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CLIMATE CHANGE

Preliminary Observations on Geoengineering Science, Federal Efforts, and Governance Issues

Statement of Frank Rusco, Director
Natural Resources and Environment

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Highlights

Highlights of GAO-10-546T, a testimony before the Committee on Science and Technology, House of Representatives

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CLIMATE CHANGE

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Why GAO Did This Study

Key scientific assessments have underscored the urgency of reducing emissions of carbon dioxide to help mitigate potentially negative effects of climate change; however, many countries with significant greenhouse gas emissions, including the United States, China, and India, have not committed to binding limits on emissions to date, and carbon dioxide levels continue to rise.

Recently, some policymakers have raised questions about geoengineering—large-scale deliberate interventions in the earth's climate system to diminish climate change or its potential impacts—and its role in a broader strategy of mitigating and adapting to climate change.

Most geoengineering proposals fall into two approaches: solar radiation management (SRM), which offset temperature increases by reflecting a small percentage of the sun's light back into space, and carbon dioxide removal (CDR), which address the root cause of climate change by removing carbon dioxide from the atmosphere.

Today's testimony focuses on GAO's preliminary observations on (1) the state of the science regarding geoengineering approaches and their effects, (2) federal involvement in geoengineering activities, and (3) the views of experts and federal officials about the extent to which federal laws and international agreements apply to geoengineering. To address these issues, GAO reviewed scientific literature and interviewed federal officials and scientific and legal experts.

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What GAO Found

Substantial uncertainties remain on the efficacy and potential environmental impacts of proposed geoengineering approaches, because geoengineering research and field experiments to date have been limited. GAO's review of relevant studies and interviews with experts to date found that relatively few modeling studies for SRM approaches have been published, and only limited small-scale testing—primarily of carbon storage activities relevant to CDR approaches—have been performed. Consequently, the experts GAO spoke with stated that a sustained effort of coordinated and cooperative research would be needed to determine whether proposed geoengineering approaches would be effective at a scale necessary to reduce temperatures and to attempt to anticipate and respond to potential unintended consequences—including the political, ethical, and economic issues surrounding the use of certain approaches. Specifically, just as the effects of climate change in general are expected to vary by region, so would the effects of certain large-scale geoengineering efforts, therefore, potentially creating relative winners and losers and thus sowing the seeds of future conflict.

Federal agencies have funded some research and small demonstration projects of certain technologies related to proposed geoengineering approaches; but these efforts have been limited, fragmented, and not coordinated as part of a federal geoengineering strategy. Officials from interagency bodies coordinating the federal response to climate change stated that their offices (1) have not developed a coordinated research strategy, (2) do not have a position on geoengineering, and (3) do not believe is it necessary to coordinate efforts due to the limited federal investment to date. In the event that the federal government decides to expand geoengineering research, GAO's interviews with experts suggest that transparency and international cooperation are key factors for any geoengineering research that poses a risk of environmental impacts beyond our borders. Further, GAO's past work indicates that a comprehensive assessment of costs and benefits that includes all relevant risks and uncertainties is a key component in strategic planning for technology-based research.

According to legal experts and federal agency officials, some existing federal laws and international agreements could apply to geoengineering research and deployment. However, some federal agencies have not yet assessed their authority to regulate geoengineering, and those that have done so have identified regulatory gaps. Although legal experts have identified some relevant international agreements and parties to two agreements have taken actions to address geoengineering, it is not certain whether and how other agreements would apply. Most scientific and legal experts GAO spoke with distinguished the governance of research from governance of deployment and noted that governance of geoengineering research with transboundary impacts, such as SRM approaches, should be addressed at the international level in a transparent manner and in consultation with the scientific community. However, the experts' views on the details of governance varied.

Mr. Chairman and Members of the Committee:

I am pleased to be here today to participate in the committee's hearing on geoengineering. Changes in the earth's climate attributable to increased concentrations of greenhouse gases may have significant environmental and economic impacts in the United States and internationally. These impacts are expected to vary across regions, countries, and economic sectors. Among other potential impacts, climate change could threaten coastal areas with rising sea levels, alter agricultural productivity, and increase the intensity and frequency of floods and tropical storms. Furthermore, the National Academies of Science (NAS) has reported that human alterations of the climate system may increase the possibility of large and abrupt regional or global climatic events, and that because abrupt climate changes of the past have not yet been fully explained, future abrupt changes cannot be predicted with any confidence, and climate surprises are to be expected.

Key scientific assessments have underscored the urgency of reducing emissions of carbon dioxide to help mitigate the negative effects of climate change; however, many countries with significant greenhouse gas emissions including the United States, China, and India, have not committed to binding limits on emissions to date, and carbon dioxide levels continue to rise.[1] In addition to mitigation, we have reported that policies to adapt to climate change could help reduce the vulnerability of countries and regions to potentially adverse impacts and may be viewed as part of a risk-management strategy for responding to climate change.[2] In particular, we reported that federal entities such as the President's Council on Environmental Quality (CEQ), the Office of Science and Technology Policy (OTSP), and the U.S. Global Change Research Program (USGCRP) had begun to develop governmentwide strategies to address climate change adaptation and reduce the nation's vulnerability to adverse impacts

[1]There are six primary greenhouse gases that are monitored and reported by countries in accordance with the United Nations Framework Convention on Climate Change: carbon dioxide, methane, and nitrous oxide, as well as three synthetic gases including hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Because greenhouse gases differ in their potential to contribute to global warming, each gas is assigned a unique weight based on its heat-absorbing ability relative to carbon dioxide over a fixed period. This provides a way to convert emissions of various greenhouse gases into a common measure, called the carbon dioxide equivalent.

[2]GAO, *Climate Change Adaptation: Strategic Federal Planning Could Help Government Officials Make More Informed Decisions*, GAO-10-113 (Washington, D.C.: Oct. 7, 2009).

from climate change. Recently, some policymakers have begun to raise questions about geoengineering—deliberate large-scale interventions in the earth's climate system to diminish climate change or its impacts—and what role, if any, it could play in a broad risk-management strategy for addressing climate change.[3]

A September 2009 study from the Royal Society[4]—the United Kingdom's national academy of science—categorized most geoengineering proposals into two approaches: solar radiation management (SRM), which would offset temperature increases by reflecting a small percentage of the sun's light back into space, thus reducing the amount of heat absorbed by the earth's atmosphere and surface, and carbon dioxide removal (CDR), which would address what scientists currently view as the root cause of climate change by removing carbon dioxide—a greenhouse gas—from the atmosphere.[5]

Examples of SRM approaches in the study include the following:

- increasing the reflectivity of the earth's surface through activities such as painting building roofs white, planting more reflective crops or biomass, or covering desert surfaces with reflective material;
- increasing the reflectivity of the atmosphere by whitening clouds over the ocean or injecting reflective aerosol particles into the stratosphere to scatter sunlight; and
- space-based methods to use shielding materials to reflect or deflect incoming solar radiation.

Examples of CDR approaches in the study include the following:

- enhancing biological, physical, or chemical land-based carbon sinks to capture and store carbon in biomass or soil (carbon sequestration), or in chemically reactive minerals (land-based enhanced weathering);

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[3]Geoengineering is also referred to as climate engineering or climate intervention.

[4]The Royal Society, *Geoengineering and the climate: science, governance and uncertainty* (London: September 2009).

[5]In addition to these two types of approaches, other large-scale interventions in the earth's climate system, such as removing other greenhouse gases from the atmosphere, have been considered as part of a potential response to reduce the impacts of climate change.

- enhancing biological, physical, or chemical ocean-based carbon sinks through the introduction of nutrients to promote phytoplankton growth (ocean fertilization), physically altering ocean circulation patterns to transfer atmospheric carbon to the deep sea, or adding chemically reactive minerals to increase ocean alkalinity (ocean-based enhanced weathering); and

- technology-based methods to remove carbon dioxide from the atmosphere (air capture) and then store the carbon dioxide—for example, in geological formations (geological sequestration).

According to the Royal Society study, while both approaches are ultimately designed to decrease temperatures, the discussed SRM approaches, once deployed, would only take a few years to reduce temperatures, but would create an artificial and approximate balance between increased atmospheric greenhouse gas concentrations and reduced sunlight that would introduce additional environmental risks and require long-term maintenance. In contrast, the discussed CDR approaches would take many decades to reduce global temperatures but, with some exceptions, involve fewer potential environmental risks because they would return the climate closer to its pre-industrial state. Additionally, certain SRM approaches, such as atmospheric aerosol injection, are considered to be relatively inexpensive to implement and generally hold greater potential for causing uneven environmental impacts beyond national or regional boundaries, thus risking undesirable social, ethical, legal, and political implications that would need to be addressed before any of these technologies are implemented. For example, the European Union has initiated a research program to study the scientific issues, as well as the policy implications of SRM geoengineering approaches. Domestically, NAS will be including geoengineering as part of its pending report on America's Climate Choices for Congress,[6] and some

[6]According to NAS, the final report for America's Climate Choices will examine issues associated with global climate change, including the science and technology challenges involved, and provide advice on actions and strategies the United States can take to respond. This report will be based on a series of workshop panels and other activities conducted in 2009.

nongovernmental organizations, such as the American Physical Society, have also undertaken studies to examine these issues in further detail.[7]

Within this context, our testimony today is based on our preliminary observations for the committee addressing (1) the general state of the science regarding geoengineering approaches and their potential effects, (2) the extent to which the federal government has sponsored or participated in geoengineering research or deployment, and (3) the views of legal experts and federal officials concerning the extent to which federal laws and international agreements apply to geoengineering activities. We expect to provide the committee with the final results of this review in a report issued later this year. Additionally, due to the interest of the committee and the strategic relevance of this topic, GAO has initiated a technology assessment on this topic which is also scheduled to be issued later this year.

To address these issues, we reviewed relevant studies from peer-reviewed literature, legal journals, and published policy studies related to geoengineering. We also identified a list of knowledgeable scientific, legal, and policy experts based on the following factors: participation on a geoengineering panel, the number of articles authored in peer-reviewed literature, and recommendations from other experts. From this list, we interviewed a sample of experts. Our interviews with other experts are ongoing. In addition, we met with officials and staff from interagency bodies coordinating the federal response to climate change, including OSTP, CEQ, and USGCRP, as well as the Department of Energy (DOE), which coordinates the Climate Change Technology Program (CCTP)—a multiagency research and development program for climate change technology. We also identified and reviewed federal laws and international agreements; interviewed international law experts; and interviewed officials from the Environmental Protection Agency's (EPA) Office of General Counsel, Marine Pollution Control Branch, and the Office of Water to discuss how federal laws are being or could be applied to activities related to geoengineering. Our work is ongoing, and we are continuing to collect and analyze information related to the objectives and findings presented in this testimony. We conducted our work on this testimony from December 2009 to March 2010 in accordance with

[7]According to its research proposal, the American Physical Society is currently conducting a study of the likely technological and economic potential of air capture technologies. Additionally, the National Commission for Energy Policy is also investigating the policy implications of geoengineering.

generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Substantial Uncertainties Remain Regarding Geoengineering Approaches and Their Potential Effects

Substantial questions remain on the efficacy and potential environmental impacts of proposed geoengineering approaches, in part, because geoengineering research and field experiments to date have been limited. According to the experts we spoke with, research related to proposed SRM geoengineering approaches is sparse. According to recent studies, much of the research into SRM approaches to date has been limited to modeling studies to assess the effects of either injecting sulfur aerosols into the stratosphere or brightening clouds to reduce incoming solar radiation at the earth's surface and produce a cooling effect. For example, one study found that combining a reduction of incoming radiation with high levels of atmospheric carbon dioxide could have substantial impacts on regional precipitation—potentially leading to reductions that could create drought in some areas.[8] Based on our literature review and interviews with experts to date, only one study has been published for a field experiment related to SRM technologies—a Russian experiment that injected aerosols into the middle troposphere.[9]

For CDR approaches, our discussions with experts, as well as our initial examination of relevant studies, found that a greater amount of research and number of field trials related to geological sequestration and ocean fertilization has occurred; but, these efforts were not necessarily designed for the purpose of applying the concepts to geoengineering. For example, according to the International Energy Agency (IEA),[10] several small-scale

[8]Gabriele C. Hegerl and Susan Solomon, "Risks of Climate Engineering," *Science* 325 (2009): 955-956.

[9]Yu. A. Izrael, V. M. Zakharov, N. N. Petrov, A. G. Ryaboshapko, V. N. Ivanov, A. V. Savchenko, Yu. V. Andreev, V. G. Eran'kov, Yu. A. Puzov, B. G. Danilyan, V. P. Kulyapin, and V. A. Gulevskii, "Field Studies of a Geo-engineering Method of Maintaining a Modern Climate with Aerosol Particles," *Russian Meteorology and Hydrology* 34, no. 10 (2009): 635-638.

[10]The IEA is an intergovernmental organization that acts as energy policy advisor to 28 member countries. Additional information on the IEA can be found at their website: http://www.iea.org. International Energy Agency, *Legal Aspects of Storing CO_2: Update and Recommendations* (Paris: 2007).

commercial applications of technology exist for injecting and monitoring the long-term storage of carbon dioxide in geologic formations. The IEA stated that the oldest of these started as a private-sector project in 1996 and now continues under funding from the European Commission. However, these projects are primarily associated with public and private initiatives to study, develop, and promote carbon capture and storage technologies as a greenhouse gas emissions reduction strategy, rather than the large scale that would be required to significantly alter the climate through geoengineering. Similarly, some ocean fertilization experiments using iron have been conducted as part of existing marine research studies or small-scale commercial operations. One expert familiar with these experiments noted that, while they improved scientific understanding of the role of iron in regulating ocean ecosystems and carbon dynamics, they were not specifically designed to determine the implications of ocean fertilization with iron as a geoengineering approach for large-scale removal of carbon dioxide from the atmosphere.[11]

Due to the limited amount of geoengineering research conducted to date, the experts we interviewed stated that a sustained program of additional research would be needed to address the significant uncertainties regarding the effectiveness and potential impacts of geoengineering approaches. Additionally, these experts noted that for certain approaches where transboundary impacts would be likely during field experiments, international cooperation for research would be necessary. Specifically, recent studies highlight the limitations of current models to accurately predict the environmental impact of SRM technologies at a regional scale—which would be necessary to accurately gauge potential impacts that might interfere with agricultural production for certain regions. Furthermore, studies indicate that, even for the most tested methods applicable to geoengineering, such as geological sequestration and ocean fertilization with iron, uncertainties remain surrounding the potential cost, effectiveness, and impacts of pursuing these approaches at a scale sufficient to reduce the amount of carbon in the atmosphere.

[11]According to the German Alfred Wegener Institute for Polar and Marine Research (AWI) and the Indian National Institute of Oceanography (NIO), the purpose of their joint ocean fertilization experiment last year was "to test a range of scientific hypotheses pertaining to the structure and functioning of Southern Ocean ecosystems and their potential impact on global cycles of biogenic elements." However, they noted that longer term experiments studying phytoplankton bloom development, and their effect on the deep ocean and underlying sediments, will have to be much larger than previous experiments.

Due to the potential for disparities in environmental outcomes from using these technologies—similar to the expected regional variation in climate change impacts—experts that we spoke with said that the political, ethical, legal, and economic issues surrounding the potential impacts of geoengineering technologies warranted close examination. These experts generally agreed that the policy implications for SRM and CDR approaches were very different. For example, certain SRM approaches, such as atmospheric aerosol injection, are generally perceived as being less costly to implement and would act more quickly to reduce temperatures than CDR approaches. However, these approaches are also associated with a greater risk of environmental impacts that cross national boundaries—which would have political, ethical, legal, and economic ramifications. Furthermore, according to several of these experts, the policy implications of SRM approaches are complicated by the fact that there are likely to be both positive and negative outcomes for nations or regions, and that one nation, group, or individual could conceivably take unilateral action to deploy one of these technologies. Experts emphasized that it is important to begin studying how the United States and the international community might address the ramifications of unilateral deployment of an SRM approach that would result in gains for some nations and losses for others. In contrast, with the exception of ocean fertilization, two of the experts we interviewed stated that most CDR approaches, such as air capture, would have limited impacts across national boundaries and could, therefore, mostly involve discussions with domestic stakeholders about societal, economic, and political impacts similar to those of existing climate change mitigation strategies. However, the Royal Society study noted that large-scale deployment of CDR approaches such as widespread afforestation—planting of forests on lands that historically have not been forested—or methods requiring substantial mineral extraction—including land or ocean-based enhanced weathering—may have unintended and significant impacts within and beyond national borders.[12]

[12]The Royal Society, *Geoengineering and the climate: science, governance and uncertainty.*

Federal Agencies Have Sponsored Some Research Activities, but These Activities Are Not Part of a Coordinated Federal Geoengineering Research Strategy

Our observations to date indicate that federal agencies such as DOE, National Science Foundation (NSF), U.S. Department of Agriculture (USDA), and others have funded some research and small-scale technology testing relevant to proposed geoengineering approaches on an ad-hoc basis. Some examples are as follows:

- For SRM approaches, DOE, through its Sandia National Laboratories, has sponsored a study investigating the potential unintended consequences and economic impacts of sulfur aerosol injection. Additionally, DOE has contributed a small amount of funding for modeling studies related to cloud-brightening and stratospheric aerosol SRM approaches at its Pacific Northwest National Laboratory—an effort that is primarily funded by the University of Calgary. For CDR approaches, DOE has sponsored research in both land-based and ocean-based carbon storage, including small-scale demonstration projects of geological sequestration as part of its Regional Carbon Sequestration Partnerships. In conjunction with other partners, DOE also provided funding for a study on carbon dioxide air capture technologies.

- NSF has funded projects relevant to both SRM and CDR approaches. For SRM approaches, NSF has sponsored some modeling studies for stratospheric aerosol injection and for a space-based SRM approach. NSF has also funded research investigating the ethical issues related to SRM approaches. For CDR approaches, NSF is supporting projects related to carbon storage in geological formations, saline aquifers, and biomass.

- Relevant to CDR approaches, USDA has supported research that examined land-based carbon storage approaches, such as biochar[13]—a way to draw carbon from the atmosphere and sequester it in charcoal created from biomass—through its Agricultural Research Service, and carbon sequestration in soil and biomass as part of its Economic Research Service.

- National Aeronautics and Space Administration (NASA) funded a research study investigating the practicality of using a solar shield in space to deflect sunlight and reduce global temperatures as part of its former

[13]Biochar is one by-product of heating biomass such as crop residue or wood wastes, in the absence of oxygen, in a process known as pyrolysis.

independent Institute for Advanced Concepts program.[14] Additionally, scientists at NASA's Ames Research Center, independent of headquarters, held a conference on SRM approaches in 2006, in conjunction with the Carnegie Institution of Washington.

- EPA has also sponsored research related to the economic implications of SRM geoengineering approaches through its National Center for Environmental Economics.

In addition to these efforts, federal officials noted that a large fraction of the existing federal research and observations on basic climate change and earth science could be relevant to improving understanding about proposed geoengineering approaches and their potential impacts. For instance, according to federal officials, ongoing research conducted by USGCRP agencies related to understanding atmospheric circulation and aerosol/cloud interactions could help improve understanding about the potential effectiveness and impacts of proposed SRM approaches. Similarly, these officials said that basic research conducted by USGCRP agencies into oceanic chemistry could help address uncertainty about the potential effectiveness and impacts of CDR approaches, such as ocean fertilization.

Staff from federal offices coordinating the U.S. response to climate change—CEQ, OSTP, and USGCRP—stated that they do not currently have a geoengineering strategy or position. Additionally, a USGCRP official stated that, while the USGCRP could establish an interagency working group to coordinate a federal effort in geoengineering research, such a group is not currently necessary because of the small amount of federal funding specifically directed toward these activities.

In the event that the federal government decides to fund a coordinated geoengineering research strategy, our review of relevant studies and interviews with experts to date identified some key factors for policymakers to consider when designing a federal strategy for geoengineering research. For example, the Royal Society study noted that

[14] According to its final report, the NASA Institute for Advanced Concepts (NIAC) was formed to provide an independent source of revolutionary aeronautical and space concepts that could dramatically impact how NASA develops and conducts its missions. As part of the NIAC selection process, the study related to SRM was selected through an open-solicitation and peer-reviewed competition, which was managed by the Universities Space Research Association, a private, nonprofit organization.

when there is a likelihood of transboundary impacts, such as the discussed SRM approaches, as well as one discussed CDR approach, ocean fertilization, transparency and international cooperation are key factors for pursuing geoengineering research. This point was reiterated by several experts at a recent panel discussion at the American Advancement for Science annual meeting. However, a couple of experts we interviewed noted that federal research for geoengineering approaches without likely transboundary impacts could be conducted independently of other countries, as is the case with the majority of currently proposed CDR approaches, such as air capture. Additionally, due to the variety of geoengineering approaches, several of the experts we interviewed recommended that federal geoengineering research should be an interdisciplinary effort across multiple agencies, and should be led by a multiagency coordinating body, such as OSTP or USGCRP.

Recent GAO work offers insights on key considerations for assessing risk and managing technology-based research programs. For example, we have reported on the advantages of using a formal risk-management approach and applying an anticipatory perspective when making decisions under substantial uncertainty.[15] Specifically, we reported that outlining the various alternative policy responses and the risks and uncertainties associated with pursuing each alternative is particularly important when prospective interventions require long lead times, high-stakes outcomes would likely result, and a delayed intervention would make impacts difficult to contain or reverse—conditions that could be considered relevant to the risks associated with climate change impacts. Furthermore, our review of DOE's FutureGen project—a program that partners with the electric power industry to design, build, and operate the world's first coal-fired, zero-emissions power plant—found that a comprehensive assessment of the costs, benefits, and risks of each technological option is an important factor when developing a strategic plan for technology-based research.[16]

[15]GAO, *Highway Safety: Foresight Issues Challenge DOT's Efforts to Assess and Respond to New Technology-Based Trends*, GAO-09-56 (Washington, D.C.: Oct. 3, 2008).

[16]GAO, *Clean Coal: DOE's Decision to Restructure FutureGen Should Be Based on a Comprehensive Analysis of Costs, Benefits, and Risks*, GAO-09-248 (Washington, D.C.: Feb. 13, 2009).

Existing Federal Laws and International Agreements Could Apply to Certain Geoengineering Activities, but Regulatory Gaps Remain

Existing federal laws and international agreements were not enacted or negotiated with the purpose or intent to cover geoengineering activities, but according to legal experts and federal officials, several existing federal laws and international agreements could apply to geoengineering research and deployment, depending upon the type, location, and sponsor of the activity. Domestically, however, interviews with agency officials to date and our past work indicate that federal agencies have not yet assessed their statutory authority to regulate geoengineering activities, and those that have done so have identified regulatory gaps. Examples include the following:

- EPA has authority under the Safe Drinking Water Act to regulate underground injections of various substances and is using this authority to develop a rule that would govern the underground injection of carbon dioxide for geological sequestration, which could be relevant to future CDR approaches. EPA issued a proposed rule on geological sequestration in July 2008. EPA officials told us that the final rule is currently scheduled to be issued in the fall of 2010. However, as EPA officials noted, the rulemaking was not intended to resolve many questions concerning how other environmental statutes may apply to injected carbon dioxide, including the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERLCA) and the Resource Conservation and Recovery Act of 1976 (RCRA), which apply to hazardous substances and wastes, respectively.[17,18] The White House recently established an interagency task force on carbon capture and storage to propose a plan to overcome the barriers to widespread deployment of these technologies. The plan will address, among other issues, legal barriers to deployment and identify areas where additional statutory authority may be necessary.
- Under the Marine Protection, Research and Sanctuaries Act of 1972, as amended, certain persons are generally prohibited from dumping material, including material for ocean fertilization, into the ocean without a permit from EPA.[19] Although EPA officials told us that the law's ocean dumping permitting process is sufficient to regulate certain ocean fertilization activities, including research projects, they noted that the law was limited to disposition of materials for fertilization by vessels or aircraft registered in the United States, vessels or aircraft departing from the United States,

[17]Pub. L. No. 96-510 (1980), as amended, *codified at* 42 U.S.C. §§ 9601-9675.

[18]Pub. L. No. 94-580 (1976), as amended, *codified at* 42 U.S.C. §§ 6921-6939f.

[19]Pub. L. No. 92-532 (1972), as amended, *codified at* 33 U.S.C. §§ 1401-1445.

federal agencies, or disposition of materials for fertilization conducted in U.S. territorial waters, which extend 12 miles from the shoreline or coastal baseline. Consequently, a domestic company could conduct ocean fertilization outside of EPA's regulatory jurisdiction and control if, for example, the company's fertilization activities took place outside U.S. territorial waters from a foreign-registered ship that embarked from a foreign port.

Additionally, agency officials and legal experts noted that other laws such as the National Environmental Policy Act of 1969 (NEPA) could also apply to certain geoengineering activities.[20] For example, NEPA requires federal agencies to evaluate the likely environmental effects of certain major federal actions by using an environmental assessment or, if the projects likely would significantly affect the environment, a more detailed environmental impact statement. A geoengineering activity could well constitute a major federal action requiring a NEPA analysis.

Although some geoengineering approaches, such as geological sequestration of carbon dioxide in underground formations, would not involve international agreements because the activities and their effects would be confined to U.S. territory, other SRM and CDR approaches would. Legal experts we spoke with identified a number of existing international agreements that could apply to geoengineering activities but none directly address the issue of geoengineering. Our initial work indicates that parties to two international agreements have taken action to address geoengineering activities, but it is still uncertain whether and how other existing international agreements that legal experts have identified as potentially relevant could apply to geoengineering.

In our work to date, legal experts have identified a number of existing international agreements, such as the 1985 Vienna Convention for the Protection of the Ozone Layer and the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, that could be relevant for injection of sulfate aerosols into the stratosphere and placement in outer space of material to reflect sunlight, respectively. However, these agreements were not drafted with the purpose or intent of applying to geoengineering activities and the parties to those treaties have not determined whether or how the agreement should apply to relevant geoengineering activities.

[20] Pub. L. No. 91-190 (1970), as amended, *codified at* 42 U.S.C. §§ 4321-4370f.

Moreover, once the parties make such determinations, they may have limited applicability because international agreements generally are only legally binding on countries that are parties to the agreement. For example, the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (also known as the London Protocol) generally prohibits the dumping of wastes or other matter into the ocean except for the wastes and matter listed in the London Protocol and for which a party to the agreement has issued a dumping permit that meets the Protocol's permitting requirements. In 2006, the parties to the London Protocol agreed to amend the Protocol to include, in certain circumstances, geological sequestration of carbon dioxide in sub-seabed geological formations on the list of wastes and other matter that could be dumped. However, only the 37 countries that are a party to the London Protocol and who have not objected to the amendment would be legally bound by it.

In two instances, the parties to international agreements have issued decisions but not amended the agreements regarding the agreement's application to ocean fertilization, including research projects. Generally these decisions by the parties are not considered to be legally binding, although they would aid in interpreting the international agreement. Specifically, the two instances are:

- Over the course of the last 2 years, parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters and the London Protocol to the Convention have decided that the scope of these agreements include ocean fertilization activities for legitimate scientific research. Accordingly, they have asked the treaties' existing scientific bodies to develop an assessment framework for countries to use in evaluating whether research proposals are legitimate scientific research and, therefore, permissible under the agreements. In addition, the parties have agreed that ocean fertilization activities other than legitimate scientific research are contrary to the aims of the agreements and should not be allowed. Meanwhile, the parties are considering a potentially legally binding resolution or amendment to the London Protocol concerning ocean fertilization.

- In 2009, the parties to the Convention on Biological Diversity issued a decision requesting that parties to the Convention ensure that ocean fertilization activities, except for certain small-scale scientific research within coastal waters, do not take place until there is an adequate scientific basis on which to justify such activities and a global, transparent, and effective control and regulatory mechanism is in place. The decision also urged the same from governments not party to the agreement.

In our interviews with legal experts to date, they suggested that governance of geoengineering research should be separated from the governance of deployment because scientists and policymakers lack critical information about geoengineering that would inform governance of deployment. The legal experts we spoke with all agreed that some type of regulation of geoengineering field experiments was necessary, but had different views as to the structure of such regulation. For example, some suggested a comprehensive international governance regime for all geoengineering research with transboundary impacts, under the auspices of the United Nations Framework Convention on Climate Change or another entity, while others suggested that existing international agreements, such as the London Convention and Protocol, could be adapted and used to address the geoengineering approaches that fall within their purview.

The scientific and policy experts we spoke with largely echoed the same themes and issues that the legal experts raised. Interviews with scientific experts to date suggest that governance issues related to geoengineering research with the potential for transboundary impacts should be addressed in a transparent, international manner in consultation with the scientific community. Some scientific and policy experts noted that the approach adopted by parties to the London Protocol engaged the scientific community about developing guidelines for assessing legitimate scientific research proposals that are not contrary to the treaties' aims, rather than prohibiting the scientific research necessary to determine the efficacy and impacts of ocean fertilization. Regarding geoengineering deployment, some scientific and policy experts noted that similar to the difficulties presented by achieving international consensus in carbon mitigation strategies—where there are definite "winners and losers" in terms of economic and environmental benefits—establishing a governance regime over geoengineering deployment for certain approaches may be equally challenging due to questions about whether deployment is warranted, how to determine an appropriate new environmental equilibrium, and compensation for adverse impacts, among other issues.

Mr. Chairman, this concludes my prepared statement. We look forward to helping this committee and Congress as a whole better understand this important issue. I would be pleased to respond to any questions that you or other members of the committee may have at this time.

GAO Contacts and Staff Acknowledgments

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