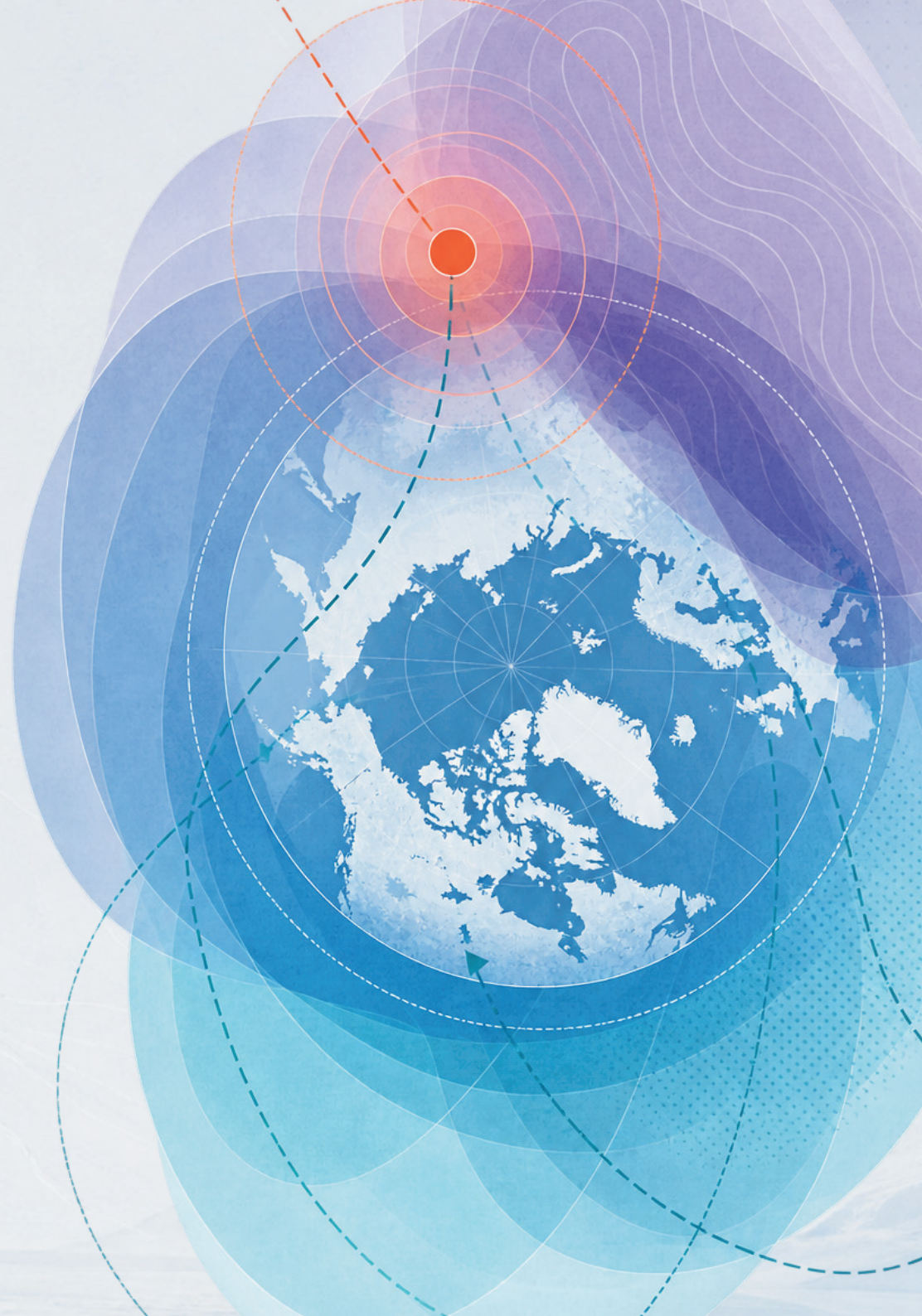


Advisory Parameters for Arctic Climate Intervention Assessments

A framework for assessing climate
interventions in the Arctic

Philip Steinberg & Romain Chuffart



Advisory Parameters for Arctic Climate Intervention Assessments

*A framework for assessing climate
interventions in the Arctic*

© Philip Steinberg & Romain Chuffart, 2026



List of Abbreviations

BBNJ Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction (2023)

CBD Convention on Biological Diversity (1992)

CDR Carbon Dioxide Removal

CO₂ Carbon dioxide

FPIC Free, Prior, and Informed Consent

GHG Greenhouse gas

ICCPR International Covenant on Civil and Political Rights (1966)

IPCC Intergovernmental Panel on Climate Change

MARPOL International Convention for the Prevention of Pollution from Ships (1973, as modified)

PAME Protection of the Arctic Marine Environment (Arctic Council)

SAI Stratospheric Aerosol Injection

SDWG Sustainable Development Working Group (Arctic Council)

SRM Solar Radiation Management (also Solar Radiation Modification)

UDHR Universal Declaration of Human Rights (1948)

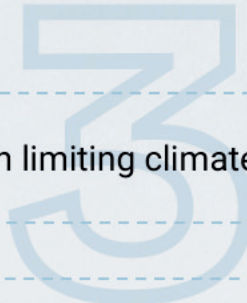
UN United Nations

UNCLOS United Nations Convention on the Law of the Sea (1982)

UNDRIP United Nations Declaration on the Rights of Indigenous Peoples (2007)

Contents

List of Abbreviations	i
Introduction	1
First-order questions	10
1.a What are the bounds of 'climate'?	11
1.b What are the appropriate scales for assessing interventions?	14
1.c What is the appropriate object of governance?	17
1.d At what point(s) in the development and implementation of a climate intervention should assessments be undertaken?	21
Second-order questions	24
2.a How can relevant constituencies be identified and engage in decision-making?	25
2.b How is risk accounted for?	28
2.c What institutions can implement ethical decisions and how?	30
2.d How can funds and mechanisms for remediation be guaranteed?	32



Third-order questions

3.a What is the intervention's effectiveness in limiting climate processes or climate impacts?	35
3.b What are the environmental impacts?	36
3.c What are the societal impacts and risks, and how are justice concerns addressed?	39
3.d Is the intervention economically viable, reversible, and sustainable across its life cycle?	41
3.e What are the consequences of disagreement, manipulation, or failure, and how governable is the intervention?	43

Appendices

45
47





Introduction

Although there is scientific consensus that drastically reducing greenhouse gas (GHG) emissions is the best way to limit unprecedented anthropogenic climate change, such interventions are yet to take place at a speed that matches that of the changing climate. To complement strategies to reduce greenhouse gas emissions, a number of scientists and policy advocates have been raising the possibility of climate intervention initiatives that would limit the degree and impacts of GHG-induced climate change.

Many of these proposed interventions are directed at the Arctic or would have a disproportionate impact on Arctic environments and societies. The Arctic is experiencing the world's fastest rate of climate change. Glacial retreat is having a direct impact on global sea-level rise and ocean circulation patterns. Arctic amplification – the feedback dynamic resulting primarily from the reduced albedo associated with declining snow and ice cover – is multiplying the impacts of climate change, regionally and globally.

For all these reasons, many proposed climate interventions have an Arctic focus, and this requires attention in particular due to the region's division into multiple states, the presence of Indigenous Peoples who are critical to Arctic governance, and the centrality of marine space beyond national jurisdiction.

Much of the scientific work assessing the feasibility of climate intervention initiatives, in the Arctic and elsewhere, has explicitly acknowledged the deep moral, legal, political, and governance questions raised by such interventions. However, there is little clarity on how the limits on climate interventions should be determined or on what mechanisms could be applied to enforce those limits. Existing international legal instruments provide partial and often ambiguous regulatory frameworks, particularly in the Arctic.

Documents on the rights of Indigenous Peoples, including the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and more recent ethical protocols by the Inuit Circumpolar Council and the Saami Council, are rarely integrated into climate intervention governance analyses despite the direct implications that modification of the environment would have for Indigenous Peoples and their territories, cultures, and livelihoods.

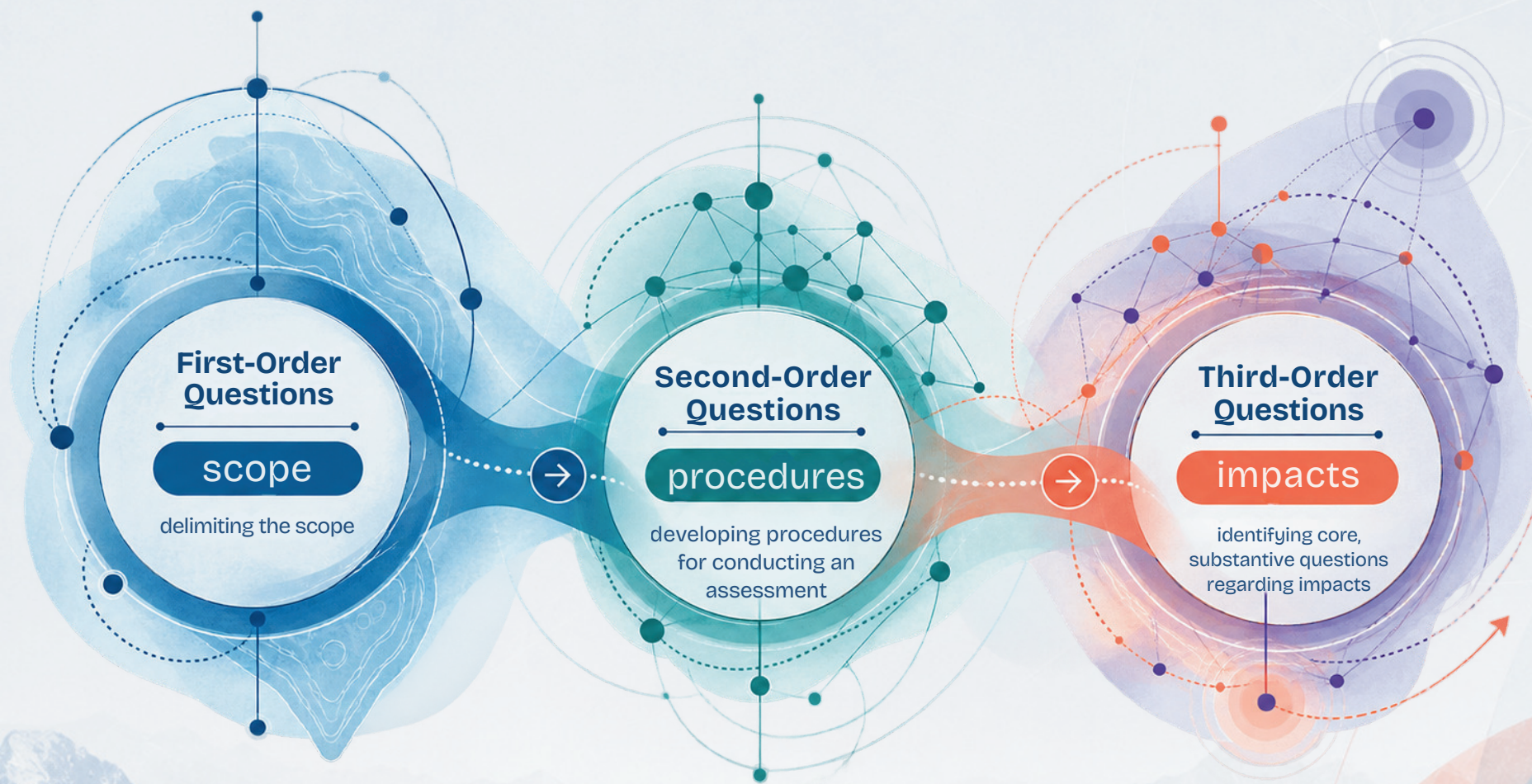
From a human rights perspective, climate intervention raises serious concerns. In 2023, the UN Human Rights Council's Report on the Impact of New Technologies Intended for Climate Protection on the Enjoyment of Human Rights deemed climate interventions potentially incompatible with human rights. Emphasising the precautionary principle, the report urged states to avoid such technologies due to their high risks and uncertainties, particularly for present and future generations, given the availability of safer alternatives (e.g., mitigation measures including, most notably, reducing GHG emissions, as well as adaptation). The report warned that climate interventions could disproportionately harm marginalised groups, especially Indigenous Peoples, whose lands are often targeted for experiments. It called for compliance with UNDRIP, including by obtaining free, prior, and informed consent (FPIC). In short, climate intervention proposals raise a number of ethical and legal concerns, and the design of an instrument for assessing them requires attentiveness to a range of factors.

To set out parameters for designing an assessment, this document revolves around three sets of questions, which should be considered sequentially when developing an assessment framework:

First-Order Questions: These are fundamental questions that delimit the scope of what must be included in an assessment of a proposed Arctic climate intervention.

Second-Order Questions: These are questions that must be addressed in developing procedures for conducting an assessment.

Third-Order Questions: These are core, substantive questions regarding impacts to be asked (and developed with further specificity) within an assessment.



Scope and Limits of This Document

The advisory parameters outlined in this document are not intended to constitute a normative toolkit (or instrument) for conducting an assessment. Rather, they have been produced to serve as a bridge between previous initiatives that have sought to evaluate the potential benefits and harms of climate interventions, in the Arctic and elsewhere (see *Appendix 1*), and the design and implementation of practicable assessment tools. The parameters thus indicate guiding, policy-relevant considerations that can inform efforts to develop such assessment instruments that can be applied, on a case-by-case basis, to proposed interventions.

These parameters have not been developed for any one specific user. Rather, given the increasing interest in Arctic climate interventions in policy and public circles and the recognition that assessment tools at some point will be required, this document seeks to advance the development of assessment tools, to complement the advance of underpinning infrastructure and the political will to regulate climate interventions.

To produce this document, the co-authors reviewed the existing literature, including the reports of previous climate impact assessment projects (*Appendix 1*). Following this, a group of experts from a wide variety of fields and institutions were brought together for a two-day workshop in Tromsø, Norway, held in February 2026 and funded by a grant from the UK Arctic Office (*Appendix 2*). Although this document has been informed by dialogue at the workshop, it was drafted subsequently by the project convenors and should not be considered a workshop report. Drafts were then reviewed by workshop participants as well as an external expert who was not in attendance.

Indigenous Peoples and Climate Interventions

The incorporation of Indigenous Peoples into the design and implementation of in situ climate intervention research projects has proved challenging, in the Arctic and beyond. Most notably, the Harvard University SCoPEX stratospheric aerosol injection initiative, which was abandoned mid-project due to protests over the lack of consultation with Indigenous Peoples proximate to the launch site in Swedish Sapmi.* The Arctic Ice Project, which sought to inhibit sea ice degradation by distributing silica beads on the sea ice surface, similarly was forced to shut down its Alaska-based operations due to local protests over consultation procedures as well as feared environmental impacts.** While other climate intervention projects in Indigenous homelands, such as the Real Ice project in the Canadian Arctic and the marine cloud brightening component of the Reef Restoration and Adaptation Project on Australia's Great Barrier Reef, have put greater effort into consultation and engagement with Indigenous Peoples, controversies remain.*** The challenges of not just obtaining prior and informed consent from Indigenous Peoples but fostering their engagement in defining climate problems and designing climate solutions would only increase if initiatives were to advance beyond the research stage.

*Oksanen, A.-A. (2023). *Dimming the midnight sun? Implications of the Sámi Council's intervention against the SCoPEX project*. *Frontiers in Climate* 5 (doi.org/10.3389/fclim.2023.994193).

** Gannon, M. (2022). A 'reckless' Arctic geoengineering project draws local criticism. *The Nome Nugget*, 9 June.

*** Busch, F., Krupa, J., Harding, A. (2025). *An indigenous perspective on climate engineering*. *Energy Research & Social Science* 125 (doi.org/10.1016/j.erss.2025.104117).

Defining 'Climate Interventions'

We define a 'climate intervention' as an action or set of actions consciously undertaken by humans with the intent of impacting global climate processes, forcings, or outcomes.

We prefer the term 'climate interventions' to others that are in use, including 'geoengineering', 'climate repair', or 'new technologies intended for climate protection'. The term 'geoengineering', in addition to placing undue emphasis on engineering solutions, also potentially includes a range of activities that are not explicitly directed at climate modification. 'Climate repair' implies a single action to get the climate 'back to normal'. In fact, interventions may need to be sustained beyond a single act of 'repair', and it is not always clear that returning 'back to normal' can or should be the goal. 'New technologies intended for climate protection' generally captures the scope and intent of what we are calling 'climate interventions'. However, as the United Nations Human Rights Council has noted, 'Attributing at this stage a "protective" function to speculative technologies may be misleading as it presupposes evidence-based knowledge that they are beneficial or desirable. It may give a false impression that there is scientific certainty about the efficacy of these technologies, which is not currently the case'.^{*}

^{*} *United Nations Human Rights Council (2023). Report on the Impact of New Technologies Intended for Climate Protection on the Enjoyment of Human Rights (A/HRC/54/47), para. 3.*

The infographic is divided into two main circular sections that overlap over a central image of the Earth's Arctic region.

CDR (Carbon Dioxide Removal)
 Carbon Dioxide Removal
 seeks to remove carbon from the atmosphere

The CDR section features a blue-toned illustration of an industrial facility on an ice floe in the Arctic. Arrows show CO₂ molecules being captured from the atmosphere and transported to the ocean floor for storage. Several CO₂ labels are present throughout the process.

SRM (Solar Radiation Management)
 Solar Radiation Management
 seeks to increase the reflectivity of the Earth-atmosphere system and thereby limit global warming

The SRM section features a red-toned illustration of the sun with dashed orange arrows representing solar radiation being reflected away from the Earth's surface by particles in the atmosphere.

Intersection:
 Some Arctic-focused interventions may have effects that cross these categories

This text is located in the purple-shaded area where the CDR and SRM circles overlap, indicating that certain interventions can have combined effects on both carbon removal and solar radiation management.

[illegible]

The infographic is divided into two main circular sections that overlap over a central image of the Earth's Arctic region.

CDR (Carbon Dioxide Removal)
 Carbon Dioxide Removal
 seeks to remove carbon from the atmosphere

The CDR section features a blue-toned illustration of an industrial facility on an ice floe in the Arctic. Arrows show CO₂ molecules being captured from the atmosphere and transported to the ocean floor for storage. Several CO₂ labels are present throughout the process.

SRM (Solar Radiation Management)
 Solar Radiation Management
 seeks to increase the reflectivity of the Earth-atmosphere system and thereby limit global warming

The SRM section features a red-toned illustration of the sun with dashed orange arrows representing solar radiation being reflected away from the Earth's surface by particles in the atmosphere.

Intersection:
 Some Arctic-focused interventions may have effects that cross these categories

This text is located in the purple-shaded area where the CDR and SRM circles overlap, indicating that certain interventions can have combined or cross-cutting effects.

The infographic is divided into two main circular sections. The left section, titled 'CDR Carbon Dioxide Removal', is blue and depicts a coastal industrial facility with arrows showing CO₂ being captured and stored underground. The right section, titled 'SRM Solar Radiation Management', is red and shows a sun with arrows reflecting off particles in the atmosphere. A central purple area contains text about Arctic-focused interventions. The bottom of the infographic features a polar map of the Arctic region.

CDR
Carbon Dioxide Removal

seeks to remove carbon from the atmosphere

SRM
Solar Radiation Management

seeks to increase the reflectivity of the Earth-atmosphere system and thereby limit global warming

Some Arctic-focused interventions may have effects that cross these categories

The infographic is divided into two main circular sections. The left section, titled 'CDR Carbon Dioxide Removal', features a blue color scheme and depicts a factory emitting CO₂ into the atmosphere, with arrows showing the gas being captured and stored underground. The right section, titled 'SRM Solar Radiation Management', features a red color scheme and shows a sun reflecting off particles in the atmosphere, with arrows indicating the reduction of solar radiation reaching the Earth's surface. A central overlapping area contains text about Arctic-focused interventions.

CDR
Carbon Dioxide
Removal

seeks to remove carbon from the atmosphere

SRM
Solar Radiation
Management

seeks to increase the reflectivity of the Earth-atmosphere system and thereby limit global warming

Some Arctic-focused interventions may have effects that cross these categories

The infographic is divided into two main circular sections that overlap over a central image of the Earth's Arctic region.

CDR (Carbon Dioxide Removal)
Carbon Dioxide Removal
 seeks to remove carbon from the atmosphere

The CDR section features a blue-toned illustration of an industrial facility on an ice floe in the Arctic. Arrows show CO₂ molecules being captured from the atmosphere and transported to the ocean for storage. A central text box notes: "Some Arctic-focused interventions may have effects that cross these categories".

SRM (Solar Radiation Management)
Solar Radiation Management
 seeks to increase the reflectivity of the Earth-atmosphere system and thereby limit global warming

The SRM section features a red-toned illustration of the sun with dashed orange arrows representing increased solar reflectivity being directed towards the Earth's surface. The same central text box is also present in this section.

The infographic is divided into two main circular sections that overlap over a central image of the Earth's Arctic region.

CDR (Carbon Dioxide Removal)
Carbon Dioxide Removal
 seeks to remove carbon from the atmosphere

The CDR section features a blue-toned illustration of an industrial facility on an ice floe in the Arctic. Arrows show CO₂ molecules being captured from the atmosphere and transported to the ocean for storage. A central text box notes: "Some Arctic-focused interventions may have effects that cross these categories".

SRM (Solar Radiation Management)
Solar Radiation Management
 seeks to increase the reflectivity of the Earth-atmosphere system and thereby limit global warming

The SRM section features a red-toned illustration of the sun with dashed orange arrows representing increased solar reflectivity being directed towards the Earth's surface. The same central text box is also present in this section.

Climate Intervention Technologies

As the IPCC has emphasised, 'reaching net zero anthropogenic CO₂ emissions is a requirement to stabilize human-induced global temperature increase'.* Therefore, implementation of the climate interventions considered here would necessarily be undertaken in coordination with primary efforts to reduce carbon emissions, which would likely require fundamental changes in societal systems of production and consumption. Source reduction in CO₂ emissions, however, is beyond the scope of this study.

Beyond reduction, there are a large number of potential climate intervention technologies. One 2024 study, focused solely on the Arctic, identifies 61.** Because of the differences in technologies and in their potential applications, any guidelines derived from the parameters identified here would need to be applied on a case-by-case basis.

Climate intervention technologies (other than reduction) are generally divided into two categories: Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM), sometimes known as Solar Radiation Modification.

CDR technologies seek to remove carbon from the atmosphere using a variety of methods ranging from relatively small-scale practices that are already common (e.g. planting trees and other vegetation to increase localised carbon capture) to interventions that are untested but have the potential for more aggressive impacts at the global scale (e.g. ocean fertilisation to increase atmospheric CO₂ uptake).

SRM technologies seek to increase the reflectivity of the Earth-atmosphere system and thereby limit global warming. As the IPCC notes, although these technologies may temporarily 'mask' the impacts of climate change, they do not fundamentally address the root cause of the climate crisis, i.e. increased carbon in the atmosphere.* SRM technologies also range from the well-established (e.g. painting rooftops white to impact microclimates) to ones that are more aspirational (e.g. stratospheric aerosol injection (SAI) to mimic the dimming effects of a volcanic eruption). Many of the climate interventions that have an Arctic focus (e.g. sea ice replenishment, glacier restoration) are primarily associated with SRM.

Because CDR alters the atmospheric concentration of greenhouse gases whereas SRM alters the planet's radiative balance without changing that concentration, CDR is generally understood to address a root cause of warming while SRM offsets its effects. On this basis, some have argued that the two sets of technologies raise fundamentally different issues.*** Nonetheless, when specific technologies are applied to the Arctic to increase albedo (e.g. through sea ice replenishment) they may also have secondary CDR impacts. For all these reasons, although we recognise the significant differences between these two sets of technologies, we adopt a definition of climate intervention that encompasses both objectives.

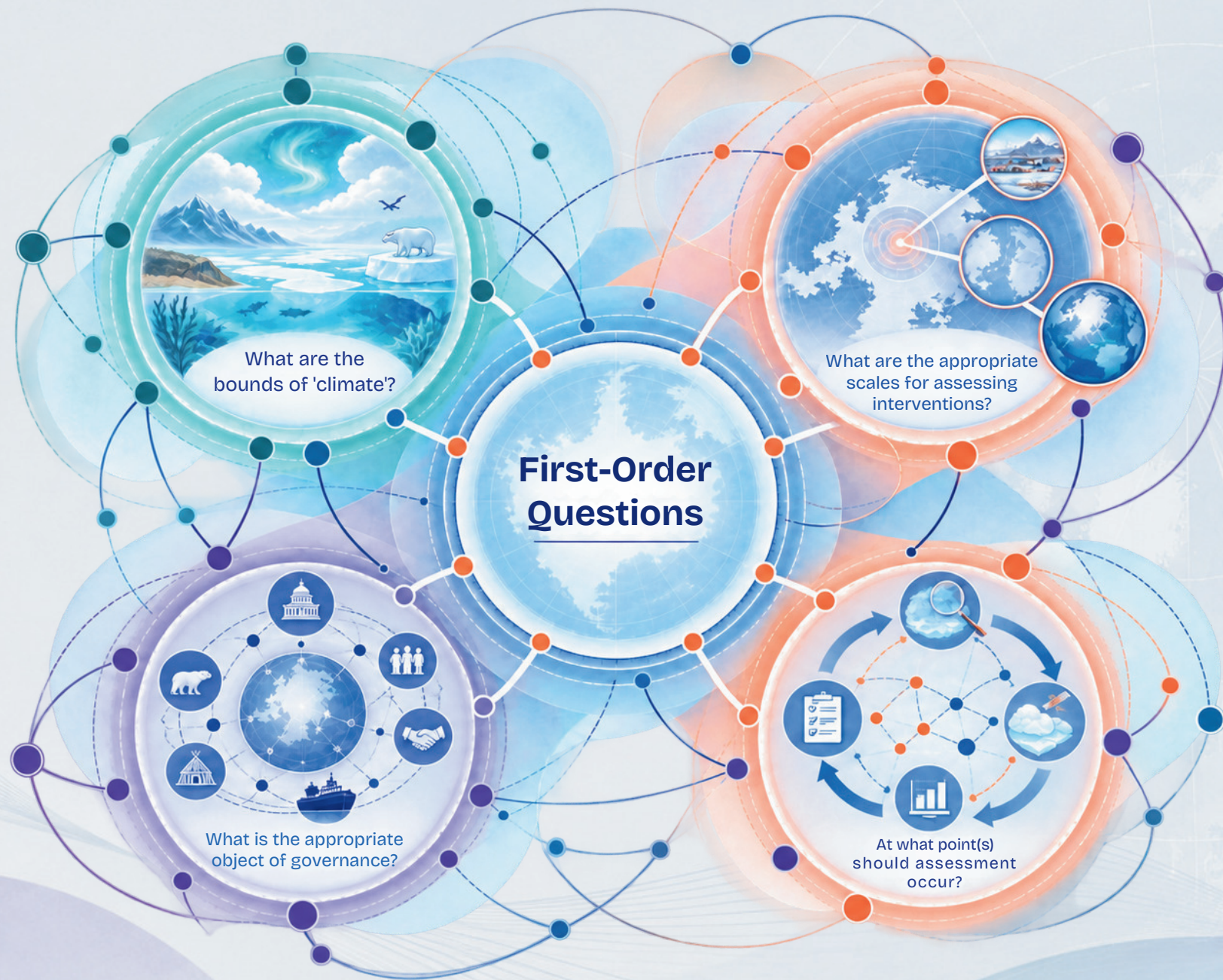
**Intergovernmental Panel on Climate Change (2023). Climate Change 2021: The Physical Science Basis: Working Group 1 Contribution to the Sixth Assessment Report of the IPCC, Summary for Policy Makers (doi.org/10.1017/9781009157896), p. 28.*

*** van Wijngaarden, A., Moore, J.C., Alfthan, B. et al. (2024). A survey of interventions to actively conserve the frozen North. Climatic Change 177, 58 (doi.org/10.1007/s10584-024-03705-6).*

**** Bala, G. (2022). Solar Radiation Modification (SRM): Assessment of SRM in the IPCC AR6 WG1 Report. https://c2g2.net/wp-content/uploads/C2G_IPCC_AR6_WGI_GBala_Slides.pdf*

First-Order Questions

Before asking the policy-relevant questions that form the core of an assessment, one must ask fundamental questions to define the scope of the topic to be assessed. The answers to these first questions set boundaries, defining the limits of what is to be included in the assessment of a proposed Arctic climate intervention.



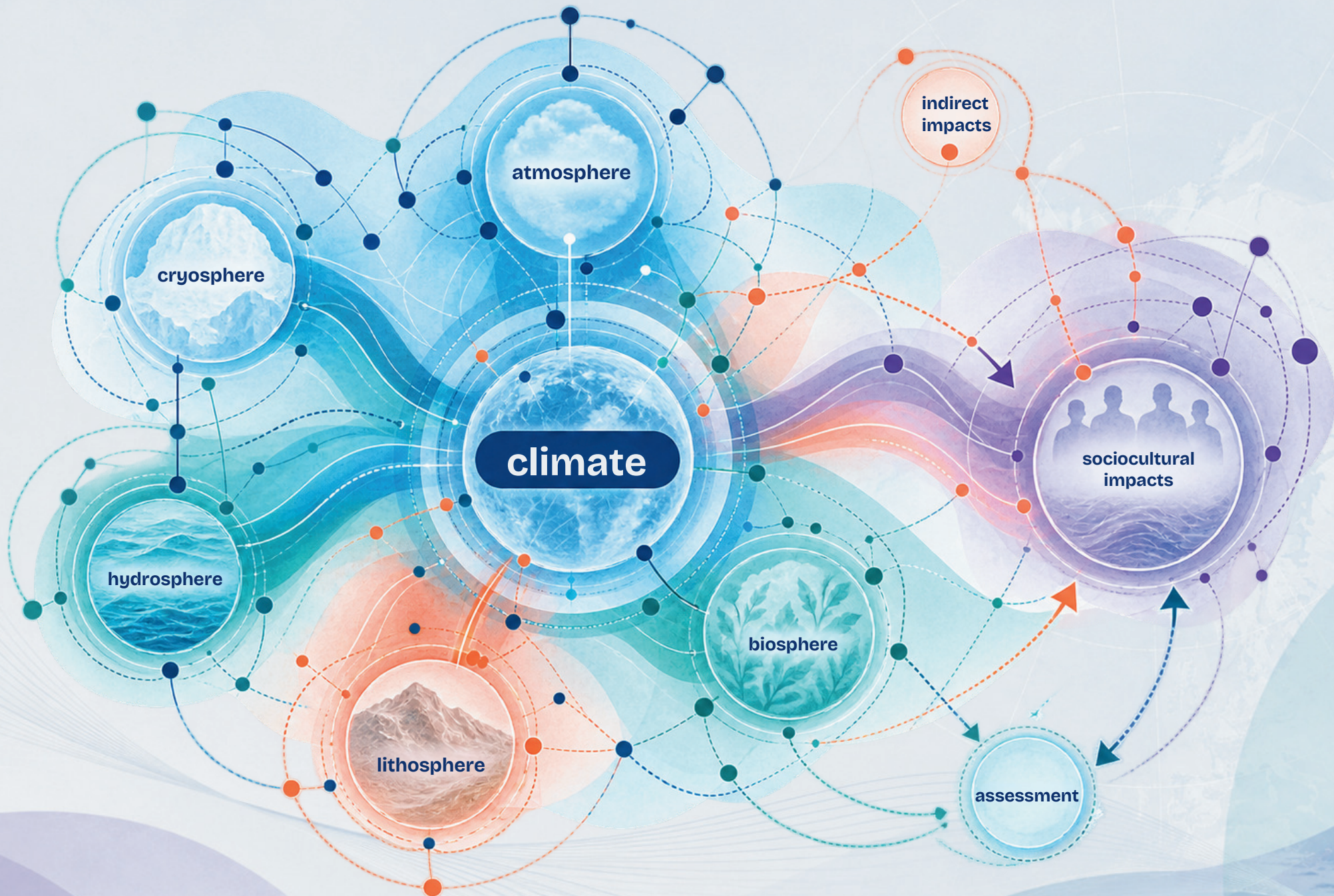
1.a

What are the bounds of 'climate'?

Defining and bounding the intended object of a 'climate intervention' is anything but straightforward, because 'climate' is an inherently capacious category.

Climatologists define climate as the long-term, statistical average of weather patterns for a region over an extended period, typically 30 years, accounting for variables such as temperature, precipitation, and wind speed and direction. Climate is thus experienced in the lower atmosphere. However, changes in the climate, including those from climate interventions, influence processes across the entire geosphere (lithosphere, hydrosphere, cryosphere, and biosphere, as well as atmosphere) and outer space. Potentially, non-climate impacts from climate interventions can be negative (e.g. marine environmental pollution from silica beads deposited on the sea ice to increase albedo) or positive (e.g. habitat restoration). Changes in climate ultimately can lead to sociocultural impacts as well, with transformations ranging from conflict to mass migrations to impacts on public health.

If the climate is ultimately connected to everything else, and if a climate intervention will necessarily have indirect impacts, then it is not immediately clear what, if anything, should be excluded from an evaluation of a proposed climate intervention. Yet an impact assessment must have limits. The challenge, then, is not whether to draw boundaries around the object of assessment, but how to draw boundaries that make the evaluation neither trivially narrow and specific nor unmanageably expansive.



What are the appropriate scales for assessing interventions?

Once the bounds of the 'climate' are defined, further determinations need to be made regarding the spatial, temporal, and technological scales to be considered in an assessment.

Turning first to the spatial, a climate intervention necessarily is, or at least seeks to be, global in scale, because the climate is an Earth system that operates on a planetary scale. Yet many technologies also have local aspects, either in their impacts, or in their sites of intervention, or both. For instance, many SRM technologies, in addition to reducing temperature globally, would have further impacts on precipitation with local variations, which could be considered either beneficial or harmful. Indeed, for some technologies, such as those designed to thicken, preserve, or restore sea ice, the primary impact is local, and it is only through cumulative local impacts that global climate impacts would be achieved. In some instances, local interventions may be undertaken solely for local benefits, with no intended global climate impact, as with efforts to restore local ice conditions valued by humans as well as flora and fauna who depend on sea ice.

Just as the scale of impact is varied, so is the scale of implementation. Some interventions, like sea ice thickening, necessarily are implemented at specific locales, though to produce a global effect such interventions must be massively upscaled across many locales, which is itself a feasibility and cost constraint. By contrast, others, such as space mirrors, which would be placed into orbit, are explicitly extra-local in their implementation, even though these technologies, too, would have local effects both because they would need to be launched from specific sites and because even orbital systems can be deliberately local in their targeting.

Any assessment tool must therefore be flexible enough to work across a number of spatial scales and be sensitive to the possibilities for the intervention's impact or its implementation to have local (or regional) components.

Incorporation of scales other than the global is essential, in particular to ensure the agency of peoples whose livelihoods and environments are specifically intertwined with the proposed intervention.

This, in turn, has bearing for the many climate intervention technologies that have particular relevance to the Arctic region, such as sea-ice thickening, where the Arctic regionalisation is direct, and, to a lesser extent, solar-radiation techniques, whose Arctic relevance lies chiefly in the geography of launch sites. Acknowledging the multiplicity of relevant scales – including the local and regional, as well as the global – that are relevant to a specific intervention is crucial, not just so that impacts can be modelled but also so that the range of relevant stakeholders and rightsholders can be identified.

Temporal scale must also be considered under an assessment of scope. Some interventions, such as space mirrors, are physically long-lived once deployed, though even these would demand ongoing maintenance, as well as monitoring to limit collision risks and ozone effects. Other technologies, such as stratospheric aerosol injection or pumping sea water to thicken sea ice, would require continual reapplication so as to avoid a termination shock during which the benefits of the intervention would be abruptly reversed.

Finally, proposed interventions are often distinguished by their apparent degree of naturalness, as 'nature-based' solutions like tree planting, accelerated weathering, and some forms of ocean fertilisation are contrasted with technologies, such as stratospheric aerosol injection or the placing of silica beads on the sea ice, which insert elements and objects that are commonly described as 'foreign' to the environment being impacted. This distinction, however, is problematic. Measures like monoculture afforestation or the introduction of crushed rock from elsewhere on the planet in large quantities cannot simply be characterised as enhancing local nature.

Conversely, stratospheric aerosol injection mimics the aerosol loading produced by volcanic eruptions, and sulphur is already present in the stratosphere, so these measures are not categorically introducing 'foreign' elements. The relevant basis for differentiating precautionary standards thus should be based not on the perceived 'naturalness' or 'foreignness' of an intervention but the extent of its impact together with its controllability and reversibility. Perceived foreignness therefore may serve as an approximate heuristic for severity, but it is not a reliable proxy for harm, and standards calibrated to it would misclassify familiar-seeming interventions with severe, irreversible effects as low-risk.

What is the appropriate object of governance?

In designing a system for evaluating (and, ultimately, regulating) Arctic climate interventions, one must make difficult decisions about the primary object to be governed.

In the design of any regulatory instrument, a fundamental choice needs to be made regarding whether the focus should be on a space, a technology, a process, a substance, an actor, or an outcome. However, this need not be an exclusive choice. For a given technology one might regulate the substance, the permitted deployment levels, the actors (e.g., by restricting private deployment), and the monitored outcome at once. The objects set out below are therefore best read as a non-exhaustive starting list rather than mutually exclusive alternatives. Given the breadth of technologies and processes involved in climate intervention, it would seem that the unifying element is a focus on the outcome (namely, the intended outcome of reversing or at least limiting climate warming).

However, an exclusive focus on outcomes provides little guidance for the actual design and implementation of a regulatory strategy. A focus on space as the object of regulation is problematic because, as noted above, a single climate intervention often crosses spatial scales. Therefore, it is not clear what the space of a climate intervention is, and in many cases its spaces would be multiple. Additionally, to the extent that the space of climate intervention is the space of the climate, this is a global space with few formal governance institutions, which would challenge regulation. In short, even as attentiveness to space (and spatial scale) is crucial so as to ensure that local-level parties are not forgotten, a focus on space as an object of regulation is unlikely to account for the geographic complexities of a proposed climate intervention.

Alternatively, a more suitable focus of regulation could be the technologies, processes (i.e. applications of technology), and substances of climate intervention. However, specific technologies involve distinct substances, operate in different environmental media, and carry incommensurable risk profiles, which, again, suggests that the development of a single assessment tool is not possible.

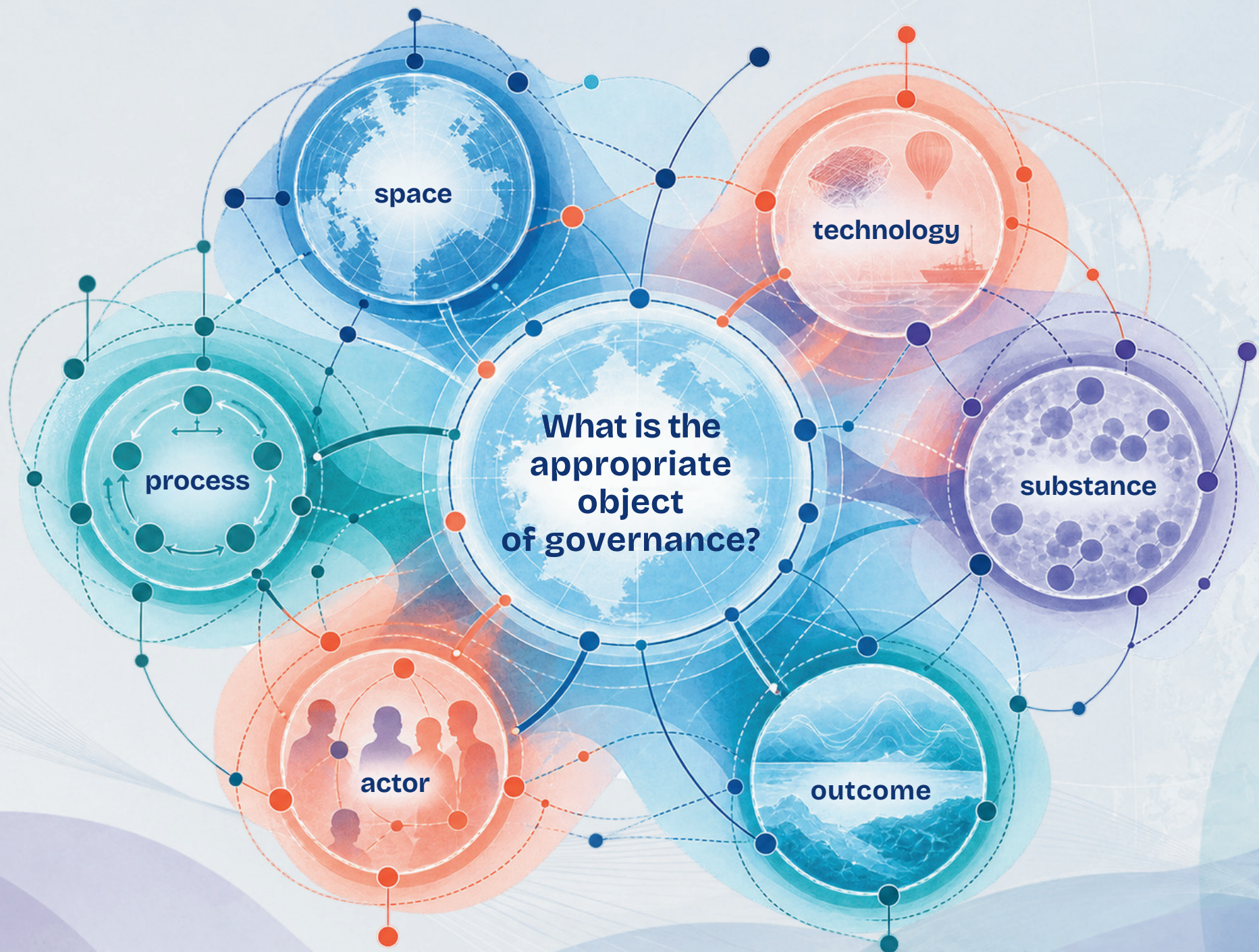
Some substances may already fall within the scope of existing regulatory instruments (e.g., marine pollution), while others are sufficiently novel that no existing category captures them. Thus, although a technology-by-technology approach is necessary, it risks fragmenting the governance landscape into a series of siloed regimes, each tailored to a particular intervention but lacking the coherence needed to address the cumulative or interactive effects of multiple interventions deployed simultaneously or in sequence. Moreover, a regulatory architecture organised around specific technologies will struggle to accommodate interventions that have not yet been developed or proposed, precisely because it lacks a unifying principle beyond the technologies themselves.

Finally, regulation could be directed at the institutions or actors that undertake climate interventions. It is here that the question of intent becomes salient, since the definition of a climate intervention adopted in this document is intent-based (i.e., an action consciously undertaken with the aim of affecting climate processes), and an actor-directed regime would have to determine intent in order to establish which activities fall within its scope.

This is difficult, however, because of how the complex network of different actors intersects with the complexity of scales. For instance, if a state or private actor were proposing the release of silica beads over sea ice in territorial seas this would be regulated by state environmental law and, in recognition that the microspheres would move beyond state boundaries, international treaties that the state had ratified (e.g. the United Nations Convention on the Law of the Sea or the International Convention for the Prevention of Pollution from Ships). However, the situation would be different if the release were to occur in international waters or, for a different technology, the atmosphere itself.

The intersection of scale and how one identifies stakeholders or rightsholders becomes further complicated when the intervention has a fundamentally local component. For instance, if Indigenous Peoples propose implementing a localised sea-ice thickening project primarily for local benefit, but with the secondary benefit of contributing to the global goal of increasing albedo (and, consequently, reducing climate change), it is not clear what (if any) oversight is appropriate at the global scale, or, if so, how it should be exercised.

In short, amidst the scalar and geographic complexity of climate interventions and, the diversity of institutions involved, the variability in who can claim to be an interested party, and the different perspectives in defining the primary goal of a climate intervention, no single approach can encompass the breadth of climate intervention technologies.



At what point(s) in the development and implementation of a climate intervention should assessments be undertaken?

Although a climate intervention is most likely to attract public attention at the point of implementation, in most cases implementation occurs within a much longer timeline, presenting a multitude of points for assessment.

Different interventions have different trajectories, and the list on the next page is not a model trajectory or an ordered sequence. It is a non-exhaustive inventory of the kinds of activity that an intervention may pass through, not strictly in the specific phased order outlined. In practice, research feeds into selection as much as it follows from it, the boundary between underlying science and intentionally directed technology development is blurred, and assessment and engagement are not a single stage but run throughout the process. The point of setting them out is only to show that there are many potential candidate moments at which assessment could be triggered.

Engagement with Indigenous Peoples and other Arctic residents should be mainstreamed across all these activities rather than inserted after the science is settled. Not only is early engagement with Indigenous Peoples ethically and legally apt, it is also scientifically sound as it facilitates incorporation of Indigenous Peoples' knowledge and politically astute as it diminishes the chance for wasting the scientific and policy effort if resistance were to emerge later in the process.

Model of Activities within a Climate Intervention

- Needs determination and strategic policy creation (e.g. a decision could be made that in order to limit climate change a way should be found to increase albedo)
- Conceptualisation or selection of climate intervention technology for achieving policy aims
- Underpinning research (e.g. computational and laboratory modelling, desk-based research, theoretical research, equipment design and engineering, and outdoor observational, physical, and chemical studies that inform understanding without constituting even a small-scale test of the proposed approach, such as field measurement of the conditions under which clouds form, dissipate, and affect the sea-ice surface, which often contribute to existing scientific fields in their own right)
- Feasibility testing (e.g. through field-based pilot studies)
- Planning and licensing
- Implementation
- Maintenance
- Technological evolution

Typically, assessment would begin with predictive impact assessment at the planning and licensing stage. Arguably, however, assessment should begin earlier if the goal is to have not just the form of intervention, but its very conceptualisation, reflect the desires of relevant communities (in this context, Indigenous Peoples as well as other Arctic inhabitants), some of whom might have insights and concerns that are excluded from the scientific perspective that typically guides earlier stages. On the other hand, the incorporation of input from outside the scientific community, even well before the point at which research would have real-world impact, must be counter-balanced by the universal right to the benefits of scientific advancement that is recognised in the Universal Declaration of Human Rights.

Furthermore, as intervention design and implementation proceed through these stages, the process is often non-linear, the stakeholders and rightsholders may change, and the scale may change as well. This suggests that engagement needs to occur at multiple stages, and that it may require different forms at the various stages.

Second-Order Questions

These are questions that must be addressed in developing procedures for conducting an assessment. Whereas the first-order questions that were considered above establish the conceptual boundaries of what is to be evaluated – the scope of climate; the spatial, temporal, and technological parameters of intervention; and the distinct considerations raised by the Arctic context – those definitional choices directly shape the procedural architecture that follows. How one answers first-order questions concerning the object of governance guides which constituencies are relevant, which risks are cognisable, which institutions bear responsibility for designing and implementing standards, and where liability can be located. The second-order questions considered below therefore should be understood not as freestanding procedural concerns, but as operational corollaries of the framing decisions taken at the first order.



2.a

How can relevant constituencies be identified and engage in decision-making?

Any assessment framework for Arctic climate interventions must establish procedures for meaningful engagement.

Engagement goes beyond the minimum threshold of Free, Prior, and Informed Consent (FPIC) as articulated in UNDRIP, and reinforced by the UN Human Rights Council Advisory Committee's 2023 Report in Relation to Climate Interventions. For Indigenous Peoples, FPIC provides an essential means for exercising their rights to self-determination. However, FPIC remains largely a reactive mechanism (i.e., one that presupposes that the scope of the intervention has already been defined, and that consulted communities are asked only to accept or reject a pre-formed proposal). This limits the breadth of decisions and the agency of the consulted communities.

Following from an understanding of the research process as an ongoing series of sites for consultation and intervention (see the first-order question on conceptualising research as iterative).

A more demanding procedural standard would involve relevant constituencies in the prior stages of problem definition, research design and the articulation of what counts as an acceptable intervention in the first place. This may entail genuine and meaningful engagement with different knowledge systems, different engagement protocols, and different value systems. At the same time, the question of whom to engage must itself be treated as open. Engagement procedures need to account for power imbalances between Indigenous communities and other communities. They also need to account for the relations with and between identifiable constituencies/ communities including future

generations and non-humans who cannot actively participate in and whose interests often are excluded from conventional consent mechanisms.

The challenge of engagement is compounded by tensions between a focus on engagement as a process (i.e. procedural justice) and the pursuit of substantive ethical ends. A process that is formally broad and inclusive may still produce an outcome that is ethically contestable, and conversely, an ethically defensible outcome may result from a flawed process. Furthermore, restricting research may itself have justice implications. As noted previously, any engagement framework must also reckon with the countervailing claim of the right to science and to benefit from scientific progress as well as with challenges resulting from the non-linear relationship between conceptualisation, modelling, in situ pilot testing, and implementation. These tensions demand context-specific protocols for particular technologies, locations, and constituencies/communities, while remaining anchored in the overarching principle that those most directly affected by an intervention must have substantive, as opposed to only formal, authority over whether and how it proceeds.

2.b

How is risk accounted for?

Any assessment framework for Arctic climate interventions must establish procedures for identifying, defining, measuring, and valuing risk.

The precautionary principle in the 1992 Convention on Biological Diversity's Conference of the Parties' 2012 Decision on Climate-Related Geoengineering and affirmed by the UN Human Rights Council Advisory Committee's Report in Relation to Climate Interventions provides some normative orientation. However, it does not resolve the practical difficulty of evaluating interventions whose impacts are characterised by uncertainty, nonlinear feedback dynamics, and cascading effects across spatial and temporal scales. Risk assessment for Arctic climate interventions should not be reduced to a single variable (e.g. a single temperature target or a specific return to baseline, however that might be determined). To fully capture all risks, any risk assessment must encompass physical, chemical, and ecological integrity, cultural continuity, and socioeconomic and individual security, and their interactions.

The problem of unknown unknowns (i.e., impacts that are not only uncertain but currently unimaginable) demands that any assessment mechanism build in iterative review, adaptive governance, and the institutional humility to acknowledge the limits of predictive modelling.

Equally important is the recognition that risk is not an objective set of data, but a function of the values and subject positions brought to bear on its assessment. For instance, what is characterised as an acceptable risk for a research institution or a state may be experienced as an existential threat by an Indigenous community where livelihoods depend

on the stability of an ecosystem. Some interventions may even be perceived as beneficial by certain actors while being deeply harmful to others, which means that risk calculation is itself a site of political contestation.

Broadening the question of risk to include multiple knowledge systems and value frameworks also expands the universe of recognised stakeholders, since asking 'risk for whom?' necessarily opens the door to concerns that a narrower, technocratic framing would exclude. At the same time, the framework must account for the risk of inaction (i.e., the possibility that failing to research or deploy certain interventions may itself produce serious harms) without allowing that consideration to override the precautionary obligations legally and ethically owed to those most exposed to potential negative consequences.

2.C

What institutions can implement ethical decisions and how?

Any assessment framework for Arctic climate interventions must establish procedures for determining which institutions can implement ethical and legal decisions.

This process cannot be separated from first-order questions regarding the scalar complexity of the interventions themselves. A given intervention may be sited locally (i.e., in a specific national jurisdiction within or outside the boundaries of what is acknowledged as 'Arctic') while producing intended or unintended effects at regional and global scales. This scalar plurality suggests the need for an iterative multi-level governance architecture in which domestic regulatory mechanisms (including all forms of impact assessment procedures, e.g. strategic, social, economic, environmental) operate in coordination with regional and international bodies.

Existing institutional frameworks offer partial but instructive models. For instance, UNCLOS and the Agreement on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction provide mechanisms for environmental governance beyond national jurisdiction. The Convention on Biological Diversity's Conference of the Parties' Decision on Climate-Related Geoengineering establishes precautionary norms at the multilateral level. The Arctic Council's working group structure offers a regional platform for integrating scientific assessment with policy guidance. The institutional challenge lies in building functional linkages among these instruments so that, at a defined threshold, locally sited interventions with transboundary implications trigger the engagement of regional or global governance mechanisms.

National measures remain indispensable and can serve as a starting point, particularly where interventions have specific, domestic impacts or points of implementation. However, they raise their own engagement and accountability questions, especially where the affected communities are Indigenous Peoples whose exercise of the right to self-determination has been limited, either because of structural limits to their political power within the state or because their political authority does not map neatly onto state jurisdictions.

The framework should therefore consider both how existing institutions might be adapted and whether entirely new mechanisms are needed. Some Arctic Council working groups' publications already provide engagement models for activities that come with significant trade-offs. For instance, the Protection of the Arctic Marine Environment working group's offshore oil and gas guidelines (2009 et seq.) or the Sustainable Development Working Group's Good Practices for Environmental Impact Assessment and Meaningful Engagement in the Arctic (2019) provide some straightforward guidelines for specific activities. As such, they create the discursive and normative space to develop sector-specific instruments for climate intervention governance.

Furthermore, while different in its regulatory scope, the precautionary approach based on best available and Indigenous knowledge as developed in the context of the 2018 Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean provides an institutional model to engage the breadth of Arctic specific knowledge and international obligations.

The central challenge, then, is not the absence of institutional models but the lack of functional integration into current frameworks, as well as attendant questions of compliance and enforcement. Climate interventions operate across jurisdictional and ecological scales, both in terms of space and time, that no single existing body was designed to govern. Any institutional architecture for climate intervention assessment must therefore be attentive to justice dimensions and capable of coordinating across governance levels as well as being responsive to the rights and knowledge systems of Indigenous Peoples and other affected communities. Overall, governance frameworks must be designed so that procedural mechanisms do not become decoupled from the substantive ethical commitments they are meant to serve.

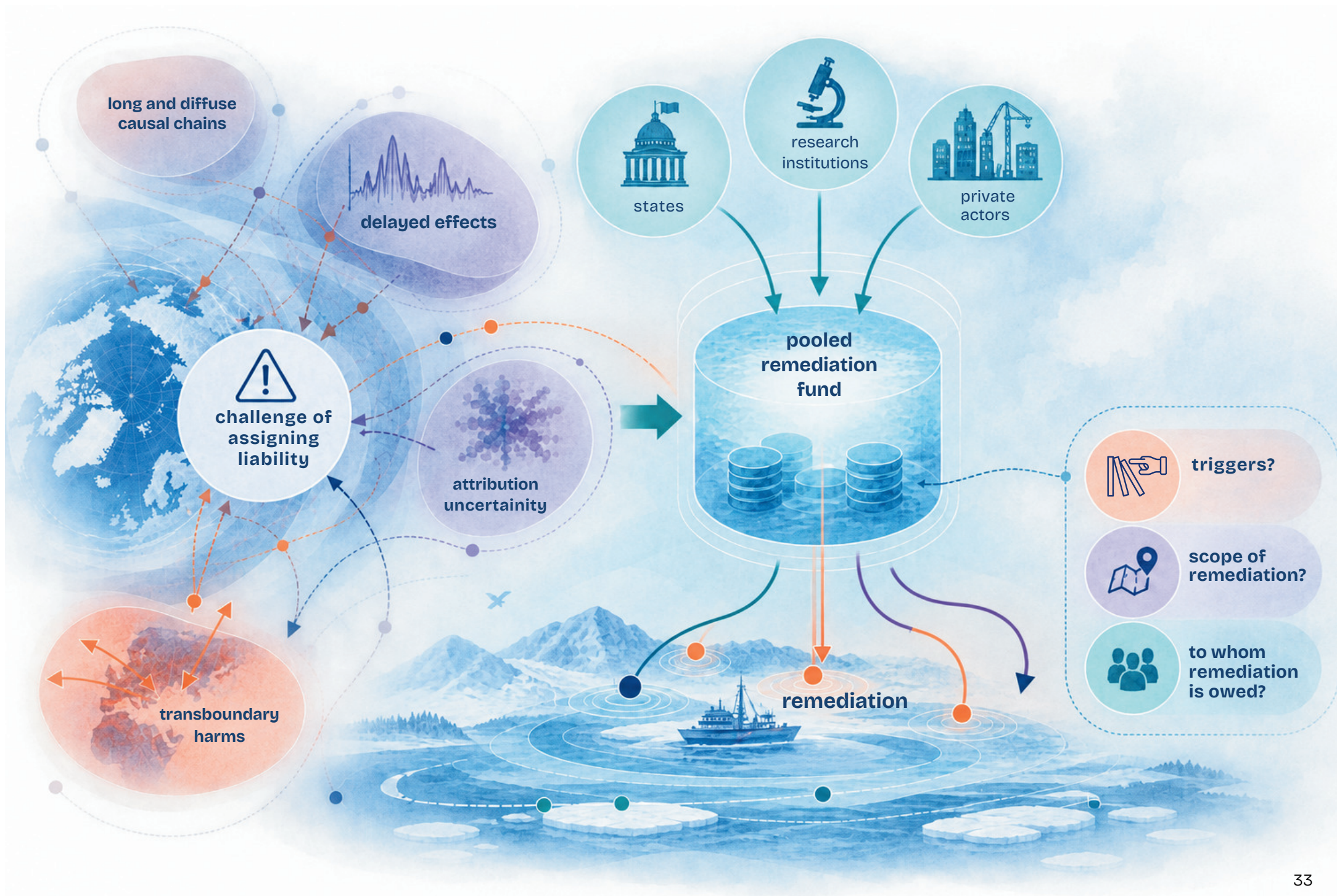
How can funds and mechanisms for remediation be guaranteed?

Any assessment framework for Arctic climate interventions must ensure that there are adequate remediation mechanisms in the event of unforeseen harms.

Given the scale of climate interventions, the uncertainty surrounding their processes and impacts, and possible gaps in the institutions that would ensure compliance, there must be robust mechanisms to provide for remediation in the event that an intervention causes harms, whether due to negligence or to unforeseeable impacts.

For many activities that threaten environmental (or other) harm, the availability of funds for remediation are guaranteed through assignment of liability. However, assigning liability in the context of climate interventions is exceptionally difficult for several reasons. The causal chains are long, diffuse, and potentially scientifically contested. The effects of an intervention may not manifest for years or decades and might not be attributable to a specific intervention with sufficient certainty.

For example, high CO₂ may trigger feedback not yet captured in Earth-system models, so isolating an intervention's contribution is itself a major research problem and a source of irreducible uncertainty. Additionally, assignment of liability can be complicated by the transboundary character of both the atmosphere and the Arctic marine environment, which means that harms may be experienced far from the site of the intervention and across multiple jurisdictions.



Existing international law provides some conceptual resources (e.g., the no-harm principle, due diligence norms, transboundary environmental damage obligations) but these were not developed for the specific characteristics of climate interventions, where the line between intended modification and unintended harm may be impossible to draw with precision and where what can be considered harms can also be benefits and vice versa.

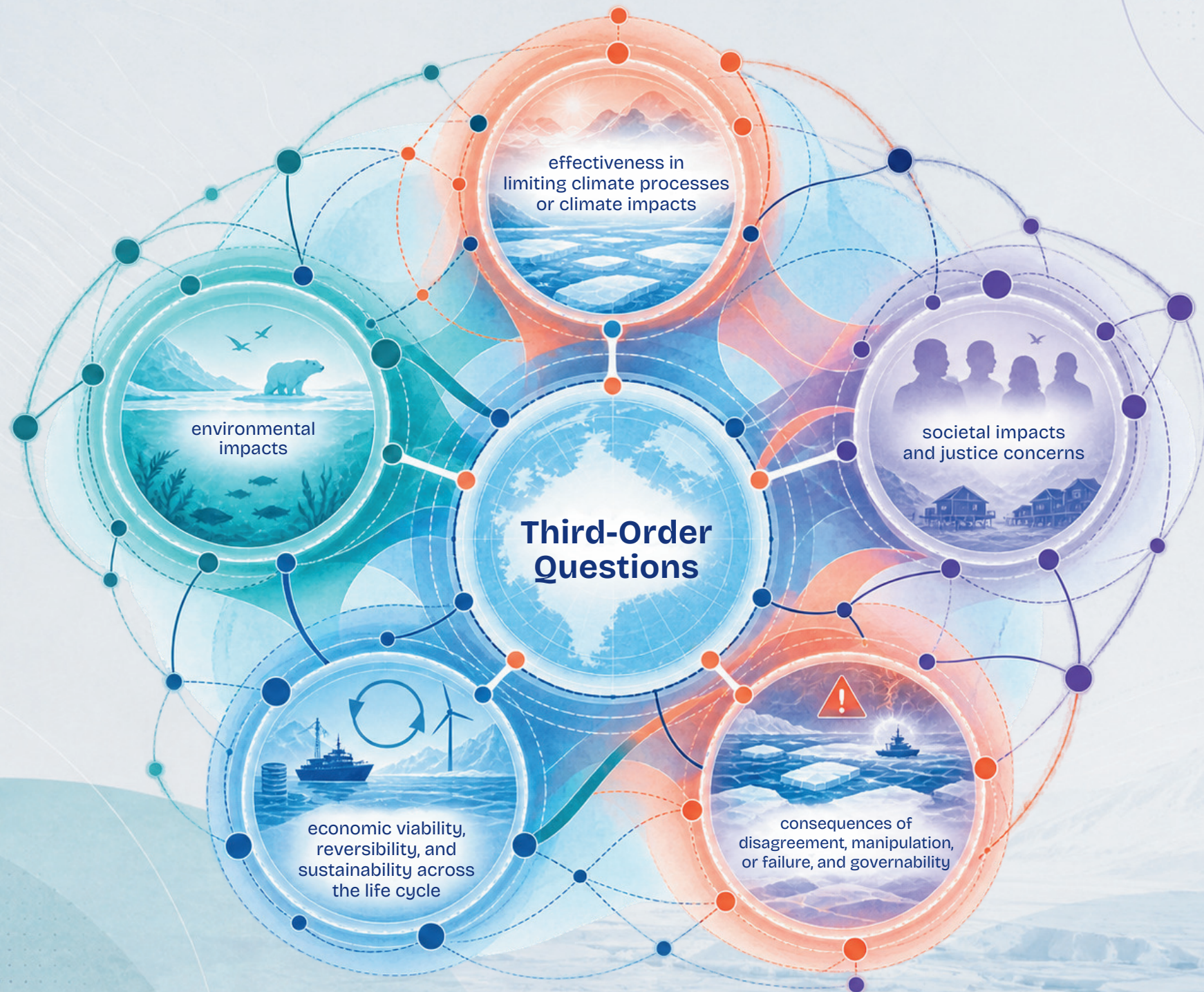
Any liability regime therefore would need to address not only the attribution of causation but also the prior questions of what counts as a compensable harm and whose standards of harm are applied in making that determination.

Given the persistent weakness of enforcement mechanisms in international environmental governance, as well as the problems with assigning liability in climate interventions, innovative approaches that build accountability into every stage of the decision-making process are required, rather than relying solely on post hoc assignment of liability. One alternative model would be a pooled remediation fund, under which there is no requirement that a single responsible party be identified before action can be taken. Such a fund could be supported through contributions from states, research institutions, and private actors engaged in climate intervention licensing, research, or deployment. It could be administered by an existing or newly established body with the technical capacity to assess claims.

Depending on design, a pooled remediation fund would need to address threshold questions such as what triggers access to the fund, the scope of remediation, including whether it extends to cultural and societal harms as well as environmental damage, and to whom remediation is owed.

Third-Order Questions

Where the first-order questions delimit the object of assessment and the second-order questions establish the procedural architecture for conducting an assessment, the third-order questions concern the substantive dimensions of the impacts that any assessment must address. They are not intended to be exhaustive. Rather, they identify the principal categories of impact and concern that must be considered, and they indicate the kinds of analysis and evidence that would need to be assembled. Each question carries its own internal complexities and trade-offs, and the answers to earlier-order questions will shape how each is framed and weighted in any given case.



3.a

What is the intervention's effectiveness in limiting climate processes or climate impacts?

Any assessment of a proposed Arctic climate intervention must evaluate its capacity to regulate observed temperatures or otherwise mitigate the targeted dimension of climate change. That targeted dimension may be planetary, such as net radiative forcing, or regional and local, such as sea-ice extent at a given site.

Theoretical and laboratory work is how efficacy is first established, and it remains central to assessing effectiveness before testing. The additional requirement is that, where possible, projected efficacy be tested against real-world conditions rather than treated as settled at the modelling stage. An assessment must also consider the intervention's demonstrated or projected efficacy under real-world conditions, including the spatial and temporal scale at which observed temperature reductions or other intended effects would be achieved, the degree of confidence in projections, and the sensitivity of outcomes to variables that may themselves be shifting as the climate changes.

Effectiveness cannot be assessed in isolation from baselines and counterfactuals. Effectiveness must also be weighed against environmental, economic, and social costs. For instance, a net cooling effect, at whatever spatial and temporal scale, is not sufficient if the cost of achieving it is disproportionate. In that regard, an assessment must specify what the intervention is being measured against. This might include specifying the current trajectory of warming, a specific emissions scenario, or a defined temperature or albedo target.

It must also address the question of additionality (i.e., whether the cooling effect would occur independently of the intervention through other means) and whether the intervention could produce perverse incentive effects by reducing the perceived urgency of emissions reductions (i.e., the so-called moral hazard concern that has been central to the climate intervention debate). The distinction between gross and net effectiveness must also be carefully considered. For instance, an intervention that produces localised cooling but generates secondary warming effects elsewhere, or that requires energy-intensive maintenance that adds to cumulative emissions, may not deliver the net benefit it appears to have forecasted.

The temporal dimension of effectiveness also warrants careful attention. Some interventions may produce rapid but temporary effects that require continuous reapplication, while others may offer slower onset but more durable outcomes. An assessment framework must consider whether the proposed intervention occurs late or early in the causal chain, while recognising that the distinction is not clean: preventing localised ice loss also maintains high albedo and so feeds back into the systemic driver of radiative forcing, and its efficacy is likely to change over time as background conditions evolve.

In all cases, the burden of demonstrating effectiveness should rest with the proponents of the intervention, and the standards of evidence should be set with reference to the precautionary obligations in relation to risks identified in the second-order questions.

What are the environmental impacts?

Any assessment must evaluate the full spectrum of physical, chemical, and ecological impacts and risks that a proposed intervention may produce, whether positive, negative, or ambiguous.

Although interventions are designed to have impacts that are primarily climatic, many have secondary impacts on terrestrial, marine, and freshwater ecosystems, on species populations, migration patterns, and trophic relationships, on hydrological cycles, ocean chemistry, and atmospheric composition, and on the broader integrity of Arctic and sub-Arctic biomes. Secondary, non-climatic impacts may either arise directly from the intervention (e.g. marine pollution from silica beads) or indirectly as a result of the change in climate (e.g. ecological damage as a result of changed precipitation patterns).

Additionally, an intervention that is sited locally may produce ecological effects that propagate across regions and ecosystems or interact with existing stressors (e.g., ocean acidification, permafrost degradation, pollutant mobilisation) in ways that amplify or redirect harm. For all these reasons, as an assessment extends to evaluate impacts that are not strictly climatic it also must be flexible with regard to temporal and spatial scale.

A particular challenge is that the relationship between a given intervention and its ecological consequences may be nonlinear and subject to threshold effects that are difficult to predict. For instance, an intervention designed to thicken or restore sea ice may benefit certain ice-dependent species while disrupting the light regimes, nutrient cycles, or habitat availability on which other organisms depend.

Similarly, interventions that alter albedo or surface temperatures may shift the phenology of key ecological processes (e.g., spring melt, primary production, breeding seasons) in ways that cascade through food webs. An assessment must therefore adopt a systems-level perspective that considers not only direct effects on target variables but also indirect, cumulative, and synergistic interactions with existing environmental dynamics.

An assessment must also consider the possibility of positive ecological outcomes. Some interventions may stabilise habitats or slow the rate of biodiversity loss in ways that complement broader conservation efforts. The evaluative challenge lies in weighing uncertain benefits against uncertain harms. It is not only a matter of comparing the possible harms and benefits of acting, but of setting both against the risk of not intervening, or of intervening too late.

An assessment framework must therefore make this double-sided risk explicit rather than treating inaction as a neutral baseline, and in doing so with appropriate attention to the values and knowledge systems of those who live within and depend upon the affected ecosystems. Indigenous Knowledge may be indispensable for identifying impacts that other scientific monitoring and assessment practices would miss, and for interpreting the significance of ecological changes within a longer temporal and cultural frame.

These perspectives are not uniform, and the framework must not presume a conservationist or anti-intervention stance on communities' behalf. What the framework requires is that affected peoples hold substantive authority over whether and how an intervention proceeds, not that they reach any particular outcome.

3.C

What are the societal impacts and risks, and how are justice concerns addressed?

Any assessment must evaluate the societal consequences of a proposed intervention across the full range of affected communities.

Prior to the distribution of harms and benefits is the question of what counts as a harm or benefit in the first place, and whose framing of it is recognised. That recognitional question precedes questions of distributive justice, since one cannot ask who bears a harm until one has settled on what counts as a harm. With that ordering in mind, an assessment must also attend to distributive justice. It must not only consider who benefits and who is harmed, but how benefits and harms are distributed across populations, geographies, and generations. An intervention that produces a net global benefit may nonetheless impose concentrated costs on a specific community or region, and the fact that a given community may already be experiencing the worst effects of climate change should be taken into consideration before that community is burdened with additional risks from the interventions designed to address those effects.

Furthermore, the question of intergenerational justice is equally pressing. For instance, interventions that create long-term dependencies, foreclose future options, or shift burdens onto future generations raise ethical concerns that must be addressed and forecasted explicitly within an assessment framework.

This must be assessed in a risk-versus-risk frame through which the burdens that that intervening would shift onto future generations have to be weighed against the burdens shifted onto them by not intervening, or by relying on emissions reductions at their current pace alone.

Beyond distributive concerns, an assessment must engage with questions of recognition and procedural justice, as well as less tangible, indirect, effects on social cohesion, collective identity, and the relationship between communities and their environments. Whose experiences and knowledge count as evidence of impact? Whose framing of harm is given weight? In the Arctic context these questions concern Indigenous Peoples in particular, whose disproportionate exposure to the consequences of environmental modification makes assessment inseparable from the broader framework of the rights of Indigenous Peoples, including rights to self-determination, cultural continuity, and the use and stewardship of traditional territories. Indigenous Peoples may experience the consequences of an intervention in registers (e.g., cultural, spiritual, relational, cosmological) that do not map onto the categories of conventional impact assessment, and the failure to recognise these dimensions constitutes a form of epistemic injustice that can compound the material harms of the intervention itself. An assessment framework must therefore be designed to encompass the full texture of how communities experience and interpret environmental change.

3.d

Is the intervention economically viable, reversible, and sustainable across its life cycle?

Any assessment must evaluate a proposed intervention not as a one-off event but as a technology with a full life cycle, encompassing research and development, deployment, ongoing maintenance, potential scaling, and eventual cessation or decommissioning. In this light, economic viability is a necessary but insufficient condition.

As was noted in the first-order question regarding the extended timeline of a climate intervention, even an intervention that revolves around the single application of a technology exists within a long and typically non-linear trajectory of conceptualisation, research, development, and application, and this adds extra dimensions to questions of economic viability. A single-application technology may also need to be applied across very many locations to produce a global effect. Scaling up sea-ice thickening pumps to a climatically meaningful level, for instance, may itself prove economically unfeasible even where each individual deployment is cost effective and inexpensive at first.

An assessment must consider therefore whether the intervention can be funded at the required scale as well as who bears the costs, how those costs are distributed across public and private actors, and whether the funding model creates dependencies or incentive structures that may distort decision-making over time (e.g., by creating vested interests in the continuation of an intervention regardless of its performance). It should also consider opportunity cost within climate finance specifically: whether funding an intervention diverts resources that would otherwise support adaptation or mitigation.

Reversibility is also a criterion that must be analysed and accounted for as it intersects with both risk and governance. Reversibility and termination shock are related but distinct: reversibility concerns whether and how an intervention can be wound down at all, while termination shock is the specific danger that abruptly ceasing a sustained intervention produces effects more severe than the original trajectory. Some interventions (e.g., stratospheric aerosol injection) would require continuous reapplication, meaning that cessation would result in a rapid return to baseline warming or, even potentially, a termination shock with consequences more severe than the original trajectory. Others may be more readily halted but may also be more difficult to scale. An assessment must evaluate what happens when an intervention stops and ask whether an intervention can simply be discontinued, whether it requires active decommissioning, whether its effects are reversible on policy-relevant timescales, and what residual impacts (e.g., environmental, social, institutional) persist after termination. The concept of technology as life cycle implies that governance does not end at deployment but must extend through the entire operational span and beyond.

Mining and extractive industries offer an instructive analogy where decommissioning obligations, ideally backed by a dedicated fund secured in advance, are meant to ensure that resources exist to manage wind-down, even though in practice such funds are often poorly executed. A comparable mechanism may be needed for climate interventions, and it would need to be designed in coordination with the remediation arrangements and funding discussed in the previous section.

A further dimension concerns the potential for technology evolution. An intervention that is assessed and approved at one stage of development may change significantly as it scales or as successor technologies are developed, raising questions about whether the original assessment remains valid and at what point a reassessment is triggered. The framework must therefore build in mechanisms for periodic review, adaptive management, and, where necessary, the capacity to withdraw approval if the intervention's life-cycle trajectory diverges from the conditions under which it was originally approved and sanctioned.

What are the consequences of disagreement, manipulation, or failure, and how governable is the intervention?

Any assessment must evaluate and confront the possibility that the conditions under which an intervention has been planned, approved, and deployed may not hold, shattering any apparent consensus that had been implied by the assessment outcome.

Disagreement may be particularly acute in the context of Arctic governance. A state, for instance, may authorise an intervention within its national jurisdiction that produces transboundary effects opposed by neighbouring states or by Indigenous Peoples whose territories span across jurisdictional boundaries. An assessment must therefore specify what happens when consensus cannot be reached. This must include whether vetoes or rights to refusal are available, how dissent is registered and weighted, and what mechanisms exist for dispute resolution. It must also consider the legitimacy costs of proceeding over the objections of affected parties, including the corrosive effect that overriding consent may have on the broader governance architecture.

In substance this is a question of governability: how durable or vulnerable the governing arrangements are, how adaptive they can be, how democratic, and what role consent plays, including whether consent once given can be withdrawn.

The risk of manipulation extends beyond bad-faith actors to structural vulnerabilities in the assessment process itself. An assessment framework that relies on scientific evidence may be used in bad faith by actors who fund, design, or selectively publish research to support predetermined conclusions. Governance processes that require stakeholder and rightsholder engagement may be captured by well-resourced interests that crowd out less powerful ones.

The framework must therefore include safeguards against procedural manipulation. This must include transparency requirements, independent review mechanisms, conflict-of-interest protocols, and provisions to protect actors whose opinions might diverge. These safeguards are especially important given the geopolitical stakes of climate intervention, where strategic interests may align with or masquerade as environmental objectives, and where the assessment process itself may be captured, manipulated, or instrumentalised by actors pursuing strategic rather than public-interest objectives. Disagreement, manipulation, and failure are the stress tests that any such assessment of governability must run.

Finally, an assessment must engage seriously with projected worst-case outcomes of an intervention. This is not only a matter of identifying the most severe plausible outcome and assigning it a probability, but of asking what the consequences would be if the intervention were to fail catastrophically, if it were to interact with other interventions or environmental changes in unanticipated ways, or if it were to create path dependencies that foreclose better alternatives. The precautionary obligations established in the previous section demand that worst-case thinking be embedded in the assessment from the outset as a constitutive element of responsible governance.

Appendices

Appendix 1

Major International Statements on Climate Intervention Initiatives, Including in the Arctic, and Other Documents Referenced in this Text

This appendix gathers the principal statements, declarations, and codes of conduct that have sought to articulate ethical or governance principles for climate interventions, in the Arctic and elsewhere, together with the legal instruments and other documents referenced in the body of this text. It is intended as a guide to the materials on which the parameters draw, and not as an exhaustive survey of the field.

1. Major Statements, Declarations, Principles, and Assessments on Climate Intervention Governance, from 2009 to the present

- Indigenous Peoples' Global Summit on Climate Change (2009). The Anchorage Declaration. Anchorage, Alaska, 24 April 2009.
- Steve Rayner, Catherine Redgwell, Julian Savulescu, Nick Pidgeon and Tim Kruger (2009). Memorandum on Draft Principles for the Conduct of Geoengineering Research (the "Oxford Principles"), reproduced in House of Commons Science and Technology Committee, The Regulation of Geoengineering, Fifth Report of Session 2009–10 (referenced below).
- Royal Society (2009). Geoengineering the Climate: Science, Governance and Uncertainty (RS Policy document 10/09). London: The Royal Society.
- House of Commons, Science and Technology Committee (2010). The Regulation of Geoengineering. Fifth Report of Session 2009–10. London: The Stationery Office.

- Asilomar International Conference on Climate Intervention Technologies (2010). The Asilomar Conference Recommendations on Principles for Research into Climate Engineering Techniques. Washington, DC: Climate Institute, November 2010.
- Hubert, A.-M. (2017). Code of Conduct for Responsible Geoengineering Research. Calgary: University of Calgary, October 2017.
- Gardiner, S. M., and Fragnière, A. (2018). The Tollgate Principles for the Governance of Geoengineering: Moving Beyond the Oxford Principles to an Ethically More Robust Approach. *Ethics, Policy & Environment* 21(2), 143–174.
- C2G (2021). Evidence Brief: Climate-Altering Approaches and the Arctic. Carnegie Climate Governance Initiative (C2G), Carnegie Council for Ethics in International Affairs. New York, 2 August 2021.
- van Wijngaarden, A., Alfthan, B., Moore, J., Kullerud, L., Kurvits, T., Mulelid, O., and Husabø, E. (2023). Compendium to the University of the Arctic Rapid Response Assessment: Frozen Arctic. UArctic, GRID-Arendal, and Arctic Centre/University of Lapland.
- American Geophysical Union (2024). Ethical Framework Principles for Climate Intervention Research. ESS Open Archive, 17 October 2024.
- Royal Society (2025). Solar Radiation Modification: Policy Briefing. London: The Royal Society, November 2025.
- Chitty, O., Barnes, J., Hanlon, L., Spence, J., and Varvares, T. (2025). The Governance of Arctic Climate Interventions: Workshop Report. Cambridge, MA: Arctic Initiative, Harvard Kennedy School, August 2025.

2. Legal Instruments Referenced in This Text

- Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (2018). Ilulissat, 3 October 2018.
- Convention on Biological Diversity (CBD) (1992). Rio de Janeiro, 5 June 1992, 1760 UNTS 79. See in particular Conference of the Parties Decision X/33 (2010), Decision XI/20 on Climate-Related Geoengineering (2012), and Decision XIII/14 (2016).
- Intergovernmental Panel on Climate Change (2023). Climate Change 2021: The Physical Science Basis. Working Group I Contribution to the Sixth Assessment Report. Summary for Policymakers. Cambridge: Cambridge University Press.
- International Convention for the Prevention of Pollution from Ships (MARPOL) (1973), as modified by the Protocol of 1978. 1340 UNTS 184.
- Protection of the Arctic Marine Environment (PAME) (2009 et seq.). Arctic Offshore Oil and Gas Guidelines. Akureyri: Arctic Council.
- Sustainable Development Working Group (SDWG) (2019). Good Practices for Environmental Impact Assessment and Meaningful Engagement in the Arctic. Akureyri: Arctic Council.
- United Nations Convention on the Law of the Sea (UNCLOS) (1982). Montego Bay, 10 December 1982, 1833 UNTS 3.
- United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) (2007). UN General Assembly Resolution 61/295, 13 September 2007.
- United Nations Human Rights Council (2023). Report on the Impact of New Technologies Intended for Climate Protection on the Enjoyment of Human Rights (A/HRC/54/47). Geneva: Advisory Committee, September 2023.
- Universal Declaration of Human Rights (1948). UN General Assembly Resolution 217 A (III), 10 December 1948.

3. Other Works Referenced in This Text

- Bolas, G. (2022). Solar Radiation Modification (SRM): Assessment of SRM in the IPCC AR6 WG1 Report. Carnegie Climate Governance Initiative (C2G).
- Busch, F., Krupa, J., Harding, A. (2025). An indigenous perspective on climate engineering. *Energy Research & Social Science* 125 (doi.org/10.1016/j.erss.2025.104117).
- Gannon, M. (2022). A 'reckless' Arctic geoengineering project draws local criticism. *The Nome Nugget*, 9 June.
- Oksanen, A.-A. (2023). Dimming the midnight sun? Implications of the Sámi Council's intervention against the SCoPEX project. *Frontiers in Climate* 5 (doi.org/10.3389/fclim.2023.994193).
- van Wijngaarden, A., Moore, J. C., Alfthan, B., et al. (2024). A survey of interventions to actively conserve the frozen North. *Climatic Change*, 177 (doi.org/10.1007/s10584-024-03705-6).

Appendix 2

The following individuals participated in the workshop held at the Fram Centre, Tromsø, Norway, on 5-6 February 2026 or contributed to reviewing the present document as an expert reviewer. Affiliations are for identification purposes only, as participants attended in their individual expert capacities. Although this document reflects the range of views and concerns expressed at the workshop, it should not be assumed that any participant endorses any or all of its recommendations nor should this document be read as a workshop report.

Mario Acquarone*, Deputy Secretary, Arctic Monitoring and Assessment Programme, Arctic Council.

Chris Armstrong, Professor of Political Theory, University of Southampton, United Kingdom.

Mia Bennett, Associate Professor, Department of Geography, University of Washington, United States.

Irus Braverman, Dr. Teresa A. Miller Professor of Law and SUNY Distinguished Professor, University at Buffalo School of Law, United States.

Simona Capisani, Associate Professor of Environmental and Political Philosophy, Durham University, UK

Romain Chuffart, Nansen Professor in Arctic Studies, University of Akureyri, Iceland.

Aaron M. Cooper, PhD Candidate, Department of Accounting and Law, University of Stavanger, Norway.

Neil Craik, Professor, School of Environment, Enterprise and Development, and Balsillie School of International Affairs, University of Waterloo, Canada.

Sophie Crump, Head of Delegation to CAFF and Climate and Environmental Advisor, Inuit Circumpolar Council, Kalaallit Nunaat (Greenland).

Katharine R. Hendry, Senior Scientist, British Antarctic Survey, United Kingdom.

Clare Heyward, Professor, Department of Philosophy, UiT – The Arctic University of Norway, Norway.

Timo Koivurova, Research Professor, Arctic Centre, University of Lapland, Finland.

Vito De Lucia, Director, Norwegian Centre for the Law of the Sea, UiT – The Arctic University of Norway.

Jeroen Oomen, Assistant Professor, Urban Futures Studio, Utrecht University, Netherlands.

Virginia Selz, Senior Program Director for the Repair Program, Ocean Visions, United States.

Jennifer Spence, Director, Arctic Initiative, Belfer Center for Science and International Affairs, Harvard Kennedy School, United States.

Philip Steinberg, Professor, Department of Geography, Durham University, United Kingdom.

Kevin Surprise, Senior Lecturer in Environmental Studies, Mount Holyoke College, United States.

Apostolos Tsiouvalas, Postdoctoral Fellow, Norwegian Centre for the Law of the Sea, UiT – The Arctic University of Norway, Norway.

Diana Ürge-Vorsatz, Vice-Chair of the Intergovernmental Panel on Climate Change; Professor, Department of Environmental Sciences and Policy, Central European University, Austria.

Albert van Wijngaarden, PhD Candidate, Scott Polar Research Institute, University of Cambridge, UK

*AMAP's participation reflects its interest in understanding potential implications of climate interventions for the Arctic environment and Arctic communities. AMAP does not advocate for, oppose, develop, regulate, or approve climate intervention technologies.





Visuals, Design & Printing: Danai M. Kontou, 2026

