IPCC Unsummarized

Unmasking Clear Warnings on Overshoot, Techno-fixes, and the Urgency of Climate Justice

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The Working Group III Contribution to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report, Climate Change 2022: Mitigation of Climate Change affirms why a rapid and equitable phaseout of fossil fuels must be the centerpiece of any science-based mitigation strategy to confront the climate emergency. Like the two companion reports that preceded it, the Working Group III report demonstrates that climate change is not a future threat but a present emergency; that the scale and severity grow with each increment of warming; and that quickly ending reliance on the fossil fuels that drive the climate crisis is the fastest, surest, most effective way to avert climate catastrophe. The three Working Group reports reflect an undeniable scientific consensus about the urgency of the climate crisis, its primary causes, and the irreversible harm that will occur if warming surpasses 1.5°C, even temporarily. The Working Group III report also reaffirms the dangers of governments' overreliance on unproven technologies like carbon capture and storage and technological carbon dioxide removal. Yet, these warnings are buried and downplayed in the report, particularly in the heavily negotiated Summary for Policymakers, among an array of models and pathways that rely on precisely such technologies, project continued use of fossil fuels for decades, and overwhelmingly assume that the world will go beyond 1.5°C for decades or longer – with surprisingly little attention paid to the human and environmental consequences such assumptions entail.

The present briefing examines that dangerous disconnect. Drawing on the full Working Group III report, the companion reports from Working Groups I and II, and the IPCC's 2018 Special Report on 1.5°C, this briefing reveals a clear consensus within the IPCC on the urgent need to transition from fossil fuels, the necessity and feasibility of staying below 1.5°C, and the risks of overshoot and future techno-fixes. It highlights the stark and surprising gap between that consensus and the mitigation pathways emphasized in the Working Group III report, particularly in the Summary for Policymakers. It examines how core assumptions and biases built into integrated assessment models and the mitigation pathways they produce help create that gap by limiting our understanding of what futures are achievable. And it highlights how the political choices made in distilling the full Working Group III report and Technical Summaries into the Summary for Policymakers can further skew our understanding of the science, the options, and the risks that accompany climate mitigation choices.

Acronym Chart

Acronym	Term
AR5	Fifth Assessment Report
AR6	Sixth Assessment Report
BE	bioenergy
BECCS	bioenergy with carbon capture and storage
CCS	carbon capture and storage
CCUS	carbon capture utilization and storage
CDR	carbon dioxide removal
DAC	direct air capture
DACCS	direct air capture with carbon capture and storage
EJ	exajoule
FN	footnote
GDP	gross domestic product
GHG	greenhouse gas
Gt	gigaton
IAM	integrated assessment model
IMP	illustrative mitigation pathways
IMP-LD	illustrative mitigation pathways with heavy reliance on renewables
IMP-Ren	illustrative mitigation pathways with energy demand reductions
IPCC	Intergovernmental Panel on Climate Change
PV	photo-voltaic
SDG	Sustainable Development Goals
SPM	Summary for Policymakers
SR	Special Report
SRM	Solar radiation management
TS	Technical Summary
WGI	Working Group I
WGII	Working Group II
WGIII	Working Group III

I. Introduction and Summary

The latest report from the Intergovernmental Panel on Climate Change (IPCC), Working Group III Contribution to the Sixth Assessment Report (AR6), Climate Change 2022: Mitigation of Climate Change, affirms why a rapid and equitable phaseout of fossil fuels must be the centerpiece of any science-based strategy to avert catastrophic levels of global warming. According to the IPCC's own findings, pathways reliant on speculative technologies purported to deliver greenhouse gas emissions reductions or removals in the future will cost lives and inflict further irreversible harm to humans and natural systems, particularly in the most vulnerable communities. The backdrop for the report's publication, including the fossil-fueled Russian invasion of Ukraine and the profit-driven energy crisis it has engendered, only underscores why breaking free from fossil fuel dependency is critical not just for the global climate but for international peace and economic stability.

The science leaves no doubt that climate change is accelerating, fossil fuels are the overwhelming cause, and avoiding an overshoot of 1.5°C warming is imperative to prevent further irreversible harm. The IPCC's most recent prior reports, from the Special Report on Global Warming of 1.5°C, to the Sixth Assessment's Working Group I and II reports, reflect an undeniable scientific consensus about the urgency of the climate crisis, its primary causes, and the irreversible harm that will occur if warming surpasses 1.5°C, even temporarily.[1] Current levels of warming are already causing permanent loss and damage to human and natural systems, and every additional fraction of a degree increases risks and erodes resilience. In the words of the UN Secretary-General António Guterres, the Working Group I and Working Group II contributions to the IPCC Sixth Assessment Report sounded a "code red for humanity"[2] and depicted an "atlas of human suffering."[3] IPCC reports have repeatedly affirmed that fossil fuels are the principal source of greenhouse gas emissions and that swift and steep reduction in those emissions is necessary to avert climate catastrophe. In the wake of the Working Group I and II reports, UN Secretary General Guterres urged that the Panel's findings "sound a death knell for coal and fossil fuels, before they destroy our planet,"[4] and he declared fossil fuels "a dead end."[5]

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[1] See IPCC, Working Group I Contribution to the IPCC's Sixth Assessment Report on The Physical Science Basis (2021) and component chapters available at: https://www.ipcc.ch/report/ar6/wg1/; IPCC, Working Group II Contribution to the IPCC Sixth Assessment Report on Climate Change Impacts, Adaptation and Vulnerability (2022) and component chapters, available at: https://www.ipcc.ch/report/ar6/wg2/; IPCC, Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018) [SR 1.5], available at https://www.ipcc.ch/sr15/.

[2] "Secretary-General Calls Latest IPCC Climate Report 'Code Red for Humanity", Stressing 'Irrefutable' Evidence of Human Influence," United Nations Secretary-General press release, August 9, 2021, https://www.un.org/press/en/2021/sgsm20847.doc.htm.

[3] The Secretary-General Remarks to Press Conference Launch of IPCC Report, Geneva, February 28, 2022, https://www.ipcc.ch/site/assets/uploads/2022/02/UN_SG_statement_WGII_Pressconference-.pdf.

[4] "Secretary-General Calls Latest IPCC Climate Report 'Code Red for Humanity', Stressing 'Irrefutable' Evidence of Human Influence," United Nations press release, August 9, 2021, https://www.un.org/press/en/2021/sgsm20847.doc.htm.

[5] "Secretary-General's video message to the Press Conference Launch of IPCC Report [scroll down for languages]," United Nations Secretary-General statements, February 28, 2022, https://www.un.org/sg/en/node/262102.

Based on these findings, one would expect the Mitigation of Climate Change report to concentrate heavily or at least very substantially on those measures and pathways that would put the world on track to avoid overshooting 1.5°C without reliance on unproven and risky technologies by curbing as rapidly as possible the primary driver of the planetary emergency: the production and use of fossil fuels. The report reflects these scenarios in what it labels Category C1 scenarios, those that limit warming to 1.5°C with no or limited overshoot, including illustrative mitigation pathways (IMPs) involving heavy reliance on renewables (IMP-Ren) and energy demand reductions (IMP-LD).

Yet, while Working Group III's findings undeniably support the urgent need to phase out coal, oil, and gas, reduce energy demand, and avoid reliance on unproven and risky technological interventions like large-scale carbon dioxide removal (CDR), the report does not foreground those measures or clearly outline the steps needed to get there. In presenting the C1 scenarios alongside a range of other modeled pathways, including scenarios that would lead to a temperature rise of over 4°C this century, one could read the report to suggest that all such pathways are equally viable or acceptable policy options — despite the Panel's stark warnings that overshooting 1.5°C, even temporarily, would be catastrophic. [See, e.g., Ch. 3, Table 3.1, at 3-17 (presenting the categories of pathways)][6] Tellingly, the word "irreversible" scarcely appears in the Working Group III report, despite Working Group II's clear, repeated message that overshooting 1.5°C, even temporarily, would result in irreversible harm. More troublingly still, even some of the C1 scenarios incorporate reliance on unproven CCS technologies to deliver "low-carbon energy," which the IPCC defines as including "fossil fuels when used with CCS," despite the IPCC's own warnings about the risks and feasibility constraints of CCS. But if that reliance proves unfounded, because CCS cannot, in fact, make fossil fuels emissions-free, even more ambitious scenarios could overshoot 1.5°C [Table 3.4, FN 4].

The lack of clarity about what it will take to avoid overshoot is not because a rapid pathway to a fossil-free future is scientifically impossible. On the contrary, the IPCC's own findings underscore the technological feasibility of swiftly ending fossil fuel emissions, scaling up electrification, and reducing energy demand. As the IPCC notes, "[t]he feasibility challenges associated with mitigation pathways are predominantly institutional and economic rather than technological and geophysical" [TS, TS-138]. Nor is it because of a lack of science demonstrating the danger of relying on carbon capture and storage (CCS) and large-scale CDR to prolong the use of fossil fuels and defer emissions reductions into the future. Working Group III explicitly states that "CCS can allow fossil fuels to be used longer" [TS 5.1, at TS-53; SPM C.4.4, at SPM-36] and that "CCS deployment will increase the shares of fossil fuels" in policy scenarios [Ch. 6, 6.7.4, at 6-118] — outcomes fundamentally at odds with the objective of eliminating the primary driver of global warming. The IPCC's own findings repeatedly warn that CCS and CDR are unproven at scale, unavailable in the near term, are of uncertain benefit for the climate, and pose significant risks of harm to humans and nature.

[6] Unless otherwise noted, bracketed citations in this analysis refer to the final published version of the Working Group III Contribution to the IPCC Sixth Assessment Report on Mitigation of Climate Change, available here: https://www.ipcc.ch/report/ar6/wg3/.

Instead, the IPCC's analysis is fundamentally constrained by socio-economic assumptions in many of the underlying models that take the most direct route to addressing the crisis off the table for reasons not based on science, but a lack of political will. These political and economic constraints often include assumed rates of economic growth, such as projections that global gross domestic product (GDP) will more than double by 2050 [SPM C.12.2, at SPM-49]. Such constraints disregard alternative, sufficiency visions for improving human welfare that prioritize reducing demand for energy and materials. Such assumptions also seemingly ignore the fact — that the IPCC itself recognizes [Ch. 3, at 3-4] — that economic growth is a main driver of emissions, and thus that curbing or reconceiving growth as something distinct from the inexorable and unquestioned increase in economic throughput of material resources is a critical part of the solution. Moreover, most models focus on least-cost mitigation measures but fail to consider the costs and damages of climate change itself in the calculus or the possibility that some modeled mitigation measures may not deliver promised emissions reductions or removals.

Assuming that mitigation measures work in practice as they do in theory is less concerning when the measure in question has been proven effective, like replacing fossil fuels with renewables or reducing energy demand. But when applied to measures like CCS and CDR, which the IPCC recognizes are unproven at scale and face significant technical and economic feasibility challenges (discussed below), that assumption results in a dangerous underestimation of the need to deploy available near-term measures known to work already, like electrification, and an overreliance in the models on delayed measures and future techno-fixes to compensate for continued emissions. Recurrent inclusion in the scientific literature of approaches, like large-scale CDR, that do nothing to reduce emissions and pose precisely the equity and justice concerns raised in the IPCC's Working Group II report, evinces a profound and dangerous disconnect between the science on the impacts and causes of climate change and the mitigation research funded by governments and corporations.

The incontrovertible nature of the physical science of climate change and its accelerating impacts, addressed in the Working Group I and II reports, is in marked contrast to the highly contested and contingent nature of the economic assumptions and policy choices considered in the Working Group III report. **While the Summary for Policymakers dilutes some of Working Group III's key messages, it cannot mask the underlying science and its clear implications regarding the needed energy transition.** As the result of a protracted and politicized negotiation process, the text of the final approved Summary for Policymakers illustrates the growing tensions between the clear and urgent need to rapidly phase out fossil fuels and the reluctance of decision-makers to acknowledge or act on that need. Yet the qualifications and carefully crafted phrases do not change the underlying reality, reflected in the full report, that the production and combustion of fossil fuels account for the overwhelming majority of global GHG emissions, that viable alternatives exist to eliminate the vast majority of fossil fuel combustion, and that relying on widespread CCS and large-scale CDR is a delay tactic and dangerous gamble.

The following analysis pulls together key observations in the report about trends, synergies, trade-offs, risks, and uncertainties important for global policymakers to heed. It highlights key takeaways from the Working Group III report in light of the IPCC's preceding findings about the current state of the climate emergency and the further damages that loom ahead if warming surpasses 1.5°C. First, the analysis unpacks the assumptions and limitations underlying the mitigation models assessed by the IPCC and against which the policy implications of the findings must be understood. Second, it underscores that phasing out fossil fuels and accelerating the deployment of renewables, storage, and demand-reduction approaches is the surest, fastest, and safest way to mitigate climate change and limit warming to 1.5°C. Third, it highlights the numerous risks, uncertainties, and costs associated with CCS, Direct Air Capture with Carbon Capture and Storage (DACCS), and Bioenergy with Carbon Capture and Storage (BECCS), the primary technologies underpinning overshoot scenarios. Finally, it shows how the most secure transition pathways are also the most supportive of other sustainable development goals and protective of global equity, environmental justice, and human rights. Read, as it must be, in the context of the IPCC's prior reports, the Working Group III report provides a clear mandate for policymakers to adopt aggressive, ambitious policies to phase out fossil fuels, beginning immediately, and a warning against supporting those measures that lock-in the fossil economy and condemn the world to overshoot 1.5°C and gambling on return.

II. Act Now, Avoid Overshoot, Center Justice – IPCC reports on physical science and climate impacts must inform mitigation choices

The IPCC's Sixth Assessment Report on the state of climate science is comprised of multiple reports, including three Working Group reports (I: Physical Science Basis, II: Impacts, Adaptation and Vulnerability, and III: Mitigation of Climate Change), Special Reports on Global Warming of 1.5°C, Climate Change and Land, and Ocean and Cryosphere in a Changing Climate, and a Synthesis Report to be released in late 2022. These preceding documents provide the backdrop to and critical context for the Working Group III report.

Climate change is no longer a future risk. It is an urgent and dangerous reality confronting people and ecosystems worldwide. Working Group I's report, The Physical Science Basis, declared categorically that climate impacts are accelerating worldwide. "Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since the Fifth Assessment Report (AR5)."[7] [WGI SPM A.3 at SPM-8]

Every ton of carbon added to the atmosphere further accelerates warming and intensifies climate impacts. Without deep reductions in the carbon dioxide and other greenhouse gas emissions that drive climate change in the coming decades, accumulated warming will pass the

[7] IPCC I, Working Group I – The Physical Science Basis, *Headline Statements from Summary for Policymakers* (August 2021), https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Headline_Statements.pdf.

critical thresholds in the Paris Agreement. Each incremental change in temperature will generate corresponding “increases in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts in some regions, and proportion of intense tropical cyclones, as well as reductions in Arctic sea ice, snow cover and permafrost.” [WGI SPM B.1-2 at SPM-14] With each increment of warming, these impacts will spread and multiply in every region of the world; with impacts more widespread and severe at 2°C of warming than 1.5°C [WGI SPM C.2 at SPM-24].

The physical science is simple and clear: staying below critical warming thresholds requires dramatically reducing CO_2 emissions. **“**From a physical science perspective, limiting human-induced global warming to a specific level requires limiting cumulative CO_2 emissions, reaching at least net zero CO_2 emissions, along with strong reductions in other greenhouse gas emissions.” [WGI SPM D.1 at SPM-27] The climate and health impacts of different mitigation pathways could be discernible within years [WGI SPM D.2 at SPM-30].

The Working Group II report on Impacts, Adaptation and Vulnerability makes clear the stark choices and disparate and potentially irreversible impacts of different mitigation pathways and timelines. CIEL and Heinrich Boell Foundation summarized these key messages in an analysis: “Beyond the Limits: New IPCC Working Group II Report Highlights How Gambling on Overshoot is Pushing the Planet Past a Point of No Return.”[8]

Overshooting 1.5°C poses grave dangers. The IPCC warns that exceeding 1.5°C in warming will result in severe and irreversible adverse impacts, limiting the capacity for adaptation and severely threatening human rights. Overshoot also increases the chance of triggering climate “tipping points” and self-reinforcing feedback loops, such as permafrost thawing and the collapse of forest ecosystems. Such events would greatly amplify warming and associated adverse impacts [WGII TS.C.13.2 at TS-43; see also WGI SPM C.3.2 at SPM-27] and make “return to a given global warming level or below ... more challenging.” **Even if temperatures could be returned to below 1.5°C following overshoot — and there is no certainty that they can — some impacts and losses will be permanent** [WGII SPM B.6, B.6.1 at SPM-20; WGII TS.C.2.5 at TS-26, TS.C.12.1 at TS-42, TS C.13 & C.13.1 at TS-42].

Even temporary overshoot will lead to severe and irreversible impacts and make adaptation more difficult. Compared to pathways that never exceed 1.5°C, those that involve even temporary overshoot, in which warming exceeds 1.5°C for several decades and then returns to or below 1.5°C, “imply severe risks and irreversible impacts in many ecosystems (high confidence)” [WGII TS.C.2.5 at TS-26].

[8] CIEL, Heinrich Boell, “Beyond the Limits: New IPCC WG II Report Highlights How Gambling on Overshoot is Pushing the Planet Past a Point of No Return,” (February 28, 2022), Available at: https://www.ciel.org/reports/ipcc-wg2-briefing/.

Moreover, overshoot thwarts adaptation. The warmer it gets, the harder it becomes to adapt to a warming world. Every fraction of a degree makes matters worse, and adaptation becomes more difficult if the temperature rise exceeds 1.5°C [WGII SPM.B.6.2 at SPM-20].

> *"Risks to ecosystem integrity, functioning and resilience are projected to escalate with every tenth of a degree increase in global warming (very high confidence). Beginning at 1.5°C warming, natural adaptation faces hard limits, driving high risks of biodiversity decline, mortality, species extinction and loss of related livelihoods (high confidence)."* [WGII TS.C.1.2 at TS-24]

Current impacts of climate change are already eroding resilience and adaptation capacity, causing irreversible harm, and the impacts of overshoot will further threaten human rights. During periods of overshoot, "[r]isks to human systems will increase, including those to infrastructure, low-lying coastal settlements, some ecosystem-based adaptation measures, and associated livelihoods (high confidence), cultural and spiritual values (medium confidence)" [WGII SPM.B.6.1 at SPM-20]. The irreversible human and ecological impacts of warming above 1.5°C include, inter alia, excess deaths from heatwaves, glacier melt, and loss of coral reefs, small islands, and cultural heritage [WGII TS.C.12.1, TS.C.13, & TS.C.13.1 at TS-42].

Climate breakdown magnifies existing social inequities. The Working Group II report recognizes that vulnerability to climate change is driven by "patterns of intersecting socio-economic development, unsustainable ocean and land use, inequity, marginalization, historical and ongoing patterns of inequity such as colonialism, and governance (high confidence)" [WGII SPM B.2 at SPM-11]. Those with the fewest resources, such as impoverished peoples and historically marginalized and oppressed groups, are especially vulnerable to climate damages [WGII SPM.B.2.4 at SPM-12], including the irreversible harm caused by an overshoot of 1.5°C. This vicious circle exacerbates climate injustice – the concept that the people who contributed least to the problem suffer its worst consequences.

Accordingly, climate responses must integrate social justice and equity and center Indigenous and local knowledge. The Working Group II report emphasizes the importance of addressing social inequities in climate vulnerabilities and responses. The IPCC affirms that centering climate justice and incorporating Indigenous rights and knowledge in climate responses is both imperative and effective [WGII SPM Introduction, at SPM-5; WGII TS.A at TS-3, TS-5].

The Working Group I and II reports demonstrate that loss and damage from climate change are already mounting worldwide. Staying below the Paris Agreement's temperature target of 1.5°C in temperature rise requires bringing emissions of CO_2 and other greenhouse gases to net zero within the next few decades and by no later than 2050. The impacts of climate change increase with every increment of warming, and going beyond 1.5°C, even temporarily, will result in irreversible harm to ecosystems, human lives, and human rights. The impacts of climate change and climate responses magnify existing social inequities. And accordingly, addressing the social inequities and centering climate is a critical requirement of climate mitigation pathways and strategies.

III. Are We Asking the Right Questions? Limitations in modeled mitigation pathways and political pressure lead to dangerous overemphasis on speculative technologies and future action

The Working Group III report includes critical findings that set important principles for effective strategies to mitigate global warming. Crucially and consistent with the warnings in the Working Group I and II reports, it affirms that limiting warming to 1.5°C without overshoot is possible. The Working Group III findings confirm that it is both technically and economically feasible to pursue rapid fossil fuel phaseout immediately, through scenarios that limit warming to 1.5°C, rather than overshoot it by gambling on the possibility of return. Included among the potential pathways forward for reducing emissions of the greenhouse gasses that cause global warming are measures that would reduce energy demand, replace fossil fuels with renewables, and massively increase electrification. [See Box TS.5, TS-39-40; Ch. 1, 1-36 (describing the IMPs, including IMP-Ren, which involves heavy reliance on renewables, and IMP-LD, which emphasizes energy demand reductions).]

The Mitigation of Climate Change also reiterates the profound risks, uncertainties, and high costs associated with the technologies on which overshoot scenarios rely, like significant deployment of CCS and large-scale technological CDR. (See *infra*, section III.) It notes that costs have not dropped significantly for CCS and may not be poised to, leaving CCS as one of the highest-cost mitigation measures with the lowest potential for emissions reductions [Figure SPM.7, at SPM-50]. The report stresses the potential emissions impact of the energy and land used for DACCS and BECCS, which reduce or eliminate the purported climate benefits of those approaches. It highlights the high cost of large-scale BECCS or DACCS deployment and the potential detrimental impact on global equity and the achievement of other sustainable development goals. And ultimately, it warns that these techniques simply may not succeed in reducing emissions or reversing temperature rise.

Figure SPM.7 of the Working Group III report is instructive. It distills into a graphic form the IPCC's consolidated analysis of the comparative emissions reduction potential by 2030 of the most widely discussed mitigation approaches and technologies, coupled with a color-coded assessment of the relative cost of their achievable reductions.[9]

[9] The costs of mitigation options presented in the Working Group III report's Figure SPM.7 do not reflect the costs of climate impacts or of mitigation co-benefits and tradeoffs. Incorporation of those costs would almost certainly increase the already wide gap between the costs of renewables and the costs of carbon capture technologies depicted in the Figure. As discussed more fully below, cost-effectiveness should not be the sole basis for assessing mitigation options.

The message of Figure SPM.7 is clear. By far the quickest, most significant, and cheapest route to reducing greenhouse emissions is through the scaling up of wind and solar energy. Significantly, with the costs of wind and solar energy continuing to decline, huge climate gains could be made through renewable deployments at a *net negative* cost (as evidenced by the figure's blue band). This decline reflects the fact that these renewables are now the cheapest form of new energy capacity for the majority of the world's population. Further expanding wind and solar could achieve significant additional gains at no or little cost (the yellow band). In total, nearly 8 Gt of annual CO_2 emissions can be avoided through wind and solar deployments at a cost of $50 per ton or less (blue to light orange). The next largest source of emissions reductions in the entire energy sector is reducing methane (CH_4) emissions from oil and gas production and transport. The majority of these reductions are achievable at little or no cost (blue to yellow). Eliminating the production and use of oil and gas driving those methane emissions could achieve even greater reductions; however, the graph does not reflect these savings. Geothermal energy could achieve further modest, but meaningful reductions at low to moderate costs (yellow to dark orange).

Within the land use category, halting deforestation and reducing the conversion of forests and other ecosystems could achieve the most significant emissions reductions, with the per-ton costs of such emissions ranging from low to moderate depending on the scale of deployment.

A still wider array of strategies – ranging from energy efficiency and demand reduction measures in the building sector to increasing public transportation and optimization measures in the shipping sector – make modest but meaningful contributions to climate mitigation efforts with a *net negative* cost due to the energy and cost savings they generate (blue).

Carbon capture technologies are at the other end of the spectrum, ranking among the highest-cost options with the lowest mitigation potential. Mitigation strategies involving CCS are notable within Figure SPM.7 for combining very low emission reduction potential with costs that range from high to extremely high (red to dark red). These strategies include CCS and Bioelectricity with CCS in the energy sector and carbon capture utilization and storage (CC(U)S) in the industrial sector. In a universe of mitigation options that includes a wide array of strategies with substantially greater mitigation potential, significantly lower costs, or both, it would be reasonable to infer that strategies relying on CCS would be low priority, particularly given the IPCC's repeated warnings about their risks of failure and unintended consequences. Despite this, and as discussed more fully herein, CCS and related strategies are pervasive in IPCC models and, as a result, in the Working Group III report built on those models.

Many options available now in all sectors are estimated to offer substantial potential to reduce net emissions by 2030. Relative potentials and costs will vary across countries and in the longer term compared to 2030.

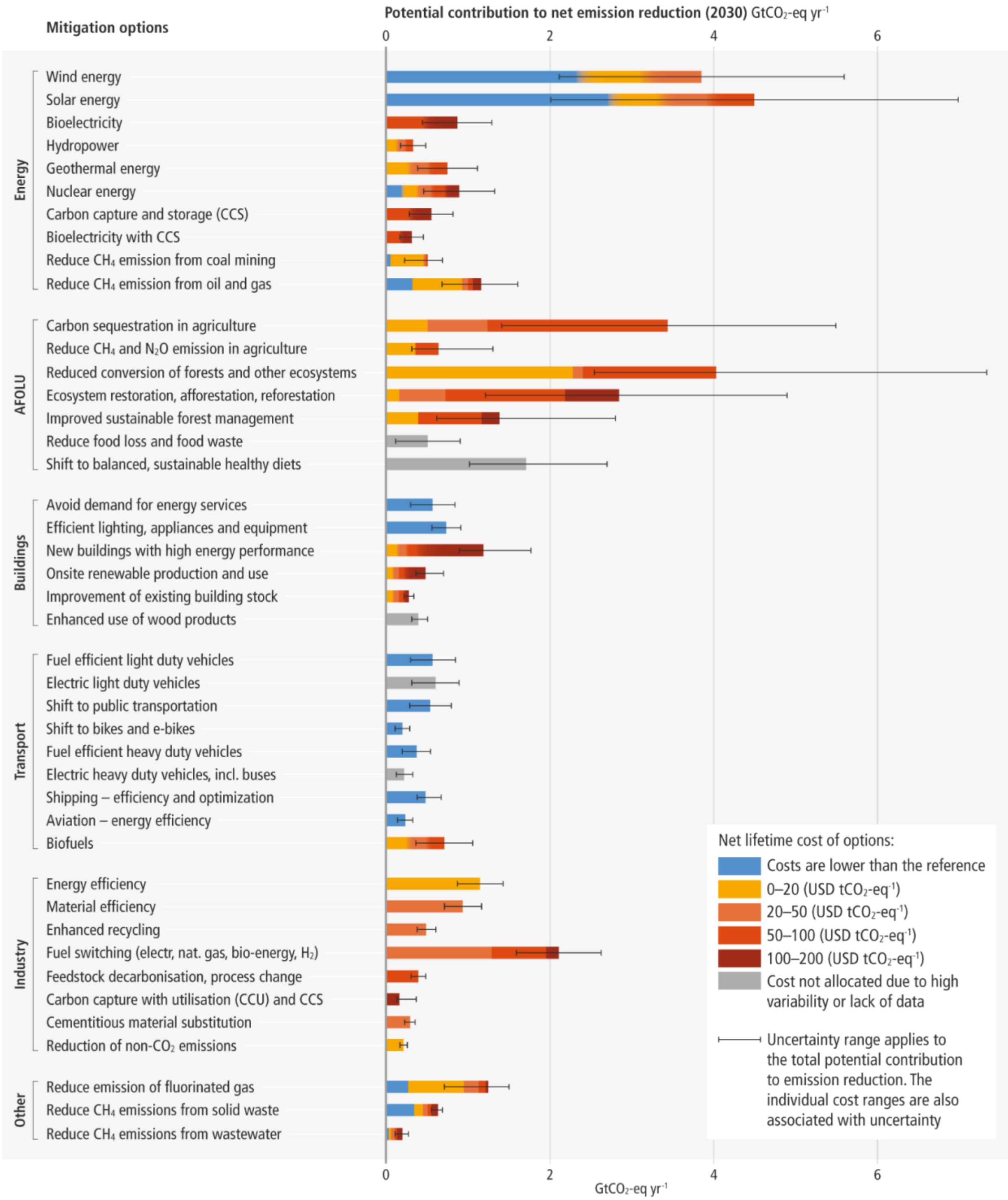

Figure SPM.7: Overview of mitigation options and their estimated ranges of costs and potentials in 2030. [Source: IPCC WGIII SPM-50]

Starkly absent, particularly when read against the backdrop of the Working Group I and II reports, is an explicit focus on the rapid phaseout of fossil fuels and non-overshoot scenarios as the only scenarios that can avoid the irreversible harm the IPCC itself predicts will occur if warming exceeds 1.5°C for any period of time.

Similarly missing is a clear message about the limitations built into the modeled scenarios and their impacts on perceptions of what is possible. The Working Group III report acknowledges that the modeled mitigation pathways it presents are subject to certain assumptions. But the Summary for Policymakers does not make plain just how much the political and economic assumptions underpinning the models and baked into the scientific literature constrain the science, narrowing the universe of possible futures considered. The IPCC has a mandate "to assess the scientific literature on all aspects of climate change, its impacts and society's options for responding to it."[10] The IPCC has both the prerogative and the responsibility to make explicit the limitations and gaps in available studies and, crucially, the assumptions upon which modeled mitigation scenarios rely. By failing to convey the full significance of these assumptions and uncertainties, the report eclipses understanding of the possible ambitious pathways that limit warming to 1.5°C while avoiding overshoot. Moreover, by presenting pathways with significant overshoot as categorically similar to those without, the report suggests that the pathways have similar certainties of success. But the modeled scenarios are not the only possible paths forward, and the ability to return from large overshoot is far from guaranteed.

The five illustrative mitigation pathways (IMPs) put forth by Working Group III are drawn from the mitigation scenarios underlying the report [TS Box TS.5, at TS-39-40]. Each scenario is the output of an integrated assessment model (IAM), which is a simplified portrayal of complex and dynamic systems, focusing on interactions between the economy, society, and the environment. The illustrative pathways represent groupings of those scenarios with similar characteristics in terms of, among other things, the speed of renewable energy deployment, the level of energy demand, reliance on carbon dioxide removal, purported negative emissions, and shifting development pathways.

As a result of this reliance, assumptions and biases embedded in IAMs affect the scenarios they produce. These assumptions and biases will, in turn, be reproduced in the illustrative pathways compiled by the IPCC.[11] Their presence within the IAMs is both acknowledged within the modeling community and by the IPCC itself. To date, however, they have not been properly addressed.

[10] "IPCC statement: Clarifying the role of the IPCC in the context of 1.5ºC," Intergovernmental Panel on Climate Change, September 21, 2017, https://www.ipcc.ch/site/assets/uploads/2017/09/statement_IPCC_role_in_the_context_of_1.5C-1-1.pdf.

[11] IAMs are largely black boxes. While articles based on them are often peer-reviewed, the models themselves rarely are. Despite their critical role in informing policy choices, policymakers have little visibility into how the models are created or kept up to date. See Simon Evans & Zeke Hausfather, Carbon Brief, *Q&A: How 'integrated assessment models' are used to study climate change* (October 2, 2018), https://www.carbonbrief.org/qa-how-integrated-assessment-models-are-used-to-study-climate-change.

First, IAMs rely predominantly on assumptions about economic growth rates[12] that effectively ignore the possibility of alternative economic paradigms as a mitigation tool. As the IPCC acknowledges, IAMs "are generally driven by economics" [Ch. 3, 3.2.2, at 3-13; see also Annex III, at I-7], not by considerations of how to safely and reliably achieve the Paris 1.5°C temperature limits in an equitable and just way. The Working Group III report recognizes that, together with population growth, assumed economic growth is a main driver of emissions [Ch. 3, at 3-4]. It also notes, however, that "[e]conomic growth is even more uncertain than the population projections" [Ch. 3, at 3-24]. And yet, most models fail to reflect mitigation possibilities if growth were limited or pursued in a different way. Models largely exclude alternative economic paradigms of precisely the type that can effectuate the transformational change needed to avoid catastrophic levels of warming. For example, mitigation models that take as a given that the global economy will at least double in size by mid-century [see SPM, C.12.2], growing at rates between 2.5 and 3.5% per annum during that period [SPM, Box 1], presume that such growth can be reconciled with emissions reductions, notwithstanding the evidence to the contrary.

Second, modeled pathways reflect assumptions about the costs of mitigation measures, including the phaseout of fossil fuels, but rarely incorporate the costs of climate damages that can be prevented through mitigation, the costs of adaptation, or the economic impacts of mitigation co-benefits and trade-offs [SPM-49, n. 67]. Although they are focused on the costs of mitigation measures, as the IPCC acknowledges, the "vast majority of IAM pathways do not consider climate impacts," which impose significant costs [Ch. 3, 3.2.2, at 3-14]. Critically, this means the models themselves compare the costs of climate mitigation against a future growth scenario *in which climate change is not happening*. In the IPCC's own words, "[t]he difficulty in fully representing the extent of climate damages in monetary terms may be the most important and challenging limitation of IAMs" [Annex III, at I-7].

> *The exclusion of costs due to the impacts of climate change or the delay or failure to mitigate it, and inattention to the distribution of those costs, is particularly concerning given that "most IAM pathways follow the cost-effectiveness approach"*
> [Ch. 3, 3.2.2, at 3-14].

As the IPCC cautions: "Regional IAM results need thus to be assessed with care, considering that emissions reductions are happening where it is most cost-effective, which needs to be separated from the fact who is ultimately paying for the mitigation costs" [Ch. 3, 3.2.2, at 3-14].

[12] In describing the key assumptions underlying the scenarios in the literature assessed, the IPCC notes, "The underlying assumptions on global GDP growth (ppp) range from 2.5 to 3.5% per year in the 2019-2050 period and 1.3 to 2.1% per year in the 2050-2100 (5-95th percentile). Many underlying assumptions are regionally differentiated." [SPM-27, Footnote 46].

Third, the choice of discount rates also significantly affects the speed of mitigation in modeled scenarios. Discount rates are ways of comparing costs throughout time and are most often used in contexts of financial accumulations like interest, capital growth, and inflation. As in many IAMs, they are also used to compare costs in models across time [Annex III, I-10]. The higher the discount rate, the more a given cost is projected to decline over time (i.e., the lower the future cost appears in present terms). The choice of discount rate has a significant effect on the rate of fossil fuel phaseout in modeled scenarios, with greater rates pushing action further into the future. "A lower discount rate increases short-term emissions reductions, lowers temperature overshoot, favours currently available mitigation options (energy efficiency, renewable energy, etc.) over future deployment of net negative emission and distributes mitigation effort more evenly between generations" [Annex III, I-10-11]. "A lower discount rate brings mitigation forward in time and uses less net negative CO_2 emissions in cases where target overshoot is allowed (Realmonte et al. 2019; Emmerling et al. 2019)" [Annex III, II-56]. As the IPCC acknowledges, "there is arguably too little sensitivity analysis of how the discount rate affects modelled outcomes." [*Id.*]

The result is a skewed picture of "least cost" or "cost-effective" action, which biases scenarios toward delayed action and reliance on carbon dioxide removal and away from rapid fossil fuel phaseout and avoidance of overshoot. *The spread of scenarios reviewed by the IPCC reflects this orientation. Of the 1,686 assessed scenarios, only 97 limit warming to 1.5°C with no or low overshoot [Ch. 3, 3-16-17].*

Because IPCC modeling primarily proceeds "as a cost-effectiveness analysis: a long-term climate stabilisation target is set to derive the optimal mitigation strategy that equalizes marginal abatement cost across sectors, GHGs and countries. This optimal mitigation strategy can be implemented by a broad set of well-coordinated sector specific policies or by comprehensive carbon pricing policies" [Annex III, I-36]. Therefore, the models featured in the WGIII report often favor the "least cost" emissions reduction pathways. The assumptions about costs are thus fundamental to the models' outputs. By excluding the costs of climate impacts and adaptation, using high discount rates, and *including* some of the costs to fossil fuel companies of phasing out their products,[13] IAMs make the business-as-usual scenario appear better in the near term. Therefore, any costs of mitigation appear higher, pushing mitigation pathways towards delay.

Thus, the basic economic methodologies on which IAMs rely tend to discount the potential damage to the world from overshoot, despite the clear warnings in the Working Group I and II reports about the danger of doing so.

[13] See discussion of stranded assets, Box TS.8 at TS-53; Ch. 6, Box 6.13, at 6-116.

Finally, because models reflect the assumptions with which they were programmed, they do not reflect the risk of failure of the technologies or measures on which the pathways rely. In particular, by assuming cost declines for and widespread availability of CCS, BECCS, and DACCS, scenarios reflect what could theoretically be achieved if technologies deployed work, but not the consequences of their failure. Put another way, even if it is likely that BECCS and DACCS would not work to remove significant quantities of carbon dioxide from the atmosphere, models that include them only show the circumstances where they do. The models also do not reflect the trade-offs or unintended consequences of investing in those technologies, such as increased emissions, delayed action, and climate catastrophe [See SPM-49, n. 67].

These biases, taken together, mean the IMPs in the Working Group III report both downplay the need for rapid fossil fuel phaseout and overstate the role that large-scale carbon capture and storage and carbon dioxide removal can or should play in climate action moving forward.

Even more powerful mitigation approaches exist and are largely overlooked by IAMs. Beyond energy efficiency, a mitigation strategy called "sufficiency" entails deep reductions (or even avoidance) in energy demand through non-technological measures like smarter design or downsizing. The IPCC does not include a robust treatment of sufficiency overall. Still, it does introduce the concept as a potential strategy for the buildings sector: "Sufficiency measures tackle the causes of GHG emissions by avoiding the demand for energy and materials over the lifecycle of buildings and appliances" [Ch. 9, at 9-4]. Sufficiency aligns with planetary boundaries and avoids overshooting carbon budgets and biophysical limits [*Id*.]. Unfortunately, while the report includes a full chapter on demand-side mitigation options for the first time, it does not examine sufficiency strategies across all sectors.[14] And where they do exist, those strategies are not captured in models.

The IPCC itself acknowledges that the pathways emerging from scenario literature do not reflect the full scope of possible mitigation measures. The report notes "concerns that IAMs are missing important dynamics, e.g. with regard to climate damages and economic co-benefits of mitigation, demand side responses, bioenergy, land degradation and management, carbon dioxide removal, rapid technological progress in the renewable energy sector, actor heterogeneity, and distributional impacts of climate change and climate policy." [Annex III, at I-37] These gaps call into question the credibility of the assumptions on which pathway projections are based, including, for example, assumptions about the availability of carbon dioxide removal technologies. [*Id.*]

[14] The new focus on demand-side measures in the Working Group III report is important, particularly for its observation that people need services to enhance their well-being, not primary energy and physical resources, and thus those new ways of providing those services can significantly reduce energy use and greenhouse gas emissions in the near-term. There is a risk, however, of giving undue emphasis to individual responsibility for global emissions. The Working Group III analysis must not be read to suggest that individual change, as opposed to systemic change, is the central solution to the climate crisis. Individual behavior change can only address a small fraction of global emissions, whereas measures to phase out the production and use of fossil fuels could eliminate the source responsible for the overwhelming majority of greenhouse gas emissions. See infra, section V (3).

The research deck is stacked, so to speak, against modeling rapid phaseout with no overshoot.

> ***Still, the IPCC's findings nonetheless affirm these four things:*** *(1) rapid emissions reductions through fossil fuel phaseout, decreased energy demand, and intensive electrification provide the most certain path to avoiding overshoot and the irreversible damage that would follow; (2) carbon capture and storage is a costly technology, unproven at scale, that prolongs fossil fuel use; (3) technological carbon dioxide removal methods are risky, speculative, and obstruct climate progress; and (4) mitigation measures must be grounded in social justice and equity.*

Sections V through VIII below discuss each of these in turn.

IV. Do We Want the Answer? Modeling problems are compounded by political pressure to avoid policy prescription in the Summary for Policymakers, particularly from fossil fuel-producing countries.

IPCC reports are among the most extensively scrutinized and peer-reviewed scientific papers on the planet. The IPCC's Sixth Assessment Report included contributions from more than 700 scientists from 90 countries,[15] though this estimate is likely conservative. Each working group report goes through two successive rounds of review, resulting in tens of thousands of written comments. For the IPCC's Fifth Assessment Report, more than 142,000 comments were considered during the course of these reviews.[16] The review process for the Sixth Assessment Report has been more extensive still, with nearly 75,000 comments received for the Working Group I report alone.[17] The full reports and the Technical Summary of each report are developed through a scientific consensus process involving input from thousands of scientists and experts from governments, academia, civil society organizations, and corporations. As discussed above – and as with any scientific effort – assumptions built into models can introduce biases, intentional or otherwise, but the process itself is designed to capture a consensus view of the available science.

The Summary for Policymakers provides the primary tool for communicating the IPCC's scientific analysis and conclusions to non-scientists, including policymakers, the media, and the public. Consistent with the scale and scope of the subject matter, IPCC's assessment reports are

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[15] Rebecca Harris, "Climate explained: How the IPCC reaches scientific consensus on climate change," The Conversation (June 29, 2021). Available at: https://theconversation.com/climate-explained-how-the-ipcc-reaches-scientific-consensus-on- climate-change-162600.

[16] IPCC Factsheet: How does the review process work? (Rev. 15 January 2015) Available at: https://www.ipcc.ch/site/assets/ uploads/2018/02/FS_review_process.pdf.

[17] R. Harris, supra note 13.

lengthy and highly technical documents. The full text of the Working Group III report, for example, runs more than 2,900 pages, excluding an additional 200 pages of annexes.[18] Each working group also produces a shorter, though still lengthy, Technical Summary – 145 pages in the case of Working Group III – written primarily for relevant experts rather than lay audiences.[19] The IPCC's extensive findings are distilled, simplified, and communicated in language accessible to non-experts through the Summary for Policymakers and the Headline Statements and Press Releases drawn therefrom, particularly in the days and weeks immediately following the release of a major report. As a result, the choices of language and emphasis in the Summary for Policymakers have a disproportionate impact on how the work of the IPCC is understood by the wider public and carried into policy-relevant spaces.

IPCC member governments negotiate each Working Group's final Summary for Policymakers. The process for preparing the SPM parallels that of other IPCC documents up through the review of the first draft of the SPM, which is prepared by the report authors and reviewed by governments and experts simultaneously with the Second Order Draft of the full report. The process diverges significantly, however, for subsequent and final drafts of the Summary for Policymakers, which are subject to review and written comments by governments alone, then reviewed and negotiated line by line by IPCC member governments. [20]

Adopting the Summary for Policymakers – and with it, the full report – through this consensus process makes it more difficult for governments to challenge later or discount a report they themselves have approved.[21] While this approval process cannot prevent relevant science from being reflected in the full report or the Technical Summary, it nonetheless provides governments both an incentive and an opportunity to shape what portions of that science are communicated to the wider world and how.

The final review of the Working Group III Summary for Policymakers was the longest in IPCC's history and was notably politicized. The final review and approval for the Working Group III Summary for Policymakers extended a full three days beyond the scheduled close of the process, culminating in the longest approval plenary session in the thirty-four-year history of the IPCC.[22] Protracted negotiations in the closing hours of the Approval Plenary delayed the publication and release of the report by several hours.[23] Observers expressed alarm that government negotiators

[18] See Working Group III full report text, available at: https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf.

[19] See Working Group III Technical Summary, available at: https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_TechnicalSummary.pdf.

[20] IPCC Factsheet: How does the review process work?, supra note 14.

[21] *See, e.g.,* R. Harris, *supra* note 13.

[22] Chloé Farand, *"Saudi Arabia dilutes fossil fuel phaseout language with technofixes in IPCC Report,"* Climate Home News (April 4, 2022). Available at: https://www.climatechangenews.com/2022/04/04/saudi-arabia-dilutes-fossil-fuel-phase-out-language -with-techno-fixes-in-ipcc-report/.

[23] Id.

appeared to be making "a political battleground" of the IPCC's findings,[24] noting, *inter alia*, efforts by major emitting countries like the United States and Germany to remove references to equity and to the responsibility of developed countries to provide climate finance.[25]

Fossil fuels and CCS were an epicenter of the political battles over the Summary for Policymakers. Heading into the final days of the IPCC negotiations, multiple credible media reports identified debates over fossil fuels as a key point of contention and delay in the ongoing negotiations.[26] Efforts by major fossil fuel producers to prioritize references to CCS, including qualifying references to fossil fuels and fossil fuel infrastructure with the phrase "unabated," were a notable driver of delay in the closing hours of the process.[27]

The protracted and politicized review process had a clear impact on the Summary for Policymakers' size, framing, and focus. Members of the media reported that the final Summary for Policymakers released at the close of negotiations on April 4, 2022, was 22 pages (more than 50%) longer than a draft dated just three weeks earlier.[28] Far from strengthening or sharpening

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[24] See, e.g., "Alarm that IPCC WGIII report on climate mitigation accepts overshoot of 1.5°C and relies on unproven technofixes that won't curb runaway climate change," Friends of the Earth International (April 4, 2022). Available at: https://www.foei.org/ipcc-wgiii-report-on-climate-mitigation/.

[25] "ActionAid USA response to the IPCC Working Group III Summary for Policymakers", Action Aid (April 5, 2022), ("While the IPCC report itself is a summary of scientific research, the Summary for Policymakers is negotiated. Attempts by countries like the United States to avoid responsibility undermine the kind of fair global cooperation that is essential for an effective response to climate change.") Available at: https://www.actionaidusa.org/news/actionaid-usa-response-to-ipcc-working-group-iii- summary-for-policymakers/.

[26] Matt McGrath, *"Climate change: Scientists race to finish key IPCC report,"* BBC News (April 3, 2022). Available at: https://www.bbc.com/news/science-environment-60959306; Ciara Nugent, *New IPCC Report Was Delayed As Scientists Debated Reliance on Carbon Capture,* Time (April 4, 2022). Available at: https://time.com/6164252/ipcc-carbon-capture-climate-mitigation/.

[27] Farand, *supra.* note 20. For examples, see IIED, Summary of the 56th Session of the Intergovernmental Panel on Climate Change and the 14th Session of Working Group III: 21 March – 4 April 2022, ENB Vol. 12 (75) (7 April 2022) Available at: https://enb.iisd.org/sites/default/files/2022-04/enb12795e.pdf. Specifically, see, e.g., *id* at 11 ("On implied annual average global GHG emissions reductions for pathways consistent with NDCs that limit warming to 2°C between 2020-2030 and between 2030-2050, SAUDI ARABIA urged inserting reference to investments in "unabated" emissions-intensive infrastructure as a barrier to accelerating reductions."); *Id.* at 11, Sec. S.B.7 ("SAUDI ARABIA and JAPAN requested specifying "unabated" CO_2 emissions in this section."); *Id.* at 14, Sec. C.4 ("On unburned fossil fuel resources, SAUDI ARABIA insisted that the estimated value of stranded assets only reflects the unabated part of fossil fuels, saying new technologies will make fossil fuels low carbon. The BAHAMAS said findings on limiting warming must reflect the 1.5°C level here and throughout the SPM. Delegates agreed to indicate that "Depending on its availability, CCS could allow fossil fuels to be used longer, reducing stranded assets." The term "stranded assets" was further explained, and the difference between pursuing a pathway to 1.5°C, or to 2°C, for fossil fuel use was specified."); *Id.* at 15, Section C.5 ("SAUDI ARABIA called for positive framing of CCS as an important element in achieving net-zero emissions. Noting that CCS is the most expensive option for reducing emissions, SAINT KITTS AND NEVIS called for a statement on the feasibility of CCS at the scale required. FRANCE said the text conveys that CCS is more important than other options, thus not reflecting the underlying chapter's balance. BRAZIL called for additional references to sustainability and sustainable development throughout Subsection C.5. FWCC noted there were 33 SPM references to CCS and only six to renewable energy.")

[28] Farand, *supra* note 20. By comparison, Working Group III's Summary for Policymakers of its Fifth Assessment Report, was 32 pages, half the length of the Summary for Policymakers for its latest report. See, IPCC, 2014: Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C.

the messages of the Summary for Policymakers, the government review process had the opposite effect in critical respects. Scientist Rebellion, a movement of hundreds of scientists advocating for systemic changes in line with scientific findings,[29] observed that key findings and messages had been "watered down" in the final version of the Summary for Policymakers compared to an early draft of the Summary leaked by the group in August 2021.[30] Highlighting instances in which warnings in the earlier report had been weakened or downplayed, the group warned that "Despite the escalating climate emergency and the total absence of emissions cuts, the framing of the final version of the SPM is still alarmingly reserved, docile and conservative."[31]

These impacts were evident in the final Summary for Policymakers' downplaying of fossil fuel phaseout as a tool for mitigation and its over-emphasis of CCS and other technological fixes to the climate crisis. References to fossil fuels in the Summary for Policymakers are scarce. The phrase "fossil fuel" appears only 20 times in the 64-page Summary for Policymakers. Even those limited references often qualify that reductions apply to "unabated" fossil fuels, that is, those without CCS or fugitive emissions reduction. Similarly, the word "oil" appears only seven times in the entire 64-page Summary for Policymakers; and six of these appearances are in conjunction with CCS and/or "Enhanced Oil Recovery."

Despite compelling evidence within the Working Group III report itself that renewable energy deployments can achieve dramatically greater emission reductions more quickly and at lower cost [see Figure SPM.7, SPM-50], CCS or carbon capture are referenced more frequently than renewables in the Summary for Policymakers. Other statements lump "fossil fuels with CCS" in with renewables under the label "very low- or zero-carbon energy sources" [see, e.g., SPM C.3, SPM-32], ignoring the fundamental differences between demonstrated, available, and increasingly competitive technologies like solar and wind, and carbon capture technologies unproven at scale and economically infeasible. Such qualifications belie the repeated failures of CCS projects to deliver on promised emissions reductions to date, perpetuating the myth that continued fossil fuel use is compatible with avoiding climate catastrophe. Elsewhere, the Summary for Policymakers couches statements about the foreseeable adverse impacts of CDR, such as pressures on land and biodiversity, in broad assertions that "[a]ll mitigation strategies face implementation challenges, including technology risks, scaling, and costs," [SPM 3.6, SPM-33] thereby masking the uniquely risky nature of large-scale CDR and the potentially devastating consequences of reliance on it.

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von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, US. Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/ ipcc_wg3_ar5_summary-for-policymakers.pdf.

[29] Kenny Stancil, *"Rebellious Climate Scientists Have Message for Humanity: 'Mobilize, Mobilize, Mobilize',"* Common Dreams (April 6, 2022). Available at: https://www.commondreams.org/news/2022/04/06/rebellious-climate-scientists-have-message- humanity-mobilize-mobilize-mobilize.

[30] *"Press Release–IPCC WGIII Summary for Policymakers watered down, says Scientist Rebellion," Scientist Rebellion (April 5, 2022).* Available at: https://scientistrebellion.com/press/.

[31] Id.

V. End Fossil Fuels First and Fastest – Rapid fossil fuel phaseout remains the clearest and most certain path to avoid overshoot and prevent irreversible impacts.

All three Working Group contributions to the IPCC's Sixth Assessment Report make clear the imperative of employing mitigation measures that provide the best chance of limiting warming to 1.5°C with no (or limited) overshoot, which requires accelerated near-term emissions reductions across all sectors [WGI Ch. 4, 4.6.2; WGII (e.g.,) SPM B.6 and TS.C.2.5 (discussing risks from overshoot)]. The mitigation measures entail urgently shifting away from fossil fuels by halting new fossil fuel development while phasing out existing fossil fuel infrastructure, scaling up renewable energy, and maximizing energy efficiency and end-use electrification. Such proven mitigation measures provide the clearest path to limiting warming to 1.5°C. The Working Group III report includes 97 no or low overshoot scenarios (C1 scenarios). Its findings affirm that the following key elements of a no (or low) overshoot pathway are technically and economically feasible.

Immediate halt to fossil fuel expansion and the rapid phaseout of existing fossil fuel production

The Working Group III report findings reiterate that avoiding an overshoot of 1.5°C requires steep, near-term emissions reductions. Both atmospheric CO_2 concentrations and the accumulated warming impact of atmospheric GHGs are cumulative. Therefore, "[d]eep GHG emissions reductions by 2030 and 2040, particularly reductions of methane emissions, lower peak warming, reduce the likelihood of overshooting warming limits and lead to less reliance on net negative CO_2 emissions that reverse warming in the latter half of the century" [SPM C.2]. Put another way, rapid near-term reductions have greater mitigation impacts and benefits than reductions decades in the future. The modeled pathways that provide the greatest chance of staying below 1.5°C without overshoot require that global GHG emissions peak by no later than 2025 and decline by a median of 43% from 2019 levels by 2030; 69% by 2040; and 84% by 2050, reaching net zero emissions by 2050-2055 [Table SPM.1 at SPM-24].

These steep reductions cannot be achieved without rapidly phasing out fossil fuels — the greatest source of emissions — through mitigation approaches that are proven, available, and deployable now. Carbon dioxide emissions from fossil fuels and industry accounted for 64% (38Gt) of total global GHG emissions in 2019, with methane – of which fossil fuel production and use are among the largest sources – contributing an additional 18% (11Gt) [SPM-6 (Fig. SPM.1)]. Thus, the IPCC notes, "the achievement of long-term temperature goals in line with the Paris Agreement requires the rapid penetration of renewable energy and a timely phasing out of fossil fuels, especially coal, from the global energy system. . . . Net zero emissions imply that fossil fuel use is minimised and replaced by renewables and other low-carbon primary forms of energy, or that the residual emissions from fossil fuels are offset by carbon dioxide removal." [Ch. 17, 17-

23] "In all scenarios, fossil fuel use is greatly reduced and unabated coal use is completely phased out by 2050" [Ch. 3, 3-47; see also *id.* At 3-57]. In scenarios with the greatest probability of limiting warming to 1.5°C with no or limited overshoot, the use of coal, oil, and gas must decline by a median of 95%, 60%, and 45%, respectively, by 2050, with phaseout completed in the second half of the century [SPM C.3.2, at SPM-32].

Projections of continued use of fossil fuels at even these levels are premised on the significant deployment of risky, unproven, and expensive CCS and/or carbon removal approaches in some of the high ambition (C1) models. [Table 3.4, FN.4 at 3-53; Table SPM.1 at SPM-22-24 (C1a and C1b pathways)] Despite the higher uncertainties, significantly lower potential, and dramatically higher costs, the reliance on CCS in these pathways allows the continued heavy use of fossil fuels to 2050 and beyond.

By contrast, in the high ambition pathways that emphasize renewable energy deployment and energy demand reduction without reliance on CCS and CDR, and which, as noted above, secure faster near and medium-term emission reductions, the use of fossil fuels declines much more quickly. [See Ch. 3 Figures 3.7 and 3.8, at 3-23 (depicting the rapid decline in residual fossil fuel emissions under the IMP-Ren and IMP-LD pathways, with no reliance on Fossil CCS or Direct Air Capture (DAC) and minimal or no reliance on BECCS, and the steep decline in fossil energy systems); *see also* SPM C.3.2 at SPM-32 (noting that in some of the modeled pathways that limit warming to 1.5°C with no or limited overshoot, the use of coal, oil, and gas is reduced by as much as 100%, 90%, and 90%, respectively, in 2050)].

Fundamentally, meeting the Paris climate targets necessitates a fossil fuel phaseout. The IPCC's Working Group III report explicitly acknowledges this: "Meeting the ambitions of the Paris Agreement will require phasing out fossil fuels from energy systems, which is technically possible and is estimated to be relatively low in cost" [Ch. 17, at 17-64]. Considering that "'committed' emissions from the existing fossil fuel-based infrastructure may consume all the remaining carbon budget in the 1.5°C scenario," [Ch. 17, at 17-65], it is not possible to stay within 1.5°C warming unless new fossil fuel projects are stopped, and existing fossil fuel infrastructure is shuttered.

Investments in fossil fuels must be halted to avoid climate catastrophe. "Limiting warming requires shifting energy investments away from fossil-fuels and towards low carbon technologies (high confidence)" [Ch. 3, 3-7]. Further investment in fossil fuels and associated infrastructure ensures higher levels of warming and irreversible impacts stemming from overshoot: **"If investments in coal and other fossil infrastructure continue, energy systems will be locked-in to higher emissions,** making it harder to limit warming to 2°C or 1.5°C *(high confidence)*" [TS-53].

Existing fossil fuel infrastructure, particularly in the power sector, also must be retired early. As the IPCC makes clear, **"Without early retirements, or reductions in utilization, the current fossil infrastructure will emit more GHGs than is compatible with limiting warming to 1.5°C."** [Box TS.8, at TS-54; see also SPM B.7.1, SPM-19]

Accelerated deployment of renewables

The IPCC recognizes that renewables are outpacing other mitigation technologies and that relying on them is a more certain strategy to deliver necessary emissions reductions. The Working Group III report recognizes the remarkable progress made by renewable energy sources, particularly when it comes to cost and feasibility. Renewable energy costs have declined rapidly, and their pace of adoption has exceeded that of other technologies like nuclear and CCS, which suggests that an **accelerated transition to renewable energy is entirely possible**.

> *"The rapid deployment and unit cost decrease of modular technologies like solar, wind, and batteries have occurred much faster than anticipated by experts and modeled in previous mitigation scenarios…In contrast, the adoption of nuclear energy and CO_2 capture and storage (CCS) in the electricity sector has been slower than the growth rates anticipated in stabilisation scenarios. Emerging evidence since AR5 indicates that small-scale technologies (e.g., solar, batteries) tend to improve faster and be adopted more quickly than large-scale technologies (nuclear, CCS) (medium confidence)." [TS-25]*

The cost competitiveness of renewables fundamentally reshapes the energy landscape and the nature of the energy transition. As the Summary for Policymakers points out, "[i]n 2020, the levelised costs of energy (LCOE) of the four renewable energy technologies could compete with fossil fuels in many places" [SPM-14]. The Technical Summary further notes: "The unit costs for several key energy system mitigation options have dropped rapidly over the last five years, notably solar PV, wind power, and batteries *(high confidence).* From 2015 to 2020, the costs of electricity from PV and wind dropped 56% and 45%, respectively, and battery prices dropped by 64%. Electricity from PV and wind is now cheaper than electricity from fossil sources in many regions, electric vehicles are increasingly competitive with internal combustion engines, and large-scale battery storage on electricity grids is increasingly viable." [TS 5.1, at TS-53]

Renewable energy technology that is proven, available, and affordable should be the centerpiece of global energy strategies — not technologies yet to be proven at scale or proven at all, or still under development. Rapid energy transition — aided by policy and financial support, including finance and technology transfer to developing countries — is key to mitigating warming. "A fast global low-carbon energy transition enabled by finance to facilitate low-carbon technology adoption in developing and particularly in least developed countries can facilitate achieving climate stabilisation targets." [TS-25] Renewable energy technologies like wind, solar, and batteries are the most feasible and promising of low-carbon technology options, and the IPCC notes their feasibility "has improved dramatically over the past few years" [TS-25].

Going all-in on renewable energy is both desirable and feasible. Emissions reduction pathways exist for getting to 100% renewable energy globally. "Scenarios have been published with 100% renewable energy systems even at a global scale, partly reflecting the rapid progress made for these technologies in the last decade (Breyer and Jefferson 2020; Creutzig et al. 2017; Jacobson et al. 2018).” [Ch. 3, 3.3.2.4, at 3-46]

Electrifying end-uses and maximizing efficiency and conservation to lower energy demand

Electrification across the energy sector is important for decarbonization, particularly as zero-carbon renewable energy becomes increasingly viable and cost-effective for generating electricity. The IPCC Working Group III report recognizes electrification as a key piece of mitigation: “Stringent emissions reductions at the level required for 2°C or 1.5°C are achieved through the increased electrification of buildings, transport, and industry, consequently all pathways entail increased electricity generation *(high confidence)*.” [TS-46] The report further notes, “Accelerated electrification of end uses such as light duty transport, space heating, and cooking is a critical near-term mitigation strategy” [Ch. 6, at 6-107].

Reducing energy demand and improving energy efficiency are also key mitigation strategies. Low energy demand can limit, and perhaps even avoid, reliance on large-scale, risky, and unproven engineered CDR. “Mitigation pathways show reductions in energy demand, relative to reference scenarios that assume continuation of current policies, through a diverse set of demand-side interventions *(high confidence)* … A **stronger emphasis on demand-side mitigation implies less dependence on CDR and, consequently, reduced pressure on land and biodiversity.”** [TS-47] Reliance on CDR can thus be substantially limited by focusing on deep cuts in emissions in the near term and lowering energy demand [Ch. 6, at 6-108].

Rapid and dramatic demand reductions are feasible. One mitigation scenario in the literature particularly demonstrates the potential for reducing energy demand: “Grubler et al. (2018) models a pathway leading to global temperature change of less than 1.5 C without CCS, taking end-use changes into account, including innovations in information technologies and changes to consumer behaviour apart from passive consumption…The conclusion is that, although providing material living standards does not guarantee that every person will live a good life, there are large potentials in achieving low energy demand with sustainable development.” [at 17-22]

Curtailing energy demand through altering consumption, mobility, and infrastructure design patterns could go a long way toward climate mitigation. According to the IPCC, implementing demand-side mitigation strategies across all sectors has the potential to reduce GHG emissions from 40 to 70% by 2050 [Ch. 5, ES, at 5-3]. Shifting to plant-based diets, adopting greater use of public transit and teleworking, and designing buildings to take advantage of passive solar are examples of such demand-side strategies. These changes involve cultural and behavioral shifts, and policy support is important to enabling structural changes and facilitating these shifts [Ch. 5 ES at 5-6; 5.6 at 5-95]. Rapid societal change is possible, as demonstrated by the (behavioral and policy) response to the Covid-19 pandemic [Ch. 5, ES, at 5-6]. While such demand-side mitigation strategies are a critical part of an overall suite of measures to address the climate emergency, individual change is no substitute for systemic change. Individual behavior measures can only ever address a small fraction of global emissions. Working Group III's inclusion of a demand-side chapter is laudable. Still, attention to individual behavior change must not detract from the central focus on the primary drivers of global emissions – chief among them, fossil fuels and resource-intensive economic growth.

The mitigation measures discussed above are, of course, not the only emissions reduction approaches that will need to be executed. They are merely starting points, subject to the many constraints of top-down IAM modeling.[32] Comprehensive and effective climate action demands transformations across all aspects of society. While the measures mentioned above apply mainly to the energy sector, mitigation strategies in other sectors such as food and agriculture are just as critical and must not be overlooked. Policymakers must not exclude other societal pathways that challenge the notion of continued global economic growth and its compatibility with ambitious climate targets, explore ways of reducing production and consumption in the Global North, and do not resort to risky technologies such as nuclear energy, CCS, and large-scale CDR.[33]

VI. Time to Put CCS in Deep Storage – Carbon capture and storage is a costly extension of the fossil fuel industry

By design, carbon capture technologies extend the fossil fuel era. The Working Group III report explicitly refers to CCS as an enabler of continued fossil fuel combustion, which is antithetical to climate action. The report states: "CCS can allow fossil fuels to be used longer" [TS 5.1, at TS-53; SPM C.4.4, at SPM-36], and "CCS deployment will increase the shares of fossil fuels" used for mitigation [Ch. 6, 6.7.4, at 6-118]. Given incontrovertible evidence that fossil fuels are the primary source of GHG emissions, a technology that prolongs or increases their use cannot be considered a mitigation measure.

Moreover, CCS technology and processes are fundamentally flawed. CCS projects to date have repeatedly failed to deliver on promised emissions reductions,[34] and the technology has not scaled or achieved cost reductions despite existing for decades. As noted above, "the adoption of nuclear energy and CO_2 capture and storage (CCS) in the electricity sector has been slower than the growth rates anticipated in stabilisation scenarios … Emerging evidence since AR5 indicates that small-scale technologies (e.g., solar, batteries) tend to improve faster and be adopted more quickly than large-scale technologies (nuclear, CCS)." [TS-24] CCS has a dismal

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[32] Some of the most important constraints and limitations have been outlined in Section II of this briefing. For a further discussion of limitations of IAMs, see Working Group III Annex III 9.5.

[33] See, e.g., Kai Kuhnhenn et al, A Societal Transformation Scenario for Staying Below 1.5°C (2021), https://www.boell.de/en/2021/11/16/societal-transformation-scenario-staying-below-15degc-summary.

[34] See e.g., Andy Rowell and Lorne Stockman, "Carbon Capture: Five Decades of False Hope, Hype, and Hot Air," Oil Change International, June 17, 2021, https://priceofoil.org/2021/06/17/carbon-capture-five-decades-of-industry-false-hope-hype- and-hot-air/; see also: "Hydrogen project lauded by Shell to boost green credentials emits more carbon than a million cars," Global Witness press release, January 20, 2022, https://www.globalwitness.org/en/press-releases /shell-plant-emissions-million-cars/.

track record. Its central role in many mitigation scenarios reviewed in the Working Group III report is premised upon a cost decline that has simply failed to materialize.

CCS cost reductions may never happen, as the financial impediments to CCS are fundamental to the process and will not disappear. "CO_2 capture costs present a key challenge… The capital cost of a coal or gas electricity generation facility with CCS is almost double one without CCS. Additionally, the energy penalty increases the fuel requirement for electricity generation by 13–44%, leading to further cost increases." [Ch. 6, at 6-38]. The bottom line, as the IPCC notes, is that CCS "always adds cost" [Ch. 6, at 6-39].

The IPCC thus recognizes that the economic feasibility of CCS technologies is questionable or unclear [Ch. 4, 4.2.5.4, at 4-44]. The Panel even explicitly states in a subsection heading, "the economic feasibility of [CCS] deployment is not yet clear" [Ch. 4, 4-44]. Although the IPCC lists several studies that indicate various levels of CCS reliance, it notes, "[s]ome limitations of CCS, including uncertain costs, lifecycle and net emissions, other biophysical resource needs, and social acceptance are acknowledged in existing studies" [Ch. 4, 4.2.5.4, at 4-45]. Most of the studies, however, do not explicitly challenge rosy CCS assumptions.

Carbon capture and storage poses other risks. Such risks include the use of toxic chemicals in capture processes, increasing air pollutants from the underlying facility, depletion of scarce water resources, risks to communities from the construction and operation of CO_2 pipelines, and potential brine displacement and CO_2 leakage during the injection and storage phase. As the IPCC acknowledges, "CCS requires considerable increases in some resources and chemicals, most notably water" [Ch. 6, at 6-39], contributing to "significant land and water tradeoffs (high confidence)" and the production of "high-salinity brines … from geologic carbon storage" [Ch. 6, at 6-126]. Moreover, there is no guarantee CO_2 can be "permanently" stored underground, and leakage back into the atmosphere undoes any purported climate benefits of CCS. The IPCC recognizes that geologic storage of CO_2 has limiting factors such as location and distribution of storage sites, which may not be proximate to CO_2 sources, and the underground pressure of reservoirs [Ch. 6, 6.4.2.5, at 6-36-37]. The report notes that "not all geologic storage is utilizable" and that long-term storage requires specific depth, thickness, and permeability conditions that may not hold [Ch. 6, 6-37]. Tautological statements like the following sentence in the Summary for Policymakers do not eliminate this uncertainty: "*If the geological storage site is appropriately selected and managed*, it is estimated that the CO_2 can be permanently isolated from the atmosphere" [SPM, C.4.6, SPM-37 (emphasis added)]. A lot is riding on that conditional phrase.

Despite foregrounding CCS, the Summary for Policymakers lays bare its limitations. The Summary for Policymakers includes several references to "unabated" fossil fuels, carving out exceptions to enable continued fossil fuel use with CCS [B.6.3, SPM-17; B.7.1, SPM-19; C.4., SPM-36]. The capture rates as defined for abated fossil fuels, however, exceed 90-95%, a capture rate that has essentially never been seen in practice. This is reflected in the Summary for Policymakers, which states, "capture rates of new installations with CCS are assumed to be 90-95% +" [Footnote 37, SPM-20], and "'unabated fossil fuels' refers to fossil fuels produced and used without interventions that substantially reduce the amount of GHG emitted throughout the life-cycle; for example, capturing 90% or more from power plants, or 50-80% of fugitive methane emissions from energy supply." [Footnote 55, SPM-36] Despite these strict definitions, the Summary for Policymakers also notes that "CCS is less mature in the power sector, as well as in cement and chemicals production," and that "regional availability of geological storage could be a limiting factor. … Implementation of CCS currently faces technological, economic, institutional, ecological-environmental and socio-cultural barriers. Currently, global rates of CCS deployment are far below those in modelled pathways limiting global warming to 1.5°C or 2°C." [SPM C.4.6, SPM-37]

With its inherent costs and track record of failure, CCS is little more than an expensive extension of fossil fuel facilities. The two most prominent methods of carbon dioxide removal — BECCS and DACCS — rely on this unproven technology and, as the IPCC repeatedly makes clear, face feasibility constraints of their own.

VII. Too Little, Too Late, with Too Many Trade-Offs – Technological carbon dioxide removal methods are risky, unproven, and obstruct climate progress

Mitigation strategies that increase the risk of overshoot entail massive costs to human lives, human rights, and ecosystems around the world. As discussed in section II above and in an earlier briefing by CIEL and Heinrich Boell, the IPCC Working Group II report warned that going beyond 1.5°C, even temporarily, will result in irreversible impacts, including damage to ecosystems and greater loss of human life. In its 2018 Special Report on Global Warming of 1.5°C, the IPCC concluded that to have at least a 66% chance of keeping warming below 1.5°C, humanity must reduce global greenhouse emissions by 45% by 2030 and achieve zero net emissions by no later than 2050 [IPCC SR1.5 SPM C.1]. In the face of rising emissions, Working Group III updated this figure to require reductions in CO_2 emissions of 48% below 2019 levels (36-69%) by 2030, with emissions effectively eliminated by the 2050s [WGI TS 36-37].

Yet even in optimistic scenarios, carbon removal technologies like BECCS and DACCS would not begin removing CO_2 from the atmosphere at any meaningful scale until 2050 or later.[35]

[35] See, e.g., IEA, *Carbon removal through BECCS and DACS in the Sustainable Development Scenario and IPCC SR1.5 Scenarios, 2030-2100* (23 Sept. 2020). Available at: https://www.iea.org/data-and-statistics/charts/carbon-removal-through- beccs-and-dacs-in-the-sustainable-development-scenario-and-ipcc-sr1-5-scenarios-2030-2100. (Showing BECCS and DACS achieving insignificant removal rates prior to 2050.) On DACs, *see also* Ryan Hanna et al., *Emergency deployment of direct air capture as a response to the climate crisis.* Nature Comm. 2021 Vol. 12:368. (Jan 14, 2021). doi: 10.1038/s41467-020-20437-0 Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/ PMC7809262/. ("An emergency DAC program, with investment of 1.2–1.9% of global GDP annually, removes 2.2–2.3 $GtCO_2\ yr^{-1}$ in 2050, 13–20 $GtCO_2\ yr^{-1}$ in 2075, and 570–840 $GtCO_2$ cumulatively over 2025–2100. Compared to a future in which policy efforts to control emissions follow current trends (SSP2-4.5), DAC substantially hastens the onset of net-zero CO_2 emissions (to 2085–2095) and peak warming (to 2090–2095); yet warming still reaches 2.4–2.5 °C in 2100. Such massive CO_2 removals hinge on near-term investment to boost the future capacity for upscaling."); Mahdi Fasihi, et al., *Techno-economic assessment*

Accordingly, such technologies are unlikely to play any significant role in bringing global greenhouse emissions to net zero in the critical period between now and 2050, when such emissions must be effectively eliminated to avoid overshooting 1.5°C.[36]

If irreversible losses are to be avoided, relying on the future deployment of unproven and potentially dangerous approaches like CDR, Solar Radiation Management, or other geoengineering technologies are not an option. The IPCC Working Group I report recognized that "[a]ffordable and environmentally and socially acceptable CDR options at scale well before 2050 are an important element of 1.5°C-consistent pathways especially in overshoot scenarios," but simultaneously acknowledged that "two extensive reviews (Lawrence et al., 2018; Nemet et al., 2018) conclude that it is implausible that any CDR technique can be implemented at scale that is needed by 2050" [WGI Ch. 4, 4.6.3.2 at 4-80].

BECCS and DACCS are even more uncertain than CCS, entail larger risks, and should not be relied upon as a "backup" in case of overshoot. Despite their inclusion in modeled scenarios, the IPCC does not unreservedly support CCS, BECCS, or DACCS. Rather, the IPCC exhaustively cautions against relying on these approaches and technologies, explaining how technological CDR approaches, especially BECCS and DACCS, present significant risks; are unproven at scale; entail great financial costs that may not follow anticipated cost curves; create additional demand for energy and other resources; and present obstacles to mitigation. Policymakers should not misread the Working Group III report as a mandate to invest financial and other resources in CCS and technological CDR but rather understand it as a warning of the dire straits the global community will be in if it comes to rely on these approaches.

The primary technologies used in overshoot scenarios – DACCS and BECCS – are entirely unproven at scale. Like the CCS on which they rely, direct air capture and large-scale bioenergy production of the type envisioned for BECCS have not been demonstrated. They exist only in projections and modeling literature. Nonetheless, both appear in IAMs (as does CCS generally) because they work on paper. Models reflect optimistic projections about the estimated potential of CDR technologies, not their real-world feasibility or sustainability.[37] (As noted by the Chairman of Market and Investment Strategy at J.P. Morgan in the context of CCS, "The highest ratio in the history of science: the number of academic papers written on CCS divided by real-life

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of CO2 direct air capture plants. J. Cleaner Prod. Vol. 224: 957-980, Table (1 July 2019) https://doi.org/10.1016/j.jclepro.2019.03.086 Available at: https://www.sciencedirect.com/science/article/pii/S0959652619307772 (Projecting that, with heavy investment in 2020s and onward total CO_2 removals by DAC would reach just 473 MtCO2/year by 2030, 4791 MtCO2/year by 2040, and 15,356 MtCO2/year by 2050).

[36] See, e.g., IPCC SR1.5 Ch. 2.3.4.1 (noting that BECCS is expected to be used predominately after mid-century (i.e., 2050)).

[37] See IPCC SR 1.5, Ch. 4.7.3.1. ("BECCS deployment is further constrained by bioenergy's carbon accounting, land, water and nutrient requirements (Section 4.3.1), its compatibility with other policy goals and limited public acceptance of both bioenergy and CCS (Section 4.3.1). Current pathways are believed to have inadequate assumptions on the development of societal support and governance structures (Vaughan and Gough, 2016). However, removing BECCS and CCS from the portfolio of available options significantly raises modelled mitigation costs (Kriegler et al., 2013; Bauer et al., 2018)"); *see also* Cross-Chapter Box 7 | Land-Based Carbon Dioxide Removal in Relation to 1.5°C of Global Warming.

implementation of it."[38]) Such models also often include generous assumptions about how much the cost for CCS, BECCS, and DACCS will decline.

Even if their costs decline, the IPCC warns against relying on DACCS and BECCS, both of which require greater study. As the IPCC notes, "[e]xcept for reforestation," several CDR approaches, including DACCS and BECCS, "have not been tested at large scale and often require more R&D [research and development]. Moreover, the reliance on CDR in scenarios has been discussed, given the possible consequences of land use related to biodiversity loss and food security (BECCS and afforestation), the reliance on uncertain storage potentials (BECCS and DACCS), water use (BECCS), energy use (DACCS), the risks of possible temperature overshoot and the consequences for meeting sustainable development goals[.]" [Ch. 3 at 3-36] The IPCC explicitly points to feasibility and sustainability constraints of CDR as a barrier to wide-scale deployment: "Upscaling the deployment of CDR depends on developing effective approaches to address feasibility and sustainability constraints especially at large scales. (*high confidence*)" [SPM C.11, at SPM-47].

Choosing to invest in technological CDR, CCS, or other techno-fixes is a political decision rather than a scientific necessity and comes with significant opportunity costs and trade-offs. Despite presenting scenarios with significant CDR, the IPCC stresses the need to prioritize emissions reduction and true mitigation strategies. [Ch. 6, 6.6.2.7, at 6-93] IPCC acknowledges that "CDR will influence the potential fossil-related stranded assets (Box 6.13). Availability of low-cost CDR can help reduce premature retirement for some fossil fuel infrastructure. CDR can allow countries to reach net zero emissions without phasing out all fossil fuels." [Ch. 6, 6.7.1.3, at 6-108] In one of its most direct explanations, the WGIII report states: "It needs to be emphasized that even in strategies with net negative CO_2 emissions, the emission reduction via more conventional mitigation measures (efficiency improvement, decarbonisation of energy supply) is much larger than the CDR contribution." [Ch. 3, at 3-36] The understanding should be reflected in policy and finance decisions where a much larger share of public dollars goes towards conventional mitigation than to CDR.

The potential downsides to relying on BECCS and DACCS are substantial. The Working Group III report points to concerns that large-scale CDR could "obstruct near-term emission reduction efforts, mask insufficient policy interventions, might lead to an overreliance on technologies that are still in their infancy, could overburden future generations, might evoke new conflicts over equitable burden-sharing, could impact food security, biodiversity or land rights, or might be perceived negatively by stakeholders and broader public audiences… **CDR deployment might not deliver the intended benefit of removing CO_2 durably from the atmosphere."** [Ch. 12, at 12-39] The IPCC recognizes that if the carbon dioxide removed through DAC is utilized in products (as in DACCU), the duration of the removal "varies with the lifetime of respective products" and could be as little as weeks in the case of synthetic fuels [Ch. 12, 12-42].

[38] Micahel Cembalest, J.P. Morgan Asset and Wealth Management, Eye on the Market: 2021 Annual Energy Paper 22 (2021), https://am.jpmorgan.com/content/dam/jpm-am-aem/global/en/insights/eye-on-the-market/future-shock-amv.pdf.

Large-scale technological CDR, especially BECCS and DACCS, are technically uncertain gambles that are neither guaranteed to provide their intended climate benefit nor meet hoped-for cost reductions. Pathways that rely on BECCS and DACCS for large-scale CDR are subject to the risks and uncertainties inherent in relying on CCS, in addition to those of bioenergy (BE) and direct air capture (DAC). The IPCC's prior reports have repeatedly recognized that CDR may be ineffective in reversing temperature rise following overshoot due to uncertainties in how the carbon cycle responds to negative emissions, the risk of rebound, and impermanence of removals.[39] [SR1.5, Ch. 2, ES, at 34; WG I, Ch. 5, 5.6.2.1 at 5-102]. Consequently, the IPCC has found reliance on CDR far riskier than energy efficiency and low-demand strategies that drastically reduce GHGs in the near term. [SR 1.5 Ch. 2, ES].

DACCS delays mitigation: The resource intensity and questionable viability of DACCS

DACCS is such a resource-intensive process that it is unlikely to provide a climate benefit even if it achieves significant scale. The IPCC notes: "At large scales, the use of DACCS has substantial implications for energy use, emissions, land, and water…Since DACCS consumes energy, its effectiveness depends on the type of energy used; the use of fossil fuels would reduce its sequestration efficiency." [Ch. 3, at 3-68] At a scale of 10 gigatons of CO_2 removal per year, DAC could require up to 100 exajoules of energy, equivalent to current total global electricity production and one-sixth of total energy supply [Ch. 12, 12.3.1.1, 12-44]. If not powered by renewable energy, the emissions from running DAC equipment could diminish or even undo any purported climate benefit. Conversely, powering energy-intensive DAC equipment with the massive quantities of renewable energy it would require would divert that energy from other uses that would avoid emissions in the first place, likely at much lower cost.

Beyond potentially failing to provide meaningful climate benefits, DACCS would also require enormous amounts of land, water, materials, and chemicals. "DACCS requires a considerable amount of energy (high confidence), and…could require a significant land footprint…Unless sourced from a clean source, this amount of energy could cause environmental damage . . . Large-scale deployment of DACCS would also require a significant quantity of materials, and energy to produce them." [Ch. 12, 12.3.1.1, at 12-44] The IPCC's Working Group II report likewise recognized that DACCS could "significantly impact food prices via demand for land and water," with most severe impacts on vulnerable populations in the Global South [WGII, Ch. 4, 4.7.6, at 4-131].

Critically, where DACCS appears in a limited number of mitigation pathways, it is primarily a proxy for cost reductions, not an indication of the technology's viability. Only a few modeled pathways explicitly include DACCS. Where it is incorporated, "[s]tringent emissions constraints in these studies lead to high carbon prices, allowing DACCS to play an important role in mitigation"

[39] CIEL, Heinrich Boell, "Beyond the Limits: New IPCC WG II Report Highlights How Gambling on Overshoot is Pushing the Planet Past a Point of No Return," (February 28, 2022), Available at: https://www.ciel.org/reports/ipcc-wg2-briefing/

[Ch. 12, 12-45]. The orientation in the models is toward showing when and how DACCS could be a cost-effective measure, not modeling whether DACCS would work and what impact it may have on the pace of mitigation if it does or does not work. Indeed, the IPCC notes that despite the lack of studies on the potential of DACCS, the literature reflects an optimistic assumption that its potential is "virtually unlimited provided that high energy requirements could be met" [Ch. 12, 12-43]. The IPCC recognizes that DACCS could "obstruct near-term emission reduction efforts," among other adverse impacts [Ch. 12, 12-39]. In other words, where IAMs model rapid overall emissions reductions, DACCS functions as a way to slow down the rate of emissions reduction by counter-balancing continued emissions with removals. Studies have shown that incorporating DACCS into an IAM "reduces the overall cost of mitigation and tends to postpone the timing of mitigation" [Ch. 12, 12-45]. These models should be understood not as calling for DACCS but as noting that cost curves for low-carbon options in "hard to abate" sectors are unclear. Moreover, they should not be read as calling for direct investment in DACCS but rather for the policies that accelerate and require the low-carbon transition itself.

BECCS pushes planetary boundaries: The speculative nature and sustainability limits of BECCS

BECCS is one of two primary sources of CDR in models, despite its largely speculative nature. "Among CDR methods, BECCS and A/R [afforestation/reforestation] are most commonly selected by IAMs to meet the requirements of likely limiting warming to 2°C or lower" [Ch. 12, at 12-55]. Between previous reports and AR6, "[t]he role of bioenergy and BECCS in mitigation pathways has been reduced" [Ch. 7, at 7-78], though it still features substantially and prominently.

Despite promised carbon removals, BECCS can have an adverse impact on climate due to land-use change. BECCS is attractive in models because it suggests a climate win-win, producing energy and removing carbon dioxide. "But ill-deployment of energy crops can also cause land carbon losses (Hanssen et al. 2020) and increased biomass demand for energy could hamper other mitigation measures such as reduced deforestation and degradation" [Ch. 7, at 7-77]. The IPCC recognized similar concerns in Working Group II, noting that conversion of non-forest land into forest plantations for BECCS can lead to a "negative carbon sink" as well as "significant loss of overall biodiversity" [WGII, Box 1.3 Nature-Based Solutions, 1-54].

Land-based CDR like BECCS or afforestation could have other significant negative impacts from land-use change. In the Summary for Policymakers of the Working Group III report, the IPCC warns: "afforestation or production of biomass crops for BECCS or biochar, when poorly implemented, can have adverse socio-economic and environmental impacts, including on biodiversity, food and water security, local livelihoods and on the rights of Indigenous Peoples, especially if implemented at large scales and where land tenure is insecure (*high confidence*)" [SPM C.11.2, at SPM-47]. The IPCC included similar warnings in its past reports. The Working Group I report on the physical science, for example, cautioned that "deployment of CDR, particularly on land, can also affect water quality and quantity, food production and biodiversity (high confidence)" [WGI TS 3.3.2 at TS-65; see also WGI SPM D.1.4 at 29]. The Working Group II report on impacts, adaptation, and vulnerability likewise noted, "[d]eployment of afforestation of naturally unforested land, or poorly implemented bioenergy, with or without carbon capture and storage, can compound climate-related risks to biodiversity, water and food security, and livelihoods, especially if implemented at large scales, especially in regions with insecure land tenure (high confidence)." [WGII SPM B.5.4 at SPM-19]. Diverting water to irrigate BECCS plantations could "double the global area and population living under severe water stress compared to the current baseline" [WGII, Ch. 4, 4.7.6, at 4-131].

Unlike other relatively location-agnostic technologies, BECCS and the bioenergy that powers it are extremely dependent on local conditions and are therefore hard to model [Ch. 7, at 7-78]. "It is difficult to disentangle bioenergy development from the overall development in the AFOLU sector given its multiple interactions with food, land, and energy systems. **It is therefore not possible to precisely determine the scale of bioenergy and BECCS deployment at which negative impacts outweigh benefits"** [Ch. 7, at 7-78].[40] Previous modeling has also ignored the many drawbacks of BECCS. For example, the IPCC's Special Report on Climate Change and Land acknowledges "that most estimates [of BECCS' technical CDR potential] do not include socio-economic barriers, the impacts of future climate change, or non-GHG climate forcing (IPCC. 2019a)" [Ch. 7, at 7-78].

One such example of modeling uncertainty is the fundamental question of which lands might be available for bioenergy crop production. Of particular importance is the identification of marginal, abandoned, or degraded land that could be used to grow bioenergy crops and which, at least in models, would not require trade-offs as the land is not currently being used for other purposes. However, "[t]he definition of marginal/abandoned/degraded land, and the methods used to assess such lands remain inconsistent across studies, causing large variation amongst them. **Furthermore, the availability of such lands has been contested since they may serve other functions (subsistence, biodiversity protection, etc.)**." [Ch. 7, at 7-79 (internal citations omitted)]

Forecasts of potential BECCS deployments contain significant additional uncertainties. Critically, the IPCC notes that BECCS, or even the advanced bioenergy production needed for BECCS, does not exist at any meaningful scale yet [Ch. 7, 7.4.4, at 7-81]. Moreover, "Studies arrive at varying mitigation potentials for bioenergy and BECCS due to the large diversity of bioenergy

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[40] Studies do exist on these issues. See, e.g., Felix Creutzig et al., *Considering sustainability thresholds for BECCS in IPCC and biodiversity assessments.* GCB BioEnergy Vol. 13(4) (15 February 2021) https://doi.org/10.1111/gcbb.12798. Available at: https://onlinelibrary.wiley.com/doi/10.1111/gcbb.12798; Vera Heck, et al., *Biomass-based negative emissions difficult to reconcile with planetary boundaries.* Nature Climate Change Vol. 8(2) (February 2018). DOI:10.1038/s41558-017-0064-y. Available at: https://www.researchgate.net/publication/322642679_Biomass-based_negative_emissions_difficult_to_reconcile_with_planetary_boundaries; Lena R. Boysen, et al., *The limits to global warming mitigation by terrestrial carbon removal.* Earth's Future Vol. 5(5) (17 May 2017) https://doi.org/10.1002/2016EF000469 Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016EF000469.

systems, and varying conditions concerning where and how they are deployed[.]" [Box 7.7, Ch. 7, at 7-79] Despite the centrality of BECCS in overshoot scenarios, estimates for the CDR potential of BECCS range by orders of magnitude [Box 7.7, Figure 1, Ch. 7, at 7-80; Ch. 7, 7.4.4, at 7-78]. Concerningly, while sustainability issues and the impacts of climate change itself profoundly affect the emissions impacts of BECCS, the IPCC notes that most estimates do not factor in these considerations [Ch. 7, at 7-78].

Not part of the policy picture: Exclusion of undeveloped and risky CDR approaches from mitigation pathways

Other CDR approaches involving technological interventions in the climate system (geoengineering) are not part of mitigation pathways. Their exclusion is appropriate because they are even further undeveloped and carry additional risks and drawbacks. Enhanced weathering, ocean fertilization, ocean alkalinity enhancement, and blue carbon management are all considered to have lower "technology readiness levels" than DACCS or BECCS [Ch. 12, Table 12.6, 12-58-61]. The mitigation potential for most remains relatively low, and the IPCC does not give them much attention.

Because most of these CDR approaches do not appear in IAM scenarios, large-scale technological CDR in IMPs and model scenarios should be understood as primarily featuring BECCS and DACCS, which comprise the bulk of non-afforestation/reforestation CDR. References to large-scale CDR should be evaluated in the context of the critiques of BECCS and DACCS outlined above and should not be construed as "placeholders" for simply any other as-yet-to-be-developed CDR technique.

VIII. Climate, Rights, and Justice – Mitigation measures must be grounded in social justice and equity

Climate action cannot be divorced from climate justice. Building on the Working Group II report's emphasis on integrating social justice and equity into climate responses, the Working Group III report concludes with a chapter calling attention to the importance of ensuring the transition to a low-carbon society is not only rapid but is also just. Centering justice in climate mitigation approaches is necessary to alleviate existing societal vulnerabilities and minimize climate harms. As the IPCC states in Working Group III: **"Accelerating climate actions and progress towards a just transition is essential to reducing climate risks and addressing sustainable development priorities, including water, food and human security (robust evidence, high agreement)"** [Ch. 17, ES at 17-3].

The mitigation pathways that avoid overshoot and limit reliance on unproven techno-fixes are also the best routes to achieving other sustainable development goals and are most protective of human rights. The critical need to phase out fossil fuels and accelerate the deployment of renewables comes with substantial co-benefits. "Phasing out fossil fuels in favor of low-carbon sources, is likely to have considerable SDG (Sustainable Development Goal) benefits… 'Sustainable transition' pathways have indicated a complete fossil phaseout which could entail numerous other co-benefits…Phasing out fossil fuels will also improve air quality (SDG-3) and premature deaths by reducing PM2.5 emissions." [Ch. 6, at 6-126] Energy efficiency and demand reduction efforts similarly have significant co-benefits and support SDGs: "Strategies to increase energy efficiency and energy conservation are, in most instances, mutually reinforcing with strategies to support sustainable development…efficient end use technologies reduce the need for resource extraction." [Ch. 6, at 6-124-125] Notably, rapid mitigation pathways not only avoid the climate impacts from overshoot but also avoid the adverse impacts to land and the subsequent impacts on human rights and biodiversity that large-scale CDR (especially BECCS) require. "End use efficiency strategies also reduce the need for, and therefore SDG tradeoffs associated with, CDR towards the end of the century and avoid temperature overshoot" [Ch. 6, at 6-125].

The converging imperatives of climate mitigation and global justice are mutually reinforcing. Mitigation measures that center justice and equity and protect human rights are more effective in achieving a sustainable transition. Striving for this transformation through durable, safe, and sustainable mitigation approaches is essential to safeguarding human rights and advancing social justice. The IPCC states plainly: "Equality and justice are central dimensions of transitions in the context of sustainable development…Neglecting issues of justice will have implications for the pace, scale and quality of the transition" [Ch. 17, at 17-65]. Moreover, the IPCC recognizes the role that social inclusion plays in advancing a sustainable and equitable transition: "Sustainable development can enhance sectoral integration and social inclusion (robust evidence, high agreement). **Inclusion merits attention because equity within and across countries is critical to transitions that are not simply rapid but also sustainable and just."** [Ch. 17, ES, at 17-3] Mitigation is urgently needed, but it must be implemented in a manner that is fair and equitable, protective of human rights, inclusive, and transparent.

Furthermore, the IPCC points to the current unjust and exploitative system of political economy as the root of the climate crisis, which underscores the necessity of deep systemic change. The WGIII report states that: "Climate change is the result of decades of unsustainable production and consumption patterns (for example energy production and land-use), as well as governance arrangements and political economic institutions that lock in resource-intensive development patterns (*robust evidence, high agreement*)" [Ch. 17, ES at 17-3]. Effectively addressing and mitigating climate change therefore demands transformative societal shifts guided by equity and sustainability. "Reframing development objectives and shifting development pathways towards sustainability can help transform these patterns and practices, allowing space for transitions to transform unsustainable systems." [Ch. 17, ES at 17-3] Half-measures, carbon trading schemes that allow entrenched interests to continue business as usual, and craven delay in the hopes that overshoot can be reversed simply will not work. Comprehensive, fundamental, and systemic changes are required to effect climate justice.

IX. Conclusion

The findings of the IPCC's Working Group III, Mitigation of Climate Change, reiterate what has been known for years: the climate crisis requires urgent, decisive action; that action must prioritize phasing out fossil fuels, deploying renewable energy production, and pursuing energy efficiency and material sufficiency; and transition pathways must center human rights and global justice. The urgency of the moment, and the limits of economic models and political imagination, have led to an increased focus on techniques like BECCS and DACCS that promise the ability to undo the harms of continued business-as-usual. But overshoot is not an ambivalent matter of math and modeling. It is an unacceptable risk and would cause enormous and irreversible damage to human society and natural ecosystems alike. Moreover, as made clear over and over by Working Group III, the techniques of large-scale CDR are largely unproven, costly, and hypothetical. There is no guarantee that a return from overshoot is possible.

Aggressive mitigation action cannot wait. The Working Group II Summary for Policymakers warns: "Any further delay in concerted anticipatory global action…will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all." [WGII, SPM.D.5.3, at SPM-35] Climate action involves both urgency and agency: urgency in that the time is nearly up to take transformative action, and agency in that it is still possible to avert the worst consequences of a warming world if we act now.

The Working Group III report should be read in light of the Working Group I and Working Group II reports and with a full understanding of the underlying models' constraints. The best available science endorses rapid fossil fuel phaseout, cautions against planning for overshoot of 1.5°C on the premise that speculative and unproven technologies can reverse temperature rise later, and emphasizes the need to center social justice in mitigation efforts. Though many techno-fixes appear in pathways provided by Working Group III, they are not supported unreservedly. Working Group III's warnings — that costs may not fall at needed rates, that social and political opposition may hamper deployment, that large-scale deployment may come with profound adverse consequences, and that, ultimately, they may not work — are the mirror to the clear message that phasing out fossil fuels and accelerating renewables, electrification, and efficiency are the pillars of secure and just mitigation pathways.