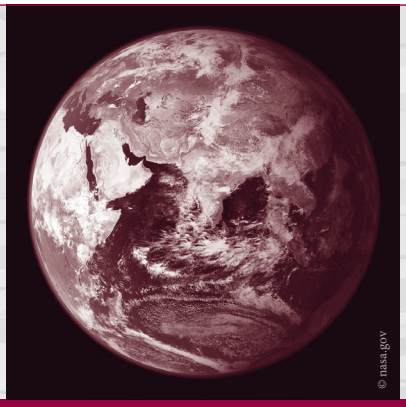
TAB OFFICE OF TECHNOLOGY ASSESSMENT AT THE GERMAN BUNDESTAG

CLIMATE ENGINEERING



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Summary

- Climate change is widely seen as the central environmental issue of our time. However, climate protection measures implemented to date are showing little impact.
- The question has been raised of whether direct technological interventions in the climate system – termed climate engineering – could be a suitable means of limiting the rise in temperature.
- Policy-makers and society would face major challenges with regard to decisions about the development and application of climate engineering, especially as the entire world population would potentially have to deal with the possible consequences of these measures.
- Decisions on the benefits of climate engineering therefore cannot be based solely on technological and scientific criteria or economic considerations. Assessment must also include ethical, legal and societal criteria.

What is involved

Strategies for **reducing anthropogenic greenhouse gas emissions** (mitigation) and **measures for adapting** to climate changes which have already occurred or are expected to occur (adaptation) are at the heart of efforts to stem climate change. Despite the various emission-reduction activities, the further rise in greenhouse gas concentrations in the atmosphere has not been halted to date.

Other options for action are – in principle, at least – available to counteract global warming, which would come into play after the greenhouse gases had been emitted into the atmosphere. These include **intentional technical interventions in the climate system**, termed **climate engineering (CE)**. The key question is whether or under what conditions climate engineering could or even should assist in combating climate change.

Climate engineering encompasses two systematically different technical approaches:

- **Carbon dioxide removal technologies** (CDR technologies) are aimed at **removing already emitted CO_2 from the atmosphere**, i.e. eliminating one of the main causes of anthropogenic climate change. This could be done, for example, by means of extensive fertilisation of the oceans with nutrients, e.g. iron, to specifically promote algal growth and the resulting transport of CO_2 into the deep ocean when the dead algae sink.
- **Radiation management technologies** (RM technologies), on the other hand, seek to **change the Earth's radiation balance**. Cooling of the Earth could theoretically be achieved, for instance, by injecting sulphur particles into the atmosphere which reflect some of the incoming solar radiation into space. This will not reduce the atmospheric CO_2 concentration, with the result that other consequences of climate change, such as the increasing acidification of the oceans, would not be remedied by this method.

Climate engineering activities

Climate engineering options have been **under increasing discussion within the scientific community since the middle of the last decade**. One key question is whether an unexpectedly momentous climate change could still be managed by implementing suitable climate engineering technologies. Potential undesirable environmental and social consequences of corresponding climate interventions are also at the focus of research. The main thrust of research at present is directed towards **expanding fundamental knowledge to permit a better assessment of climate engineering** without committing such research to a definite intention to develop the corresponding technologies.

To date, the **general public** around the world has had **little involvement in the discourse relating to** climate engineering,

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and **debate at a policy-making and societal level** is taking place in **only very few countries** at present. Important contributions are being made by the **US, the UK and Germany** where legislative bodies and/or governments have already addressed the issue. Although practically all policy statements stress the priority of reducing emissions, **UK and US political representatives** are calling for **further research and regulatory work** with reference to the possibility of momentous climate change. In Germany the **Federal Government** has committed itself to ensuring that climate engineering is not implemented without adequate knowledge and international regulatory mechanisms. **No comparable policy activities** can be reported to date from **other countries**.

Climate engineering is currently seeing its status significantly enhanced as the issue has been taken up by the **Intergovernmental Panel on Climate Change (IPCC). Growing politicisation** and **increased media attention** can be expected as a consequence.

Political and Societal discourse required

Climate engineering can be regarded as a **potentially highly controversial issue**. In particular, the unprecedented global nature of certain climate engineering technologies may trigger public concern and societal opposition. The aim, therefore, ought to be to establish a **discourse and communication process within society as a whole** in order to achieve the broadest possible consensus on how to proceed with these technologies and to ensure that society is involved in decisions in the context of climate engineering. The key questions are **whether, for what reasons** and **how climate engineering** could and should be researched and, if appropriate, implemented.

Improved information provision seems to be absolutely essential to enable the general public to take a constructive role in assessment and decision-making processes relating to climate engineering. A good knowledge base and a communication process based on this could be actively promoted via a **communication and information strategy**. The possible spectrum ranges from intensive internet activities to networked information and discussion events for interested members of the public which would offer an early forum for dialogue among the various stakeholders from the public, the scientific community and policy-makers.

Scientific and technological state of knowledge

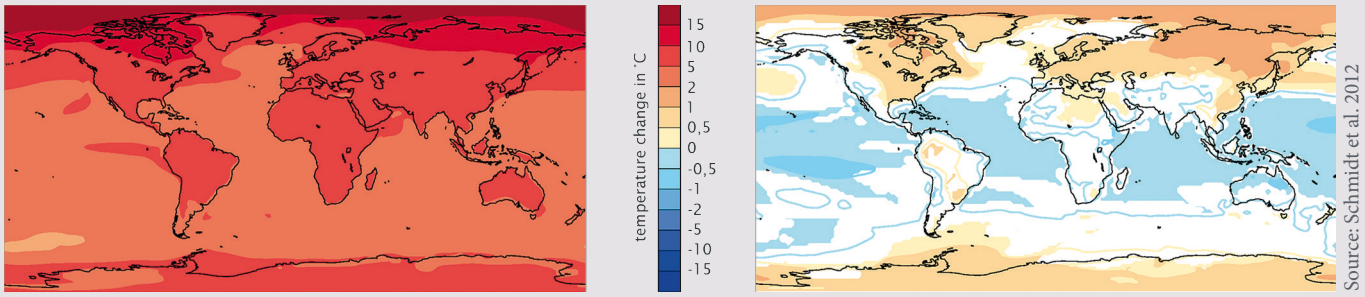
The **level of technological and scientific knowledge** on the effects and side effects of various climate engineering options is **still very limited**.

Based on the current level of knowledge, **none of the CDR concepts discussed so far would be capable of substantially reducing the temperature of the Earth**. Nevertheless, certain CDR options could become meaningful and, under certain circumstances, **important climate protection tools to complement emission reduction measures** in the longer term. CDR concepts which permit regional application might seem attractive because they can be expected to generate rather minor environmental side effects whose geographical impact is limited.

With reference to the **RM options**, computer simulations indicate that relevant climate interventions could result in a **(rapid) reduction in average global temperatures by several degrees Celsius**, though the temperature reduction would be unevenly distributed around the globe. At the same time, there would be **changes in other climate variables** for which there is an almost complete lack of knowledge to date with regard to their quality, extent and regional prevalence.

From a technical perspective, **some of the CDR options** are already at the **development and testing** stage, whereas the **RM options** are only **hypothetical concepts**.

Climate engineering measures, which in terms of their design call for large- to global-scale application, would presumably inevitably entail **serious environmental side effects** and thus



Modelling of temperature changes in the climate scenario with a CO_2 concentration four times higher than the pre-industrial level (left) and in the scenario of the application of RM technologies to maintain the pre-industrial global average temperature despite the high CO_2 concentration (right). A uniform temperature reduction through RM measures would probably not be achievable; the consequence would be overcooling of the tropics and warming of the polar regions.

far-reaching impacts on human living conditions if implemented. Socioscientific research into the social implications of climate engineering is still at a very early stage. Overall, it is highly uncertain at present whether the environmental and social impacts of a major technical intervention in the climate system would be less serious than those without such intervention.

Decades of further research would probably be necessary before substantial progress could be achieved in the scientific assessment and technical development of climate engineering.

Research policy

One key question is whether and in what form climate engineering research should be specifically promoted beyond the current framework. A decision to halt further research work could mean **foregoing the ability to exert influence on developments on the international stage**. Geman research can also make **important contributions to the international debate**. At the same time, **Germany** is already one of the **leading countries in terms of research** in the field of climate engineering. Even greater commitment ought not to give cause for misinterpretation, i.e. that Germany regards the current climate policy measures as not (or no longer) productive. The research motives and targets should therefore be communicated accurately and transparently.

Specific climate engineering proposals (selection)

Conversion of biomass into biochar: This should allow the carbon fixed in the biomass to remain removed from the atmosphere for a relatively long period.

CO_2 air capture and CO_2 storage: CO_2 could be filtered directly from the air in a system comparable to CCS technology. However, this would require huge plants.

Space mirrors: Mirrors positioned between the Sun and the Earth could direct some of the solar radiation back into space.

Cloud albedo enhancement: The albedo of low clouds over the oceans could be enhanced by seeding with sea salt crystals, as a result of which they reflect more sunlight. This could be carried out by a fleet of unmanned boats.

Computer representations
Source: Holmes et al. 2013; Latham et al. 2012

Scientific basic research and socioscientific accompanying research could be expanded in particular with reference to the following aspects:

- To date only a rudimentary empirical data base is available on the **perception and assessment of climate engineering by the general public in Germany and the world**, and this urgently needs to be extended with a view to ensuring societal involvement.
- More intensive research on climate engineering could **impact on political efforts to reduce greenhouse gas emissions**. Such developments should be anticipated at an early stage and suitable options for action in response should be developed.
- The various options relating to climate engineering are mostly being investigated in terms of their climate policy benefit in isolation from each other and without reference to possible adaptation strategies. A combination of all the available measures could possibly offer a productive approach, for which reason greater emphasis should be given to examining the **benefits and risks of portfolio approaches**.
- The level of knowledge of the benefit and cost aspects of climate engineering is still rudimentary and is limited to the

Arguments in favour of climate engineering:

- It may not be possible to meet climate policy targets (e.g. the 2°C target) without climate engineering.
- Climate engineering may enable climate change to be managed more easily and more cost-effectively than using mitigation and adaptation measures.
- Ready-to-use, fast-acting climate engineering technologies ought to be available in the event of unexpectedly dramatic climate change so that it is still possible to avert momentous developments.

Arguments against climate engineering:

- The mere prospect of climate engineering could undermine mitigation efforts.
- The risks of technical climate interventions cannot be predicted, and their use is too hazardous.
- Halting the climate engineering measures may result in a sudden rise in temperature which could overwhelm the ability of ecosystems to adapt.
- Climate engineering technologies could be implemented unilaterally, even if this does not appear to be justified from a political or ethical perspective.

direct costs of relevant measures. However, any assessment based on economic considerations requires knowledge of the **macroeconomic consequences** of these strategies, about which little is known and which require further investigation.

With regard to the **regionally implementable CDR options** which could prospectively play an important role in climate protection policy, more intensive **application- and practically-based research** would appear to be necessary.

Legal framework and regulatory options

To date there are no **specific regulations** at a national, European or international legal level which address climate engineering in general and which could effectively prevent activities that may have negative impacts on the environment and humankind. There are a number of **reasons in favour of prompt international regulation, at least for research on climate engineering**: For example, large-scale field trials conducted without due care could themselves entail adverse environmental impacts. In view of the global character of many climate engineering options, undesirable developments can only be avoided by implementing regulations enshrined in international law.

Although **customary international law** contains certain rules which can be applied to all states, their content and interaction are too indefinite to permit statements about the permissibility of climate engineering activities. With regard to **international conventions**, only the signatories to the **London Protocol** (on the prevention of marine pollution) and the **Convention on Biological Diversity (CBD)** have recognised a relevant requirement for regulation. Although the decisions of the conference of the parties to the Convention on Biological Diversity address climate engineering activities in general, no legally binding effect results from this. The regulations of the London Protocol (once they come into force) are only legally binding on the signatory states and have only addressed climate engineering activities relating to ocean fertilisation.

A wide range of options is open for the further development of a regulation for climate engineering. **Extending the regulations under the Convention on Biological Diversity further** could be a good option since it is possible to build here on existing work, particularly if a more in-depth regulation is deemed an urgent necessity. One option, for instance, would be to **extend the regulatory approaches drawn up under the London Protocol to other climate engineering options** too and to make them an integral part of the Convention on Biological Diversity. Regulation under the **United Nations Framework Convention on Climate Change (UNFCCC)** appears attractive because of the closeness of the thematic link, though this could increase the already great complexity of international climate policy and thus jeopardise it. An alternative action would ultimately be to move towards a **new climate engineering-specific regime based on international law**. However, this can only be recommended as a long-term option since the negotiations needed to conclude a new convention can take several years.

It may be assumed that Germany could play a major part in drafting an international regulation for climate engineering in light of the country's political weight, but also in view of its pioneering role in climate protection.

TAB report no. 159

Climate engineering

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www.tab-beim-bundestag.de/en/research/u9900.html

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