ENERGY POLICY: THE KEY TO LIMITING GLOBAL WARMING

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INTRODUCTION

At the request of Congress, the EPA conducted a major study of the policy options available to stabilize current levels of atmospheric greenhouse gas concentrations.[1] The major sectors contributing to emissions (energy, industry, agriculture, forestry), and the major greenhouse gases (carbon dioxide, chlorofluorocarbons, methane, nitrous oxide) were considered on a global basis. Scenarios of future greenhouse gas emissions, concentrations, and global warming were developed assuming that there is no policy response to the greenhouse gas buildup. Promising domestic and international policy options that could slow the buildup of greenhouse gases and global warming were then evaluated including: phasing out CFCs (chlorofluorocarbons), halting deforestation and initiating reforestation, increasing energy efficiency in transportation, buildings, and industry, placing a carbon emission fee on fossil fuels, and developing non-fossil fuel technology. This paper summarizes this scenario analysis, emphasizing the intimate connection between energy policy and the buildup of greenhouse gases and the rate of warming over the coming decades.

CURRENT TRENDS

Greenhouse gases are accumulating rapidly in the atmosphere. The concentration of carbon dioxide has increased 25% since preindustrial times, the concentration of methane has more than doubled, and CFCs have been introduced into the atmosphere for the first time.[2] During the 1980s carbon dioxide accounted for about half of increases in the greenhouse effect, followed by CFCs and methane (Figure 1a).[3] Considering the sources by activity, energy production and use accounted for about three-fifths, deforestation and agriculture accounted for about one fifth, and CFC use accounted for about one fifth (Figure 1b).[4]

Carbon dioxide emissions from fossil fuels grew rapidly from the end of World War II until the first "energy crisis" in 1973, after which time dramatic increases in energy efficiency, coupled secondarily with slower economic growth and the penetration of nuclear power, moderated emissions increases, particularly in industrialized countries took place.[5] Carbon dioxide concentrations continued to increase, however, because emissions remain greater than uptake by the oceans and any other sinks (Figure 2). Indeed, enormous reductions from current emissions would be required to stabilize greenhouse gas concentrations at current levels (Table 1).

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[1] D. Lashof and D. Tirpak, *Policy Options for Stabilizing Global Climate* (Draft Report to Congress, U.S. EPA, Washington, D.C.) 1989.

[2] V. Siegenthaler and H. Oeschger, "Biospheric CO_2 Emissions During the Past 200 Years Reconstructed by Deconvolution of Ice Core Data," *Tellus 39B*:140-145, 1987.; B. Stauffer, G. Fischer, A. Neftel, and H. Oeschger, "Increase of Atmospheric Methane Recorded in Antartica Ice Cores," *Science 229:*1386-1389, 1985.; R. Rasmussen and M. Khalil, "Atmospheric Trace Gases:Trends and Distributions Over the Last Decade," *Science 232:* 1623-1625, 1986.

[3] J. Hanson, I. Fung, A. Lacis, S. Lebedeff, D. Rind, R. Reudy, G. Russell, P. Stone, "Global Climate Changes as Forecast by the GISS 3-D Model," *Journal of Geophysical Research 93:*9341-9364, 1988.

[4] Lashof and Tirpak, *op cit.*

[5] G. Marland, "Fossil Fuels CO_2 Emissions: Three Countries Account for 50% in 1986," *CDIAC Communications* (Winter) 1989.

TABLE 1

REDUCTION IN ANTHROPOGENIC EMISSIONS REQUIRED TO STABILIZE CONCENTRATIONS

GAS	REDUCTION REQUIRED
Carbon Dioxide	50-80%
Methane	10-20%
Nitrous Oxide	80-85%
Chlorofluorocarbons	75-100%
Carbon Monoxide, Nitrogen Oxides	Freeze

Source: Lashof and Tirpak, *op cit.*

Future emissions of greenhouse gases are highly uncertain because future rates of economic growth and technological change cannot be predicted. In particular, the rate of future energy efficiency improvements is a critical parameter that is difficult to anticipate. An enormous potential for efficiency improvements has been documented with current technology, and many technological opportunities remain to be explored.[6] With the 1986 oil price collapse and the dismantling of Federal energy policy, however, the momentum for energy efficiency seems to be dissipating (at least in the United States). U.S. carbon dioxide emissions have increased about 5% between 1986 and 1988.[7] While this rate of growth is unlikely to continue indefinitely, a return to steadily increasing emissions is certainly possible in the absence of new policy initiatives.

In order to consistently explore some of the interacting factors that will determine future emissions, the EPA developed two alternative scenarios that assume no policy response to the greenhouse gas buildup. The Slowly Changing World (SCW) scenario assumes relatively sluggish economic growth but concomitantly slow technological change and capital stock turn-over. The Rapidly Changing World (RCW) scenario assumes more robust growth and technological change. These scenarios are intended to describe alternative self-consistent pictures of how the world might evolve and as such do not bound the full range of possible outcomes. They do provide a useful basis for analyzing the need for and impact of policy options. Based on these scenarios, it appears likely that the buildup of greenhouse gases will reach a level equivalent to a doubling of atmospheric carbon dioxide during the second quarter of the next century unless policy measures are adopted to alter current trends. Combining the range embodied in these scenarios with a range of uncertainty reflecting the sensitivity of the climate system to increases in greenhouse gases implies that the Earth is likely to warm between 2 and 6 degrees Celsius by the end of the next century (Figure 3). Even greater warming is possible if assumed rates of energy efficiency improvements do not materialize or if a number of positive feedbacks combine to amplify the climate system's response to increases in greenhouse gases.[8]

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[6] R. Cavanagh, C. Calwell, D. Goldstein, R. Watson, "Towards a National Energy Policy," *World Policy Journal* 239-264 (Spring) 1989.

[7] G. Marland and T. Boden, Testimony Before the Senate Committee on Energy and Natural Resources, July 26, 1989.

[8] D. Lashof, "The Dynamic Greenhouse: Feedback Processes That May Influence Future Concentrations of Atmospheric Trace Gases and Climate Changes," *Climatic Change* 14:213-242, 1989.

POLICY RESPONSES

There is a growing consensus that the risks associated with the "No Response" scenarios outlined above are unacceptable.[9] An attempt to formulate policy responses to reduce these risks has therefore begun.The EPA developed two "Stabilizing Policy" scenarios to explore what could be done to reduce the rate of warming from the levels obtained in the SCW and RCW scenarios discussed above. These scenarios (labeled SCWP and RCWP in Figure 3) involve a rate of warming that is at least 60% slower than in the corresponding No Response scenario given common assumptions regarding the sensitivity of the climate system. The Stabilizing Policy scenarios still involve considerable risk, however, as the world could still warm by more than 2 degrees Centigrade by 2100. A Rapid Reduction scenario was therefore developed to examine the kinds of policies that might be needed to achieve a greater level of climate stability.

Many individual policy measures account for the differences in emissions and warming between the No Response, the Stabilizing Policy, and the Rapid Reduction scenarios (Figures 4 and 5). Three major conclusions can be drawn from this analysis:

1. There are no silver bullets.
2. Energy efficiency is essential.
3. Energy efficiency is not sufficient.

Multiple Measures

No one of the measures illustrated in Figures 4 and 5 by itself appears to make a dramatic difference, but in combination they are able to effectively limit the greenhouse gas buildup. It is essential to keep this in mind in examining the potential contribution of individual technologies (e.g. photovoltaics) or policies aimed at individual sectors (e.g. automobiles). An individual measure that can reduce emissions by just a few percent is in fact very significant when combined with numerous other measures that achieve similar reductions.

The Need for Efficiency

Energy efficiency is essential to the success of any overall strategy to reduce greenhouse gas emissions because in a world of rapidly expanding demand all feasible supply options would have to be pursued simultaneously to prevent supply bottlenecks. Thus, for example, even if the market share of renewables increased rapidly there would still be large absolute increases in the consumption of fossil fuels. In the long-run, barring the development of economically and environmentally sound fusion power, the total energy that can be supplied by renewables is limited by land-use constraints, and long before absolute constraints are encountered, costs would rise sharply as the best sites are used up. Particularly troubling in a high demand worlds is the prospect of large-scale synthetic fuel production from coal as oil and gas resources are depleted. The environmental impacts of such a path would be devastatingeven in the absence of the enormous increase in carbon dioxide emissions that would be involved.

Fortunately, the opportunities for cost-effective energy efficiency increases are enormous. Examples of potential savings are given in Table 2. Similar potential exists in industry, although the savings are more difficult to describe because they depend on the details of

[9] See for example, *Report of the International Conference on the Assessment of the Role of Carbon Dioxide and Other Greenhouse Gases in Climate Variations and Associated Impacts,* Conference Statement, Villach, Austria (October 15,1985, WMO-NO 661), and *The Changing Atmosphere: Implications for Global Security,* Conference Statement, Toronto, Canada (June 30, 1988).

individual processes. The key to understanding the value of energy efficiency is to recognize that there is no demand for energy *per se*, rather individuals and firms demand the services that energy use can provide, such as a comfortable indoor environment, food preservation, and mobility. If such services can be provided using less primary energy the economy and the environment both benefit.

Table 2.

Examples of the Potential for Improved Energy Efficiency[10]

Energy Use	Current Intensity	Potential Intensity	Savings
Commercial Lighting	8.0 kWh/ft2/yr	1.5 kWh/ft2/yr	81%
Frost-Free Refrigerator	1100 kWh/yr	200 kWh/yr	82%
Electric Water Heater	3500 kWh/yr	1000 kWh/yr	71%
Windows in Commercial Buildings	70,000 Btu/ft2/yr	20,000 Btu/ft2/yr	71%
Windows in Residential Buildings	35 million Btu/yr	14 million Btu/yr	60%
Car Light Truck	420 gallons/yr	210 gallons/yr	50%

A wide variety of market failures and distortions create a strong bias toward energy supply rather than efficient use in delivering energy services. Even without considering environmental externalities, mismatches between purchasers and users, differential access to capital, and lack of information conspire to prevent the most efficient available technology from entering and penetrating the market. Policies designed to overcome these market failures based on least-cost energy planning (which puts supply and demand options on an equal footing) can dramatically reduce greenhouse gas emissions at a negative social cost.[11] In the EPA RCWP scenario, energy efficiency improvements account for about a 15% decrease in warming commitment by 2050 and a 25% decrease by 2100.

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[10] Estimates based on currently available technology. Natural Resources Defence Council, *Cooling the Greenhouse: Vital First Steps to Combat Global Warming* (NRDC, Washington, D.C.) 1989.

[11] *Ibid.*; H. Geller, "National Energy Efficiency Platform: Description and Potential Impact," Energy Efficiency Issues Paper No. 2, American Council for an Energy-Efficient Economy, July 1989.

THE ROLE OF RENEWABLE ENERGY

Although the potential from energy efficiency improvements is enormous, the reductions in greenhouse gas emissions required to stabilize climate cannot be obtained from efficiency improvements alone. While aggressive efficiency programs can be expected to decrease absolute energy demand and greenhouse gas emissions in industrialized countries, the enormous need to expand energy services in developing countries implies that efficiency improvements will at best moderate the growth in total demand. Thus if an effective greenhouse gas reduction strategy is adopted, renewable energy supplies will be needed in industrialized countries to replace existing supply systems as they are retired, and there will be an enormous requirement for renewables in developing countries to avoid new commitments to fossil fuels, particularly coal.

In the EPA's RCWP scenario, renewables account for a decrease in warming commitment similar to that from efficiency improvements--about 15% in 2050 and 25% in 2100. Much of this contribution comes from developing countries, although there is also significant penetration in industrialized countries. These scenarios particularly emphasize the potential contribution from modernizing biomass energy, both for producing electricity and fuels. Biomass is particularly important because current nonrenewable exploitation of biomass is contributing significantly to greenhouse gas emissions, whereas a commitment to reforestation in order to sustainably produce biomass energy would produce a net sink for carbon dioxide. Biomass systems are also particularly well suited to the needs and resources in developing countries. More generally, solar electric systems will be critical to avoid new commitments to coal-based power generation. In the long run, solar-based hydrogen production (using inexpensive photovoltaics or direct photolysis) may provide the best hope of developing a carbon-free energy system.

CONCLUSION

Human activity, particularly energy production and use, is now affecting the environment on a global scale. Continued increases in greenhouse gas concentrations along current trends would lead to unprecedented climatic changes, although regional impacts cannot be predicted in detail. The international community therefore faces an extraordinary challenge of risk management.

Although global warming is a long-term phenomenon, policies to begin stabilizing the atmosphere must be adopted immediately in order to minimize the risks of catastrophic climate change at the lowest possible cost. To get started on the path toward a stable atmosphere, last year's Toronto Conference on the Changing Atmosphere adopted a goal of reducing global CO_2 emissions 20% by the year 2005.[12] When the very low current level of per capita emissions in developing countries is taken into account, it is clear that the industrialized countries must cut faster and deeper than the world as a whole. Correspondingly at least twenty-six Senators have signed a letter to President Bush calling for a 20% reduction in U.S. CO_2 emissions by the year 2000.

The Natural Resources Defense Council has made preliminary calculations showing how this goal could be achieved.[13] The results show that by relying primarily on energy efficiency, with some contribution from renewable energy and reforestation, CO_2 emissions could be reduced 20% by 2000 while promoting other environmental and economic objectives. The U.S. Department of Energy has begun a process of public hearings and analysis that is intended to lead to the adoption of a "National Energy Strategy" by the end of 1990. This planning process is a crucial opportunity to implement least-cost planning principles in order to develop a detailed program to translate this emission reduction goal into reality.

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[12] Toronto Conference Statement, *op cit.*

[13] Natural Resources Defense Council, 1989, *op cit.*

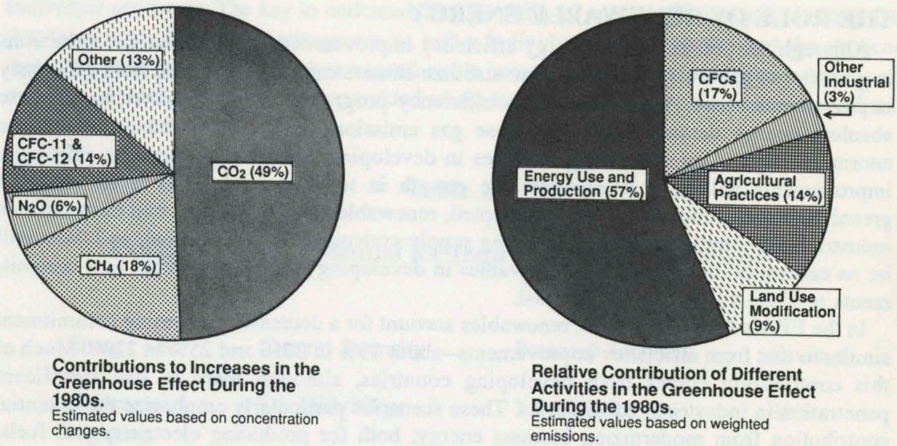


Figure 1. Relative Contributions to Increases in the Greenhouse Effect During the 1980s. (a) Based on Hansen et al., 1988, *op cit.* (b) Estimated based on emissions weighted according to (a). Source: Lashof and Tirpak, 1989, *op cit.*

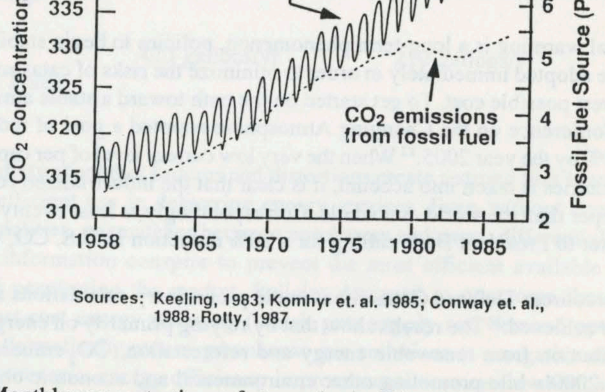


Figure 2. Monthly concentrations of atmospheric CO_2 at Mauna Loa Observatory, Hawaii, and global annual emissions of CO_2 from fossil fuel combustion. The yearly oscillation in CO_2 concentrations is explained mainly by the annual cycle of photosynthesis and respiration of plants in the northern hemisphere. Note that CO_2 concentrations have continued to increase since 1979, despite relatively constant emissions; this is because emissions have remained substantially larger than net removal, which is primarily by ocean uptake. Source: Lashof and Tirpak, 1989, *op cit.*

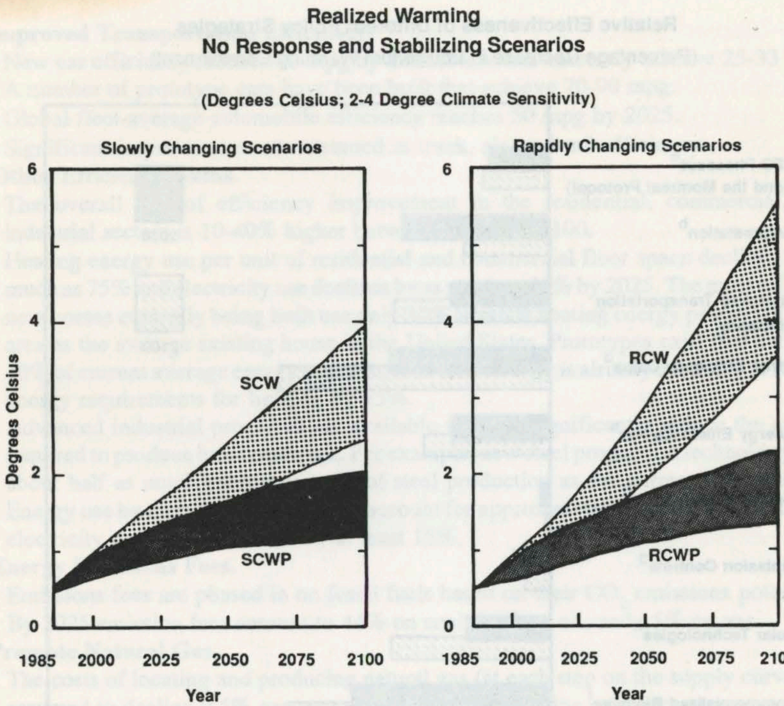


Figure 3. Realized warming in the No Response and Stabilizing Policy scenarios. The shading represents an uncertainty range based on a climate sensitivity of 2-4°C from doubling carbon dioxide concentrations. The scenarios are Slowly Changing World (SCW), Slowly Changing World with Stabilizing Policies (SCWP), Rapidly Changing World (RCW), and Rapidly Changing World with Stabilizing Policies (RCWP). For a given climate sensitivity, the rate of warming is at least 60% lower in the Stabilizing Policy scenarios compared to the No Response scenarios. Source: Lashof and Tirpak, *op cit.*

Impact of Stabilizing Policies on Global Warming—Notes

a. CFC Phaseout.

- Complete phaseout of fully halogenated CFCs by 2003 and a freeze on methylchloroform.
- Full participation in industrialized countries and 94% participation in developing countries.
- No controls on CFC substitutes (HCFCs).

b. Reforestation.

- Reforestation efforts are expanded dramatically starting in 1990 and deforestation halts by 2025. Deforestation is currently estimated to be 10 million hectares per year. The maximum rate of reforestation (which occurs between 1990 and 2015) is 26 million hectares per year; the current rate of reforestation is about 1 million hectares per year.
- The biosphere changes from a net source of about 0.7 billion tons of carbon per tear in 1985 to a net sink for CO_2 by 2000.
- Net uptake reaches 0.7 billion tons of carbon per year by 2025.
- One billion hectares are reforested by 2100 (an area roughly equal to the size of the United States; a 25% increase over the current forest area).

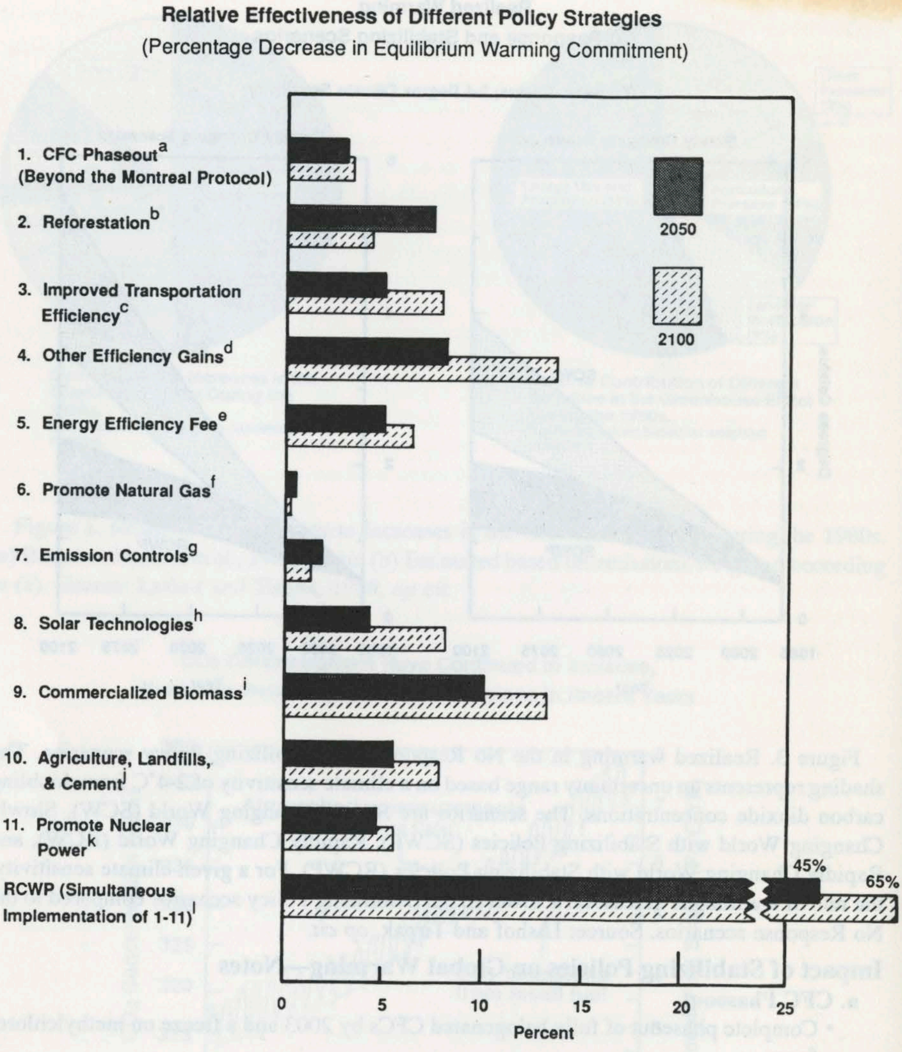


Figure 4. Reduction in warming commitment from individual components of the RCWP scenario. Percent reduction in equilibrium warming commitment over preindustrial levels in 2050 and 2100 due to 11 separate measures as well as all measures in the RCWP. Source: Lashof and Tirpak, *op cit.*

c. Improved Transportation Efficiency.

- New car efficiency reaches 40 mpg by 2000. New cars currently achieve 25-33 mpg. A number of prototype cars have been built that achieve 70-90 mpg.
- Global fleet-average automobile efficiency reaches 50 mpg by 2025.
- Significant improvements are assumed in truck, air, and rail efficiency.

d. Other Efficiency Gains.

- The overall rate of efficiency improvement in the residential, commercial, and industrial sectors is 10-40% higher between 2025 and 2100.
- Heating energy use per unit of residential and commercial floor space declines by as much as 75% and electricity use declines by as much as 50% by 2025. The most efficient new homes currently being built use only 30% as much heating energy per unit of floor area as the average existing house in the United States. Prototypes exist that use only 10% of current average energy requirements. Technology is already available to reduce energy requirements for lighting by 75%.
- Advanced industrial processes are available that can significantly reduce the energy required to produce basic materials. For example, new steel production technology uses about half as much energy per unit of steel production as the current U.S. average. Energy use by electric motors, which account for approximately 70% of U.S. industrial electricity use can be reduced by at least 15%.

e. Energy Emissions Fees.

- Emissions fees are phased in on fossil fuels based on their CO_2 emissions potential.
- By 2025 emission fees amount to 44% on coal, 24% on oil, and 15% on gas.

f. Promote Natural Gas.

- The costs of locating and producing natural gas (at each step on the supply curve) are assumed to decline 0.5% per year more rapidly than in the reference case.
- The share of fossil energy supplied by gas in 2025 is 26% versus 21% in the reference case and 22% currently. U.S. gas use in 2025 is about equal to the 1973 peak level. (Total gas production is actually somewhat lower in the policy case compared with the reference case because of lower total demand and competition with non-fossil fuels, particularly biomass).

g. Emission Controls.

- Low NO_x technology (equivalent of Selective Catalytic Reduction) is required in all new combustors by 2025.

h. Solar Technologies.

- The cost of electricity from solar technologies (PV, thermal, wind, etc.) is marginally competitive with electricity from oil and gas by 2000 (DOE goals) and strongly competitive by 2025. Solar photovoltaic (PV) cells are currently competitive for may remote power genertion needs, especially in developing countries. Dramatic progress has been made recently in reducing the costs of producing PV systems, particularly with thin-film amorphous silicon technology. Progress has also been made with solar thermal technology; 600 Megawatts of solar-thermal electrical capacity is currently being constructed under commercial contracts with Southern California Edison. The cost of production is expected to be about 8 cents/kilowatt-hour.
- Solar supplies 17% of global electricity in 2025 versus 4% in the reference case.

i. Commercialized Biomass.

- The productivity of tree plantations (tons/hectare/year) increases 65% by 2000 and the cost of energy produced from biomass declines about 50% by 2925. Between 2000 and 2100, 380 million hectares of plantations devoted to biomass production are gradually established. This represents about 9% of current forest and woodland area.

- Biomass-fired combustion turbines and biomass converted to gaseous and liquid fuels supply 21% of primary energy in 2025 versus 1% in the reference case. Currently, tradtional uses of biomass, mostly for cooking, account for roughly 10% of global enegy consumption. Traditional biomass use is extremely inefficient—approximately 10% in typical stoves. This energy use is not included in most tabulations of global energy supplies.

j. Agriculture, Landfills, and Cement.

- Methane emissions per unit of rice cultivation and domestic animals, and nitrous oxide emissions per unit of nitrogen fertilizer, are assumed to decline by 0.5% per year.
- Gas recovery and recycling are assumed to reduce methane emissions from landfills by 2% per year in industrialized countries; emissions level off by 2025 in developing countries.
- Demand for cement is assumed to be 25% less than in the reference case.

k. Promote Nuclear.

- The cost of nuclear technology declines by 0.5%/yr.
- Nuclear supplies 17% of electricity in 2025 versus 15% in the reference case. Currently nuclear supplies about 15% of electricity.
- Approximately 600 new power plants are built worldwide by 2025 (assuming 1000 MW per plant).

l. RCWP Scenario.

- The Rapidly Changing World with Stabilizing Policies (RCWP) scenario is obtained by applying all of the above assumptions simultaneously to the reference Rapidly Changing World (RCW) scenario.
- The total reduction is not equal to the sum of the individual measures.

Figure 5 — NOTES

Impact Of Rapid Reduction Polocies On Global Warming

[a]High carbon emissions fees are imposed on the production of fossil fuels in proportion to the CO_2 emissions potential. In this case, fees of \$8.50/GJ were imposed on unconventional oil production, \$5.70/GJ on coal, \$2.30/GJ on oil, and \$1.10/GJ on natural gas. These fee levels are specified in 1985\$ and are phased in over the period between 1985 and 2050.

[b]A percentage excise tax, proportional to the carbon content of the fuel, was levied on fuel use. Consumption taxes were also imposed in the RCWP case. In this case, the tax on coal consumption was increased from 28% of the price to 40%; the tax on oil use was increased from 20% to 30%; the tax on natural gas use was increased from 13% to 20%; the tax on electricity use was increased from 0 to 5%. These taxes were phased in and fully applied by 2025.

[c]Assumes that the average efficiency of new cars in the U.S. reaches 50 mpg (4.7 liters/100km) in 2000 and that global fleet-average auto efficiencies reach 65 mpg in 2025 (3.6 liters/100/km) and 100 mpg (2.4 liters/100 km) in 2050.

[d]Assumes that the rate of technical efficiency improvement in the residential and commercial sectors improves substantially beyond that assumed in the RCWP case. In this case, the rate of efficiency improvement in the residential and commercial sectors is increased so that a net gain in efficiency of 50% relative to the RCWP case is achieved in all regions.

[e]Assumes that, by 2050, average power plant conversion efficiency improves by 50% relative to the RCWP case. In this scenario the design efficiencies of all types of generating plants improve significantly. For example, by 2025, oil-fired generating stations achieve an average conversion efficiency roughly equivalent to that achieved by combined-cycle units

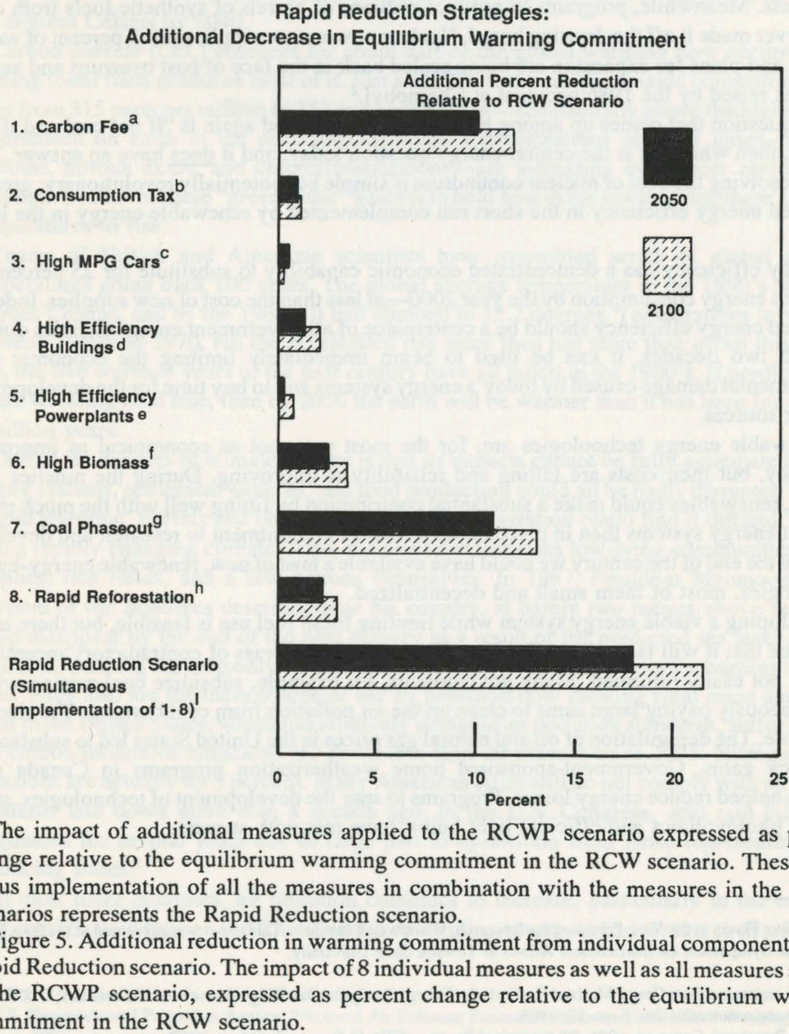
today.

[f]The availability of commercial biomass was doubled relative to the assumptions in the RCWP case. In this case the rate of increase in biomass productivity is assumed to be at the high end of the range suggested by the U.S. DOE Biofuels Program. Conversion costs were assumed to fall by half relative to assumptions in the RCWP case.

[g]Environmental fees of about $20/GJ (in 1985$) are phased in by 2050. This has the effect of gradually making coal uncompetitive in utility markets.

[h]A rapid rate of global reforestation is assumed. In this case deforestation is halted by 2000 and the biota become a net sink for CO_2 at a rate of about 1 Pg C per year by 2025, about twice the level of carbon storage assumed in the RCWP case.

[i]Impact on warming when all of the above measures are implemented simultaneously. The impact is much less than the sum of the individual components because many of the measures are not additive.



The impact of additional measures applied to the RCWP scenario expressed as percent change relative to the equilibrium warming commitment in the RCW scenario. Thesimultaneous implementation of all the measures in combination with the measures in the RCWP scenarios represents the Rapid Reduction scenario.

Figure 5. Additional reduction in warming commitment from individual components of the Rapid Reduction scenario. The impact of 8 individual measures as well as all measures applied to the RCWP scenario, expressed as percent change relative to the equilibrium warming commitment in the RCW scenario.