ARCTIC SEA ICE

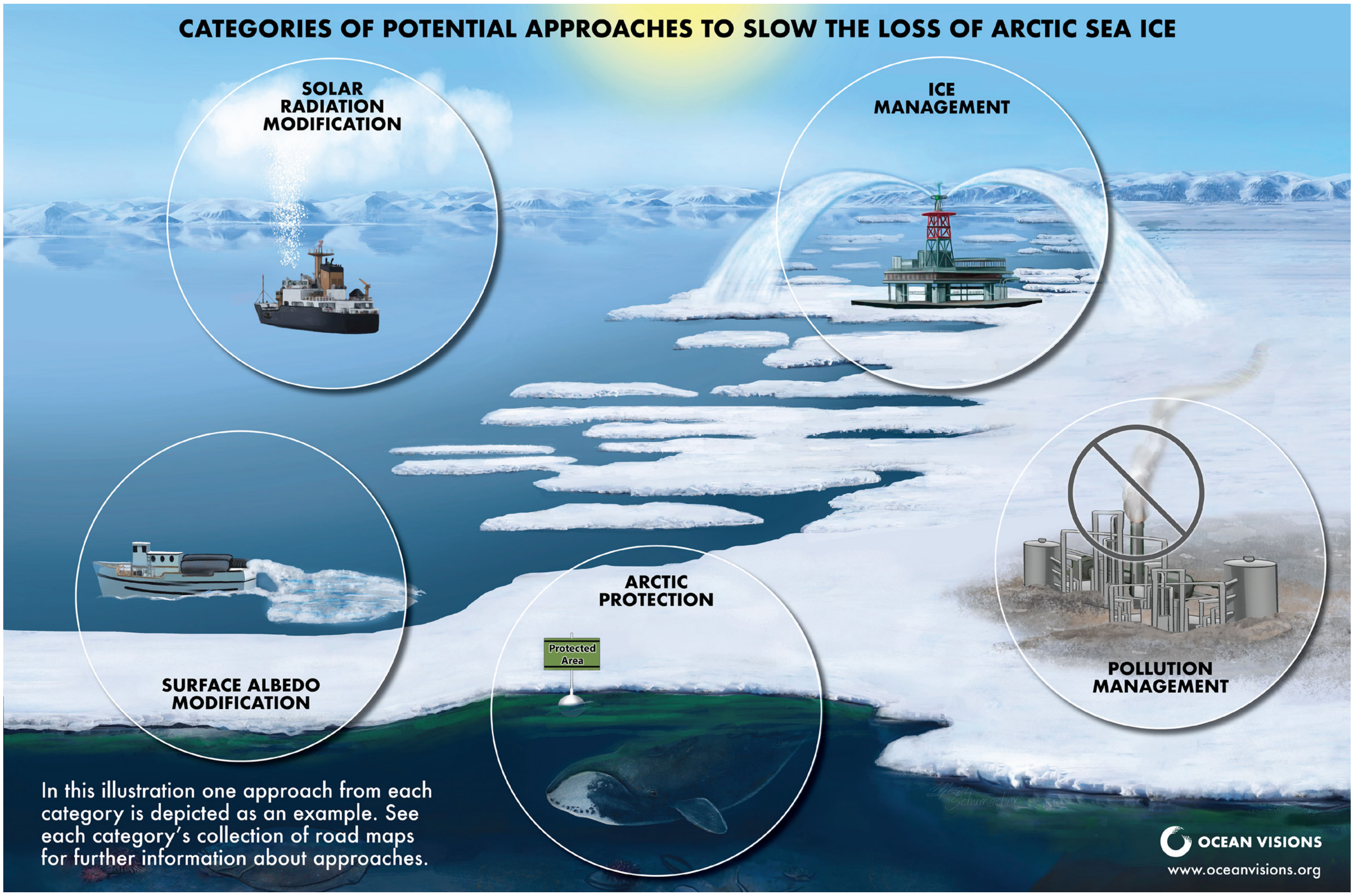
This assessment of approaches to slow Arctic Sea ice loss identifies potential mitigation strategies and highlights the need for increased collaborative and careful research.

The loss of Arctic summer sea ice is one of the most visible and alarming indicators of climate change. As global temperatures rise due to increasing greenhouse gas concentrations in our atmosphere, the Arctic region has been warming three to four times faster than the global average, accompanied by a significant loss of summer sea ice, which results in more heat being trapped in the Arctic Ocean rather than reflecting back into space. This accelerated warming is causing profound impacts to the Arctic, its ecosystems and people, the ocean, and the global climate system. At current rates of loss, summer sea ice is expected to disappear as early as 2035.

The UN General Assembly recently adopted a resolution proclaiming 2025-2034 as the Decade of Action for Cryospheric Sciences. Some scientists and engineers have started to research approaches to try to slow down sea ice loss, and more effort and investment is needed.

Ocean Visions—in partnership with an international, multidisciplinary team of experts spanning climate and earth science, governance, and Arctic issues—has synthesized the best available science and assessed potential approaches to slow or reverse Arctic sea ice loss across categories such as potential impact, scalability, cost, technology readiness, socio-ecological co-benefits and risks, and governance considerations. Each of those categories contains further assessment parameters, offering a deep dive into each approach. The road map also identifies existing knowledge gaps and identifies first-order priorities needed to advance understanding of each approach.

The map reviews 21 different approaches in five main categories: **Arctic Protection; Pollution Management; Ice Management; Surface Albedo Modification; and Solar Radiation Modification**. Within each category, some approaches would be applied directly in the Arctic region, while others would be applied at a global scale.



EXAMPLES OF POTENTIAL ARCTIC-SPECIFIC APPROACHES

CATEGORY → ARCTIC PROTECTION

- **Area-based protections in the Arctic**, where the Arctic marine environment would be protected through restrictions of human activities, especially commercial activities. While the ecological benefits of marine protected areas are well-established, the climate benefits are uncertain, and the ability of protected areas to slow the loss of Arctic sea ice is unknown and requires further research.

CATEGORY → POLLUTION MANAGEMENT

- **Black carbon emissions reductions from wildland fire management**, where fire management practices are prioritized to reduce black carbon pollution. Wildland fires are an increasingly significant source of black carbon emissions in the Arctic, but the impact of reducing these emissions on sea ice and Arctic temperatures is unknown. Increased monitoring of black carbon emissions and understanding of how fire management techniques may reduce climate impacts are needed.

CATEGORY → ICE MANAGEMENT

- **Ice thickening**, where Arctic sea ice is enhanced by pumping water onto the sea ice surface to thicken the ice. Modeling studies estimate that this approach could decrease temperatures in the Arctic and maintain summer sea ice for up to 60 years. Ice thickening has potential to reach demonstration scale in the next 10 years. Rapid investment in careful research and development to assess potential impacts on sea-ice associated species and ecosystems, as well as for changes in surface salinity, temperature, and biogeochemical fluxes, and to advance technological readiness is needed.

CATEGORY → SOLAR RADIATION MODIFICATION

- **Mixed-phase cloud thinning**, where low- to mid-altitude clouds in the Arctic would be seeded with particles to stimulate ice production and diminish the heat-trapping capacity of the clouds during winter. Models suggest this approach could decrease temperatures in the Arctic and increase the area and thickness of existing sea ice. This approach has a likely high ease of reversibility, but there are knowledge gaps around how the process might change regional precipitation patterns. This approach requires further research and development to understand its potential.

CATEGORY → SURFACE ALBEDO MODIFICATION

- **Hollow glass microspheres**, where small silicon dioxide particles would be spread across the ice surface. Studies estimate this approach could decrease temperatures in the Arctic, increase sea ice thickness and concentration, and decrease melt; however, these findings are dependent on the specific attributes of the microspheres, which are still being studied. This approach needs further research around unknown impacts on marine ecosystems, food webs, and human diets, as well as technological readiness.

EXAMPLES OF POTENTIAL GLOBAL APPROACHES

CATEGORY → POLLUTION MANAGEMENT

- **Methane emissions reductions**, where targeted mitigations, such as reducing leaks and venting in the oil and gas sector, aim to reduce methane emissions and produce short-term cooling. Because methane is well-mixed in the atmosphere, emissions reductions could happen anywhere on the globe and have an effect, leading to temperature decreases both globally and in the Arctic. While many technologies to support methane reductions are well-developed, key gaps remain around mobilizing funding and finance to support action on methane.

CATEGORY → SOLAR RADIATION MODIFICATION

- **Stratospheric aerosol injection**, where small reflective particles are released into the upper atmosphere (stratosphere) to increase the reflection and scattering of incoming sunlight. Modeling studies estimate this approach could lower global temperatures. This is one of the approaches that has received the most attention and study. There are calls from scientists for a robust transdisciplinary scientific review process of this approach by a global body, similar to the Intergovernmental Panel on Climate Change. Governance frameworks that can build off detailed recommendations by experts are also needed.

CATEGORY → SURFACE ALBEDO MODIFICATION

- **Sea foam or films**, where microbubbles or reflective foams would be applied to the seawater surface to increase reflectivity. This approach has been modeled for lower latitude areas with high amounts of solar radiation, as well as in the Arctic. Models suggest this approach could decrease global temperature and increase Arctic sea ice extent. Further research is needed to assess if non-toxic foams or bubbles could be developed and how these foams or bubbles might impact seawater biogeochemistry and phytoplankton.

These examples illustrate the potential of many of the approaches counterbalanced with the high degree of uncertainty for most due to the lack of research to date. The road map includes many more details about all of the 21 approaches, including potential impacts, risks, and co-benefits.

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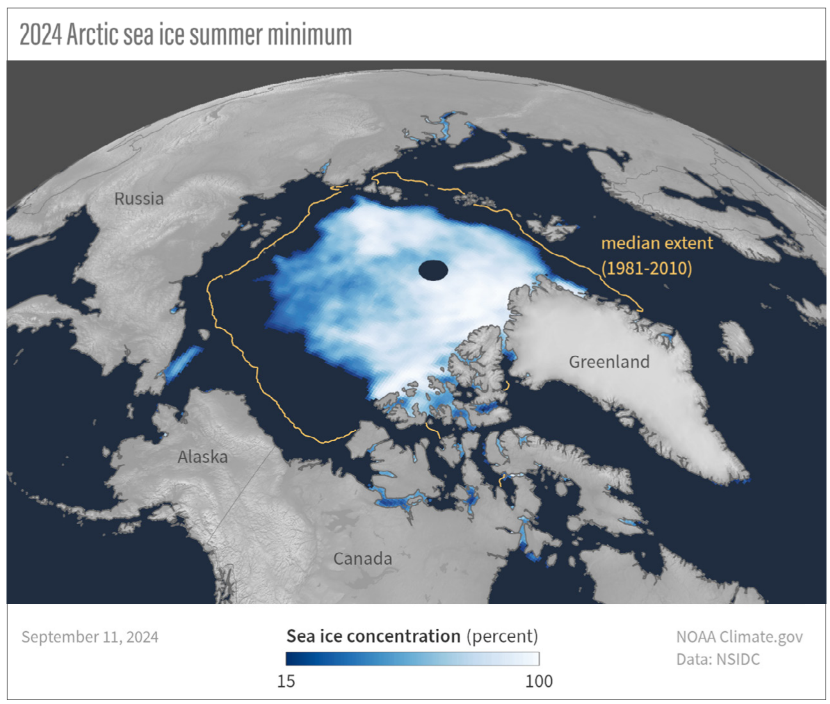

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THE ASSESSMENT FOUND

- At least 15 of the 21 identified approaches could likely move to demonstration projects or beyond in the next ten years, a crucial window for action to save summer sea ice.
- Some of the approaches, such as technologies to rapidly reduce carbon dioxide emissions, are already mature. Others, such as ice thickening, are still very early stage and are prime targets for accelerated research and development.
- Preliminary evidence from modeling studies included in the assessment indicates potential for Arctic-specific and global cooling effects for about half of the approaches. However, these estimates are highly uncertain, and estimates of temperature impacts are non-existent for about half of the pathways.
- Studies of nine of the approaches suggest potential for sea ice to be maintained or restored. For two of the approaches, studies report conflicting results.
- For nine of the approaches the potential impact on sea ice is unknown.
- Carbon dioxide emissions reductions alone are unlikely to stop continued sea ice loss.

A collection of summary tables and figures is available here.

Importantly, across most of the approaches there are substantial knowledge gaps concerning governance and justice that must be front and center in any work to increase understanding and foster inclusive and transparent decision-making.

Ocean Visions' road map highlights the importance of accelerating and scaling up investment into "must-have" actions—including global greenhouse gas emissions reductions, especially methane; carbon dioxide removal; and reducing localized black carbon emissions caused by shipping and wildland fires. At the same time, to manage the risk that these activities may not be enough to slow Arctic sea ice loss, the road map points to a number of additional approaches that merit investment in further research and development to fill knowledge gaps about impacts, risks, and feasibility.

The road map is a living document that will be updated as new knowledge is available and as feedback is received.

Ocean Visions will now focus attention on advancing the first-order priorities identified in the map: mobilizing resources to support work on a subset of those priorities, developing detailed research plans and frameworks, and expanding the community of people and institutions dedicating time and resources to responsible research of different approaches. If you are interested in being involved in any way, please contact kerry@oceanvisions.org.

ABOUT OCEAN VISIONS

Ocean Visions is a non-profit organization that catalyzes innovation at the intersection of the ocean and climate crises. We facilitate multisector collaborations from within our Network and beyond, working with leading research institutions, the private sector, and public-interest organizations to fully explore and advance responsible and effective ocean-based climate solutions. In short, we work to stabilize the climate and restore ocean health. To learn more, visit **www.oceanvisions.org** or follow us on **X** and **LinkedIn**.