IPCC's upcoming 6th Assessment Report: Mitigation of Climate Change

March 2022

The Intergovernmental Panel on Climate Change (IPCC) is releasing the third of its four-part, Sixth Assessment Report (AR6) in April 2022.. The Working Group III (AR6 WGIII) report will be the most comprehensive review of how we can mitigate climate change - since the 5th assessment (AR5) in 2014, and the IPCC's three recent special reports (SR1.5 in 2018 and the 2019 SRCCL and SROCC).[1]

The report will be ratified after a plenary negotiation in which governments formally approve the summary for policymakers, ensuring high credibility in both science and policy communities. The outline is already approved, and the report will cover a broad spectrum of topics, from mitigation pathways and in-depth sectoral analysis to finance, international cooperation, net-zero and carbon dioxide removal. For the first time in IPCC history, chapters dedicated to technology, innovation and demand-side measures are included.

This briefing covers some of the major developments in our knowledge of mitigation since the IPCC's AR5 was published in 2014. Today, mitigation literature largely reflects the 2015 Paris Agreement, increasing net-zero commitments and the growing need for action from non-governmental stakeholders including businesses, industry and financial institutions.

1. Since AR5 greenhouse gas emissions have continued to climb

We are nowhere near on track to achieve the Paris targets of keeping warming below 2°C, and ideally 1.5°C. Current national climate plans (NDCs) will see us warm by about 2.7°C this century, or possibly even higher.[2] If CO_2 emissions continue at current rates, we will exhaust the remaining 1.5°C carbon budget in the early 2030s.[3] The energy infrastructure from planned and current fossil fuels alone commits us to about 846 $GtCO_2$ (more than double what's left in our 1.5°C carbon budget) and every year we add more carbon-intensive infrastructure than we decommission.

Of the greenhouse gases (GHGs), CO_2 causes most warming due to its high concentration and long lifetime in the atmosphere. Despite efforts to reduce emissions, our burning of fossil fuels adds more CO_2 to the atmosphere, pushing the cumulative atmospheric concentration to unsustainable highs. Between 1850-2019, coal, oil and gas accounted for ~66% of cumulative CO_2 emissions, with land-use change responsible for about 32%.

But since AR5, there has been greater recognition of increasing emissions of methane (CH_4) and nitrous oxide (N_2O). Both are potent GHGs that trap about 34 and 300 times more heat than CO_2 respectively (over a 100 year period). Methane is responsible for almost a quarter of human-caused warming to date, and concentrations are increasing faster now than at any time since the 1980s. Today, methane emissions are two-and-a-half times above pre-industrial levels. The AR6 WGI SPM authors emphasised that "strong, rapid and sustained reductions" in methane emissions would have the dual impact of limiting "the warming effect resulting from declining aerosol pollution" and improving air quality.

Between 2008-2017, agriculture and waste contributed most to the rise, followed by the fossil fuel industry. However, estimating by exactly how much, and from where, methane emissions are increasing is a topic of continued research and debate. For example, some researchers have found that the role of North American shale gas (so called "fracking") has been significantly underestimated in calculating the global methane emissions.

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[1]WGIII will be third of four separate reports published in the AR6 cycle. 'The Physical Science Basis' which detailed the current state of the climate was published on 9 August 2021 and the second report 'impacts, adaptation and vulnerability' was released in March 2022.

[2]These numbers are based on pre-Glasgow estimates. If you add all pre-Glasgow net-zero pledges to the NDCs this brings the world on track for 2.2°C, according to UNEP (or about 2.1°C in IEA assessments), page 12, section 7 of the 2021 Emissions Gap Executive Summary.

[3] Most recent estimates show that only 440 Gt CO_2 is left from 2020 to stand even a 50% chance of 1.5°C. Global emissions were over 40 Gt CO_2 in 2019, and if annual emissions are similar in the next decade it will be used up in the 2030s.

Emissions of N_2O have risen 20% from pre-industrial levels, with the fastest growth observed in the last 50 years, mainly due to nitrogen additions to croplands through fertilisers.

In 2018, global GHG emissions were about 57% higher than in 1990 and about 43% higher than in 2000. Emissions continued to rise in 2019, when they reached about 59 $GtCO_2e$. But in 2020, the COVID-19 pandemic led to a historical large drop in CO_2 emissions from fossil fuels and industry. During the height of global lockdowns, daily emissions dropped by 17% compared to 2019, levels not seen since 2006, and people around the world were allowed a short respite from deadly air pollution. Since then, emissions have rebounded, and were the highest yet last year. However, research has shown that rebuilding the economy in a more green, sustainable, just and climate-centred way represents a far greater opportunity than the short,lockdown-triggered emissions break, which will have little impact in the long run.

2. Without a drastic boost in climate ambition, our hopes of achieving the Paris Goals of 1.5°C and 2°C without "overshoot" are out of reach

We are increasingly likely to "overshoot" average global temperatures of 1.5°C and 2°C (meaning that global average temperature temporarily (on order of decades) exceeds the temperature target before reducing again. This can only occur if atmospheric GHG concentrations are lowered - and this is through carbon dioxide removal (CDR), which is by no means a given (see below)). Growing research shows that, for the same end of century temperature increase, overshooting is likely to lead to more climate damages (some of which are irreversible) - like biodiversity loss and extreme weather - than if we get there with no overshoot.[4]

Delaying mitigation means we will have to cut more emissions each year to stay Paris-aligned by 2030. We already knew the dangers of delayed mitigation in 2014, when the IPCC stated that scenarios with high emissions through to 2030 would have higher long-term economic costs, and would "substantially increase the difficulty of the transition" and "narrow the range of options consistent with... 2°C". Today, average annual emissions cuts needed to stay below 1.5°C are four times higher than they would have been if collective mitigation and ambition started in 2010, according to UNEP. This highlights the need to act fast.

Investment levels are also nowhere near to what we need to stay Paris aligned. The 2015 Paris Agreement recognised the key role finance plays in both mitigation and adaptation - it placed investors and financial commitments centre stage for climate policy and action. However, climate finance has only increased slightly since AR5, reaching about USD 579 billion in 2018/2017. This is about ten times less than the estimated USD 6.3 trillion needed every year by 2030 to stay Paris aligned.

Since AR5, the split between public and private climate finance has remained relatively stable (about 44% public and 56% private in 2018). Private finance has, however, outpaced public finance in the energy sector, and increasingly so in transport, reflecting a more mature renewable energy market and the fact that projects are now perceived to be less risky. The private sector is expressing increasing concern over the risks of climate impacts, but climate-related financial risks remain underestimated by financial institutions and decision makers.[5]

3. The richest 1% emit more than twice the poorest 50%

Since AR5, there has been increased interest in the 'national responsibility' for climate change, as well as the links to other sustainability, development and social issues. The US is responsible for about 20% of cumulative historical emissions, followed by China, Russia, Brazil and Indonesia. Just looking at national emissions does not, however, complete the picture, as the unequal size, wealth and carbon

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[4] Zickfeld, K. and Herrington, T., 2015. and; Ricke, Katharine L., and Caldeira, K., 2014 and; Tachiiri, K., Hajima, T. and Kawamiya, M., 2019.
[5] Some disclosure measures, like the Task Force on Climate-Related Financial Disclosure (TCFD) may also be largely ineffective, as the assumption that transparency will automatically lead investors to 'rationally' respond by moving climate finance from high- to low-carbon assets could be oversimplified.

intensity of populations need to be factored in. Looking at emissions relative to population size, developing countries tend to have lower per-capita emissions and, if emissions are normalised to population, China, Brazil and Indonesia do not even make the top 20.

The richest 1% worldwide emit more than twice the combined share of the poorest 50%, according to UNEP. Activities that emit a lot, but only benefit a few, include flying and driving SUVs. For example, if emissions from SUVs were counted as a nation, it would rank 7th in the world. As COVID-19 caused carbon emissions to fall last year, the SUV sector continued to see emissions rise. In 2018, only 2% to 4% of people got on an international flight, and 1% of the global population are responsible for about half of CO_2 emitted from all commercial flights. The aviation industry is responsible for 2.4% of global emission, as such these 1% users could be contributing about 450 million tonnes of CO_2 each year - about the same as South Africa's annual emissions.

Research, including last month's landmark AR6 WGII report, shows that climate change affects people differently by gender, race and ethnicity, and these all link to economic vulnerability. Marginalised groups have less access to energy, and use less. For example, women's carbon footprints are generally lower than men's, mostly due to reduced meat consumption and driving, though this varies across nations.[6] But, even though women generally emit less, their inclusion in policy making can lead to better climate policy. Climate groups are now recognising that disadvantage is the result of many interacting systems of oppression.

4. But there is hope: since AR5 national and corporate net-zero commitments have exploded and renewable energy has continued to outperform forecasts.

Since AR5, there has been a substantial growth in climate policy, legislation and treaties at both international, national and sub-national levels. Most importantly, in 2015, the Paris Agreement was signed. The Paris Agreement Article 4 seeks to achieve a "balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases", which can be interpreted as net zero greenhouse gas emissions (not just CO2). Renewable energy has also continued to massively outperform forecasts, making it a post-AR5 success story. Just in 2020, the amount of new renewable electricity capacity added rose by 45% to 280 gigawatts, the largest year-on-year increase since 1999 (more in box below), while costs have fallen sharply in that time. And, more recently, the concept of 'net-zero' entered the policy arena in full force.

In 2014, the IPCC was not directly using net-zero language, but concluded that limiting the cumulative emissions of GHGs to zero was key to stopping climate change. In 2018, the IPCC outlined that to limit warming to 1.5°C, CO_2 emissions would need to fall by about 45% in 2030 (relative to 2010 levels), and global net-zero had to be reached around 2050. WG1 of AR6 (released in August 2021) outlined the need not only for a cut in CO2 emissions, but also strong reductions in other GHGs[7]. In 2019, the UK became the first G7 economy to legislate for net-zero. Today, 136 countries with 85% of the world's population, covering 88% of global emissions have set net zero targets, although the targets and timing of how they are delivered remain under criticism for being too vague. This 2021 paper sets out ways that governments could begin to add clarity and accountability; issues considered key to delivering net zero GHG emissions, in pursuit of the Paris targets.

[6] See reference 1, 2 and 3
[7] IPCC AR6 WGI D.1

What does achieving net-zero actually look like?

There are many scenarios assessing how we can get to net-zero, and we await the IPCC's assessment to get an up-to-date, global view. However, some of the key points likely to appear are summarised here.

Achieving the Paris goals requires rapid mitigation across the full range of GHGs. Scientists have shown that, even if CO_2 emissions are Paris-aligned, ignoring methane emissions will lead to overshooting the Paris agreed temperature goals, while abating N_2O emissions would help achieve the temperature targets as well as a suite of Sustainable Development Goals (SDGs).

Renewable electrification is key. A consistent success story since AR5 is the rapid deployment and falling costs of Renewable Energy (RE), such as solar, wind and batteries, which have massively outpaced and exceeded the expert expectations outlined in AR5. But we still need to ramp up. The amount of solar PV and wind deployment has to be twice what has already been announced globally to stay on a 1.5°C trajectory, according to the IEA. We also need to boost funding to clean energy solutions, as many of the technologies needed for hard-to-abate sectors are still in development and annual investment into clean energy needs to triple to USD 3.6 trillion through 2030.

Fossil fuel use needs to decline dramatically. Global coal emissions needed to have peaked in 2020, and all coal-fired power plants need to be shut by 2040 at the latest, a Climate Analytics analysis based on the IPCC's 2018 report shows. For OECD nations, all coal use should be phased out by 2031. This was echoed by the IEA in 2021 - it concluded that for net-zero, all unabated coal and oil power plants need to be phased out by 2040. Increasing energy efficiency is also key. In the IEA's net-zero compliant scenario, the energy intensity of the global economy decreases by 4% a year between 2020 and 2030 - more than double the average rate of the last decade.

Some degree of carbon removal is needed. Net-zero is achieved when the emissions going into the atmosphere are balanced by those removed. It is possible to achieve global net-zero while still allowing for emissions in some sectors - as long as these 'hard to abate' emissions are also being removed and permanently stored. Methods of removal range from enhancing natural carbon drawdown through reforestation, restoration and the protection of nature, to 'negative emissions technology' like direct air capture (DAC) and bioenergy with carbon capture and storage (BECCS). In the last few years, more attention has been paid to the 'net' part of net-zero, as pretty much all published scenarios that bring us within 1.5°C or 2.0°C rely on some form of CDR.

Transforming the Agriculture, Forestry and Other Land Use (AFOLU) sector is crucial. Today, it accounts for nearly a quarter of global GHG emissions and sectoral emissions have been climbing in recent years. Livestock production and rice cultivation are the main culprits. The sector is also a carbon sink, as plants and biomass draw CO_2 from the atmosphere when they grow. Transforming the sector can both reduce emissions - for example, by changing farming and livestock methods - as well as remove emissions from the atmosphere, including measures like planting more (and protecting existing) forests. However, reforestation and better land management alone will not be enough. Some estimates suggest that transforming the AFOLU sector could at most account for 30% of the mitigation needed to stay below 1.5°C. However, the recent hype that planting trees and investing in land can solve the climate crisis is risking delayed mitigation and greenwashing.

Urban planning needs to consider carbon emissions from the get go. The current scale and speed of urbanisation is unprecedented in human history, and since AR5 it has become even more clear that urban areas contribute the majority (about 70%) of the global footprint, posing an enormous challenge for climate mitigation. New urban planning presents a unique opportunity to reduce carbon lock-in.

Many more aspects of mitigation and gaps in our knowledge will be explored by the IPCC in this report. For example, the IPCC will dedicate a chapter to demand-side mitigation for the first time, which will explore how behaviour and lifestyle changes can reduce emissions, like shifts in diets, transport, buildings and the efficient use of materials and energy. In general, scientists agree that systemic infrastructural and behavioral change will be part of the transition to a low-carbon society, but the feasibility and mitigation potential of demand-side measures remain a knowledge gap.

5. Looking ahead, transparency is key

Net-zero targets should not be seen as end-points, but rather as milestones on the path to negative emissions, milestones that require detailed roadmaps as well as short-term goals. NGOs, scientists and the public continue to demand mitigation plans and net-zero targets that are clear and transparent, asking policymakers, businesses and financiers to clarify the scope, fairness and approach to decarbonisation.

Over the past years, integrated assessment models (IAMs) have been a critical tool for climate policymakers, but they have also come under intense scrutiny due to issues like the huge reliance on CDR, especially BECCS, in many scenarios. However, over reliance on IAMs have been criticised given its opaque design and economic assumptions which can result in modelling outcomes that overemphasise CDR.

In a 2020 paper, the co-chairs of the upcoming WGIII report outlined how the IPCC has taken steps to increase transparency this time around. They said the new report will contain some notable criticisms of IAMs, including the uncertainties, CDR and limits to land. It is, however, important to note that the IPCC itself is not advocating for any scenarios, including those with large amounts of CDR. Instead, the IPCC findings are a reflection of the state of climate modelling, as well as previous emissions pathways and scenario research.

Is it possible to stay Paris aligned without carbon removal?

Many of the scenarios used in earlier IPCC reports (including the special report on 1.5C) relied heavily on negative emissions in the second half of the century. Modelled negative emissions were primarily achieved by inputting a large amount of BECCS and/or forest protection/planting in the future scenarios.

The numbers for future CDR are often huge, though they vary across models and scenarios. For example, in the IPCC's special report on 1.5°C, the cumulative carbon removal needed by the end of the century was estimated to be somewhere between 100 and 1000 billion tonnes of CO_2. For perspective, we emit more than 40 billion tonnes a year now, so even in the very lowest scenario we would have to remove more than two years' worth of global CO_2 emissions.

Academics and NGOs have also pointed to the fact that all methods of carbon removal come with side effects and trade-offs that are context and method dependent - such as the huge land areas needed for BECCS, or energy requirements for Direct Air Capture with Carbon Storage (DACCS) (a technology which some scientist predict could remove tens of $GtCO_2$ by the end of century). Land-based carbon removals also come with other trade-offs, such as increased competition for agricultural land and disruption of biodiversity. There has also recently been an increased recognition that unrealistically high carbon removal projections could be encouraging delayed action and greenwashing.

In this report, the IPCC intends to explain the limitations and trade-offs of carbon removal carefully, while assessing the amount of CDR in many of the scenarios. There has also been a new wave of scientific literature looking at how to achieve the Paris goals with no carbon removal whatsoever. These pathways show us that net-zero without the ‘net’ (let’s call it ‘true zero’) requires much more rapid transformations of the energy system and larger near-term emissions cuts. These scenarios also lead to multiple other benefits (so-called ‘co-benefits’) like avoiding drastic land-use change, as well as benefiting food systems, biodiversity and the environment in the long-term.

6. Further reading and academic papers

1. Since AR5 greenhouse gas emissions have continued to climb

Explainers and reports

- “Climate Commitments Not On Track to Meet Paris Agreement Goals” as NDC Synthesis Report is Published, UNFCCC, Feb 2021
- Global methane assessment, summary for decision makers, UNEP, 2021
- Scientists concerned by ‘record high’ global methane emissions, Carbon Brief, 2020

Selected academic research studies and reviews

- Global carbon budget 2021, Global Carbon Project, 2021.
- Emisisons gap report 2021, UNEP, 2021
- Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target, Nature, 2019
- Increasing anthropogenic methane emissions arise equally from agricultural and fossil fuel sources, Environment Research, 2020
- Ideas and perspectives: is shale gas a major driver of recent increase in global atmospheric methane? Biogeosciences, 2019
- A comprehensive quantification of global nitrous oxide sources and sinks, Nature, 2020
- Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement, Nature Climate Change, 2020
- Air pollution declines during COVID-19 lockdowns mitigate the global health burden, Environmental Research, 2021
- Current and future global climate impacts resulting from COVID-19, Nature Climate Change, 2020

2. A lack of ambitious mitigation has made us increasingly likely to ‘overshoot’ the Paris Goals of 1.5°C and 2°C.

Explainers and reports

- Special Report: Special Report: Global warming of 1.5°C, IPCC, 2018
- Global Landscape of Climate Finance 2021, Climate Policy Initiative, 2021
- Financing Climate Futures, UNEP, 2018
- Interactive: How climate finance ‘flows’ around the world, Carbon brief, 2018

Selected academic research studies and reviews

- Climate finance policy in practice: a review of the evidence, Climate Policy, 2021
- The broken $100-billion promise of climate finance — and how to fix it, Nature, 2021
- Where are the gaps in climate finance? LSE, 2016
- Where climate cash is flowing and why it’s not enough, Nature, 2019
- Climate finance shadow report 2020, Oxfam, 2020
- Supporting the Momentum of Paris: A Systems Approach to Accelerating Climate Finance, Climate Policy Initiative

3. The richest 1% emit more than twice the poorest 50%

Explainers and reports

- Which countries are historically responsible for climate change? Carbon Brief, 2021
- Climate change has worsened global economic inequality, Stanford, 2019
- Carbon emissions fell across all sectors in 2020 except for one – SUVs, IEA, 2021
- Tackling gender inequality is 'crucial' for climate adaptation, Carbon Brief, 2020

Selected academic research studies and reviews

- The decoupling of economic growth from carbon emissions: UK evidence, UK Government, 2019
- The global scale, distribution and growth of aviation: Implications for climate change, Global Environmental Change, 2020
- CO2 emissions from commercial aviation, ICCT, 2019
- Making climate change adaptation programmes in sub-Saharan Africa more gender responsive: insights from implementing organizations on the barriers and opportunities, Climate and Development, 2017
- Linking Climate and Inequality, IMF, 2021
- Global warming has increased global economic inequality, PNAS, 2019

4. But there is hope: since AR5 national and corporate net-zero commitments have exploded and renewable energy has continued to outperform forecasts

Explainers and reports

- Net zero: a short history, Energy & Climate Intelligence Unit, 2021
- Net Zero Tracker, University of Oxford, 2022
- World Energy Outlook 2021, IEA, 2021
- Net zero by 2050, IEA, 2021
- Coal phase-out, Climate Analystics, 2019
- Renewables are stronger than ever as they power through the pandemic, IEA, 2021

Selected academic research studies and reviews

- Delayed emergence of a global temperature response after emission mitigation, Nature Communications, 2020
- Meeting well-below 2°C target would increase energy sector jobs globally, One Earth, 2021
- A case for transparent net-zero carbon targets, Communications Earth & Environment, 2021
- Moving toward Net-Zero Emissions Requires New Alliances for Carbon Dioxide Removal, One Earth, 2020
- Contribution of the land sector to a 1.5 °C world, Nature Climate Change, 2019
- Beyond Technology: Demand-Side Solutions for Climate Change Mitigation, Annual Review of Environment and Resources, 2016

5. Looking ahead, transparency is key

Explainers and reports

- In-depth Q&A: The IPCC's special report on climate change at 1.5C, Carbon Brief, 2018
- Climate scientists: concept of net zero is a dangerous trap, The Conversation, 2021
- The problem with "net zero", Sierra Club, 2021

Selected academic research studies and reviews

- Net-zero emissions targets are vague: three ways to fix, Nature, 2021
- The meaning of net zero and how to get it right, Nature Climate Change, 2021
- A case for transparent net-zero carbon targets, Communications Earth & Environment, 2021
- Intergovernmental Panel on Climate Change: Transparency and integrated assessment modeling, Wiley, 2020

- Imagining the corridor of climate mitigation – What is at stake in IPCC's politics of anticipation? Environmental Science and Policy, 2021
- The role of direct air capture and negative emissions technologies in the shared socioeconomic pathways towards +1.5°C and +2°C futures, Environment Research Letter, 2021
- The Value of BECCS in IAMs: a Review, Current Sustainable/Renewable Energy Report, 2019
- Land-use futures in the shared socio-economic pathways, Global Environmental Change, 2017
- An inter-model assessment of the role of direct air capture in deep mitigation pathways, Nature Communications, 2019