CLIMATE ANALYTICS

PIK

Rescuing 1.5°C

New evidence on the highest possible ambition to deliver the Paris Agreement

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About Climate Analytics

Climate Analytics is a global climate science and policy institute. Our mission is to deliver cutting-edge science, analysis and support to accelerate climate action and keep warming below 1.5°C.

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Summary

Due to insufficient action in recent years, the world will very likely reach 1.5°C of warming by the early 2030s. This means the world is headed towards a period of overshoot of the Paris Agreement's 1.5°C limit.

The high risks and damages of overshooting 1.5°C have been well established by the scientific community. Policy needs to now focus on limiting both the magnitude and duration of overshoot to bring warming back below 1.5°C before 2100.

Overshooting 1.5°C does not mean we need change the Paris Agreement's goals, but rather double down on their implementation. 1.5°C was chosen for good reason. Ten years on from Paris, the science is starker than ever – 1.5°C is planetary limit beyond which climate impacts escalate and risk triggering catastrophic tipping points.

Legally, morally and politically, the Paris Agreement's 1.5°C limit stands. It now acts as a North Star, guiding ambition and action for the world to avoid long-term overshoot of 1.5°C and the catastrophic impacts this would entail.

This new study shows how to limit the overshoot of 1.5°C to the lowest possible level and return warming back well below 1.5°C by 2100 by looking at the highest possible ambition that could be undertaken by countries, starting in 2025.

What does the 1.5°C limit in the Paris Agreement mean?

Ten years ago in Paris, the world acknowledged that the former 2°C goal held by the international community was not a safe level of warming and strengthened the temperature goal in its Article 2.1 to hold warming *well below* 2°C and pursue efforts to limit warming to 1.5°C.

This *explicitly* works in tandem with the Agreement's Article 4.1 which calls for reaching net zero GHG emissions globally in the second half of the century. This net zero requirement, which has now been adopted by many countries, is essential for driving global temperatures down from peak levels. Together, they are to be seen as representing **one Paris goal**: to peak warming as close to 1.5°C as possible and bring temperatures back below this threshold towards a safer climate before 2100.

Highest Possible Ambition

The International Court of Justice's recent Advisory Opinion on climate change reemphasises that countries have a legal duty to reflect the highest possible ambition in their NDCs to collectively secure the Paris Agreement's 1.5°C limit. To guide collective policy action in line with these obligations, this report presents new evidence on what "highest possible ambition" towards the Paris goals could mean at the global level.

Global energy and emissions pathways have been a critical line of evidence to help inform what highest possible ambition could entail. However, the 1.5°C-aligned pathways assessed in the most recent IPCC cycle (AR6) are becoming increasingly outdated. Since their creation five years ago, the world has failed to cut emissions, sending global temperatures racing towards the 1.5°C limit. On the other hand, in the last five years renewable energy and other zero-carbon technologies have decreased substantially in cost and are far more cost-competitive than anticipated and can be scaled up faster.

Our new Highest Possible Ambition (HPA) scenario updates these pathways, starting from today's emission levels (2025) and energy market dynamics to achieve the safest possible temperature outcome within physical, technological and economic feasibility limits. It provides an updated evidence base on how to achieve the Paris goal, starting from where we find ourselves in 2025.

Key findings from the HPA scenario:

- **Global warming can be halted in the next 15 to 20 years and return below 1.5°C by 2100 in line with the Paris goal** following a period of overshoot of the warming limit. In the HPA scenario, temperatures exceed 1.5°C for 40 years and peak at around 1.7°C before declining to ~1.2°C by 2100. This is shown in Figure ES1.
- **Overshoot of 1.5°C is at least a decade longer and 0.1°C higher than in 1.5°C net zero aligned IPCC AR6 scenarios** due to the political failure to cut emissions over the last five years. Overshoot is highly dangerous and must be limited as much as possible to reduce climate risks.
- **The world can achieve net zero CO_2 before 2050 and go on to reach net zero greenhouse gas emissions in the 2060s,** supported by a rapid phaseout of fossil fuels and scale-up of carbon dioxide removal (CDR). The HPA scenario achieves net zero CO_2 / GHGs around 10 years earlier than in AR6 scenarios, ensuring

that temperatures not only peak, but start to decline back below 1.5°C well before 2100 towards a safer climate. Despite starting five years later, and at higher levels of emissions than the IPCC AR6 scenarios, the Highest Possible Ambition scenario catches up with these scenarios around 2040. This is underpinned by the technological revolution in renewables and electrification which makes rapid change more possible than anticipated previously.

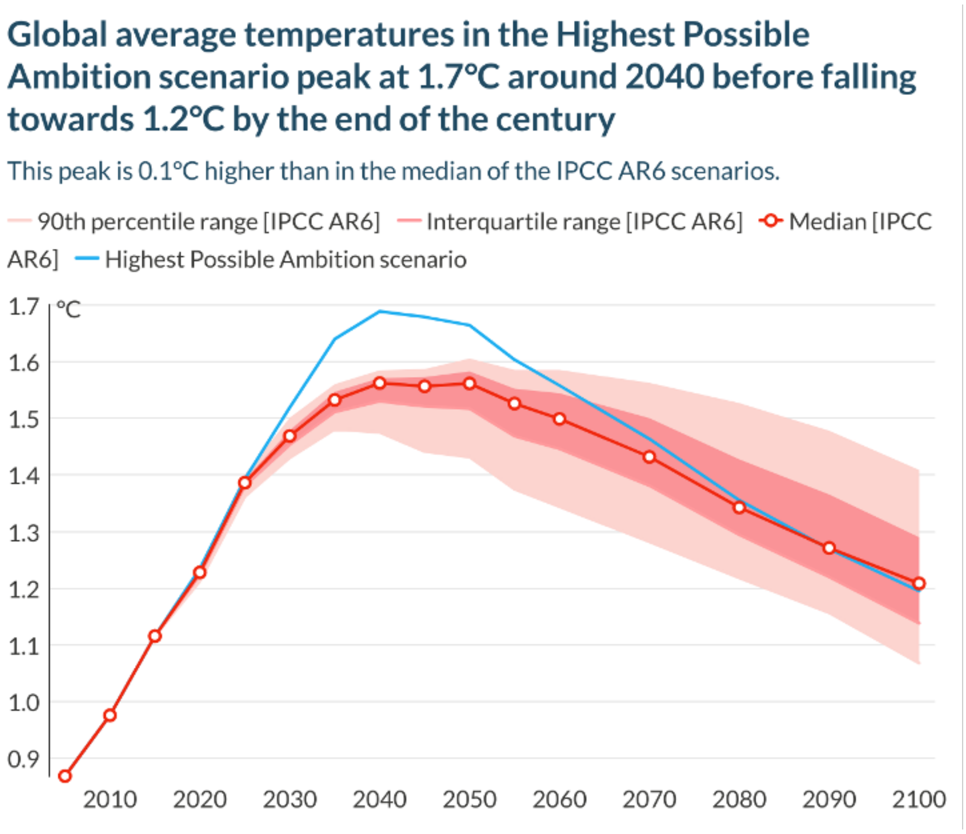


Figure ES1 compares the global average temperatures out to 2100 in the Highest Possible Ambition scenario with the IPCC AR6 scenarios.

Key emissions benchmarks along the high ambition road

In the HPA scenario, global emissions fall around a fifth by 2030 compared to 2019 levels at a rate similar to the first five years of the AR6 scenarios. This sets the stage for far steeper reductions (11% per year) and radical systemic transformation over the 2030s.

Cutting emissions by a fifth from this delayed starting point does not represent a reduction in ambition from the commonly quoted call to “halve emission by 2030”. The AR6 scenarios cut emissions 41% in their first decade of action (2020-2030) compared to 49% in the first ten years of the HPA scenario (2025-2035).

The rapid scale up of renewables and storage, combined with widescale electrification of the energy system, enables the HPA to overtake AR6 scenarios before 2040 to compensate (as much as is possible) for the extra cumulative emissions from 2020–2025. This is shown in Table ES1.

Table ES 1: Global GHG emissions reduction benchmarks in the HPA and IPCC AR6 scenarios (expressed as global emissions reductions relative to 2019)

	2025	2030	2035	2040	2045	2050
IPCC AR6 median	22%	41%	56%	66%	76%	85%
HPA scenario	~0%	17%	49%	73%	88%	95%

The four key levers of the high ambition roadmap

The HPA scenario identifies four key levers at the heart of the transformation of our energy and land-use systems. These levers must be pulled in parallel to minimise the magnitude and duration of 1.5°C overshoot and keep the Paris goal in reach. They are:

1. **Widespread electrification powered by renewables.** In the HPA scenario, over two-thirds of the energy system is powered by renewable electricity by 2050, driven by the rapid rollout of wind, solar, and battery storage. This level of electrification far exceeds AR6 scenarios, which rely more on biomass and assume a slower fossil fuel phaseout. Renewable electrification is the mainstay of the energy transition, as it significantly outperforms all other options on cost, scalability and energy efficiency. The HPA scenario sees global electricity generation nearly quadruple by 2050, with wind and solar supplying over 90% of electricity demand. Renewables capacity grows significantly, with a 3.5-fold increase by 2030 – just ahead of the global tripling goal agreed at COP28.

2. **A much faster phaseout of fossil fuels**. Clean electricity pushes fossil fuels out of the energy system at pace and scale. Production and consumption of all fossil fuels peak immediately and fall rapidly, with coal effectively phased out by the 2040s, gas in the 2050s and oil in the 2060s. Advanced economies take the lead in phasing out fossil fuels, achieving a fossil-free economy by mid-century. The pace of phaseout substantially exceeds the levels seen in AR6 scenarios, as it is the most important action needed to halt warming. The result is a fossil free global economy by 2070 and a healthier, fairer and safer future for all. Carbon capture and storage (CCS) equipped to fossil fuels plays a negligible role in the transition – with electrification and other zero-carbon options able to eliminate fossil fuels entirely from the energy system.

3. **Carbon dioxide removal (CDR) at a commercial scale.** The HPA scenario rapidly scales CDR from the 2030s onwards, with engineered removals reaching over 5 $GtCO_2$/yr by 2050, supported by limited removals of around 2 $GtCO_2$/yr from the land-use system. The HPA scenario avoids large-scale nature-based CDR, given the risks of overreliance on natural sinks in a warming world. By 2100, cumulative removals drive cooling of around 0.23°C from peak warming levels. CDR needs to happen alongside the fossil fuel phaseout; it is not a substitute for it. Without largescale negative CO_2 emissions driven by CDR, we will not be able to bring temperatures back below 1.5°C. However, even if CDR technologies ultimately scale half as quickly, the HPA scenario would still see temperatures back below 1.5°C by the end of the century.

4. **Faster action on methane.** As a short-lived yet highly potent greenhouse gas, faster action to cut methane emissions can play an important role in peaking emissions as soon as possible, reducing peak temperatures and supporting long-term temperature decline. In the HPA scenario, methane emissions fall around 20% by 2030 and 32% by 2035 (relative to 2020), driven particularly by emissions reductions from fossil fuel extraction, in addition to more modest reductions in agriculture and waste.

The HPA scenario achieves net zero CO_2 emissions before 2050, and net zero GHG emissions by the early 2060s. These milestones are key to stopping warming and then driving temperatures back down to below 1.5°C pre-2100. Governments should revisit their existing net zero commitments, accelerating them where necessary to ensure global alignment with the HPA scenario. While some countries will move ahead of the global average and others behind, it is essential that the world reaches net zero in line with the HPA scenario to help minimise the extent and duration of overshoot.

The above roadmap lights the path forward to a safer climate well below the 1.5°C warming limit, avoiding spiralling human, environmental and economic costs driven by climate breakdown. The longer we delay, the more disruptive the necessary action will become. The HPA scenario shows that while a temporary overshoot of the 1.5°C limit is now inevitable, we can still get warming below 1.5°C before 2100, if we redouble our efforts towards it.

While overshoot is a political failure, it does not nullify the intended goals of the Paris Agreement. On the contrary, it puts us on red alert and must focus minds on what needs to be done now. The 1.5°C warming limit remains the enduring legal, political and moral anchor of the international climate process. It is still to be fought for and can be achieved. The choice of the future we want is ours.

Table of Contents

Introduction 1

Outline 5

Methods summary 7

Rescuing 1.5°C 9

Deep reductions in greenhouse gas emissions: catching up on lost time 9

Reaching net-zero sooner: limiting overshoot 11

Long-term warming can be brought back below 1.5°C 12

Key levers to achieving highest possible ambition 15

Lever 1: Rapid renewable electrification – the powerhouse 16

Lever 2: A rapid fossil fuel phaseout 23

Lever 3: Cutting methane to curb peak temperatures and bring temperature down in the long-term 27

Lever 4: Carbon dioxide removal as an inevitable part of the pathway to bring temperatures back below 1.5°C 29

The costs of delay 34

Conclusion 36

Policy implications of the HPA scenario 38

Actions for the next five years 38

Longer-term actions 39

References 41

Methods Annex 52

Key assumptions underpinning the HPA scenario 52

Uncertainties in our temperature assessment process 55

Representation of methane mitigation in the HPA 56

Introduction

In 2015, the world committed to 'holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels' (UNFCCC 2015, Art. 2.1a).

Since that time, the scientific, policy and political consensus around the significance of the 1.5°C limit has strengthened. The IPCC found with "high confidence" that "warming of 1.5°C is not considered 'safe' for most nations, communities, ecosystems and sectors and poses significant risks to natural and human systems" (IPCC 2018). In 2025, the International Court of Justice Advisory Opinion on the Obligations of States in Respect of Climate Change concluded that limiting warming to 1.5°C is recognised as the primary temperature goal of the Paris Agreement, based on the best available science and the subsequent legal interpretations of the goal in the Glasgow Climate Pact in 2021 and the Global Stocktake in 2023 (ICJ 2025).

However, ten years after the Paris Agreement, global temperatures are rapidly approaching 1.5°C. 2024 marked the first calendar year in which the annual observed global average temperatures exceeded 1.5°C of warming (WMO 2025), of which 1.36°C was attributable to human–induced warming (Forster *et al* 2025).

The Paris Agreement's long-term temperature goal is measured as an average of human-induced temperature increases over two to three decades, not over a single year or shorter timescales. As such, breaching 1.5°C in any single year does not mean that the limit has been broken. Nevertheless, record-breaking temperatures are a strong indication that we are rapidly approaching this threshold (Bevacqua *et al* 2025, Cannon 2025).

It is not yet possible to calculate average global temperatures over a twenty-year period centred on 2024, as this would require temperature data for 2014–2034. However, the average temperature over 2015–2024 was 1.24°C, with this decadal average temperature increasing at a rate of 0.27°C per decade (Forster *et al* 2025). Given the lack of sufficient action to date, it seems all but inevitable that long-term average temperatures will overshoot 1.5°C. Based on current emissions trajectories, 1.5°C of warming (as a 20-year average) could be reached as early as 2030 (Climate Analytics 2025).

At the heart of these rising temperatures is a collective political failure to cut emissions in line with the science. The IPCC identified that peaking emissions pre-2025 and achieving deep, rapid, and sustained cuts thereafter was essential to limiting warming to 1.5°C with no or low overshoot (IPCC 2023). Unfortunately, we have not yet peaked emissions – in 2024, fossil CO_2 emissions still rose by 0.8% from 2023 levels (Friedlingstein *et al* 2025).

Combined with rising temperatures, this insufficient action to cut emissions have led to premature and incorrect claims that the Paris Agreement's long-term temperature goal has been breached and/or is no longer achievable, fuelling speculation over the need for a new, weaker target, such as limiting warming to 2°C. However, these claims fail to account for the scientific, political, ethical and moral imperatives that remain to limit peak warming to as close to 1.5°C as possible, and to bring long-term temperatures back below 1.5°C on a declining pathway.

Given the current status of global emissions and temperature increases, this report assesses what can and needs to be done to limit the magnitude and duration of overshoot of the 1.5°C limit and all of its adverse consequences.

Article 2.1 of the Paris Agreement replaced the previous international climate agreement to "hold warming below 2°C", established in Cancun (COP 16) and Copenhagen (COP 15) (UNFCCC 2009, 2010). This was supported by a UNFCCC review, which concluded that it was "inadequate" to see warming of 2°C as safe, and that 1.5°C was a demonstrably safer (but still not safe) level of warming (UNFCCC 2015a). This led to the Paris Agreement focusing on "well below" 2°C (rather than merely "below" 2°C), and "pursuing efforts" towards 1.5°C.

Ten years on from the Paris Agreement, the science has only become clearer. As temperatures rise above 1.5°C, we will see increasingly devastating climate impacts such as lethal heat, marine heatwaves, droughts and flooding, as well as increased risk of triggering a range of tipping points in the climate system (IPCC 2021, Möller *et al* 2024). Increasingly, 1.5°C is identified as a physical limit beyond which the scale, severity and frequency of climate impacts escalate substantially, with these impacts disproportionately affecting the most vulnerable. Many of these risks and impacts grow with the overall extent and duration of overshoot (Schleussner *et al* 2024, Dickau *et al* 2025, Reisinger *et al* 2025). This reinforces the importance of limiting peak warming to as close to 1.5°C as possible, even if there is temporary overshoot.

The Paris Agreement does not exclude the possibility of a limited overshoot of 1.5°C, nor does it imply that stabilising warming at 1.5°C is the designated outcome of the agreement (as is sometimes assumed). This is due to the combination of Article 2.1 and Article 4.1, which commits parties to achieving global net zero greenhouse gas (GHG) emissions in the second half of the century (UNFCCC 2015, Art. 4.1), which would in turn lead to declining temperatures. Bringing temperatures back below 1.5°C is critical, particularly to avoid long-term catastrophic climate impacts such as multi-metre sea level rise in the coming centuries (IPCC 2023, Stokes *et al* 2025), and to reduce the risk of triggering key tipping points (Lenton *et al* 2025). Article 4.1 was designed with the knowledge that a sustained warming level of 1.5°C was not safe in the long-term, particularly for the most vulnerable countries.

Taken together, these provisions of the agreement mean that a small and temporary overshoot of the 1.5°C limit is still in line with the Paris Agreement, providing long-term temperatures decline back below 1.5°C and towards safe levels by 2100.

This outcome can be seen clearly in the IPCC AR6-assessed emissions scenarios that align with both Article 2.1 and 4.1 of the Paris Agreement (Riahi *et al* 2022), which are described as the "C1a" scenarios in the IPCC AR6 report.[1] These scenarios allow for a "limited" overshoot of up to 0.1°C above 1.5°C for 20–30 years before returning to around 1.2°C of warming by 2100. This outcome is not incidental, but is a direct result of the way in which both Articles 2.1 and 4.1 were negotiated.

The legal and ethical imperative of limiting peak warming to as close to 1.5°C as possible, and bringing long-term warming below 1.5°C, endures even as we approach and potentially exceed this threshold (Rogelj and Rajamani 2025). A temporary exceedance does not render the goal irrelevant. Instead, it should act as a wake-up call to Parties, to redouble action in line with the highest possible ambition, achieving net-zero CO_2 emissions to halt warming and achieving net-zero GHG emissions to reduce temperatures thereafter.

[1] The IPCC AR6 identified a set of scenarios which limit warming to 1.5°C with no or limited overshoot, termed the C1 scenarios. Within this set, a subset which also achieve net zero greenhouse gas emissions pre-2100 were identified, which were termed the C1a scenarios. These scenarios are compatible with both Article 2.1 and 4.1 of the Paris Agreement. This report refers to these scenarios as the IPCC AR6 scenarios, noting that the IPCC AR6 database includes a wide range of other scenarios (including many that are not compatible with 1.5°C).

The latest assessment report from the IPCC AR6 WGIII and the associated scenario ensemble provide a wealth of evidence on the pace at which emissions need to be reduced to align with the Paris Agreement's temperature goal, and the mitigation options needed to achieve this. However, the scenarios assessed there were produced around 2020 and are now at least five years old. Recent years have seen multiple developments which render these pathways increasingly outdated for two key reasons:

1. These pathways assumed that coordinated mitigation action began in 2020, with global GHG emissions falling by 22% over 2019–2025 on average in the 1.5°C-compatible pathways (median, 5th-95th range of 7-39%) (Byers *et al* 2022). Such reductions have not transpired, with emissions continuing to trend upwards over the 2020s. Recent developments suggest this growth may be slowing, as clean energy technologies roll out at record pace. This has led some analysts to predict that a global peak in emissions could be on the horizon. However, global GHG emissions in 2025 are expected to be comparable to emissions levels in 2019. As a result, 1.5°C-aligned climate action must be recalibrated starting from emissions levels in 2025 that are around 25% higher than those assumed in IPCC AR6 scenarios.
2. Signals of the rapidly accelerating energy transition have only become more prominent. Over the ten years since the Paris Agreement, we have witnessed significant cost declines in solar, wind and batteries, with their deployment continuing to break records around the world. Almost 600 GW of renewables were added in 2024 – up 20% from additions in 2023 – marking the highest annual increase on record (IRENA 2025a). Wind and solar are the cheapest form of new generation in most contexts, and are undercutting existing fossil fuel plants in three-quarters of the world (IEA 2024b, IRENA 2025b). These rapidly changing market dynamics are not reflected in the existing IPCC assessed pathways. Incorporating them could fundamentally redraw the achievable paths forward for the energy transition (Achakulwisut *et al* 2023).

Given the confusion surrounding the applicability of the Paris Agreement's long-term temperature goal, and the reliance on an outdated evidence base to guide action, there is a clear need for new evidence to guide policy action. As this report shows, the key elements of the Paris Agreement provide a guide to what needs to happen to minimise overshoot of the 1.5°C limit and to bring global warming back to the lowest possible level by 2100.

In collaboration with the Potsdam Institute for Climate Impact Research (PIK), we have developed a new and ambitious roadmap for global emissions and the energy system. Presented in this report, this new scenario is calibrated to global emissions in 2025, and accounts for the vast potential for renewable technologies to transform our energy system in a cost-beneficial and socially inclusive way. It provides a blueprint for the actions needed to limit the extent and duration of overshoot, get back below 1.5°C well before 2100, and keep the Paris goal in sight.

Outline

Section 2 of the report summarises the modelling framework used to develop this scenario. We provide a brief summary of the methodology underpinning our analysis, with further details in the Methods Annex.

Section 3 of the report explores the emissions and temperature outcomes of the scenario in greater depth. We show that aggressive emissions cuts starting in 2025 can achieve net zero CO_2 emissions by mid-century and net zero GHG emissions by around 2060 – returning global warming to well below 1.5°C before 2100. To achieve this, total GHG emissions need to fall around 20% between 2025–2030 and then decline rapidly by about two-thirds over the 2030s, to reach 73% below 2019 levels in 2040.

Due to the historical failure to cut emissions, our scenario projects peak warming of 1.7°C around mid-century before temperatures start declining. The delay in cutting emissions over the past five years leads to a higher magnitude and duration of overshoot compared to the IPCC AR6 scenarios. Specifically, our scenario indicates a peak temperature of 1.7°C with approximately 40 years of overshoot – at least 0.1°C higher and a decade longer than these pathways. This has broadly tripled our cumulative exposure to overshoot. In addition, earth system feedbacks not yet included in our quantitative assessment could result in peak warming higher than 1.7°C.

Warming will continue until we reach net zero CO_2 emissions (MacDougall *et al* 2020). Reaching net zero CO_2 as fast as possible is therefore essential for limiting peak warming. Meanwhile, reaching net zero GHG emissions is key to achieving long-term temperature decline (Möller *et al* 2024). In our roadmap, the world achieves net zero CO_2 around 2045 and goes on to reach net zero GHG emissions in the 2060s, ensuring that temperatures not only peak, but start to decline back below 1.5°C. While overshoot is now inevitable, it remains possible to limit the magnitude and duration of overshoot and bring temperatures back well below 1.5°C before 2100.

Section 4 of the report defines the key levers that underpin the emissions reductions seen in Section 3, highlighting concrete milestones and actions that can transform the global energy system.

Behind these rapid emissions reductions is the swift emergence of a new energy system based on renewable electricity. In these scenarios, electricity demand more than triples by 2050, and electricity provides more than two-thirds of final energy demand directly. Wind, solar and batteries are the driving force of the transition, providing clean, cheap and reliable electricity to the world and powering buses, heat pumps, factories and more. Rapid electrification pushes fossil fuels out of the mix, with coal effectively phased out by the 2040s, gas by the 2050s and oil by the 2060s. Advanced economies lead the way, phasing out all fossil fuels pre-2050.

However, as global warming exceeds 1.5°C, simply phasing out fossil fuel emissions is not enough to meet our goals – this can stop temperatures rising but cannot bring them back down. Deep reductions in non-CO_2 emissions, particularly methane, are critical. A rapid scale-up of carbon dioxide removal (CDR) methods is also essential to draw down and durably store CO_2 from the atmosphere. Our pathway keeps CDR deployment broadly within the latest sustainability and feasibility constraints identified in the literature and avoids large-scale reliance on temporary removals from afforestation/reforestation. CDR serves as an essential, complementary action to the phaseout of fossil fuels, but is not a substitute for it. It must be rapidly scaled up in addition to emissions reductions to keep the Paris goal within reach.

Section 5 of the report further discusses the costs of delay. It is still possible to rescue 1.5°C. However, the delay of the past five years has come at a cost. Not only will temperatures be higher for longer (with additional climate impacts), but making up for lost time will mean an even more rapid transition to a zero-carbon world than before. This will have implications for the levels of asset stranding and early retirement of fossil fuel infrastructure.

Section 6 of the report provides conclusions. As global temperatures approach 1.5°C, the world has a choice. Do we abandon the Paris Agreement, or do we reaffirm our commitment to it? As climate impacts escalate, the urgency and desirability of limiting overshoot and getting temperatures back below 1.5°C has never been stronger. The key provisions of the Paris Agreement, including the temperature goal, and the obligation to peak emissions as soon as possible and achieve net zero GHG emissions in the second half of this century—as well as the first Global Stocktake—provide an operational guide to what needs to be done to reduce overshoot and get back on track.

Despite all the challenges facing us, the feasibility and inevitability of the energy transition continue to shine through. This report provides critical evidence for those who wish to redouble their efforts in line with 1.5°C, accelerate the transition and deliver a safer world to future generations.

Methods summary

We introduce the "Highest Possible Ambition" (HPA) scenario, which provides a global pathway, starting from today's energy system and emissions levels, to minimise overshoot of 1.5°C and bring temperatures back below 1.5°C before 2100, while keeping reliance on CDR and wider use of carbon capture and storage (CCS)[2] within feasibility and sustainability constraints.

We produce this scenario using the REMIND integrated assessment modelling (IAM) framework (Baumstark *et al* 2021, Luderer *et al* 2023). REMIND is a global multi-regional model that captures relationships between the economy, the climate system and the energy sector. It is a hybrid model which links together a detailed representation of the energy system with a macro-economic model and a simple climate module (Keppo *et al* 2021). For further details, see model documentation presented in Luderer *et al* (2023).

The majority of existing IAM scenarios in the literature to date assume that globally coordinated action to cut emissions begins in 2020. In the HPA scenario, we constrain global emissions to follow the current policy trajectory until 2025. This means the pathway is accounting for our historical failure to peak and reduce emissions rapidly over the first half of the 2020s. After this, we drive the REMIND model to meet the lowest possible carbon budget within the model's techno-economic constraints. We are therefore exploring the feasibility range of the model to look for the lowest possible temperature outcomes that are techno-economically and geo-physically feasible. We note that the feasibility of a scenario is a broader concept that includes socio-political

[2] CCS and CDR are interrelated but separate approaches. CCS refers to the process of capturing carbon dioxide from a source using chemical processes and storing it geologically. The CO_2 can come from a range of sources, including combustion of fossil fuels / biomass, industrial process emissions or directly from the atmosphere. CDR refers to the direct removal of CO_2 from the atmosphere. Some CDR approaches rely on CCS (biomass with CCS or direct air capture with CCS), while others do not (e.g., enhanced weathering or afforestation/reforestation).

and cultural dimensions (Brutschin *et al* 2021). While a model may identify a scenario as feasible or infeasible based on its underlying constraints and assumptions, this does not imply that the outcome is definitely feasible or infeasible in the real world.

We then apply a range of additional constraints and developments to the REMIND model to produce the HPA scenario through:

- **Regionally differentiated carbon prices:** Rather than applying a globally uniform carbon price, there is a spread of carbon prices across regions, which converge to a globally uniform price by 2070. Regions with higher GDP per-capita have higher near-term carbon prices and therefore cut emissions faster.
- **Improvements in addressing energy equality:** We model demand-side action in advanced economies which reduces energy demand relative to a current policy reference scenario. In parallel, the scenario enables a faster scale-up of energy service demands in low-income countries, helping reduce interregional inequality in energy service demands.
- **Inclusion of sustainability and feasibility bounds for biomass, CCS and CDR, aligned with literature:** Biomass availability is limited to ~80 EJ/yr, total underground carbon sequestration is limited to 8.6 $GtCO_2$/yr (across fossil, biomass, process emissions and direct air capture), and individual CDR methods broadly align with literature defined constraints.

Throughout the report, we compare the outcomes of the HPA scenario to the 1.5°C-compatible pathways assessed in IPCC AR6 (IPCC 2022). We focus on the C1a scenarios, which are compatible with both limiting warming to 1.5°C with no/limited overshoot, and achieving net zero GHG emissions pre-2100. There are 50 such scenarios, and we report the median, interquartile range and 90th percentile range in our comparison plots and statistics.[3] We describe these pathways as the IPCC AR6 scenarios, although we note that they are not the only path.

More details on the methods can be found in the Methods Annex.

[3] We note that the literature for the analysis of scenario ensembles is developing, and alternative proposals that would reduce the reliance on summary statistics such as medians are being proposed. Nevertheless, given the profile of these summary statistics in critical reports such as the IPCC's AR6 report, we show them here to enable a comparison between the HPA scenario and the findings of the IPCC AR6 WGIII report.

Rescuing 1.5°C

The following section explores how global greenhouse gas emissions and temperatures evolve in the HPA scenario.

Deep reductions in greenhouse gas emissions: catching up on lost time

Every year of delay in cutting emissions depletes our remaining carbon budget and reduces the space for future emissions – meaning we have to get to net zero even faster. As emissions have continued to rise, we also have to reduce emissions from a higher starting point. Taken together, this means we have to achieve larger reductions in a shorter period of time – significant escalations of both ambition and action are essential.

Rescuing 1.5°C will require rapid and deep reductions in GHG emissions. In the HPA scenario, global annual GHG emissions fall by almost 20% over the next five years from 2025–2030. This is broadly similar to the rate of emissions reductions in the IPCC AR6 scenarios, in which global GHG emissions fall 22% over the first five years of action (2020–2025). However, despite the similar overall pace of cuts, as the IPCC AR6 scenarios start to cut emissions five years earlier than the HPA scenario, they achieve a 41% reduction by 2030, more than twice the level of the HPA scenario (17%).

In the HPA scenario, the remainder of the 2020s build the foundations for the 2030s, which then serve as a decade of unprecedented transformation. Over these ten years, GHG emissions fall by two-thirds, reaching almost a quarter of today's levels by 2040. This rapid transition is made possible by the ongoing energy revolution in solar, wind, batteries and the possibility for deep electrification that this creates. However, it will not be possible without international coordination, cooperation and commitment to the highest possible ambition in NDCs and long-term strategies, as well as a laser focus on implementation and delivery.

As a result of the failure to cut emissions over 2019–2025, the HPA scenario has total modelled GHG emissions in 2025 which are 0.2% higher (~100 $MtCO_2e$ / yr) than 2019 levels.

Due to the delay in peaking emissions, global GHG emissions remain at higher levels than those modelled in the IPCC AR6 scenarios until the late 2030s. However, it is possible to catch up. By 2040, global GHG emissions are below the median level of the IPCC AR6 scenarios. Figure 1 shows global GHG emissions, comparing the HPA and IPCC AR6 scenarios, with the percentage reductions relative to 2019 given by Table 1.

In the Highest Possible Ambition scenario, global GHG emissions fall fast and catch up with the IPCC AR6 scenarios by the late 2030s

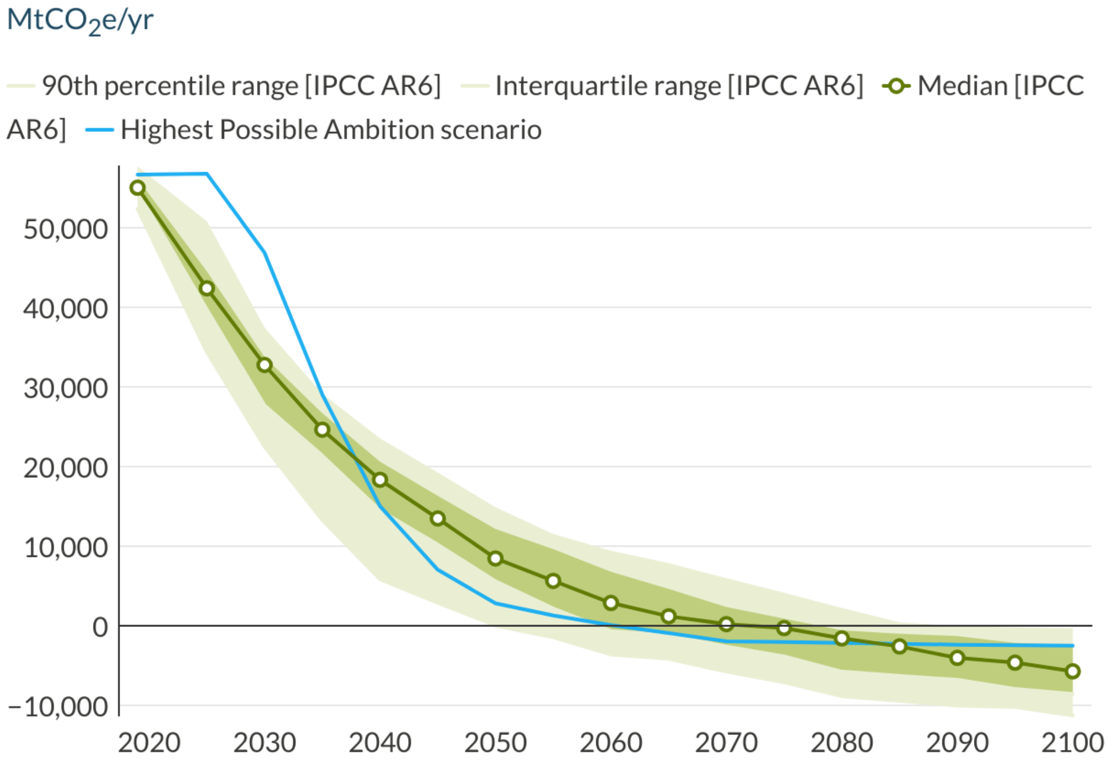


Figure 1 compares global GHG emissions in the Highest Possible Ambition scenario with the IPCC AR6 scenarios

Table 1: Percentage reductions in GHG emissions relative to 2019 in each scenario

	2025	2030	2035	2040	2045	2050
IPCC AR6 median values	22%	41%	56%	66%	76%	85%
HPA scenario	~0%	17%	49%	73%	88%	95%

Crucially, although global emissions are higher until the late 2030s than the IPCC's AR6 ensemble, this does not mean the new scenario "lacks ambition'' or "goes slower". In the IPCC AR6 scenarios, global emissions fall at a rate of ~5% per year over the 2020s, and a similar rate in the 2030s. In this new scenario, emissions fall at around 4% per year out to 2030, but after this emissions cuts accelerate to 11% per year over the 2030s, with emissions falling two-thirds in a single decade.

Table 2 shows the percentage reductions in GHG emissions achieved over the first 5 to 30 years after globally coordinated action to cut emissions begins. While the HPA scenario shows slightly smaller reductions in the first five years of action than the IPCC AR6 scenarios, after this the HPA scenario achieves deeper reductions than the IPCC-assessed scenarios. This is the only feasible way to (at least partially) compensate for the additional cumulative emissions that are locked in over the period 2020–2025.

Table 2: Percentage reductions in GHG emissions over the first N years of the scenario

	5 years	10 years	15 years	20 years	25 years	30 years
IPCC AR6 median values	22%	41%	56%	66%	76%	85%
HPA scenario	17%	49%	73%	88%	95%	98%

Reaching net-zero sooner: limiting overshoot

Warming will continue until we reach net zero CO_2 emissions (MacDougall *et al* 2020). Reaching net zero CO_2 as fast as possible is therefore critical to limiting the extent of temperature overshoot. Meanwhile, reaching net zero GHG emissions is key to achieving long-term temperature decline (Möller *et al* 2024).

In our scenario, while near-term emissions are higher, the rapid reductions achieved quickly put the world on a path to net zero emissions. The scenario achieves net zero CO_2 in 2045, five to ten years before the median 1.5°C scenario in the IPCC AR6. Meanwhile, net zero GHGs is achieved in the early 2060s, around a decade ahead of the median IPCC AR6 scenario, to compensate for the higher cumulative CO_2 emissions (Figure 2).

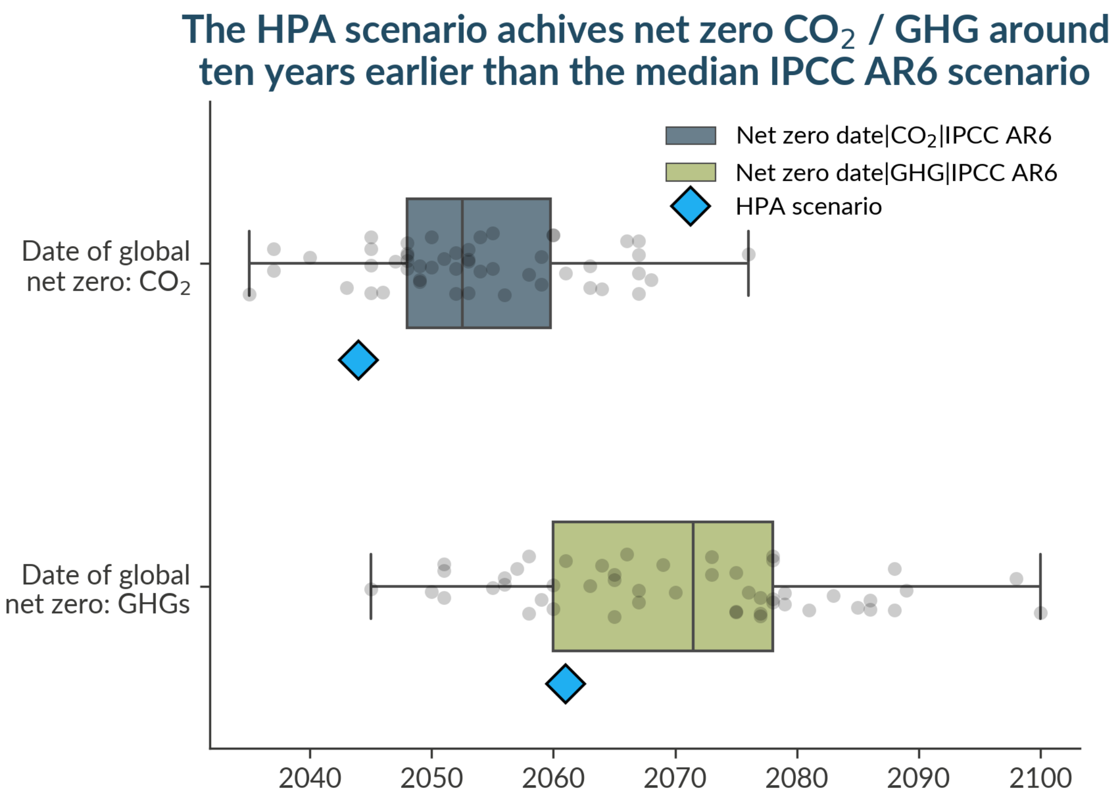


Figure 2 compares global net zero CO_2 /GHG emissions dates in the Highest Possible Ambition scenario with the IPCC AR6 scenarios. Each dot represents a different IPCC AR6 scenario, while the boxes show the median and interquartile range. The blue diamond represents the HPA scenario.

Long-term warming can be brought back below 1.5°C

Our latest scenario shows that, despite a historical failure to cut emissions in line with what the science requires, we can still catch up with the IPCC AR6 scenarios. However, not all costs can be avoided. The delay in cutting emissions over the past five years leads to higher peak temperatures and a greater degree of overshoot.

We assess the likely temperature outcomes of our scenarios using the standard AR6 temperature assessment pipeline (Kikstra *et al* 2022). The results are shown in Figure 3 below.

Global average temperatures in the Highest Possible Ambition scenario peak at 1.7°C around 2040 before falling towards 1.2°C by the end of the century

This peak is 0.1°C higher than in the median of the IPCC AR6 scenarios.

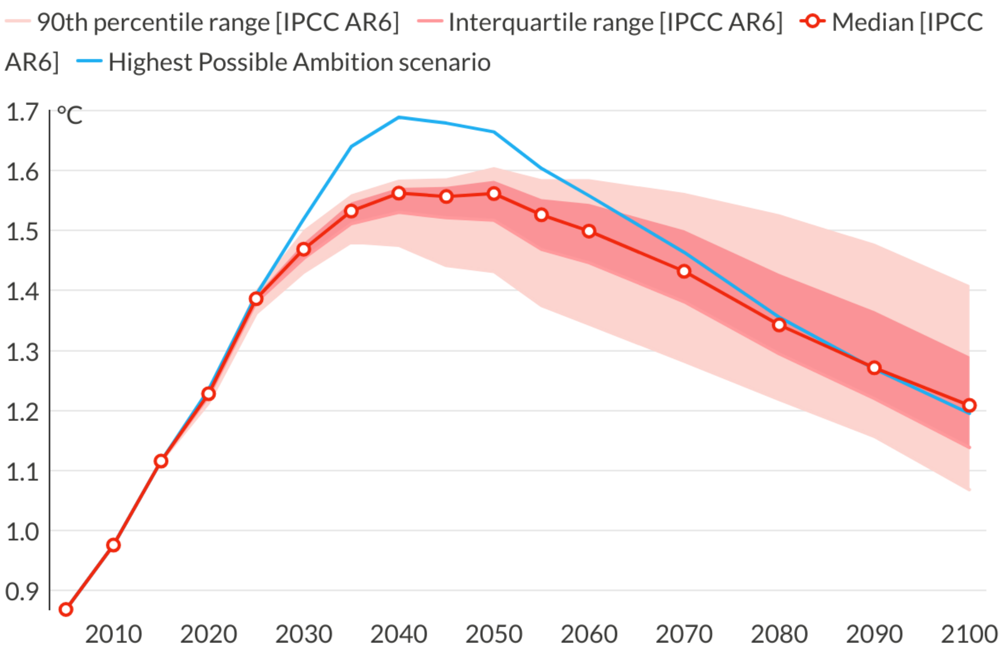


Figure 3 compares the global average temperatures out to 2100 in the Highest Possible Ambition scenario with the IPCC AR6 scenarios.

In this new scenario, global average temperatures peak around 2040 at almost 1.7°C. They then begin to fall as net negative CO_2 emissions, coupled with strong reductions in non-CO_2 emissions, begin to bring temperatures back down. In this scenario, by 2100 temperatures are back at ~1.2°C, and on a strong declining trajectory.

However, the cost of delay (compared to the IPCC AR6 scenarios) is at least 0.1°C higher and around a decade longer overshoot – with temperatures exceeding 1.5°C for around 40 years in this new scenario (compared to 30 years in the IPCC AR6).

These additional costs will have huge impacts on vulnerable communities and ecosystems and will pour further fuel on the fire of the climate crisis.

We quantify the temperature outcomes of the HPA scenario using the IPCC AR6 standard temperature assessment pipeline, which remains the most up-to-date, publicly available open-source temperature pipeline. This approach is crucial as it enables direct comparison between our scenario and IPCC AR6. However, the science of temperature assessments is continually improving and evolving. In particular, updates to account for recent reductions in sulphur emissions and the latest earth system observations[4] could lead to higher temperature projections. For more details see the Methods Annex.

This work does not account for these factors. Therefore, our temperature estimates of peak warming at ~1.7°C and warming of ~1.2°C by 2100 is likely at the lower end of what can still be achieved. If uncertainties in the climate system go against us, we could see even higher peak temperatures, even under a world cutting emissions in line with the highest possible ambition.

However, this scenario clearly shows that 1.5°C is not lost. While overshoot is now inevitable, it is possible to limit the magnitude and duration of overshoot and bring temperatures back below 1.5°C pre-2100. At the heart of this is rapid and sustained cuts in global emissions, starting immediately, accelerating throughout the 2030s and leading to net zero CO_2 in the 2040s and net zero greenhouse gases in the 2060s. To achieve this will require a fundamental transformation of the energy and land-use systems. This is a transformation that is already underway, and which we now turn our focus to.

[4] 2023 and 2024 reported anomalously high temperatures, the reasons for which are still a question of scientific investigation. Some analysis suggests that this could be due to changes in earth system feedbacks such as reductions in the land-sink, or changes in cloud albedo. If this is the case, the sensitivity of the climate system to GHG emissions could change.

Key levers to achieving highest possible ambition

Rapid reductions in global GHG emissions on the road to net zero are essential to rescue 1.5°C. But how can these reductions be achieved? This section sets out some of the key levers of the transition to net zero GHG emissions as described by the HPA scenario. We set out four key levers, which are described in Figure 4. These levers are not a menu of options, but a set of critical levers, all of which need to be pulled in order to cut GHG emissions in line with the highest possible ambition and limit the magnitude and duration of overshoot. Any shortfall in ambition in any one lever would either require additional action in another lever (which may not be feasible) or would lead to increased overshoot and a further escalation in climate impacts and risks. Alongside these four levers, action to curb deforestation emissions and end ecosystem loss is essential, although the HPA scenario avoids overreliance on land-based sinks.

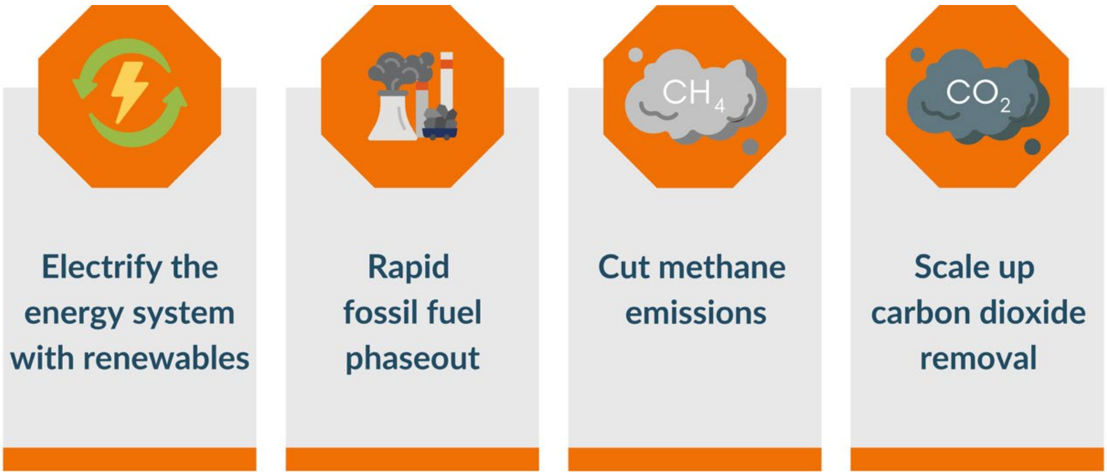


Figure 4 shows the four key levers in the Highest Possible Ambition scenario

Lever 1: Rapid renewable electrification – the powerhouse

By 2050, more than two thirds of the energy system is directly powered by renewable electricity, underpinned by rapid deployment of wind, solar, and battery storage systems. This level of electrification substantially exceeds the levels seen in IPCC AR6 scenarios, which rely more heavily on biomass, as well as having a slower phaseout of fossil fuels.

Over 60% of global fossil fuel demand and energy-related emissions come from the end-use sectors – from gas being burned in boilers, oil in cars, and coal in power plants and industrial factories (IEA 2024c). Displacing these fuels is essential to cutting emissions at sufficient pace and scale.

In the past a wide range of energy carriers have been proposed to drive the transition, from hydrogen to biofuels to ammonia. However, the central lever of the energy transition will be wind- and solar-powered electrification, as a direct result of lower costs, scalability and efficiency (Luderer *et al* 2022).

Electricity has fundamental advantages over other options (Ember 2025). In particular, electrification allows for much higher conversion efficiencies of final energy into actual useful energy service demands. Electric cars are around four times as efficient as internal combustion engines[5] (T&E 2025). Meanwhile heat pumps are three to five times as efficient as fossil gas boilers, as they utilise ambient heat as an energy source (IEA 2022). When compared to other zero-carbon alternatives, electrification also avoids the costs and losses associated with converting electricity to green hydrogen and synthetic fuels.

Electrification is energy efficiency[6], and the fuel-saving advantages of electrification mean that it has a significant advantage over all competing fuels, in any sector or process where electrification is possible. And with over 75% of final energy demand open to electrification, the race towards electricity is only just beginning (Ember 2025).

The HPA scenario leans into the electrification and energy efficiency imperatives, with grids and cables, batteries, heat pumps and other technologies delivering electricity to

[5] Most of the energy released in burning petrol/diesel is lost as heat and noise rather than useful movement.
[6] We note that while electrification can drive significant improvements in energy efficiency, other efficiency measures will also be crucial, such as insulation in buildings and improved appliance efficiency.

power industry, buildings and transport systems at high efficiency, low costs and zero emissions. The share of energy demand met by electricity more than triples by 2050, to almost two-thirds of the entire energy system.

Electrification provides almost two-thirds of energy demand by 2050

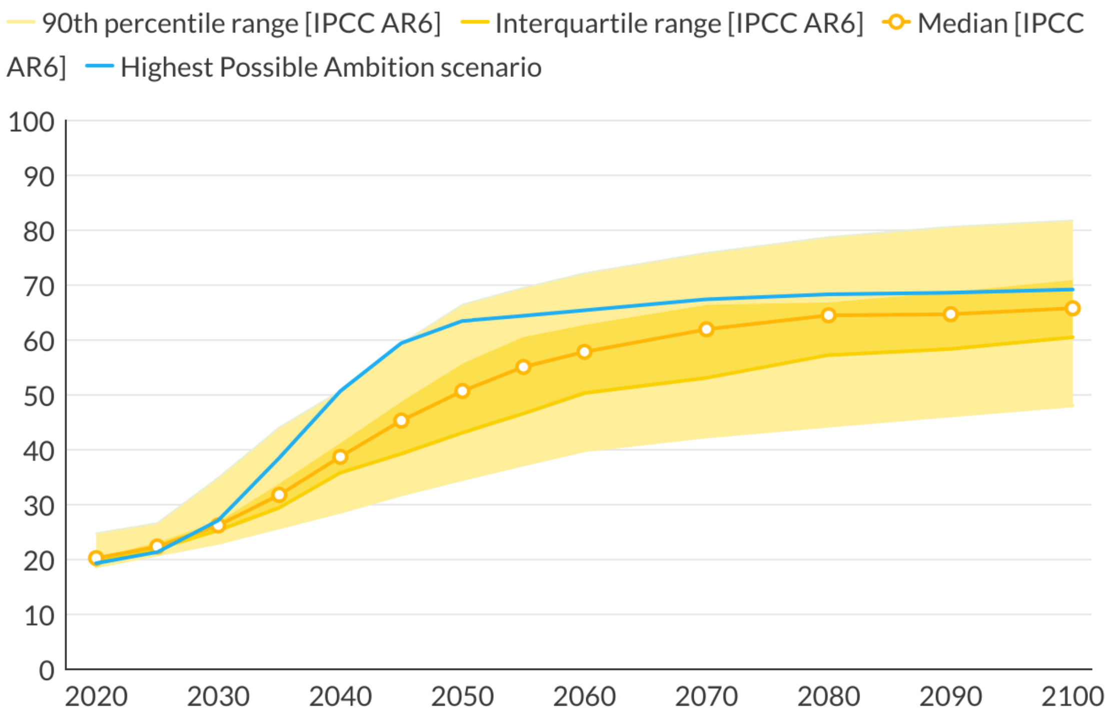


Figure 5 compares the share of global final energy demand that is met by electricity in the Highest Possible Ambition scenario with the IPCC AR6 scenarios.

Direct electrification emerges as the workhorse of the transition. However, not all sectors are fully electrified by 2050. The remaining 37% of energy demand comes from:

- The remaining fossil fuels, which provide around 11% of final energy demand in 2050. This is largely due to remaining oil demand in hard-to-electrify long-distance transport, such as aviation and shipping, and oil for use as a feedstock in the chemicals sector. Oil production and use is fully phased out by 2070 through reliance on biofuels and synthetic fuels (see the following section: Lever 2: A rapid fossil fuel phaseout).
- Some minimal biomass demand, which provides around 9% of final energy demand in 2050. Total biomass demand in these scenarios is limited to around

80 EJ/yr, to avoid unsustainable reliance on biomass. This biomass is used in hard-to-electrify sectors such as aviation and shipping, as well as to displace fossil feedstocks in the chemicals sector.

- Zero-carbon heat provides 5% of total demand, with consumption concentrated in industry and buildings sector.
- The remaining 12% of final energy demand comes from indirect electrification via synthetic fuels, both hydrogen-based fuels and synthetic hydrocarbons. The majority of this is hydrogen, which provides around 7% of final energy demand in 2050, while synthetic fuels provide the final ~5% of final energy demand.

We highlight that this analysis includes non-energy demand, where biomass and fossil fuels are used as feedstocks, as well as demand for the standard end-use sectors of buildings, transport and industry. If non-energy demand is excluded from the analysis, then the share of electricity in global final energy in 2050 grows to 69%, with the share of fossil fuels reduced to 7.5%, and the share of biomass reduced to 7%.

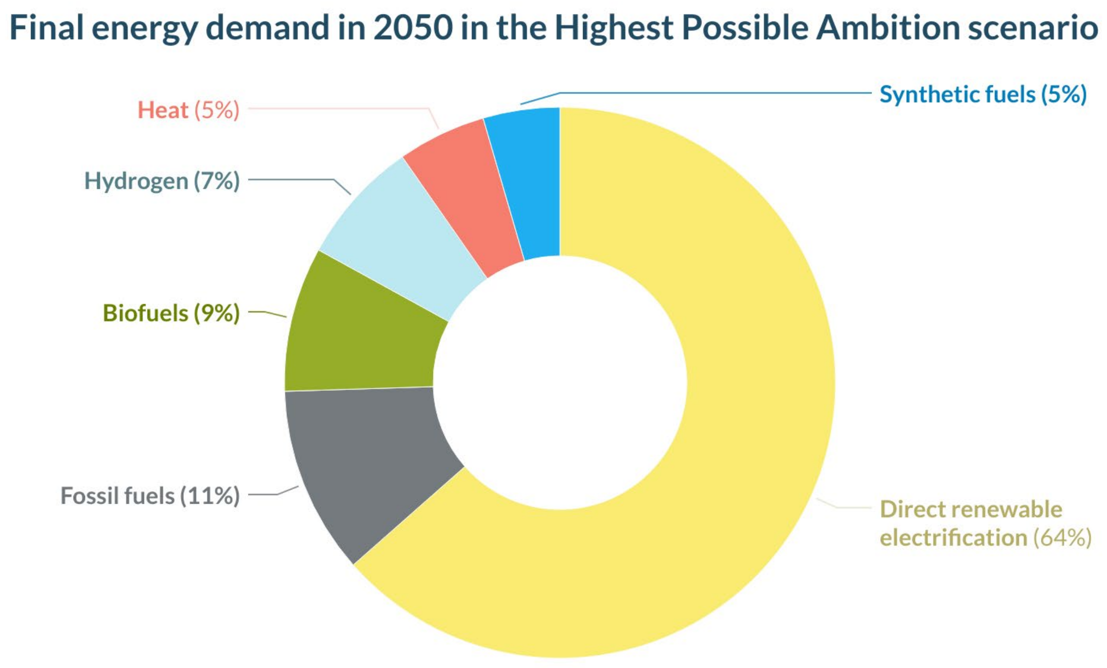


Figure 6 shows the final energy demand breakdown of the new Highest Possible Ambition scenario.

REMIND 3.5 models assume green hydrogen and synthetic fuels as the two main options for indirect electrification. Hydrogen can enter directly as a substitute for fossil fuels in some industrial sectors like iron and steel, or be used as an input to producing synthetic fuels.[7] Large-scale deployment of synthetic fuels will be very challenging, due to the high demands for electricity required to produce these fuels, as well as the need for a sustainable CO_2 feedstock.

In 2050, around a third of total electricity generation is used to produce hydrogen and synthetic fuels in the HPA scenario, supplying 12% of final energy demand via indirect electrification. Meanwhile, the remaining two-thirds of electricity generation provides 63% of final energy demand via direct electrification. This shows the fundamental efficiency advantage of direct electrification. While there are cost and maturity barriers to direct electrification technologies, many of these can be overcome through innovation and technological improvements. The scope for innovation is often not fully represented in the models, which could therefore underestimate the potential for direct electrification.

In particular, the rapid decline in battery costs and improvements to their performance could enable electrification to compete in additional sectors such as shipping (Kersey *et al* 2022). Electrification options in the cement sector[8] could also enable deeper electrification, but are not included in the REMIND model (Pehl *et al* 2024). The share of hydrogen and synfuel deployment seen in this scenario should be seen as an upper bound on the levels necessary, which could be further reduced by increased direct electrification.

Underpinning this transition to an electrified economy is the rapid deployment of wind and solar, supported by battery storage systems. Box 1: The renewables era explores this in further detail.

The HPA scenario envisages only a limited role for synthetic fuels or biomass in the energy system. This is for a range of reasons. In the case of synthetic fuels, this is due to the significant efficiency and cost penalties associated with their production. It is much cheaper and more efficient to directly use renewable electricity, than to convert electricity to hydrogen (with associated conversion losses), capture CO_2 from a sustainable source (i.e. atmospheric CO_2), and blend these together to make synthetic

[7] We define synthetic fuels as those which are produced by blending hydrogen and CO_2 to produce a synthetic hydrocarbon. We distinguish this from the direct use of hydrogen, as direct use of hydrogen has lower costs and efficiency penalties than converting it into synthetic fuels.
[8] Electrifying heat demand in cement production would cut ~40% of emissions in cement, while making it easier to capture the remaining process-based emissions via CCS (as the concentration of CO_2 would be much higher in the absence of combustion exhaust gases in the flue stream).

fuels in a low-efficiency process. Therefore, wherever electrification is an option, the benefits of electrification over synthetic fuels are huge. Synthetic fuel deployment in the HPA is concentrated in areas where electrification will be challenging, and where hydrogen also suffers from energy density challenges, such as aviation and shipping.

In the case of biomass, this is due to a combination of efficiency considerations and sustainability limits. First, biofuels still rely on combustion as the process to convert the chemical energy stored in the fuel into useful energy for the end-user. In almost all cases, direct electrification is a much more efficient process than biomass. However, the main limitation on biofuel usage is the scale at which biofuels can be sustainably produced. Biofuels have a range of significant sustainability challenges, including indirect land-use change emissions associated with dedicated biomass crops, competition with food production and potential risks to food security, the impacts of monoculture biomass plantations on biodiversity, and potential conflict with traditional users of land such as indigenous peoples (Energy Transitions Committee 2021).

If these limitations are properly accounted for, then the level of biomass that can be supplied while not transgressing climate, biodiversity and societal safeguards is likely very limited. Recent analysis has suggested this could be as low as 30–50 EJ/yr, which is the same size or less than current global biomass demand (Energy Transitions Committee 2021).

We limit biomass production to the lowest levels possible, to minimise potential negative impacts of large-scale biomass production. Total biomass supply is limited to below 80 EJ/yr. With this limited supply of biomass, biofuels play a marginal role in the energy system. The limited portfolio of biomass is deployed in solid, liquid and gaseous form, across the energy sectors of transport, buildings and industry. However, it plays at best a limited role in each, with direct electrification the foundation of the energy system. Providing 80 EJ/yr of biomass supply may also not be possible without transgressing climate, biodiversity and societal safeguards. If this is the case, the role of biofuels in the energy system would need to be further limited, and direct electrification increased.

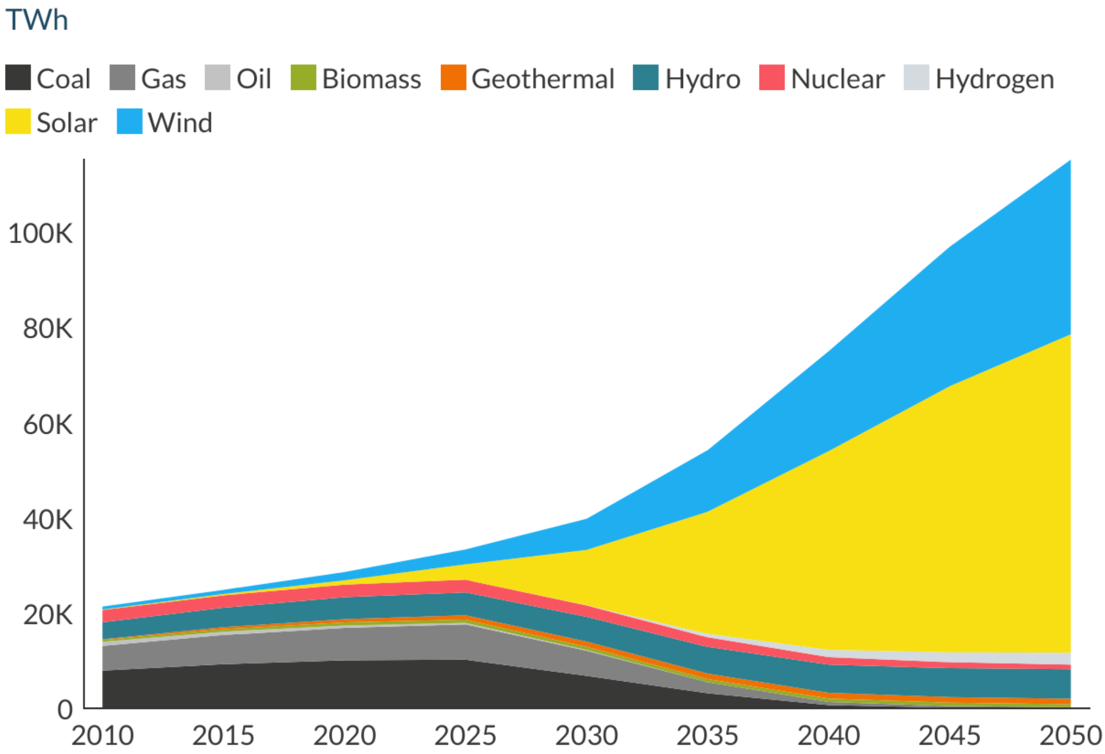
Box 1: The renewables era

With over three-quarters of final energy provided by electricity (whether indirectly or directly), the new HPA scenario sees a vast expansion in electricity generation by mid-century. Power generation almost quadruples from today's levels to almost 120,000 TWh by 2050. The acceleration in global power demand is particularly marked across the 2030s and 2040s, when electricity demand grows at around 3,500–4,000 TWh/yr, equivalent to around double India's current annual electricity consumption. This transition is driven in particular by wind and solar, which provide over 90% of electricity demand by 2050 (Figure 7). This is supported by large-scale deployment of batteries to help store electricity produced by variable renewables.

Global renewables capacity grows 3.5-fold by 2030 relative to 2022 levels, reaching 11.9 TW in 2030. This is broadly in line with (although slightly ahead of) the tripling goal agreed at COP28. However, by 2035 capacity has doubled again in five years, to reach around seven times higher than 2022 levels, and by 2050 goal renewable capacity is almost twenty times higher than 2022 levels. Rapid renewable electrification alongside adequate grid infrastructure and flexibility is the cornerstone of any transition that keeps the Paris Agreement's long-term temperature goal alive.

Surging renewables in the power sector push fossil fuels out of the mix, even as electricity grows rapidly. Both coal and gas are effectively phased out of the power sector by 2040, with both contributing less than 1% of electricity generation at this point.

Global electricity mix



Share of global electricity generation

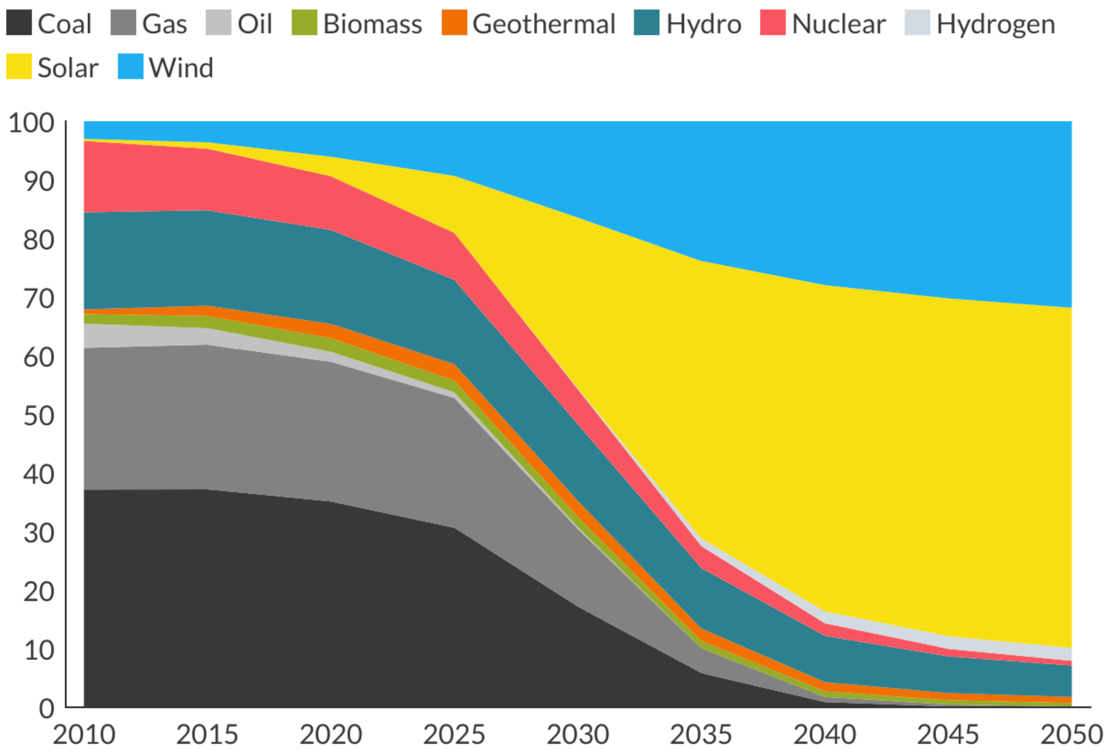


Figure 7: (a) shows the global electricity mix and (b) the share of global electricity generation of the Highest Possible Ambition scenario out to 2050.

Lever 2: A rapid fossil fuel phaseout

Clean electricity pushes fossil fuels out of the energy system at pace and scale. Production and consumption of all fossil fuels peak immediately and fall rapidly, with coal effectively phased out by the 2040s, gas in the 2050s and oil in the 2060s. The pace of phaseout substantially exceeds the levels seen in IPCC AR6 scenarios, which rely more heavily on fossil CCS and CDR to enable continued fossil fuel use, and have less need to reduce temperatures in the long-term (because they modelled lower peak temperatures).

Electrification and renewables are the cornerstones of a fossil fuel phaseout. In this scenario, the production and use of coal, oil, and gas each peak immediately in 2025 and fall rapidly towards zero.

Figure 8 highlights the trajectories for global fossil fuel production and use in the HPA scenario across the century, with the percentage reductions relative to 2025 shown in Table 3.

Coal production falls fastest, with total production down by almost a third in 2030 relative to 2025 levels. This is driven particularly by the power sector, with around 60% of the reduction in coal over 2025–2030 coming from closing coal-fired power stations. This continues through the 2030s but is complemented by increasing action to phase out coal use in industry, particularly in steel, as electric arc furnaces and hydrogen direct reduction furnaces replace the traditional blast furnace route. Coal production and use is essentially phased out in the 2040s.

Global fossil fuel production, including non-energy use, falls to zero in the Highest Possible Ambition scenario

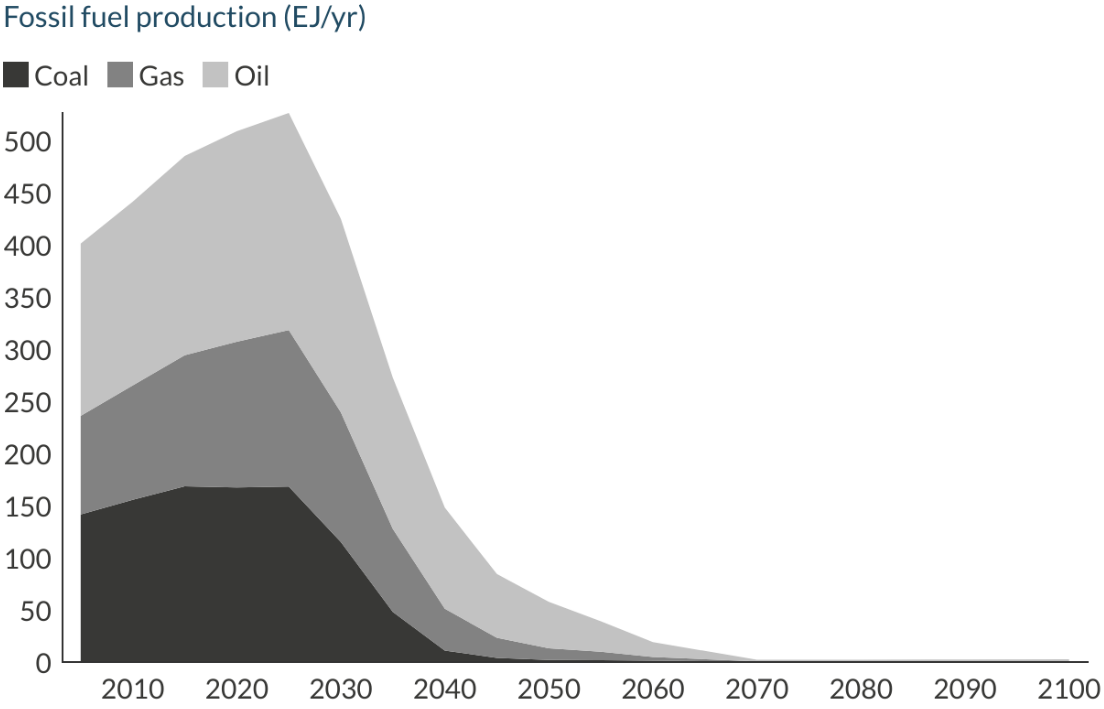


Figure 8 shows the global fossil fuel production in terms of total primary energy supply/demand out to 2100 in the Highest Possible Ambition scenario.

Table 3: Reductions in fossil fuel production in the Highest Possible Ambition scenario relative to 2025 levels

	2030	2040	2050	2060	2070
Coal	-32%	-93%	-99%	-99%	-100%
Oil[9]	-11%	-53%	-79%	-93%	-99%
Gas	-17%	-73%	-92%	-98%	-100%
Oil and Gas	-13%	-62%	-84%	-95%	-100%
Total fossil fuel production	-19%	-72%	-89%	-96%	-100%

[9] Oil production falls 99.2% by 2070. Combined oil and gas production falls 99.5% (so 100% to the nearest percent), and total fossil demand falls 99.6%.

However, phasing out coal alone is not enough, and is complemented by deep reductions in oil and gas production. Combined production of oil and gas falls 13% by 2030, over 60% by 2040 and over 80% by 2050. Gas production is effectively phased out in the 2050s and early 2060s, while oil is effectively phased out in the late 2060s.[10] Total fossil fuel production is cut by around a fifth in 2030 and almost three-quarters by 2040. This means that total fossil fuel production falls 4% a year from now until 2030 in the HPA scenario.

The result is a fossil free economy by 2070. Importantly, this includes non-energy use. Key to eliminating the use of fossil fuels in non-energy (i.e. as a chemical feedstock) is the use of alternative feedstocks, particularly those based on sustainable biomass and synthetic feedstocks produced using green hydrogen and CO_2 captured from the air. In 2050, half of total fossil fuel feedstock demand has been replaced by alternative feedstocks. Bio-based feedstocks scale-up is limited by the availability of sustainable biomass, and synthetic feedstocks face the same challenges of synthetic fuels – the demands for large amounts of electricity, and need for a sustainable carbon feedstock (which in these scenarios comes largely from direct air capture).

However, even if the scale-up of alternative feedstocks is slower than in the HPA scenario, the overall trajectory of the fossil fuel phaseout would remain largely unchanged. At most it would introduce a small tail of residual fossil fuels in the feedstock sector. Since around 90% of fossil fuels are used in the energy sector (Zanon-Zotin *et al* 2024), renewable-based electrification would displace and virtually eliminate demand for fuel fuels.

Advanced economies take the lead in this transition, achieving a fully fossil-free economy by 2050. There is a small tail of fossil fuels remaining in emerging and developing markets, but this is fully eliminated by 2070.

Fossil fuel production and the demand for fossil fuels are not independent variables but are deeply linked. Expanding fossil fuel production can help to sustain demand for fossil fuels via lower prices, infrastructural lock-in, the entrenchment of vested interests against a transition and more (Erickson *et al* 2018). Meanwhile, as demand for fossil fuels peaks and declines (driven by the rapid growth in renewables and electrification) then some fossil fuel production assets will become stranded and need to be retired (Mercure *et al* 2018). Ensuring a just transition in fossil fuel production is essential and

[10] Defined as >95% reductions in fossil fuel production relative to 2025

will require careful planning and clear policies to support countries and communities who are economically dependent on fossil fuel production.

Phasing out fossil fuels would bring a wide range of benefits: preventing millions of deaths from fossil fuel air pollution (Lelieveld *et al* 2023); alleviate associated health and socio-economic injustices (Vohra *et al* 2025); reduce negative impacts on biodiversity from fossil fuel extraction (Earth Insight 2025); and ultimately prevent further escalation of the climate emergency. A fossil free future is not only achievable, but desirable, in order to create a healthier, fairer and safer future for all.

CCS fitted to fossil fuels has at best a marginal role in the HPA scenario. Deployment peaks in 2050 with under 500 MtCO_2 / year of fossil-based emissions being captured and stored, approximately 80% lower than the median IPCC AR6 scenario. As fossil fuels are fully phased out by 2070, the role for fossil CCS is at best temporary. If no fossil CCS was deployed, even without alternative technologies and options replacing it, cumulative CO_2 emissions by 2100 would only be 13 GtCO_2 higher. This means that fossil CCS deployment over the whole century captures only a third of one years' current fossil CO_2 emissions, highlighting the marginal role that this technology plays in the HPA scenario.

Fossil CCS deployment is lower than in the IPCC AR6 scenarios for two reasons. First, deployment is lower because the HPA includes limits on the rate at which CO_2 can be stored underground. With competition for a finite CO_2 storage resource, the HPA scenario prioritises this resource for CDR deployment and CCS capturing process-based emissions from industry. This means there is much less room for fossil CCS. Secondly, deployment is lower because the HPA scenario better accounts for the growing portfolio of zero-carbon options which could replace fossil CCS in a range of sectors. This includes improved representation of the potential for electrification in industry, better representation of the potential for a fossil-free power sector driven by renewables and short- and long-term electricity storage, and representation of hydrogen and synthetic fuels which can displace fossil fuels in areas where electrification potentially still faces barriers.

Claims that calls for a fossil-fuel phaseout lack scientific basis (Carrington and Stockton 2023) are not supported by the evidence. Indeed, as we move into a period of overshooting 1.5°C, the need for a fossil phaseout becomes only greater, in order to maximise the achievability of long-term temperature reductions.

As the prospects of overshoot of 1.5°C increase, so does the need to take urgent action to peak warming and bring temperatures back down. Doing so will require deep reductions in non-CO_2 emissions and scaling up CDR to the maximum levels that are achievable within sustainable bounds (see the following sections). However, the scale to which non-CO_2 emissions can be eliminated remains uncertain (Harmsen *et al* 2023), and the challenges facing rapid scale-up of CDR are also immense (Smith *et al* 2024).

This means that, if net zero GHG emissions are to be reached in the second half of the century, it is essential that fossil fuel production and use is cut to the very lowest levels possible. Allowing fossil fuel use to continue will fundamentally undermine efforts to reduce long-term temperatures. Without a fossil phase-out, rather than bringing temperatures down, CDR and reductions in non-CO_2 emissions will be simply offset a limited amount of continued fossil-based warming. A fossil fuel phaseout is therefore a key lever in bring temperatures back below 1.5°C.

Lever 3: Cutting methane to curb peak temperatures and bring temperature down in the long-term

Cutting methane emissions helps reduce peak temperatures and contributes to long-term temperature decline. Methane emissions fall around 20% by 2030 (relative to 2025), driven particularly by reductions in methane emissions from the energy system, with more modest (although still substantial) reductions in agriculture and waste emissions.

Together with a fossil phaseout and strong CDR deployment, rapid reductions in methane (and other short-lived climate pollutants) are essential to limiting peak warming and driving down temperatures after the peak.

Methane is a highly potent greenhouse gas, with a warming effect over 20 years of around 80 times that of CO_2. However, methane also has a much shorter lifetime in the atmosphere, with a pulse of methane emissions lasting for around 12 years in the atmosphere before being oxidized to CO_2. If methane being removed by these natural oxidative processes is not fully replaced by new emissions (because methane emissions are falling over time), then the net radiative forcing from methane will fall. This means that reducing methane emissions can lead to long-term temperature decline.

Cutting methane emissions is therefore essential, both to limit peak warming and to bring temperatures back down again after overshoot. Methane emissions fall 18% over 2020s in the HPA scenario, 31% by 2035 and 48% by 2050, relative to 2020. This is driven particularly by very strong reductions in methane emissions from fossil fuel extraction, which are approximately halved over the 2020s, cut 90% by 2040 and essentially eliminated in their entirety by mid-century. Around a third/three-quarters of the energy sector methane reductions achieved by 2030/2040 are indirectly driven by the reduction in overall fossil fuel extraction, while the rest is driven by increased deployment of mitigation measures to directly reduce fugitive emissions along the fossil fuel supply chain. Meanwhile there are more modest reductions in methane in waste and agriculture (Figure 9).

Methane emissions fall rapidly in the HPA scenario to help limit peak warming and drive long-term temperature decline

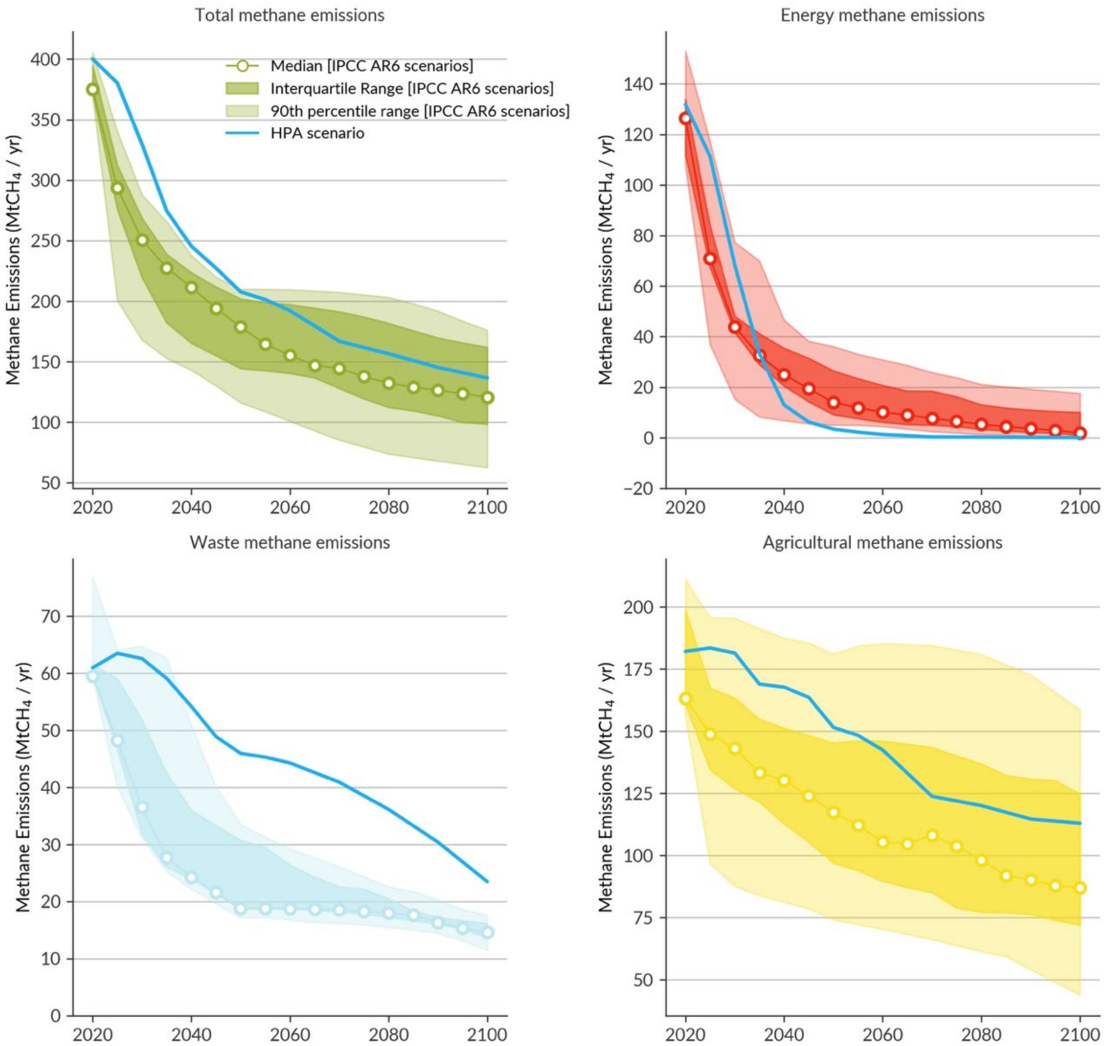


Figure 9 compares methane emissions in MtCH$_4$/yr in the Highest Possible Ambition scenario with the IPCC AR6 scenarios. Panels show: Top left (total methane emissions), top right (energy), bottom left (waste), bottom right (agriculture)

The reason for this difference is largely due to differences in the underlying drivers of emissions and the cost and availability of mitigation options. The driver of energy sector methane emissions is fossil fuel extraction, which by the 2030s is in freefall towards zero in the HPA scenario. Meanwhile the drivers of methane emissions in waste and agriculture are largely landfill sites and demand for animal proteins. This scenario uses a middle-of-the-road socio-economic setup in which there is continued growth in demand, particularly in emerging markets (Fricko *et al* 2017). This difference explains a large amount of the variation between methane emissions from energy and the other sectors. This also highlights the importance of working to reduce growing demand for animal protein around the world – a shift which would bring profound health and biodiversity benefits, as well as climate benefits (UNEP 2023, Rockström *et al* 2025). Secondly, for any fossil fuels which *are* being produced in the future, there are a wide range of very low-cost (or even negative-cost) options to reduce fugitive emissions from fossil fuel extraction (IEA 2024a), while abatement costs in waste and agriculture are often higher (Harmsen *et al* 2023).

It is important to highlight the substantial uncertainty in methane abatement. Other sources identify that waste sector methane emissions could be almost halved by 2030 (EPA 2019), which goes beyond the reductions in the HPA scenario. Further work should explore the potential to cut methane at pace from all sectors. More information on the assumptions around methane emissions in the HPA scenario can be found in the Methods Annex.

Lever 4: Carbon dioxide removal as an inevitable part of the pathway to bring temperatures back below 1.5°C

CDR deployment in the HPA scenario scales rapidly from the 2030s onwards, reaching 8 $GtCO_2$/yr by 2050, driven by a mix of direct air capture with CCS (DACCS), biomass with CCS (BECCS) and afforestation/reforestation (A/R). By 2100, the scenario has removed cumulative totals of 150 $GtCO_2$ via the land system, 180 $GtCO_2$ via DACCS and 200 $GtCO_2$ via BECCS. This cumulative CDR deployment drives around 0.23°C of cooling. The HPA scenario can still bring temperatures below 1.5°C pre-2100, even if CDR deployment is lower than modelled in the central case.

The renewable electrification and fossil fuel phaseout levers can collectively put a handbrake on primary driver of climate change, turning off the tap of fossil-driven emissions that are currently pouring into the atmosphere. However, in a world that has overshot 1.5°C, these levers alone will not be enough. Further action will be needed to bring temperatures back down below 1.5°C. Key to this is achieving net-negative CO_2 emissions, which will require the deployment of CDR to some level.

In the past, IAM scenarios have been heavily criticised for overreliance on CDR, which can dilute the pressure and urgency for action to reduce fossil fuel use (Anderson and Peters 2016, Grant *et al* 2021). These criticisms are valid, and excessive CDR deployment that enables continued fossil fuel use remains an issue in many global pathways.

The HPA scenario assumes levels of CDR deployment from conventional land-based and engineered methods broadly within previously identified sustainability and feasibility bounds in the literature (Deprez *et al* 2024, Grant *et al* 2021, Kazlou *et al* 2024, Gidden *et al* 2025). Total CDR is shown in Table 4.

Overall:

- BECCS deployment grows to around 3 $GtCO_2$/yr in 2050 and is sustained at these levels going forwards.
- DACCS removes around 2.5 $GtCO_2$/yr in 2050 and grows post-2050 towards 4 $GtCO_2$/yr removals by 2100.
- Conventional CDR from land-use peaks at 2.7 $GtCO_2$/yr in 2050 and then declines towards 2 $GtCO_2$/yr by 2100. This is important, as emerging evidence continues to emphasise the risk of over-relying on a volatile and potentially declining land-use sink.

Too many pathways have put too large an emphasis on CDR from tree-planting as a climate solution – and while the right trees in the right places (and more importantly, ending deforestation and promoting ecosystem restoration) has a role to play, it is no replacement for deep reductions in fossil fuel production and use. For more details on the land-use transition in the HPA scenario, see Box 2.

Box 2: The role of the land sector in the HPA scenario

In this report, we use a detailed energy system model, REMIND 3.5, to model a global pathway for the energy system that minimises the magnitude and duration of overshoot, and brings temperatures back below 1.5°C pre-2100. While REMIND can be coupled with the land-use model MAgPIE, in this analysis we use a reduced-form emulator of MAgPIE to capture the most critical land-use dynamics. This provides less detail on the land-use transition than a fully coupled run with MAgPIE would do. Here, we highlight two key elements of the land-use transition in the HPA scenario.

First, **rapid reductions in deforestation and tree-cover loss** are a critical elements of the HPA scenario. Gross emissions from forest loss fall to near zero by 2040, with remaining emissions likely arising from legacy processes such as soil decomposition that continue even in the absence of forest loss.

Secondly, the **carbon sink from land-use systems expands** in the HPA, but there is **reduced reliance on the land-use sink** compared to the IPCC AR6 scenarios, particularly in the second half of the century. Anthropogenic removals from the land-use sector stabilise in the HPA scenario at around 2 $GtCO_2$ / year. This is around half the level in the median IPCC AR6 scenario, in which removals from the land-use sector are around 4 $GtCO_2$ / year over 2050–2100.

The HPA scenario's total removals from the land-use sector aligns broadly with the levels of carbon sequestration that could be achieved via reforestation alone, according to recent studies. This would therefore reduce the need to afforest large areas of land which did not previously have trees on, and would reduce some of the adverse biodiversity and socio-economic impacts that large-scale afforestation could bring (Fesenmyer *et al* 2025, Wang *et al* 2025).

Table 4: CDR deployment in the HPA scenario

	2030	2050	2100
BECCS (Mt CO_2/yr)	50	3100	3000
DACCS (Mt CO_2 /yr)	36	2600	3700
Land-Use (Mt CO_2 /yr)	180	2700	2300

The level of CDR deployment in the HPA scenario is lower than seen in the AR6 scenarios for BECCS and A/R, and similar to the AR6 scenarios in the case of DACCS

(Figure 10).[11] However, it still remains a large-scale expansion of a new sector of carbon removal that will require dedicated policy and support to ensure successful scaling. We explore the implications of failing to scale CDR to this level in Box 3: What if we fail at scaling CDR?

The HPA scenario relies less heavily on CDR than the IPCC AR6 scenarios with particularly less BECCS and A/R deployment

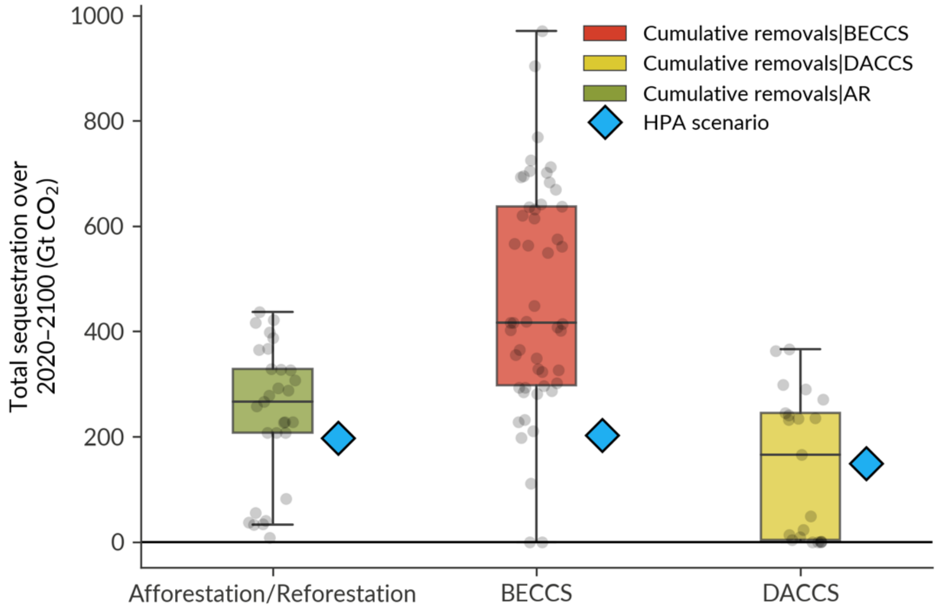


Figure 10 compares CDR deployment in the Highest Possible Ambition scenario with the IPCC AR6 scenarios. Each dot represents a different IPCC AR6 scenario, while the boxes show the median and interquartile range. The blue diamond represents the HPA scenario.

CDR deployment is no excuse to slow down the pace of fossil phaseout. As highlighted before, to get temperatures back down below 1.5°C as fast as possible, we need to simultaneously phase out fossil fuels while rolling out CDR. It's not one or the other, it's both.

Box 3: What if we fail at scaling CDR?

While this scenario deploys CDR at lower levels than many scenarios in the literature, it still represents unprecedented growth of an entire new sector of the economy – with engineered removals (BECCS and DACCS) growing from close to zero today to

[11] Only 21 C1a scenarios model DACCS as a CDR route. Within this, there are a set of scenarios which explicitly constrain DACCS to be zero or close to zero. The distributions shown here are highly influenced by the particular set of scenarios which modelled DACCS in IPCC AR6.

over 5.5 $GtCO_2$/yr by 2050. The challenges that the world would face in scaling CDR to these levels are very large.

At the same time, this scenario only includes three levers for carbon dioxide removal and excludes a range of other options which could make some contribution towards total drawdown, including ocean or land-based enhanced weathering, biochar and ecosystem restoration (Smith *et al* 2024). These options also face major challenges to scaling rapidly, but they could potentially make a material contribution by 2050, which could reduce the burden on the remaining levers.

However, there is a real chance that the world will fail to deploy CDR to the levels seen in this scenario. This does not push 1.5°C out of reach on its own. For example, if BECCS and DACCS deployment only reach 1 $GtCO_2$/yr by 2050, and fail to scale any further post-2050, then cumulative sequestration from BECCS and DACCS would be around 125 $GtCO_2$ by 2100 – down from the approximately 400 $GtCO_2$ that is otherwise stored in the scenario.

Using the median transient climate response to cumulative emissions (TCRE), this would lead to mid-century temperatures being 0.015°C higher, and end-of-century temperatures up by 0.12°C. As a result, peak temperatures would just surpass 1.7°C, and in 2100 temperatures would be just above 1.3°C, still well below 1.5°C.

In reality, reduced BECCS and DACCS deployment could also free up additional biomass and electricity to be used in decarbonisation elsewhere. Therefore, the real temperature impact could be slightly lower, although the exact impacts of reduced BECCS/DACCS are not possible to ascertain without producing additional scenarios.

In a world where every 0.1°C matters, it makes sense to try and scale CDR as fast as possible. But the HPA scenario is still able to rescue 1.5°C, even with significantly reduced CDR deployment. The foundation of this scenario is a rapid transition to renewable electricity – and while CDR plays a key role, the scenario is robust enough to withstand alternative assumptions about the pace of rollout, because it achieves a fossil phaseout.

The costs of delay

Our collective failure to cut emissions over the 2020-2025 period does not mean that the Paris Agreement's long-term temperature goal is out of reach. The HPA scenario highlights that, while overshoot is now inevitable, it is still possible to limit the magnitude of duration of overshoot and bring temperatures back down below 1.5°C before 2100. Moreover, regardless of the extent of overshoot the world will experience, 1.5°C will endure as an ethical, legal, and scientific imperative.

Our new scenario, if implemented, would avoid huge climate impacts compared to our current emissions trajectory. However, it still carries with it substantially increased risks compared to if we had started to cut global emissions in line with the IPCC AR6-assessed scenarios in 2020. The delay of the last five years does not come for free.

We are now locked into a world of greater climate impacts and risks, and will also need to slash emissions even faster, leading to increased asset stranding and greater transition risks. Every year of further delay will only exacerbate climate and transition risks, putting the world on a collision course with chaos.

When looking at climate risks, maximum overshoot temperatures could be greater by 0.1°C and last around 10 years longer, with peak warming at around 1.7°C and the duration of overshoot at around 40 years, compared to the IPCC AR6 scenarios. This takes us deeper and longer into the danger zone, where risks of crossing irreversible tipping points are much higher and climate impacts escalate much faster.

One way to quantify the level of overshoot is the degree-years of overshoot above 1.5°C – the years above 1.5°C multiplied by the exceedance temperature. This gives a quantification of our exposure to climate risks from overshoot, with the higher the value, the higher the risk.

The overall degree-years of overshoot above 1.5°C in the HPA scenario are 4.3°C-years, compared to the median IPCC AR6 scenario's overshoot of 1.3°C-years. That is, there is more than triple the cumulative exposure to overshoot due to the delay in taking action[12].

As many irreversible climate impacts such as permafrost and ocean changes scale strongly with overshoot exposure (Dickau *et al* 2025), this represents a very worrying and unfortunate commitment to increase risk exposure. Any further delays will only exacerbate these climate risks.

At the same time, the pathway back towards a "safe" climate zone is steeper now than it was five years ago. Previous analysis has highlighted how every year that emissions fail to fall means there is more work to do in less time going forwards (Höhne *et al* 2020). This remains the case even more so today.

Figure 11 shows the rate at which coal and gas capacity is retired at the global level, comparing the HPA scenario to the IPCC AR6 scenarios. It looks at the rates over the first ten years of action, which is the 2020s for the IPCC AR6 scenarios and the 2025-2035 window for the HPA scenario.

While the rates of coal retirement remain broadly the same between the AR6 and HPA scenarios, the rate at which gas power stations must be retired is much greater in the new scenario. In the HPA scenario, almost 75 GW/yr of fossil gas capacity is retired per year over 2025–2035, whereas in the median IPCC AR6 scenario net gas capacity could remain broadly flat over the first ten years of these scenarios (with some variation on both sides). As a result, total fossil capacity retirements in the HPA scenario reach 200 GW/yr capacity reductions over 2025–2035, which is higher than all but one scenario from the IPCC's AR6 report, with the average AR6 scenario only needing to retire 100 GW/yr of fossil capacity.

[12] The degree-years metric refers to the sum of the years spent above overshoot, each weighted by the degree of overshoot. It can be thought of as the area between the 1.5°C temperature threshold and the scenario's temperature curve.

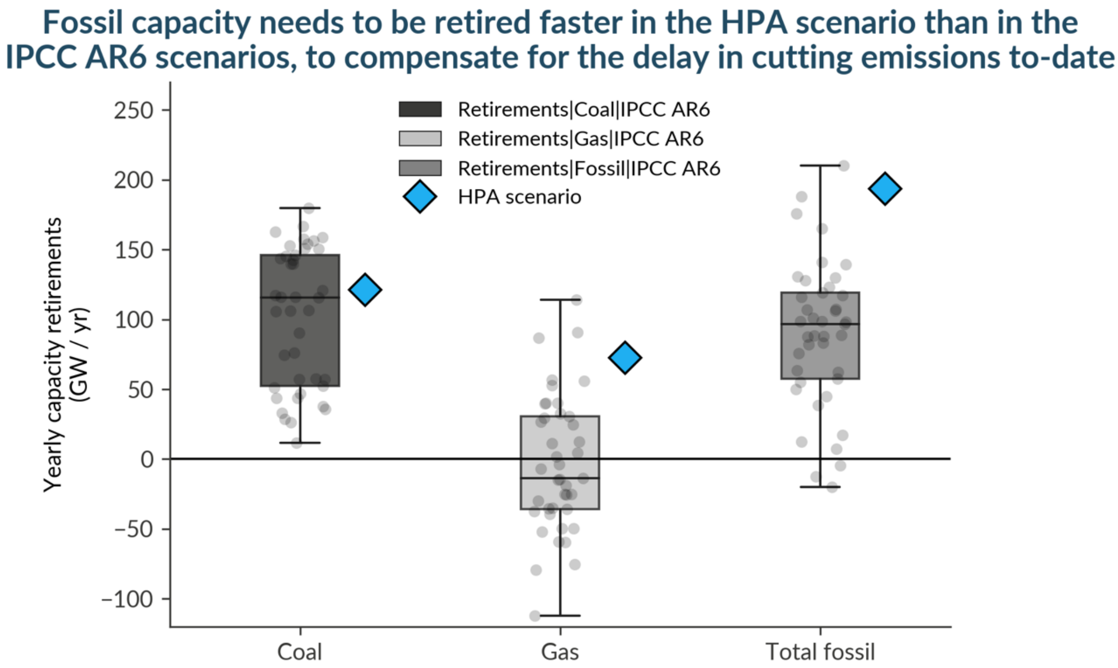


Figure 11 shows the rate at which fossil-fuelled power plants are retired in the first ten years of action in a scenario. It compares the Highest Possible Ambition scenario with the IPCC AR6 scenarios. Each dot represents a different IPCC AR6 scenario, while the boxes show the median and interquartile range. The blue diamond represents the HPA scenario. Data for the IPCC AR6 scenarios covers 2020–2030, while data for the HPA scenario covers 2025–2035 (as the scenario starts 5 years later than the IPCC AR6 scenarios).

This analysis shows that it is still possible to bend the emissions curve, limit peak temperatures and bring them back below 1.5°C before 2100. But it is harder and more disruptive than it was five years ago and comes with greater climate risks. Any further delay and new fossil fuel developments will simply lock-in further fossil assets that will be stranded in the coming zero-carbon economy, while committing us to higher temperatures and greater risks of triggering climate tipping points.

Conclusion

As global temperatures approach 1.5°C, uncertainty about whether it is still possible to meet the Paris Agreement's temperature goal (and if so how) is only growing. At the same time, the mitigation pathways used to inform global climate action are becoming increasingly outdated. This report provides an updated global emissions pathway that addresses the evidence gap and uses it to demonstrate how we can still meet the goals set in Paris in 2015, beginning with immediate action in 2025 and a decade of accelerating implementation thereafter.

In summary, our analysis shows:

- Global warming can be halted within the next 15 to 20 years.
- Overshooting 1.5°C by 0.2°C is now very likely unavoidable, due to the failure to cut global emissions to date. The duration of overshoot would likely be for at least 40 years.
- Peak global warming will reach at least 1.7°C.
- Achieving net zero CO2 emissions by the 2040s is feasible and will halt long-term warming.
- Achieving net zero greenhouse gas emissions by the 2060s remains feasible and will result in warming dropping from peak levels.
- Warming can be brought well below 1.5°C by 2100, to around 1.2°C.
- The delay of the last five years has roughly tripled our overall exposure to overshoot.

Table 5 summarises the outcomes of the HPA scenario in comparison to the IPCC AR6 scenarios.

Table 5: Summary of the Highest Possible Ambition scenario compared to the IPCC AR6 scenarios

	IPCC AR6 scenarios	HPA scenario
Peak warming	1.6°C [1.4–1.6]	1.7°C
2100 warming	1.2°C [1.1–1.4]	1.2°C
Max overshoot of 1.5°C	0.1°C	0.2°C
Duration of overshoot	~30 years	~40 years
Peak emissions	Pre-2025	2025
Net zero CO_2	2050–55	2045
Net zero GHGs	2070–75	2060

While it is possible to bring temperatures back well below 1.5°C by 2100, the world has to now achieve deeper emissions reductions in less time. The pace of change in the energy system will have to significantly accelerate, requiring a more disruptive transition with increased asset stranding. Every year that we fail to cut emissions in line with the highest possible ambition locks in additional climate and transition risks.

We identify four key levers for the transition: renewable-driven electrification, a fossil phaseout, upscaling CDR, and curbing methane emissions. While these are not the only actions that need to be taken to bring temperatures back below 1.5°C, they represent the core of the scenario. Together, they would deliver a fossil-free energy system powered by wind, solar and batteries, with zero-carbon electricity at the heart of industry, buildings and transport systems, and one that is able to remove significant amounts of carbon from the atmosphere per year.

Policy implications of the HPA scenario

What do decisionmakers need to do to align with the HPA scenario? We identify a range of actions, based on the levers identified above.

Actions for the next five years

Over the next five years, annual global emissions fall by 10 $GtCO_2e$ in the HPA, at an average rate of 2 $GtCO_2e$ per year. This is particularly driven by the renewable electrification lever, which leads to substantial reductions in fossil fuels. Methane reductions also play a central role, while other levers (including scaling CDR deployment) have a smaller impact by 2030 (Figure 12).

Accelerating renewables deployment to push fossil fuels out of the power sector contributes around 40% of the emissions reductions needed by 2030. Renewable capacity more than triples relative to 2022 levels, to almost 12 TW by 2030. While this represents a significant growth from today's levels, the IEA estimates that under current policies and market conditions renewables could already reach 9.5-10.5 TW by 2030 (IEA 2025a). An acceleration is needed, but this goal is clearly within reach.

Renewables then displace both fossil-based electricity in the power system and fossil molecules in the end-use sectors by electrification. Fossil-based electricity falls by 5600 TWh over 2022–2030, to reach 12,200 TWh in 2030. Meanwhile at the same time total electricity generation grows to 39,800 TWh by 2030, up from 28,900 TWh in 2022. This provides the majority of the clean energy required to push fossil fuels out of transport, industry and buildings. Emissions reductions in these sectors provide another 30% of the emissions cuts required by 2030.

Another key action is reducing methane emissions – which fall around 1.5 $GtCO_2e$ over 2025 to 2030. This is driven particularly by reductions in the energy sector, which fall around 40% over the next five years.

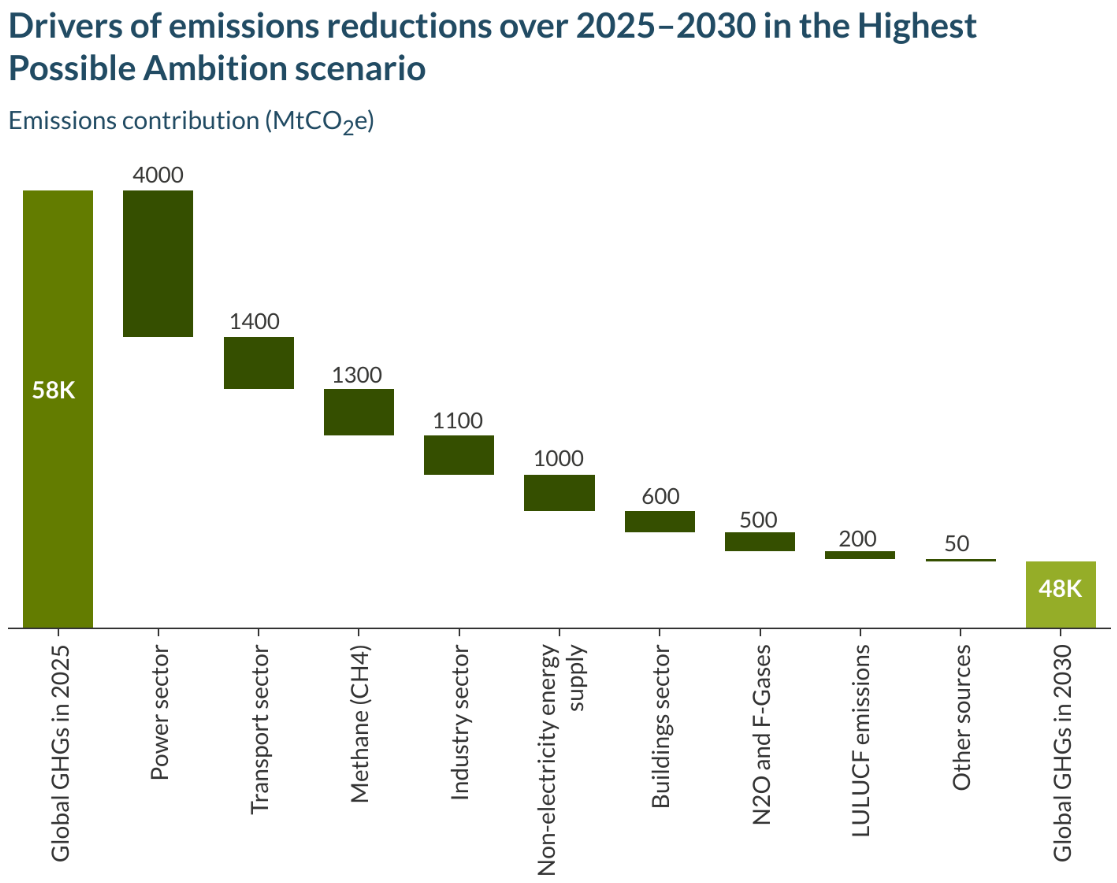


Figure 12 shows the different drivers of emissions reductions over 2025–2030 in the Highest Possible Ambition scenario.

Longer-term actions

Our analysis highlights the central importance of achieving net zero CO_2 before mid-century and net zero GHGs in the 2060s.

These dates are earlier than those which were identified by previous IPCC reports. This suggests that countries should revisit their existing net zero targets, and update these to be in line with the latest science as evidenced here.

We note that not all countries will achieve net zero at the same time, with some countries (especially those with the largest transition capacities) achieving net zero ahead of the global average, and others behind the average. This would broadly entail advanced economies achieving net zero GHGs ahead of emerging and developing markets. The implications for individual regions and countries will be further explored in a following analysis that delves deeper into the details of the HPA scenario.

However, by explicitly committing as a world to achieve global net zero CO_2 emissions prior to 2050, and net zero GHG emissions soon after, and ensuring that national net zero targets are sufficient to achieve the global benchmarks identified here, the world can ensure that we peak warming pre- mid-century and get temperatures on a pathway to below 1.5°C pre-2100.

Ambitious net-zero targets can also act as guardrails for a country's climate policy and energy transition plans. Once these targets have been set, then near-term policies and actions can be implemented to ensure alignment with these goals, including the near-term actions highlighted above.

In the face of rising emissions and escalating climate impacts, many feel hopeless. And given the profound loss that climate impacts are inflicting on present and future generations and ecosystems, grief and lament is a justified response.

But grief is not the same as despair. We still have agency. Our ability to peak and reduce emissions at pace is only growing, driven by the unstoppable momentum of wind, solar, batteries and electrification technologies. The future remains in our (collective) hands. It remains possible to limit peak warming and get temperatures back below 1.5°C pre-2100. There is still time to embark on a rescue mission for the global climate system, one that would help avoid the worst impacts of the climate crisis, and the risk of triggering cascading tipping points.

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Methods Annex

Key assumptions underpinning the HPA scenario

The range of additional constraints and developments to the REMIND model to produce the HPA scenario are summarised below.

First, the scenario includes **regionally differentiated carbon prices.** Carbon prices in REMIND are a proxy for overall regulatory effort and should not be seen as a policy-prescriptive statement in favour of solely carbon pricing. However, they capture, in broad terms, the efforts that countries have taken to phase out emissions, subject to national constraints.

Many historical IAM scenarios have used a global uniform carbon price, drawing on economic thinking that suggests this would deliver a cost-optimal outcome, by enabling emissions to be cut where they are the cheapest (Bauer *et al* 2020). However, a globally uniform carbon price also has been criticised as unfair, as it can lead to developing regions with lower mitigation costs taking a higher share of the overall burden (Stern *et al* 2012, Bauer *et al* 2020). While this could be a cost-effective outcome, it might go against the UNFCCC's principles of equity and common but differentiated responsibilities and respective capabilities (CBDR-RC).

More importantly, growing research has highlighted that not all countries have the same institutional capacity to drive rapid emissions reductions (Brutschin *et al* 2022, Gidden *et al* 2023). The IPCC's AR6 report highlighted the lack of institutional capacity in many emerging and developing economies as one of the main feasibility challenges in 1.5°C aligned scenarios (IPCC 2022). Regardless of whether globally uniform climate action is fair, the question also remains whether it is feasible or realistic. Looking at the current geographical distribution of innovation, investment and deployment of zero–carbon technologies highlights that this has been concentrated in advanced economies and China to date, although this is beginning to change (IEA 2025c). Better incorporating socio-political and institutional capacity constraints in mitigation pathways could shift the balance of mitigation ambition between advanced and emerging economies towards the advanced economies (Muttitt *et al* 2023).

Therefore, rather than assuming a globally uniform price, we apply regionally differentiated carbon prices, with the spread in price given by a countries' GDP per capita in 2015. Carbon prices then converge to a global average by 2070. This represents a world in which all countries begin the energy transition immediately, with advanced economies take the lead. Importantly, this means the scenario is not attempting to be a "globally cost-optimal scenario" as conceived of within a theoretical economic setting (Bauer *et al* 2020). Rather, it represents a deviation from this cost-optimal scenario to better capture the real-world potential for rapid emissions reductions globally. In this sense, it attempts to align with the Paris Agreement, which does not call for globally cost-effective emissions reductions, but those that align with the "highest possible ambition", which varies from country to country. It is important to note that this scenario does not align with a specific equity principle, and further international cooperation and support, including financial transfers, would be needed to fully ensure an equitable distribution of effort within mitigation.

Secondly, the HPA scenario takes steps to **address energy inequality.** Current energy inequality is rampant, both between countries and within countries (Oswald *et al* 2020, Kikstra *et al* 2021). IAM scenarios have been criticised in the past for exacerbating inequalities in income, energy demand and other key metrics between advanced and emerging economies (Millward-Hopkins *et al* 2024). At the same time, demand-side solutions are an essential, but still at times neglected, lever in climate policy (Creutzig *et al* 2018, 2022, 2024). We make a first step to addressing these issues, acknowledging that this could be further refined in future scenarios. Final energy demand per capita in advanced economies is reduced by 25%, relative to a current policies scenario in which no explicit demand-side actions are considered. This reduction is phased in linearly over the 2025–2040 period. We remain agnostic about how much of this reduction is achieved by improved efficiency (delivering the same energy service demands but at lower final energy requirements), and how much is achieved by changes to consumer demand (such as reduced demand for consumer goods that would reduce industrial output). At the same time, final energy demand per capita in the low-income countries[13] is increased by 25% relative to the current policies reference scenario, which is set up

[13] Defined here as Sub-Saharan Africa and Asia excl. China and Japan, using the regional resolution of REMIND.

using SSP2-based assumptions around GDP and population growth.[14] This represents a world in which:

1. **Concerted action from advanced economies to implement demand-side strategies reduces the scale of their energy demand**
2. **Faster growth in energy demand accelerated development in low-income countries**

Inter-regional inequality diminishes by 2100, although it is not fully eliminated Further work could be done to further develop the implementation of this demand-side action, but this represents a first step towards addressing energy inequality in our pathway, while simultaneously increasing the representation of demand-side climate strategies in advanced economies.

Third, in this scenario, **biomass, CCS and CDR are limited to within sustainability and feasibility bounds defined in the literature.** The HPA scenario limits primary biomass supply to ~80 EJ/yr, across both energy (excluding traditional biomass) and non-energy uses (i.e. bio-based feedstocks). This is approximately 60% higher than current biomass supply globally (IEA 2025b). Much biomass supply currently is a disaster for both climate, biodiversity and social reasons – with largescale land-use change emissions, destruction of old-growth primary forests and biodiverse ecosystems, and the exclusion of traditional land users (German *et al* 2011, Jeswani *et al* 2020, Tudge *et al* 2021). Literature exploring the sustainable potential for biomass has often highlighted 100 EJ/yr (Creutzig *et al* 2015), although recent assessments suggest the potential could be even lower (Energy Transitions Committee 2021). To represent a precautionary approach to bio-energy reliance, we use the lowest level that REMIND can achieve while still satisfying the climate goals and techno-economic constraints. Meanwhile total geological sequestration via CCS is limited to 8.6 $GtCO_2$ /yr (Grant *et al* 2022). The combination of limited CCS and limited biomass represents an implicit constraint on the deployment of biomass with CCS (BECCS), while DACCS is also limited via cost penalties on the rapid scale-up of a nascent technology. The detailed land-used model MAgPIE, which can be coupled with REMIND, was not activated in this scenario, which instead utilised a MAgPIE emulator to capture key biomass supply and land-use emissions dynamics. However, afforestation/reforestation is kept to a conservative

[14] SSP2 represents a “middle-of-the-road” scenario in which GDP and population growth continue broadly along historical trends

level that still implies stopping and reversing deforestation, without largescale growth in tree cover.

The Highest Possible Ambition scenario is therefore one which starts from today's realities, reduces emissions as fast as possible, while enabling greater differentiation between regions at different places in their energy transition, and avoiding excess reliance on biomass, CCS or CDR deployment.

Uncertainties in our temperature assessment process

We highlight two key areas where the use of the standard AR6-style temperature assessment pipeline may need to be updated, and how this could impact on our results.

First, this pipeline harmonises historical emissions to data collected in the process of CMIP6 (Hoesly *et al* 2018), which provided an estimate of all relevant emissions in 2015. In the case of sulphur, this could be leading to an overestimation of emissions, as more recent data updates have provided a lower estimate for 2015 emissions (Hoesly *et al* 2024), and subsequent implementation of low-sulphur shipping rules have further reduced emissions. This matters because sulphur particulates have a very strong cooling effect, with sulphur having reduced global temperatures by around 0.5°C between 1750–2019, according to the IPCC (Szopa *et al* 2021). The rapid drop in sulphur emissions that occurred due to the new shipping rules have already been estimated to increase temperatures by ~0.04 to 0.05°C (Hausfather 2025). If this scenario is overestimating sulphur emissions, it could be underestimating warming slightly. We test harmonising sulphur emissions to the latest available data and re-running the temperature assessment using FaIR (Leach *et al* 2021), and find that this could increase peak temperatures by 0.015°C.

Second, and more importantly, this pipeline uses climate models which were calibrated based on historical emissions and temperature outcomes pre-2020. This means that they do not account for the anomalous warming observed in 2023/24, where record heat was observed around the world. If these spikes were due primarily to reduction in sulphur emissions, as argued by some (Quaglia and Visioni 2024), and the fundamental relationship between emissions and temperatures have not changed, then recalibrating the model based on the latest emissions will have little impact. However, if the record heat of 2023/24 was due in part to the emergence of new dynamics in the climate system, whether a collapsing land sink (Curran and Curran 2025, Ke *et al* 2024), cloud feedbacks (Goessling *et al* 2025) or other positive feedback loops, then the relationship between emissions and temperature could be changing. We may get more warming for the same emissions.

Representation of methane mitigation in the HPA

We use the most optimistic marginal abatement cost (MAC) curves from recent literature (Harmsen *et al* 2023), which produced optimistic, medium and pessimistic MAC curves for non-CO_2 emissions. These curves represent the widespread uncertainty around the applicability of different abatement options to different areas, and how effective each abatement option could be. If in reality the applicability of methane abatement options is reduced (e.g. to the medium MAC curve), then methane emissions could be higher. On the other hand, if alternative demand assumptions were made, for example which includes a significant reduction in landfill sites and their associated methane emissions from anaerobic digestion, or a steady shift towards plant-based diets, then methane emissions could be reduced further. This just highlights the widespread uncertainty around future methane emissions and how fast they can be cut. The only way to reduce this uncertainty is to work as hard as possible to address the underlying drivers of methane emissions (waste, animal protein and fossil fuel extraction), while supporting the rapid scale-up of abatement options in all sectors to help identify solutions that work versus those which are abatement dead ends.

The result of falling methane emissions in this scenario is a rapid reduction in radiative forcing from the pathways. Radiative forcing from methane peaks in the 2020s at around 0.5 W/m^2, and by 2100 has halved to 0.25 W/m^2. This is a significant contributor to temperature decline in the scenarios.

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