1. **Climate Overshoot and Potential Responses: An Overview**

Climate overshoot—exceeding the Paris Agreement's aim to limit global temperature rise to 1.5 °C above preindustrial levels—is increasingly likely to occur, due to cumulative emissions of CO_2 and other greenhouse gases (GHGs). The international community can reduce the likelihood, severity, and consequences of climate overshoot through a combination of four distinct and potentially complementary approaches. This note 1) introduces the four major approaches, 2) shows one way they might complement each other to reduce climate risks, and 3) identifies some ways in which responses to climate overshoot may interact with the UN's Sustainable Development Goals (SDGs).

Companion notes provide further detail on the potential role of three of the four approaches in managing climate overshoot and summarize the most relevant conclusions of the recent IPCC reports.

Four Approaches to Reducing Impacts from Climate Overshoot

There are four distinct approaches to reducing climate risks, none of which can be adequate alone. An effective global effort to reduce climate risks, particularly in the context of overshoot, will combine approaches to take advantage of the distinct and complementary contributions of each, while minimizing associated risks:

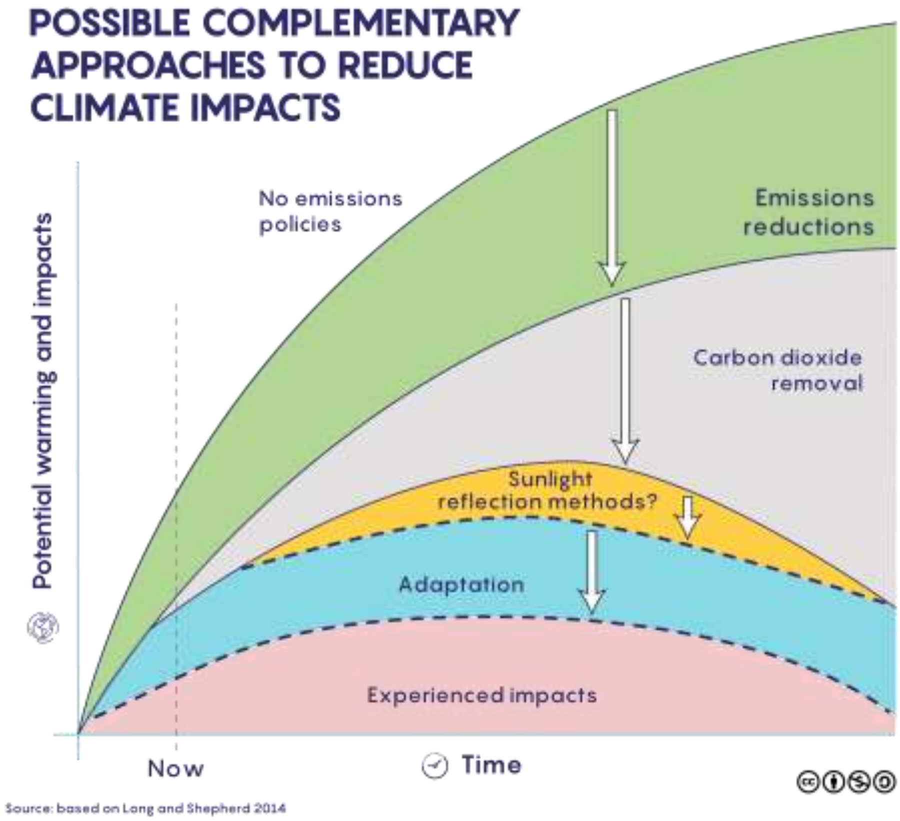
- *Emissions reductions*—Because cumulative GHG emissions are the cause of global warming, reducing them to slow and eventually stop their atmospheric build-up must be the primary approach to protecting people and nature from climate change. But deep emissions reductions have not been achieved thus far, take time to slow global warming, and cannot stop continued heating from previous emissions still present in the atmosphere. (Since emissions cuts are the central focus of most assessments, and focusing on managing overshoot does not change their primacy, we do not dedicate a separate note to this approach.)

- *Adaptation*—Adaptation to climate change allows society to adjust and build resilience to escalating impacts, and to help nature do the same. Yet while adaptation to warming is essential, adaptation needs and capacities vary widely and there are hard limits to how much adaptation can achieve. Most adaptation involves local actions targeting local benefits. Because many adaptation actions are costly or politically difficult, adaptation is often inadequate. Adaptation shortfalls are universal, but are especially consequential for developing countries, which are facing the most severe climate impacts.

- *Carbon dioxide removal* (CDR)—Removing CO_2 from the atmosphere after it has been emitted can supplement emissions reductions by 1) enabling return from overshoot if done at large enough scale, and 2) offsetting emissions that are most difficult to eliminate rapidly, such as those from aircraft, ships, and steel mills. But like emissions cuts, carbon removal is slow to act, and the types of CDR with the largest potential are more expensive than emissions cuts. CDR will also take time to develop and scale. Current net-zero commitments and low-emission scenarios rely on extreme scale-up of CDR technologies that appear promising, but whose success and acceptable impact and cost are not yet assured.

- *Sunlight reflection methods* (SRM)—SRM appears capable of reducing global temperatures and other impacts much faster than emissions reductions or CDR. Unlike adaptation, SRM's effects would be global, not local. But SRM would present several novel challenges. Its restoration of prior climate conditions would be imperfect. It would have environmental impacts, which presently appear modest or correctible but need more study. And it poses serious new governance challenges for managing overshoot, including the need to maintain and control interventions over multiple decades while emissions cuts and adaptation scale up.

The following figure shows one possible idealized strategy that integrates all four approaches to reduce impacts from climate overshoot. Many such combined strategies are possible in principle, but they all present serious challenges of integrated risk assessment, action, and governance. Any integrated strategy should be based on careful assessment of the benefits, risks, and uncertainties of each approach in the context of evolving climate risks. Combined strategies must also consider potential interactions, both helpful and harmful, between approaches. For example, some observers have worried that focusing on the other three approaches might reinforce present obstacles to achieving necessary large-scale emissions cuts.



Sustainable Development Goals (SDGs)

Any climate strategy will be pursued in the context of other societal objectives, prominently including the SDGs. The SDGs form the core of the UN's 2030 Agenda for Sustainable Development. The 17 SDGs and their 169 associated targets aim to end poverty, achieve gender equality, reduce inequality, and secure other global public goods. Reducing risks of climate overshoot through combined strategies as described above may entail various trade-offs or conflicts with pursuit of other SDGs. For example,

- Reducing emissions may undermine efforts to "ensure access to affordable, reliable, sustainable and modern energy for all" (SDG 7).
- Adaptation to climate change may come at the expense of initiatives to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (SDG 4) through competition for limited resources.
- Some forms of carbon removal may compromise programs to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture" (SDG 2) by shifting land use away from farming.
- SRM may imperil efforts to "ensure availability and sustainable management of water and sanitation for all" (SDG 6) in some locations by disrupting precipitation patterns.

To the extent such trade-offs are unavoidable, they will present major challenges to global governance.
of this nature are likely to be unavoidable and pose major challenges for global governance.

2. Intergovernmental Panel on Climate Change Sixth Assessment Report (2021-2022)

This brief summarizes key findings from the Sixth Assessment Report (AR6) recently released by the Intergovernmental Panel on Climate Change (IPCC). The IPCC provides comprehensive scientific assessments of climate change for the international community. Major advances in knowledge reported in AR6 relative to the previous Fifth Assessment Report (2013-2014) include:

- Stronger evidence that observed changes in weather and climate extremes are attributable to human emissions of greenhouse gases (GHGs).
- Stronger support for projections that variation and extremes in precipitation and surface water flows will increase with future climate change.
- Increased estimates of impacts and damages from any specified level of global warming.

The following sections present core findings from each of the IPCC's three working groups.

Working Group I (WGI)

WGI is focused on the physical science of climate change. The report confirms that climate change is already occurring, based on observed increases in global average temperature and precipitation, deteriorating glaciers and polar ice, ocean acidification, sea level rise, and changes in species distribution. Heat waves, floods, droughts, and tropical cyclone activity are all worsening.

Under medium to high emissions scenarios—pathways with moderate or weak climate action—Earth is on course to exceed 2 °C above preindustrial levels by late this century, with potentially severe impacts. The lowest emissions scenarios—pathways with aggressive (and disruptive) climate action—are projected to keep the planet within 2 °C warming with correspondingly lower impacts. Under all scenarios, Earth is on course to exceed the more protective 1.5 °C goal by 2040. Increased warming will worsen negative climate effects beyond their already elevated states. As emissions of carbon dioxide (CO_2), the most important GHG, increase, natural uptake of CO_2 by both ocean and lands will weaken.

Ocean warming and acidification, ice-sheet loss, sea level rise, and many other changes caused by excess atmospheric GHG concentrations will be irreversible for centuries to millennia. Climate-related impacts will increase in all regions of the world and will be more severe under 2 °C than under 1.5 °C warming. Abrupt or irreversible changes in climate or climate-sensitive systems are unlikely but cannot be ruled out.

Working Group II (WGII)

WGII is concerned with climate impacts, adaptation, and vulnerability. Climate impacts on nature and people, including food and water insecurity, declining health, and economic damages, are increasing in scope and severity. More than 3 billion people are highly vulnerable to climate change.

In the near term (2021-2040), risks to human and natural systems will increase, and many are now unavoidable. In the mid to long term (2041-2100), such risks, including decreased water availability, threats to food production, and health and economic impacts, will increase further, although their rate of increase can be moderated by strong near-term actions to reduce emissions, strengthen adaptation, and remove CO_2 from the atmosphere. Many places will experience multiple impacts simultaneously, creating complex compound risks that can spread across sectors and regions. Overshooting 1.5 °C will increase risks, more severely with greater magnitude and duration of overshoot.

Adaptation to climate change is progressing, but gaps between current efforts and projected needs are widening. Most present adaptation measures address water-related risks. Others target agriculture, forests and other ecosystems, the built environment, and energy systems. Some ecosystems are reaching hard limits to adaptation, beyond which severe harms become unavoidable. Many human systems are facing softer limits, with various social, economic, or political factors constraining use of known ways to reduce risks. These constraints can sometimes be overcome, for example by providing additional finance, but human adaptation will also face harder limits. Maladaptive practices, which unnecessarily increase climate risk or vulnerability, are widespread and growing.

Working Group III (WGIII)

WGIII assesses emissions projections and ways to mitigate climate change by cutting emissions or increasing removals. Even if countries fulfil their current Nationally Determined Contributions (NDCs) under the Paris Agreement, the world is on course to exceed the 1.5 °C target, with global mean temperature estimated to reach about 2.8 °C by 2100. Continuing current policies (which are weaker than NDC targets) will bring still more warming, with global temperature reaching about 3.2 °C by the end of the century. Meeting either the 1.5 °C or 2 °C targets would require global emissions to peak within three years (by 2025), then decline rapidly.

To pursue these steep cuts, rapid expansion of carbon-free technologies like solar and wind energy is becoming more technically and economically feasible, and an expanding portfolio of regulatory instruments like emissions standards and carbon pricing is available to promote their adoption. Yet achieving these ambitious goals will also require both stronger international cooperation, and early closure of many high-emitting facilities. Projected emissions from current and planned fossil-fuel infrastructure alone roughly exhaust the budget of remaining cumulative emissions compatible with staying within 2 °C.

Returning to 1.5 °C after overshoot will require removing hundreds of billions of tons CO_2 from the atmosphere by 2100. Meeting the 1.5 °C goal with little or no overshoot will require faster and earlier scale-up of both emissions cuts and removals, so that remaining human-sourced emissions are fully offset by removals—bringing global emissions to net-zero—by the early 2050s; meeting the 2 °C goal will require reaching net-zero by the early 2070s. Methods for achieving such large-scale removals include bioenergy with carbon capture and storage, direct air capture, and planting trees, with each method carrying risks that vary with technology, site-specific context, and scale. Pursuing multiple forms of climate response in the context of overshoot and broader socio-political aims such as the Sustainable Development Goals will involve both potential synergies and complex and difficult trade-offs.

3. **Adaptation**

Adaptation to climate change allows society to adjust and build resilience to escalating impacts, and to help nature do the same. Adaptation options may be categorized as follows:

- *Structural and physical*—These include 1) engineered and built environment (e.g., seawalls and coastal protection structures), 2) technological (e.g., new crop and animal varieties), 3) ecosystem-based (e.g., wetland and floodplain conservation and restoration), and 4) service strategies (e.g., social safety nets and social protection).

- *Social*—These include educational (e.g., awareness-raising and integrating into curricula), informational (e.g., hazard and vulnerability mapping), and behavioural strategies (e.g., household preparation and evacuation planning).

- *Institutional*—These include economic (e.g., taxes and subsidies), legal and regulatory (e.g., land zoning laws and building standards), and policy and programmatic strategies (e.g., national and regional adaptation plans).

Adaptation, and in particular adaptation finance, is frequently considered in the context of the pledge made by developed countries at the 2009 UN climate summit in Copenhagen to provide $100 billion in climate finance (for mitigation and adaptation) annually to developing countries by 2020, a pledge that has yet to be met.

While adaptation to warming is essential, it is subject to limits. Soft limits to adaptation are reached when options for avoiding intolerable risks may exist but are not currently available. Hard limits to adaptation are reached when intolerable risks become unavoidable.

Governance challenges associated with climate adaptation include 1) closing the gap between global adaptation needs and actual achievements (not least with respect to funding), 2) reckoning with limits to adaptation and providing for complementary, mutually supportive approaches, and 3) better aligning global and local interests in climate risk reduction. Addressing these challenges individually and collectively is likely to involve trade-offs.

The following sections present core findings from two recent, prominent reports. Taken together, they juxtapose the benefits of—and pathways toward—adaptation against current gaps in finance and implementation.

The Global Commission on Adaptation Report *Adapt Now* (2019)

Adapt Now (2019) was the flagship report of the Global Commission on Adaptation. This 22-member commission was formed in 2018 to accelerate adaptation by raising awareness and promoting concrete solutions, and is regarded by many as the most high-profile body dedicated solely to adaptation. *Adapt Now* summarized the Commission's approach and outlined a series of recommendations; the following provides an overview of its contents.

According to the Commission, adaptation to climate change should be accelerated for multiple reasons:

- *To protect society*—Adaptation will help reduce climate impacts. Since impacts will disproportionately harm the poor and women, adaptation will moderate the extent to which climate change will exacerbate existing inequities. And since impacts will place an unfair burden on future generations, adaptation will promote intergenerational justice.

- *To protect the environment*—One-quarter of species is facing extinction, about one-quarter of ice-free land is subject to degradation, and the ocean is warming and acidifying. Adaptation will help reduce these and other threats to nature.

- *To reduce economic damages*—Investing $1.8 trillion in five areas from 2020 to 2030 could generate $7.1 trillion in total net benefits. These areas include early warning systems, climate-resilient infrastructure, improved dryland agriculture crop production, mangrove protection, and improved water resources management.

Key recommendations for accelerating adaptation include:

- Increased spending on agricultural research and development, promoting climate-smart agriculture, and empowering small-scale farmers can make food systems more resilient.
- Efforts to protect and restore natural systems should be significantly increased, natural assets and ecosystem services should be fully valued, and resources for nature conservation should be expanded.
- Water resources should be managed better and more efficiently.
- Improved climate risk information and technical capacity-building, greater investment in nature-based solutions, and assistance targeted specifically at inhabitants of informal settlements can enhance urban resilience.
- Existing infrastructure should be made climate-proof, and new infrastructure should be built according to green design principles. Public-private partnerships can improve prospects for investments in infrastructure.
- Disaster risk management, including improved planning, early warning systems, and expanded social safety nets can strengthen preparation for, responses to, and recovery from extreme weather events.

UNEP *Adaptation Gap Report* 2021

UNEP releases annual *Adaptation Gap Reports* to highlight the difference between global adaptation needs and actual activities. The *Adaptation Gap Report* is the most visible regular assessment of the state of adaptation. The following summarizes the most recent (2021) version of the report.

UNEP divides adaptation into three elements:

- *Planning*—Adaptation is slowly being mainstreamed into (integrated as a routine feature of) public planning processes worldwide. These processes are showing incremental improvements in terms of comprehensiveness, inclusiveness, implementability, integration, and monitoring and evaluation.
- *Finance*—Adaptation financing requirements that have been publicly declared by developing country governments are five to ten times greater than current international public adaptation finance flows. These needs relate primarily to agriculture, infrastructure, water, and disaster risk management sectors. Private finance (either domestic or international) is unlikely to fill the gap in these and other sectors.
- *Implementation*—Rates of adaptation implementation remain low. Limited data on the effectiveness of adaptation measures, combined with escalating climate impacts, suggest that implementation may fail to keep pace with growing climate risks.

4. **Carbon Dioxide Removal**

Carbon dioxide removal (CDR), also known as carbon removal or negative emissions technologies, refers to a set of technologies and practices that remove carbon dioxide (CO_2)—the most important greenhouse gas—from the atmosphere and storing it on a permanent and reliable basis to reduce global warming. Some CDR methods employ transport and storage infrastructure that is similarly used by point-source carbon capture and storage (CCS) to store CO_2, but CDR differs from CCS in that it captures carbon from the ambient air.

Thus, in the context of climate overshoot, CDR can supplement emissions reductions in two specific ways:

- *Removing CO_2 from the atmosphere after it has been emitted*—CDR could be used to remove excess atmospheric CO_2, and thus reduce global warming, at a faster rate than would naturally occur. Removing emissions would enable 1) recovering from overshoot by removing an amount of atmospheric CO_2 sufficient to return global average temperatures back to the exceeded warming goal, and 2) reaching net-zero emissions, that is, the point at which CO_2 emissions are balanced by CO_2 removals.

- *Offsetting emissions that are particularly costly or difficult to avoid*—Emissions from the cement, steel, chemicals, aluminium, trucking, shipping, and aviation sectors are particularly costly, if not impossible, to reduce. Assuming these industries are maintained in the future, CDR could be used to compensate for their hard-to-abate carbon pollution.

All CDR techniques can contribute in these ways, but all have drawbacks, some of which apply to all forms of CDR and others which apply to individual techniques. General limitations and risks include:

- *Negligible climate benefits at small scale*—Significantly reducing atmospheric CO_2 concentrations and associated climate risks will require operating CDR at large scale.

- *Slow to act*—As with emissions cuts, significantly reducing climate risks will require decades of (large-scale) carbon removal.

- *Lacks incentives*—CDR currently offers few financial rewards; large-scale use will require meaningful incentives to motivate implementation.

- *Moral hazard*—Moral hazard refers to the possibility that researching, developing, or deploying CDR could weaken efforts to cut emissions, because individual actors and/or special interests embrace the idea that future CDR can substitute for present-day emissions.

- *Risk of leakage*—Stored carbon may, under certain conditions and depending on the storage medium, be released back to the atmosphere.

- *Localized risks*—Other risks associated with CDR tend to be local in nature but vary according to method.

The duration of carbon storage may vary from short-term (years to decades) to permanent (approximately 100,000 years or more). Storage in the land biosphere (trees and soils) is typically short-term, while storage in the geosphere (underground) is usually permanent. Permanent storage is essential to meaningful climate risk reduction.

CO_2 removed by CDR may also be used to produce valuable goods and services through carbon capture and utilization (CCU), but such products typically decompose quickly, returning their embedded carbon to the atmosphere and thereby limiting the climate benefits of CCU.

CDR methods can be roughly divided into biological and industrial techniques (the estimates of cost and storage potential that follow derive from IPCC AR6, with some subject to dispute). Biological techniques rely on the uptake of CO_2 by plants and soils to remove carbon from the atmosphere and store it in natural carbon sinks.

Compared to industrial CDR, biological CDR has a smaller carbon removal capacity but is more mature. Biological methods include:

- *Tree planting*—Forestry projects have been used as offsets in both voluntary and mandatory carbon markets for decades. The vulnerability of forests to wildfires, diseases, and other threats raises questions about the permanence of CO_2 stored in trees. Cost: \$0-240/tCO_2 (per ton).

- *Soil carbon sequestration*—Soil carbon sequestration consists of a suite of agricultural practices that stimulate CO_2 uptake in soils. These include no-till farming, planting cover crops, and crop rotation. Cost: \$45-100/tCO_2. Potential: 0.6-9.3 GtCO_2/year. Readiness level: mature.

- *Biochar*—Biochar is a charcoal-like substance composed of stable CO_2 produced when biomass is heated under low-oxygen conditions. It can be produced using multiple feedstocks and spread over agricultural land to improve crop yields. Cost: \$10-345/tCO_2. Potential: 0.3-6.6 GtCO_2/year. Readiness level: demonstration.

By contrast, industrial CDR techniques rely on technology to remove carbon from the atmosphere. Compared to biological CDR, industrial CDR has a larger carbon removal capacity but is less mature. Industrial methods include:

- *Bioenergy carbon capture and storage* (BECCS)—BECCS would involve combusting biomass to generate electricity, capturing the CO_2 released as a by-product, and permanently storing the CO_2 (generally underground). Because biomass absorbs atmospheric CO_2, capturing and storing the CO_2 produced by combustion would result in net carbon removal. The prospect of large-scale BECCS deployment and related land use change has raised serious concerns about food and water security and the security of land tenure, particularly in developing countries. Cost: \$15-400/tCO_2. Potential: 0.5-11 GtCO_2/year. Readiness level: demonstration.

- *Direct air carbon capture and storage* (DACCS)—DACCS would entail capturing CO_2 directly from the ambient air through chemical means and permanently storing it. The relatively low concentration of CO_2 in the atmosphere makes the DACCS capture process energy-intensive and thus comparatively expensive. To ensure that the CO_2 directly captured and stored is net-negative, DACCS would need to be powered by low-carbon energy sources. Cost: \$100-300/tCO_2. Potential: 5-40 GtCO_2/year. Readiness level: demonstration.

- *Enhanced weathering*—Natural chemical rock weathering could be accelerated by grinding rocks like olivine and basalt and spreading the powder over croplands or forests in tropical and subtropical areas, drawing down atmospheric CO_2. The mining, grinding, and distribution infrastructure required to implement enhanced weathering would be vast and costly. Cost: \$50-200/tCO_2. Potential: 2-4 GtCO_2/year. Readiness level: pilot.

- *Ocean alkalinity enhancement*—This method involves adding alkaline substances like lime to surface waters to enhance absorption of atmospheric CO_2 by the ocean and reduce ocean acidification. Cost: \$40-260/tCO_2. Potential: 1-100 GtCO_2/year. Readiness level: conceptual.

Governance challenges associated with CDR include 1) incentivizing technology development and large-scale use, 2) ensuring permanent and reliable storage of CO_2, 3) managing risks (primarily local) in an effective and comprehensive manner, and 4) avoiding moral hazard using institutional or other safeguards. Future global governance of CDR will likely be centred on the Paris Agreement Article 6 carbon market mechanisms, but these are neither finalized nor designed to facilitate large-scale CDR.

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5. Sunlight Reflection Methods

Sunlight reflection methods (SRM), also known as solar radiation management, solar radiation modification, or solar geoengineering, are a group of proposed technologies that would reflect a small fraction of incoming sunlight back to space to partially offset climate change. The leading proposed technique would use small particles, called aerosols, suspended in the air.

Compared to other approaches to reducing climate risk, SRM appears to have three distinct attributes:

- *Global scale*—Leading proposals for SRM would produce global-scale effects, but some SRM techniques might be able to be used locally in certain situations.
- *Fast-acting*—SRM could reduce temperatures, some precipitation changes, and associated impacts quickly, with effects on the climate system being felt within a year.
- *Low cost*—The direct implementation costs of leading proposals for SRM appear relatively low. Related to this, the technical and logistical barriers to using SRM also seem modest.

The possible combination of global-scale effects delivered at low cost makes SRM a high-leverage set of technologies. The fast-acting nature of this high-leverage approach makes SRM particularly well-suited to "shave the peak" off the sort of dangerous multidecadal warming likely to result from climate overshoot (see figure in Overview briefing).

But SRM entails significant limitations and risks, which makes this approach controversial and has constrained research funding:

- *Imperfect climate restoration*—Because blocking some sunlight is not the same as removing or avoiding emissions of GHGs, SRM could not perfectly compensate for climate change. Consequently, using SRM to slow global warming could steer the climate toward conditions closer *but not identical* to previous, historical climates; the most significant differences would likely manifest as imperfect restoration of, and possible net changes in, regional precipitation patterns. Nevertheless, such a novel climate may more closely resemble preindustrial conditions—and thus be safer for people and nature—than a similarly novel climate brought about by global warming but without SRM.
- *Temporary effects*—Since aerosols ultimately fall back to Earth, the effects of SRM would be temporary unless aerosols were continuously replenished, at least until the decision was made to cease and gradually phase-out the intervention. If SRM were suddenly halted, and not resumed, while atmospheric GHG concentrations remained at unsafe levels, the planet would rapidly warm, producing a dangerous "termination shock."
- *Moral hazard*—Moral hazard refers to the possibility that implementing, researching, or merely talking about SRM could weaken efforts to cut emissions. This might occur because individual actors come to believe that emissions cuts are no longer necessary to stop global warming and/or because special interests promote the idea that SRM is a cheap substitute for emissions reductions.
- *Technological lock-in*—Some observers argue that researching and/or discussing SRM could create a "slippery slope" in which vested interests push for implementation.
- *Unilateralism*—The relative affordability of SAI would seem to enable many countries to implement the technology on their own, potentially imposing their preferred level of cooling on the rest of the world and/or generating international disputes and tensions.

Implementing SRM would entail considerable uncertainty. Any assessment of the desirability of SRM would need to compare, on the one hand, the anticipated benefits, costs, risks, and uncertainties of a world with both climate change and SRM, to the anticipated benefits, costs, risks, and uncertainties of a world with climate change but no SRM, on the other. Decisions regarding SRM are thus likely to involve difficult risk-risk trade-offs.

Research has focused principally on two techniques:

- Stratospheric aerosol injection (SAI)—This technique would involve dispersing aerosols in the upper atmosphere (stratosphere). SAI is inspired by the known effects of large volcanic eruptions, sulphates from which cause global temperatures to measurably decline in the year or two that follow. Possible side effects from using sulphates include delayed recovery of the ozone layer. Other candidate aerosols include calcite, the use of which may avoid these side effects. Using any aerosol, however, will likely produce slightly whiter skies (although perhaps barely perceptible). SAI could be implemented by a fleet of aircraft at an estimated annual cost of tens of billions of dollars.

- Marine cloud brightening (MCB)—This method would involve spraying seawater from ships into low-lying clouds, causing them to whiten and increasing their reflectivity. More reflective clouds would cool underlying waters in the same way that ship tracks reduce temperatures in their wake. MCB might be capable of cooling small patches of ocean surface; areas off the western coasts of North and South America and Africa offer particularly suitable conditions. Such patchy application would, however, result in patchy effects at regional and global levels, which could exacerbate some climate impacts.

Apart from SAI and MCB, space-based technologies, for example, reflectors stationed at a stable point between the Earth and the sun, have also been proposed as a type of SRM, but their implementation appears infeasible in the next few decades due to extremely high-cost estimates and deep uncertainties.

Cirrus cloud thinning (CCT) is similar to, but technically not a form of, SRM. CCT would involve seeding high-altitude clouds above the poles to facilitate heat flow out of the atmosphere. Unlike SRM, which would block incoming sunlight, CCT would act primarily by increasing the amount of heat transferred from the Earth's surface back to space.

Individual applications of CCT and MCB would have local effects, i.e., effects would be limited to within tens of kilometres of the intervention site and would subside in less than a day. However, such local applications could be aggregated to cool wider areas, possibly up to global scale.

Governance challenges associated with SRM include 1) gaining international agreement on whether to use the technology, under what conditions, how much cooling to pursue, how to implement it, and when and how to halt it, 2) avoiding moral hazard using institutional or other safeguards, 3) ensuring long-term planning and durable management including redundancies to provide for continuous operations until SRM is phased out, to avoid termination shock, 4) building multilateral or other cooperative mechanisms to prevent unilateral use, and 5) compensating countries demonstrably harmed by SRM. Currently, SRM is subject to virtually no meaningful global governance that is specific to SRM.