POLICY IMPLICATIONS OF GREENHOUSE WARMING

Policy Implications of Greenhouse Warming—Synthesis Panel

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Mitigation

Greenhouse warming is a global phenomenon, an important fact with regard to mitigation because releases of greenhouse gases have the same potential effect on global climate regardless of their country of origin. An efficient mitigation strategy for the United States would allow the United States to take cooperative action in other countries; some of the most attractive low-cost mitigation options may be in the poorest developing countries.

This analysis of mitigation costs and the potential for reducing potential greenhouse warming was developed by the Mitigation Panel and is derived almost entirely from experience and data in the United States. The analytical framework is general, however, and could be applied in other countries.

The application of this framework to a diverse array of mitigation options is a pioneering effort. These "first-order" analyses are meant only to be initial estimates of the cost-effectiveness of these options. They demonstrate a method that can be used in determining appropriate mitigation options. The intent is to illustrate the manner in which options should be evaluated with the best estimates available.

This analysis is a cross-sectional, as opposed to a longitudinal, analysis of options over time. It does not attempt, for example, to project future levels of economic activity and their implications for greenhouse gas emissions. The analysis does account, however, for future consequences of current actions. The direct effect of each option on greenhouse gas emissions is assessed. The panel does not examine those options under the different overall emission rates that might occur at future times. This analysis must therefore be seen as an initial assessment of mitigation options in terms of their return on investment under current conditions. A subsequent analysis should consider appropriate strategies under conditions existing at the time.

TABLE 6.1 Brief Descriptions of Mitigation Options Considered in This Study for the United States

RESIDENTIAL AND COMMERCIAL ENERGY MANAGEMENT	
Electricity Efficiency Measures	
White Surfaces/Vegetation	Reduce air conditioning use and the urban heat island effect by 25% through planting vegetation and painting roofs white at 50% of U.S. residences.
Residential Lighting	Reduce lighting energy consumption by 50% in all U.S. residences through replacement of incandescent lighting (2.5 inside and 1 outside light bulb per residence) with compact fluorescents.
Residential Water Heating	Improve efficiency by 40 to 70% through efficient tanks, increased insulation, low-flow devices, and alternative water heating systems.
Commercial Water Heating	Improve efficiency by 40 to 60% through residential measures mentioned above, heat pumps, and heat recovery systems.
Commercial Lighting	Reduce lighting energy consumption by 30 to 60% by replacing 100% of commercial light fixtures with compact fluorescent lighting, reflectors, occupancy sensors, and daylighting.
Commercial Cooking	Use additional insulation, seals, improved heating elements, reflective pans, and other measures to increase efficiency 20 to 30%.
Commercial Cooling	Use improved heat pumps, chillers, window treatments, and other measures to reduce commercial cooling energy use by 30 to 70%.
Commercial Refrigeration	Improve efficiency 20 to 40% through improved compressors, air barriers and food case enclosures, and other measures.
Residential Appliances	Improve efficiency of refrigeration and dishwashers by 10 to 30% through implementation of new appliance standards for refrigeration, and use of no-heat drying cycles in dishwashers.
Residential Space Heating	Reduce energy consumption by 40 to 60% through improved and increased insulation, window glazing, and weather stripping along with increased use of heat pumps and solar heating.
Commercial and Industrial Space Heating	Reduce energy consumption by 20 to 30% using measures similar to that for the residential sector.
Commercial Ventilation	Improve efficiency 30 to 50% through improved distribution systems, energy-efficient motors, and various other measures.

TABLE 6.1 *(continued)*

Oil and Gas Efficiency	Reduce residential and commercial building fossil fuel energy use by 50% through improved efficiency measures similar to the ones listed under electricity efficiency.
Fuel Switching	Improve overall efficiency by 60 to 70% through switching 10% of building electricity use from electric resistance heat to natural gas heating.
INDUSTRIAL ENERGY MANAGEMENT	
Co-generation	Replace existing industrial energy systems with an additional 25,000 MW of co-generation plants to produce heat and power simultaneously.
Electricity Efficiency	Improve electricity efficiency up to 30% through use of more efficient motors, electrical drive systems, lighting, and industrial process modifications.
Fuel Efficiency	Reduce fuel consumption up to 30% by improving energy management, waste heat recovery, boiler modifications, and other industrial process enhancements.
Fuel Switching	Switch 0.6 quads[a] of current coal consumption in industrial plants to natural gas or oil.
New Process Technology	Increase recycling and reduce energy consumption primarily in the primary metals, pulp and paper, chemicals, and petroleum refining industries through new, less energy intensive process innovations.
TRANSPORTATION ENERGY MANAGEMENT	
Vehicle Efficiency	
Light Vehicles	Use technology to improve on-road fuel economy to 25 mpg (32.5 mpg in CAFE[b] terms) with no changes in the existing fleet.
	Improve on-road fuel economy to 36 mpg (46.8 mpg CAFE) with measures that require changes in the existing fleet such as downsizing.
Heavy Trucks	Use measures similar to that for light vehicles to improve heavy truck efficiency up to 14 mpg (18.2 mpg CAFE).
Aircraft	Implement improved fanjet and other technologies to improve fuel efficiency by 20% to 130 to 140 seat-miles per gallon.

(Table 6.1 continues)

TABLE 6.1 *(continued)*

Alternative Fuels	
Methanol from Biomass	Replace all existing gasoline vehicles with those that use methanol produced from biomass.
Hydrogen from Nonfossil Fuels	Replace gasoline with hydrogen created from electricity generated from nonfossil fuel sources.
Electricity from Nonfossil Fuels	Use electricity from nonfossil fuel sources such as nuclear and solar energy directly in transportation vehicles.
Transportation Demand Management	Reduce solo commuting by eliminating 25 per cent of the employer-provided parking spaces and placing a tax on the remaining spaces to reduce solo commuting by an additional 15 percent.
ELECTRICITY AND FUEL SUPPLY	
Heat Rate Improvements	Improve heat rates (efficiency) of existing plants by up to 4% through improved plant operation and maintenance.
Advanced Coal	Improve overall thermal efficiency of coal plants by 10% through use of integrated gasification combined cycle, pressurized fluidized-bed, and advanced pulverized coal combustion systems.
Natural Gas	Replace all existing fossil-fuel-fired plants with gas turbine combined cycle systems to both improve thermal efficiency of current natural gas combustion systems and replace fossil fuels such as coal and oil that generate more CO_2 than natural gas.
Nuclear	Replace all existing fossil-fuel-fired plants with nuclear power plants such as advanced light-water reactors.
Hydroelectric	Replace fossil-fuel-fired plants with remaining hydroelectric generation capability of 2 quads.
Geothermal	Replace fossil-fuel-fired plants with remaining geothermal generation potential of 3.5 quads.
Biomass	Replace fossil-fuel-fired plants with biomass generation potential of 2.4 quads.
Solar Photovoltaics	Replace fossil-fuel-fired plants with solar photovoltaics generation potential of 2.5 quads.
Solar Thermal	Replace fossil-fuel-fired plants with solar thermal generation potential of 2.6 quads.

TABLE 6.1 *(continued)*

Wind	Replace fossil-fuel-fired plants with wind generation potential of 5.3 quads.
CO_2 Disposal	Collect and dispose of all CO_2 generated by fossil-fuel-fired plants into the deep ocean or depleted gas and oil fields.
NONENERGY EMISSION REDUCTION	
Halocarbons	
Not-in-kind	Modify or replace existing equipment to use non-CFC materials as cleaning and blowing agents, aerosols, and refrigerants.
Conservation	Upgrade equipment and retrain personnel to improve conservation and recycling of CFC materials.
HCFC/HFC-Aerosols, etc.	Substitute cleaning and blowing agents and aerosols with fluorocarbon substitutes.
HFC-Chillers	Retrofit or replace existing chillers to use fluorocarbon substitutes.
HFC-Auto Air Conditioning	Replace existing automobile air conditioners with equipment that utilizes fluorocarbon substitutes.
HFC-Appliance	Replace all domestic refrigerators with those using fluorocarbon substitutes.
HCFC-Other Refrigeration	Replace commercial refrigeration equipment such as that used in supermarkets and transportation with that using fluorocarbon substitutes.
HCFC/HFC-Appliance Insulation	Replace domestic refrigerator insulation with fluorocarbon substitutes.
Agriculture (domestic)	
Paddy Rice	Eliminate all paddy rice production.
Ruminant Animals	Reduce ruminant animal production by 25%.
Nitrogenous Fertilizers	Reduce nitrogenous fertilizer use by 5%.
Landfill Gas Collection	Reduce landfill gas generation by 60 to 65% by collecting and burning in a flare or energy recovery system.
GEOENGINEERING	
Reforestation	Reforest 28.7 Mha of economically or environmentally marginal crop and pasture lands and nonfederal forest lands to sequester 10% of U.S. CO_2 emissions.

(Table 6.1 continues)

TABLE 6.1 *(continued)*

Sunlight Screening	
Space Mirrors	Place 50,000 100-km^2 mirrors in the earth's orbit to reflect incoming sunlight.
Stratospheric Dust[c]	Use guns or balloons to maintain a dust cloud in the stratosphere to increase the sunlight reflection.
Stratospheric Bubbles	Place billions of aluminized, hydrogen-filled balloons in the stratosphere to provide a reflective screen.
Low Stratospheric Dust[c]	Use aircraft to maintain a cloud of dust in the low stratosphere to reflect sunlight.
Low Stratospheric Soot[c]	Decrease efficiency of burning in engines of aircraft flying in the low stratosphere to maintain a thin cloud of soot to intercept sunlight.
Cloud Stimulation[c]	Burn sulfur in ships or power plants to form sulfate aerosol in order to stimulate additional low marine clouds to reflect sunlight.
Ocean Biomass Stimulation	Place iron in the oceans to stimulate generation of CO_2-absorbing phytoplankton.
Atmospheric CFC Removal	Use lasers to break up CFCs in the atmosphere.

[a]1 quad = 1 quadrillion Btu = 10^{15} Btu.
[b]Corporate average fuel economy.
[c]These options cause or alter chemical reactions in the atmosphere and should not be implemented without careful assessment of their direct and indirect consequences.

SOURCE: Chapter 11 of the Mitigation Panel report.

TABLE 6.2 Comparison of Selected Mitigation Options in the United States

Mitigation Option	Net Implementation Cost[a]	Potential Emission[b] Reduction (t CO_2 equivalent per year)
Building energy efficiency	Net benefit	900 million[c]
Vehicle efficiency (no fleet change)	Net benefit	300 million
Industrial energy management	Net benefit to low cost	500 million
Transportation system management	Net benefit to low cost	50 million
Power plant heat rate improvements	Net benefit to low cost	50 million
Landfill gas collection	Low cost	200 million
Halocarbon-CFC usage reduction	Low cost	1400 million
Agriculture	Low cost	200 million
Reforestation	Low to moderate cost[d]	200 million
Electricity supply	Low to moderate cost[d]	1000 million[e]

[a]Net benefit = cost less than or equal to zero
Low cost = cost between $1 and $9 per ton of CO_2 equivalent
Moderate cost = cost between $10 and $99 per ton of CO_2 equivalent
High cost = cost of $100 or more per ton of CO_2 equivalent

[b]This "maximum feasible" potential emission reduction assumes 100 percent implementation of each option in reasonable applications and is an optimistic "upper bound" on emission reductions.

[c]This depends on the actual implementation level and is controversial. This represents a middle value of possible rates.

[d]Some portions do fall in low cost, but it is not possible to determine the amount of reductions obtainable at that cost.

[e]The potential emission reduction for electricity supply options is actually 1700 Mt CO_2 equivalent per year, but 1000 Mt is shown here to remove the double-counting effect (see p. 61 for an explanation of double-counting).

NOTE: Here and throughout this report, tons are metric.

SOURCE: Chapter 11 of the Mitigation Panel report.

TABLE 6.3 Cost-Effectiveness Ordering of Geoengineering Mitigation Options

Mitigation Option	Net Implementation Cost	Potential Emission Mitigation (t CO_2 equivalent per year)
Low stratospheric soot	Low	8 billion to 25 billion
Low stratospheric dust, aircraft delivery	Low	8 billion to 80 billion
Stratospheric dust (guns or balloon lift)	Low	4 trillion or amount desired
Cloud stimulated by provision of cloud condensation nuclei	Low	4 trillion or amount desired
Stimulation of ocean biomass with iron	Low to moderate	7 billion or amount desired
Stratospheric bubbles (multiple balloons)	Low to moderate	4 trillion or amount desired
Space mirrors	Low to moderate	4 trillion or amount desired
Atmospheric CFC removal	Unknown	Unknown

NOTE: The feasibility and possible side-effects of these geoengineering options are poorly understood. Their possible effects on the climate system and its chemistry need considerably more study and research. They should not be implemented without careful assessment of their direct and indirect consequences.

Cost-effectiveness estimates are categorized as either savings (for less than 0), low (0 to $9/t CO_2 equivalent), moderate ($10 to $99/t CO_2 equivalent), or high (>$100/t CO_2 equivalent). Potential emission savings (which in some cases include not only the annual emissions, but also changes in atmospheric concentrations already in the atmosphere—stock) for the geoengineering options are also shown. These options do not reduce the flow of emissions into the atmosphere but rather alter the amount of warming resulting from those emissions. Mitigation options are placed in order of cost-effectiveness.

The CO_2-equivalent reductions are determined by calculating the equivalent reduction in radiative forcing.

Here and throughout this report, tons are metric.

SOURCE: Chapter 11 of the report of the Mitigation Panel.