Can extreme Arctic climate change be avoided with cost effective mitigation?

THE ISSUE. Because the Arctic is warming much faster than the global average, Arctic nations have a special interest to understand climate responses to reductions in greenhouse gas (GHG) emissions and to assess whether immediate investment in aggressive mitigation (actions to limit the magnitude or rate of harmful change) makes good economic sense.

WHY IT MATTERS. Climate warming threatens a wide variety of environmental harm on a global scale, with notable high rates of change in the Arctic. But can reduced GHG emissions stabilize the climate to forestall worsening impacts and, if so, how can society best evaluate the true social costs of additional emissions to promote reduction? Decision makers and the public need to understand how mitigation efforts might still reduce the threats of global warming so they can make rational choices with emerging tools to determine the relative cost–benefit of policy and regulatory options.

STATE OF KNOWLEDGE. May 2017 marked the first time that the monthly global concentration of carbon dioxide (\(\text{CO}_2\)) in the atmosphere reached 400 parts per million (ppm), dramatically up from a preindustrial level of about 284 ppm. By May 2020, the global concentration trend exceeded 417 ppm, despite a sudden decline in GHG emissions following the global COVID-19 economic downturn. If unchecked, carbon emissions are still on track to reach 750 ppm or higher by 2100. Scientists concluded years ago that the planet can no longer evade significant warming during this century, primarily because of GHG retention and heat already mixed into ocean depths. But if global GHG emissions were quickly and dramatically reduced, then many dangerous outcomes—such as cryosphere loss, sea level rise, and severe weather events—could still be partially avoided.

A popular international modeling scenario that stabilizes the global GHG budget by 2100 (with ~60 percent emission reduction from peak in 2040) is known as “representative concentration pathway 4.5.” It aims to limit the increase of radiant energy due to GHGs to 4.5 watts per meter squared (relative to preindustrial levels, consistent with ~630 ppm \(\text{CO}_2\)). This moderate policy scenario would be relatively inexpensive but implies that nations must undertake mitigation simultaneously, implementing a phased and standardized emissions pricing structure that increases over time.

Recent Arctic climate model projections indicate that GHG emission mitigation could slow temperature changes by the second half of this century. Relative to the 1981–2005 baseline, results from a collection of general circulation models show an Arctic end-of-century mean temperature increase of 12.6°F in late autumn. By contrast, with no mitigation, Arctic mean temperature projections increase by 23.4°F. Either way leads to transformative disruption of Arctic ecosystems and economies, with new projections of an Arctic mean increase of 6 to 18°F in late autumn by 2100, depending on future emissions.

Though integrated modeling efforts continually improve, they all consistently build a strong case that opportunities for mitigation are highly time sensitive. Prompt implementation could still make a significant difference in future climate outcomes. Given the magnitude of disruption projected beyond mid-century, mitigation policies based on science will seek to avoid extreme climate change and the ruinous scenarios likely to follow from uncontrolled emissions.

WHERE THE RESEARCH IS HEADED. Now that science has identified a potential path of climate stabilization, the information can be coupled with socioeconomic factors to address specific cost–benefit trade-offs that may guide ongoing decisions about how much society should invest in a broad menu of carbon reduction efforts. Robust modeling offers the best hope to achieve predictive skill in estimating not only the degree to which destructive climate change impacts might yet be mitigated under future scenarios but also the means for better estimating
the true social costs of GHG emissions. Although many aspects of emerging social cost estimates remain controversial, they all recognize common direction: GHG emissions cause substantial economic harm but also allow for economic growth and prosperity, so we must develop a sophisticated process that most accurately represents future cost–benefit into present monetary values. This approach yields a dollar estimate of net damages society incurs from each metric ton increase in GHG emissions, although different approaches yield highly divergent estimates, ranging from $9 to $266 per ton. Social cost tools may help identify specific policies that deserve priority, such as stringent but feasible reductions in potent climate forcers (like black carbon, methane, nitrous oxides). Such tools may also stimulate new approaches to GHG sequestration or geoengineering efforts or further incentivize growth of renewable energy sources. Increasingly sophisticated tools may also reduce persistent public skepticism about how climate and economic benefits of reduced GHG emissions are calculated.

A central concern often arises whether the social cost of carbon calculation is capable of providing fair and complete monetary values. Discounting based on the time value of money may be appropriate for private financial decisions within a single lifetime, but the same logic does not easily apply to intergenerational decisions about public goods over an international scale. In that complicated context, the estimated costs of mitigating actions are prone to exaggeration and the estimated costs of climate inaction are prone to understatement. Whether one accepts a low or high social cost of carbon, economic studies consistently demonstrate that pursuing mitigation strategies now—such as pricing GHG emissions, promoting carbon capture technologies, and redesigning infrastructure—proves far less costly than paying perpetually for compounding damages that result from inaction. Moving forward, as modeling revisions continually reduce uncertainty, an updated social cost approach shows merit and properly frames a constructive path to advance further necessary systemic and behavioral changes.

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**Key references**

1. AMAP. 2021. Arctic climate change update 2021: Key trends and impacts. Summary for policy-makers, 16. Tromsø, Norway: Arctic Monitoring and Assessment Programme (AMAP).
2. Johnson, L., and C. Hope. 2012. The social cost of carbon in U.S. regulatory impact analyses: An introduction and critique. Journal of Environmental Studies and Sciences 2 (3):205–21. doi:10.1007/s13412-012-0087-7.
3. (NAS) National Academy of Sciences, Engineering and Medicine. 2017. Valuing climate damages: Updating estimation of the social cost of carbon dioxide. Washington, DC: The National Academies Press. doi:10.17226/24651.
4. Overland, J., W. Muyin, J. Walsh, and J. C. Stroeve. 2013. Future Arctic climate changes: Adaptation and mitigation timescales. Earth’s Future 2. doi:10.1002/2013EF000162.
5. Stocker, T. F., D. Qin, G. K. Plattner, et al. 2013. IPCC, 2013: Summary for policymakers. In Climate change 2013: The physical basis. New York, NY: Cambridge Univ. Press. doi:10.1007/978107415324.004.
6. Washington, W. M., R. Knutti, G. A. Meehl, H. Teng, C. Tebaldi, D. Lawrence, L. Buja, and W. G. Strand 2009. How much climate change can be avoided by mitigation? Geophysical Research Letters 36 (8):108703. doi:10.1029/2008GL037074.

**Supplementary material**

Supplemental material for this article can be accessed on the publisher’s website

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