Chapter 1

Summary

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Chapter 1
Summary

CLIMATE CHANGE AND GREENHOUSE GASES

The first photographs from space brought home the fact that Earth is an integrated and isolated system. Concern that human impacts could be changing the equilibrium of this system grew in the 1970s as theories about ozone depletion and the ‘‘greenhouse effect developed. The concept of the Earth changing over various time scales was not *new:* solar and astronomical cycles, the waxing and waning of ice ages, and seasonal changes have long been recognized. What was new was the realization that humans can have a lasting and far-reaching impact on Earth’s natural fluctuations and cycles.

Potential human impacts on climate are linked to the globally increasing emission of “greenhouse gases’ [1] through activities such as burning fossil fuels (coal, oil, natural gas); deforestation; fertilizing croplands; and heating, air-conditioning, and lighting buildings. Greenhouse gases, like other atmospheric gases, allow sunlight to reach and warm the Earth’s surface; unlike other atmospheric gases, however, they trap much of the heat and keep it from escaping back into space. Such gases, therefore, aid in warming the surface of the Earth. Some of them-the chlorofluorocarbons (CFCs) and halons—also react with sunlight in the upper atmosphere to destroy the ozone layer around the Earth. In industrialized countries, greenhouse gas emissions are primarily related to energy use; with only 20 percent of the world population, these countries account for 75 percent of annual energy use, In developing countries, current greenhouse gas emissions are tied primarily to changes in land use practices (e.g., deforestation).

We cannot yet predict the magnitude of climatic effects from greenhouse gas emissions with accuracy. But it is clear that the decision to limit emissions cannot await the time when the full impacts are evident. The lag time between emission of the gases and their full impact is on the order of decades to centuries;[2] so too is the time needed to reverse any effects. Today’s emissions thus commit the planet to changes well into the 21st century. And the lag times between identification of policy options, legislation of controls, and actual implementation can also be considerable. For example, the recent reauthorization of the Clean Air Act took 10 years; implementation of the Act will begin now and continue over the next 10 to 20 years.

Among individual countries, the United States is the leading contributor of greenhouse gases. With 5 percent of the world’s population, the United States accounts for about 20 percent of the worlds warming commitment (ref. 56; see figure l-la). U.S. CO_2 emissions (20 percent of the global total) originate almost exclusively from fossil fuel combustion. Anthropogenic sources of methane in the United States account for about 6 percent of global emissions from all sources; among the anthropogenic sources, landfills, coal mining, and domestic animals account for most of the U.S. total (2, 24). The United States also consumes between 20 and 30 percent of the world’sCFC-11 and CFC-12, the two most damaging chlorofluorocarbons in terms of global warming. Roughly 60 to 70 percent of these CFCs are used in air-conditioning or in the production of thermal insulation; these gases are scheduled to be phased out by the year 2000 under the revised Montreal Protocol. U.S. nitrous oxide emissions (roughly 15 to 20 percent of the manmade global total; refs. 6, 24) originate primarily from fertilizer breakdown and high-temperature fossil-fuel combustion. Greenhouse gas emissions are closely entwined in the United States with energy use; currently, America uses about 15 times more energy per person than does the typical developing country.

The warming commitment or ‘‘radiative forcing caused by the different ***greenhouse*** gases is not equal. It depends on the absorbing characteristics, concentration in the atmosphere, and the lifetime of each gas. Although the other gases are more potent on a per molecule basis, currently CO_2 accounts for

[2]The atmospheric lifetime of CO_2 is 50 to 200 years; N_2O, about 150 years; CFCs and halons, from 60 to 400 years; and CH_4, 10 years. CFC replacements allowed under the Montreal Protocol for the next several decades have lifetimes of less than 40 years,

[3]The U.S. Department of Energy (DOE) found that of an 18-percent reduction in residential energy use between 1972 and 1984, one-third was due to behavioral changes (53).

Box l-A—The OTA Study in Context

The six congressional committees requesting this assessment asked OTA to focus on a very specific question: ‘‘Can the United States reduce carbon dioxide emissions in the near term?”

Changing by Degrees does not examine in depth many equally difficult questions such as the science of climate change, the uncertainties and state of atmospheric modeling, or the projected ecological effects of global warming. Rather, most of OTA’s resources have been devoted to analyzing technical options to decrease CO_2, although methane, nitrous oxide, and chlorofluorocarbon (CFC) emissions are addressed wherever possible. At the time of their request, the congressional committees were well aware of ongoing international efforts to phase out CFCs and halons; since OTA’s study began, successful negotiations have been completed.

To answer the question Congress posed, OTA focuses specifically on potential emissions reductions in the next 25 years. The analysis is structured around six key sectors of the U.S. economy: Buildings, Transportation, Manufacturing, Energy Supply, Forestry, and Food. To the extent possible, the report quantifies the potential for emissions reduction within each sector—areas where gains in efficiency, product substitution, conservation, or other technical options can ameliorate increases in CO_2 and other greenhouse gases. A selection of policy options that appear to offer the most promise for achieving these reductions in the United States is presented. OTA was charged to look abroad as well, so the special needs of Eastern Europe, the U. S. S. R,, and developing countries-with respect to both energy and natural resource issues—are also addressed.

In our detailed analysis of potential emissions reductions for the United States, we consider an extensive suite of technical options. For example, we estimate the potential increments of CO_2 reduction from electric utility fuel switching, possible improvements in automobile efficiency, changes in commercial building construction, more efficient manufacturing processes, etc. Most of the options relate to decreasing emissions, although some, such as reforestation, involve recapturing gases already emitted to the atmosphere.

The assessment lays out three paths: a Base case (“business as usual”), a Moderate (essentially “no-cost”) case, and a Tough case. Only the last fulfills the congressional request and reduces future $C0_2$ emissions—to a level in 2015 that is 20 to 35 percent lower than today. Some will argue that our estimates of emissions reductions are both politically unattainable and costly. Others will decry a 20-to 35-percent reduction as not being nearly enough; the Intergovernmental Panel on Climate Change and the U.S. Environmental Protection Agency recently estimated that the world must reduce CO_2 emissions by at least 50 to 80 percent to stabilize the atmosphere. Congress’ request that we work within a 25-year timeframe in the study proved to be a two-edged analytic sword. It forced OTA to take a close look at where U.S. $C0_2$ emissions were heading without policy intervention. But, 25 years also is too short a period to include a scenario in which fossil fuels are supplanted with such nonfossil fuel sources as renewable and improved nuclear energy sources.

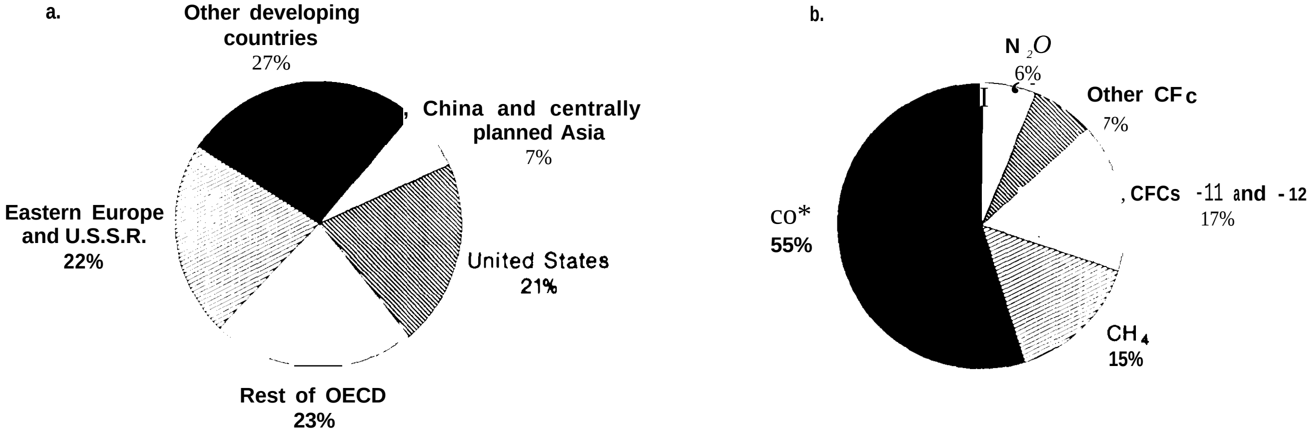
Indeed, the United States described 25 years hence in this report does not sound fundamentally different from what we know today. However, an underlying theme in OTA’s report is that a strong R&D effort is pivotal to bringing non-$C0_2$ (i.e., nonfossil fuel) sources to commercialization as quickly as possible, even as all sectors of the economy move to use more efficient equipment and decrease energy consumption. If long-term R&D is geared to that purpose, then new nonfossil supply technologies can start to replace existing powerplants and equipment early in the next century.

Many of the technical options evaluated here are worth pursuing for other reasons in addition to climate change, because they address other important U.S. goals such as energy security, local environmental quality, and economic competitiveness. They can reduce emissions in the short-term, reduce total energy demand, and serve to bridge the U.S. economy from a fossil-fuel age to a nonfossil future.

The warming commitment or ‘‘radiative forcing’ caused by the different greenhouse gases is not equal. It depends on the absorbing characteristics, concentration in the atmosphere, and the lifetime of each gas. Although the other gases are more potent on a per molecule basis, currently CO_2 accounts for an estimated 55 percent of the commitment to global warming. This is largely due to the fact that so much CO_2 has been emitted worldwide (6 billion metric tons of carbon in 1988) as to swamp the higher radiative forcings per unit of the other gases (24). Still, CFCs are responsible for 24 percent of the current commitment to global warming; CH_4 is responsible for 15 percent and N_2O for 6 percent (see figure l-lb).

Recently, public interest and concern over global changes intensified with the discovery of the annual ozone hole over Antarctica, thinning ozone over the

Figure I-I—Greenhouse Gas Emissions in 1985, by Region, and the Contribution of Each Greenhouse Gas to Global Warming in the 1980s



NOTE: Figure at left shows the share of greenhouse gas emissions by region, weighted by their contribution to radiative forcing between 1980 and 1990. It includes all greenhouse gases and CO_2 from deforestation and fossil fuel use. Estimates for CO_2 emissions from deforestation *range* from less than 10 to about 30 percent of total CO_2. If the upper range proves to be correct, developing countries' shares would be larger. Figure at right shows the contribution of each of the manmade greenhouse gases to the change in radiative forcing from 1980 to 1990. The contribution from urban ozone may also be significant, but cannot be quantified at present.

SOURCES: Figure at left: adapted from U.S. Environmental Protection Agency, 1990. Figure at right: Intergovernmental Panel on Climate Change, Scientific *Assessment of Climate Change,* Summary and Report, World Meteorological Organization/U.N. Environment Program (Cambridge, MA: Cambridge University Press, 1990).

Arctic, the severe drought of 1988, and recent abnormal weather patterns in Europe. International concern was demonstrated by the recent rapid renegotiation of the Montreal Protocol to completely phase out CFCs and assist developing countries in achieving that goal. Many industrialized countries, principally in Europe, have further called for a 20-percent reduction in CO_2 emissions from the developed world by 2000 or shortly thereafter; several have pledged to freeze or reduce emissions whether or not the rest of the world participates.

Meanwhile, there is debate here as to whether and when a freeze or a 20-percent reduction in U.S. greenhouse gas emissions could be achieved in the near-term. A 20-percent reduction in U.S. $C0_2$ emissions would represent a 3-percent decline in current worldwide emissions of CO_2 and less than a 2-percent decline in current worldwide emissions of all greenhouse gases. More importantly, however, even if a 20-percent cut by all developed Nations could be achieved, it would not be enough to stabilize the atmosphere at today's level, let alone to reduce greenhouse gases to pre-industrial levels. To stabilize the atmosphere, the Intergovernmental Panel on Climate Change (24) and the Environmental Protection Agency (EPA) (56) suggest, would require much more—up to an 80-percent global reduction in CO_2 emissions from current levels as well as significant reductions in the other greenhouse gases. To achieve this under the combined pressures of economic and population growth, nonfossil fuel technologies such as solar or nuclear power would be needed to replace much of today's fossil fuel use.

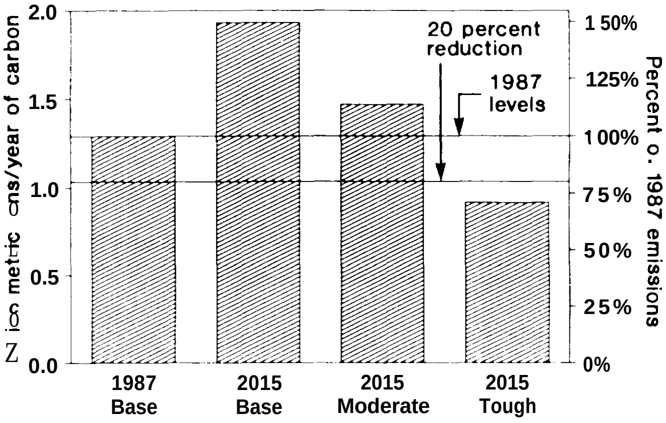
Energy conservation is the logical first step for the United States if it wishes to reduce its own CO_2 emissions below present levels over the next 25 years. For comparison, if no actions are taken, emissions of CO_2 will likely rise 50 percent during the next quarter century. Under a set of modest policies designed to encourage people to choose technologies that are cost-effective, emissions of CO_2 probably will rise about 15 percent over the next 25 years. This policy package is labeled OTA's "Moderate' scenario.

OTA also identified an energy conservation, energy-supply, and forest-management package that can achieve a 20- to 35-percent emissions reduction. This package is labeled OTA's "Tough" scenario. While difficult to achieve, major technological breakthroughs are not needed. Existing equipment would not have to be instantly scrapped and replaced with untested prototypes. The requisite energy-related technologies are either already available or are demonstrated and close to commercialization today. Most of the forestry-related practices also are proven and already commercialized. OTA's Tough scenario thus does not represent ''maximum technical potential. ' Although it could be argued, for example, that there is a ''technical potential' for a massive return to nuclear power by 2015, we assume that this is not feasible for the United States, given lead times and current public concerns. Likewise, we assume that a massive penetration of solar-based electricity generation will not take place by then. Nor will most people be driving 80 mile per gallon (mpg) cars, although prototypes are available today. In each of these cases, though, increased research, development, and demonstration (RD&D) could bring substantial benefits within a half-century.

In the OTA analysis of' energy-related activities, only those technical options that would result in CO_2 emissions reductions without loss of comfort or convenience were examined. If implemented, the energy conservation options discussed in our Moderate scenario would likely save consumers money over the lifetime of, for example, an energy-using appliance, given today energy costs. Greater reductions are quite feasible, as our Tough scenario shows, with technologies that are either technically challenging or more expensive. Even greater reductions are possible if consumers can be persuaded to forego some amenity or comfort;[3] however, because many such actions are reversible, they may not continue if energy prices drop and so are not considered here.

U.S. carbon dioxide emissions in 1987 expressed as carbon equivalents were about 1.3 billion metric tons per year (see figure 1-2). OTA projects that under 'business-as-usual'" conditions (i.e., our Base case) emissions in 2015 will rise to 1.9 billion metric tons per year. In order to reduce emission levels 20 percent below 1987 levels by 2015 (i.e., to about 1.0 billion metric tons), we must not only attain zero growth over the 1987 level, but must also trim that level by an additional 0.3 billion metric tons. As figure 1-2 shows, a 20-percent emissions reduction is much more than OTA's Moderate scenario but less than its Tough scenario.

Figure 1-2-Summary of OTA's Analysis of Carbon Emissions With and Without "Moderate" and "Tough" Controls



SOURCE: Office of Technology Assessment, 1991.

During the 1970s the extraordinary freeze in energy consumption-while the Gross National Product (GNP) grew 35 percent—was about two-thirds due to increases in energy efficiency and one-third due to structural change[5] in the economy. Investments in more efficient technologies were facilitated by higher energy prices and the regulatory climate. We already have shown our ability as a Nation to change our energy consumption patterns.

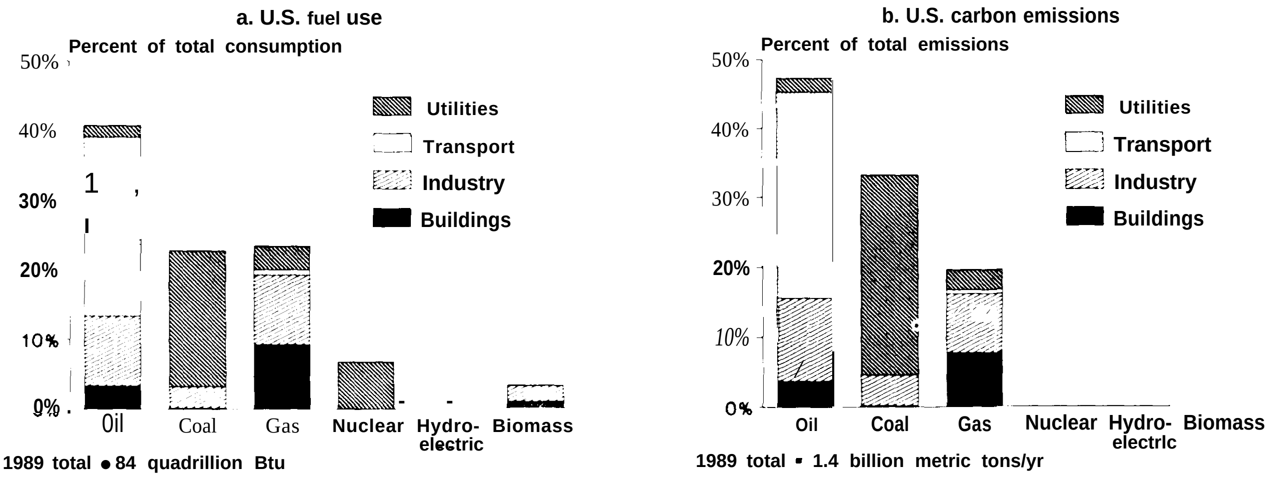
The Nation's track record gives us confidence that such improvements could continue to be achieved, especially if energy prices were to significantly rise again. To achieve lasting reductions in energy consumption, government signals (e.g., pricing and regulatory policies) need to be consistent and reinforcing. Otherwise we are likely to see reversals—as in the 1980s, when energy prices decreased and U.S. fossil fuel consumption started climbing again. For example, higher gasoline prices in the 1970s and early 1980s led to increased purchases of fuel-efficient automobiles. As gasoline prices fell and long-term energy problems were discounted by national leaders, car buyers shifted their attention away from efficiency toward higher luxury and power. Similarly, Federal R&D funding for renewable technology plummeted 90 percent (in constant dollars), from $1.3 billion in 1980 to $0.14 billion in

[3] The U S Department of Energy (DOE) found that of an 18-percent reduction in residential energy use between 1972 and 1984, one-third was due to behavioral changes (53).

[4] U S CO_2 emissions were 4.7 billion metric tons. For the purposes of this report, all emissions are shown as weight of carbon. To convert to CO_2 equivalent, multiply the weight of carbon by 3.67.

[5] I.e., declines in energy-intensive industry and increases in the service sector. For further details see ref. 47.

Figure 1-3—U.S. Energy Consumption and Associated Carbon Emissions in 1989



NOTE: Emission estimates in the right-hand figure calculated by multiplying fuel use (from left-hand figure) by fossil-fuel carbon emission factors. Coal, 55 to 60 lbs C/mmBtu; oil, 45 lbs C/mmBtu; gas, 32 lbs C/mm Btu. Wood emissions are similar to coal; however in the United States, wood is currently regrown, so we show no net emissions for biomass.

SOURCES: Office of Technology Assessment, 1991, using DOE, '1990.

1990 (see figure 1-6 below), The United States has recently become a net importer of solar thermal and wind systems after dominating the market in the mid- 1980s.

A variety of policy interventions will be required to reduce CO_2 emissions 20 to 35 percent below current levels by the year 2015. These could include regulatory ''push' and market ''pull' mechanisms to provide maximum encouragement and flexibility. They could affect both energy supply and demand and forestry and agricultural practices. Without an increase in and refocusing of current Federal initiatives—including performance standards, incentive programs, energy taxes, and RD&D activities—the use of greenhouse gas reducing technologies is unlikely to increase greatly in the next few decades.

Many of the measures discussed in this study will have ancillary environmental benefits, including abating acid rain, urban smog, ozone depletion in the stratosphere, and groundwater contamination. Decreasing oil use—primarily affecting the transportation sector—will reduce our dependence on foreign oil. Developing and producing renewable energy technologies with worldwide applicability may strengthen U.S. trade markets and our competitiveness abroad. Given that about a dozen industrialized countries have officially pledged to stabilize or reduce CO_2 emissions by 2005, and that energy demand in rapidly growing, developing countries must increase, burgeoning markets for efficient and lower CO_2-emitting technologies are likely. The United States, as the world's largest producer of greenhouse gases, has an opportunity both to set a good example and be in the forefront of developing new markets for the associated technologies and products.

U.S. SECTORAL ANALYSES AND PROJECTIONS OF CO_2 EMISSIONS

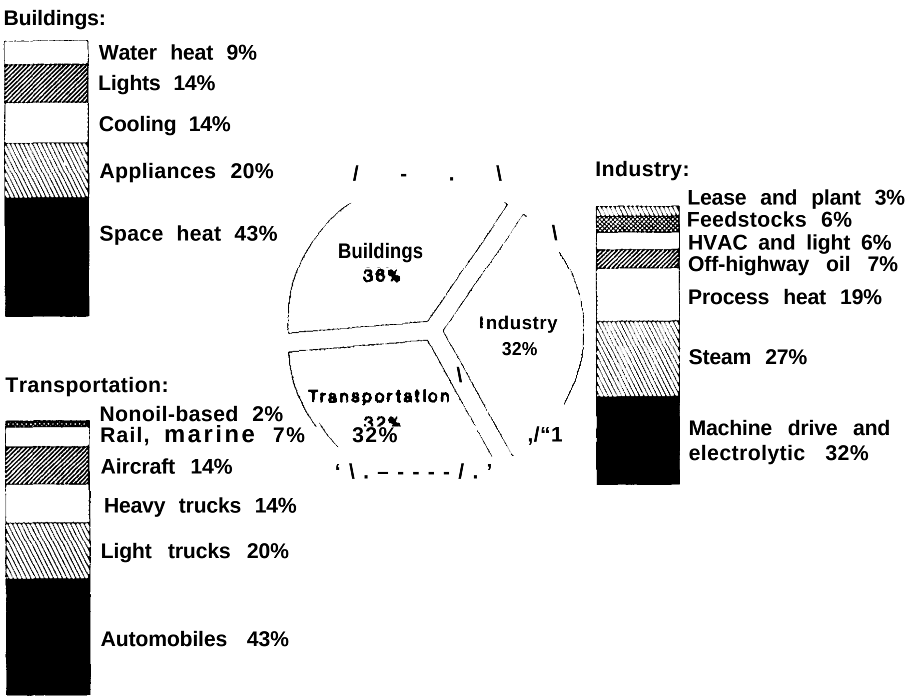
Current Emissions

Total U.S. energy use has risen since 1987, the year OTA's modeling effort begins. In 1989, energy use was about 84 quads (quadrillion British thermal units). As shown in figure 1-3a, in 1989 oil accounted for about 40 percent, coal and gas each provided about 23 percent, nuclear power provided 7 percent, and hydroelectric power and biomass each contributed about 3 to 4 percent of energy use.[7]

[6]As of January 1991, Austria, Australia, Canada, Denmark, France, Germany, Italy, Japan, The Netherlands, New Zealand, Norway, Sweden, United Kingdom, Some of these countries' policies are still subject to change.

[7]Data for 1989 energy consumption are from ref. 54.

Figure 1-4-1987 U.S. CO_2 Emissions by Sector



NOTE: Total carbon emissions from all three sectors equaled about 1.3 billion metric tons in 1987. Emissions have continued to increase since then.

SOURCE: Office of Technology Assessment, 1991.

About two-thirds of the total energy was used directly as fuel in "end uses," for example as gasoline to run our cars and natural gas to heat our homes. Another 35 percent was used to generate electricity; well over half of that electricity was generated from coal.

Carbon dioxide emissions (as carbon) from energy use in the United States in 1989 totaled about 1.4 billion metric tons (this is up from 1,3 billion metric tons in 1987), about 20 percent of the world total. As shown in figure l-3b, oil accounted for about 48 percent of carbon emissions, coal about 34 percent, and natural gas about 18 percent. One-third of the energy was used to generate electricity. Oil dominates direct uses; coal dominates electricity generation. Coal and wood contain the highest concentrations of carbon per unit energy--commonly about 55 to 60 pounds of carbon per million Btu (lbs C/mmBtu). Natural gas has the lowest concentrations (32 lbs C/mmBtu) and petroleum is intermediate (45 lbs C/mmBtu).

When the emissions from the generation of electricity are allocated to the sector in which the electricity is used, total emissions from energy use are roughly equal in the buildings, transportation, and industrial sectors. Figure 1-4 displays emissions by sector, as well as the major components within each sector. We have detailed estimates of how energy was used in 1987, the reference year for our model. For that year, 36 percent of carbon emissions were from the buildings sector—about 20 percent from activities within our homes and apartments and 16 percent from energy use in commercial buildings.[8] Another 32 percent of emissions are transportation related and 32 percent come from industry.

Future Emissions Scenarios

For the energy-related sectors, OTA projected future CO_2 emissions under a "business as usual" scenario--our baseline or ''Base' case. Two scenarios were then modeled, based on ''Moderate' and ''Tough" technical measures respectively (see

[8]Of the 36 percent of total CO_2 emissions coming from the buildings sector, one-third is from fossil fuels (i.e., oil and gas) burned directly within residential and commercial buildings; two-thirds come indirectly as a result of the generation of electricity used in buildings.

box 1-B for a description of the model). Moderate measures typically require some initial capital investment but later save money through future fuel savings; in most cases savings more than compensate for initial costs. None of the measures are difficult to achieve technically, though inducing consumers to use them may not be easy.

The ''Tough' measures would lower energy demand even further, but in many cases at a higher cost for the same level of convenience and comfort All of the Tough measures analyzed are technically feasible, but most are not based on the best available prototypes or practices; OTA made judgments about what will be feasible for widespread use. Fully implementing the Tough measures would be challenging-politically, logistically, and perhaps economically.

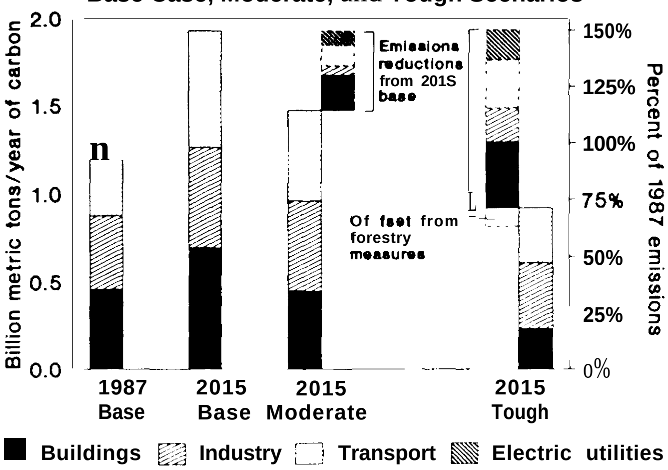
The model only included energy-related sectors. For the forestry sector, OTA independently evaluated Moderate and Tough measures; these were chosen by the same criteria as measures in the model (i.e., difficulty and cost) and estimates of $C0_2$ uptake over time were calculated. Data were not sufficient to calculate potential emissions reductions from the food sector.

Overall Modeling Results

Based on the OTA energy modeling analysis, under current trends and regulations carbon emissions by 2015 will be close to 50 percent greater than today's level—almost 1.9 billion metric tons per year (see figure 1-5). This Base case projection assumes that some efficiency improvements will occur even in the absence of new legislation. For example, by then we assume new homes will require 15 percent less heating, recently adopted appliance standards will have taken effect, and new cars will average close to 37 mpg.

By adopting all Moderate measures that lower energy demand, CO_2 emissions in 2015 could be held to about a 22-percent increase over 1987 levels. The emissions savings achieved by the Moderate measures are shown for each demand sector (buildings, transportation, industry) as well as for electricity supply in figure 1-5. Changes in the fuel mix used to generate electricity can lower emissions an additional 6 to 7 percent, The Moderate forestry

Figure 1-5-Carbon Emissions Under the Base Case, Moderate, and Tough Scenarios



NOTE: The boxes outlined with dashed lines represent the *reductions* in carbon emissions associated with control measures applied in each of the three demand-side sectors (i.e., buildings, industry, and transportation) and electricity supply (electric utilities); additional *carbon offsets* afforded by forestry measures are also shown. The boxes outlined with solid lines represent *total* emissions from each demand-side sector. Emissions associated with electricity generation have been allocated to the three demand-side sectors.

SOURCE: Office of Technology Assessment, 1991.

measures provide about a 0.2-percent offset in carbon emissions by 2015. All Moderate measures together hold emissions to 15 percent above 1987 levels.

Finally, OTA's Tough scenario could lower net emissions by 2015 (excluding offsets from forestry measures) to 29 percent below 1987 levels—i.e., to about 0.9 billion metric tons per year. This is about half of our Base case forecast for 2015. Tough forestry measures could reduce emissions another 7 percent. The detailed emissions reductions estimated for the Tough scenario analysis are shown in table 1-1, by individual measures within sectors.

costs

While we think the Moderate scenario is achievable at a net savings,[9] nonetheless substantial shifts in the economy would have to occur. For example, energy expenditures would be 15 percent lower than they would be otherwise, but the cost of appliances, cars, and houses would be higher.

[9] We believe that overall savings are possible because, on balance, fuel savings (assuming projected 2015 prices) will exceed annual capital and operating costs.

Box l-B—The OTA CO_2 Emissions Reduction Model

OTA developed a simple energy accounting model to estimate the effectiveness of various technical options for lowering CO_2 emissions. The model is based on a larger system of energy and economic models used by the Gas Research Institute (GRI) to forecast energy use through 2010 (23)[1]. Of all the integrated energy/economic forecasting models available, the GRI approach includes the greatest detail on the demand side for specific technologies. (Other models may contain, for example, estimates of total residential electricity demand, but do not include breakdowns of heating, cooling, refrigerators, freezers, clothes dryers, etc.) With such information, changes in CO_2 emissions can be simulated in detail based on changes in technology.

GRI provided OTA with detailed output from its model simulations of energy use through 2010. We, in turn, built a very much simplified set of models by "modeling" GRITS detailed output. For example, to estimate the energy demand for heating homes, GRI's residential sector model starts with the number of existing furnaces, heat pumps, and electric heaters. It then forecasts the number that must be replaced through time (with more efficient technology) based on typical equipment lifetimes. The number of new homes (which, of course, must also be heated) is forecast based on economic conditions. Whether consumers buy gas, oil, or electric heaters is forecast in part based on economics and in part on historical buying habits,

OTA took the GRI forecasts of energy use by each technology category (e.g., gas furnaces) and built a series of simple models that simulate the number and energy efficiency of each technology type through time, based ***only*** on the GRI detailed output data, rather than the economic decisions that influence the forecast. Note that for two categories-highway vehicles and electric utilities-we felt that the GRI model did not have adequate detail for our needs. For highway vehicles, we used Oak Ridge National Laboratory's "Alternative Motor Fuel Use Model" (but used GRI's oil price assumptions for consistency). For electric utilities, we built our own model using detailed data from the U.S. Department of Energy's Energy Information Administration.

We total all the energy use and CO_2 emissions from each technology and sector. This forms the basis for our Base case forecast that emissions will be approximately 50 percent above today's level by 2015. In the Base case (business as usual), OTA implicitly assumes GRI's economic forecast of GNP growth averaging 2.3 percent per year and energy price increases averaging 1.7 percent per year for coal, 3.7 percent per year for oil, and 4.8 percent per year for natural gas over the next two decades. This represents a reasonable future picture barring major changes in energy supply, economic, or regulatory conditions.

Then we estimate the effect of changes in technology (e.g., more efficient gas furnaces than included in the GRI forecast) or policy (e.g., forcing coal-fired plants to retire after 40 years of operation) in two alternative scenarios: "Moderate" and "Tough." Our model, for the most part, assumes the same level of "services" as the GRI base case. In the alternative scenarios, CO_2 emissions are reduced, for example, by using more efficient furnaces, switching fuel, or insulating houses, but ***not*** by assuming people keep their homes at lower temperatures in the winter or warmer in the summer like they currently do. In a few cases, most notably the transportation options, all "services" are not identical. For example, one of the measures that we include is to reinstate a 55 mph speed limit. Under our most aggressive scenario, we assume that cars will be somewhat smaller than they are today (for either economic or regulatory reasons). Both of these include some loss of convenience to consumers.

[1]The GRI modeling system has as its core the U.S. Energy Model, developed by Data Resources, Inc. (DRI). The model includes four submodels: the industrial sector, residential sector, commercial sector, and electric utilities. Economic projections, which drive the Energy Model, come from the DRI Macroeconomic Model of the U.S. economy. Additional inputs are generated from the Industrial Sector Technology Use Model, developed by Energy and Environmental Analysis, Inc.; the GRI Hydrocarbon Supply Model; and the RDI Coal Model, developed by Resource Data International.

Many of the Tough scenario measures entail costs in excess of projected fuel savings; others are cost effective over their lifetime but are difficult to implement. A rough estimate of the cost range for the Tough scenario is a savings of $20 billion to a cost of about $150 billion per year (in 1987 dollars) by 2015, after subtracting fuel savings (assuming forecasted 2015 fuel prices).[10] This range is equal to savings of a few tenths of a percent to a cost up to 1.8 percent of the Gross National Product (GNP) projected for 2015. For comparison, all environmental compliance costs today are about 1.5 percent of

[10]For example, We assume that oil prices by 2015 will be about $50 per barrel.

Table I-I—Measures To Lower U.S. Carbon Emissions
(expressed as percentage of 1987 total emissions)[a]

	Reductions in 2015 Moderate (in percent)	Reductions in 2015 Tough (in percent)
DEMAND-SIDE MEASURES		
Residential buildings		
New investments:		
Shell efficiency	1.3	2.0
Heating and cooling equipment	0.1	0.4 to 0.6
Water heaters and appliances	1.2	1.5 to 2.3
O&M, retrofits:		
Shell efficiency	0.8	0.9
Lights	0.6	0.8
All residential measures together	4	5.6 to 6.6
Commercial buildings		
New investments:		
Shell efficiency	2.3	4.0
Heating and cooling equipment	1.0	1.2 to 1.9
Lights	2.1	3.0
Office equipment	1.6	2.1
Water heaters and appliances	0.1	0.1
Cogeneration	0.2	1.5 to 2.3
O&M, retrofits:		
Shell efficiency	0.8	0.8
Lights	0.5	0.5
All commercial measures together	8.5	13 to 15
Transportation		
New investments:		
New auto efficiency	0.8	3.5 to 3.8
New light truck efficiency	0.5	2.5 to 2.7
New heavy truck efficiency	0.4	2.4 to 2.4
Non-highway efficiency	0.5	1.2
O&M, retrofits:		
improved public transit	0.2	3.5
Truck inspection & maintenance	0.3	0.4
Traffic flow improvements/ 55 mph speed limit	1.2	1.4
RIdesharing/parking controls	0.4	1.0
All transportation measures together	4	14 to 15

	Reductions in 2015 Moderate (in percent)	Reductions in 2015 Tough (in percent)
Industry		
New investments:		
Efficient motors	1.2	3.7 to 4.0
Lighting	0.5	0.7 to 0.8
Process change, top 4 industries	3.0	8.2
Fuel switch to gas	0.0	2.4 to 2.7
Cogeneration	0.8	5.2 to 5.8
O&M, retrofits:		
Housekeeping	1.9	2.0
Lighting	0.1	0.2
All industrial measures together	8	17 to 18
ELECTRIC UTILITY SUPPLY-SIDE MEASURES		
Existing plant measures:		
Improved nuclear utilization	4.1	4.1
Fossil efficiency improvements	1.7	1.7
Upgraded hydroelectric plants	0.5	0.5
Natural gas co-firing	—	3.7
New plant measures:		
No new coal; higher fraction of new nonfossil sources	—	0.0 to 4.7
CO_2 emission rate standards	0.4	0.0 to 0.1
All utility supply-side measures together	6.6	9.9 to 14
FORESTRY MEASURES		
Afforestation:		
Conservation Reserve Program	0.2	0.2
Urban trees	—	0.7
Additional tree planting	—	2.3
Increased timber productivity	—	3.1
increased use of biomass fuels	—	1.2
All forestry measures together	0.2	7.5

[a]1 percent of 1987 emissions = 13 milllon metric tons C = 0,7 percent of 2015 emissions.

SOURCE Office of Technology Assessment, 1991.

GNP; direct fossil fuel and electricity consumption purchases account for about 9 percent of GNP.

Other groups have tried to estimate the costs of CO_2 reductions, but with different control scenarios, often a carbon tax. For example, using several short-term econometric models (i.e., analyses that extend only to the year 2000), the Congressional Budget Office (CBO) estimated that a $100 per ton carbon tax phased in by the year 2000 would hold CO_2 emissions at just about current levels or reduce them to 25 percent below current levels by 2000 (45). By the end of the first decade, GNP would be lowered by about 0.5 to 2.0 percent (about $40 to $130 billion per year in 1987 dollars). However, GNP effects over the first few years of a suddenly instituted policy could be 5 percent or more.

CBO also looked at two longer term econometric models that forecast energy use past 2000, one constructed by the Environmental Protection Agency (EPA) and the other by the Electric Power Research Institute (EPRI). These models' projections for Base case energy use in 2015 are reasonably close to each other and to OTA's Base case and thus offer useful comparisons of reductions and costs. The model used by EPA forecasts that holding emissions to 10 to 15 percent below current levels would lower GNP by about 1 to 1.3 percent by the year 2015. The EPRI model forecasts that holding emissions to 20 percent below current levels would lower GNP about 3 percent by that year.

The costs associated with any scenario depend on many factors—including the price of fuel projected under Base case conditions. For example, we are assuming the price of crude oil will be $42 per barrel (in 1987 dollars) by the year 2010(23) and about $50 per barrel by 2015.[11] Net costs for an emissions reduction scenario would be higher if 2015 fuel prices are lower than projected; for example, if oil prices are $5 per barrel lower in 2015 than we forecast (and other energy prices remain the same as forecast), costs will be about $15 billion higher. Similarly, net costs would be lower if energy prices rise more than projected. No quantitative estimates have been made of the ancillary air, water, soil, health, economic, and energy security benefits that result from reducing energy use and associated pollutants.

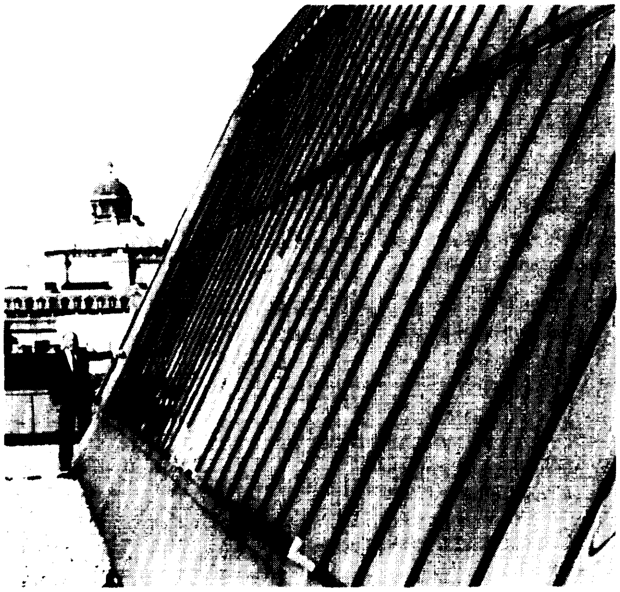


Photo credit: Chip Moore

Solar panels supply all of the hot water and up to 70 percent of the space heating needed for the 80,000-square-foot building in which OTA is housed.

OPTIONS FOR REDUCING U.S. EMISSIONS

The major options available or likely to be available for reducing CO_2 emissions in the near-term fall into three categories:

1. increasing energy conversion and efficiency in end-use technologies,
2. changing use patterns to conserve energy, and
3. shifting energy supply away from high CO_2-emitting fuels.

Additional options to offset CO_2 emissions are primarily forestry-related or agricultural. If Congress chooses to pursue any of these options, it obviously will also seek: to assure continuous economic progress.

When choosing policy options Congress must consider two interdependent components: the universe of possible technical (or in some cases, behavioral) changes and the policy instruments (e.g., taxes, regulations, financial incentives) available to require or encourage the technical change. One policy option, for example, would be to reduce CO_2 emissions through regulations (i.e., a policy instrument) to require more fuel-efficient autos (i.e., a technical option). An alternative or perhaps complementary policy option would be to use a high "gas guzzler' tax (i.e., policy instrument) to stimulate purchase of fuel-efficient autos.

Technical Options

This report identifies a range of CO_2-reducing technical options available or likely to be available to the Nation over the next 25 years, and what their contribution might be. There are a large number of technical options to pick from and many targets of opportunity within each sector, as figure 1-4 shows. Significant progress in reducing U.S. CO_2 emissions will require that most of these options be pursued simultaneously.

Presently available energy "supply" options for achieving major CO_2 reductions over the 25-year timeframe of this assessment include: replacing high carbon-emitting fuels (e.g., coal) with lower carbon-emitting fuels (e.g., natural gas); using high-efficiency, electricity-generating technologies (e.g., high-efficiency gas turbines or cogeneration); and using nonfossil fuels.

While nonfossil energy offers the greatest long-term potential for achieving deep cuts in CO_2 emissions, we cannot count on large-scale use of

11 For comparison, DOE's Energy Information Administration estimated the price of oil to be $28 to $46 per barrel by 2010; the American Gas Association projected $48 per barrel in 2015.

nonfossil energy sources to replace fossil fuels within 25 years. These sources do not yet offer the performance, costs, or social acceptance needed to fully displace fossil fuels in such a relatively short period of time (42). Only three nonfossil sources are presently being used on a significant scale in the United States: hydroelectric power, biomass, and nuclear light-water reactors (LWRs). Because of a combination of low baseload demand growth, cost, and environmental and social problems, no orders for new LWRs have been initiated in over a decade and there are no plans underway to build new reactors in the United States. Environmental factors set an upper limit on the number of potential new dam sites for hydroelectric facilities and on biomass production.

On the energy "end use" side, the technical options available today are primarily more efficient technologies or changes in energy use patterns. The first requires time and investment, whether for old equipment to be replaced or new equipment to be purchased. Changing energy use can include immediate (but reversible) changes such as fewer miles driven, lights dimmed, etc. In addition to the currently available technical options there is a large menu of additional options that could be developed over time. A diverse suite of energy R&D is ongoing, but what it will make available in the next quarter century depends greatly on Federal funding for demonstration.

Several technical options are available in the forestry sector to provide some offsets of CO_2 emissions. Increasing forest productivity and planting new trees can result in increased carbon storage that offsets fossil-fuel related emissions. Planting short-rotation tree crops for use as biomass fuels can partially replace the use of fossil fuels in some situations. These and other forestry options have attendant uncertainties and difficulties. For example, attempts to increase productivity focus on the timber component of forests (i.e., the commercially valuable portion). However, it is unclear whether increases in timber productivity actually indicate whether or not productivity in the entire forest has increased,

Policy Instruments

Policy instruments are the means government uses to require or encourage a desired technical or behavioral response. Many potential targets exist within each sector to achieve CO_2 emissions reductions (see figure 1-4). Whatever the CO_2 reduction goal, Congress will have to use a variety of policy instruments to stimulate a diverse set of decisionmakers to use the appropriate fuels, technologies, and forestry and agricultural practices and to adopt energy use patterns that conserve energy.

Identifying the relevant decisionmakers will be critical to selection of appropriate policy instruments. Within the energy system, for example, appliance and lighting use patterns represent the collective decisions of nearly all Americans. In contrast, utility fuel choices are made within a relatively small community of decisionmakers (e.g., utility executives, State regulators, and segments of the financial community).

Certain generalizations nonetheless can provide guidance:

- Decisionmakers generally prefer lower cost options and many individuals prefer low first-cost options over low life-cycle cost options.
- Highly efficient "cutting edge" technologies often have relatively lower life-cycle costs but higher front-end costs.
- Historically, fragmented decisionmaking reinforces the preference for low first costs, especially in the buildings sector-decisions relevant to efficiency are made by developers and builders, not by the occupants who will be paying the energy bills.

A wide range of possible policy instruments could be used to influence decisionmakers. Table 1-2 groups them into six generic categories:

1. taxes;
2. financial incentives;
3. marketable permits;
4. regulations;
5. research, development, and demonstration (RD&D); and
6. information and public education.

Just as there is no single technical option that is a cure-all, many policy instruments will be needed. The synergisms possible among taxation, regulation, incentives, information, and RD&D programs are key to significantly reducing emissions. Taxes, if properly set, can be used to adjust prices to tilt purchase decisions. Regulation (codes and standards) can be used to remove the least efficient equipment, appliances, and buildings from the

Table 1-2—Policy Instruments To Reduce CO_2

	Taxes			Financial incentives			Marketable permits	Regulations		RD & D		Information	
	Energy tax	Carbon tax	Purchase tax	Tax incentive	Low cost loans	Direct payments		Performance standards	Building codes	R&D	Demonstration	Labels/ rating	Audits
Commercial buildings													
Thermal integrity	√	√	—	√	√	√	—	—	√	√	√	√	√
Appliance/lighting	√	√	√	√	—	√	—	√	—	√	—	√	√
Usage patterns	√	√	—	—	—	—	—	—	—	—	—	—	√
Residential buildings													
Thermal integrity	√	√	—	√	√	√	—	—	√	√	√	√	√
Appliance/lighting	√	√	√	√	√	√	—	√	—	—	—	√	√
Usage patterns	√	√	—	—	—	—	—	—	—	—	—	—	√
Transportation													
Small car/truck efficiency	√	√	√	√	√	√	—	√	—	√	√	√	—
Alternate fuels	—	√	—	√	√	√	—	—	—	√	√	—	—
Off highway[a]	√	√	—	—	—	—	—	√	√	—	—	—	—
Vehicle miles traveled	√	√	—	—	—	—	—	—	—	—	—	—	—
Manufacturing													
Efficiency	√	√	—	—	—	—	√	—	√	√	—	—	—
Recycling	√	√	—	√	—	√	—	—	—	—	—	—	√
Energy supply													
High to low carbon fuels	—	√	—	—	—	—	√	—	—	√	√	—	—
Renewable	√	√	—	√	—	√	√	—	√	√	—	—	—
Cogeneration	√	√	—	√	—	—	√	—	—	—	—	—	—
Efficiency, existing plants	√	√	—	—	—	—	√	—	—	—	—	—	√
Forests													
Recycling	—	—	—	√	—	√	—	√	—	—	—	√	—
Increased productivity	—	√	—	√	—	√	—	—	—	√	—	—	—
Afforestation	—	√	—	√	—	√	—	—	—	—	—	—	—
Biomass	√	√	—	√	—	—	—	—	√	√	—	—	
Food													
Farm inputs	—	√	—	—	—	√	—	√	—	—	√	√	√
Farm operation & efficiency	—	√	—	√	—	√		√	—	√	—	—	—
Food processing	—	√	—	—	—	—	=	—	√	—	√	—	√

[a]Heavy equipment, aircraft.

SOURCE: Office of Technology Assessment, 1991.

market. Incentive and information programs can be used to clarify cost information and help create a market for improved energy performance. Education programs also provide consumers with the knowledge and information needed to make wiser energy choices. Government-sponsored RD&D can help provide producers and consumers with new technical options that can be used to reach national goals, as well as reduce, by cost-sharing, the risk to industry of developing these new options.

Taxes

Taxes offer a way to make high CO_2-emitting technical options more expensive than lower CO_2-emitting options. If Congress so desires, new tax monies could help fund incentive programs, offset the budget deficit, or replace other existing taxes.

Three possibilities include: 1) a general energy tax, 2) a carbon tax, and 3) initial purchase taxes. A general energy tax is levied on the energy (i.e., Btu) content of fuels. A carbon tax is set to reflect the fact that some fuels emit more carbon per unit of energy than do others. Both of these are thus "fuel" taxes. An initial purchase tax is levied on energy-consuming technologies, rather than fuels; the tax would be based on estimates of lifetime energy use or carbon emissions.

The first-a general energy tax-would stimulate greater energy efficiency, regardless of whether energy is derived from fossil or nonfossil fuels. By making all energy more expensive, it would apply pressure to reduce total energy use. On the other hand, a carbon tax would not only stimulate energy efficiency, but also shift the energy system from high carbon-emitting fossil fuels to nonfossil fuels or lower carbon-emitting fuels (e.g., natural gas).

Initial purchase taxes could have effects broadly similar to either an energy or carbon tax, depending on whether they were based on lifetime energy use or carbon emissions. Because consumers are often more concerned with the initial cost of a technology than with ''life-cycle' costs (i.e., including fuel costs), purchase taxes can be more effective than either type of fuel tax in many situations, An example of an initial purchase tax is the current ''gas guzzler' tax on autos, which was increased in the 1990 Omnibus Budget Reconciliation Act (Public Law 101 -508). In a similar fashion, a tax on less efficient appliances or houses could serve to reduce consumer preferences for lower initial costs rather than life-cycle costs.

Photo credit: Chevron

The Trans-Alaska pipeline has been in operation since 1977. North Slope oil production is currently declining, and a little less than 2 million barrels of crude oil per day now flow through the 800-mile pipeline. The United States currently uses 17 million barrels of oil each day.

Energy and carbon taxes have the advantage of affecting all emitters simultaneously, rather than focusing on a few selected technologies. A carbon tax is a particularly effective way of targeting the heaviest economic sanctions against the worst emitters of CO_2. A carbon tax would stimulate greater demand for natural gas relative to other fossil fuels. This, in turn, could drive natural gas prospecting and resource recovery technology development. Over the longer term, it could also motivate development of noncarbon energy sources whereas a straight energy tax would probably not.

Financial Incentives

Through financial incentives (e.g., tax incentives, low cost loans, and direct payment subsidies), the government pays part of the costs of utilizing desirable fuels, technologies, or practices. Tax incentives can be powerful instruments for stimulating desired actions by corporations and individual taxpayers looking for ways to reduce tax liabilities; however, tax incentives have little effect on those who pay low or no taxes.

Low-cost loans either defray some portion of loan interest or eliminate lender risk by insuring against loss. Low-cost loans can be effective policy instruments to stimulate utilization of CO_2-reducing technical options by both individuals and corporations. Direct payments for utilization of $C0_2$-reducing options (e.g., cash bonus for scrapping an old, fuel-inefficient car) are especially effective in stimulating the use of desired options by low-income or financially strapped decisionmakers.

Marketable Permits

Marketable permits and carbon taxes are closely related. Under a marketable permit system, policymakers fix the amount of carbon that can be emitted. The government then issues the allowed number of permits to emit a given amount of carbon. Permits can be bought and sold by energy users just like fuels. For example, for every 1 million Btu's of coal purchased, the user must also own (or purchase) permits to emit 57 pounds of carbon. To burn 1 million Btu's of natural gas, the user must own or purchase permits to emit *32* pounds of carbon. If demand for energy rises, the price of a carbon permit will rise to reflect the cost of lowering emissions. Some holders of permits will find ways to lower emissions (e.g., purchase more efficient equipment, switch from coal to natural gas) so that they can sell their permits (at a profit) to others. Theoretically, the effective price of fossil fuels will rise just high enough to meet the allowed carbon emission target. Just how high prices will rise, however, is difficult to forecast.

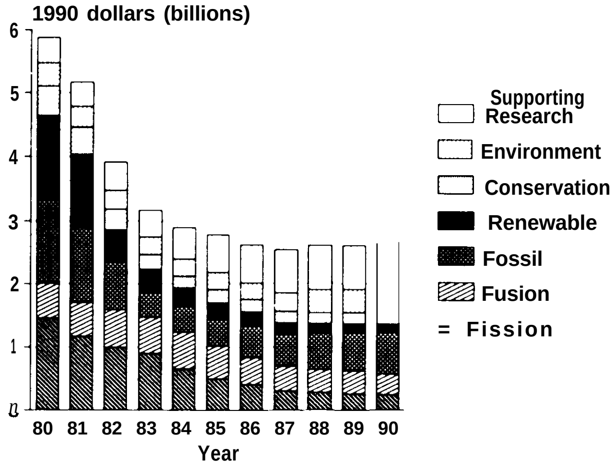
Marketable emission permits is the current U.S. method for enforcing the Montreal Protocol and controlling CFC emissions. A marketable permit system also is the regulatory mechanism for limiting emissions of sulfur dioxide to control acid rain under the new Clean Air Act Amendments (Public Law 101-549).

Marketable permits could be required for all fossil fuel users or only for large users such as electric utilities, factories, and even large commercial installations. Permits could be required for wholesalers who sell gasoline, rather than for individual drivers.

Regulations

Regulations are policy instruments that can eliminate inefficient and/or high CO_2-emitting activities from the market. They can take the form, for example, of performance standards and building

Figure 1-6-Federal Government Funding for Energy Supply R&D, 1980 to 1990



NOTE: The bars represent Federal budget authority for research, development, and technology demonstrations, in 1990 dollars. "Supporting" refers to research in basic energy sciences.

SOURCES: J.P. Holdren, "Energy in Transition," *Scientific American* 263(3):156-163, September 1990, original data compiled from the Office of Management and Budget, *Budget of the United States Government, Fiscal Years 1990 Through 1991* (Washington, DC: U.S. Government Printing Office, 1980 through 1990); Inter-society Working Group/American Association for the Advancement of Science, *Research and Development FY 1980-1997* (Washington, DC: 1980 through 1990); and *Environmental and Energy Study Conference, Weekly Bulletin(s)* and *Special Report(s)* (Washington, DC: several years).

codes. Performance standards can be established for many diverse types of technologies (e.g., lighting standards) and applied nationwide; they are currently used for automobile efficiency and appliance efficiency. Building codes traditionally have been the province of local governments and their effective use depends on enforcement at that level.

Research, Development, and Demonstration (RD&D)

Through RD&D, government can search for and free-tune technological frees to the greenhouse gas emissions problem. In fact, climate change can only be effectively addressed over the long-term with the development and worldwide use of better nonfossil energy sources. Government can speed the process of testing and commercializing many energy-supply and end-use technologies. However, only about 5 percent of the $2.7 billion national budget for energy technology R&D in 1990 was devoted to renewable (including biomass energy) and only 7 percent to energy conservation. Fossil fuels had 25 percent of the research budget, nuclear fusion 12 percent, and nuclear fission 9 percent (see figure 1-6).

Information

Information as a policy instrument has the potential to change the awareness level and perceptions of decisionmakers. Information programs rest on the assumption that if decisionmakers are better informed they will make better decisions. The most common goal of information programs is to stimulate decisionmakers to opt for least cost (life-cycle) savings, as opposed to initial-purchase savings, in their energy decisions. For example, although the most efficient model of an appliance usually costs more initially, energy savings accrue over its useful life. Information can be supplied by Federal, State, or local governments, utility programs (see 'Demand-Side Management' below), manufacturers, or nongovernmental organizations (NGOs).

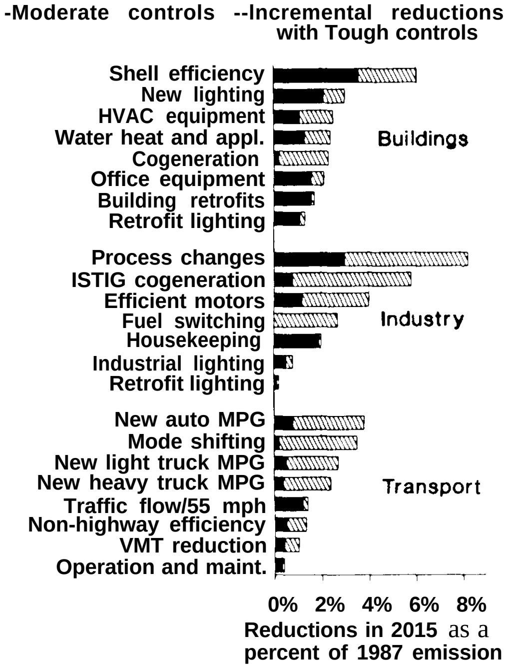
Information can be delivered to all decisionmakers in many ways, for example via label and rating systems and audits. Label and rating systems serve to provide purchasers with a basis for comparing front-end versus life-cycle costs at the time of purchase. Energy audits provide building owners and occupants with information they need when considering whether to purchase, rent, or retrofit alternatives. Energy audits can be effectively coupled with financial incentives to carry out retrofits that provide greater efficiency, and thus reduced CO_2 emissions.

Sectoral Policy Options

Buildings Sector

Figure 1-7 summarizes the emissions reductions possible for each ' 'demand-side" option modeled by OTA under both the Moderate and Tough scenarios. For buildings, improving shell efficiency and lighting are the two technical options with the greatest potential for lowering $C0_2$ emissions. Under the Base case, OTA assumes that by 2015 new homes and apartments will be designed such that they need about 15 percent less heating and 8 percent less cooling than current new homes. By adopting Moderate shell efficiency measures, such as thicker insulation and better windows, new homes will require an estimated 50 percent less heat and 25 percent less air-conditioning than today's average new home (27). With Tough measures, homes can be built to require an estimated 85 percent less heat and 45 percent less air-conditioning (20).

Figure 1 -7—Demand-Side Measures



NOTE: Reductions presented as a percentage of total U.S. carbon emissions in 1987.

SOURCE: Office of Technology Assessment, 1991.

As shown in table 1-1, Moderate shell improvements in new residential buildings can reduce U.S. carbon emissions by 1.3 percent of current levels by 2015. By implementing Tough improvements in the North and Moderate ones in the South, reductions of 2 percent in new residential buildings might be achieved. Tough measures for new commercial building shells can achieve reductions equal to 4 percent of 1987 levels by 2015.

Existing homes can also be made more efficient by installing more efficient heating and cooling equipment, insulation, windows, etc. The Base case assumes that existing homes will require 6 percent less heating by 2015 because of replacements and improvements that will happen anyway. Moderate measures boost this to 25 percent by 2015 and Tough measures boost it to 40 percent by 2015 (20). Tough measures in the North and Moderate ones in the South would reduce carbon emissions from existing buildings by 4 percent by 2000, but would have a declining effect thereafter as many of the older homes are replaced by new ones.

Improving the efficiency of lighting in new commercial buildings is another technical option that can yield substantial reductions. The Tough scenario measures together—a combination of high-efficiency fluorescent bulbs and ballasts, improved reflectors, and better use of daylight—would lower lighting energy needs by 60 percent in these buildings (18). This achieves reductions equal to 3 percent of 1987 emissions by 2015.

Gains in commercial buildings can also be made by simply replacing existing bulbs with high-efficiency ones—without replacing fixtures—as shown under the ‘‘Operation and Maintenance’ heading of table 1-1. Replacing the most heavily used incandescent bulbs in homes with compact fluorescent and using high-efficiency fluorescent in commercial buildings can lower emissions by 1.3 percent under our Tough scenario.

The instruments listed in table 1-2 and the policies described below appear to offer the most promise to achieve these reductions. While a carbon tax will certainly help, because there are so many different decisionmakers-some of whom may not be that responsive to price changes-a larger arsenal of policy instruments is needed. These include demand-side management (with the utilities as partners) as well as a series of targeted financial sanctions, incentives, and regulations.

Demand-Side Management (DSM)-DSM refers to electric utility programs designed to encourage customers to modify their patterns of energy use. Particularly promising-from a global warming perspective—are those situations where utilities allow energy conservation to compete with traditional supply technologies (e.g., powerplants) to balance energy supply and demand. DSM can be an effective approach to reduce energy consumption by improving building shells as well as the equipment inside buildings. In some cases, utilities pay for rebate programs, give out high-efficiency light bulbs, or otherwise stimulate end-use efficiency improvements, and save energy at a fraction of the cost of new power supplies.

Demand-side management can result in greater investments in energy efficiency than customers would otherwise make. Utility programs have long time horizons and can capture the potential in both the new and retrofit markets, for both equipment efficiency and building shell improvements. There is already considerable support for DSM by many State energy offices, State legislatures, and public utility commissions.[12]

However, in order for DSM to stimulate significant investment in conservation, incentive structures must be changed so that utilities can profit from demand-side investments. Any Federal legislation concerning DSM would need to be general enough to allow States flexibility in implementation and specific enough to have a genuine impact on conservation. Congress could provide funding to evaluate various incentive structures currently being examined by States and utilities. Should Congress wish to pursue more direct action, it could require States to formally consider demand-side resources in their planning, with oversight by the Federal Energy Regulatory Commission (FERC).

The Federal and State Governments share the regulation of electric utilities, and there is a history of tension over this sharing of jurisdiction (48). Congress can play a powerful leadership role in the direction of utility planning through legislation that guides FERC (which has jurisdiction over wholesale electricity transactions). An example of such legislation is the Public Utility Regulatory Policies Act of 1978 (PURPA), which required utilities to purchase electricity from qualifying facilities at avoided cost. Recently Congress addressed some aspects of this; for example, the Omnibus Budget Reconciliation Act amended PURPA to eliminate the 80-megawatt capacity limitation for qualifying facilities fueled by wind, geothermal, solar, or waste energy.

Further, the Federal Government could mandate that environmental externalities be considered in evaluating supply-side options (as New York State has done-i. e., penalizing polluting options based on estimates of the costs of environmental damage that would accrue; ref. 33). Congress has already mandated, in the 1980 Pacific Northwest Electric Power Planning and Conservation Act (Public Law 96-501), that the Northwest Power Planning Council adopt rate structures that give conservation measures a cost break over other, more traditional supply-side measures.

Technology-Specific ReguZations--Congress can directly mandate efficiency improvements through appliance standards and building energy codes.

[12]For a discussion of State initiatives in least-cost planning, see ref. 40.

Appliance Standards-Appliance standards, by fiat, remove inefficient appliances from the market. The National Appliance Energy Conservation Act (Public Law 100-12), passed in 1987, are expected to lower residential energy use by up to 10 percent by the year 2000 (17), However, even stricter standards are possible.[13] The law requires review of appliance standards twice during the 1990s, which provides an opportunity to obtain additional energy reductions through more stringent standards. Congress could also consider extending standards to other equipment such as commercial heating, ventilation, and air-conditioning equipment; lightbulbs; and building components such as windows.

Standards could be even more effective if used in conjunction with other incentives. Policies such as utility programs, appliance labeling, and tax schemes provide incentives to do more than standards require.

Building Energy Codes—Building energy codes serve a function analogous to that of appliance standards by preventing the least efficient buildings from being constructed. Building codes have traditionally been under the jurisdiction of States and localities. Currently, there is little support from the States or the construction industry for a mandatory national building code. In 1976, Congress enacted legislation that required the development of the Building Energy Performance Standards (BEPS), a mandatory national code based on performance standards. In 1983, the law was modified to be a mandator-y code only for Federal buildings.

Greater energy savings could be achieved by:

1. mandating compliance with a uniform code or creating incentives for States to adopt the national code;
2. developing a more stringent national code; and
3. increasing funding for implementation and enforcement.

The National Affordable Housing Act of 1990 (Public Law 101-922) requires the Department of Housing and Urban Development (HUD) to develop energy efficiency standards for new public housing and for housing subject to mortgages under the National Housing Act.[14]

Financial Measures-congress can choose from among several sector-specific financial mechanisms, including building tax credits and subsidies and initial purchasetaxes for appliances and other equipment.

Building Tax Credits and Subsidies--Tax credits and subsidies for using more efficient technologies can promote retrofitting of existing residential and commercial buildings. The Federal Government, for example, passed legislation that provided solar and conservation tax credits for the years 1978 through 1984. By 1983, 24 million households claimed a residential tax credit of up to $700 each for investments in energy conservation; however, no evaluation or monitoring of energy saved by this program was ever conducted. The 1986 Tax Reform Act allowed the energy conservation tax credits for residential use to expire but extended residential solar tax credits and some commercial energy conservation Credits.[15]

The Federal Government currently funds several subsidy programs. The Institutional Conservation Program, the Weatherization Assistance Program, and the Low Income Home Energy Assistance Program all pay for some energy conservation measures in low-income housing. The recently expired Solar Energy and Energy Conservation Bank helped finance energy conservation and cost-effective solar energy in low- and moderate-income housing and in commercial buildings owned by nonprofit organizations. Under these programs, the Federal Government provides funding to States, who in turn provide matching grants and loan subsidies. Such programs could be reinstated or expanded.

Initial Purchase Taxes and Rebates for Appliances and Other Equipment—An initial purchase tax scaled to penalize inefficient equipment could accelerate the market penetration of efficient equipment, Examples include a lump-sum tax on appliances and equipment at the time of purchase. Taxes collected on the most polluting items could be used

13The amendments define all energy-efficiency improvements with a payback of 3 years or less as economically justified. Any paybacks longer than 3 years must be shown to be economically justified.

14I e, mortgages that include a loan, under the National Housing Act, for financing energy.conse~lng improvements or adding solar energy systems.

15The omnibus Budget Reconciliation Act of 1990 extended the 1 ()-percent business energy tax credit for solar and geothermal property through Dec. 31, 1991 to provide a rebate on the least polluting items. However, although an initial purchase tax sends appropriate signals regarding consumer purchasing decisions, it would not—unlike an energy or carbon tax--change use of an appliance once it is purchased.

Consumer Information and Marketing Programs-Lack of information and uncertainty have been identified as key barriers to greater investment in energy conservation in the buildings sector. The large number of highly cost-effective investments in energy efficiency that are not chosen by consumers indicates that price alone does not stimulate optimal investment decisions. Therefore, information dissemination is a key element of several of the policy options discussed above, including the sector-specific financial measures and general energy and carbon taxes.

***Home** Energy Rating Systems-The* Federal Government has been involved in home energy rating systems—which tell buyers how efficient their prospective homes or offices are-through its role in the mortgage market. In addition, the National Affordable Housing Act of 1990 requires HUD to develop a plan to make housing more affordable through mortgage financing incentives for energy efficiency. The Federal Government could play a further role by developing a uniform energy rating system for all residential and commercial buildings, making it easier and less expensive for lenders to include energy costs in their mortgage evaluations.

State Information Programs-The State Energy Conservation Program (SECP) provides financial assistance to the State energy offices to promote energy efficiency and conservation in commercial and residential buildings. The Energy Extension Service (EES) is a Federal/State effort to provide small-scale energy users with individually tailored technical assistance for energy conservation and increased use of renewable. The SECP and the EES were consolidated under the 1990 State Energy Conservation Programs Improvement Act (Public Law 101-440).

Energy Audits—The Federal Residential Conservation Service, created in 1978, mandated that gas and electric utilities provide their customers with onsite energy audits. The program was implemented in 1981 and recently expired. There has been little evaluation of the program, and little reliable information has been kept on its success in reducing energy consumption. However, while it is unclear whether information from audits alone is enough to encourage conservation, it would certainly seem to be useful when combined with other measures.

Building Research, Development, and Demonstration--Major barriers to private investment in RD&D in the buildings sector include the fragmented structure of this sector and the short-term perspective of many of the decisionmakers (e.g., builders, renters). In addition, the U.S. Government currently spends a negligible amount on housing research. In contrast, in countries such as Sweden and Japan, RD&D spending has been part of a trend toward energy-efficient prefabricated housing. This spending has contributed to the energy efficiency of homes through standardization of energy-saving features and quality control in the design and manufacture of building components.

As a step, Congress has required HUD, in the National Affordable Housing Act of 1990, to develop a plan to encourage and improve energy efficiency in newly constructed, rehabilitated, and existing housing; and demonstrate various methods of improving the energy efficiency of existing housing. Such projects should encourage the development of “energy efficiency businesses’ that can bridge the gap between owners, builders and occupants of buildings. Congress also required HUD to encourage the use of private energy service companies in public housing projects.

The Federal Energy Management Program (FEMP), administered by the Department of Energy, works with government agencies to implement cost-effective, energy-efficiency improvements. Congress could authorize FEMP to test and demonstrate performance, acceptance, and cost-effectiveness of new technologies in Federal buildings.

Transportation Sector

Urban passenger travel in cars and light trucks (i.e., light vehicles) in the United States requires the largest share of transport energy, consuming 15 percent of the world’s oil production. The two main opportunities for reducing transportation’s contribution to global warming are measures to increase the energy efficiency of light vehicles and measures to encourage urban passengers to drive less. Thus, under OTA’s modeling exercise, the major reductions come from higher auto and truck efficiency, better control of traffic, and, under the Tough scenario, more use of public transit (see figure 1-7).

With respect to auto efficiency, our Base case assumes that new cars will average about 32 mpg by 2000 and about 37 mpg by 2010. Under the Moderate scenario, new car efficiency averages 35 mpg by 2000 (9) and 39 mpg by 2010 (1 O). Under the Tough scenario, we assume a range of new car efficiencies. For example, efficiencies of 39 mpg by 2000 and 55 mpg by 2010 might be possible even if consumers maintain their current preferences for car size and performance (10). If consumers are willing to buy smaller cars, new car fleet average efficiencies of 42 mpg by 2000 and 58 mpg by 2010 might be achievable, Given this range of assumptions, reductions amount to about 3.5 to 3.8 percent of current emissions by 2015 (see table l-l).

Reductions of about 2.5 to 2.7 percent from light trucks and another 2.4 percent from medium- and heavy-duty trucks are achievable under our Tough scenario, as well.

Traffic speed affects fuel consumption, too. By reinstating the 55 mile-per-hour speed limit and by reducing traffic congestion in urban areas in order to speed up travel, reductions of 1.4 percent by 2015 are possible under our Tough scenario. *G

Measures to move people out of their cars and into mass transit under the Tough scenario would yield reductions of about 3.5 percent by 2015. To achieve this, however, urban auto traffic would have to be reduced by 10 percent through urban light rail, busways, and improved urban design. Additionally, 5 percent of car travel between cities would have to shift *to* high-speed intercity rail.

The following four policy instruments will promote new car efficiency: gasoline taxes, vehicle taxes and rebates, fuel economy standards, and incentives for vehicle manufacturers. In addition, improved operation and maintenance practices will reduce energy use in existing cars. Two other measures, transportation control measures (TCMs) and controlling settlement patterns, can help reduce CO_2 by reducing vehicle miles traveled.

Gasoline Taxes—A gasoline tax would create incentives for both increased efficiency and reduced travel. Taxes would induce consumers to use less fuel while leaving them free to choose how they adjust their behavior. In concert with increasing fuel economy standards (see below), a long-term impact on the efficiency of the vehicle fleet could be achieved.

Although the effectiveness of taxes is hard to predict from studies of past responses to price changes, one might expect a 10-percent hike in gasoline prices to yield a 1- to 6-percent drop in gas consumption.[17] A 50-percent increase in price might reduce consumption 5 to 20 percent over the near term, even more over the longer term. A doubling or tripling in price (approaching the costs in Europe and Japan) might yield an immediate decrease of 13 to 20 percent and a longer term response of a 35- to 40-percent reduction in gasoline consumption. About half of this longer term adjustment to high price is expected from driving less, and the other half from more efficient vehicles. For example, consumers might choose to spend money on fuel-efficient technologies or to use mass transit, carpool, or simply travel less.

A gasoline tax, however, is regressive and thus affects the poor proportionately more than the rich.[18] To ameliorate this, Congress could provide rebates to low-income households. It could also phase in the tax to give consumers time to adjust their purchasing decisions and operation and management practices.

Vehicle Taxes and Rebates—Taxes on inefficient vehicles can create incentives to choose better fuel economy and forego large size and extra power. Such a program would be most effective if accompanied by rebates for highly efficient cars. In a ‘‘revenue neutral” program, the money taken in from the taxes would be redistributed through the rebates. The Federal Gas Guzzler Tax[19] already applies to cars with fuel economies below certain thresholds; the Omnibus Budget Reconciliation Act of 1990 recently doubled the tax for cars getting less than 22.5 mpg.

16Cars use gasoline most efficiently in the range of 35 to 45 mph; slower travel (due to congestion) and faster travel lead to losses in efficiency.

17Two recent studies *(4,* 8) review the *"elasticity'* of gasoline use relative to price (i.e., the ratio of the percentage change in use to the percentage change in price).

[8 For example, in 1985, households with earnings exceeding $'35,)()() spent 4 percent of income on gasoline whereas households earning $5,()()0 to $10,000 spent 11 percent.

19The Energy Tax Act of 1978 (Public Law 95-618).

Photo credit: Bressler Editorial Cartoons, New York, Artist: Packer

A World War II poster encouraging car pooling. Urban commuters average 1.2 passengers per vehicle to and from work.

An expanded program of auto purchase taxes and rebates could complement fuel economy standards and taxes, but it could also pose serious trade difficulties as long as the high-efficiency end of the auto market is dominated by imports. If implemented suddenly, such measures would put domestic manufacturers at a disadvantage; on the other hand, measures designed to protect domestic manufacturers might conflict with General Agreement on Tariffs and Trade (GATT) rules.

Fuel Economy Standards-Standards influence the tradeoffs among cost, performance, size, and efficiency that underlie the development and introduction of new models. The current fuel economy standards for cars, in place since 1978, have helped to increase auto fuel economy (21), More stringent standards can both lower $C0_2$ emissions and reduce our dependence on imported oil. Redesigned standards that vary with vehicle volume can help minimize the burden on U.S. manufacturers that offer a full range of car sizes (31, 49).

Incentives for Vehicle Manufacturers-One incentive, aimed at producers instead of consumers, is the use of government-sponsored competitions to induce manufacturers to develop high-efficiency or alternate-fueled cars. A variant of the incentive scheme injects competitive elements into a high-efficiency rebate program. For example, the government could identify a few classes of vehicles most in need of fuel economy improvement and offer a competitive reward in the form of consumer rebates on a large (e.g., 200,000 units) production run of a new vehicle achieving the best fuel economy above a specified threshold.

Efficient Vehicle Operating Practices----Changes in vehicle operating practices offer small potential reductions individually but often have short startup times and do not require large, upfront capital investment. They include reimposing (and enforcing) the 55-mph speed limit; requiring efficiency inspections for trucks; and charging efficiency-promoting parking fees at Federal offices.

Transportation Control Measures (TCMs)— TCMs include a wide variety of measures to reduce the number of vehicle miles traveled (VMT) and lower congestion. They are attractive because they typically have short startup times and low capital costs, and can reduce energy use and greenhouse emissions even within existing settlement and employment patterns. In aggregate, TCMs appear to hold modest promise for reducing VMT. They include:

- ridesharing (promotion and matching services);
- employer-based transportation management (high parking charges, transit or vanpool subsidies, and expedited transactions-e. g., bus passes, van leasing, and insurance made available at work);
- High-Occupancy Vehicle (HOV) lanes (restricting lanes on freeways to cars with three or four occupants and to buses);
- parking management (parking taxes or development surcharges, restricting street parking, and mandating high parking charges at workplaces);
- Park and Ride (intercept drivers near their origins);

- mass transit improvements (bus service expansion, operational changes, and fare changes);
- travel substitution (telecommunications, work-at-home, 4-day work weeks);
- traffic flow improvements (sophisticated signals, ramp metering, intersection improvement); and
- bicycling promotion.

Under the Energy Tax Act of 1978, employer-provided vanpools between an employee's residence and place of work were excludable from the employee's income if the vehicle was capable of carrying nine people. Congress could consider reinstating this provision or a variation of it.

Under present law, employer-provided transit passes, tokens, fare cards, and employer reimbursements for travel over $15 per month are considered taxable income. However, under current Federal tax law the value of parking provided to an employee is excludable from the gross income as a fringe benefit. Congress could consider making reimbursements for public transportation nontaxable or making parking taxable.

Controlling Settlement Patterns—Long-term reductions in emissions can be achieved by changing patterns of settlement to reduce the need for travel. This can be accomplished through higher densities, or through mixing uses so that residences, jobs, and services are roughly balanced at a local scale. When more destinations are close to home, more trips can be made by foot; when densities are higher, public transit can serve more people effectively.

In the United States, except possibly for some high-growth areas in the South and West, efforts to change the shape of settlement in major cities may meet local resistance. Nevertheless, some changes are feasible in suburban areas nationwide, Stringent suburban restrictions on development—sometimes only on commercial and industrial development, sometimes on new residential development as well—have been attempted in some regions of the United States (12).

Transportation RD&D-American automakers lag behind their Japanese, and to a lesser extent their European, counterparts in moving research results to the market (3). In the 1980s, a program to support more aggressive research and development in the American auto industry-the Cooperative Automotive Research Program-was briefly attempted by the Department of Transportation. A revived, combined government/industry program could be successful if domestic automakers, their suppliers, and innovative research companies all are key players. The program could target important efficiency areas such as continuously variable transmissions, energy-storage systems, new engine designs for heavy trucks, improved safety for lighter vehicles, and innovations to permit increased intermodal freight.

An area of longer term research that deserves special attention is development of truly clean, economically acceptable, alternative fuels and a supporting infrastructure. Fuels with the greatest potential-electricity or hydrogen from noncarbon energy sources (e.g., solar and nuclear) and woody biomass fuels grown on a sustainable basis—are the furthest from large-scale technical viability. Research in these areas could be expanded, with parallel programs to assess and demonstrate the actual performance of a variety of fuels.

Manufacturing Sector

For manufacturing, as shown in figure 1-7, three types of technical improvements offer the greatest promise. The first area is ‘ ‘process changes. ’ The top four manufacturing energy consumers (paper, chemicals, petroleum, and primary metals)--which account for more than 75 percent of energy use in this sector—improved their energy efficiency by between 2.3 and 4.3 percent per year between 1980 and 1985 (52). If this pace can be maintained, as we assume in our Tough scenario, reductions equal to about 8 percent of current emissions (by 2015) will result.

Cogenerating electricity and steam for industrial processes is a second promising option. When utilities generate electricity, about two-thirds of the energy from burning the fuel is released as heat. If electricity is generated at industrial sites where the heat can be used, the efficiency of fossil fuel use can be increased dramatically. Under our Tough scenario, we assume that 90 percent of new and replacement industrial steam boilers will cogenerate electricity. Such measures can lead to reductions equivalent to about 5.8 percent of current total U.S. emissions.

More efficient motors are a third technical improvement that can lead to substantial improvements. Moderate and Tough measures might improve motor efficiencies by 10 percent and 30 percent (l), respectively, yielding reductions of about 1.2 percent by 2015 under the Moderate scenario and 4 percent under the Tough one.

The following policy instruments could encourage these technical measures: carbon taxes, DSM, efficiency standards, marketable permits, tax incentives, informational policies, and RD&D.

Carbon Tax-A carbon tax would levy economic penalties against the highest industrial emitters of CO_2. Under such an approach, the tax would be highest on coal, low for natural gas, and zero for noncarbon sources (e.g., wind, solar, geothermal, or nuclear). For industries where the cost of energy is particularly important, carbon taxes should encourage energy efficiency, fuel switching and cogeneration.

Using several econometric models, the Congressional Budget Office estimated that a carbon tax of $100 per ton would lower CO_2 emissions from industry by between 10 and 35 percent by the year 2000. The higher reduction estimate reflects a 70-percent reduction in coal use,

Demand-Side Management-DSM programs—joint programs between electric utilities and their customers discussed previously-can help lower electricity use in the industrial sector. The major programs are:

1. rebates to customers who install approved equipment;
2. low-interest loans to customers for conservation installations; and
3. installation of conservation equipment at utility cost (37).

Many large industrial customers of electric utilities receive special lower rates because they supply the utility with a large, dependable portion of electricity demand. Utility programs could facilitate reductions in greenhouse gas emissions if these special rates were contingent on efficient use of electricity. This differs from demand-side management in that the financial burden of improving energy efficiency is placed on the manufacturer, not the utility.

Standards—A more traditional regulatory policy is to require efficiency standards for common energy-using equipment, similar to those existing for automobiles and some appliances. Motors would be the most likely candidate for this approach.

Photo credit: American Iron and Steel Institute

About 60 percent of the fossil fuels and electricity used by industry provides process heat, steam, and cogenerated heat and steam. Energy in manufacturing is also used for feedstocks, mechanical drive, electrolysis, lighting, and space heat.

Marketable Permits--CO_2 emissions can be regulated by requiring permits for emissions; manufacturers could be issued permits based, for example, on some percentage of their 1990 emissions. Reductions might be accomplished by installing energy-efficient technologies and fuel switching; offsets could result from approved reforestation/afforestation projects. It would be up to the manufacturer to choose the most cost-effective strategy. Marketable permits would allow firms to trade their unused carbon rights to a firm that is exceeding its budget.

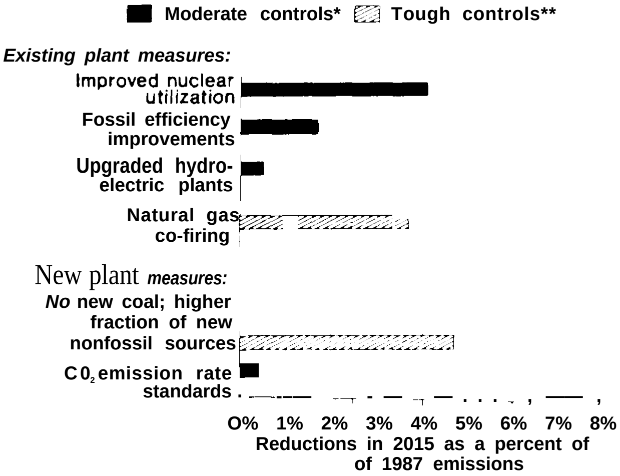
Manufacturing Tax Incentives-Much industrial equipment is old and energy-inefficient compared to the best available technology. In many cases, replacing old equipment improves energy efficiency by 10 to 50 percent. Financial policies, such as tax credits or accelerated tax depreciation schedules, aimed at stimulating rapid replacement of older equipment have the potential to stimulate improvements in energy use, Such policies have a precedent: the Energy Tax Act of 1978 provided a 10-percent added ''energy investment tax credit" for certain energy-conservation investments (as well as tax credits for some energy-supply investments). The tax credits were available until 1985 and applied to a specific list of technologies. However, rather than specify which technologies qualify, Congress could foster innovation by offering similar-or greater-tax breaks for company-chosen conservation technologies.

Informational Policies-A barrier to reducing emissions in the manufacturing sector is lack of information about how to improve energy use-especially for smaller, less energy-intensive industries. Informational policies can include performance goals, the collection of performance data, labeling of the energy performance of equipment, training, and performance audits.

Renewed support for cooperative government/industry information-sharing programs could help. For example, DOE's Energy Analysis and Diagnostic Center program funds faculty and students at several universities to perform free energy audits for small and medium-sized manufacturers in more than 30 States. Because costs saved by manufacturers translate to increased taxable income, the program can provide additional tax revenues to the Federal Government. The biggest cost savings have come from efficiency improvements associated with cogeneration, space heating, lighting, and process equipment maintenance and replacement (in descending order of savings; ref. 25). This program could be expanded or new programs could be modeled after it.

Manufacturing R&D—Research and development sponsored by DOE's Office of Industrial Programs in waste energy reduction and industrial process efficiency, if funded, are projected to save more than 3 to 4 percent of energy used by industry per year over the next decade. Research areas identified by Oak Ridge National Laboratory as particularly promising are: improved use of catalysts in chemical production; intelligent sensors and controls; and heat recovery and cogeneration (16). R&D in nonenergy areas, such as materials science, also holds promise for partial replacement of energy-intensive materials like steel and aluminum. Likewise, research and development to improve the quality of products made with recycled materials could help reduce energy use by increasing the

Figure I-8--Electric Utility Supply-Side Measures



• assureing Moderate demand-side measures
• assuming Tough demand-side measures

NOTE: Reductions presented as a percentage of total U.S. carbon emissions in 1987.

SOURCE: Office of Technology Assessment, 1991.

demand for recycled materials such as paper, steel, and aluminum.

Electricity Generation

About one-third of U.S. carbon emissions come from generating electricity (see figure 1-3); by 2015 under our Base case this may be as high as 45 percent. Thus measures that lower the rate of carbon emissions per kilowatt-hour (kWh) of electricity generated would translate into substantial reductions.

Figure 1-8 shows OTA's estimate of the technical potential for emissions reductions in the electric utility sector depending on the demand for electricity and the stringency of policies. Moderate utility supply-side measures can lower emissions by about 6.6 percent (see table l-l). The two with the greatest reduction potential are: 1) increasing the efficiency of fossil fuel-fired plants (by about 5 percent) through improved maintenance (14); and 2) operating existing nuclear powerplants 70 percent of the time (similar to Western Europe and Japan (16) and extending their useful life to 45 years.

Our Tough measures eliminate coal use wherever possible. A combination of renewable energy sources, nuclear plants with improved designs that may be available after 2005, and high-efficiency gas turbines are the only new utility plants built under the

Tough scenario. However, if all the Tough demand-side measures in the buildings and industrial sectors are implemented, growth in demand for electricity is so low that very few new plants are needed through 2015. Thus, the only way to lower emissions under this scenario is to either cofire existing coal plants (e.g., with 50 percent natural gas), or retire existing coal plants after 40 years of operation (rather than the typical 60 years) and replace them with renewable or nuclear fuels or natural gas. The former measure would reduce emissions by about 3.7 percent by 2015; the latter, by about 4.7 percent of current levels by 2015.

The following policy options could be used to encourage these technical measures: carbon taxes, marketable permits, subsidizing noncarbon sources, emissions limits and standards, and RD&D.

***Carbon Taxes*—A** carbon tax, if set high enough, would encourage fuel switching and conservation. A carbon tax in the range of $75 to $150 per ton would make natural gas a more economic choice than coal at many facilities. A carbon tax would also provide added motivation to develop more noncarbon energy sources.

***Marketable** Permits---Utilities* could be issued marketable permits for CO_2 emissions allowed from their coal-fired units, based on their generation in a historic year (e.g., 1990) multiplied by an allowed emission rate. Under this approach some utilities could curtail coal use more than necessary to meet their limits and sell permits to others exceeding their limits.

A variant on the above approach is to simply issue permits for a limited amount of coal use in existing facilities. Such an approach would be simpler to administer than emission permits, but it does not give credit to more efficient coal plants or to those plants that use lower CO_2-emitting coals.

To hold new coal plant construction between now and 2015 to a predetermined level, a limited number of coal permits (or carbon permits specific to coal plants) could be auctioned each year to the highest bidder. If such a policy were adopted in combination with marketable permits for existing coal plants, utilities could be allowed to freely trade among new and existing facilities.

Subsidize Noncarbon Sources-Any of the general financial instruments, such as a carbon tax or fossil fuel energy tax, will serve to encourage use of nonfossil sources for electricity generation. According to one estimate (42), a 2 cent-per-kWh subsidy or its equivalent[20] for only renewable sources of electricity might double the contribution of renewable sources of electricity by 2010-i. e., allow them to supply 40 percent of new demand under a Base case growth scenario. Under our Tough scenario, we assume nonfossil sources can provide between 30 and 45 percent of new demand (depending on the success of other demand-side measures).

CO_2 ***Emission Limits and Efficiency Standards*—** Congress could mandate reductions by setting $C0_2$ emission limits or efficiency standards. For example, an emission rate limit of 0.55 pounds carbon per kWh (lbs C/kWh) would require a typical Midwestern plant burning Illinois coal to burn between about 10 and 30 percent gas, depending on its efficiency. At 0.55 lbs C/kWh, the most efficient new coal burning technologies (e.g., integrated coal gasification combined cycle, or IGCC) would just qualify burning coal alone.

Two somewhat different strategies could be pursued to set $C0_2$ emission limits for new plants. If the intent is to force development of ultra-efficient coal technologies, then a standard in the range of 0.35 to 0.40 lbs C/kWh would be appropriate. Molten carbonate fuel cells, if successful, might be able to achieve such emission rates using bituminous coals. If the intent is to limit new fossil fuel-fired generation to the cleanest sources only—advanced combined cycle turbines burning gas—then a new source performance standard of about 0.25 lbs C/kWh would be more appropriate. To speed up replacement of old plants with new, lower emitting ones, Congress could mandate the retirement of existing fossil-fuel-fired plants earlier than their expected lifetime of 60 years.

In addition, powerplant efficiencies are not routinely monitored and industry attention to methods for improving efficiencies is only fairly recent (15). To demonstrate how better monitoring affects energy efficiency, Congress could require TVA and the Federal power agencies (e.g., Bonneville Power Authority) to undertake improvement at their own facilities. About 4 percent of the electricity gener-

[20] A 2 cent-per-kWh subsidy is equivalent to a carbon tax of $75 per ton of carbon for coal and about $150 per ton of carbon for natural gas.

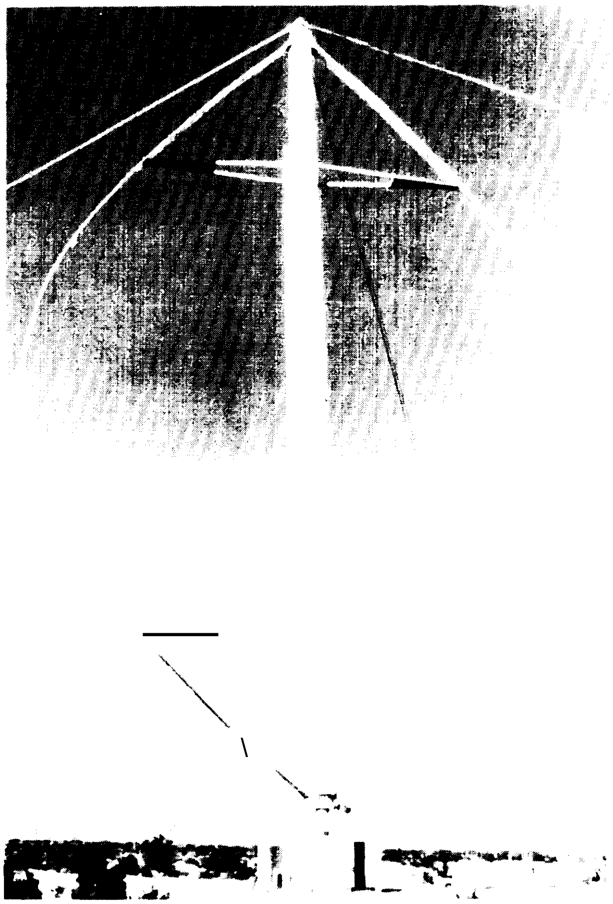


Photo credit: Southern California Edison Co,

A 500-kW wind turbine mounted on a vertical axis is insensitive to wind direction. All renewable sources of energy (wind, solar, geothermal, hydro, and biomass) currently contribute 5 to 10 percent of U.S. energy supply.

ated from fossil fuels comes from Federal power agency facilities (13).

The Federal Government, through the Federal Energy Regulatory Commission (FERC), also has indirect ability to influence private utility operations through its authority over the prices and conditions of interstate wholesale power sales. If Congress feels that the State Public Utility Commissions are not identifying and enforcing efficiency improvements, it could direct FERC to consider these issues when regulating interstate wholesale power sales.

Energy RD&D Funding-Over the last decade, Federal funding for renewable energy, conservation, and nuclear (fission) R&D fell rapidly (see figure 1-6). The 1990 combined energy technology R&D budgets (in 1990 dollars) for these three categories were 82 percent lower than they were in 1980. To reinstate the funding levels of 10 years ago would require adding about $2.6 billion. By doing so, the Federal Government could hasten the development and demonstration of supply technologies that would reduce greenhouse gas emissions. The most promising of these technologies include: commercial fuel cells; storage technologies for solar electricity; biomass-driven turbines; variable-speed wind turbines; and better designs for nuclear powerplants. Many experts estimate that these technologies could be commercially available within the next few decades.

The government could also play a role in reducing the perceived risk of new technologies and integrating renewable energy sources in existing energy systems by conducting demonstration projects or, perhaps, providing government-backed loans. To encourage new nuclear energy sources, a two-track process appears best: the Department of Energy could help fund full-scale demonstrations of both new ‘‘evolutionary’ light water reactors and “revolutionary’ design changes such as a modular high-temperature gas reactor.

For existing nuclear powerplants, the goal should be to increase the number of hours of operation, rather than to increase efficiency of fuel use, A Department of Energy demonstration program (coordinated with the Nuclear Regulatory Commission) might bring U.S. hours of nuclear plant operation from well below to above the average for Western Europe and Japan. Key elements of such a program would include improving preventive maintenance; installing automated controls to improve reactor operation; and speeding up time spent refueling.

Forests

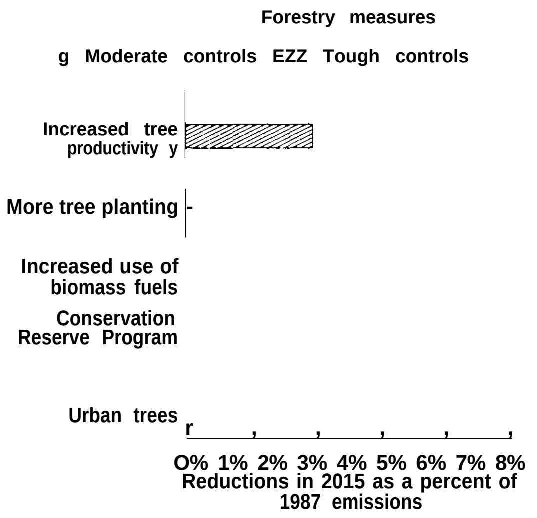
Forestry-related measures with the greatest potential to offset carbon emissions include increasing the productivity of existing forests, planting trees in new areas, and growing tree crops for biomass energy; we consider these to be Tough measures, with the exception of ongoing tree planting in the Conservation Reserve program. As shown in figure 1-9, OTA estimates that the increased carbon uptake from increasing productivity on about 60 million hectares of timberland might be equivalent to annual emissions reductions of about 3 percent of current levels by 2015. Planting new trees (i.e., afforestation) on farmland and other nonforested areas and in cities might result in carbon storage equivalent to emissions reductions of about 12 percent of current levels by 2015. Planting trees for biomass energy might result in an additional reduction of about 1 percent by 2015.

There are several caveats to this potential for offsetting emissions. Trees planted today can continue to store carbon beyond this report's 25-year timeframe. But this carbon eventually will be released to the atmosphere, either when trees die and decompose naturally, when they are harvested and burned, or when products made from wood eventually decompose. Unless the wood is used to displace fossil fuel use or is permanently stored under conditions that do not allow decomposition, carbon offsets in later years will dwindle, These estimates also assume that increasing the productivity of a forest's commercial timber component is equivalent to increasing the productivity of the entire forest ecosystem, but this assumption needs to be tested. Finally, forests—and the feasibility of using forestry practices to offset emissions-are likely to be affected by future climate changes. Therefore, forestry options in industrialized countries such as the United States cannot be considered a substitute for reducing total energy use, but rather as a way of ''buying' time while developing alternative nonfossil fuel sources and improving the efficiency of energy use in general.

Congress could promote management practices that increase carbon storage or offset CO_2 emissions by augmenting existing forest management and tree planting programs of the U.S. Forest Service (USFS) and the Agricultural Stabilization and Conservation Service, and by enhancing the biomass energy research program of the Department of Energy. In addition to direct support for such programs, Congress also could consider using financial mechanisms (e.g., changing income tax policies to encourage more investments in forest management; imposing a tax on fossil fuels to make biomass fuels more competitive).

Incentives To Increase Carbon Storage on Forest Lands—Incentives to increase productivity—i.e., net carbon storage-will differ for publicly and privately owned forests. On public lands, which are located mostly in the West, management objectives

Figure 1-9--Forestry Measures



NOTE: Offsets presented as a percentage of total U.S. carbon emissions in 1987.

SOURCE: Office of Technology Assessment, 1991.

are determined by planning processes legislated by Congress.[21] Government investments in *these lands* are likely to focus on reforestation and timber stand management. Congress could direct the USFS and Bureau of Land Management to, for example, increase reforestation activities and to conduct research on the ability of ''new forestry' practices that proponents contend might help to both maintain higher levels of diversity and allow commodity production.

Privately owned forests are most extensive in the East and South. For nonindustry private forests, Congress could continue to increase assistance to States and private landowners under programs such as the Forestry Incentives Program and the Agricultural Conservation Program. These programs currently reach only about 2 percent of nonindustry private owners (32), even though these owners undertake over 40 percent of all reforestation. The Interior and Related Agencies Appropriations Act for fiscal year 1991 almost doubled funding for the USFS's State and private forestry programs, which include tree planting and management. The 1990 Food, Agriculture, Conservation, and Trade Act (Public Law 101-624), known as the 1990 Farm Bill,

[21]E.g., for National Forests in the Renewable Resources Planning Act (Public Law 93-378) and National Forest Management Act (Public Law 94-585), within the framework set forth in the Multiple-Use and Sustained-Yield Act of 1960 (Public Law 86-5 17).

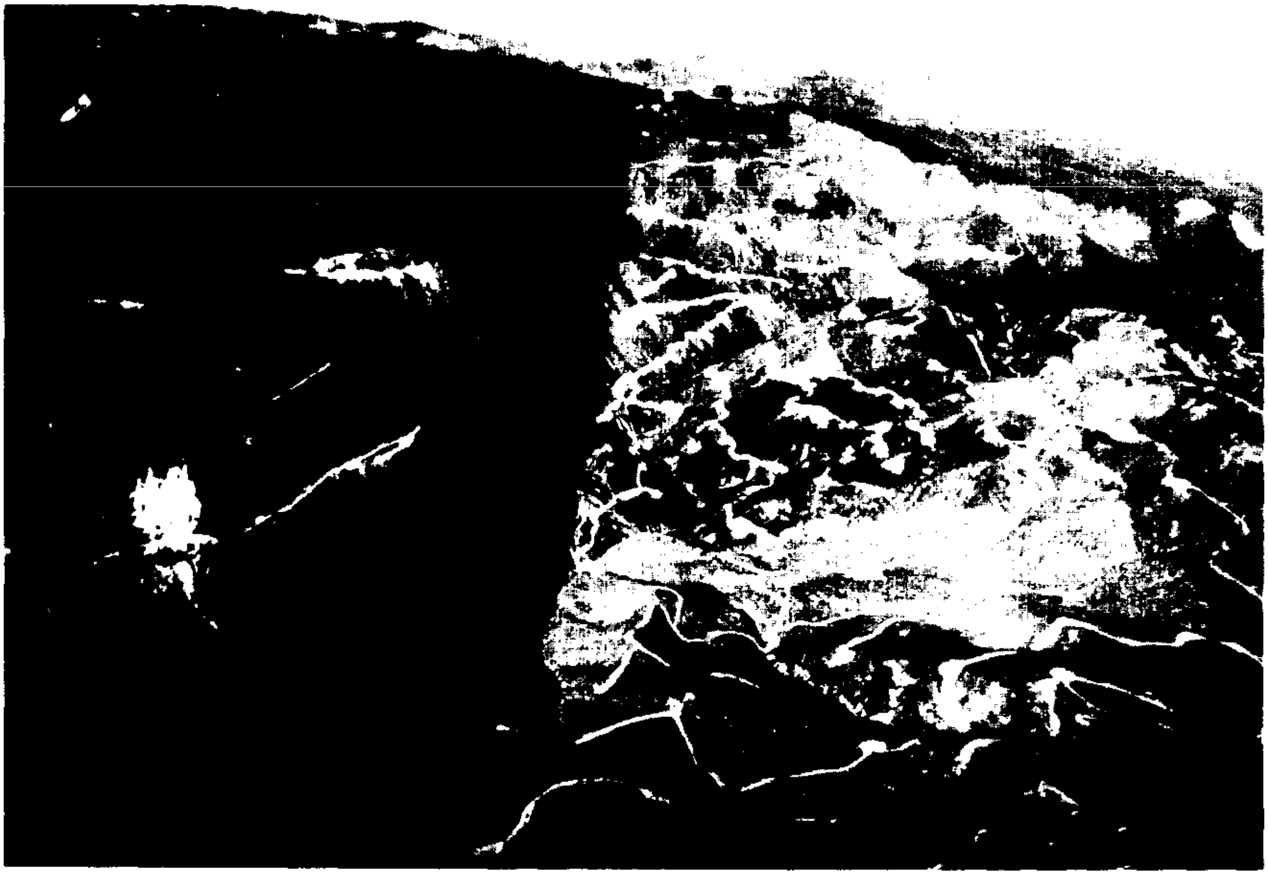


Photo credit: James P. Blair (c) 1990 National Geographic Society

The effects of clearcutting U.S. forests can be seen on the steep slopes of the Mount Baker-Snoqualmie National Forest below the Clearwater Wilderness.

also authorized a forestry stewardship program in which the USFS would work with State and local governments, land grant universities, and the private sector to improve resource management on privately owned forest land.

For industry-owned timberland, investments might be stimulated through changes in capital gains provisions (e.g., restoring preferential tax rates or providing a partial exclusion from taxable income for timber held longer than 20 years) or allowing full annual deductions for expenses, as well as by increasing funding for Federal assistance programs. One possibility for increasing support of such programs is to use funds that would accrue if below-cost timber sales in National Forests were eliminated.

Incentives for Growing New Trees on Unforested and Urban Lands—Mechanisms to promote afforestation include the Conservation Reserve Program (CRP), the President's proposed America the Beautiful program, and financial incentives such as tax credits for carbon storage. In general, any tree-planting program needs to consider the costs of maintaining trees in a healthy state once planted; this will be even more critical as climate changes occur.

Congress could expand the CRP by increasing its tree-planting goals and its incentives for enrolling land for tree planting (e.g., higher rentals, greater share of reforestation costs, longer contracts) .22 The 1990 Farm Bill expanded CRP eligibility criteria to include, for example, marginal pasture lands previously converted to wetlands or wildlife habitat,

[22]Under the CRP, farmers who take lands out of production for 10 years receive annual rental payments from the Federal Government and a one-time payment for one-half the cost of establishing protective vegetation.

marginal pasture lands to be converted to trees in or near riparian areas, and croplands that contribute to water quality degradation.[23] Another option would be to, encourage new shelterbelts, perhaps through tax credits or by conservation compliance requirements tied to commodity support programs.

The 1990 Farm Bill authorized startup funds for the America the Beautiful tree-planting program, as well as funds for urban and community tree planting and maintenance. The Interior and Related Agencies Appropriations Act for fiscal year 1991 did not fired the program, although, as noted above, tree planting was included in funding for the USFS's State and private forestry programs. Infrastructure for increased planting also may need to be developed, since current planting is near the historical peak, and funding for long-term maintenance also will be needed.

Congress also could consider providing tax incentives (similar to those once more widely available for energy conservation) for properly planting and maintaining urban trees, especially near homes and buildings to save energy used for cooling.

Incentives for Biomass Energy To Offset $C0_2$ Emissions--Growing short-rotation woody crops on nonforested land for use as an energy source shows some promise. Congress could increase funding for Department of Energy research on uncertainties regarding long-term productivity, including effects on nutrient availability, and costs. Increasing fossil fuel taxes would make biomass fuels more competitive. Even then, farmers wishing to invest in biomass crops maybe limited by loss of base acreage in commodity support programs and by lack of revenues for several years. Thus, changes in support programs or provision of some subsidy may be needed to stimulate investments in biomass crops on current cropland.

Food Sector

In the other U.S. sectors, $C0_2$ is the primary focus of OTA's analysis, although both CFCs (e.g., in buildings and transportation) and methane (e.g., from natural gas production and distribution) also are assessed. The food sector, though, differs in two important aspects. First, the relative importance of methane (CH_4) and N_20 emissions is greater than in other sectors. Although estimates are uncertain, the food sector may account for one-third of global CH_4 emissions and anywhere from one-tenth to one-fifth of current global N_2O emissions. Its contribution to total U.S. CH_4 emissions is roughly 9 percent (its contribution to U.S. N_20 emissions is uncertain, though).

Second, fossil fuel-related $C0_2$ emissions (i.e., from farm machinery, irrigation equipment, fertilizer manufacturing, food transport, processing and packaging, and cooking) and CFC emissions (primarily from refrigeration) are subsumed in the transportation, industry, and buildings analyses summarized earlier. Further, $C0_2$ emissions from agricultural-related deforestation in the United States are very small (although they are very important in developing countries). To place the food sector in perspective, though, we estimate that it accounts for at least 8 percent of total U.S. $C0_2$ emissions and about 5 percent of U.S. CFC-11 and CFC-12 emissions (worldwide, it may account for one-fifth of global CO_2 emissions and up to 15 percent of globalCFC-11 and CFC-12 emissions).[24]

In the past, congressional concern about agriculture largely has focused on farm production, promotion, and income. With the passage of the 1985 Food Security Act, Congress began dealing with some of the environmental impacts of U.S. agriculture. Although the 1990 Farm Bill expanded these efforts, including extending the CRP until 1995, additional steps can still be taken, as discussed below for methane and nitrous oxide emissions,

Some of the opportunities discussed earlier for the buildings, industry, and transportation sectors also can affect food sector activities (e.g., more efficient cooking, processing and packaging, etc.). In addition, fossil fuel-related $C0_2$ emissions from the U.S. food system could be reduced by making fertilizer manufacture, farm machinery, and irrigation more energy efficient.

[23] This will enhance the chances of achieving the CRP's goal of reducing soil erosion problems; some of these lands could be devoted to tree planting.

[24] About 70 percent of the U.S. food sector's CO_2 emissions (i.e., about 5 percent of total U.S. CO_2 emissions) comes from fossil fuel combustion for food refrigeration, residential cooking, and food processing and packaging; the remainder comes from farm machinery, fertilizer manufacturing, and onfarm electricity use. These CO_2 emissions do not represent a complete accounting of emissions from the U.S. food sector; for example, CO_2 emissions associated with food transport are not included.

Reducing Methane Emissions—U.S. methane emissions from the food sector are primarily from ruminant anumals (e.g., cattle, sheep). Congress could direct the U.S. Department of Agriculture (USDA) to determine the potential for techniques such as improved nutrient management, feed additives, and manure management to reduce methane emissions. To limit future growth in, or even reduce, livestock populations in the United States, Congress could consider reducing or removing price supports for feed grains, which might make beef and dairy products more expensive (although it is unclear if the costs would rise or fall over the long term). Such a policy could cause large near-term economic disruptions for some farmers and portions of the food industry, however,

Reducing N_20 Emissions—To reduce nitrous oxide emissions, Congress could modify commodity program policies, which now encourage monocropping and heavy fertilizer use, to give farmers more control over the types of crops they plant without losing program crop base acreage and support payments.[25] Congress Could provide cropping flexibility only to those farmers who adopt environmentally sound cropping patterns. Congress also could make implementation of best management practices (BMPs) a prerequisite for receiving Federal price and income supports. BMPs, designed by the Soil Conservation Service (SCS) to reduce soil degradation and water contamination from agricultural activities, include more efficient fertilizer use, water impoundments, permanent vegetative cover, and manure storage.[26] At present, however, the SCS does not have statutory authority to promulgate enforceable regulations. Such a cross-compliance policy also would not apply to the one-third of U.S. croplands that are not enrolled in Federal farm support programs. In addition, enrolling more farm land in the CRP would help reduce N_2O emissions from fertilizer use (as well as CO_2 emissions from onfarm fossil fuel use and offsite fertilizer manufacturing).

Food RD&D--The development of an accurate emissions database for the food sector is perhaps the most critical research priority. Increased research is needed to quantify CO_2 emissions from agricultural land-clearing activities, CH_4 emissions from ruminant animals (and from rice cultivation, particularly in the developing world), and N_2O emissions from nitrogenous fertilizers. The emissions reduction potential of different alternative practices must also be investigated; for example, support is needed for research on methane-reducing techniques, especially for livestock in confined and range-management systems. Congress also could increase funding for RD&D efforts to develop new alternative practices, especially those that simultaneously increase crop yields and reduce greenhouse gas emissions per unit of food output.

U.S. INFLUENCE ON THE REST OF THE WORLD

There are many reasons why the U.S. Congress should seek to promote the reduction of greenhouse gas emissions abroad. First, climate change is a global problem. Solutions must come from all emitters, as reductions made by one country will only make a small dent in total greenhouse gas emissions.

Second, emissions of greenhouse gases will rise in the developing countries. Because the developing countries have higher growth rates for energy use, population, and Gross National Product (GNP) than do industrialized countries, and because their current energy use per person is so low, their emissions of greenhouse gases will continue to rise signnificantly, Stabilizing or even reducing greenhouse gas emissions from developing countries will be next to impossible to achieve (at least until nonfossil energy sources are widely available), given their need to increase energy consumption for supplying basic services. However, the United States could influence emissions growth rates in developing countries and also assist these countries to achieve economic progress by helping them to increase energy production based on nonfossil fuels (e.g., solar or nuclear) and to make both their energy production and consumption more efficient.

Third, energy-related improvements may be cheaper and relatively greater—at least in the short term—in developing countries, Eastern

[25] The 1990 Farm Bill now allows farmers to plant a limited amount of selected crops on land designated for other commodity program crops without losing program benefits.

[26] This idea also could be extended to other energy-intensive inputs such as pesticides and irrigation water. For example, the SCS could establish guidelines on how, and in what quantities, various inputs should be applied to crops in specific regions of the country.

Europe, and the U.S.S.R. than in the United States. For example, because energy use in all the sectors of the U.S.S.R. and Eastern Europe is relatively inefficient, significant efficiency gains may be achieved at modest expense. In developing countries, much of the energy infrastructure is yet to be built; these countries can take advantage, for example, of new technologies that may be cost-effective for new construction but expensive for retrofits.

Fourth, tropical deforestation contributes between 7 and about 30 percent of worldwide CO_2 emissions; these forests are being lost at an estimated rate of over 17 million hectares per year-an area exceeding that of Virginia and West Virginia combined. In addition, much more than CO_2 emissions is at stake. Tropical forests harbor at least half of the world's species, are the source of many products used by people living in the forests and elsewhere in the world (e.g. , medicines, nuts, fibers, fruits), and serve many critical functions such as watershed protection.

Developing Countries

The OECD countries (which include the United States), U. S. S. R., and Eastern Europe currently contribute about one-half to two-thirds of all greenhouse gas emissions, mostly from combustion of fossil fuels to power their economies (see figure 1-1; note the caveat on the figure regarding how the wide range of estimates of CO_2 emissions from deforestation affects estimates of the relative contribution from each region). In contrast, developing countries contribute about one-third to one-half of emissions, mostly from land use changes and practices (e.g., deforestation of tropical forests, cultivation of rice, and raising of livestock).

Most current forest-related greenhouse emissions come from tropical forests, which are located almost exclusively in developing countries and which are being felled, burned, and degraded on an unprecedented scale.[27] In contrast, loss of temperate zone forests, located mostly in developed countries, currently contributes little to $C0_2$ emissions, although many of these forests were cleared in the past.

The major causes of tropical deforestation and degradation are the conversion of forests to temporary agriculture (e.g., ''shifting' cultivation) and permanent agriculture (including cattle ranching), and poor timber harvesting practices. However, these are driven by underlying social, economic, and political factors—poverty and lack of land tenure for most people, national development policies, and foreign debts—that are exacerbated by rapid population growth (60). These factors encourage rapid exploitation of natural resources, for example to expand development and obtain foreign currency for servicing debts.

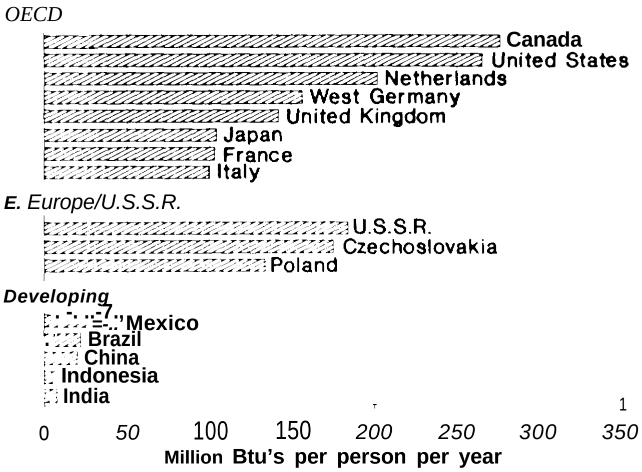
Emissions from fossil fuel use in developing countries are relatively less important now but will increase significantly in the future. Decisions that these countries make within the next 5 to 10 years about how to pursue economic growth and expand energy services and infrastructure (e.g., industrial bases, electric generation) will influence their share of emissions for decades to come. The ongoing OTA assessment, "Fueling Development: Energy and Technology in Developing Countries, " will continue to examine this issue. A background report (51) discusses linkages between energy use, economic development, and environmental quality.

Figure 1-10 shows the great disparity in per-capita energy use in different parts of the world. Although a person in a developing country uses about one-fifteenth the amount of energy as does the average U.S. citizen,[28] even modest gains in per-capita and total economic growth in these countries translates into emissions that will exceed those from the developed world within a few decades. And such growth is likely to be more than moderate. Developing countries have been increasing their total energy use by approximately 6 percent per year, in contrast to 1 percent in OECD countries, and they increased their electrical power consumption by an average of 8 percent per year between 1971 and 1987; most of the added electrical capacity was provided by conventional power-plants (which are high CO_2 emitters) and was used for manufacturing and in buildings (43). Further increases will be needed since many countries are continuing to fully electrify cities and beginning or continuing rural electrifica-

[27] '*Deforestation" means converting forest land to other vegetation or uses (e.g., pasture, cropland, darns). "Degradation" involves practices that leave trees as the predominant vegetation but degrade overall forest quality (e.g., soil erosion; damages to trees and streams from selective logging).

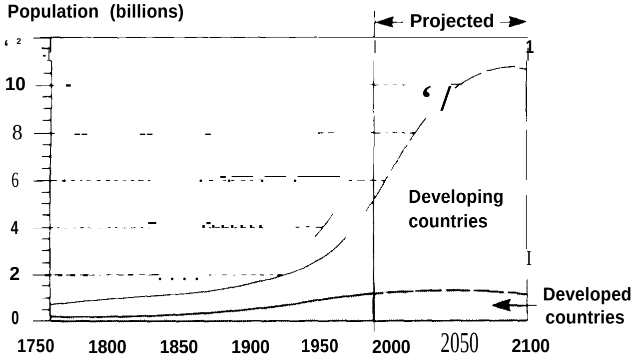
[28] The average American uses about 260 million Btu's. The average for the entire developing world (defined by the World Bank as ''lower and middle income' countries) is about 20 million Btu's. The average for the selected developing countries shown in figure 1-10 is 25 million Btu's.

Figure 1-10—Per Capita Energy Consumption



SOURCES: U.S. Congress, Office of Technology Assessment, *Energy in Developing Countries, OTA-E-486* (Washington, DC: U.S. Government Printing Office, January 1991),

Figure 1-11—World Population Growth, 1750-2100



SOURCE: Population Reference Bureau, *1990 World Population Data Sheet* (Washington, DC: 1990).

tion programs, and since refrigeration and air-conditioning are becoming more widely available. Moreover, rapid population growth, in combination with economic growth, will continue to fuel increased demands for energy and land resources long beyond the time frame of this study; the world population now grows by over 10,000 people per hour (figure 1-11), with virtually all of that growth occurring in developing countries.

U.S.S.R. and Eastern Europe

The economies of the U.S.S.R. and of Eastern European countries have been centrally planned for decades but now are changing, rapidly in some cases.[29] These countries account for about one-fifth of current global greenhouse gas emissions, mostly from the combustion of fossil fuels to provide energy. In 1988, the U.S.S.R. accounted for 18 percent of global primary energy consumption, Eastern Europe for 6 percent. The energy infrastructure in place in these countries is generally old and inefficient.

Efforts to promote energy conservation and efficiency in Eastern Europe and the U. S. S. R., and thereby reduce future growth in carbon emissions, face major obstacles. First, energy is highly subsidized, so consumers (particularly industries) bear only a small portion of its real costs.[30] Second, the central economic planning systems set rigid quotas for production (i.e., gross output) of goods and services. Enterprises must consume virtually all of the supplies allocated to them by central planners, even when not all are needed, in order to receive the same amount next year. Third, the production quotas require investments in heavy industries (e.g., steel, aluminum, chemicals) at the expense of services and consumer goods. Finally, implementation of plans for alternative energy sources is hindered by a fragmentation of responsibilities among multiple government agencies.

Thus, even when opportunities exist, there are strong disincentives to save energy and raw materials or to invest in energy efficiency. These obstacles have led to high industrial demand for energy, energy-inefficient production of goods and services, less availability of electricity for nonindustrial consumers, low standards of living, and severe environmental problems in many areas.

U.S. Policy Options To Help Limit Greenhouse Gas Emissions Abroad

Earlier sections in this summary set forth specific policy options that the United States could pursue to reduce or offset its own greenhouse gas emissions. By taking such actions to reduce its own emissions, the United States can provide leadership through

[29] Eastern Europe as defined here includes Bulgaria, Czechoslovakia, East Germany (prior to unification with West Germany), Hungary, Poland, and Romania.

[30] In Poland, for example, subsidies accounted for 49 percent of the delivered price of coal and 83 percent of the delivered Price of natural gas in 1987 (ref. 41).

example. In the broader context, the United States also can work towards the adoption of international conventions and protocols regarding climate change, similar to those developed for phasing out CFCs and halons.

The United States also can attempt to help developing countries, Eastern Europe, and the U.S.S.R. to minimize their greenhouse gas emissions, without hindering the prospects for needed economic development. Indeed, strategies to lower greenhouse emissions can simultaneously help these nations become more economically efficient. Numerous existing programs and organizations in the United States and on the international scene directly influence development and indirectly can affect greenhouse gas emissions (see box l-C). The United States, for example, provides direct bilateral assistance through the U.S. Agency for International Development (A. I,D.). Numerous other U.S. agencies--such as the State Department, the Commerce Department, the U.S. Trade Representative, the Treasury Department, the Agriculture Department, and the Environmental Protection Agency—support technology transfer and development assistance in certain areas. Through these U.S. and international organizations, the United States currently contributes about $9 billion annually in foreign aid assistance (including bilateral aid, food aid, security-related economic support funds, and multilateral aid) to developing countries.[31]

The United States can continue to work through its own bilateral assistance programs and international organizations, as well as through NGOs, to increase the development and transfer of technologies and policies related to energy, family planning, and land use and management practices that provide sustainable alternatives to deforestation and dependence on fossil fuels. General congressional issues regarding developing countries, the U. S. S. R,, and Eastern Europe fall into five categories:

- technology transfer and trade;
- building local institutional capacities;
- redirecting energy policies;
- redirecting natural resource policies; and
- redirecting family planning assistance policies.

Technology Transfer and Trade With Other Countries

The opportunity seems ripe for U.S. businesses to increase exports of energy-efficient and renewable energy technologies (as well as CFC-free technologies) to developing countries, since much of the energy infrastructure needed to fulfill development aspirations has yet to be built. For example, a market of $370 to $900 billion for electric power equipment is expected over the next 20 years (43). In addition, the U.S.S.R. and Eastern Europe have antiquated infrastructures in place; in these countries, the United States could provide modern equipment, as well as engineering and management services.

The U.S. Government promotes private sector technology transfer to non-OECD countries through government departmental programs (e.g., the Committee on Renewable Energy Commerce and Trade, or CORECT, led by the Department of Energy) and through independent government agencies and corporations (e.g., Eximbank, Overseas Private Investment Corp.). Some programs focus directly on energy technologies, while others are more general in nature.

Options-Congress could attempt to facilitate U.S. trade in renewable and efficient energy technologies in several ways. First, it could expand the financial resources of agencies that fund feasibility studies and project preparation (e.g., A. I.D., U.S. Trade and Development Program) or that provide financing for exports (e.g., Eximbank, Overseas Private Investment Corp.), as well as direct them to focus some resources on specific technology areas. For example, the fiscal year 1990 Foreign Operations Appropriations Act (Public Law 101-167) directs Eximbank to set aside 5 percent of its energy industry export funds for renewable energy projects. The Act also directed A.I.D. to focus on energy efficiency, renewable energy resources, and least-cost energy planning in the development of national energy plans, but additional funds were not appropriated. The Overseas Private Investment Corp. is planning a $100 million Environmental Investment Fund.

[31] Compared to other countries, U.S. foreign aid and assistance is a relatively smaller percentage of its GNP. The U.S. portion was 0.19 percent in 1987 and 0.21 percent in 1988. In 1987, the larger Western European countries provided an average of 0.42 percent and Japan provided 0.31 percent; Notway topped the list at 1.1 percent.

Box l-C—Agencies and Organizations That Can Influence Greenhouse Emissions Abroad

This box briefly describes major U.S. and international "players" looking at climate change. While no organization seems to place a premium on discouraging climate-modifying emissions for that ***reason*** alone, most are exploring the ways in which their policies and programs may affect climate change. In addition to those listed below, there are also many regional organizations, industry-sponsored consortia, non-governmental organizations, and philanthropic foundations that influence energy and environment policy internationally.

U.S. Government Agencies

The *Agency for International Development* is the lead agency for administering foreign economic assistance, through training, education and research, policy advice, technical assistance, and technology transfer. It is the second largest bilateral aid donor in the world (following Japan), spending over $2 billion in 1989 on nonmilitary Overseas Development Assistance. Of that sum, about 1 percent (between $100 to $2(X) million) is spent on energy projects. A.I.D. is presently undertaking an inventory of its activities and their related effect on climate change.

The Department of Agriculture promotes U.S. agricultural products and coordinates agricultural trade policy with other U.S. agencies. The Forest Service administers timber sales and other activities in national forests and is involved in international forestry issues. The Agricultural Stabilization and Conservation Service administers programs that provide cost-sharing for tree planting and forest management.

The Department of Commerce supports U.S. manufacturers and businesses in pursuing overseas export opportunities, collects and disseminates commercial information, and supports other U.S. overseas programs, including the Eximbank and the Overseas Private Investment Corp.

The *Department of Energy* is exploring, as a part of the forthcoming National Energy Strategy, how the U.S. energy program contributes to climate change problems and what technologies may be best suited to mitigate the problems. Among other programs, the department leads the multi-agency Committee on Renewable Energy Commerce and Trade, which promotes trade of U.S. renewable energy technologies.

The Department of State has responsibility for overall conduct of U.S. foreign policy. It is the lead agency in negotiating any international agreements and heads U.S. participation in the IPCC! process.

The Department of Treasury has primary responsibility for U.S. financial policies affecting other countries and for international financial institutions. The department's Office of Multilateral Development Banks directs the U.S. Executive Directors that sit on the boards of the multilateral development banks (e.g., the World Bank); through the directors, the United States has been active in scrutinizing the banks' environmental policies. The department examines approximately 400 bank projects per year that might have adverse environmental effects.

The Environmental Protection Agency is examining climate change issues (including energy use, deforestation, sea-level rise, CFCs, and methane) in developed and developing counties; it provided technical support for U.S. involvement in the IPCC.

The U.S. Trade Representative is charged with formulating overall trade policy and with bilateral and multilateral trade negotiations.

Independent U.S. Agencies/Corporations

The *Export-import Bank* (Eximbank) is an independent government agency that facilitates exports of U.S. goods and services, particularly in developing countries. Its main programs include direct loans to foreign borrowers, export credit guarantees and insurance, and discount loans. Since it is not a development assistance agency, it must have a reasonable assurance of repayment.

The *Overseas Private Investment Corp.* (OPIC) is a public/private corporation created by Congress that directly finances projects sponsored by U.S. private investors in developing countries and provides insurance against political risks for U.S. private investments in those countries. In 1987, OPIC accounted for over $8 billion in insurance and $230 million in directly financed projects.

The *U.S. Trade and Development Program,* housed in the U.S. International Development Cooperation Agency, funds feasibility and planning studies for projects involving export markets for U.S. goods and services; its focus is primarily on large public sector projects.

Continued on next page

Box l-C--Agencies and Organizations That Can Influence Greenhouse Emissions Abroad-Continued

Multilateral **Development Banks (MDBs)**

The *World Bank, the* largest multilateral development bank, spent approximately$15 billion in 1989, including $3.3 billion in the energy sector. Bank funding for free-standing environmental projects from 1990 through 1992 is expected to be about $1.3 billion. The Bank recently issued an operational directive outlining procedures for assessing the environmental consequences of proposed projects; it is too early to ascertain its effects. In 1990, the United States lost its position as the largest international aid donor to Japan This change will reduce the U.S. voting share in the Bank.[1]

The three regional MDBs--the ***Asian Development Bank, African Development Bank,*** and ***Inter-American Development Bank—are also*** major sources of assistance and have a larger role than the World Bank in many countries, for example in Central America. The latter two banks have provided about $1 billion for energy sector projects since 1988. The Inter-American Development Bank, like the World Bank, has established procedures for evaluating environmental impacts.

United Nations Agencies

The UN *Development Program* (UNDP) provides funding and advisory services to developing countries dealing with trade in development technology. It spent approximately $122 million in 1988 for natural resource, energy, and environment projects.

The UN Food and Agriculture Organization (FAO) is active in rural and agricultural research and development, fuelwood and charcoal projects, and forestry issues (including coordinating the Tropical Forestry Action Plan).

The UN Population Fund (UNFPA) provides technical and monetary assistance to developing countries on population issues. It provided about $169 million in 1988 for programs in 141 developing countries.

The UN Environment Program (UNEP) coordinates environmenta1 activities within the United Nations and led the development of the Montreal Protocol to Protect the Ozone Layer. Along with the World Meteorological Organization, UNEP coordinated the Intergovernmental Panel on Climate Change (IPCC), and is one of the managers of the World Climate program.

The UN Industrial Development Organization (UNIDO) promotes industrialization in developing countries and provides assistance to improve industrial use of energy.

The World Meteorological Organization (WMO) monitors climate trends, provides a framework for research on global climate models, and facilitates the exchange of meteorological information between countries, Along with UNEP, it plays an important role in many activities involving climate change issues (see UNEP above).

International Science and Natural Resource Organizations

The *International Council of Scientific Unions coordinates* scientific research projects worldwide and works with non-governmental organizations and intergovernmental agencies. It runs the International Geosphere-Biosphere Program and is a joint manager of the World Climate Program with UNEP and WMO.

The Intergovernmental Panel on Climate Change (WCC), setup in 1988 under the auspices of UNEP and WMO, has been the primary international forum for addressing climate change. Its three working groups were charged with: 1) assessing scientific evidence on climate change; 2) assessing likely impacts resulting from such change; and 3) considering possible response strategies for limiting or adapting to climate change. The groups were chaired by the United Kingdom, U. S. S.R., and United States, respectively. The IPCC's final report was presented to the UN General Assembly in the fall of 1990.

Other organizations focus on agriculture and forestry. The ***International Fund for Agricultural Development,*** funded by OPEC and OECD members, makes financial resources available on confessional terms for agricultural development in developing countries. The ***Consultative Group on International Agricultural Research is*** a network of organizations that conducts agricultural research in developing countries. The ***International Tropical Timber Organization*** provides a framework for coordination between tropical timber producing and consuming countries, and the ***Tropical Forestry Action Plan*** attempts to enhance donor coopemtion and funding in sustainable forestry management.

11111984, the United States had 19.5 percent of the voting power in the World Bank. This was larger than the combined *voting power* of the next three highest donors.

On December 26, 1990, the United States announced that it will double the number of joint trade-promotion programs in 1991; top priority will be given to helping the U.S.S.R. increase its oil and gas exploration and production capabilities—a means of obtaining needed hard currency, In December 1990, the President also approved credit guarantees for Soviet purchases of up to $1 billion in American commodities, making the U.S.S.R. eligible for some Eximbank credits and guarantees. However, the continuing upheaval in the U.S.S.R. suggests that the Soviets may be unable to take full advantage of these programs for some time. In addition, the June 1990 trade agreement signed by President Bush will not be submitted to Congress for approval until Soviet emigration laws are revised, so "Most Favored Nation" status cannot yet be conferred on the U.S.S.R.

Second, Congress could continue the process of streamlining restrictions on technology exports to Eastern Europe and the U.S.S.R. This could be done as part of the reauthorization of the Export Administration Act and/or by providing new directions on U.S. participation in the Coordinating Committee on Multilateral Export Controls (COCOM), a nontreaty agreement among 17 Western countries established to harmonize export control policies.

Third, Congress could provide further direction regarding ''tied-aid' financing (i.e., linking foreign aid to financing of foreign purchases of U.S products); such financing runs counter to free market policies but is used by other OECD countries. Congress already appropriated some resources for tied-aid financing to Eximbank, which decided to join with A.I.D. in creating a $500 million tied-aid pool to leverage financing for exports of U.S. products.

Congress also could consider supporting-with the cooperation of the host countries and perhaps in conjunction with other donor countries-technology research and/or assistance centers in Eastern Europe and developing countries. EPA already is coordinating the establishment of the Budapest Center in Hungary, and A.I.D. has proposed that a Global Energy Efficiency Initiative be developed to promote pricing reform, end-use energy efficiency, cogeneration, and private-sector activities.

Photo credit: W Westermeyer

St. Basil's Cathedral, located on the edge of Red Square in Moscow, U.S.S.R. The Soviet infrastructure is both massive and inefficient; investments are needed both in new, more efficient facilities and in retrofitting existing facilities for better energy use.

Building Local Institutional Capacities

Many developing country and Eastern European governmental agencies and NGOS lack the resources and experience needed to plan and implement projects, meet requirements of international donors, and assess the impact of policies and budgets on resources (29, 61). Building the institutional capacities of these governmental agencies and NGOs is critical to the success of energy and natural resource policies and programs. Bilateral agencies such as A.I.D. and multilateral assistance agencies such as the World Bank, United Nations Development Program (UNDP), and United Nations Environment Program (UNEP) already provide some assistance to help build these institutional capabilities.[32]

[32] The 1989 International Development and Finance Act (Public Law 101-24.0) requires the U.S. Executive Directors to the multilateral development banks to promote increased assistance and support for non-U.S. NGOs.

Options--Congress could direct A.I.D. to evaluate the effectiveness of its activities in this area. If found lacking, Congress could direct A.I.D. to increase its emphasis on this component, This would likely require increased funding for education and training; environmental information gathering and analysis; conservation planning and policy analysis; and coordination of regional authorities and community-based organizations.

Redirecting Natural Resources Policy

Most developing country economies are based on natural resources (29, 61), many of which have been exploited rapidly during the past few decades. However, short-term revenue gains have come at the expense of the underlying resource base and the long-term economic outlook for some countries. During the 1980s, for example, some countries that once were net exporters of tropical hardwood products found that their forests could no longer maintain a positive export flow. Resource depletion in one area also can have unintended consequences elsewhere----e. g., upland deforestation has increased silting of reservoirs and flooding in many downstream areas.

Many national and multilateral development policies foster resource exploitation, including subsidies for cattle ranching and short-term, low-rent licenses for timber harvesting. Fortunately, direct bilateral and multilateral assistance is beginning to be restructured to promote more environmentally sensitive economic development, although much more needs to be done. A. I.D., the World Bank, the Inter-American Development Bank, and UNDP, among others, are all developing or have recently adopted environmental assessment guidelines.

In addition, the food sector in developing countries is a major direct source of greenhouse gas emissions, particularly methane from cultivating rice and raising livestock. Most people in developing countries also rely on biomass fuels to meet their cooking and heating needs,, in some cases, this has led to localized deforestation (from cutting fuelwood) or loss of soil nutrients (when dung and agricultural residues are used as fuels).

Options--Congress could influence what happens in tropical forests through several means:

1. encourage continued change in multilateral development bank (MDB) policies. For example, Congress should continue to review MDB progress in implementing environmental impact assessment procedures, and in making loans contingent on host country development policies (e.g., eliminating subsidies that encourage inappropriate cattle ranching and poor logging);
2. increase funding for A.I.D. projects on agroforestry, sustainable agriculture, natural forest management, and nontimber forest products;
3. direct A.I.D. and the State Department to help make the Tropical Forestry Action Plan and the International Tropical Timber Organization, both of which have been severely criticized lately, more effective vehicles for promoting forest conservation and improved commercial forest management;
4. support development of a global forestry conservation protocol;
5. address family planning, land reform, and debt reduction issues; and
6. provide directions for U.S. participation as a donor in the new Global Environmental Facility, established in November 1990 (and coordinated by UNEP, UNDP, and the World Bank) to provide funding for projects on greenhouse gases (e.g., non-CO_2-emitting **energy sources,** energy efficiency, reforestation, CFC substitutes), biological diversity, and marine pollution.

The United States also can have some influence on emissions directly emanating from the food sectors of developing countries. Some of the policies described above for tropical forests, for example, would specifically involve agricultural projects. U.S. bilateral aid programs could attempt to introduce more efficient (in terms of greenhouse gas emissions) agricultural practices; this must, however, be carefully tailored to fit existing social traditions and economic conditions. At the same time, Congress could help fund, through U.S. bilateral aid programs and through multilateral lending organizations, various research organizations (e.g., the Consultative Group on International Agricultural Research centers) so that they could expand existing programs in developing countries to include methane reductions from livestock.

Redirecting Energy Policies

A. I.D., United Nations agencies, and the World Bank's Energy Sector Management Assistance Program provided over $200 million in fiscal year 1988 for energy-related grants and assistance; in addition, over $6 billion was provided for energy-related loans. Including technical assistance from other countries and technical support derived from portions of the loans, total technical assistance for energy may be on the order of $500 million per year-less than 1 percent of total annual energy expenditures by developing countries (28).

Until recently, much of this assistance, particularly that from bank loans, focused on conventional energy supply projects such as large hydroelectric dams and coal plants. In 1989, for example, World Bank lending for solar, geothermal, and wood-based energy projects amounted to less than 1 percent of its energy sector funding. Similarly, energy efficiency has not been a significant focus (57).

Options-Congress could redirect U.S. (and attempt to redirect multilateral) energy policies away from large-scale energy projects, such as oil- and coal-fired powerplants, and toward energy efficiency, renewable technologies, and least-cost planning. Congress could ensure that A,I.D. and the Department of Treasury have sufficient resources allocated to comply with the provisions of the fiscal year 1990 Foreign Operations Appropriations Act (Public Law 101-167), which is a step in this direction.[33]

Congress also could consider expanding A.I.D.'s Office of Energy program, which provides assistance to developing countries in formulating strategies for price reform. Similarly, it could encourage A.I.D. and the MDBs to work with the Eastern European and Soviet governments to initiate reforms in pricing policies.

To overcome agency reluctance to fund small projects, Congress could promote "bundling"-combining several small energy projects into one large project that supplies a substantial amount of energy and involves financial scales customarily handled by large development banks (e.g., $5 million or more). Public Law 101-167 instructs the Secretary of Treasury to work with borrowing countries to develop loans for bundled projects on end-use energy efficiency and renewable energy,

Photo credit: African Development Foundation

The juxtaposition of old and new technology: Guide leads oxen around solar cells at water pump, part of the Basaisa Project, Egypt.

Congress also could promote greater funding by smaller development organizations.[34] For example, the Inter-American Foundation (IAF) and the African Development Foundation (ADF) work closely with the larger Inter-American and African Development Banks to find or implement community-scale, grassroots development programs. These smaller foundations generally have a greater ability to examine smaller scale, modular programs than do their parent organizations, but to date they have rarely been involved in energy projects.

Population Policy Issues

The U.S. Government supported the right of couples worldwide to control the number and spacing of their children beginning in the mid-1960s; under the Foreign Assistance Act as amended in 1965, family planning is considered an important contributor to economic development and improved health and nutrition (11, 46). Most nations now firmly support family planning assistance.

However, at the world population conference held in Mexico City in 1984, the United States reversed its historic position by declaring that population growth was a "neutral' factor and that economic

[33] Public Law 101-167 directed A.I.D. to *identify* key middle- and low-income countries in which energy and forestry policies could significantly reduce greenhouse gas emissions, Four countries—China, Brazil, Indonesia, India-appear to emit as much greenhouse gases as the other developing countries combined. Other countries considered strong candidates for attention include Poland, Egypt, Mexico, Thailand, Colombia, the Philippines, Bangladesh, Nigeria, and Zaire. A.I.D. currently does not provide direct assistance to China, Poland, or Mexico.

[34] Other mechanisms to facilitate private-sector trade in energy-efficient and renewable energy technologies were discussed above (see "Technology Transfer and Trade With Other Countries" above).

development could compensate for any population level. Associated with this change were new restrictions on A.I.D. Thus, two important international population assistance programs lost U.S. funds-the International Planned Parenthood Federation at the end of 1984, and the United Nations Population Fund (UNFPA) in early 1986. Moreover, U.S. funding earmarked specifically for A. I.D. 's main population account has declined in recent years, from $290 million in fiscal year 1985 to an estimated $218 million in fiscal year 1990 (44).[35]

Some people argue that family planning assistance should be reduced or eliminated as a part of international aid (1 1). However, the UNFPA (38) concluded that more assistance is needed if the world's population is to stabilize--sometime early in the 22d century-at a level of 10 or 11 billion people (this is the UN's ''mid-range' projection). In particular, more assistance is needed to eliminate the large ''unmet need' for family planning services; the UNFPA estimates that the additional direct cost of providing contraceptive services would likely be less than $1 billion per year, but that several billion dollars per year also are needed for a range of backup activities (e.g., education and communication, women's programs, research and evaluation).

Any global Warmin g policies thus must include decisions on the U.S. role in international family planning. As indicated above, this issue has been and still is highly contentious. Nevertheless, Congress could reconsider the appropriate level of funding, how funds should be distributed, and under what restrictions or sanctions they should be distributed.

CONCLUDING REMARKS

Currently, the United States and other industrialized countries (including the U.S.S.R. and Eastern Europe) contribute up to two-thirds of all greenhouse gas emissions, mostly from fossil fuels used to power these highly energy-consumptive societies. There are opportunities for industrialized countries to stabilize or decrease their annual emissions of greenhouse gases. However, some sectors in Eastern Europe and the U.S.S.R. are; also likely to increase CO_2 emissions still further. In the U. S. S. R., for example, there is only 1 car for every 25 people. In Poland and Hungary, living areas average 10 to 15 square meters per person as opposed to the U.S. average of 60.

Developing countries currently contribute at least one-third of greenhouse gases, mostly from land use changes and practices (e.g., tropical deforestation, rice cultivation, and livestock). But, CO_2 emissions will surely rise for developing nations still building an industrial base, just beginning to supply electricity to their people, and increasing the use of modern methods for cooking, heating, and transportation. Efficiency investments, while crucial to growth, can only decrease the need for new power; they can not eliminate it. Thus, if current trends continue, the greenhouse gas contribution from developing countries will grow quickly within a few decades to equal or exceed those from the developed world.

Social, cultural, and economic differences will be of paramount importance in any international negotiations that take place regarding climate change, For example, reductions in per-capita living standards (which reflect many of the above factors) are not a desirable policy goal, especially for countries that are well below the average. A goal for these countries is to decouple greenhouse gas emissions from desired economic growth. Conceptually, there are several ways to achieve this-switching to nonfossil fuels (e.g., solar, nuclear), increasing the efficiency of energy and materials use, reversing tropical deforestation, and implementing sustainable use of forest and agricultural resources. Moreover, no examination of the nature and dynamics of development, natural resource and energy use, and environmental protection can omit consideration of population growth nor, for that matter, issues such as foreign debt.

Options for the U.S. Congress are limited when dealing with the actions of other sovereign nations. However, Congress could directly encourage reductions in greenhouse gas emissions by adjusting aid policies and processes to take greenhouse gases into account. It could also encourage development and transfer of appropriate technology, encourage corporate ventures into nongreenhouse gas emitting technologies, and work towards adoption of international protocols.

[35]These are actual or estimated expenditures and vary slightly from official authorizations. Total funding for population-related projects was slightly higher, because some family planning projects also are funded under other accounts.

The United States is the world's leading industrial society and largest single producer of CO_2. Major reductions of $C0_2$ and other greenhouse gases will require significant new initiatives by the Federal Government, the private sector, and individual citizens. The economic cost of these initiatives could be considerable. And many of these efforts must be sustained over decades.

OTA's analyses suggest that if the United States enacts a ''Moderate set of low-cost technical options, CO_2 emissions in 2015 will be about 15 percent higher than 1987 levels. If the United States enacts a ''Tbugh' package, CO_2 emissions in 2015 could be as much as 35 percent below 1987 levels.

But, if the United States takes no action, emissions could increase by 50 percent in the next 25 years. This would continue the trend seen in the 1980s. Since the last two oil crises in the 1970s, concerted efforts to conserve energy have dwindled on all fronts-from government research and development to personal purchasing decisions. Many other goals diluted these efforts as energy prices dropped in the 1980s.

Now, as we begin the 1990s, several overarching issues loom on the horizon-energy insecurity, m demonstrated by the events in the Persian Gulf; domestic environmental problems as evidenced by numerous oiI spills and persistent air pollution; global environmental degradation such as the Antarctic ozone hole, and tropical deforestation; and sustainablc development as the Third World struggles to bring burgeoning populations into the industrial age and compete in world markets.

All of these concerns are difficult to control unilaterally, yet the changes they could induce in the average (J. S. citizen's 1ifc over the next few decades may be profound. However, a common thread runs through these issues and can serve as an overall national g(~al-efficient energy use and conservation of' natural resources. Ultimately, achieving this goal can help to sustain industrial output, competitiveness, and our overall quality of life. However, getting there will not be easy. Many of the options identified in this report can help move us in this direction while simultaneously reducing greenhouse gases.

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