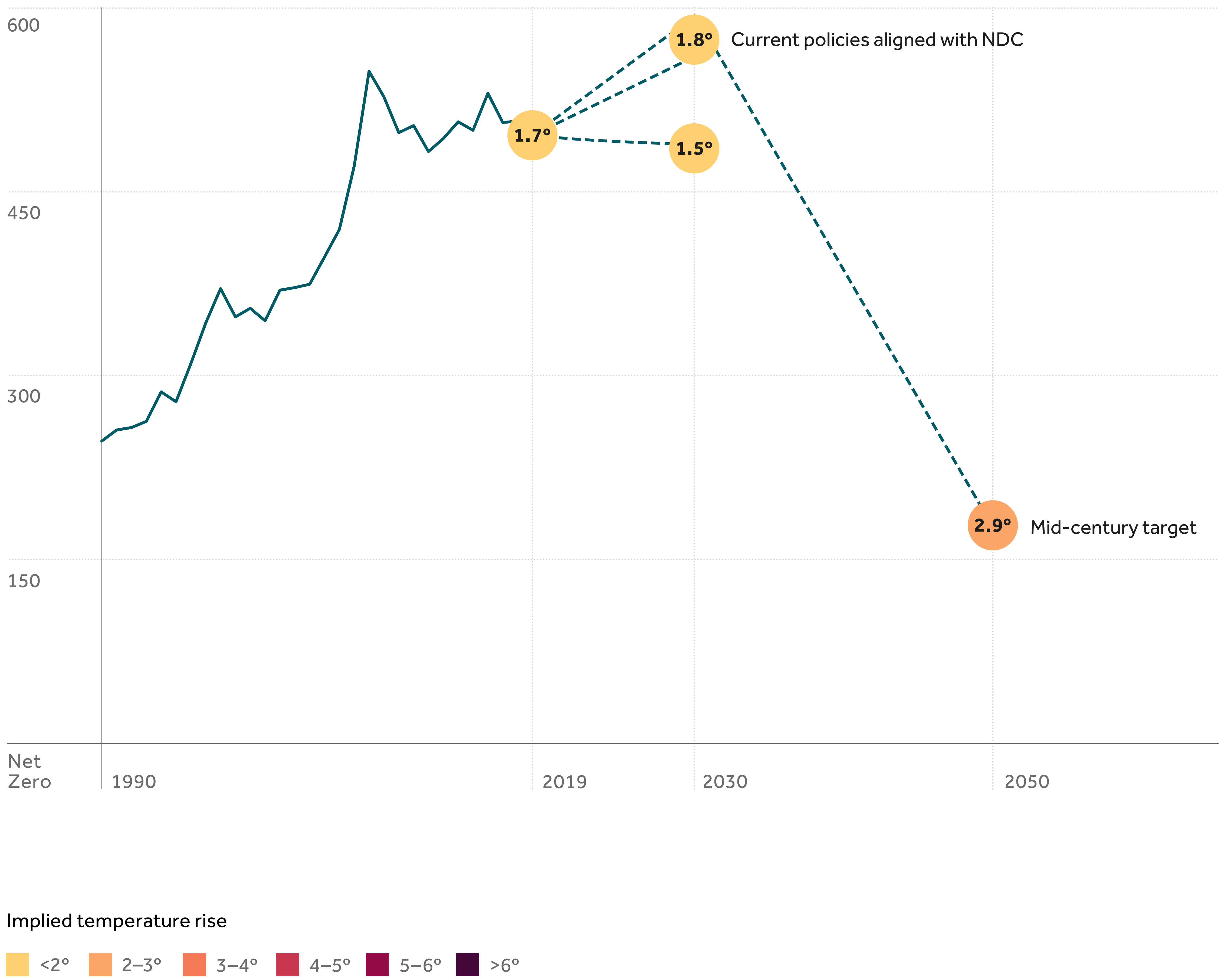
National Strategy to Reduce Short-Lived Climate Pollutants (2020)[126] This strategy presents a roadmap to reduce short-lived climate pollutants including black carbon, methane, tropospheric ozone and HFCs.

GDP
US$1,293 billion

Population
127million

Under Mexico's latest NDC, we estimate greenhouse gas emissions per capita would rise from 3.9 tons of CO_2e in 2019 to 4.2 tons by 2030. Its current policies imply a small increase to 4 tons over the same period.[122]

GHG Emissions ($MtCO_2e$)

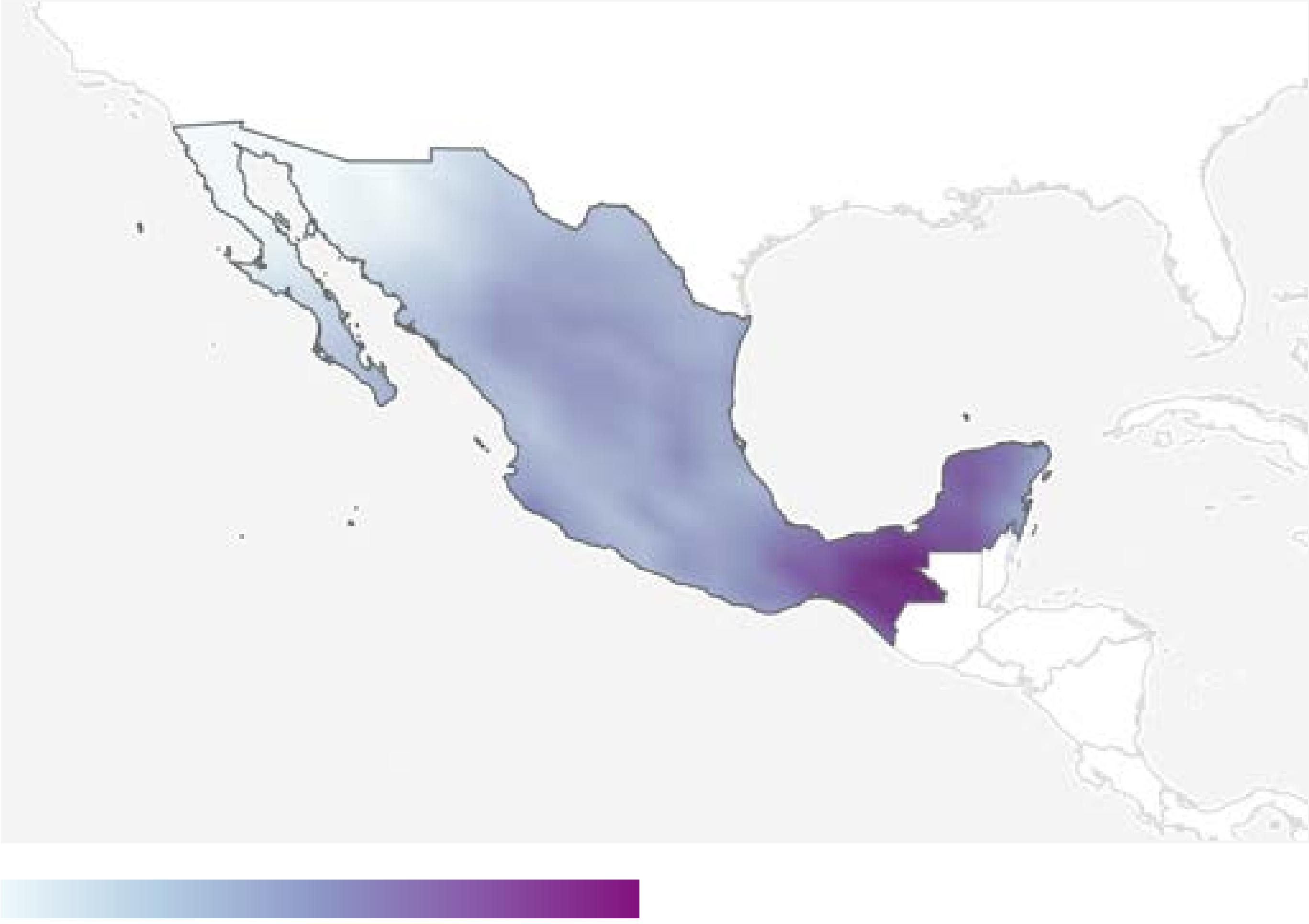


Mexico

Historical drought

Frequency of dry days based on global climate projections from the CMIP6 initiative.

Projected change in drought by 2050



Summary of physical risk exposure

Mexico's climate and physical risk vary strongly from north to south. The temperate north is most exposed to droughts and water scarcity, threatening population and industrial centers in the northwest. While these risks remain severe, they are less of a threat for the lower-temperature mountainous central area and tropical south, where most of the population are clustered.

Mexico is strongly affected by both Atlantic and Pacific tropical storms and hurricanes. More than half of its population live along the coast, where there are significant levels of tourist-related infrastructure. A 50% projected increase in the frequency of the most intense events, as well as their associated increased rainfall,[127] coupled with rising sea levels are expected to put more people and resorts at risk of extreme floods.

With less rain and warmer temperatures, water stress and drought conditions are expected to worsen,[128] aggravating conditions in the drier northern part of the country. Mexico is already one of the driest countries in the G20.

In turn, agriculture will be severely impacted, with some studies projecting a 26-35% decrease in crop yields[129] – potentially triggering large migratory waves due to lower agricultural employment and reduced access to basic resources.

Recent events

Hurricane Patricia - 2015

Hurricane Patricia – the strongest tropical cyclone ever recorded in the western hemisphere, with winds reaching 345km/h – made landfall in October 2015 on the western coast of Mexico. Fortunately, the storm caused minimal damage (around US $325 million,[130] mostly impacting agriculture and infrastructure) and casualties, as it quickly weakened to a tropical depression when it made landfall and avoided the most densely populated areas.

2050 projections

Change in average temperature
+2.0°C

Change in precipitation
-0.5%

Change in water stress
+110%

Russia

Russia's 2050 net zero target[131] aligns with a 2°C+ trajectory. We estimate its latest 2030 NDC[132] and current policies to align with a 3.0°C–4.0°C trajectory.

Key climate-related policies

System of Green Project Financing (2021)[134] The system prepares for the launch of schemes to finance green projects and initiatives, including sustainable development and mitigating the emission of pollutants and greenhouse gases.

Energy Strategy 2035 (2021)[135] This latest energy strategy describes the expected development of the country's energy sector over the next 15 years. The strategy focuses on fossil fuels industries. It describes how Russia aims to secure its energy-exports position internationally by projecting an increase in production of coal and gas. The strategy only briefly outlines planning for energy efficiency, renewables other than hydro, and alternative synthetic fuels.

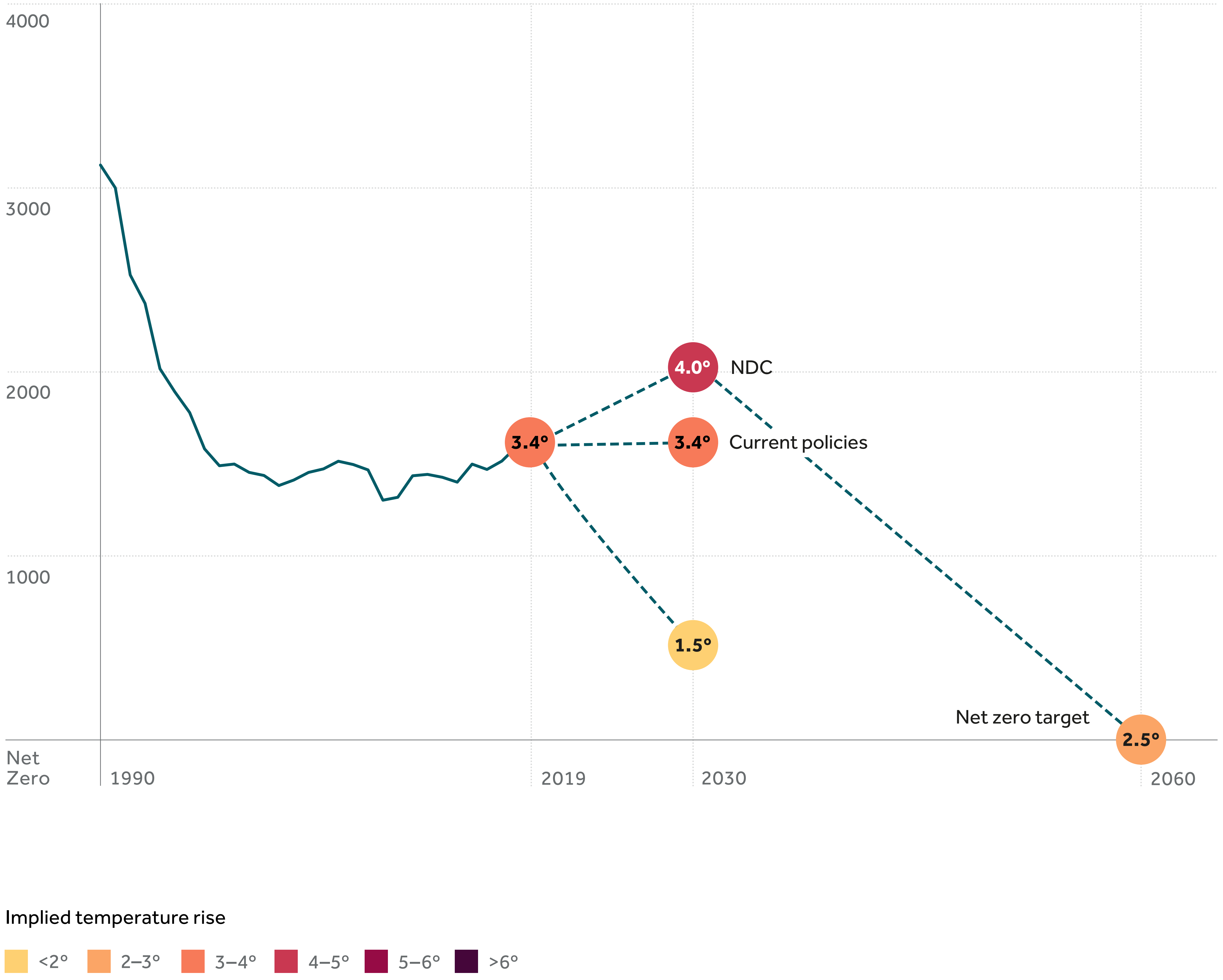
Transport strategy until 2030 (2021)[136] The Russian Federation expects to reduce transport emissions by 1.2% compared to 2017.

GDP
US$1,776 billion

Population
144 million

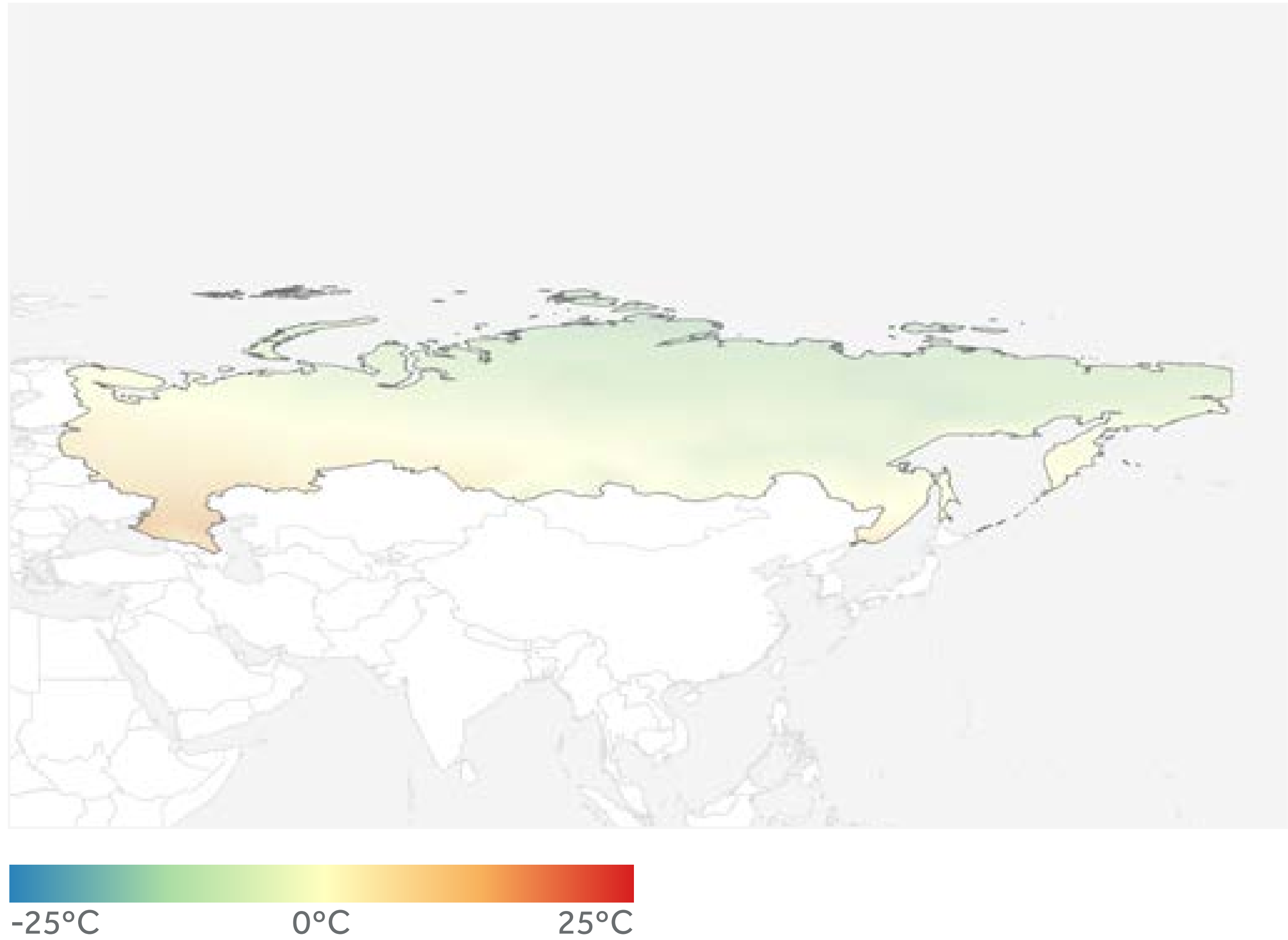
Under Russia's latest NDC, we estimate greenhouse gas emissions per capita would rise from 11 tons of CO_2e in 2019 to 14.3 tons by 2030. Its current policies imply a small increase to 11.3 tons over the same period.[133]

GHG Emissions ($MtCO_2e$)



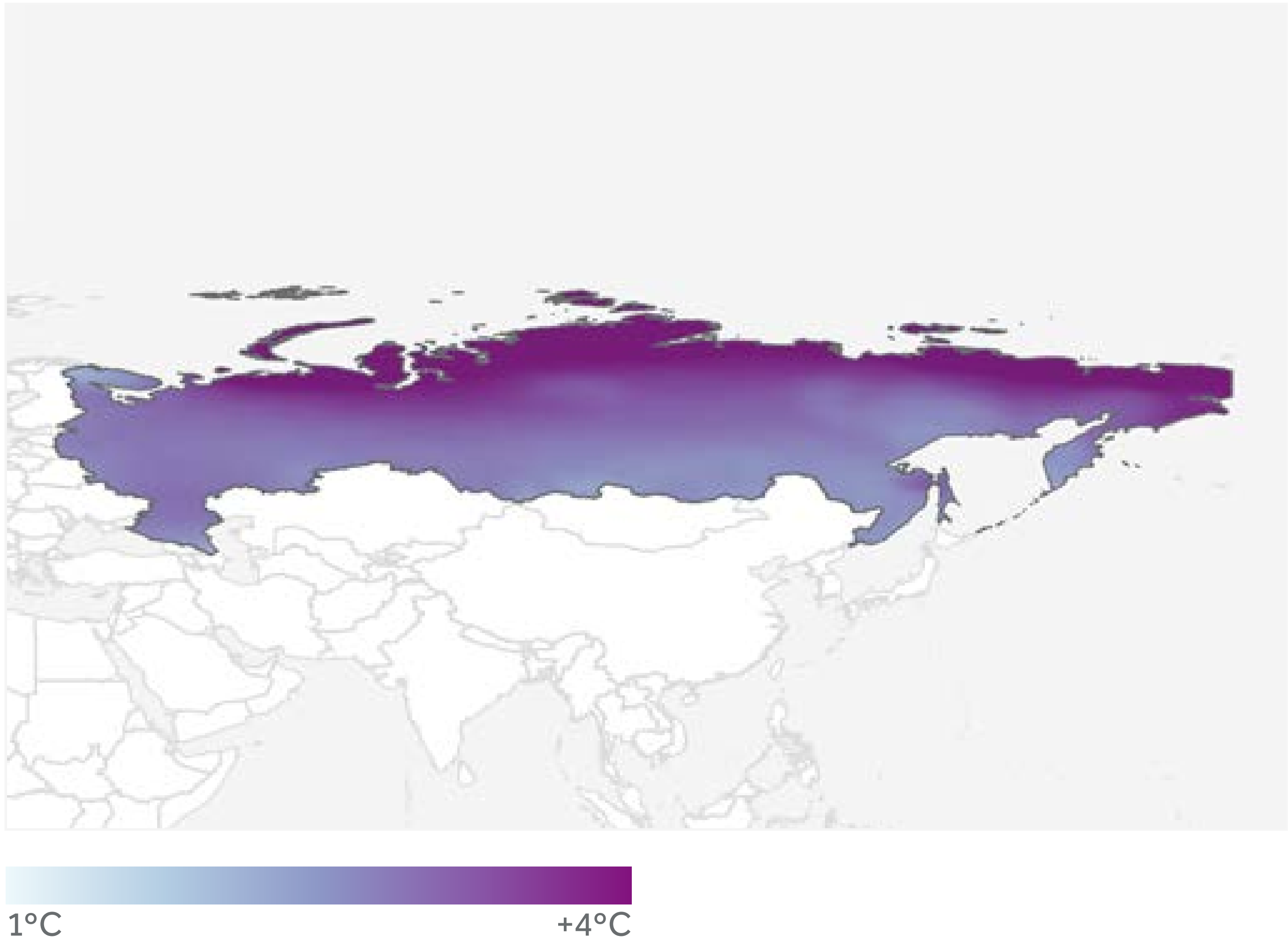
Russia

Historical average temperature



Average annual temperature based on global climate projections from the CMIP6 initiative.

Projected change in average temperature by 2050



Summary of physical risk exposure

The biggest country in the world by landmass, almost all types of climates can be found there, with mean temperatures ranging from -19 to 15°C. Consequently, climate change imposes a diverse set of physical risks on Russia.

Temperatures are rising more quickly than almost all other G20 countries, with up to +3.1°C expected by 2050. This rise will increase the risk of heatwaves and associated wildfires, leading to air pollution and health impacts, especially in urban centers. Such events will also significantly affect Russian large boreal forests, which act as a carbon sink of global significance.

However, the most significant threat from a warmer climate is arguably the melting of permafrost that will destabilize soils and damage infrastructure across large parts of the country. Annual damages could reach US $1 billion to 2 billion. In the process large quantities of methane could also be released, which is a significant greenhouse gas with a warming potential almost 30 times higher than CO_2.[137]

Some sectors may at least temporarily benefit from climate change, such as agriculture through a slight increase in crop yields or shipping in the Arctic north. However, these sectoral and local benefits are highly unlikely to outweigh the potentially large negative impacts of climate change on the Russian economy by 2050.[138]

Recent events

The 2010 heatwave

During spring and summer 2010, Russia faced the most dramatic heatwave and drought events in recent history. Record-temperature dry conditions across the country caused a 70% yield decrease for wheat in major production regions, leading to an export ban that impacted food security around the globe. The accompanying heatwave starting resulted in significant wildfires and air pollution with an estimated 56,000 casualties due to smog and intense heat.[139]

2050 projections

Change in average temperature

+3.1°C

Change in precipitation

+1.7%

Change in water stress

-9%

Saudi Arabia

Saudi Arabia's 2060 net zero target[140] aligns with a 2.5°C-3.0°C trajectory. We estimate its latest 2030 NDC[141] and current policies to align with a c. 4°C+ trajectory

Key climate-related policies

National Renewable Energy Program (NREP) (revised 2019)[143]
This policy aims to implement the 'Vision 2030' renewable energy targets of 27.3 GW of renewable power capacity by 2023 and 58.7 GW by 2030. Renewable power capacity is auctioned through competitive tenders.

Saudi Green Initiative (2022)[144] The main objective of the initiative consists off planting 10 billion trees across the country. Other targets include decarbonizing the transport sector through rail investments, increasing energy efficiency and upscaling renewables.

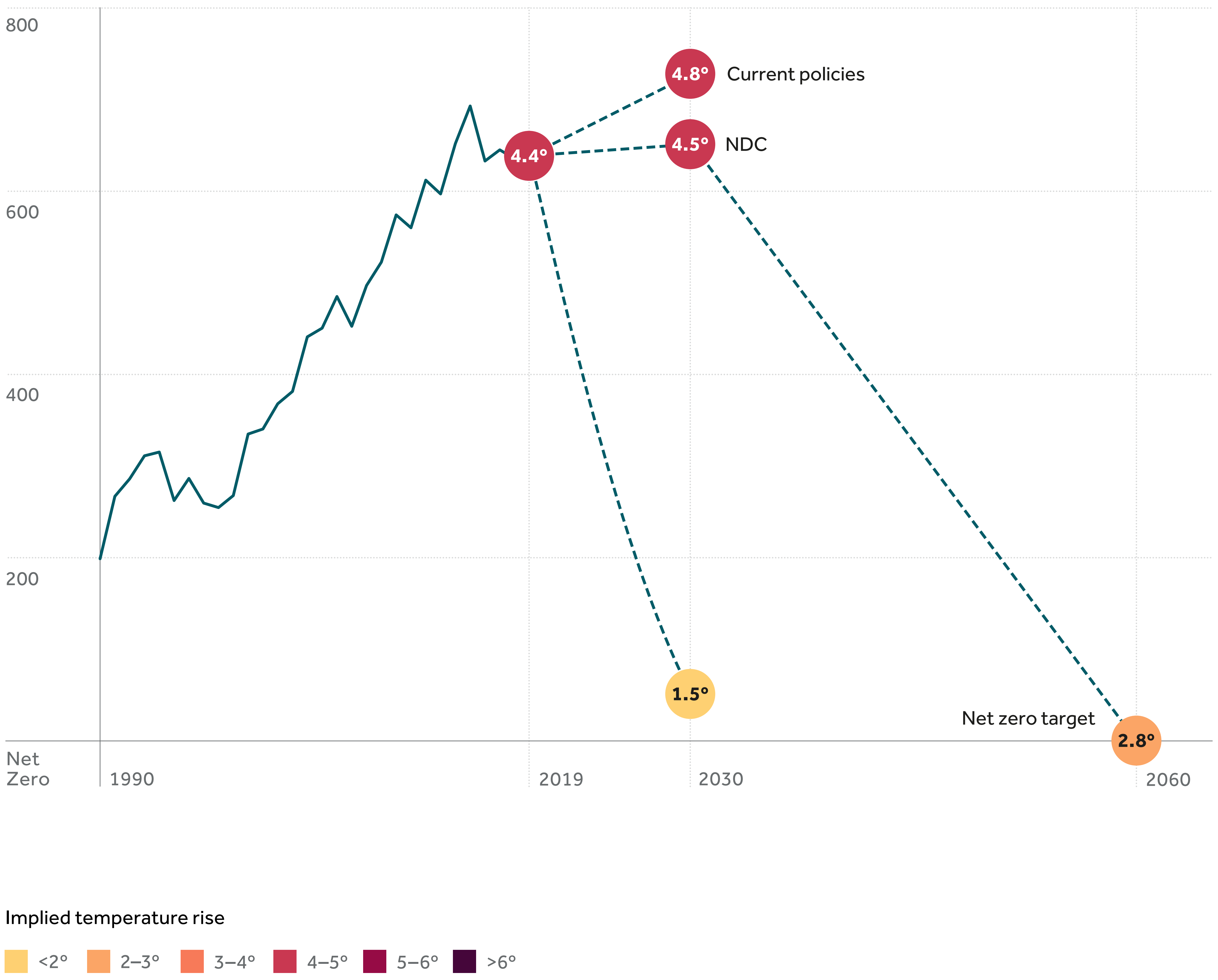
Fossil fuel price reform (2017)[145] This is a series of reforms to the country's fiscal policies towards fossil fuels. The reforms include reducing cuts to fossil fuel subsidies to reach parity with international gasoline prices, increasing the price of diesel via taxes up to 90% of international prices, as well as raising the price of other fuels between 2018 and 2025.

GDP
US$834 billion

Population
36 million

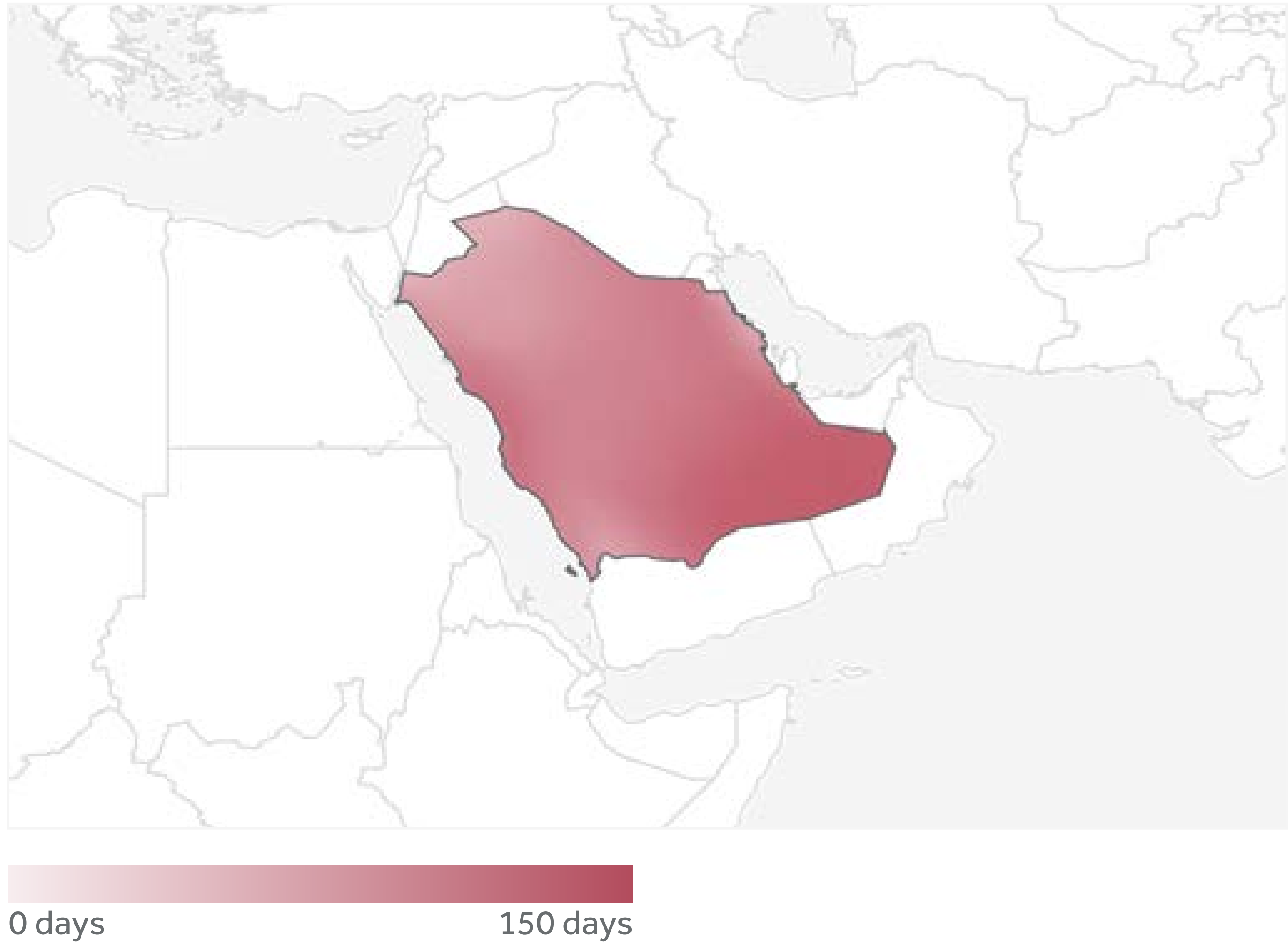
Under Saudi Arabia's latest NDC, we estimate greenhouse gas emissions per capita would fall from 18.6 tons of CO_2e in 2019 to 16.6 tons by 2030. Its current policies imply a small decrease to 18.5 tons over the same period.[142]

GHG Emissions ($MtCO_2e$)



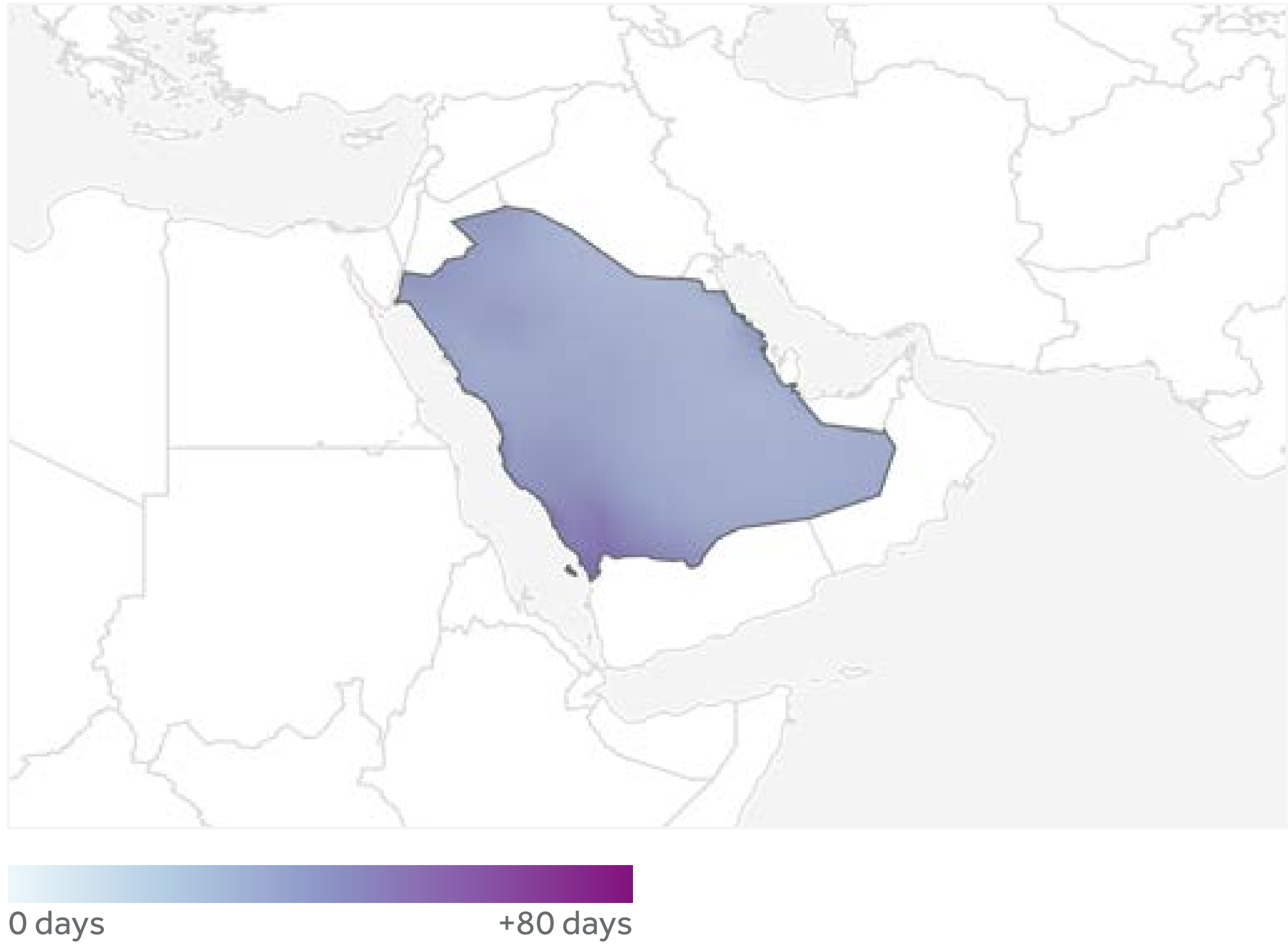
Saudi Arabia

Historical exposure to heatwaves



Frequency of days above 35°C, based on global climate projections from the CMIP6 initiative.

Projected change in exposure to heatwaves by 2050



Recent events

The 2009 flooding of Jeddah

In November 2009, the country's second largest city of Jeddah was flooded by torrents of mixed water and sediments. Strong run-offs, created by heavy rainfall that lasted three hours, were worsened by the city's limited drainage system. The flood caused severe damage to infrastructure, destroyed more than 10,000 properties and killed at least 122 people,[148] mostly in unplanned settlements.

2050 projections

Change in average temperature

+2.4°C

Change in precipitation

+39.3%

Change in water stress

+391%

Summary of physical risk exposure

Mostly covered by desert, Saudi Arabia is already highly exposed to hot and dry conditions, with limited rainfall over the year. Research on the impacts of climate change on the country is still limited, but some trends can be highlighted.

Water stress levels are extremely high and rising temperature will further strain resources due to higher rates of evapotranspiration.[146] With the onset of climate change, droughts will occur more frequently, especially in the north.

Saudi Arabia regularly experiences sandstorms, generated by a combination of strong winds, dry conditions and a lack of vegetation; their frequency and intensity are expected to further increase. These events have significant economic consequences, by damaging infrastructure, disrupting maritime, railway and flight transport, reducing crop yields and negatively impacting human health, especially for people with respiratory problems. In the whole MENA region, sand and dust storm-related costs have been estimated at US $13 billion annually.[147]

Despite its arid climate, the country can be impacted by irregular flash floods from intense precipitation events, which can cause damage in urban centers and result in human casualties. The lack of a natural drainage system in Saudi Arabia, with no permanent river, increases its vulnerability to such events.

Saudi Arabia's coast is elevated and resistant to erosion, meaning the impact of sea-level rise should be limited in comparison to other G20 countries. However, sea-level rise still threatens to damage energy-focused port infrastructure, which is a unique vulnerability for Saudi Arabia given 24% of its GDP in 2019 was linked to oil production.

South Africa

South Africa's 2050 net zero target[149] is Paris-aligned. However, we estimate its latest 2030 NDC[150] and current policies to align with a 2°C+ trajectory.

Key climate-related policies

Integrated Resource Plan for electricity (2011/2019)[152]
The Integrated Resource Plan (2019) is the first update of the original 2011 plan. It aims to decommission over 35 GW (of 42 GW currently operating) of Eskom's coal-generation capacity by 2050, with 5.4 GW already by 2022 and 10.5 GW by 2030.

Biofuels Regulatory Framework (BRF) (2020)[153] The Biofuels Industrial Strategy, which falls under the Petroleum Products Act, mandates biofuel blending of 2%-10% for bioethanol and a minimum of 5% for biodiesel from 2015 onwards. The Biofuels Regulatory Framework (BRF) implements the Biofuels Industrial Strategy.

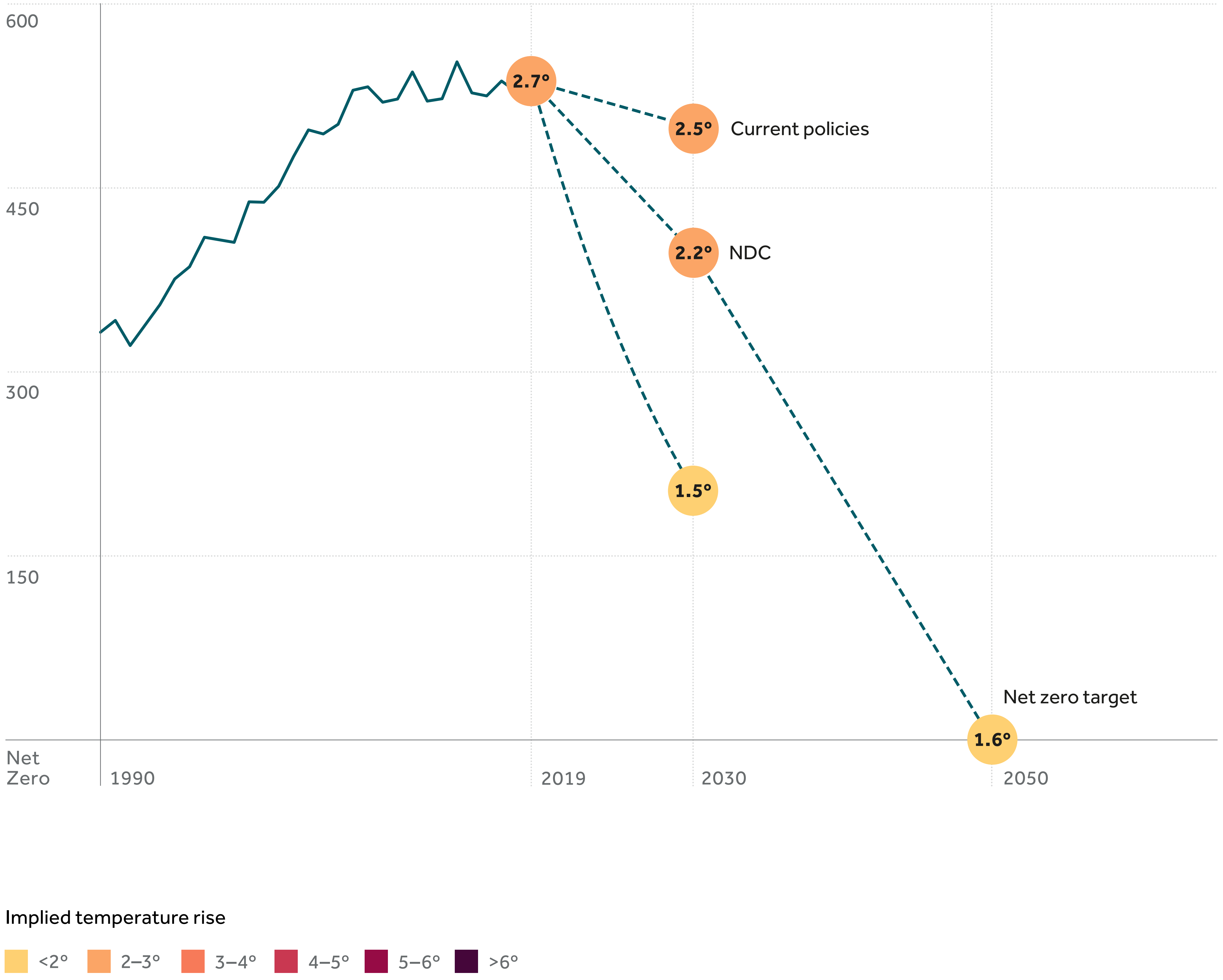
Carbon Tax South Africa (2019)[154] The initial marginal carbon tax rate will be ZA R120 per tonof CO_2e. Considering various thresholds, the effective tax rate is much lower and ranges between six and 48 rand per ton depending on the industry.

GDP
US$420 billion

Population
60 million

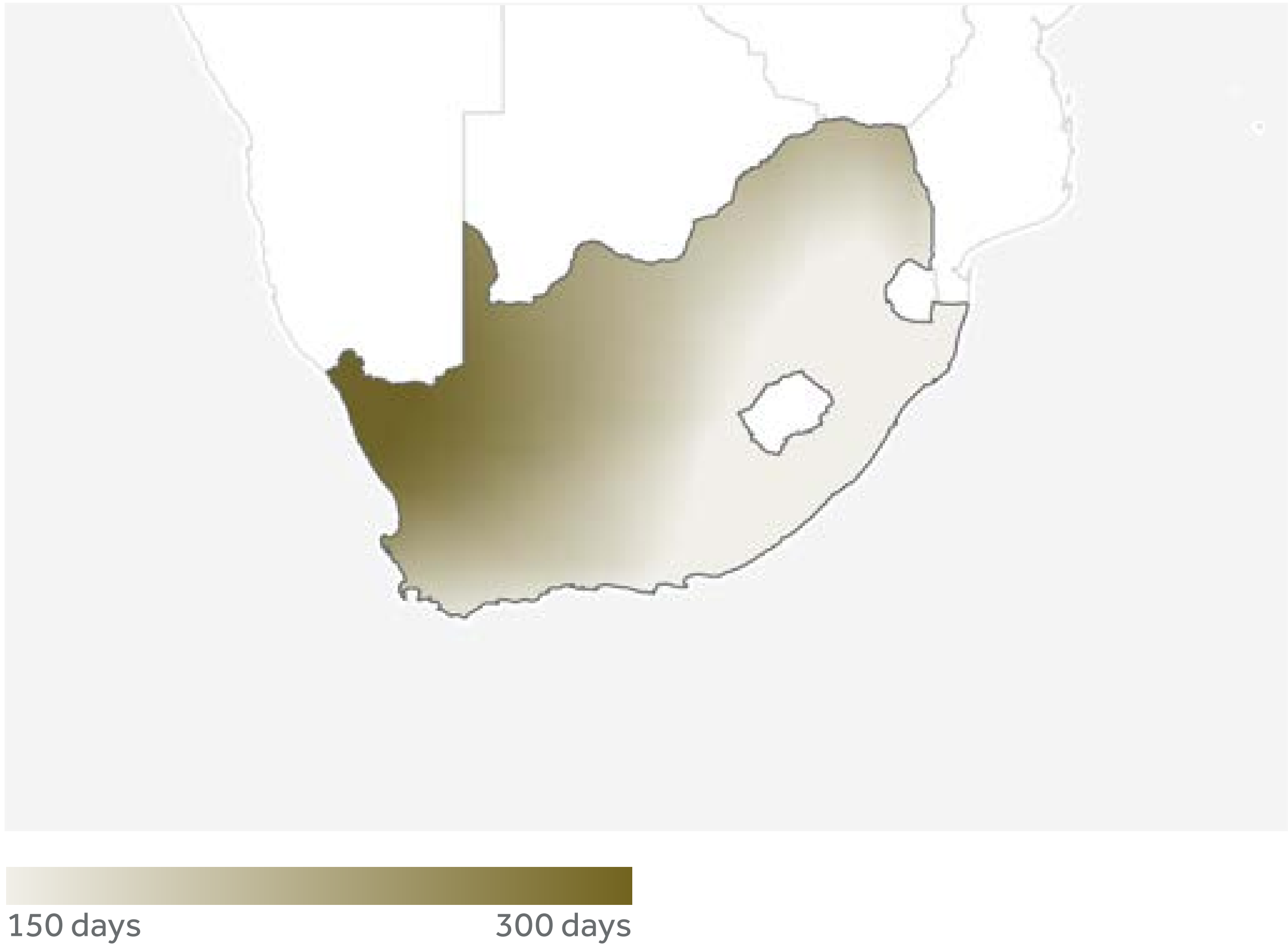
Under South Africa's latest NDC, we estimate greenhouse gas emissions per capita would fall from 9.2 tons of CO_2e in 2019 to 6 tons by 2030. Its current policies imply a reduction to 7.5 tons over the same period.[151]

GHG Emissions (MtCO₂e)



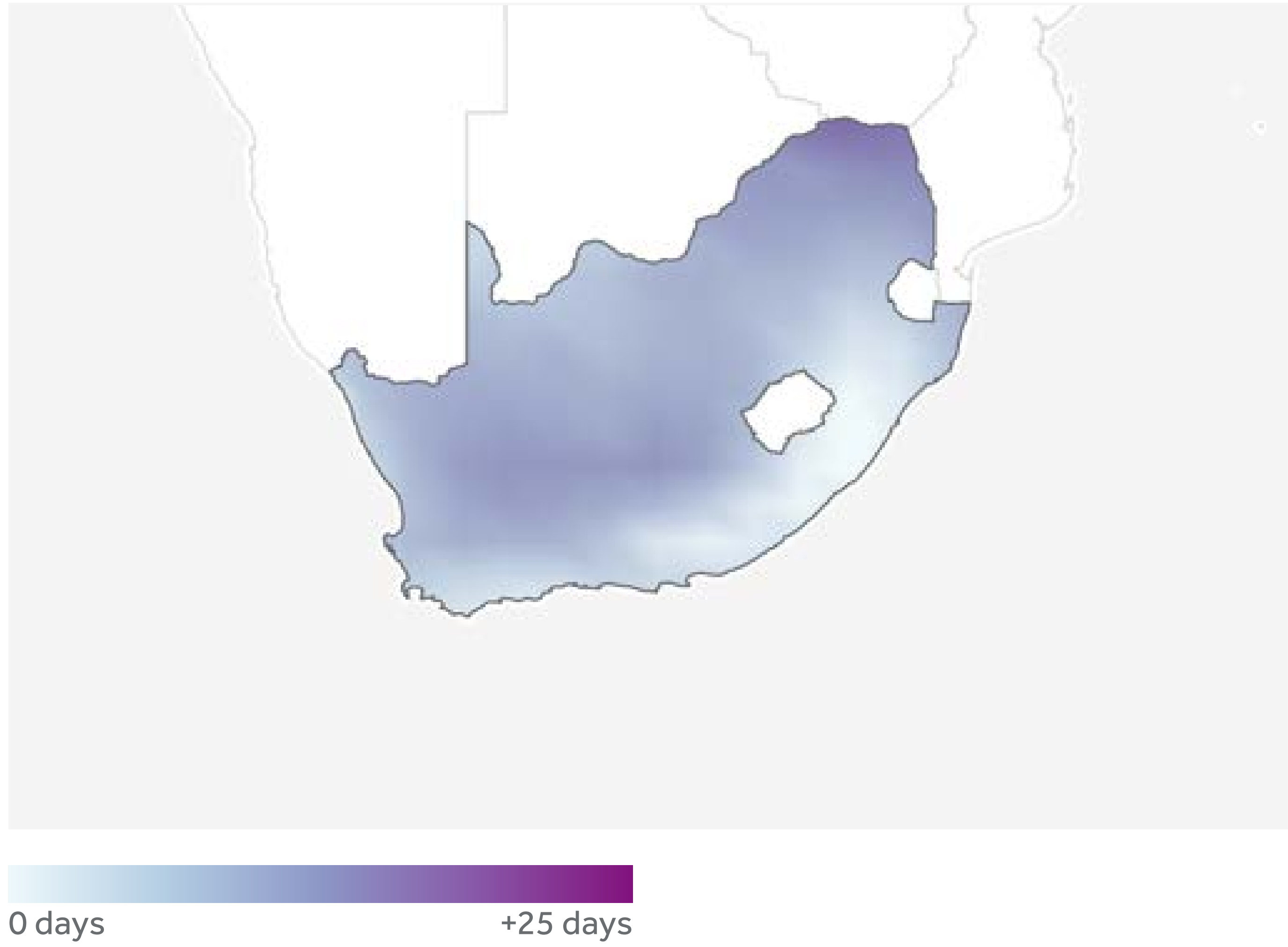
South Africa

Historical drought



Frequency of dry days based on global climate projections from the CMIP6 initiative.

Projected change in drought by 2050



Recent events

The Cape Town water crisis in 2018
Cape Town faced a water crisis in 2017 and 2018, following a three-year-long rainfall deficit that led to severe water shortages. Strict water restrictions were widely implemented, both on industry and the urban population. In February 2018, water was limited to 50 liters per day per person – a third of the average daily use in the UK – a limitation which was in place until intense rains in June 2018 allowed for the easing of restrictions. The economic impact on agriculture has been estimated as at least US $400 million, impacting 30,000 jobs and reducing exports by 13-20%.[157]

2050 projections

Change in average temperature
+2.1°C

Change in precipitation
-0.8%

Change in water stress
+82%

Summary of physical risk exposure

South Africa's warm and temperate climate is strongly influenced by its position between the Atlantic Ocean and the Indian Ocean. The country is on average relatively arid, with most rain on the eastern coast bordering the Indian Ocean.

The likelihood of severe drought is expected to rise by 39% by 2050,[155] threatening its agricultural sector. Although crop diversity may limit the risk of catastrophic failure, negative impacts are projected for all major crops, with maize production for example projected to decrease by 10-16% without adaptation measures.[156]

Moreover, multi-annual droughts can strongly limit water availability and could result in recurrent water use restrictions in densely populated areas, which potential impacts on livelihoods, industry and tourism.

At the same time, South Africa is also exposed to occasional flash floods and riverine inundations, mainly due to heavy rains and cyclone events from the Indian Ocean and Atlantic Ocean, with their intensity and frequency expected to increase, both in terms of wind speed and rainfall. This will continue to damage infrastructure, notably in coastal areas.

Turkey

Turkey's 2050 net zero target[158] is Paris-aligned. We estimate its latest 2030 NDC[159] and current policies to align with a 2.0°C-3.0°C trajectory.

GDP
US$815 billion

Population
85 million

Under Turkey's latest NDC, we estimate greenhouse gas emissions per capita would rise from 5.2 tons of CO_2e in 2019 to 9.8 by 2030. Its current policies imply an increase to 7.9 tons over the same period.[160]

Key climate-related policies

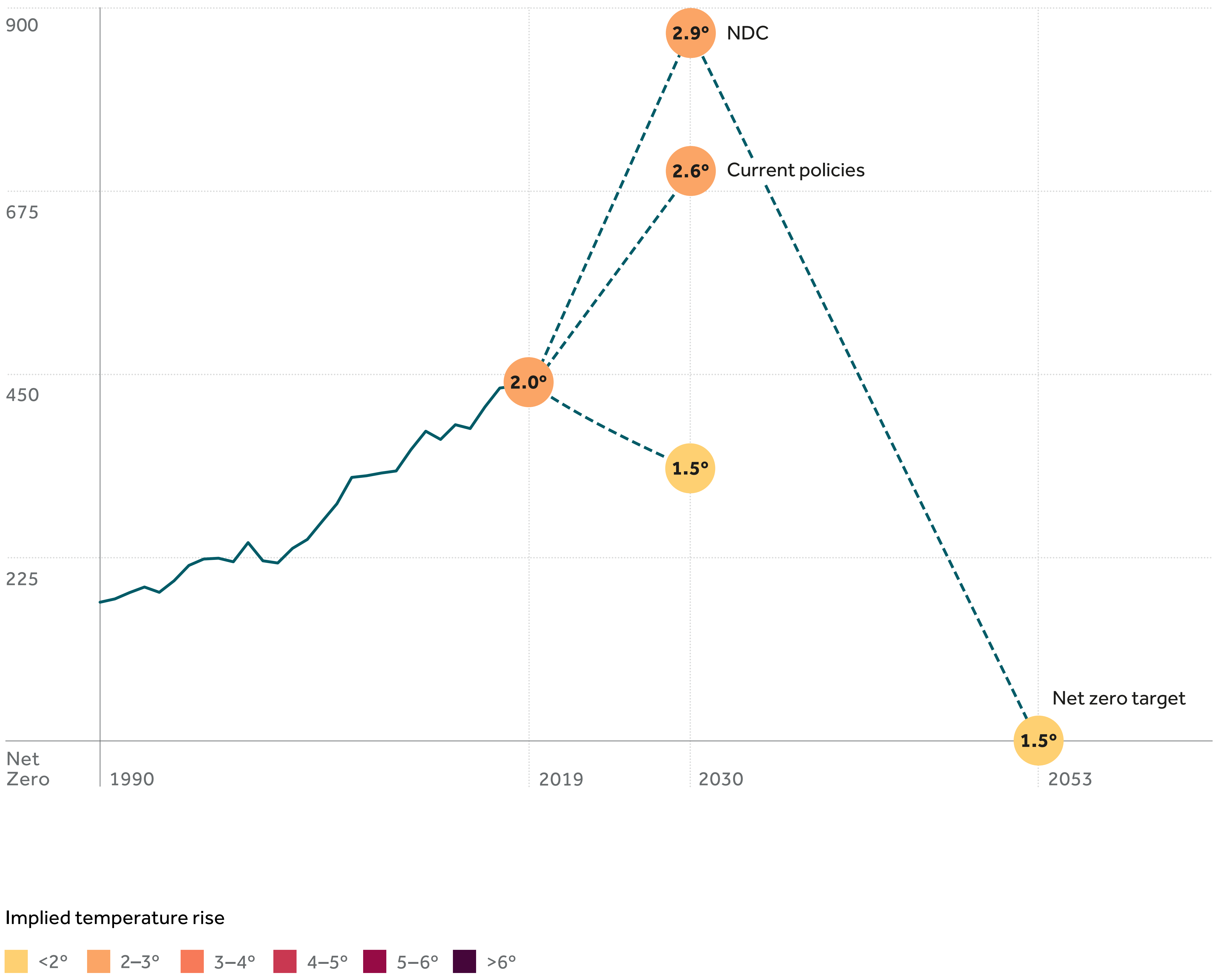
11th Development Plan (2019)[161] The plan sets a target for 38.8% of electricity production to come from renewables by 2023.

Initiative to plant 252 million saplings (2021)[162] The initiative targets to plant 252 million saplings by the end of 2022.

Green Deal Action Plan (2021)[163] The action plan mainly aims to establish Turkey's compliance with the European Green Deal issued by the European Union.

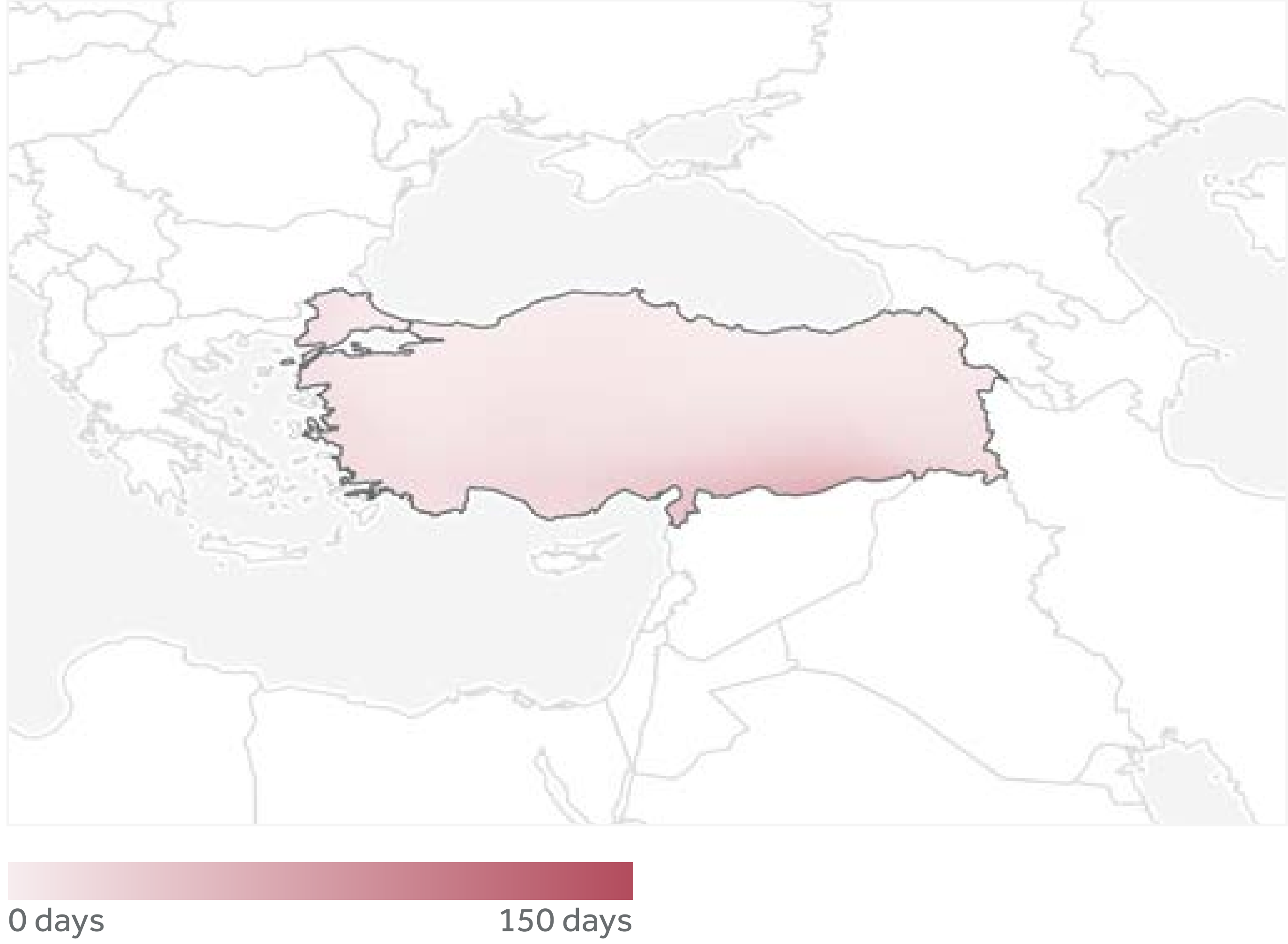
Motor Vehicle Tax Law (2021)[164] Presidential Decree No. 3471 redetermines special consumption tax rates for electric passenger cars. The rates increase proportional to engine power – engines up to 85 kW increase from 3% to 10%, 85-120 kW from 7% to 25%, and for over 120 kW from 15% to 60%.

GHG Emissions ($MtCO_2e$)



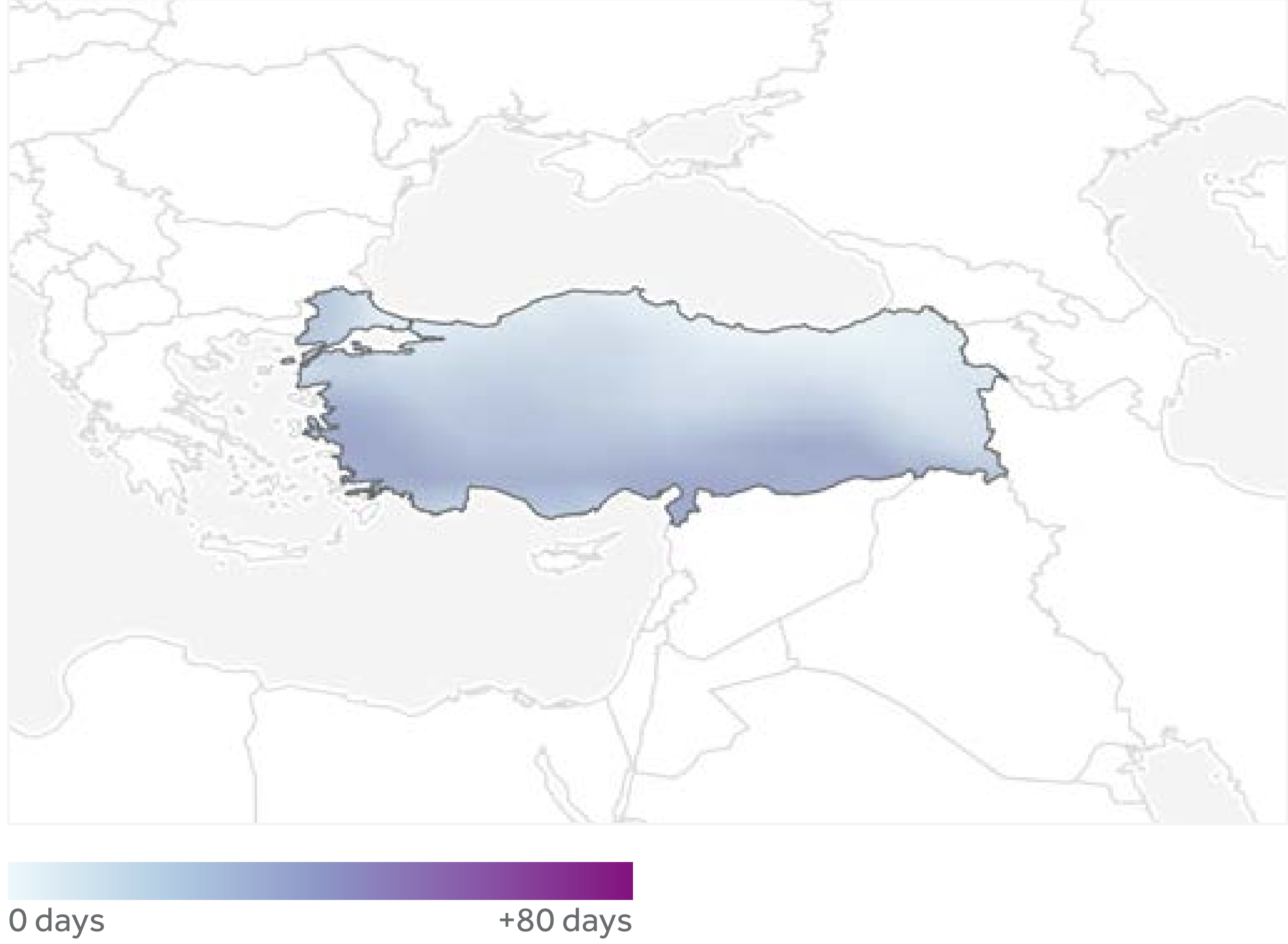
Turkey

Historical exposure to heatwaves



Frequency of days above 35°C, based on global climate projections from the CMIP6 initiative.

Projected change in exposure to heatwaves by 2050



Summary of physical risk exposure

Turkey's climate is varied, with most of the country experiencing dry and warm conditions, except for some regions along the northern coast.

Water stress levels in Turkey are among the highest in the G20 and are expected to increase with rising temperatures. Intensified by severe droughts, which will become more likely in the agricultural center of the country, competition for water use between agriculture and other sectors is likely to increase.

Warmer and drier conditions will increase wildfire risk across the country, with potential to causing damage to infrastructure and ecosystems, as well as health risk due to air pollution. Heatwave-related mortality and tropical diseases are on the rise, especially Zika virus and dengue fever.[165]

Coastal areas will be impacted by drier conditions that could damage the country's image and tourism industry, especially if water restrictions would have to be implemented. The high density of tourist resorts in coastal areas also puts the industry at risk from sea-level rise, where coastal flooding of low-lying plains and the erosion of rocky shores can damage key infrastructure. Expected annual damages from sea-level rise could amount to US $1.1 to 1.8 billion by 2050.[166]

Recent events

The 2021 wildfires
Catastrophic wildfires spread in Turkey in July and August 2021, causing nine casualties and a large number of evacuations, including thousands of tourists. Though wildfires are common in Turkey during summer, the intensity of the 2021 event exceeds any fire on record by a factor of four.[167] Exceptionally dry and hot conditions with record-breaking temperatures, laid the groundwork for the wildfires during the spring and early summer. Wildfire risk is expected to increase significantly in the Mediterranean region of the country, leading to more intense and more frequent fires that may no longer allow natural ecosystems to recover.

2050 projections

Change in average temperature
+2.4°C

Change in precipitation
-0.8%

Change in water stress
+185%

United Kingdom

The United Kingdom's 2050 net zero target[168] is Paris-aligned. We estimate that its latest 2030 NDC[169] and current policies are broadly aligned with this target.

Key climate-related policies

Ten Point Plan for a Green Industrial Revolution (2020)[171] The plan outlines policy interventions in the energy, buildings, transport, nature and technology sectors.

Transport Decarbonisation Strategy (2021) This strategy sets out a framework to decarbonize the UK's transport sector. It includes several commitments, such as increasing cycling and walking, increasing the share of zero-emissions buses, decarbonizing railways and supporting the development of a zero-emissions fleet of cars, vans, motorcycles and scooters.

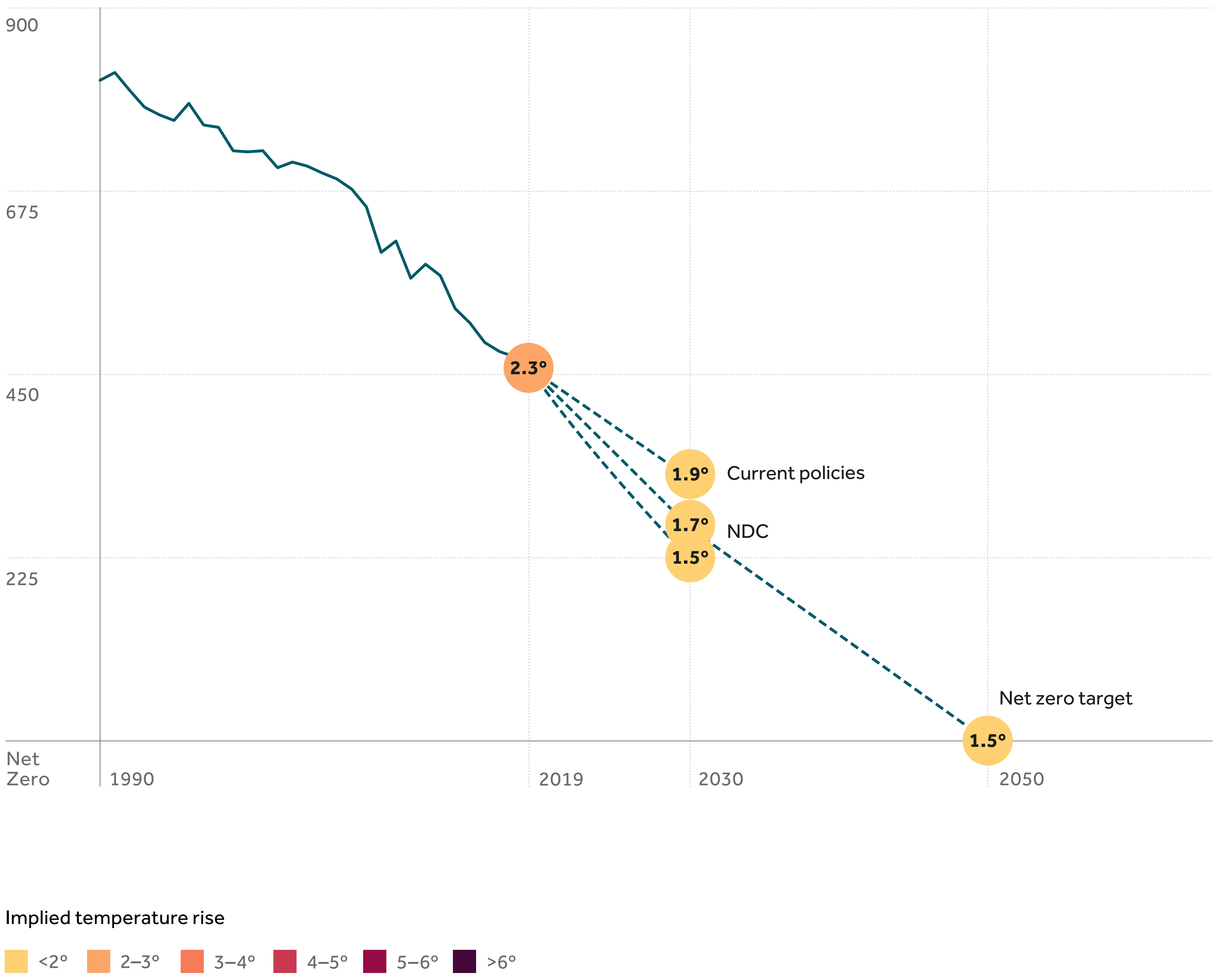
Energy White Paper (2020)[172] The main objective of the strategy is to transform the energy system by moving away from coal and investing in clean sources for energy supply, such offshore wind energy, pledging to generate carbon-free electricity by 2050. The document also lays out a plan to establish the UK-ETS (Emissions Trading System) to replace the EU-ETS.

GDP
US$3,187 billion

Population
67 million

Under The United Kingdom's latest NDC, we estimate greenhouse gas emissions per capita would fall from 6.8 tons of CO_2e in 2019 to 3.7 tons by 2030. Its current policies imply a reduction to 4.5 tons over the same period.[170]

GHG Emissions ($MtCO_2e$)



United Kingdom

Historical precipitation

500mm 2000mm

Average annual precipitation based on global climate projections from the CMIP6 initiative.

Projected change in precipitation by 2050

-20mm 0 +20mm

Summary of physical risk exposure

The United Kingdom has a temperate climate with mild winters and relatively cool summers. The 2022 summer gave a glimpse of the major shift to the country's heat exposure brought by climate change and the potential consequences for health, infrastructure and transport.

Though heat exposure will remain moderate overall compared to many other G20 members, the low preparedness of the country to more frequent acute heat events will impact many sectors, disrupting public transport (e.g., via rail buckling) and raising health concerns among the elderly (who comprise almost 20% of the population).

Flood risks are expected to increase due to more frequent and more intense precipitation events (the wettest day may become 10% wetter by 2050[173]). The country has indeed already faced water-related risks, with high rainfall events and storms in the south and west a yearly occurrence and large-scale riverine floods disrupting transport and damaging property. The Environment Agency estimates 5.2 million properties are currently at risk of flooding[174] (a number expected to double in the next 50 years).

Increased intensity and frequency of North Atlantic storms leave the south and west coasts of the UK vulnerable to property damage from storm surges. A recent study[175] suggests up to 160,000 properties are at risk of forced relocation by 2050.

Recent events

The 2013-14 winter floods
During the 2013-14 winter, the UK witnessed successive severe storms bringing heavy and prolonged rainfall, including the wettest January on record in some regions. The damage was not due to a single meteorological event, but the recurrence of intense rainfall and high wind. Impacts included an estimated GB £1.3 billion damage, 17 casualties and long-lasting transport disruption.[176]

2050 projections

Change in average temperature
+1.0°C

Change in precipitation
+0.1%

Change in water stress
-33%

United States

The United States' 2050 net zero target[177] is aligned with a 2°C+ warming trajectory. We estimate its latest 2030 NDC[178] and current policies to align with a c. 3.0°C and 3.5°C+ trajectory respectively.

Key climate-related policies

Light-duty vehicles GHG Emissions Standard (2021)[180] In 2021, EPA revised the GHG emissions standards for passenger cars and light trucks for model years 2023-2026, aiming for a fleet average of 52 miles per gallon by 2026.

American Innovation and Manufacturing (AIM) Act (2021)[181] As part of its Covid-19 relief efforts, this act seeks to support the American manufacturing sector, while providing new authorities in three main areas, to phase down the production and consumption of listed HFCs, manage HFCs and their substitutes, and facilitate the transition to next-generation technologies.

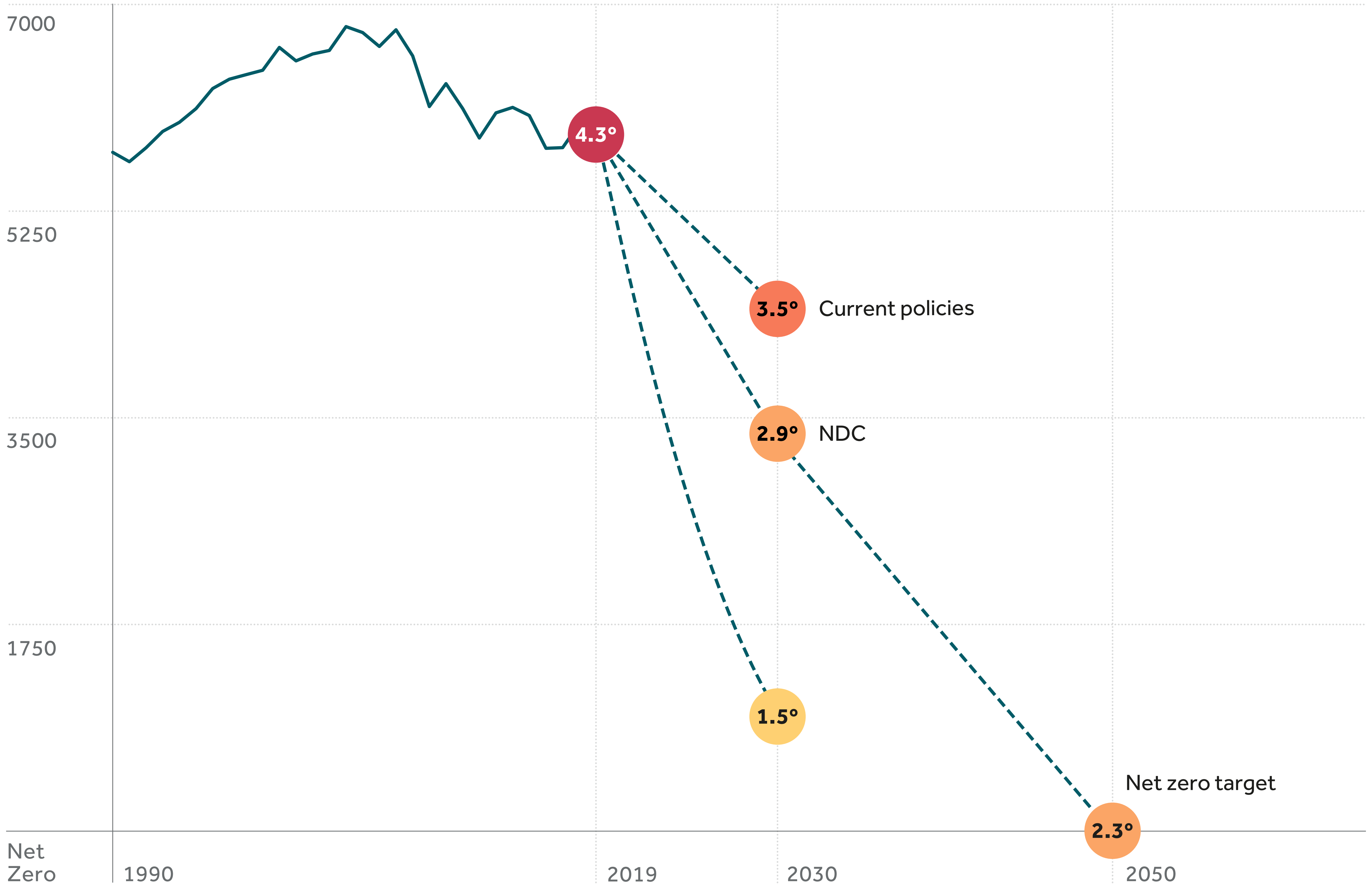
Inflation Reduction Act (IRA) (2022)[182] The IRA injects US $369billion in the form of tax credits, grants and loans directed to develop and deploy the clean energy technologies and investments that will be essential to decarbonization of the economy.

GDP
US$22,996 billion

Population
338 million

Under the United States' latest NDC, we estimate greenhouse gas emissions per capita would fall from 17.9 tons of CO_2e in 2019 to 9.5 tons by 2030. Its current policies imply a lower reduction to 12.7 tons over the same period.[179]

GHG Emissions ($MtCO_2e$)

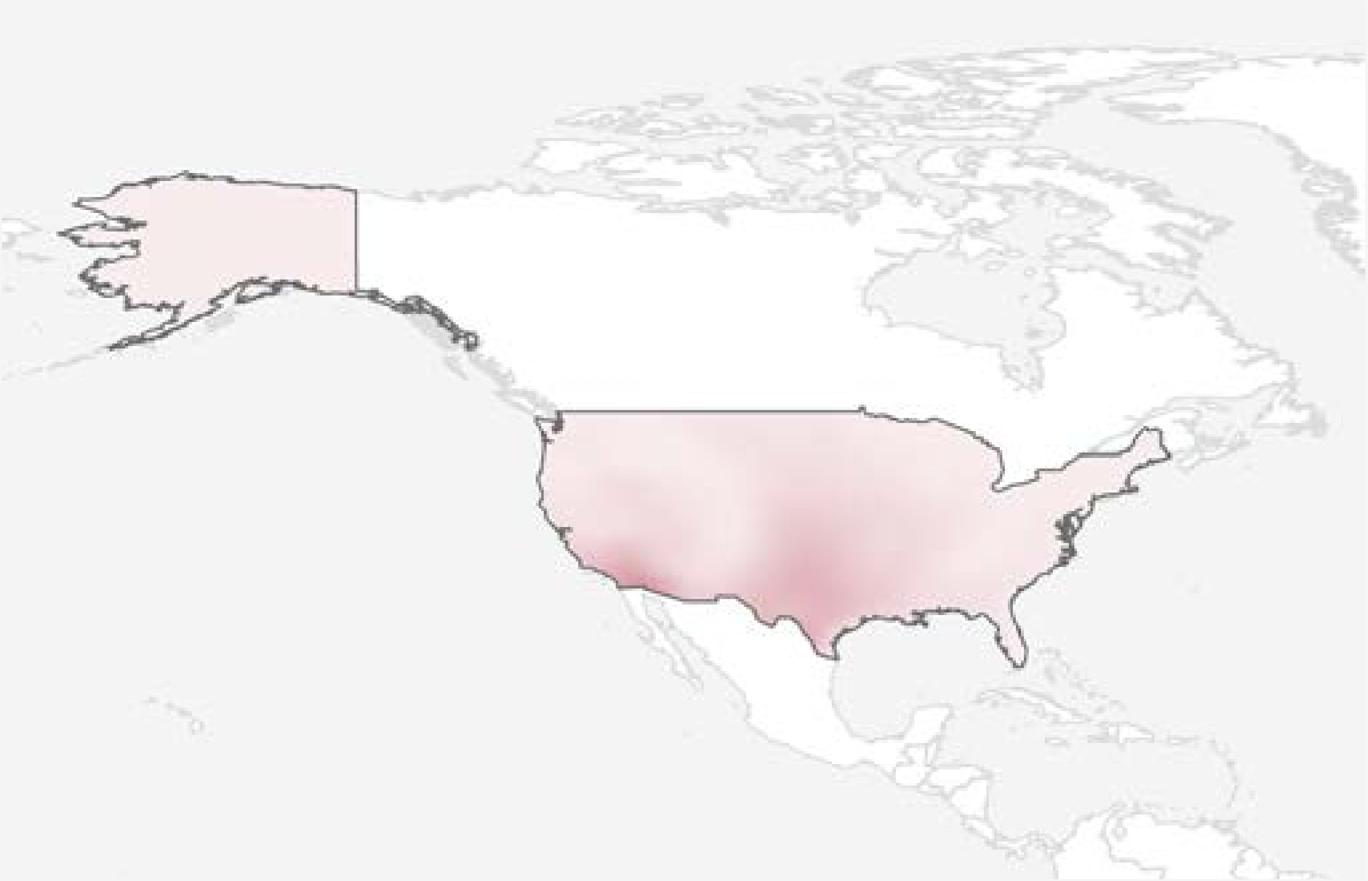


Implied temperature rise

<2° 2–3° 3–4° 4–5° 5–6° >6°

United States

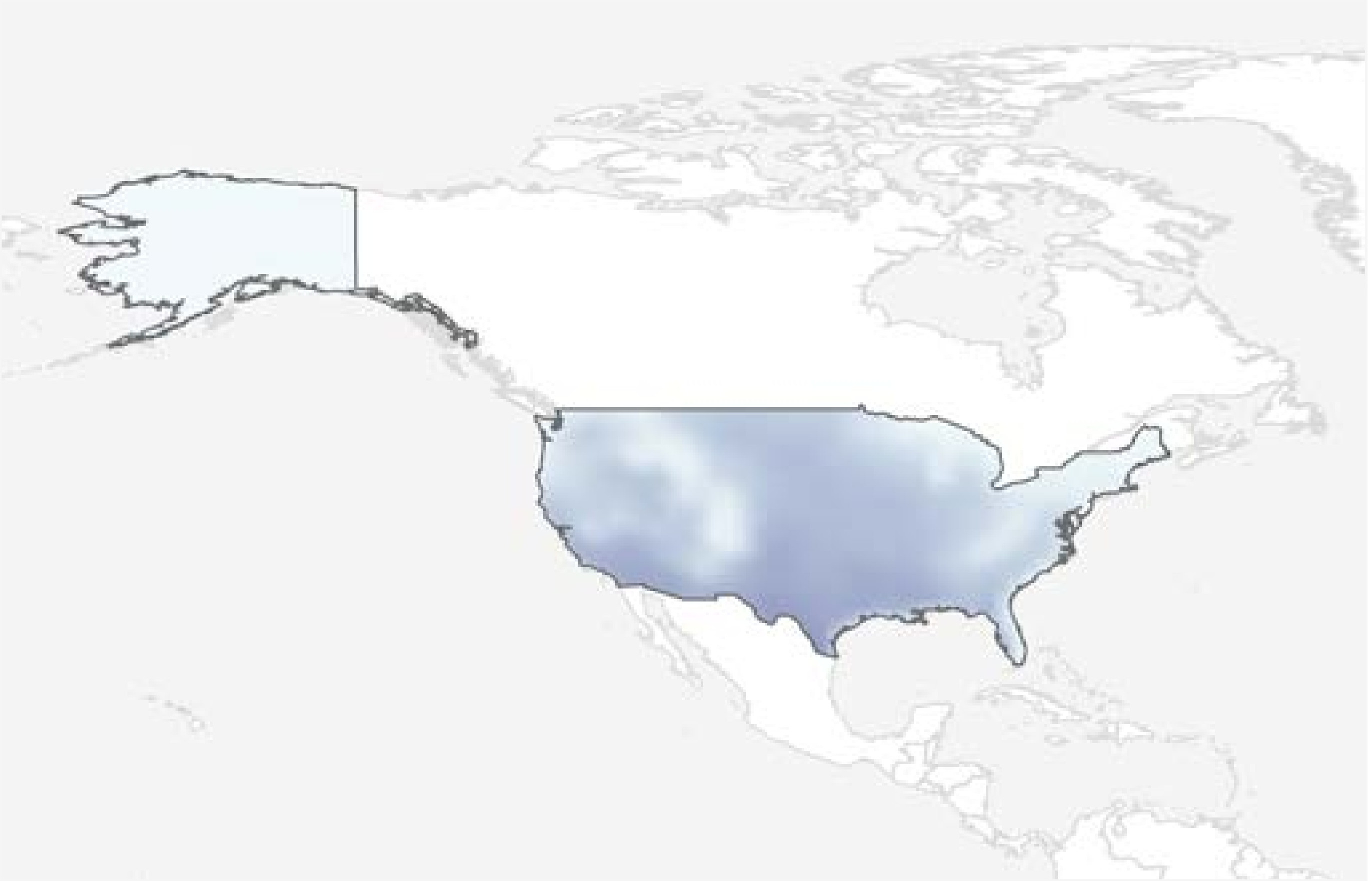
Historical exposure to heatwaves



0 days 150 days

Frequency of days above 35°C, based on global climate projections from the CMIP6 initiative.

Projected change in exposure to heatwaves by 2050



0 days +80 days

Summary of physical risk exposure

The United States has a variety of climates across its large landmass – from a Mediterranean climate in California to subtropical conditions in Florida, as well as mountainous and desert regions in its center. The impacts of climate change will therefore be highly diverse.

Rising temperatures across the country will affect residential and commercial energy consumption, in a country where almost 90% of households use air conditioning.[183] The increase in energy consumption for cooling is expected to be most significant in the southeast, costing up to US $600 million annually in Florida.[184] As a result of rising temperatures, labor productivity could decrease by 5% to 10% in the southern states.[185]

In the absence of adaptation, studies show that maize yields could significantly decrease (possibly by up to 18% by 2050[186]) in the agriculturally productive center and south of the country. As the US is one of the main global food exporters, agricultural impacts will push up food prices, and potentially destabilize global food security.

Drier and warmer conditions are also leading to an increase in wildfire risk across the US, particularly in California, where 14 of the 20 most intense wildfires have occurred in the past 10 years.[187] Destruction of properties in these populated areas is expected to rise.

The south and western coasts are highly exposed to storms and hurricanes that are expected to become increasingly intense in the coming decades, bringing stronger winds and higher rainfall accumulation. In turn, recovery periods between extreme hurricanes and storms may become potentially too short to allow for full repair of damaged property and infrastructure and contribute to significant population moves.

Recent events

Hurricane Harvey - 2017

Hurricane Harvey hit Texas in August 2017, causing US $125 billion in damage[188] according to the National Hurricane Center – the second most costly following Hurricane Katrina in 2005. Most damages were due to large-scale flooding caused by torrential rains that accompanied the storm as it made landfall three times in a week, impacting different areas of Texas, including highly populated Houston. Climate change impacts – on the atmosphere, ocean temperatures and sea level – are making storms and hurricanes more intense in the region.

2050 projections

Change in average temperature

+2.7°C

Change in precipitation

+0.6%

Change in water stress

+39%

European Union

European Union’s 2050 net zero target[189] is Paris-aligned, as is its latest 2030 NDC[190] target. However, we estimate its current policies to align with a 2°C+ trajectory.

GDP
US$17,089 billion

Population[192]
447 million

Under the EU’s latest NDC, we estimate greenhouse gas emissions per capita would fall from 7.6 tons of CO_2e in 2019 to 4.4 tons by 2030. Its current policies imply a reduction to 6 tons over the same period.[191]

Key climate-related policies

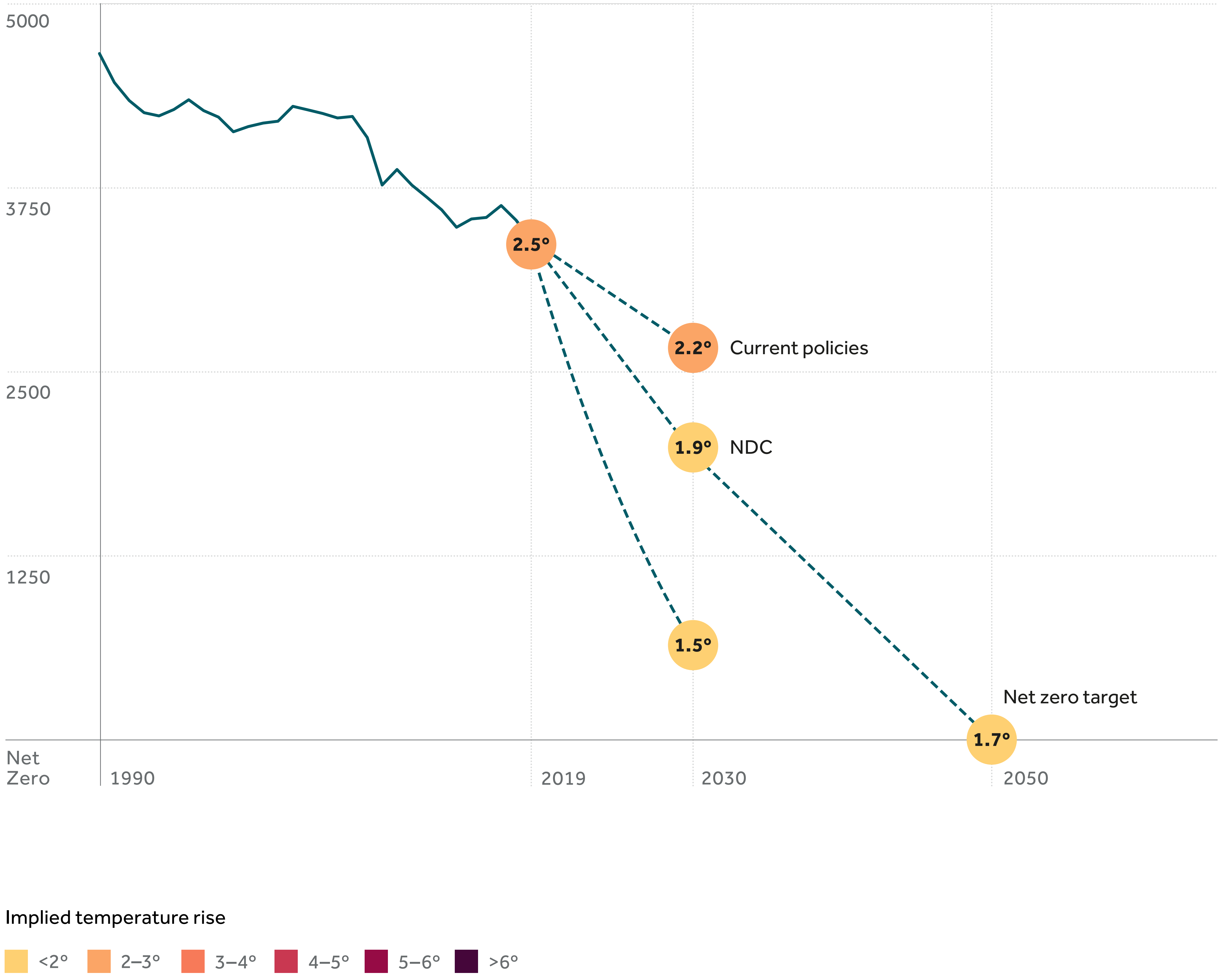
Fit for 55 package (2022 – in progress)[193] The package sets a wide range of legislative proposals to achieve the 2030 emissions reduction target. It includes the expansion of the current Emissions Trading System to cover additional sectors, updates to the Effort Sharing Regulation, improvements in the renewables and energy efficiency targets and a carbon border adjustment mechanism.

European Green Deal (2019)[194] This is a roadmap of key policies for achieving a transition to a low-carbon and sustainable economy, including the EU’s climate neutrality by 2050 target.

EU Farm to Fork Strategy (2020)[195] Part of the European Green Deal, it is a strategy published by the European Commission for promoting fair, healthy and environmentally friendly food systems.

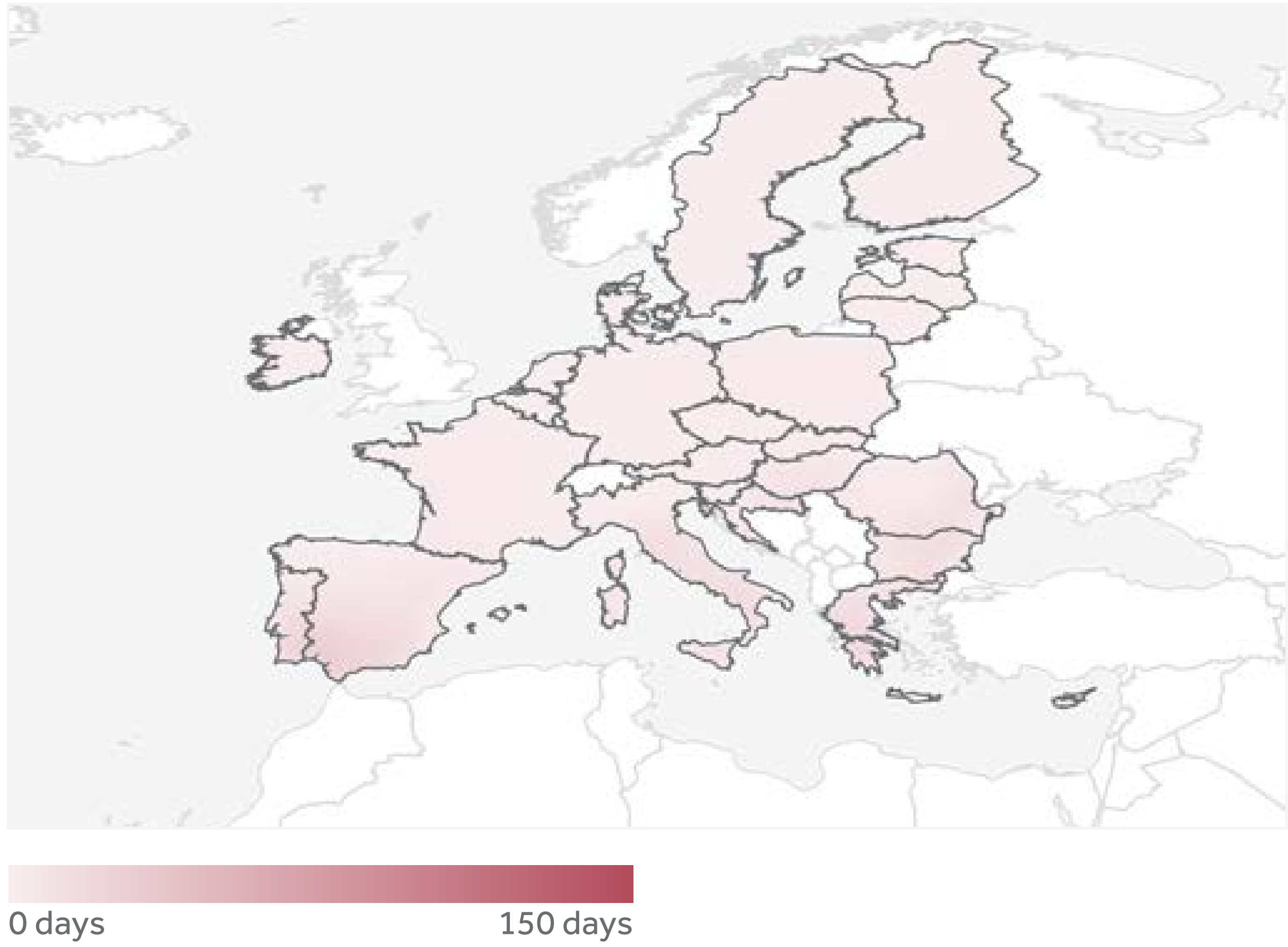
3 Billion Trees Pledge – map tree counter (2021)[196] Under the European Green Deal, the EU biodiversity strategy for 2030 commits to planting at least 3 billion additional trees in the EU by 2030 in respect of ecological principles.

GHG Emissions ($MtCO_2e$)



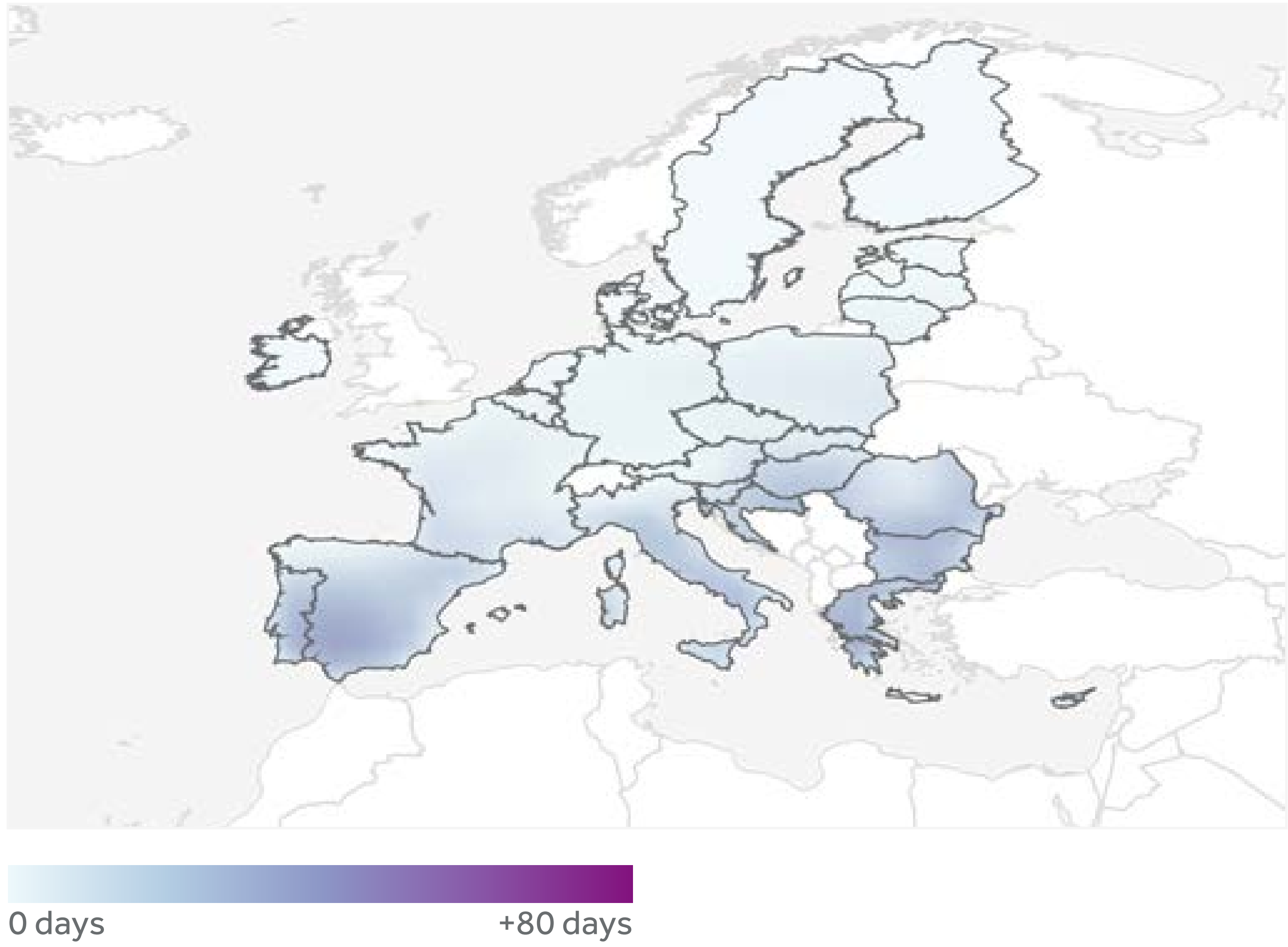
European Union

Historical exposure to heatwaves



Frequency of days above 35°C, based on global climate projections from the CMIP6 initiative.

Projected change in exposure to heatwaves by 2050



Recent events

The summer 2022 heatwaves
In the summer of 2022, much of Europe was hit by regular, persistent heatwaves that resulted in record-breaking temperatures in France, Italy, Portugal and Spain. Around 53,000 excess deaths were estimated, although further analysis is required to quantify the heat-related casualties.[198] The heatwaves were accompanied by droughts, leading to intense wildfires, especially in France and Italy. In northeast Italy, a glacier collapse caused an ice avalanche that killed 11 people. The total impact is yet to be calculated, but provide a possible snapshot of what the European climate could look like by the middle of the century.

2050 projections

Change in average temperature
+2.1°C

Change in precipitation
+0%

Change in water stress
-25%

Summary of physical risk exposure

The European Union, consisting of 27 different countries, has many diverse climates. From Scandinavia to the Mediterranean, it will therefore experience a variety of heterogenous impacts from climate change.

The effects of rising temperatures will vary strongly across Europe, with potential short-term benefits (e.g., increased crop yields) in the north and strong negative impacts in the Mediterranean regions. This could widen the existing inequality gap between northern and southern countries, and contribute to political instability.

In the southern and central regions, warmer and drier conditions, especially in spring and summer, can decrease food production and jeopardize the economy of highly specialized agricultural sectors. Life-threatening heat conditions are expected to occur more frequently in the Mediterranean, with maximum temperatures reaching 50°C.

Furthermore, flood risks are expected to increase, especially in northern Europe, where coastal areas are also threatened by sea-level rise. Adaptation measures (at the national scale in the Netherlands or at the local level as seen in Venice) could minimize these risks, although adaptation planning currently varies greatly across the EU. According to some estimates, annual expected damages from floods (currently estimated at EUR €1.25 billion), could reach hundreds of billions of euros in the absence of efficient adaptation measures.[197]

Annex

This annex includes a description of the data, methodologies and references used in our Implied Temperature Rise (ITR) evaluations and physical risk assessments.

A) CLAIM model

The methodology to define the national carbon budgets is critical in the determination of the ITR. We rely on the CLAIM methodology developed by Beyond Ratings.[1] It enables the computation of national GHG budgets compliant with any average temperature target and time horizon (for this report a 2°C compliant scenario is selected). The global budget sharing among countries is a source of scientific and diplomatic controversy. There are two main methodologies: the egalitarian approach and the grandfathering approach. Hybrid approaches are also possible (See Giraud et al. 2017 for further details[2]). The egalitarian approach consists of allocating the same right to emit carbon dioxide to every human being, while the grandfathering approach relies on the idea that the global carbon budget should be divided along the criterion of current carbon emissions, meaning that the weight of each country in global emissions remains stable over time. The CLAIM approach does not assign a national budget following a unique criterion, such as "capacity" or "responsibility." It offers a statistical, and non-normative, approach, which avoids choosing between egalitarian or grandfathering sharing that would be seen as non-consensual.

B) Database of decarbonization targets, trajectories, policies and sectoral abatement potentials

The ambition assessments presented within this report focus on the G20 countries. However, we rely on a database covering a wider set of countries, which allows for greater accuracy in the estimation of global ITR.

Historical emissions
Our historical GHG emissions inventories includes the land use, land-use change and forestry (LULUCF) sector. The emissions inventories from this sector are collected by IIASA based on UNFCCC and FAO reported emissions.[3] The emissions from the other sectors are based on the Primap-hist[4] database of the Potsdam Institute (mostly emissions from energy-use, industry and agriculture).

Net Zero targets
Our database currently covers 89 countries that have already set net zero commitments (See Figure 12 of this annex), representing 84% of global GHG emissions.[5] The database builds on information from 'Net Zero Tracker' from ClimateWatch.[6] These net zero targets can appear in a number of forms, with most countries presenting them as formal submissions to the UNFCCC or as national policy documents. However, commitments from several countries (including Saudi Arabia, for example) are currently only based on verbal pledges from political leaders. Our net zero emissions trajectories are harmonized on our historical inventories and are calibrated on the 'end point' announced by the countries, namely the horizon of their net zero target. (This is most often 2050, but some countries committed to achieve net zero emissions by 2060, like China, or 2045 like Germany.)

Figure 12: National Net Zero commitments[7]

	Law	Policy Document	Oral Political Pledge
Now		Bhutan, Benin, Comoros, Madagascar, Suriname	Guyana
2030		Barbados, Maldives	
2035	Finland		
2040		Iceland, Austria, Antigua and Barbuda	
2045	Germany, Sweden	Nepal	
2050	Australia, Canada, Denmark, EU27, Fiji, France, Hungary, Ireland, Japan, South Korea, Luxembourg, Portugal, Spain, United Kingdom, New Zealand	Andorra, Armenia, Belize, Brazil, Cabo Verde, Cambodia, Chile, Colombia, Costa Rica, Croatia, Dominican Republic, Italy, Lao PDR, Latvia, Malta, Marshall Islands, Monaco, Namibia, Nauru, Norway, Panama, Seychelles, Slovenia, Solomon Islands, South Africa, Switzerland, Turkey, United States, Uruguay	Argentina, Estonia, Israel, Jamaica, Malawi, Malaysia, United Arab Emirates, Thailand, Vietnam
2060	Russia	China, Indonesia, Nigeria, Singapore, Sri Lanka, Ukraine	Bahrain, Kazakhstan, Saudi Arabia
2070		India	Mauritius

Sources: FTSE Russell & Beyond Ratings Research based on Climate Watch and Net Zero Tracker data.

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NDC targets

The 194 country parties to the Paris Agreement have submitted a Nationally Determined Contribution (NDC), as required. However only 131 of these NDCs are concrete enough to be quantifiable, representing 93.1% of global emissions. The commitments of some developing countries have both conditional (to financing) and unconditional parts. In our assessments, we consider only the unconditional component of the NDC targets.

As part of the Paris Agreement,[8] countries had committed to update their NDCs prior to COP26. At the time of writing,[9] only 128 countries,[10] representing 91.6% of global emissions, have submitted a new or updated NDC, of which only 106 are quantifiable. Additionally, since our last report (prior to COP26), 37 countries submitted new NDCs, representing 48% of global emissions. Our NDC emissions trajectories are harmonized on our historical inventories and are calibrated on the 'end point' in 2030 deduced from the information provided by the countries in their NDCs.

Current Policies trajectories

In this report, we use 'current policies' emissions trajectories constructed by the NewClimate Institute and IIASA that provide annual emissions estimates from 2021 to 2030. Both institutes have a long history in estimating the impact of current policies on future GHG emissions. The methods used for developing the current policy scenarios are presented in detail in Nascimento et al. (2021)[11] and described in detail elsewhere (Kuramochi et al., 2018,[12] 2021;[13] den Elzen et al., 2019;[14] Fekete et al., 2021[15]), see also our COP26 Net Zero Atlas.[16]

The NewClimate Institute/IIASA database of current policy trajectories update for this report covers the G20 countries, accounting for 75% of global emissions. See Figure 13 for illustration. For France, Italy and Germany, which are only available in aggregated form as part of the EU27 in the NewClimate and IIASA datasets, we use the reference scenarios produced in the framework of the 'Fit for 55' package.[17] Our 'current policies' emissions trajectories are based eventually on the growth rates (between 2019 and 2030) deduced from the trajectories provided by NewClimate and IIASA and harmonized on our historical inventories.

Other data

G20 GDP and population data were source from Trading Economics[18] and The World Population Review.[19]

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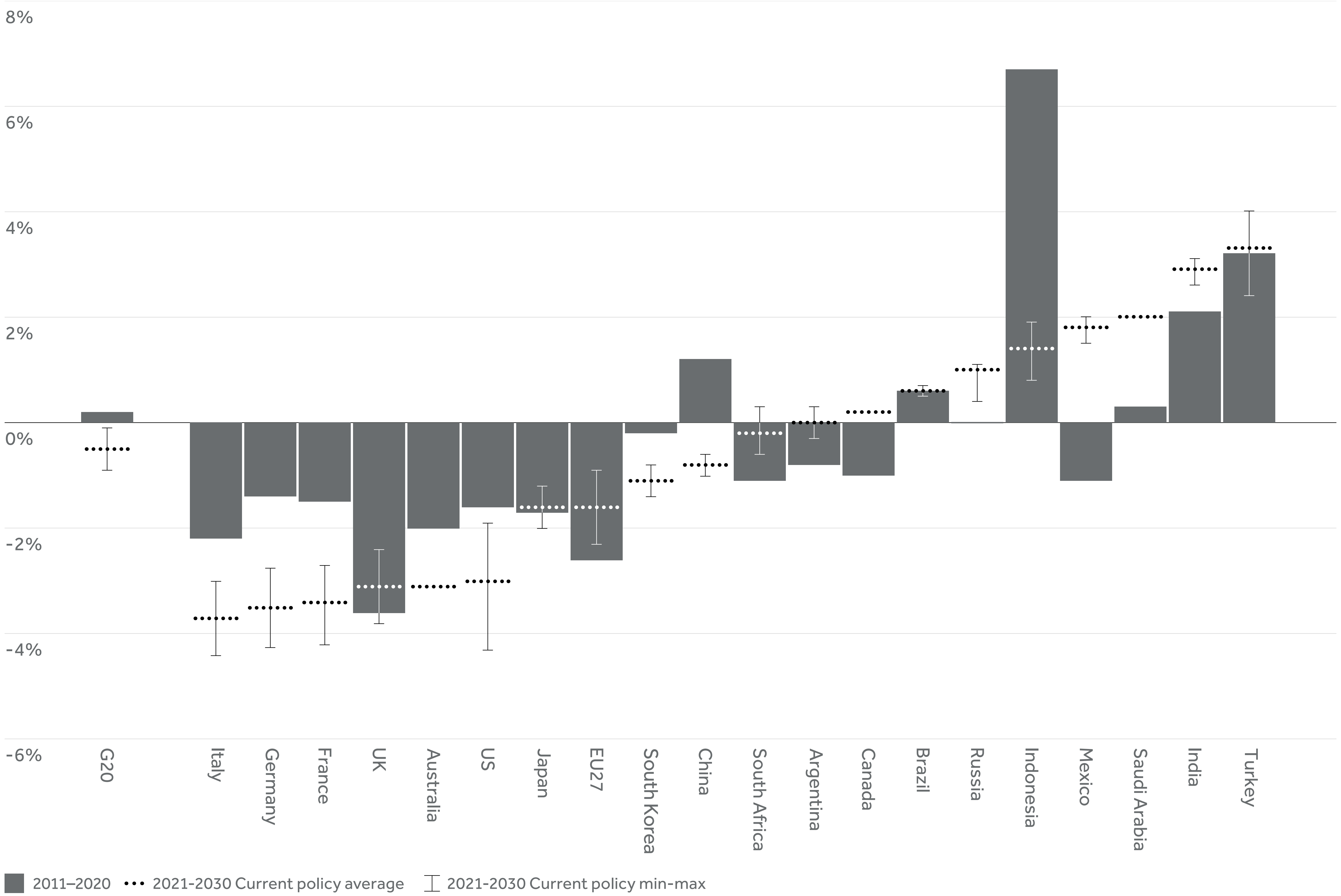
Figure 13: Projected emissions growth in the G20 countries based on current policies – comparison between previous decade and next decade



Source: Research from IIASA and NewClimate Institute, update from Nascimento et al., 2021.[20]

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Figure 14: Implied Temperature Rise for G20 countries (COP27 values)

Country	NDC Targets (2030)	Net Zero Targets (2050)	Current policies (2030)
India	1.6	1.4	1.6
France	1.7	1.6	1.8
United Kingdom	1.7	1.5	1.9
Italy	1.8	1.6	1.9
Mexico	1.8	2.9	1.8
European Union	1.9	1.6	2.2
Germany	1.9	1.7	2.3
South Africa	2.2	1.6	2.5
Japan	2.3	1.9	2.6
Brazil	2.3	1.6	2.4
Indonesia	2.4	1.7	2.4
Argentina	2.4	1.6	2.5
South Korea	2.8	2.2	3.3
United States	2.9	2.3	3.5
China	2.9	2.3	2.8
Turkey	2.9	1.5	2.6
Canada	3.2	2.3	4.5
Australia	3.5	2.3	3.5
Russia	4.0	2.5	3.4
Saudi Arabia	4.5	2.8	4.8

Source: FTSE Russell & Beyond Ratings Research

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Figure 15: National climate commitments within our database – 1 of 10 (The cut-off date for new commitments was October 15th 2022).

Country	Quantifiable NDC Target	Updated/New NDC before COP27	Current Policies	Net-zero target
Afghanistan				
Albania	•	•		
Algeria				
Andorra		•		•
Angola	•	•		
Antigua and Barbuda		•		•
Argentina	•	•	•	•
Armenia	•	•		
Australia	•	•	•	•
Austria	•	•	•	•
Azerbaijan	•			
Bahrain		•		•
Bangladesh	•	•		
Barbados	•	•		•
Belarus	•	•		
Belgium	•	•	•	•
Belize		•		•
Benin	•	•		•
Bhutan		•		•
Bolivia		•		

Source: FTSE Russell & Beyond Ratings Research

Figure 15: National climate commitments within our database – 2 of 10 (The cut-off date for new commitments was October 15th 2022).

Country	Quantifiable NDC Target	Updated/New NDC before COP27	Current Policies	Net-zero target
Bosnia & Herzegovina	●	●		
Botswana	●			
Brazil	●	●	●	●
Brunei				
Bulgaria	●	●	●	●
Burkina Faso	●	●		
Burundi	●	●		
Cabo Verde		●		●
Cambodia		●		●
Cameroon	●	●		
Canada	●	●	●	●
Central African Republic	●	●		
Chad	●	●		
Chile	●	●	●	●
China	●	●	●	●
Colombia	●	●	●	●
Comoros	●	●		
Congo	●	●		
Cook Islands				
Costa Rica	●	●		●

Source: FTSE Russell & Beyond Ratings Research

Figure 15: National climate commitments within our database – 3 of 10 (The cut-off date for new commitments was October 15th 2022).

Country	Quantifiable NDC Target	Updated/New NDC before COP27	Current Policies	Net-zero target
Côte d'Ivoire	●			
Croatia	●	●	●	●
Cuba		●		
Cyprus	●	●	●	●
Czech Republic	●	●	●	●
Dem. People's Rep. Korea		●		
Dem. Rep. Congo	●	●	●	
Denmark	●	●	●	●
Djibouti				
Dominica		●		
Dominican Republic	●	●		●
Ecuador	●	●		●
Egypt		●		
El Salvador		●		
Equatorial Guinea				
Eritrea	●			
Estonia	●	●	●	●
Eswatini		●		
Ethiopia	●	●	●	
Fiji		●		●

Source: FTSE Russell & Beyond Ratings Research

Figure 15: National climate commitments within our database – 4 of 10 (The cut-off date for new commitments was October 15th 2022).

Country	Quantifiable NDC Target	Updated/New NDC before COP27	Current Policies	Net-zero target
Finland	•	•	•	•
France	•	•	•	•
Gabon	•	•		
Georgia	•	•		
Germany	•	•	•	•
Ghana	•	•		
Greece	•	•	•	•
Grenada		•		
Guatemala	•	•		
Guinea	•	•		
Guinea-Bissau	•	•		•
Guyana				•
Haiti	•	•		
Honduras	•	•		
Hungary	•	•	•	•
Iceland	•	•		•
India	•	•	•	•
Indonesia	•	•	•	•
Iran	•			
Iraq	•			

Source: FTSE Russell & Beyond Ratings Research

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Figure 15: National climate commitments within our database – 5 of 10 (The cut-off date for new commitments was October 15th 2022).

Country	Quantifiable NDC Target	Updated/New NDC before COP27	Current Policies	Net-zero target
Ireland	•	•	•	•
Israel	•	•	•	•
Italy	•	•	•	•
Jamaica	•	•		•
Japan	•	•	•	•
Jordan	•	•		
Kazakhstan	•		•	•
Kenya	•	•		
Kiribati				
Korea	•	•	•	•
Kuwait	•	•		
Kyrgyz Republic	•	•		
Lao PDR	•	•		•
Latvia	•	•	•	•
Lebanon	•	•		
Lesotho				
Liberia	•	•		
Libya				
Liechtenstein				
Lithuania	•	•	•	•

Source: FTSE Russell & Beyond Ratings Research

Figure 15: National climate commitments within our database – 6 of 10 (The cut-off date for new commitments was October 15th 2022).

Country	Quantifiable NDC Target	Updated/New NDC before COP27	Current Policies	Net-zero target
Luxembourg	●	●	●	●
Madagascar				●
Malawi	●	●		
Malaysia	●	●	●	●
Maldives		●		●
Mali	●	●		
Malta	●	●	●	●
Marshall Islands		●		●
Mauritania	●	●		
Mauritius	●	●		●
Mexico	●	●	●	●
Micronesia				
Moldova	●	●		
Monaco		●		●
Mongolia	●	●		
Montenegro	●	●		
Morocco	●	●	●	
Mozambique		●		
Myanmar		●		
Namibia	●	●		●

Source: FTSE Russell & Beyond Ratings Research

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Figure 15: National climate commitments within our database – 7 of 10 (The cut-off date for new commitments was October 15th 2022).

Country	Quantifiable NDC Target	Updated/New NDC before COP27	Current Policies	Net-zero target
Nauru		●		●
Nepal		●		●
Netherlands	●	●	●	●
New Zealand	●	●		●
Nicaragua		●		
Niger	●	●		
Nigeria	●	●		●
Niue				
North Macedonia	●	●		
Norway	●	●	●	●
Oman	●	●		
Pakistan	●	●		
Palau				
Panama		●		●
Papua New Guinea		●		
Paraguay	●	●		
Peru	●	●		
Philippines	●		●	
Poland	●	●	●	●
Portugal	●	●	●	●

Source: FTSE Russell & Beyond Ratings Research

Figure 15: National climate commitments within our database – 8 of 10 (The cut-off date for new commitments was October 15th 2022).

Country	Quantifiable NDC Target	Updated/New NDC before COP27	Current Policies	Net-zero target
Qatar		●		
Romania	●	●	●	●
Russia	●		●	●
Rwanda	●	●		
Samoa		●		
San Marino				
São Tomé and Principe		●		
Saudi Arabia	●	●	●	●
Senegal	●			
Serbia	●	●		
Seychelles	●	●		●
Sierra Leone		●		
Singapore	●	●	●	●
Slovak Republic	●	●	●	●
Slovenia	●	●	●	●
Solomon Islands		●		●
Somalia		●		
South Africa	●	●	●	●
South Sudan		●		
Spain	●	●	●	●

Source: FTSE Russell & Beyond Ratings Research

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Figure 15: National climate commitments within our database – 9 of 10 (The cut-off date for new commitments was October 15th 2022).

Country	Quantifiable NDC Target	Updated/New NDC before COP27	Current Policies	Net-zero target
Sri Lanka		●		●
St. Kitts and Nevis		●		
St. Lucia		●		
St. Vincent and the Grenadines		●		
Sudan		●		
Suriname		●		●
Sweden	●	●	●	●
Switzerland	●	●		●
Syrian Arab Republic				
Tajikistan	●	●		
Tanzania	●	●		
Thailand	●	●	●	●
The Bahamas				
The Gambia		●		
Timor-Leste				
Togo	●	●		
Tonga		●		
Trinidad and Tobago	●			
Tunisia	●	●		
Turkey	●		●	●

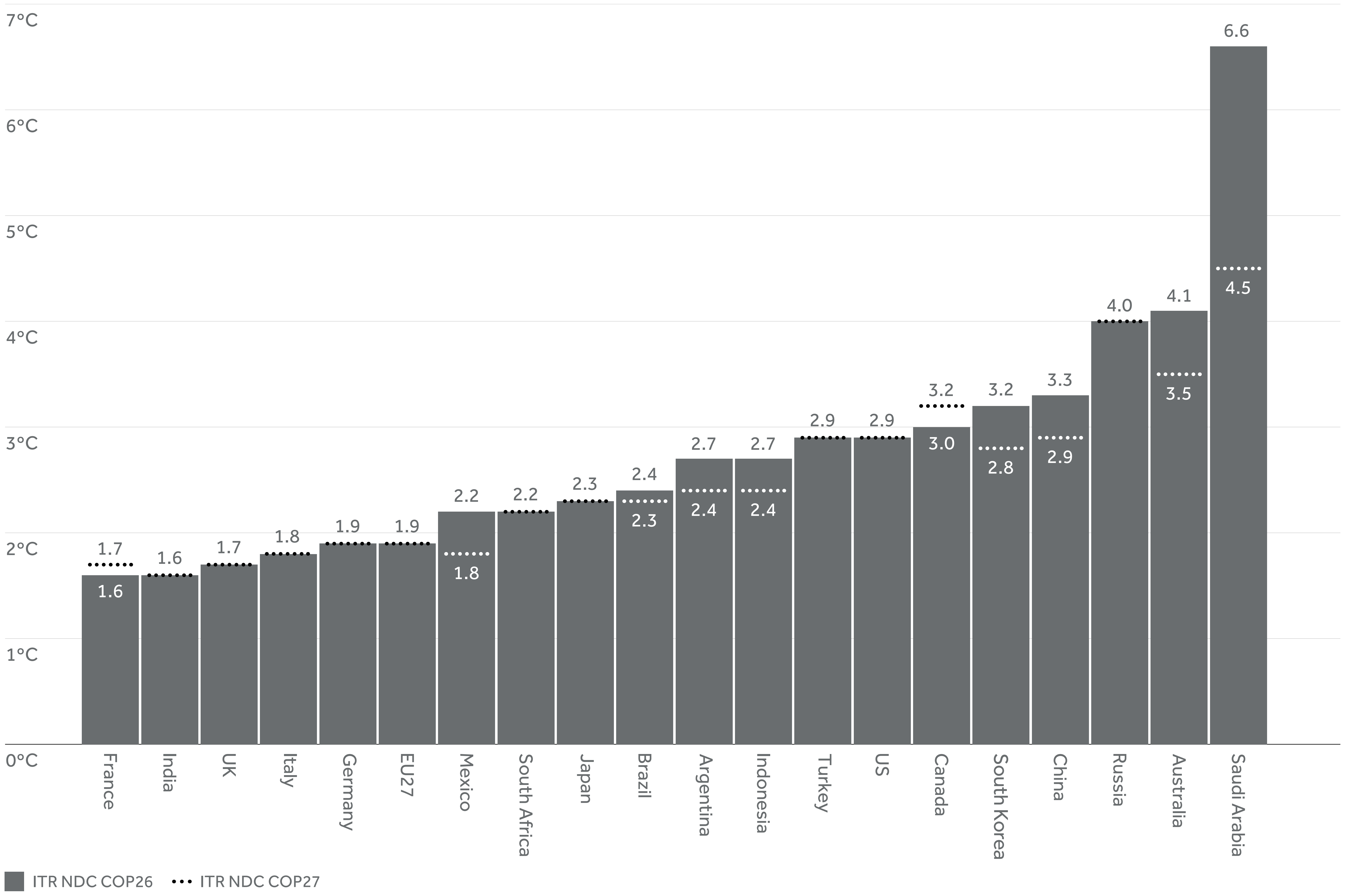
Source: FTSE Russell & Beyond Ratings Research

Figure 15: National climate commitments within our database – 10 of 10 (The cut-off date for new commitments was October 15th 2022).

Country	Quantifiable NDC Target	Updated/New NDC before COP27	Current Policies	Net-zero target
Turkmenistan				
Tuvalu				
Uganda	•	•		
Ukraine	•	•	•	•
United Arab Emirates	•	•		•
United Kingdom	•	•	•	•
United States	•	•	•	•
Uruguay	•			•
Uzbekistan	•	•		
Vanuatu		•		
Venezuela	•	•		
Vietnam	•	•		•
Yemen				
Zambia		•		
Zimbabwe		•		

Source: FTSE Russell & Beyond Ratings Research

Figure 16: Implied Temperature Rise for selected countries based on NDCs from the COP26 and COP27 for the G20 countries (in degree Celsius)



Source: FTSE Russell & Beyond Ratings Research

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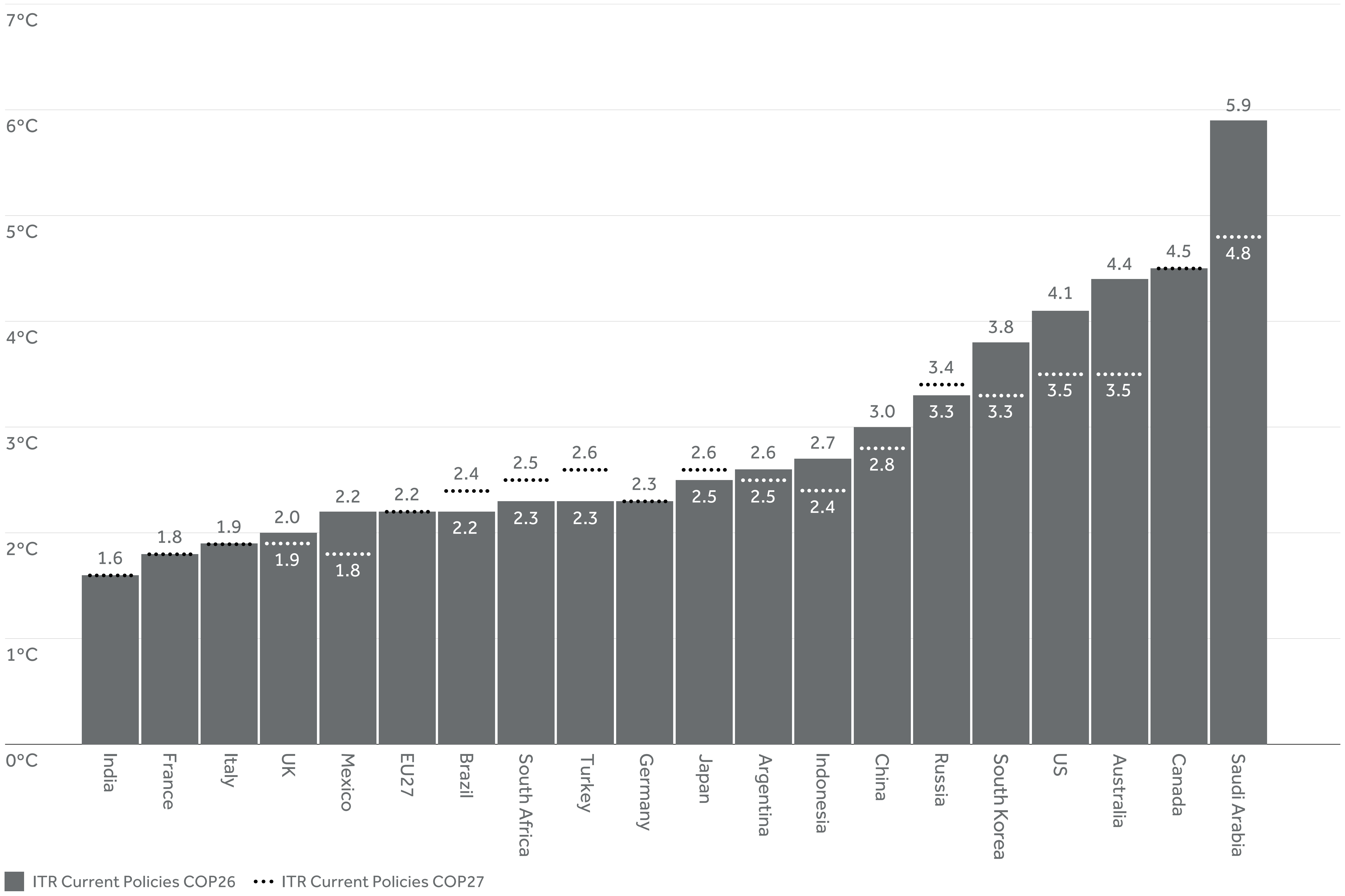
Figure 17: Implied Temperature Rise for selected countries based on current policies from the COP26 and COP27 for the G20 countries (in degree Celsius)



Source: FTSE Russell & Beyond Ratings Research

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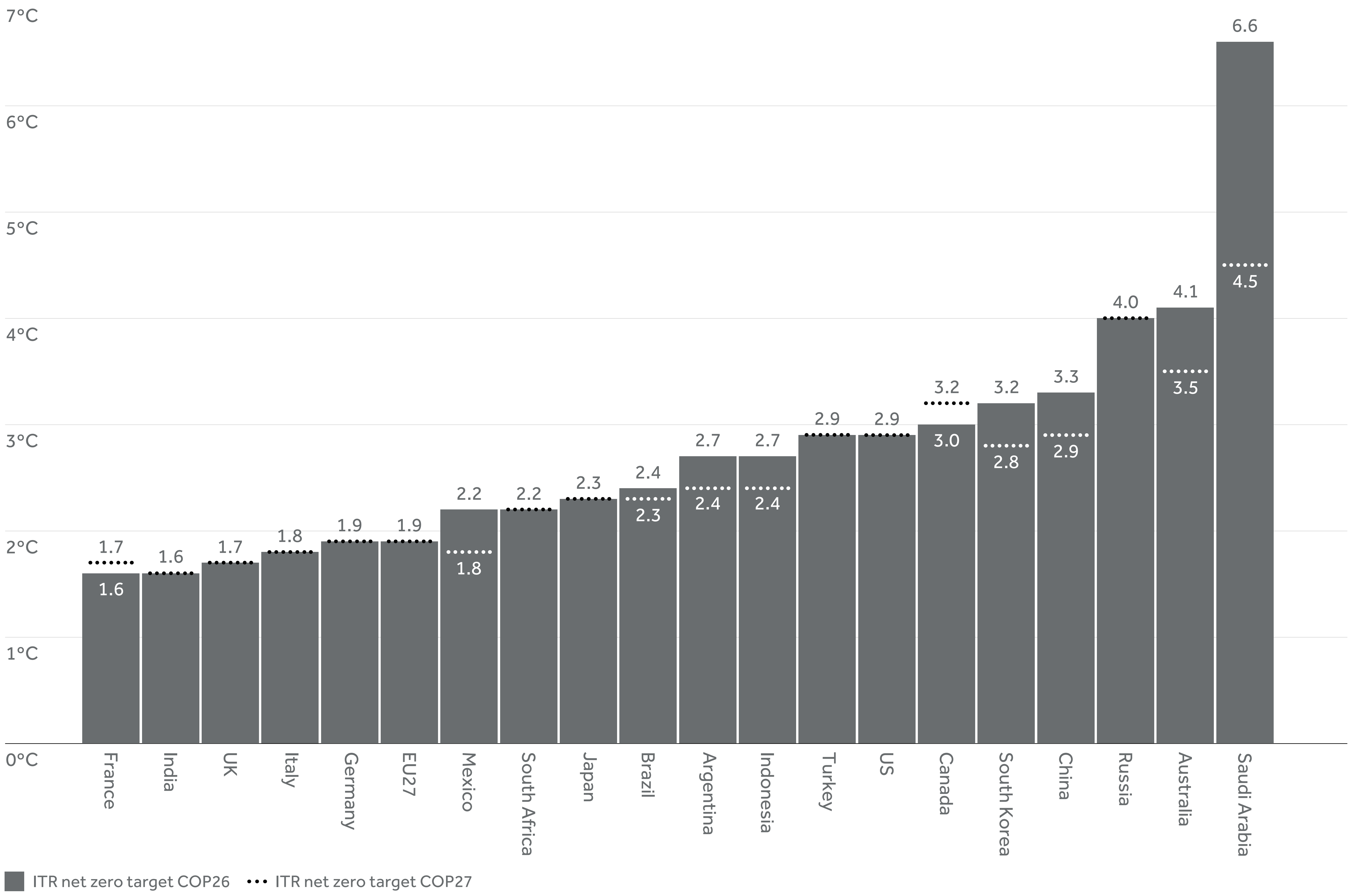
Figure 18: Implied Temperature Rise for selected countries based on Net Zero Targets from the COP26 and COP27 for the G20 countries (in degree Celsius)



Source: FTSE Russell & Beyond Ratings Research

Climate data processing

For each hazard described in the country profiles (average temperature, frequency of very hot days, precipitation and frequency of dry days), we use raw climate data to calculate specific indicators that describe the hazard's frequency and/or intensity. For instance, raw data describing the daily maximum temperature are processed into a frequency of heatwaves. We analyzed both past and forward-looking exposures to climate hazards for each country. Details of the periods of interest for each hazard can be found in Figure 19.

Forward-looking data is based on the IPCC SSP5-8.5 climate scenario,[21] following a 'hope for the best, plan for the worst' type of approach. It is worth noting that, before 2050, the choice of scenario is not the main driver of climate uncertainty, since the different scenarios start to diverge around mid-century. However, to account for the climate models uncertainty and to avoid relying on a single model, we perform a multi-model analysis. For each country and each indicator, we extract the multi-model average value for the country and all climate models used for the analysis.

Figure 19: List of climate indicators used to describe current or recent and future climate hazards

Hazard	Climate indicator	Historical	Future	Raw climate data source
Heatwaves	Number of days with temperature higher than 35°C in a year	2005	2050	CMIP6 climate modelling initiative **Download from ESGF platform** *(see figure 20 for details of the models)*
Droughts	Number of dry days in a year	2005	2050	CMIP6 climate modelling initiative **Download from ESGF platform** *(see figure 20 for details of the models)*
Water stress	Water stress index (ratio of water demand over water supply)	2020	2040	World Resources Institute
Coastal floods	Inundation depth for a 1/100-year event (inundation caused by storm surge)	2020	2050	World Resources Institute
Temperature	Average annual temperature	NA	2050	CMIP6 climate modelling initiative **Download from ESGF platform** *(see figure 20 for details of the models)*

Source: Beyond Ratings.

Chapter 2: Physical Risk

Data sources

Raw climate data are taken from global climate models or specific models for floods and water stress. To account for short-term variations of the climate system, long-term average values are required to adequately represent past and future climate. Here, we use averages over 20-year time segments: the climate indicators for the historical and 2050 periods are the result of the average over 1995-2014 and 2041-2060, respectively.

Figure 20: List of climate models

Data	Source
CMCC-ESM2	Centro Euro-Mediterraneo sui Cambiamenti Climatici (Italy)
MPI-ESM1-2-HR	Max Planck Institute for Meteorology (Germany)
NorESM2-MM	Norwegian Meteorological Institute and NORCE Norwegian Research Centre AS (Norway)
EC-Earth-3	30 research institutes from 12 European countries
HadGEM3-GC31-MM	Met Office Hadley Centre (UK)
MIROC6	Center for Climate System, University of Tokyo, Japan Agency for Marine-Earth Science and Technology, and National Institute for Environmental Studies (Japan)

Source: Beyond Ratings.

Endnotes

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1 More detail can be found in Emin, G. et al., 2021, How to measure the temperature of sovereign assets, FTSE Russell [FTSE Russell]

2 The population projections are based on UNdata.

3 Based on research from IIASA and NewClimate Institute, updating emissions projections from Nascimento, L.et al., 2021, Tracking climate mitigation efforts in 30 major emitters: Economy-wide projections and progress on key sectoral policies.

4 The CLAIM model enables the computation of national GHG budgets compliant with any average temperature target and time horizon (2°C compliant scenario here). This method does not assign a national budget following a unique criterion – such as "capacity" or "responsibility." It offers a statistical, and non-normative, approach, which avoids choosing between either egalitarian or "grandfathering" sharing that would be seen as non-consensual (see Giraud et al. 2017 for further details).

5 See on the NGFS Scenario Explorer hosted by IIASA. [NGFS]

6 To calculate the implied temperature rise (referred to as the "2019 level" in the ambition cards), we suppose that annual GHG emissions do not change until 2030 and remain at their 2019 level.

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169 United Kingdom First NDC (Updated Submission) | Emissions reductions of 68% below 1990 levels by 2030 [UNFCCC]

170 IIASA and NewClimate Institute | Tracking climate mitigation efforts in 30 major emitters from Nascimento, L.et al., 2021 [New Climate Institute]

Chapter 4: Country Profiles

171 The Ten Point Plan for a Green Industrial Revolution [HM Government]

172 Energy White Paper (2020) [GOV]

173 The World Bank Climate Change Knowledge Portal - Climate Risk Profile - United Kingdom (2021). [World Bank]

174 House of Lords Library - Housing developments on functional flood plains (2021) [House of Lords]

175 Sayers, P., et al., Responding to climate change around England's coast - The scale of the transformational challenge, Ocean & Coastal Management, Volume 225, 106187 (2022) [Science Direct]

176 Environment Agency - The costs and impacts of the winter 2013 to 2014 floods (2014) [GOV UK]

United States

177 Net zero target year: 2050 [The Long-Term Strategy of the United States]

178 USA First NDC (After rejoining the Paris Agreement): Emissions reductions of at 50-52% below 2005 levels by 2030 [UNFCCC]

179 IIASA and NewClimate Institute | Tracking climate mitigation efforts in 30 major emitters from Nascimento, L.et al., 2021 [New Climate Institute]

180 Regulations for Greenhouse Gas Emissions from Passenger Cars and Trucks [EPA]

181 Final Rule - Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program under the AIM Act [EPA]

182 Preliminary Report: The Climate and Energy Impacts of the Inflation Reduction Act of 2022 [Repeat]

183 US Energy Information Administration (2022) [EIA]

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187 Department of Forestry and Fire Protection California (2022) [Fire Cal]

188 Amadeo, K. Hurricane Harvey Facts, Damage and Costs (2019) [Lamar]

European Union

189 Net zero target year: 2050 [European Climate Law 2021]

190 European Union First NDC (Updated submission): Emissions reductions of at least 55% below 1990 levels by 2030 [UNFCCC]

191 IIASA and NewClimate Institute | Tracking climate mitigation efforts in 30 major emitters from Nascimento, L.et al., 2021 [New Climate Institute]

192 Eurostat, Population and population change statistics. [Eurostat]

193 Fair, just and deliverable: EU's "Fit for 55" climate package success hinges on bringing every city and region on board [COR]

194 A European Green Deal [COR]

195 Farm to Fork strategy [European Commission]

194 3 Billion Trees Pledge [European Commission]

195 Vousdoukas, Michalis I., et al. Climatic and socioeconomic controls of future coastal flood risk in Europe Nature Climate Change 8.9 (2018): 776-780. [Nature]

196 Eurostat - Excess mortality hits +16%, highest 2022 value so far (2022) [EC Europa]

Annex: Data & Methodologies

1 How to measure the temperature of sovereign assets [FTSE Russell]

2 National Carbon Reduction Commitments: Identifying the Most Consensual Burden Sharing [Archives]

3 For further information please contact forsell@iiasa.ac.at

4 The PRIMAP-hist national historical emissions time series (1750-2019) [HISTCR dataset]

5 Based on 2019 GHG emissions

6 Net-zero Target Status | Net-Zero Targets | Climate Watch [Climate Watch]

7 FTSE Russell & Beyond Ratings Research based on Climate Watch and Net Zero Tracker data. Notes: 1) Singapore committed to reaching net-zero GHG-emissions "by or around mid-century". We take 2060 as a target date for this target; 2) Mexico has set a 50% emissions reduction target by 2050 compared to 2000 level. We do not include this within this diagram, but use this to compute a temperature associated with it as part of our "Net Zero" mid-century targets.; 3) A number of countries (Bhutan, Benin, Comoros, Guyana, Madagascar, Suriname) have proclaimed that they have already reach net zero or carbon neutrality. 4) Note that Turkey's Net Zero target has a target data of 2053. 5) There are a 10 EU member states that do not have domestic net zero targets (i.e. in addition to the EU's target) and so do not appear on this chart. [Climate watch and FTSE Russell]

8 Article 4 of the Agreement defines an iterative process consisting in a new/updated and more ambitious NDC every five years. The first (I)NDCs were submitted in the context of COP21, implying there will be a new batch of NDCs for COP26. [UNFCCC Paris Agreement]

9 20th of October 2021

10 The 27 Member States of the European Union are included in this group, although there is only one official NDC submitted by the EU on behalf of its Member States

11 IIASA and NewClimate Institute | Tracking climate mitigation efforts in 30 major emitters from Nascimento, L.et al., 2021 [New Climate Institute]

12 Greenhouse Gas Mitigation Scenarios For Major Emitting Countries – Analysis Of Current Climate Policies And Mitigation Commitments: 2021 Update [New Climate Institute]

13 Greenhouse gas emission scenarios in nine key non-G20 countries: An assessment of progress toward 2030 climate targets [Science Direct]

14 Are the G20 economies making enough progress to meet their NDC targets? [Science Direct]

15 A review of successful climate change mitigation policies in major emitting economies and the potential of global replication [Science Direct]

16 The COP26 Net Zero Atlas, FTSE Russell [FTSE Russell]

17 EU Reference Scenario 2020 [European Commission]

18 List of G20 Countries [Trading economics]

19 G20 Countries 2022 [World population review]

20 IIASA and NewClimate Institute | Tracking climate mitigation efforts in 30 major emitters from Nascimento, L.et al., 2021 [New Climate Institute]

21 Shared Socio-economic Pathways (SSPs) have been developed to complement the existing greenhouse gas emission pathways (Representative Concentration Pathways or RCPs) with socio-economic scenarios. SSP5 assumes a rapid growth of the global economy, fossil fuel-developed and energy-intensive, leading to a strong increase in greenhouse gases, with large socio-economic challenges to mitigation, but more technological means to reduce vulnerability (Kriegler et al., 2016). SSP5-8.5 represents the high end of the range of future pathways, leading to a global warming of 4 to 5°C by 2100 (IPCC, 2021), 8.5W/m² being the excess energy flux in the atmosphere (or radiative forcing) due to the anthropogenic greenhouse effect expected in 2100.

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