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WHITE HOUSE STAFFING MEMORANDUM

DATE: 10-5 ACTION/CONCURRENCE/COMMENT DUE BY: 10-6SUBJECT: Climate Change Memo

	ACTION	FYI		ACTION	FYI
VICE PRESIDENT	☒	☐	McCURRY	☐	☒
BOWLES	☒	☐	McGINTY	☐	☐
McLARTY	☐	☐	NASH	☐	☐
PODESTA	☒	☐	RADD	☐	☐
MATHEWS	☒	☐	REED	☐	☐
RAINES	☒	☐	RUFF	☐	☐
BAER	☐	☐	SMITH	☐	☐
BERGER	☒	☐	SOSNIK	☐	☐
ECHAVESTE	☐	☐	SPERLING	☐	☐
EMANUEL	☒	☐	STREETT	☐	☐
GIBBONS	☐	☐	TARULLO	☐	☐
HILLEY	☒	☐	VERVEER	☐	☐
IBARRA	☐	☐	WALDMAN	☐	☐
KLAIN	☒	☐	YELLEN	☒	☐
LEWIS	☐	☐		☐	☐
LINDSEY	☐	☐		☐	☐
MARSHALL	☐	☐		☐	☐
				☐	☐

REMARKS:

Comments to this office.

RESPONSE:

THE WHITE HOUSE
WASHINGTON

October 4, 1997

MEMORANDUM FOR THE PRESIDENT

FROM: GENE SPERLING
KATHLEEN McGINTY
DANIEL TARULLO
JIM STEINBERG
TODD STERN

SUBJECT: Climate Change Recommendations

Together with principals, we have worked hard over the past several weeks to put together options for you on climate change. As we note below, we have reached consensus in many areas -- such as our general stance towards developing countries, and a preliminary package of policies that we could embrace independently of the international negotiations. But reflecting the magnitudes of the tradeoffs involved in this issue, we have not been able to reach full Cabinet consensus on some fundamental aspects of our policy stance. This memorandum therefore presents three different plans, with their supporters and their pros and cons.

The memorandum is organized into four sections:

- I. Summary of difficulties we face
- II. Developing country policy
- III. Common components of all three options
- IV. The three options

I. SUMMARY OF DIFFICULTIES

As we have emphasized in previous memos and meetings, the complexity of the issue is reflected in four different constraints:

- Environmental. This issue is the premier environmental challenge of our generation. The environmental community is pushing for strong, early action to reduce greenhouse gas emissions.
- Diplomatic. Much of the world is calling for deep, early emissions reductions. The European Union is proposing 10-15 percent cuts from 1990 emissions levels by 2010; Japan is proposing 0-5 percent cuts in the same period.

- Economic. Costs are substantially higher the earlier emissions reductions are required. The cost of deep, early emissions reductions could be very large.
- Business/Labor/Hill. Aggressive approaches would expose us to well-financed campaigns -- by major corporations and labor unions -- that demagogue our policies as excessively costly and as a large energy tax increase.

In essence, the three different plans represent different views about the importance of the first two constraints relative to the second two constraints:

- The first plan moves away from the 1990 target and substitutes a lower-cost approach for achieving emissions reductions. This strategy emphasizes the third and fourth constraints by allowing a more gradual adjustment period.
- The second plan commits the nation to 1990 by 2015 or 2020 -- while capping the economic cost. It tries to address all four constraints, but could be viewed as not meeting any of them adequately.
- The third plan, which involves a commitment to 1990 levels by 2010 or 2015 while capping the cost at a higher level than under the second plan, emphasizes the importance of our environmental responsibilities and maximizes our chances for (but does not in any way guarantee) a successful agreement at Kyoto.

II. DEVELOPING COUNTRY POLICY

Given domestic political realities and the underlying environmental imperative, your advisers favor a tougher line on developing countries than we have taken to date. It is important to emphasize that developing countries are unlikely to agree to even our current demands, let alone tougher ones, in the foreseeable future. Furthermore, we will get little (if any) support from other developed countries for our position. *The position recommended by your advisers on this issue could very well endanger an agreement being signed this December in Kyoto.*

In particular, your advisers favor pushing for a "Kyoto Mandate" this December. The mandate would set the terms for a new round of negotiations with respect to:

- Binding emissions targets for key developing countries (China, India, etc.); and
- A "graduation mechanism," under which countries automatically assume additional obligations as they develop.

Developing country targets would be less stringent than those for developed countries, and might include a ceiling on costs.

There is some disagreement among your advisers on exactly how to proceed as we seek greater commitments from developing countries.

- Under the “two-step approach,” which is favored by the State Department, Energy Department and your environmental team, we would try to reach agreement among developed countries in Kyoto, but not seek to implement that agreement until negotiations with respect to developing country commitments are complete (several years, at a minimum). One possibility would be for you to issue an authoritative statement that we would not submit a treaty for ratification until the Kyoto Mandate was met. Another possibility would be to take a formal reservation to any agreement in Kyoto for the same purpose.
- Under the “one-step approach,” which is favored by some on the economics team, we would decline to adopt an agreement in Kyoto, and not adopt any new agreement with respect to developed country commitments until developing country commitments are agreed as well.

The two-step approach offers the possibility of maintaining momentum in the international negotiations (although even this approach will provoke a negative reaction abroad and could preclude an agreement in Kyoto). The cost is that we will have committed to a target and timetable before we know what we'll get from developing countries. It is unclear how the Senate would react to such a strategy.

Our best approach may be to maintain some ambiguity about our precise intentions: to emphasize that we won't bring back a treaty without real commitments from the developing countries. Since we don't know precisely how other countries will react to the one-step or two-step approach, it may be best to emphasize the general point -- and to maintain some flexibility for our negotiators in Kyoto.

Regardless of our approach, however, demanding binding targets from key developing countries implies that we will not be ratifying any international climate agreement for at least several years. Furthermore, insisting on a Kyoto Mandate may produce an extremely negative reaction abroad, and that reaction could preclude any agreement in Kyoto even under the two-step approach.

III. COMMON COMPONENTS OF ALL THREE PLANS

In addition to toughening our stance on developing countries, your advisers agree that the following policy components should form part of any plan on climate change:

1. Tax cuts

There is much interest in a Climate Change Tax Plan package of tax *cuts* in the near term

to spur energy efficiency and lower-carbon technologies. But there are two critical questions about such a tax package:

- An overall strategic question, given the budget agreement, is whether we want to offer tax cuts in any area. A potential danger with proposing a Climate Change Tax Plan -- emphasized in particular by Secretary Rubin -- is that we could open up a bidding war over tax cuts generally. If we decide to include tax cuts in our FY 1999 budget anyway, this is clearly less of a problem.
- A specific question, if we decide to offer a tax cut package, is how best to design the package. Treasury is working with DOE, EPA, and other agencies to put together a package of tax cuts amounting to perhaps \$1.5 billion per year. But according to Treasury staff, the options are unlikely to produce carbon reductions for less than \$100 per ton.

Some of the preliminary ideas include: tax subsidies to convert coal-fired power plants to gas; extension of the existing tax incentive for wind and "closed loop" biomass energy; tax credits for purchases of "superstar" energy-efficient devices and fuel-efficient cars; investment credits for energy-efficient buildings; and an expanded research tax credit for energy-efficiency research. The package will be further developed and refined over the next week. The goal is to be prepared in case you want to announce the broad outlines of a tax cut plan when you announce our overall policy package later this month.

2. Federal R&D effort

Your advisers support an aggressive Federal technology and R&D effort, including an additional \$500 million per year starting in FY 1999 and ramping up to an additional \$1 billion by FY 2003. The Department of Energy's 5-Labs study, the Department of Energy's 11-Nation Labs draft study, and the recent report from the President's Committee of Advisors on Science and Technology (PCAST) have all studied potential technologies that could help to reduce the cost of carbon emissions reductions.

The effort would focus on promising areas including:

- Energy efficient equipment (e.g., a public service campaign to attract attention to the "Energy Star" label);
- 21st Century Housing (streamline federal, state, and local building and utility regulations in ways that encourage innovation in construction);
- Expanded Partnership for the Next Generation Vehicle (expand work on the next generation vehicle technologies including fuel cells; and expand PNGV to include light trucks/sport-utility vehicles);

- PNGV for Heavy Trucks (partnership with engine manufacturers to double the efficiency of heavy-duty trucks for civilian and military applications);
- Industries of the Future (enhance industry/government research partnerships in areas such as chemicals, aluminum, forest products and steel manufacturing technologies); and
- Renewables R&D (expand research partnerships in key renewable technologies such as wind, photovoltaics, geothermal, biomass and hydropower to accelerate cost reductions).

DOE and EPA believe that such a package could have a substantial effect on carbon emissions by 2010. Others believe that the package will be beneficial, but that its results will only manifest themselves over a longer period of time.

3. Federal procurement system

The federal government spends more than \$7 billion per year on energy. While Federal energy consumption is a tiny fraction of the total U.S. energy consumption, we are still the nation's single largest consumer of energy. Significant strides have already been made during the past decade -- energy consumption per square foot in federal buildings, for instance, is down by 15 percent from the 1985 level, and energy use in federal vehicles (both civilian and military) is down about 27 percent from 1985. We can still do more, for example by expanding the use of Energy Savings Performance Contracts, reinventing federal procurement, taking a "sustainable design" approach to federal facilities, and developing more efficient military propulsion systems. This effort could include a 6-12 month review of existing Executive Orders on purchases and a directive to federal agencies to prepare greenhouse gas reductions plans.

4. Industry out-reach

Several industries have approached us recently to offer cooperation in reducing greenhouse gases. Steel, for example, believes it could reduce emissions 10 percent *below* 1990 levels by 2010 with a sectoral plan. The cement industry believes it can significantly reduce emissions in the same time frame.

Your advisers recommend that you ask leading industrial sectors to prepare greenhouse gas reduction plans over the next 6-12 months. These plans could help inform our domestic implementation strategies, including the design of our domestic emissions trading program. It could also help build a constituency for action among moderate business groups.

5. 5-Year Science Reviews

Under the existing climate treaty, the Intergovernmental Panel on Climate Change is charged with reviewing the state of the science every five years. Several corporate and Congressional leaders have suggested supplementing these reviews with additional studies by the

National Academy of Sciences or your Committee of Advisors on Science and Technology (PCAST), on a similar 5-year cycle.

6. Emphasize long-term goal of stabilizing concentrations

The goal of the existing climate treaty is "to stabilize concentrations of greenhouse gases in the atmosphere at levels that avoid dangerous anthropogenic interference with the climate system." However, the Parties to the climate treaty have never defined precisely what levels are dangerous. Support for a specific, long-term goal would be well-received in both the business and environmental communities. Many business constituencies have advocated focus on the long-term goal, to assist with planning. Environmental constituencies believe such a focus would help educate the public.

Your advisers believe the United States should announce support for a specific, long-term goal. The task of defining the goal (e.g., to keep concentrations of greenhouse gases from significantly exceeding twice pre-industrial levels, or roughly 550 ppm) could be assigned to the National Academy of Sciences as part of the first five-year scientific review mentioned above.

7. Global Environmental Facility

The United States is significantly in arrears to the Global Environmental Facility, which assists developing countries in reducing greenhouse gas emissions. (Of the \$430 million pledged for FY93-FY97, we have been able to contribute roughly \$185 million.) These arrears reduce our leverage with developing countries in negotiations under the climate treaty.

Your advisers recommend you reemphasize your strong commitment to the Global Environment Facility and support clearing U.S. arrears at the earliest practical date. Funding for the Global Environment Facility should be pursued as a top priority.

8. Bilateral dialogues

We are pursuing bilateral dialogues with key developing countries (including China, Brazil and India) to promote clean energy. Often, interest in energy efficiency and renewable energy is greater in these settings than in the politicized, multilateral setting of the Climate Convention. Discussions focus on regulatory structures for clean energy development, technical assistance, export credit and related items.

You or members of your Cabinet will sign several agreements of this type during your upcoming trip to Latin America. Work is underway in this area in connection with the Jiang Zemin state visit later this month. Your advisers recommend that we pursue these dialogues with increased effort in the years ahead.

9. Other possibilities

Other possible elements, which have not yet been fully vetted, include a renewable portfolio standard and other carbon-reducing policies in electricity deregulation; National Environmental Policy Act (NEPA) guidance with respect to greenhouse gas emissions; common energy-efficiency guidelines for export credit agencies; a corporate greenhouse gas reporting system modeled after Toxic Release Inventory; and streamlined standards to improve energy efficiency, where appropriate.

IV. THREE OPTIONS

PACKAGE 1

OVERALL STRATEGY

- The long-term goal of the treaty is to *stabilize concentrations* of greenhouse gases in the atmosphere at a level that will prevent dangerous anthropogenic interference with the climate system. This goal could be achieved with concentrations at or somewhat above a doubling of pre-industrial levels in the next one hundred years.
- The strategy here is to propose the least-cost approach, both in terms of timing and developing countries, to stabilizing concentrations over the long run. The logic is that only by proceeding in this least-cost approach could we get domestic agreement to undertake a serious climate change policy.

TARGETS AND TIMETABLES

- Concentrations can be stabilized through the following targets and timetables:
 - Reduce emissions growth* in the United States in the near term (for example, growth from 2000-2010 less than growth over 1990-2000); then
 - Eliminate emissions growth* in developed countries 10 to 20 years after treaty is signed (e.g., 2010-2020); then
 - Reduce emissions levels* in developed countries gradually to reach — and then to decline below — 1990 levels in later years to be decided, stabilizing concentrations.
- This timetable begins effective action soon to establish Presidential leadership.
- The schedule of reducing emissions and emissions growth is determined by the degree of economic cost that is acceptable, coupled with the rate of improvement in emissions-reduction technologies that results from increases in carbon prices.
- As in the second plan (see below), there would be periodic review of the underlying science, the data on the path of emissions, and the economic impact, to allow for adjustments in the policy.
- Insist on the current U.S. flexibility positions of international trading, multiple multi-year targets, joint implementation (subsidies of non-carbon energy sources in developing countries), banking, and borrowing.

DEVELOPING COUNTRIES

- The goal is the least-cost global approach to stabilization of carbon concentrations in the atmosphere.
- Negotiate and begin a new Kyoto Mandate, requiring developing country participation (in stages), starting with more-advanced (Annex B) developing countries, with graduation as countries develop. Developing countries commit to reduce the rate of growth of emissions consistent with stabilizing carbon concentrations and continued economic growth, with ceilings on costs.
- One-step: the U.S. will not initial agreement until Annex B countries have binding commitments.

DOMESTIC IMPLEMENTATION

- Develop a tradable permits system, with auction of all permits (rather than grandfathering), in the near term; impose the system at a level of emissions near the baseline (for example, with an implied permit price of perhaps \$10 per ton). The system could take effect while the Kyoto Mandate was negotiated, to emphasize U.S. leadership and credibility; or it could be postponed until the treaty was ratified, as an incentive for developing-country compliance. (A carbon tax, if feasible, would be an alternative method of implementation.)
- Change the number of permits in small, gradual, predetermined steps, based on economic cost and aggressive technological progress (with the implied permit price rising to perhaps \$22 per ton or more by 2015). As in the second plan below, review domestic implementation system periodically.
- A portion of funds raised would be used for cost-effective technology research and diffusion programs, including basic research. The bulk would be available for a range of domestic priorities (tax relief for individuals; business investment incentives; the solution to the fiscal effects of the demographic imbalance; infrastructure; etc.) chosen to make the program attractive.
- Begin a series of voluntary industry programs to develop plans to meet the targets.
- Provide for banking and borrowing to deal with short-term fluctuations. Borrowed permits would be issued at a premium cost, and banked permits could be resold later at higher prices.
- Provide economic growth insurance or a cost cap on permits that would allow the sale of additional permits. The price would be set consistent with our estimate of the acceptable

economic cost, and would be high enough to encourage emissions-efficient investment choices in the near term. (If the cost cap were in effect over an extended period, the target would not be met.)

- These policies are market-oriented. There would be no inefficient, command-and-control regulations used to reduce emissions.
- Include common components listed above.

SUPPORTERS

Larry Summers, Janet Yellen, Frank Raines, Secretary Daley, and Secretary Herman.

PROS

- The principal benefit of this approach is that it reduces the cost of beginning to address climate change by allowing more time for the economy to adjust gradually to the new constraints being placed on it.
- Business and labor groups would support this approach.
- The approach would also be strongly supported by leading economists, such as William Nordhaus of Yale. It is consistent with the economics consensus on the least-cost path to the environmental goal of stabilizing concentrations in the very long run.

CONS

- This approach would be completely unacceptable to the environmental and international communities. We could respond that if the emissions path it envisions is met, it would stabilize concentrations and thus produce the same climate benefits as other paths that are substantially more economically costly.
- This option depends on steep -- and possibly implausible -- emissions reductions in distant decades to achieve our environmental goals.
- It would be awkward to reconcile this approach with previous statements made by both you and the Vice President. We could respond that we are starting over with a new Kyoto Mandate, and that part of that mandate will be to achieve environmental goals through the least-cost approach.
- There is no chance of an international agreement in Kyoto or the near future with this proposal. But if an agreement is reached that incorporates this approach, it may be much easier to ratify.

PACKAGE 2

OVERALL STRATEGY

- This approach involves a hybrid plan that includes a commitment to reduce emissions to 1990 levels by 2015 or 2020 with a safety valve to cap economic costs.
- The approach begins with the tax cuts, R&D, and other initial steps in the common components section above, before the permit system becomes effective.
- The safety valve would ensure that permit prices could never rise above some ceiling, by allowing the U.S. Government to sell an open-ended number of additional permits at that price. This approach thus allows you to set an ambitious goal for the country while insuring that the costs are not excessive. But with a relatively low ceiling price, the overwhelming majority of economists will claim that we could not possibly avoid having to trigger the safety valve and thus fail to meet the stated goal of 1990 by 2015 or 2020. Opponents could attack the approach as lacking in credibility.

TARGET AND TIMETABLE

- 1990 by 2015 *or* 1990 by 2020, with a safety valve (explained below). The purpose of the safety valve is to allow us to adopt a relatively aggressive target and timetable, with the understanding that we will only meet it if possible to do so at reasonable cost.
- An issue that needs to be resolved is how the safety valve would be handled in the international negotiations, if at all.
- Additional reductions (to be determined) after 2015 or 2020.
- Support international trading and joint implementation.

DEVELOPING COUNTRY

- Kyoto Mandate for negotiations, with a goal for them to be completed by 1999.

DOMESTIC IMPLEMENTATION

Initial actions

- Common components plan. Emphasize tax cuts and R&D to build corporate support.
- Emphasize commitment to market-oriented policy tools to reduce emissions.

- Avoid decisions about grandfathering vs. auctions. Instead appoint commission to suggest structure of domestic emissions trading program -- auctioning with tax cuts, or grandfathering with an excess profits tax.
 - The commission would work with industry groups to evaluate their vision of the trading system.
 - The commission would also study possible adjustment programs for areas and sectors that will bear a disproportionate burden from emissions reductions.
 - One possibility would be to give the commission's recommendations base-closing legislative treatment, although there may be concerns about such a mechanism given the scope and importance of the commission's work.
 - Deadline for commission to report would be early 1999 or 12 months following treaty.

Domestic emissions trading program (with safety valve) starts in 2005

- Commission decides on structure of permit program.
- The permit requirements between 2005 and the first review in 2008 could be set slightly below business-as-usual levels.
- Ceiling on permit price, as defined below, to cap economic costs

Safety valve (ceiling on price) in permit trading system

- The tradeable permit system would include a safety valve: the U.S. government would stand ready to sell a potentially unlimited number of permits at a given price, ensuring that the permit price could not rise above that level. *This safety valve is absolutely essential to the domestic viability of this approach.*
- The price would start at \$10 per ton in 2005 and rise in real terms by \$1-\$2 per year (0.25-0.5 cents per gallon) until it reaches \$30 per ton in 2015 or 2020.
- If any funds are raised from the safety valve mechanism, they could be devoted to further emissions reductions -- additional tax cuts for families, for carbon-reducing investments by businesses or families, tax cuts for R&D, Federal investments in R&D or energy-efficiency, or for investments in carbon-reducing efforts in other countries.

5-Year review process

- The Clean Air Act requires EPA to undertake a regular 5-year review of air quality

standards, and other statutes require similar reviews. Similarly, every five years, a commission -- which builds on the implementation commission above -- would review progress on emissions reductions, and how the economy was responding. It would then make recommendations to the President and Congress about how to adjust the policy stance toward climate change.

- The commission to report on domestic implementation (mentioned above) would be the first of these commissions. The first report would thus occur in 1999 or 12 months following the treaty. The second report would be in 2004, and the third in 2009. The third commission report would be able to evaluate the operation of the domestic permit system after four years of experience (since the permit system will begin in 2005).

SUPPORTERS

Gene Sperling and Katie McGinty constructed this compromise plan, as requested by Erskine. They worked closely with Todd Stern in developing a package that the three of them support with one difference. Gene supports a 1990 by 2020 timetable, while Katie supports the 1990 by 2015 timetable.

Gene feels that the 2020 date is important for three reasons:

1. It boosts the credibility of the relatively low price ceiling in the plan, by allowing more time for the economy to adjust before the timetable binds and thus raising the probability that the safety valve would not have to be invoked;
2. It attenuates corporate and union opposition to the plan; and
3. It allows us some room to bargain from at the international negotiations in Kyoto and beyond.

Katie feels that the 2015 date is important for three reasons:

1. Your announcement of any date after 2015 would pose unacceptable risks of immediately cratering the Kyoto negotiations.
2. With any date later than 2015, there is little or no chance that we will be able to convince the international community to accept other components of our position (e.g., joint implementation, Annex I international trading, the safety valve, and our developing country stance).
3. A 2015 timetable offers at least some possibility of support from moderate environmental groups -- especially if we also commit to some reductions, even small ones, from 1990 levels by 2020.

Secretary Pena and Secretary Slater both support the package. Todd Stern supports it with a 1990 by 2015 timetable.

Dan Tarullo supports a hybrid of Package 1 and Package 2. As in Package 1, he supports starting the domestic implementation package immediately upon agreeing to a treaty, not in 2005. He also believes strongly in auctioning permits or some other mechanism of raising revenue, rather than grandfathering permits. But he believes that we can commit to 1990 levels by 2020, with the explicit acknowledgment that the uncertainties of technological development and diffusion, as well as consumer behavior. He favors a reassessment in 2007 to see if the targets and timetables need to be adjusted.

Your economic team urges that if you choose this option, you should choose the 2020 timetable and emphasize that you will *not* use command-and-control regulations to avoid invoking the safety valve. They would also urge a careful analysis of the best level for the trigger price.

NOTES

The fundamental strategy here is four-fold:

- First, we will focus our entire policy efforts up to 2005 on tax cuts, R&D efforts, Federal energy efficiency improvements, and the other components of the policy package listed in Section III of the memo.
- Second, the permit system would start in 2005 -- so that the debate over energy price increases explicitly pertain only to 2005 and beyond. At the same time, environmental groups will appreciate that the permit system begins within the next 10 years.
- Third, the plan puts a ceiling on the permit price to limit the economic downside and stunt opposition attacks about the economic costs involved.
- Finally, the plan still gives the nation a goal of reaching 1990 emission levels by 2015 or 2020 -- a goal that is subject to a cost cap, but is more binding than the non-binding aim agreed at Rio.

The main problem with this option is that it may be harshly criticized as promising more than the implementation plan can deliver. Current models almost uniformly suggest that we would not be able to meet our target and timetable at a price below \$30 -- i.e., that we could not avoid triggering the safety valve. To put the point another way, this approach will limit the permit price to \$10 to \$30 per ton (\$15 to \$45 billion year). But economic models almost uniformly suggest that permit prices would have to be substantially higher to achieve 1990 emissions levels in 2015 or 2020. Therefore we could be attacked on our credibility -- that our plan did not contain enough restraint to meet its stated emissions reduction goal.

Those who support this option believe that the answer to the credibility argument is not a fight over economic models. Rather, they argue that in the face of incredible uncertainty over events twenty years away, it is best to put forward a sound -- even if highly optimistic -- plan for the nation. In particular, we should not unnecessarily impose economic hardship when technological breakthroughs, new scientific understandings or successful international trading could lower costs. If we take on the economic model debate directly, we will almost certainly lose. The best tact is to emphasize the uncertainty, and to note that future administrations and Congresses will assess new information every 5 years and make appropriate adjustments. We could get some outside validation for our emphasis on uncertainty from those who believe that international trading is possible, from those who believe that economic models tend to exaggerate the costs of meeting environmental goals, and from those who believe that technological development and diffusion could respond strongly to even a limited price signal. The safety valve idea could also receive outside validation: similar ideas have been embraced by Resources for the Future and Brookings, although they may not agree with our trigger price.

Another key aspect of defending this plan is to emphasize that we are not supporting using command-and-control measures if the ceiling price does not produce the full reductions needed to hit the emissions target. Specifically, when asked about whether setting an optimistic target with the ceiling price would mean that higher energy taxes or command-and-control regulations in the future, we should state that we are against such measures and that we would assume that future Congresses would also oppose such measures. Without this guarantee, opponents may feel threatened instead of comforted by our reasonable ceiling. Furthermore, we would point out that such scenarios would not take place for a decade, and that we would not expect future Congresses to support such command and control alternatives as well.

With this posture, we would be arguing that we are committed to reaching 1990 levels by 2015 or 2020 -- but not at any cost. We would not expect future administrations or Congresses to allow the costs of complying with the treaty to become extreme or excessive. We would also note that the 5-year reviews would allow us to adjust our policy stance as more information becomes available. Finally, it is important to note that we would still taking real steps to reduce emissions even if the safety valve *is* triggered. Indeed, the *policy steps* under this approach if the safety valve were triggered are equivalent to those proposed under Plan 3. Even with the cap, the cost to polluting would be higher than today, and thus we would divert emissions from the business-as-usual path. We would also start the emissions trading program by the relatively early date of 2005, which should help to address some of the concerns environmental groups may have with this approach.

PROS

- Seeks to hit a middle ground -- still proclaims a target and timetable, but only at reasonable economic cost. With a target of 1990 by 2015 or 2020 -- tempered by the safety valve, but still stronger than our Rio commitment -- we would have a chance of remaining "in the game" in the international and environmental communities. By limiting the economic costs, we could avoid undue disruption to the economy and stunt potential attacks.

- Permit system starts in 2005, so that we begin to deflect from business-as-usual path within a decade. The early start date would also help utilities to integrate their planning for reductions of NOX (under EPA's recent clean air rule) and carbon emissions.
- Consistent with our language of "binding but *realistic*" and "reducing emissions while we grow the economy."
- Starting with only tax cuts and R&D for 7 years, and not beginning the permit system until 2005, *may* make it harder for the Administration to be demagogued on tax increases.

CONS

- Risks splitting the loaf and pleasing no one:
 - Business groups may still demagogue the plan, arguing for example that \$20 per ton is approximately the same size as the BTU tax proposed in 1993. If we decide that the plan would be revenue-neutral, we could respond with that point, and note that it would not become effective for several years.
 - Business groups could also charge that the combination of a relatively tight target and timetable with a low trigger price would imply that command-and-control regulations would be used to fill the gap. We could respond by emphasizing our commitment to market-based solutions.
 - Many environmental groups will oppose, arguing that the 2015 or 2020 date is too late and that the safety valve undermines our environmental commitment. We could respond that on their optimistic predictions about new technologies, the safety valve would not be needed. We could also respond that our policy is a politically realistic way of addressing the climate change problem. Some more moderate groups may support the package, especially in light of the 2005 start for the permit system and if the package includes further reductions beyond 2015 or 2020. Although environmental groups are calling for reductions below 1990 levels by 2010, a relevant threshold for many of them is reductions below 1990 levels at least by 2020.
- Mainstream models almost uniformly suggest that without worldwide international trading, there is little likelihood that we could avoid triggering the safety valve at \$30 per ton. Some of your advisers could be forced to admit that the overwhelming weight of conventional economic analysis suggests that the safety valve would be triggered.
- Will seriously complicate international negotiations. In combination, the 2015 or 2020 date, our domestic cost cap and our insistence that developing countries do more will be perceived as lack of U.S. leadership.

PACKAGE 3

OVERALL STRATEGY

- This package is similar to Package 2 in containing a safety valve, but it involves steeper emissions reductions and higher economic costs than under Package 2. In this sense, it conforms most closely to the first two constraints noted in the first section above (environmental and international). It involves less dramatic reductions than those proposed by the EU or Japan, but has some chance of being accepted internationally. Despite provisions that cap the permit price at about \$50 per ton, this package would likely be strongly opposed by much of the U.S. business community. And as above, the cost cap comes with a real risk: it implies that we could fail to reduce emissions to 1990 levels by 2010 or 2015.

TARGET AND TIMETABLE

- 1990 levels by 2010 with safety valve *or* 1990 levels by 2015 with safety valve
- Further reductions at a later date.
- The permit price would be capped at roughly \$50 per ton by allowing the U.S. Government to sell an unlimited number of additional permits at that price.
- Require adequate provisions for international emissions trading, joint implementation and banking.

DEVELOPING COUNTRIES

- Two-step approach as outlined above. Kyoto Mandate for negotiations, with a goal for them to be completed by 1999.

DOMESTIC IMPLEMENTATION

- Domestic permit trading system, with a safety valve that ensures a ceiling of about \$50 on the permit price.
- Common components plan. Emphasize tax cuts and R&D in near term to build corporate support.

SUPPORTERS

Carol Browner, Secretary Babbitt, and Brian Atwood support the plan -- but only with the 1990 by 2010 timetable.

Jim Steinberg supports this package, emphasizing the importance of a credible trigger price (one set high enough that it could be defended as a reasonable estimate of the cost of meeting the target).

Jack Gibbons supports this approach, but emphasizes the importance of a significant reduction in the 2020-2030 timeframe linked to a long-term stabilization goal.

Strobe Talbott supports this general approach. He could also be supportive of Plan 2. Secretary Glickman supports this package, but is also willing to support Plan 2.

PROS

- Kyoto agreement perhaps possible (especially if 1990 by 2010), although not guaranteed -- especially given the safety valve and our position with respect to developing countries.
- Some support from environmental groups (especially if 1990 by 2010), although some will consider the emissions reductions to be too weak and the safety valve to be problematic.
- Stronger start in addressing environmental problem limits need to depend on steep -- and arguably implausible -- emissions reductions in distant decades to reach environmental goals.

CONS

- The commitment would be attacked as the largest energy tax hike in history -- costing \$75 billion per year. Despite the safety valve, many would charge that a commitment of this nature could have substantially adverse effects on the economy.
- Strong corporate opposition -- especially if 1990 by 2010 -- for not allowing enough time for the economy to adjust.
- Relative to the \$30 ceiling in Plan 2, this plan would produce greater economic dislocation and more powerful ammunition for opponents that want to attack the economic costs of the plan.
- The ceiling poses many of the same tensions as in Plan 2. A \$50 ceiling may prove inadequate to meet a target of 1990 by 2010.



THE CHAIRMAN

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

October 3, 1997

MEMORANDUM FOR THE PRESIDENT

FROM: JANET YELLEN *JY*
LAWRENCE SUMMERS *LS*

SUBJECT: Targets and Timetables for Reducing Greenhouse Gas Emissions

Executive Summary

This memo provides a preliminary evaluation of the likely economic consequences for the United States of a program to attain 1990 CO₂ emissions levels by 2010. It concludes that the attainment of such a goal would necessitate at least a doubling in energy prices and impose substantial economic costs. In contrast, a more gradual emissions reduction path that eliminates emissions growth by 2010-2020 and reduces emissions to 1990 levels thereafter captures nearly identical environmental benefits as the more aggressive approach while entailing costs between one tenth and one third as large.

If attained through domestic emissions reductions alone the "1990 by 2010" target requires a reduction in CO₂ emissions of roughly 30% relative to projected 2010 emissions assuming "business as usual". *The reduction in energy use needed to meet this goal would be comparable to that achieved during the decade of the OPEC price hikes, so that energy price increases of similar magnitude are likely.* Economic analysis and historical precedent suggest that energy price increases of this size would have stagflationary consequences. As in the decade of the oil shocks, both unemployment and inflation would undoubtedly rise, at least for a time.

An "idealized" system of international permit trading among Annex I countries could hypothetically halve the change in carbon emissions prices needed to attain a 1990 by 2010 goal. This would mean paying Russia and other Eastern European countries to reduce emissions in place of the United States. However, such an arrangement could prove infeasible for a number of reasons, including difficulties in establishing adequate enforcement and monitoring mechanisms in the near term. Joint implementation with non-Annex I countries is likely to marginally reduce the impact on energy prices in the United States.

The memo argues that a more gradual timetable for emissions reduction can deliver virtually identical environmental benefits at a fraction of the cost. The aggressive "1990 by 2010" path is extremely inefficient because it requires premature scrapping of capital and foregoes the considerable advantages of waiting for the development of carbon-lean technologies

before replacing existing plant and equipment. In contrast, a timetable that eliminates emissions growth in the second decade of the program (2010-2020) and reduces emissions to 1990 levels and below in subsequent decades is consistent with a long-term goal of stabilizing atmospheric CO₂ concentrations. *The total cost of this "back-loaded" approach is likely one third to one tenth that of the "front-loaded" 1990 by 2010 program.* Implementation of the gradual timetable requires an early, modest increase in the price of carbon emissions, along with a credible commitment to further emissions price increases over time.

In comparison with a more gradual emissions reduction timetable, the environmental benefits of an aggressive abatement target are minimal. For example, the expected difference in global average temperature in 2100 along a fast-takeoff abatement path that attains 1990 emissions by 2010 and a slow-takeoff abatement path that peaks in 2015 and attains 1990 emissions by 2040 is less than 0.05 degrees Celsius. Between now and 2100, global average temperature is expected to rise about 2½ degrees Celsius irrespective of the path chosen for Annex I stabilization, assuming developing countries continue with business as usual.

The body of this memorandum lays out the rationale for these conclusions.

I. Introduction

The Framework Convention on Climate Change signed at the 1992 earth summit in Rio de Janeiro called for carbon dioxide emissions in 2000 at 1990 levels. Most countries, including the United States, are unlikely to achieve these emissions reductions. But the Rio approach remains historically important, and most quantitative proposals that have been advanced in the run up to Kyoto can be understood as variants of the Rio target and timetable. In particular, a proposal to "stabilize CO₂ emissions at 1990 levels by 2010" (and variants thereof, including a more stringent proposal by several EU countries to stabilize at 10% below 1990 levels by 2010) has received considerable attention.

This memo assesses the consequences for the U.S. economy of a program to attain 1990 CO₂ emissions levels by 2010. It compares the costs and cost effectiveness of this baseline proposal with those of alternative targets and timetables that entail a less rapid initial reduction in CO₂ emissions levels. The conclusions described here rely on the substantial body of economic analysis that has been conducted by researchers worldwide, including the Intergovernmental Panel on Climate Change (IPCC), and Administration economists.

II. 1990 by 2010: The Scope of the Task

To appreciate the ambitiousness of a program to curb U.S. emissions levels to 1990 by 2010 it is necessary to recognize that, by 2010, emissions are likely to exceed their 1990 levels by about 31 percent.¹ As of 1996, energy related carbon emissions were already 9 percent above 1990 levels. Growth in the economy through the end of the next decade would further raise energy use and carbon emissions. Even under an optimistic assumption concerning the pace of improvement of energy efficiency (0.9 percent per year), there would be further increases in carbon emissions of about 22 percent over current levels by 2010 if we continue with business as usual. A substantial increase in the price of carbon emissions will be needed to induce such a large emissions decline.

An increase in the price of carbon emissions--whether achieved through a system of tradeable emissions permits or a carbon tax--creates incentives to reduce emissions in two separate ways: by reducing overall energy use; and by inducing switches among fuels, away from high-carbon fuels like coal and toward low- and no-carbon fuels, such as natural gas and renewable energy. Reasonable estimates suggest that interfuel substitution in response to higher carbon emissions prices could accomplish between 25 and 45 percent of the overall task, with the remainder occurring through reduced energy use. The implication is that overall energy use must

¹ This assumes a 2.4 percent annual GDP growth rate. Even with a more moderate assumption of 2.2 percent annual GDP growth, carbon emissions in 2010 would exceed their 1990 level by about 28 percent.

decline by about 15% to 18% relative to "business as usual" levels to attain the 1990 by 2010 emissions target. Energy use *does* respond to changes in the price of energy; but history suggests that the responsiveness is *low* over periods as short as a decade. In particular, the experience of the United States during the 1970s and 1980s suggests that energy prices would need to at least double--as they did during the OPEC oil shock period--to attain a 1990 by 2010 target.

Comparison with the Oil Shocks. Figure 1 shows aggregate energy use in the United States and the relative price of energy over the period 1960 to 1990. During the oil-shock period --1973 to 1984--energy use remained virtually constant in absolute terms while GDP grew about 2.5% per annum in real terms. The relative price of energy rose about 130 percent during these years. Again assuming a 0.9 percent pace of improvement in energy efficiency with constant energy prices, the 130 percent energy price hike served to reduce energy use about 16 percent relative to the "business as usual" baseline. *This experience suggests that an increase in relative energy prices roughly comparable to the 130% OPEC-induced rise will be needed to lower energy use by the 15 to 18 percent required to reach the 1990 by 2010 target. A 130% increase in energy prices translates into a carbon tax of roughly \$170 per ton.*

Model results. Numerous economic/energy models have been used to estimate the impact of a 1990 by 2010 program on energy prices. These models arrive at the same conclusion as was generated above using no model whatsoever: a program to achieve 1990 emissions by 2010 would likely entail *at least* a doubling of energy prices. A broad range of models place the carbon permit price required to achieve 1990 emissions by 2010 in the range of \$80 to \$250 per ton. If fully passed through to energy prices, a permit price of \$100 per ton, for example, entails a 76 percent increase in energy prices. The impact on the prices of different sources of energy are all large, but the effect on coal is particularly severe. The price of coal would more than triple, while the price of a barrel of petroleum would increase by about fifty percent. Gas at the pump would increase in price by about 26 cents. Relative to the BTU tax proposed by the Administration in 1993 a \$100 implicit carbon tax is about 5 times as large. Thus, attaining a goal of 1990 by 2010 would have very large effects on our economy.

Evidence from International Comparisons. A final piece of evidence confirming the conclusion that a strong price signal over a long period of time is necessary to alter energy use comes from comparisons of energy usage between the United States and Europe. It should hardly be surprising that energy use per dollar of GDP is lower in Europe than the United States. Energy prices in Europe have long been substantially higher--roughly double U.S. energy prices. Moreover, major differences in living patterns between the United States and Europe result in higher European energy efficiency. In addition to the geographical "advantage", from an energy efficiency standpoint, of Europe's higher population density, resulting in lower transportation requirements, Europe has locked in place many long-run adaptations to high energy prices. Innovations in the design of housing and transportation systems and the configuration of residential areas have occurred in response to high energy prices. But in spite of its natural advantages and its long history of high energy prices, energy per dollar of GDP is only 44% lower in Europe than in the United States. This means that even if the United States were to

become Europe--energywise per dollar of GDP--its energy savings, even in the long run, would be no greater than 44 percent. This U.S.-Europe comparison supports the conclusions drawn from the natural experiment of the oil shock: namely, a return to 1990 emissions will not occur without very major price measures over a long period of time.

The Role of Technology and the Scope for "No Regrets" Policies. According to the preceding assessment, a large price inducement is necessary to meet a 1990 by 2010 target. Your economic advisers agree on this conclusion. However several of your advisers are more optimistic about the chances of achieving a 1990 by 2010 target. They emphasize the current availability of "no regrets" (cost-saving) technologies that promise substantial opportunities for abatement. A recent report by the Department of Energy research laboratories, for example, catalogues emissions-saving technologies that, by their calculations, are currently "cost effective." If put in place now, such practices could allegedly reduce emissions by between 30 to 50 percent of the amount needed to reach a 1990 by 2010 target. Even so, the report finds that "aggressive" and "invigorated" government policies--including potentially costly and intrusive regulations and standards--as well as a \$50 carbon tax would be necessary to reach the 1990 by 2010 target.

Your economic advisers agree that there now exist unused technological opportunities for emissions reduction, but we question by what means, over what time frame, and at what expense government policies could change private behavior if such opportunities are currently underutilized. Engineering studies generally ignore the sometimes subtle disadvantages of available cost-saving technologies or overestimate their hypothetical returns. An example is illustrative: significant energy and cost savings could result if consumers replace incandescent bulbs with compact fluorescents. Over the long lifetime of such bulbs there would also be a substantial monetary gain. However, actual adoption of these light bulbs has been slow to date, possibly due to pure inertia, possibly because consumers dislike their color, or perhaps because they apply a high "discount rate" when valuing energy savings that accrue after the purchaser may have switched residence. Several recent studies have demonstrated that the actual returns to home improvement investments, such as attic insulation, often fall short of those predicted by engineering studies.

Regardless of the reasons, if consumers have not adopted "no regrets" measures at a faster rate, it is likely that additional incentives will be necessary for them to change their minds. Rather than stressing the mere availability of alternative technologies, your economic advisers insist on realistic estimates of likely rates of adoption and diffusion and they stress the need for economic incentives--in the form of a higher implicit price for carbon emissions--to induce the adoption of emissions-saving technology. They point out too that the baseline energy demand estimates used to predict the price increase needed to attain a 1990 by 2010 target already assume substantial ongoing improvements in energy efficiency due to the diffusion of existing technologies and the development of new ones. Significant adoption of such technologies is necessary merely to meet this assumed baseline. Finally, it is important to note that the DOE labs study includes as part of its policy package to reach 1990 emissions by 2010 extensive

regulations, including stringent CAFE and appliance standards and national building codes--command and control policies that your economic advisers would oppose--along with a \$50 carbon tax.

To summarize, your economic advisers consider it unrealistic to predict a substantial increase in the pace of adoption of new emissions-saving technologies in the absence of a large increase in the price of carbon emissions--and hence of energy. Based in part on the evidence from the energy shocks of the 1970s, in part on international comparisons, and in part on model results, they are optimistic that such an increase in prices would bring forth a reduction in CO₂ emissions--with larger responses to a given price change likelier the longer the time period for response. The evidence is strong that a very large price increase will be necessary to attain emissions reductions of 20 to 30 percent over a period as short as a decade. *Moreover, other approaches that apparently do not involve large price increases (such as performance standards) will impose even higher costs on the American economy.*

III. Why are the costs of early emissions reductions so high?

The previous section argued that a "1990 by 2010" target would entail high carbon emissions prices and significant economic costs. This section shows that the 1990 by 2010 timepath for emissions reductions is so aggressive as to be inefficient--in the sense of raising substantially the total projected economic cost of reaching a given environmental goal. There are three major reasons why an aggressive takeoff in curtailing emissions raises overall costs: (1) it induces premature obsolescence of the capital stock because it does not allow adequate time for the capital stock to turn over naturally; (2) it provides insufficient lead time to develop and implement new technologies; (3) it causes a significant stagflationary short-term macroeconomic shock. Additionally, an aggressive timetable for emissions reductions does not allow time for the resolution of uncertainty and it does not take advantage of the time-value of money (resources not spent on emissions reductions early on can be invested at a positive return which could purchase more emissions reductions later).

The Role of Turnover of the Capital Stock. The most clear-cut and easily quantifiable reason for the high price tag associated with rapid emissions reductions relates to the need for premature replacement of plant and equipment in response to large increases in the price of carbon emissions. It is expensive enough to replace plants that are fully depreciated, but vastly more so if those plants are still in the prime of their productive lives. Within 20 to 40 years, much of our existing plant and equipment will be ready for replacement anyway; therefore building in greater carbon efficiency at that time will be relatively cheap. *It is important to emphasize that the case we are making here is not based on procrastinating for the sake of avoiding the problem; rather, it is based on simple principles of hard-headed business efficiency.*

The advantage of a more gradual emissions reduction timetable in avoiding the large

costs associated with premature obsolescence of the capital stock can be illustrated by considering electrical power generation. The case of electricity generation is important in its own right since this industry is responsible for 88% of coal use and more than one third of all carbon dioxide emissions in the United States. But the principle concerning the costs of premature replacement applies broadly because reduced greenhouse gas emissions may entail the accelerated retrofitting of housing and commercial structures, the premature scrapping of vehicles and appliances, and the premature replacement of plant and equipment in energy intensive industries.

Figure 2 illustrates the effect of an accelerated retirement schedule for today's U.S. electric power generation capacity installed during the last 40 years. Imagine, to take an extreme case, that a timetable is adopted that necessitates replacing all power plants with less-polluting technology within ten years. This would require retiring 630 out of 670 gigawatts of generating capacity before the end of its normal life span, or 94 percent of the total. If the timetable were extended so that all power plants instead had to be replaced within 20 years, the accelerated replacement of capacity would affect 450 gigawatts of capacity, or 67 percent of the total. Allowing this additional 10 years for turnover avoids the premature retirement of 27 percent of existing electric power plant capacity. With a 30 year horizon, complete turnover would mean accelerated retirement of only 21 percent of the total capacity and, with a 40 year timetable, there would be almost no additional costs due to premature obsolescence.^{2, 3}

The Advantage of Waiting for Superior Technologies. The example of electric power generation also illustrates a second important reason why a gradual takeoff in curbing greenhouse gas emissions is ultimately less costly: new technologies take a long time to develop. Waiting until these new technologies are available before making expensive emissions-saving investments offers the potential of both lower economic costs and higher environmental payoffs. Under a tight target and timetable with its associated high carbon emissions price, electric utilities will be forced to replace existing capacity in the very near future and to rely on currently available lean-carbon technologies, likely gas-turbine plants. If some delay can be factored in, however, they will be able to install more effective and less costly alternative technologies. A rapid timetable forces long-term investments to be made before superior technologies have been

²The distribution has been truncated at 40 years, the average lifespan of existing electric power plants. A few plants of yet older vintage are still in use.

³The same exercise can be performed for coal-fired power plants. These generators produce the most carbon per kilowatt hour of electricity and thus will have a high incidence of replacement even under a moderate abatement plan. If a complete change-over of coal plants were to be accomplished in 10 years, 96 percent of total capacity would be retired early. If retirement occurred over 20 years, only 64 percent would be retired early. Allowing an additional 10 years for turnover would avoid premature retirement of one-third of existing coal-fired plant capacity.

developed and refined.

Implication: The Need for a Credible, Long-Term Price Increase. The example of electricity generation illustrates two general principles. First, the responsiveness of both demand and supply are greater in the long run than in the short run. This means that, with a longer horizon, any given amount of abatement can be accomplished with a smaller increase in carbon emissions prices. Second, and perhaps even more important for policy, any credible emissions reduction strategy must include both a price increase at the outset and also a clear commitment to maintain and likely increase prices further over time. Without such a commitment, the changes in behavior required to meet even a long-run target of emissions reduction will likely not occur. Consider a utility that today is drawing up its plans for a new power plant. That utility will choose among today's technologies, which vary in their costs and CO₂ emissions. In order to induce the utility to choose a more costly, lean-emissions technology today, it must be clear that CO₂ emissions will be costly enough over the 40 years or more lifetime of the plant to justify a more expensive investment option today. A large cumulative reduction in emissions can be achieved over the long term with only a modest carbon emissions price increase now, but only if the commitment to still higher prices in the future is credible and clear.

Stagflationary Macroeconomic Impact. From a macroeconomic perspective, increases in energy prices constitute an adverse "supply shock." Such developments are stagflationary--even if anticipated--because they raise both inflation and unemployment simultaneously, creating a painful macroeconomic dilemma. As noted above, a plan to attain 1990 emissions levels by 2010 would require a change in energy prices over the first decade of the 21st century at least comparable in magnitude to the two oil shocks of the 1970s. Those shocks are widely acknowledged to have raised both unemployment and inflation. Similarly, the energy price increases required by a 1990 by 2010 program would raise inflation, lower real wages, and raise unemployment. Unemployment in the four years after the first oil shock averaged 7.2 percent in comparison to 5.0 percent in the four years prior; and unemployment rose further, to an average of 8.6 percent, in the four-year aftermath of the second oil shock.⁴ Although the increases in energy prices associated with a treaty to reduce greenhouse gases would be anticipated, rather than a surprise, we should nevertheless expect that the efforts of the Federal Reserve to contain inflation, coupled with likely efforts on the part of workers to recoup real wage losses will lead to a period of higher unemployment.

Furthermore, it is important to note that most model-based estimates of the costs of a program to attain 1990 emissions levels by 2010 assume that resources are fully employed, thereby ignoring these potential short-term effects. Such models therefore provide no assessment of the consequent increases in unemployment.

⁴ There is debate about how much of this was due directly to the oil shocks, because there was a simultaneous decline in productivity growth and transfers of real income to OPEC producers.

IV. Quantifying the Economic Costs of Gradual versus Fast Take-off

The relative costs of gradual versus fast takeoff timetables in curbing CO₂ emissions has recently been analyzed by the Stanford Energy Modeling Forum (EMF-14).⁵ The Stanford group used six large-scale economic/energy models to compare the total projected cost of two alternative emissions reduction time paths--one "frontloaded", the second more "backloaded". *Importantly, both paths were designed eventually to stabilize atmospheric concentrations of CO₂ at double the pre-industrial level--550 ppmv.*⁶ Although a high degree of uncertainty is inherent in particular numerical estimates from individual models, the simulations nevertheless point to some robust qualitative conclusions. *The major conclusion to be drawn from this project is that an emissions reductions path characterized by an aggressive initial phase is substantially more costly--3 to 10 times more costly--than a path with a slower takeoff but larger eventual reductions.*

To enable a comparison of the costs of gradual and rapid takeoff strategies, the EMF investigators asked each of six modeling groups to simulate the economic impacts of two alternative strategies to attain stabilization of CO₂ concentrations at 550 ppmv. The first strategy (the WG-1 path) corresponds to an emissions pathway published in 1994 by Working Group 1 (WG-1) of the Intergovernmental Panel on Climate Change (IPCC). The working group computed a set of global CO₂ emissions pathways consistent with stabilization of concentrations at 550 ppmv and several alternative concentration levels. The WG-1 path entails an immediate departure from the baseline or "business as usual" emissions path. Subsequently, Wigley, Richels and Edmonds (WRE) published an alternative set of emissions profiles to achieve the same concentration targets. In contrast to the WG-1 paths, the WRE emissions path was constructed to follow the baseline or "business as usual" scenario in the early years with sharper reductions after this initial phase. Wigley, Richels and Edmonds hypothesized that their more gradual takeoff emissions pathways would yield identical environmental objectives with substantially lower economic costs, for the reasons discussed above. The EMF-14 exercise validates this hypothesis.

⁵ To enable meaningful comparisons of results across models, the EMF has coordinated a series of projects in which a number of large scale energy models are used to estimate the impact of given, specified emissions reduction scenarios under common standardized, benchmark assumptions concerning population and economic activity, discount rates, energy resource availability and prices and technology availability.

⁶ All energy models make numerous simplifications and approximations in order to describe the energy sector globally and over the span of a century or more. In particular, all of the models assume full employment, thereby abstracting from the likely short-run macroeconomic costs of an emissions reduction program.

The EMF-14 comparison project assessed the total costs to the OECD, the EEFSU (Eastern Europe and the former Soviet Union) and the non-Annex I countries of the WG-1 and WRE pathways to stabilization of CO₂ concentrations at 550 ppmv. The appropriate economic measure of total cost is the present discounted value of losses in future consumption relative to a "business as usual" scenario. Estimates of regional costs depend on the extent of burden sharing--namely, the assumed "division of labor"--between Annex I and non-Annex I countries in controlling emissions as well as the extent of international emissions trading. Recall that, by the end of the next century--by 2100-- assuming "business as usual"--non-Annex I countries will have more than 90 percent of CO₂ emissions. Thus, developing country participation is absolutely essential to achieving stabilization of concentrations. Consistent with the Berlin Mandate, the simulations assumed that the burden of emissions reduction would fall on Annex I countries exclusively during the early decades; that by 2030, non-Annex I countries would begin to participate; and by 2050, a full transition to targets based on equal per capita emissions rights is assumed.

Figure 3 plots the OECD emissions paths in the WG-1 and WRE scenarios. Under the WG-1 scenario, OECD emissions begin to decline immediately and continue to decline for roughly four decades. For example, OECD emissions fall 10 percent below initial levels ten years after implementation. This corresponds roughly to the requirement of a "1990 by 2010" timetable--that emissions decline about 15 percent from their projected 2000 level during the decade between 2000 and 2010. In contrast, OECD emissions along the WRE path continue to rise for roughly two decades--corresponding closely to a plan calling for emissions to peak around 2020--return to 1990 levels around 2040 and decline substantially further in subsequent decades.

Table 1 illustrates a robust conclusion that emerges from this exercise: fast takeoff in emissions reductions greatly increases the costs. Table 1 shows the cost for both the aggressive (WG-1) and gradual (WRE) paths--both with and without idealized international trading of permits. In 10 out of 12 simulations--for six different models with and without permit trading--the costs on the gradual WRE path is less than a third of the cost on the corresponding fast take-off path. Taking account of the likely adverse short-run macroeconomic consequences of an aggressive path would further strengthen this conclusion.

Table 2 illustrates a second, robust conclusion from the EMF-14 exercise: a viable system of international permit trading would very much reduce OECD costs. With global permit trading, the sharp, early emissions reductions required of OECD countries under the aggressive (WG-1) approach would be avoided through the purchase of emissions permits from countries with lower abatement costs. The average reduction in cost is 56 percent.⁷

⁷ The computations in Table 2 verify that the gradual (WRE) path, which permits emissions to depart relatively little from business as usual for several decades, is a substantially less costly than the alternative WG-1 path with its sharper immediate reductions. Since both

Finally, it is important to note that in most of the EMF models, policy actions to raise carbon emissions prices must be taken at the inception of the gradual (WRE) program and a commitment to increasing emissions prices over time is required to achieve additional emissions reductions. Naturally, the required initial carbon emissions price is substantially lower, at the outset, under the gradual (WRE) than under the aggressive (WG-1) path. Thus, although the gradual emissions path initially approximates the business as usual baseline, credible incentives must be put into place immediately, and strengthened over time, to achieve the needed investments in carbon-efficient technologies.

V. The Environmental Consequences of Gradual versus Fast Takeoff.

While the excess cost of a fast, compared to a gradual emissions reduction path is large, the difference in projected global temperatures over the next century between the fast and the gradual paths is quite small, both in absolute amount and relative to temperature changes expected even if an aggressive policy path is adopted. Under "business as usual" assumptions, average global temperatures are expected to rise about 1 degree Celsius by 2050 and about 2½ degrees Celsius by 2100. An aggressive Annex I emissions reduction path that stabilizes emissions at 1990 levels by 2010 and maintains emissions at the 1990 level thereafter would mitigate this temperature increase by roughly 0.1 degrees by 2050 and 0.2 degrees by 2100.⁸ In contrast, a more gradual Annex I emissions path that peaks around 2015, stabilizes emissions at 1990 levels by 2040, and holds emissions constant at 1990 levels thereafter yields virtually identical environmental benefits: the temperature difference between the aggressive and gradual paths diverges by no more than 0.05 degrees at any time over the next century. Similarly, the temperature differences along the aggressive WG-1 and less aggressive WRE paths--both designed ultimately to stabilize concentrations at 550 ppmv--differ by a maximum of 0.2 degrees over the next several centuries.⁹

paths are arbitrarily chosen to conform with the 550 ppmv concentration target, a natural question concerns the characteristics of an optimal or least-cost path for achieving this concentration target. An important recent study by Alan Manne and Richard Richels uses their MERGE model (included in the EMF-14 project) to compute the least-cost path with 550 ppmv stabilization and international permit trading. The optimal path, while not identical to the WRE path, is similar in character. This least-cost path peaks approximately three decades after the initiation of the program and declines thereafter.

⁸ Successful stabilization would require very large cuts from "business as usual" in China, India, and other non-Annex I countries.

⁹ If a model assumes that sulfur dioxide emissions decline with the decline in carbon dioxide emissions under climate policy (as predicted, given the extent of sulfur emissions associated with fossil fuel combustion, and incorporated in the IPCC's IS92 emissions

The limited climatological impact of even an extremely aggressive emissions reduction program measured in terms of temperature impacts during the next century reflects the extremely long lags involved in the underlying physical processes and the dependence of temperature on the total stock of carbon dioxide in the atmosphere, rather than the flow of emissions at a given time. Emissions reductions do matter to temperature, but only over an extremely long horizon. The cumulative nature of the process suggests that there is little effect on global temperature from a gradual rather than from a fast abatement takeoff. The addition to the total stock of carbon from a gradual rather than a fast start to abatement adds relatively little to the total atmospheric stock of CO₂ between now and 2100 for four separate reasons: the difference in carbon emissions between a gradual and a fast start over the initial decades of abatement is only a small fraction of total emissions in that period; the stock of CO₂ in the atmosphere is itself the result of many decades of emissions; some of the CO₂ emissions of the early decades will have been re-absorbed; and the most serious build-up in CO₂ under business as usual occurs late in the next century, as a consequence of burgeoning emissions from non-Annex I countries.

Even the potential for a catastrophic environmental event, such as the melting of the West Antarctic ice sheet, a runaway greenhouse effect (e.g., from release of trapped methane with the melting of the permafrost), or a structural change in ocean currents such as the Gulf Stream, which the preceding abstracts from, does not fundamentally affect the basic trade-offs between the high costs of fast vs. gradual takeoff paths. These factors do, however, add--perhaps greatly--to the urgency of adopting moderate long-term greenhouse gas concentration targets and a program involving an immediate, albeit moderate, increase in the price of CO₂ emissions.

VI. International Trading of Permits

As has already been noted, an effective system of international carbon emissions permit trading among Annex I countries could substantially diminish the cost of a CO₂ abatement program. An Annex I trading system could, potentially, reduce the size of the carbon emissions price to attain a 1990 by 2010 goal by up to 50%. Moreover, joint implementation projects with non-Annex I countries could, hypothetically, reduce this figure by half again.

Although international trading and joint implementation--so-called "where flexibility"--has enormous advantages in theory, your economic advisers are concerned that substantial barriers would stand in the way of implementing any workable analogue of such an idealized system--at least in the near term. Consequently, they stress that Annex I international permit trading and joint implementation between the U.S. and non-Annex I countries realistically can

projections), the more aggressive WG-1 path will be *warmer* than the WRE path between 2000 and 2040. This result reflects the negative impact of sulfate aerosols on the greenhouse effect. Early and substantial cuts in fossil fuel combustion, while decreasing the carbon emissions that warm the atmosphere, also decrease the sulfate aerosols that cool the atmosphere.

serve only a limited role in reducing the costs associated with meeting a "1990 by 2010" target.

A *hypothetical* example shows how an international trading system would work, and why it would reduce each participant country's abatement costs. Suppose, ideally, that every country adopts a domestic permit system to implement its Kyoto target. Absent international trading, the price of emissions permits would surely differ across countries, reflecting differing marginal costs of abatement internationally. With different permit prices in different national markets, profit-seeking traders would be motivated to buy permits in countries where they are cheap and resell them in countries where they are more expensive. Such arbitrage activities would create an international permit market, bringing permit prices into equality worldwide. This idealized system promotes global efficiency in achieving any worldwide abatement goal. Countries with permit prices below world levels have the incentive to reduce emissions more than they otherwise would in order to profit in the international permit market. Countries with high permit prices would have the incentive to purchase permits, thereby relaxing their Kyoto emissions constraints. The U.S. government could avoid any direct participation in such a system as long as it deems foreign-issued permits presented to the U.S. government by U.S. carbon-emitting entities as valid as those issued by the U.S. government itself.

The preceding description of how an international permit trading system would work provides an idealized picture of its possibilities. But the actual benefits of such a system are apt to fall short of this utopian portrayal in part because countries are not obliged to fulfill their Kyoto commitments via a domestic permit trading scheme; indeed, few Annex I countries have indicated an intention to do so. For example, consider a government that has decided to limit domestic emissions through regulatory controls. International permit sales that result in tighter domestic constraints could well be politically unpopular so that a government would hesitate before selling its emissions rights to the United States. Similarly, international permit sales by a country that is meeting its Kyoto obligations through domestic carbon or energy taxes would necessitate a hike in those taxes. In either case, international trading would involve government to government negotiations, and difficult political decisions. In contrast, in the idealized system, trades result from profit-oriented transactions among individuals, mediated through the market.

Monitoring and enforcement issues are also likely to be paramount in insuring the workability of international trading. If domestic enforcement is effective in all countries, so that, in the aggregate, consumers and firms in each country actually limit their emissions to the national permit levels, international permit sales by private agents in the country actually translate into lower domestic emissions. But consider the difficulties that can occur with imperfect enforcement. If the government of a country--country X--finds it difficult either to measure domestic emissions or to enforce the purchase of permits by domestic emitters, then reductions in X's emissions may be insufficient to reach the Kyoto target. Those firms or individuals in X that are lucky enough to have been assigned the rights to X's permits will be able to sell them, at a quick profit, on the international market. With imperfect enforcement, international sales, without corresponding domestic emissions reductions, could emanate from countries with the weakest systems of enforcement. To prevent such "paper trades", which profit

some participants and increase emissions, many countries, including the United States, will want controls to ensure the integrity of international permits. Buyers, too, will want clear concrete guarantees of the validity of permits so as to be sure they are not being passed counterfeit goods. These controls and guarantees will surely inhibit the efficiency of the market and render some--possibly much--of the estimated savings illusory. In fact, most of the benefits projected from the international sale of permits come from inducing emissions reductions from countries in Eastern Europe and the former Soviet Union--countries with particularly weak tax collection and enforcement mechanisms. Without these countries in the scheme the gains from international trading of permits will be very small.

Joint implementation with non-Annex I countries also has the potential to reduce the U.S. burden of attaining any given timetable. Under this type of approach, U.S. businesses could receive credit for the construction of nuclear, oil, or natural gas electricity generation plants in China if it were confidently expected that China would instead have constructed coal-fired plants with much higher CO₂ emissions. Certification of such credits might be overseen by an international agency to ensure that the projects were emissions-replacing. Such a project-by-project system is likely the most that is feasible in the absence of quantitative targets. Your economics advisers have concerns about even this level of endeavor due to the inherent difficulty in establishing that a particular set of projects has actually reduced a country's emissions, absent a reference path enabling a clear quantitative comparison. For example, the construction of a nuclear power plant in place of a coal-powered plant in China could indirectly raise CO₂ emissions elsewhere in the Chinese economy--partially offsetting the direct CO₂ reducing effect of the project--if the reduced demand for coal lowers its domestic price and encourages greater use elsewhere in the Chinese economy. A project-oriented approach to joint implementation will, in effect, constitute a limited form of international trading with high transaction costs. As a result, it will probably capture only a small fraction of the total benefits of full international trading. In contrast, model results concerning the benefits of joint implementation treat it as equivalent to idealized international trading.

VII. Recycling of Revenues

The ultimate economic cost of an emissions abatement program depends upon how the revenues realized from carbon taxes or auctioned permits are used. It has been estimated that the efficiency loss from collecting an extra dollar of tax revenue amounts to around 30 cents. If the revenues from a carbon tax or auctioned permits are used to reduce inefficient taxes inhibiting work or investment, the resulting gains would partially offset the micro-efficiency losses from energy curtailment. The simple lesson is that the costs of emissions abatement may be greatly reduced if the revenues from the taxes levied can be put to good use.

So far we have approached the recycling of revenues from the standpoint of microeconomic efficiency. There is also the potential for using the revenues to abate the macroeconomic consequences of the emissions program. The oil shocks are believed by many

economists to have resulted in increased unemployment because workers resisted the fall in real wages that was associated with the inflationary impact of higher energy prices. Increased wage demands added inflationary pressures to the economy that could only be suppressed by tighter monetary policy. Thus it might be argued that the effects of the real wage shock on inflation and unemployment could be diminished by lowering payroll or other worker taxes to offset the real wage losses from higher energy prices.

But England's experience points to the need for caution in assessing the potential for revenue recycling to allay the macroeconomic consequences of the rising energy costs. In 1979, immediately after her election, Margaret Thatcher increased the VAT tax and simultaneously decreased the income tax. These two policy changes had offsetting effects on real after tax incomes, and therefore might have been expected to have had no effect on wage bargaining. However, the increase in the VAT tax resulted in an immediately noticeable increase in the CPI. A wage-price spiral ensued as workers attempted to maintain their pre-tax real wages.

VIII. Policy Implications

The foregoing arguments point to the attractiveness, from both an economic and environmental standpoint, of a U.S. policy to raise the price of carbon emissions--either through a carbon tax or a system of auctioned permits--by a moderate amount--for example, between \$5 and \$15 per ton of carbon--in the near term, with further increases scheduled over the longer term. A realistic target and timetable corresponding to such a program would entail continued emissions growth in the first decade of the program, say 2000-2010; elimination of emissions growth in the second decade (2010-2020) and reductions in emissions thereafter. This program entails significant, early policy action and is consistent with a strong U.S. commitment to attaining the ultimate objective of the Framework Convention--namely to stabilize atmospheric concentrations of CO₂ and hence global temperatures.

Figure 1: Energy Prices and Changes in Energy Use
OPEC price hikes lowered energy use substantially

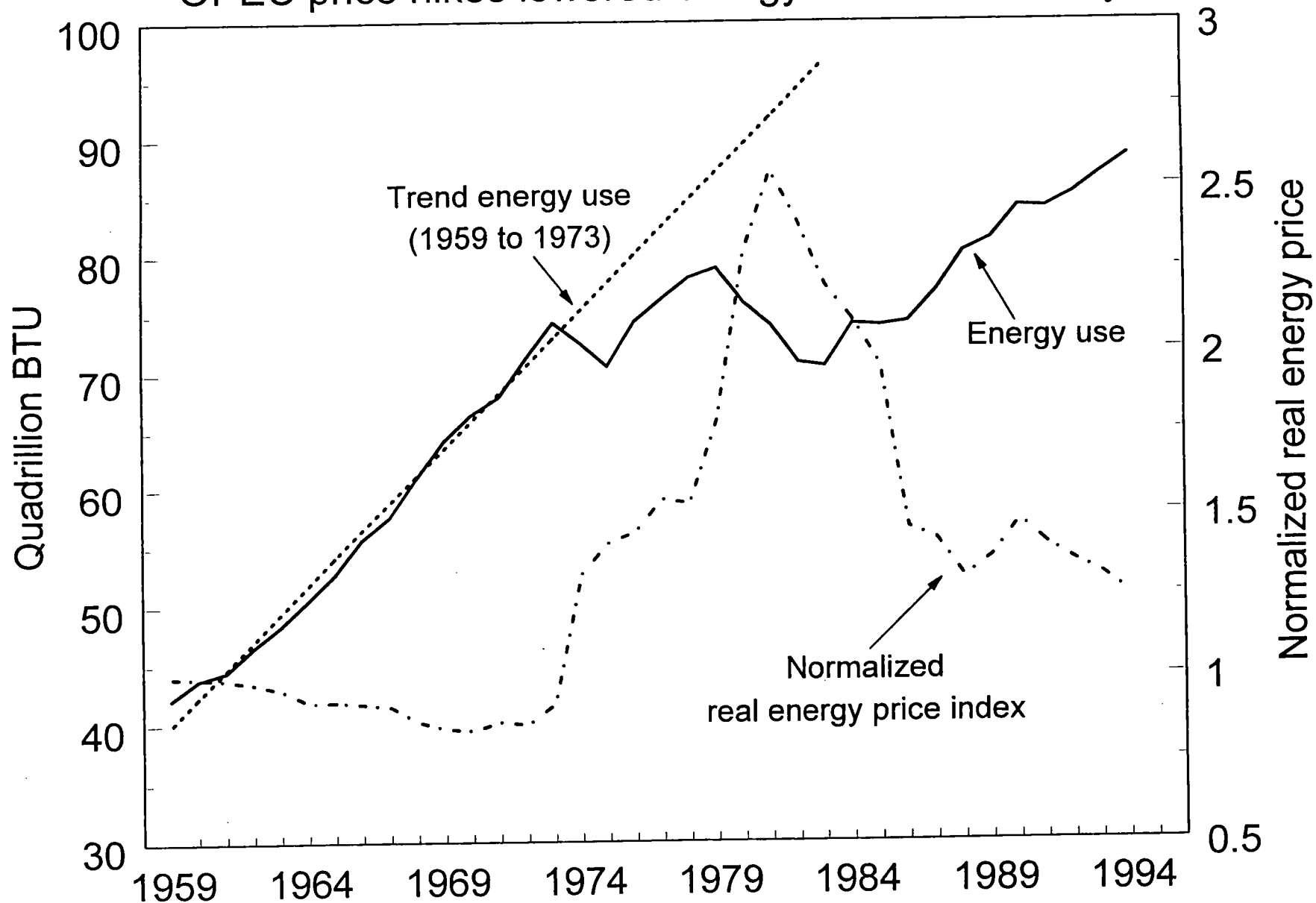
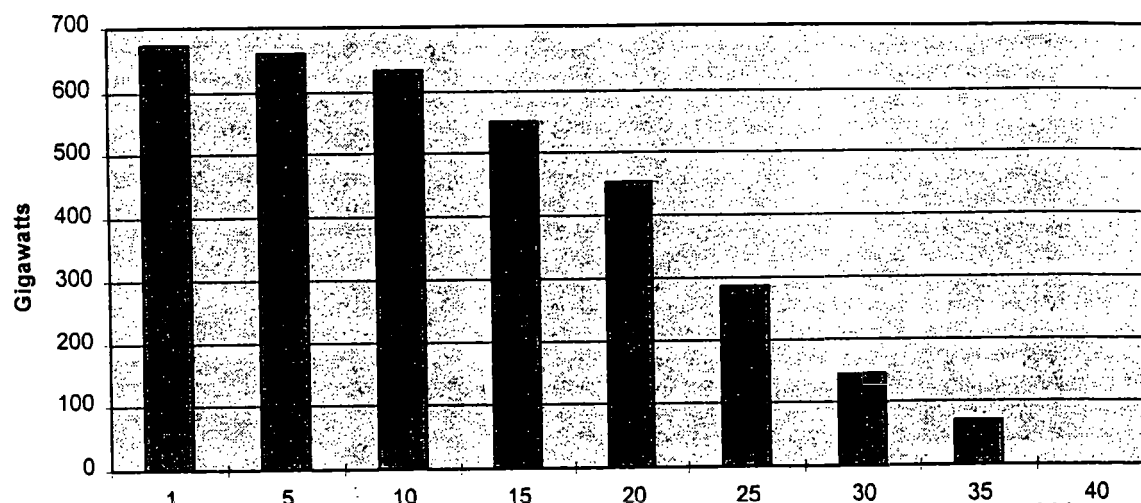


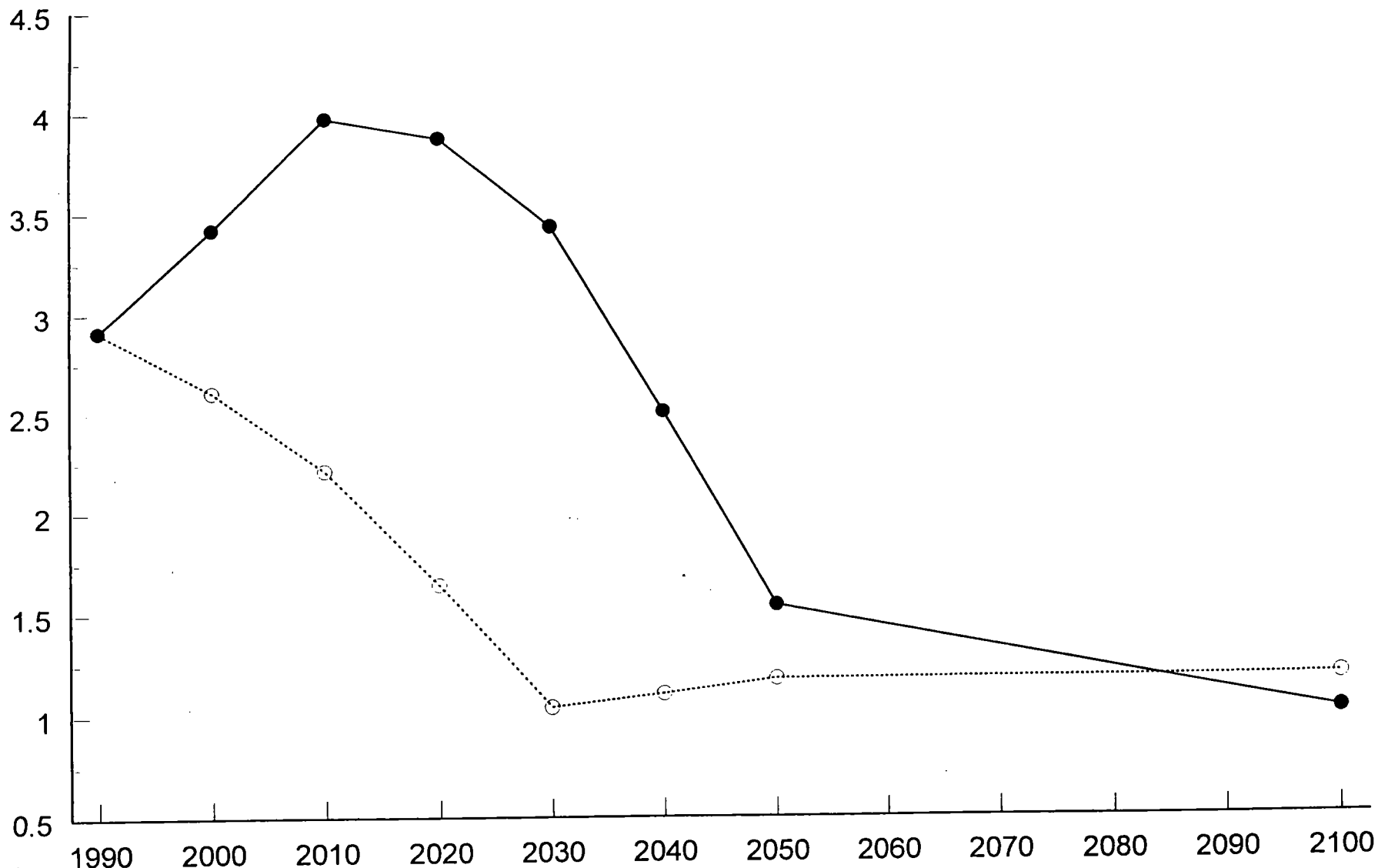
Figure 2: Accelerated Retirement of Electric Power Plant Capacity



Bar height shows capacity to retire early if complete change-over occurs within number of years indicated on the axis. Normal life span of a generator is 40 years.

Figure 3: WRE and WG-1 Emissions Pathways for OECD
to Stabilize Concentrations at 550 ppmv

billion tons of carbon



Source: M...e and Richels

Table 1

**The Effects of Emissions Pathway on Consumption Losses by OECD Countries,
No International Permit Trading (trillions of 1990 U.S. dollars)^a**

Model	WRE	WG1	WRE/WG1
CETA	1.83	5.94	0.31
CPBRIVM	0.64	3.25	0.20
FUND	9.82	11.71	0.84
MERGE	0.85	6.12	0.14
MiniCAM	1.58	6.51	0.24
SGM	1.84	6.17	0.30
		Average:	0.34

**The Effects of Emissions Pathway on Consumption Losses by OECD Countries,
International Permit Trading (trillions of 1990 U.S. dollars)^a**

Model	WRE	WG1	WRE/WG1
CETA	1.86	4.03	0.46
CPBRIVM	0.17	0.99	0.17
FUND	1.47	4.97	0.30
MERGE	0.60	3.24	0.19
MiniCAM	0.54	3.44	0.16
SGM	0.13	1.48	0.088
		Average:	0.23

^a Losses measure the present discounted value of foregone consumption through 2100 in trillions of 1990 U.S. dollars.

Table 2

**The Effects of International Permit Trading on Consumption Losses by OECD Countries,
WRE Emissions Pathway to 550 ppmv Stabilization (trillions of 1990 U.S. dollars)^a**

Model	Trading	No Trading	Trading/No Trading
CETA	1.86	1.83	1.02
CPBRIVM	0.17	0.64	0.27
FUND	1.47	9.82	0.15
MERGE	0.60	0.85	0.71
MiniCAM	0.54	1.58	0.34
SGM	0.13	1.84	0.07
		Average:	0.43

**The Effects of International Permit Trading on Consumption Losses by OECD Countries,
WG1 Emissions Pathway to 550 ppmv Stabilization (trillions of 1990 U.S. dollars)^a**

Model	Trading	No Trading	Trading/No Trading
CETA	4.03	5.94	0.68
CPBRIVM	0.99	3.25	0.30
FUND	4.97	11.71	0.42
MERGE	3.24	6.12	0.53
MiniCAM	3.44	6.51	0.53
SGM	1.48	6.17	0.24
		Average:	0.45

^a Losses measure the present discounted value of foregone consumption through 2100 in trillions of 1990 U.S. dollars.

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Global Climate Change: Which Way Forward?

I. Economic costs

There is no doubt that we must take action to begin to stabilize and eventually reduce our emissions of greenhouse gases. Economic evidence indicates, however, that meeting the targets and timetables for emissions reductions that are currently on the negotiating table would require severe and unpopular actions. None of the lead signatories on the recent economists' letter supporting action on climate change believes that returning carbon emissions to 1990 levels by 2010 is warranted.

Achieving the 1990 level of emissions by 2010 would entail greater restraint on energy consumption than resulted from the OPEC oil price increases of the 1970s. Moreover, it could only be accomplished by imposing an energy tax — or the economic equivalent thereof — more than four times larger than our 1993 BTU tax proposal. Advances in technology and mechanisms for international burden-sharing would help cushion this impact somewhat, but even with the most effective possible measures in place on these fronts, an aggressive program would still inflict considerable economic pain. For all these reasons, an ambitious approach would face severe Congressional opposition and have other highly adverse political consequences.

There is a better alternative available to the Administration: A more gradual program of emissions restraint would capture most of the environmental benefits of an ambitious program, and at only a small fraction of the economic cost.

Broadly speaking, there are two possible ways to satisfy the obligations we might sign onto in Kyoto: We can reduce our domestic use of carbon, or we can buy our way out of at least part of the obligation by paying other countries to reduce their emissions. The next several subsections consider five possible approaches to advancing these objectives: a tax on carbon emissions; a system of tradeable permits; command-and-control regulation; investment in technology; and international cost-reduction measures.

A. Carbon taxes

The most straightforward way to reduce carbon emissions is to tax them. Imposing a tax would increase the incentive to become "carbon-efficient."

The magnitude of the required tax would depend on the aggressiveness of the objective. If the objective is to return emissions to 1990 levels by 2010, then the tax would have to be between \$80 per ton and \$250 per ton of carbon emissions. This tax would have to be introduced within the next few years, ramp up to this level by 2010, and continue to rise thereafter.

- A tax of this magnitude would be 4-12 times larger than the BTU tax that was proposed in 1993.
- Even an \$80-per-ton tax (i.e., a tax at the lower end of the estimated required range)

would reduce the standard of living of the average family by about \$880; this is roughly equivalent to 1-½ week's worth of take-home pay. Furthermore, a tax of this type would be highly regressive: the relative burden on the lowest fifth of the population would be 6 times as great as the burden on the highest fifth.

- A tax of this magnitude would damage the performance of the macroeconomy as well. It would produce stagflation — a period with higher inflation and more unemployment.

Notwithstanding these severe impacts, your economic advisers believe that a tax on carbon emissions compares favorably to other methods of restraining carbon emissions. With the exception of an auction-based permit approach — discussed below — other methods would impose greater costs on consumers and the overall economy.

B. Tradeable permits

Another approach to restraining emissions would involve creating a domestic emissions trading program. At the center of this type of program is a *permit*, which would entitle the holder to emit a certain amount of carbon into the atmosphere. Such a program could be implemented either by auctioning permits, or by giving them away. Many designs for the give-away are possible, but one much-discussed option would involve “grandfathering” existing emitters.

Grandfathering would probably be unworkable and would surely be unfair. It would publically reward polluters. Moreover, it would give as much as \$200 billion per year to corporations that would in any event pass along most of the price increase to consumers, and it could be administratively extremely complex, depending on the details of implementation. If a permit-based approach is selected rather than a tax-based approach, we would therefore strongly prefer auctioning the permits rather than grandfathering them. Either auctioning or grandfathering, however, would result in a large increase in the price of energy to consumers, and so would be perceived as essentially equivalent to an increase in taxes.

Some observers have claimed that the sulfur-dioxide program serves as a good model for how a carbon trading program would work, and in particular illustrates that carbon emissions could probably be reduced at surprisingly low cost. In fact, this is not the case. A carbon trading program would be 100 times as large as the sulfur-dioxide program, making any extrapolation extremely speculative. Moreover, a substantial portion of the acknowledged success of the sulfur-dioxide program derives from the fact that it replaced an enormously burdensome set of command-and-control regulations, and the fact that it enjoyed some good luck, notably in the form of a steep decline in freight rail rates. Neither of these factors can be expected to operate in the case of a carbon program.

C. Regulation

Reductions in emissions could be achieved by command-and-control regulation. But this approach is tremendously inefficient, is easily circumvented by firms and consumers, and, to the extent that it is not circumvented, would impose enormous new costs on consumers who are restricted from making the product choices that they prefer. This is exemplified by the U.S. experience with CAFE standards, which: applied only to new cars, perversely increasing the incentive to hold onto used cars that emitted more; reduced the cost of driving additional miles, causing increases in miles driven to offset increased fuel efficiency; and did not apply equally to light trucks, inducing in part the enormous growth of Sport Utility Vehicles, which now account for one-half of new car sales. As a result, CAFE standards have proven to be a particularly expensive way to reduce gasoline demand: studies indicate that increasing CAFE standards by 1 mpg in one year would cost as much as \$11 for every gallon of gasoline saved, and that the price per ton of carbon removed by tighter CAFE standards is more than \$100, or 4-25 times the costs through other approaches such as a carbon tax. To the extent that they were binding, tighter standards would also force consumers to forgo their obvious attraction to the (relatively) fuel-inefficient vehicles which now dominate sales.

D. Technology

One alternative to raising the price of carbon is to improve the efficiency with which it is utilized. In the very long run, technology determines what can be achieved in reducing carbon emissions, so provision of major new research funding and perhaps funding for diffusing technology is important.

A recent Energy Department study (the "5 Labs Study") concludes that an ambitious program of investment in technology development and diffusion could move the nation one-third of the way toward meeting the 1990 level of emissions *at no net cost — or possibly even net benefit — to the economy*. John Deutch, your economics advisers, and many other outside reviewers believe that this conclusion is founded on unrealistic assumptions. For example, the report assumes that firms can be induced to invest \$50-90 billion per year beyond current levels in energy-efficient technologies and other measures for conservation. But because such additional effort on energy conservation would force firms to redirect 7 percent of their total investment in new equipment, it could only be accomplished by offering costly incentives.

(Grubs may have dropped) Although the potential for technology to make a positive contribution is real, it is limited. Renewable sources of energy today account for just 8 percent of all energy supplied in the US economy. Experts in energy efficiency currently estimate that these sources could account for 3 percent of total energy supply by 2010.

E. International cost-reduction measures

As you know, the United States has suggested two approaches for reducing what we

would have to do domestically to lower greenhouse-gas emissions: international permit trading, and "joint implementation." But the practical difficulties of establishing these mechanisms imply that they will only be able to make marginal contributions, at most, in the near future.

- International emissions trading has not been accepted by other nations. Even if such trading were to be accepted, other governments choosing to implement their own domestic emissions reductions through regulatory approaches or through energy taxes probably would not be willing to tighten those domestic restrictions in order to profit from permit sales to the United States.
- Both international permit trading and joint implementation raise difficult issues of monitoring and enforcement. For example, every country in the system would be tempted to allow its firms to fraudulently sell their emissions rights into the international market, garner the resulting revenue, and exceed their allowed level of emissions.
- There is some scope for joint implementation in which emissions credits would be given for carbon-saving investments in developing countries. Such an approach should be explored thoroughly but cautiously. The major difficulty in such programs is that they may entail paying for investments that would have been made even in the absence of the subsidy, and thus not result in any reduction in greenhouse gas emissions.

Even assuming the most optimistic scenarios for technology and successful implementation of domestic and international trading, it will still not be possible for us to achieve 1990 emissions levels without substantial increases in the price of energy — on the order of 4 to 10 times the amount of the BTU tax. Regardless of how the restraint on carbon emissions is imposed, energy users and emitters will pass the costs down to consumers. A recent EPI study warning of the loss of 2 million jobs is typical of the reaction that an aggressive proposal would elicit. Other opponents of such a proposal would include most large companies, all energy-intensive small businesses, organized labor, consumer groups, and those fearful about competitiveness. It is likely that moderate sources of analysis (e.g., Brookings, AEI, IIE, and mainstream Democratic economists such as Alan Blinder and William Nordhaus) would oppose ambitious commitments.

II. The link between the economy and the environment

There are two key questions concerning the link between the economy and the environment. First, assuming all countries faithfully executed all of the commitments contained in proposals currently on the negotiating table, would the desired environmental benefits necessarily follow? As you know, the answer to this question is "no," because developing countries would not be required to take on binding commitments under any agreement currently under consideration for approval in Kyoto.

The non-participation of developing countries is a fatal flaw for one simple reason: A ton of carbon does the same amount of damage no matter whether it is emitted in Baltimore or in

Bangkok. Therefore, from an environmental perspective, it is equally important to control emissions anywhere in the world. But as you also are aware, the politics of enforcing binding commitments on developing countries is extremely difficult. (The economics is also difficult, given that a sensible policy would have to leave room for the developing countries to improve their average standard of living.)

A second question concerning the link between the economy and the environment is whether the incremental environmental benefits justify the extra costs associated with an accelerated program rather than a more gradual one. The figure at the end of this document suggests that the case for an aggressive program is weak. This figure compares projected increases in global average atmospheric temperature in three different cases: (1) a "*business as usual*" case; (2) an *ambitious* case in which industrialized countries return their emissions to 1990 levels by 2010 and developing countries stabilize their emissions at 2020 levels in 2020 (an extremely optimistic assumption); and (3) a more *gradual* case in which industrialized countries stabilize their emissions in 2015 and return to 1990 levels by 2040, and developing countries stabilize in 2040 at 2040 levels.

As can be seen in the figure, even by 2100, the difference between the ambitious and gradual strategies is only 0.2 degree Celsius. Moreover, virtually all of this difference reflects the difference in assumptions regarding actions taken by developing countries. The difference in actions taken by developed countries contributes only 0.02 (two one-hundredths) of one degree. These amounts are small, not only in absolute terms, but also relative to the 1.7 degree increase in the global average temperature that is projected to take place over the next century even under an ambitious policy.

Furthermore, the gradual strategy captures about two-thirds of the environmental benefits generated by the ambitious strategy in spite of the lesser assumed commitments of developing countries along the more gradual path. Separate results show that the economic costs of the more gradual approach would be only *one-tenth to one-third* as great as the costs of the ambitious approach. This difference in cost reflects two main considerations: (1) retrofitting is extremely costly compared to replacing capital stock that has lived out its full life; and (2) the longer one delays before investing in new plant and equipment, the better the technology that will be available; forcing investment on to proceed on an accelerated schedule guarantees that inferior capital will be locked in place for a long period of time.

In summary, gradual approaches have nearly the same environmental benefits as ambitious approaches, at only a small fraction of the economic cost.

III. Suggested approaches

The foregoing analysis indicates that the U.S. should promote Kyoto as a "turning point" rather than a "finishing point." A constructive alternative proposal from the United States could include:

TARGET AND TIMETABLE

- The long-term goal of the treaty is to *stabilize concentrations* of greenhouse gases in the atmosphere at a level that will prevent dangerous anthropogenic interference with the climate system. This goal could be achieved with concentrations at or somewhat above a doubling of pre-industrial levels in the next one hundred years.
- Concentrations can be stabilized through the following targets and timetables:
 - Reduce emissions growth* in the United States in the near term (for example, growth from 2000-2010 less than growth over 1990-2000); then
 - Eliminate emissions growth* in developed countries 10 to 20 years after treaty is signed (e.g., 2010-2020); then
 - Reduce emissions levels* in developed countries gradually to reach — and then to decline below — 1990 levels in later years to be decided, stabilizing concentrations.
- This timetable begins effective action soon to establish Presidential leadership.
- This approach also includes periodic review of the underlying science, the data on the path of emissions, and the economic impact, to allow for adjustments in the policy.
- Insist on the current U.S. flexibility positions of international trading, multiple multi-year targets, joint implementation (subsidies of non-carbon energy sources in developing countries), banking, and borrowing.

DEVELOPING COUNTRIES

- The goal is the least-cost global approach to stabilization of carbon concentrations in the atmosphere.
- Negotiate and begin a new Kyoto Mandate, requiring developing country participation (in stages), starting with more-advanced (Annex B) developing countries, with graduation as countries develop. Developing countries commit to reduce the rate of growth of emissions consistent with stabilizing carbon concentrations and continued economic growth, with ceilings on costs.
- In a one-step process, the United States will not initial the agreement until the Annex B countries have binding commitments.

DOMESTIC IMPLEMENTATION

- Develop a tradable permits system, with auction of all permits (rather than grandfathering), in the near term; impose the system early at a level of emissions near the baseline (for example, with an implied permit price of perhaps \$10 per ton), with enactment as soon as possible, to show U.S. leadership. (A carbon tax, if feasible, would be an alternative method of implementation.)
- Change the number of permits in small, gradual, predetermined steps, based on economic cost and aggressive technological progress (with the implied permit price rising to perhaps \$22 per ton by 2015), subject to periodic review.
- A portion of funds raised would be used for cost-effective technology research and diffusion programs, including basic research. The bulk would be available for a range of domestic priorities (tax relief for individuals; business investment incentives; the solution to the fiscal effects of the demographic imbalance; infrastructure; etc.) chosen to make the program attractive.
- Begin a series of voluntary industry programs (perhaps modeled after PNGV) to develop plans to meet the targets.
- The United States would lead toward a global ban on fossil fuel subsidies.
- Provide for banking and borrowing to deal with short-term fluctuations. Borrowed permits would be issued at a premium cost, and banked permits could be resold later at higher prices.
- Provide economic growth insurance or a cost cap on permits that would allow the sale of additional permits. The price would be set consistent with our estimate of the acceptable economic cost, and would be high enough to encourage emissions-efficient investment choices in the near term. (If the cost cap were in effect over an extended period, the target would not be met.)
- These policies are market-oriented. There would be no inefficient, command-and-control regulations used to reduce emissions.

September 28, 1997

MEMORANDUM FOR THE PRESIDENT

FROM: GENE SPERLING
DANIEL TARULLO
KATHLEEN McGINTY

SUBJECT: Climate change

As promised in our climate change workplan, this memorandum provides more detail on some of the issues that were raised during our meeting on September 18. We also held a principals meeting on Friday, and will hold another one tomorrow, to pin down specific recommendations from the NEC/CEQ principals. We will then put together an NEC/CEQ recommendations memorandum and a briefing book that contains the underlying memoranda from the principals and other background materials. The recommendations memo and briefing book will be submitted to you by the end of next week, to inform your thinking before the October 6 White House conference.

Specifically, this memorandum:

- Outlines the sources of current emissions in the United States;
- Discusses several aspects of a tradeable permits system, including:
 - The benefits of a permit trading system relative to traditional regulation;
 - The lessons offered by the SO₂ trading program; and
 - Direct allocation versus auctioning with revenue recycling;
- Explores some of the costs and benefits of a gradual versus aggressive approach; and
- Explores a possible escape clause mechanism to limit the costs of a permit system.

I. SOURCES OF EMISSIONS IN THE UNITED STATES

Carbon dioxide (CO₂) accounts for more than 85 percent of U.S. greenhouse gas emissions. Roughly one-third of CO₂ emissions are from transportation, one-third from buildings and one-third from industry.¹ U.S. CO₂ emissions are now approximately 10 percent above 1990 levels, and are projected to be 28 percent over 1990 levels by 2010 absent policy interventions. Other greenhouse gases include methane (from landfills and livestock), nitrous oxide, and some engineered chemicals such as CFCs and HFCs.

In addition to the discussion below, the appendix -- produced by Jack Gibbons -- presents more detailed data and figures on the sources of emissions.

TRANSPORTATION

Transportation contributes 31 percent of U.S. CO₂ emissions. Its emissions are growing by about 2 percent (10 million tons) per year -- roughly twice as fast as industry and buildings -- because of increases in vehicle miles traveled and the increasing popularity of fuel-inefficient sport utility vehicles, minivans and pick-up trucks (which together now account for almost half of all new passenger vehicle sales).

Transportation: Sources of CO₂ emissions

Source	Emissions in millions of tons	As % of transportation emissions
Automobiles	152	34.9%
Light trucks	101	23.2%
Heavy trucks	67	15.4%
Aircraft	57	13.1%
Other	59	13.4%
TOTAL	437	100.0%

¹ In this accounting, the CO₂ produced to generate electricity is charged to the sector using the electricity. Taken together, emissions from all electricity production amount to 36 percent of CO₂ emissions.

BUILDINGS

Residential buildings produce 19 percent of U.S. CO₂ emissions, and commercial buildings account for another 15 percent -- implying that buildings account for over a third of total emissions. Emissions from both residential and commercial buildings are growing by 1 percent annually (2.6 and 2.1 million tons respectively). Energy demand in residential buildings is greatest for heating, electrical appliances, and air conditioning. In commercial buildings, demand is greatest for lighting, electric equipment, and air conditioning.

Buildings: Sources of CO₂ emissions

Source	Emissions in millions of tons	As % of building emissions
Space heat	211	43.0%
Appliances	98	20.0%
Cooling	69	14.0%
Lights	69	14.0%
Water heat	44	9.0%
TOTAL	490	100.0%

INDUSTRY

Industries produce about a third of all CO₂ emissions. Emissions from this source are expected to grow at 0.8 percent per year (4 million tons). About 80 percent of all industrial CO₂ emissions come from petroleum refining, chemicals, paper, lumber, and metals.

Industry: Sources of CO₂ emissions

Source	Emissions in millions of tons	% of industry emissions
Machine drive/electrolytic	149	32.0%
Steam	126	27.0%
Process heat	89	19.0%
Off-road equipment	33	7.0%
Heat/air conditioning/light	28	6.0%
Feedstocks/other	42	9.0%
TOTAL	466	100.0%

ELECTRICITY GENERATION

As noted, the CO₂ produced to generate electricity is charged to the sector using the electricity in the accounting above. Emissions from all electricity production amount to 36 percent of CO₂ emissions.

The table below shows that coal accounts for 50 percent of electricity generated in the U.S., but 77 percent of CO₂ emissions from electricity generation. Coal produces 72 percent more greenhouse gases than natural gas per unit of energy delivered -- which is why a carbon emissions reduction program would have a much larger impact on coal prices than on natural gas or other energy prices.

On average, the electric energy produced by an electric generator is only about a third of the energy input -- the other two-thirds is released as waste into the air or nearby waters. As more generation occurs closer to industrial and commercial sites, it should be easier to capture more of the heat from electric generation that would otherwise be wasted.

Electricity

Source	Share of electricity CO ₂ emissions	Share of electricity generation
Oil	1.9%	1.5%
Natural gas	20.7%	23.0%
Coal	77.4%	50.1%
Nuclear	--	15.8%
Hydro & renewables	--	9.6%
TOTAL	100.0%	100.0%

II. Tradeable Permits

During our meeting with you, we discussed a tradeable permits system for reducing carbon emissions. This section examines several questions related to tradeable permits.

Tradeable Permits Versus Mandated Standards

A natural question about tradeable permits is why they reduce the costs associated with meeting a given emissions reduction objective. Wouldn't it be easier and more straightforward to mandate standards on items such as automobile fuel efficiency?

Mandated standards are more costly than market-based systems to reducing pollution for

two reasons: First, standards usually only affect the market for new equipment; they do not increase the incentive for owners of existing equipment to scrap their old, inefficient capital more rapidly. Second, standards do not affect the incentive to conserve energy once the new equipment is purchased. For products where additional usage is discretionary (such as cars, but unlike refrigerators), this can be significant. A standard for automobile efficiency does not increase incentives to cut out wasteful driving. A tradeable permits system, on the other hand, focuses directly on the activity in question, allowing reductions to take place wherever they are cheapest and imposing no arbitrary constraint on incentives for further improvement. And in most cases, a tradeable permits system is less administratively costly.

An illustrative example

An example may be helpful. Assume that there are two types of coal-fired plants, both of which emit 100,000 tons of carbon per year. The first type can easily switch to less carbon-intensive fuels (such as natural gas), and thereby reduce carbon emissions even for a given level of energy output (since natural gas has less carbon per BTU than coal). To be more specific, this first type of power plant can achieve carbon emissions reductions at a cost of \$25 for every carbon ton reduction. The second type, however, was designed in a manner that makes it extremely difficult to switch fuel to reduce emissions: it can achieve emissions reductions only at a cost of \$150 per ton.

The average cost of mandating that carbon emissions at all plants fall by 30 percent is therefore \$2.6 million per plant (\$0.75 million at the first type, and \$4.5 million at the second). Under a permit system, however, the total cost would be dramatically reduced by allowing the second type of plant to buy permits from the first type. This way, a 30 percent reduction in total emissions would cost only \$1.5 million per plant (all of the 60,000 ton reduction would occur at the first type of plant, at a cost of \$25 per ton). In this example, the permit system produces a cost saving of over 70 percent *to achieve the same environmental goal*. This level of cost saving is not unrealistic: studies by environmental economists often find that market-based systems reduce the cost of environmental regulations by as much as 90 percent.

CAFE standards

You mentioned the specific case of fuel efficiency standards. The CAFE standard for automobiles was introduced in 1978 at a level of 18 mpg, and tightened until it reached 27.5 mpg in 1985. Fuel efficiency rose significantly during the same period, with average miles per gallon increasing by roughly 50 percent between 1975 and 1985. But it is difficult to determine whether fuel efficiency rose because of the CAFE standards or because of higher fuel prices: The two oil shocks in the 1970's increased consumer demand for more efficient vehicles.

Since 1985, fuel efficiency has remained stagnant. Since real gasoline prices have fallen steadily in the 1980's and 1990's, fuel economy would likely have fallen -- rather than remained stagnant -- over this period if not for the CAFE standards. Technology relevant to fuel economy

has continued to improve at a rate that would allow fuel efficiency to climb about 2 percent per year, but auto makers are using this improved technology to add features such as increased vehicle horsepower and size, not fuel economy. Indeed, the past decade has seen a dramatic rise in sales of fuel-inefficient light trucks -- first minivans and pick-ups, then sport utility vehicles -- which now account for nearly half of all passenger vehicle sales.

Proponents of fuel efficiency standards argue that further increases in CAFE standards could re-route this trend of technical improvement to greater mileage. Some have proposed modifications to CAFE to make it more flexible and cost-efficient, such as allowing trading between companies, or (as part of a broader emissions trading program) with other sectors. Fuel-efficiency standards could also be used to promote commercial introduction of PNGV vehicles with double or triple current fuel economy. (At present, our PNGV partners have pledged only to develop prototypes, but have not committed to sell them.)

Raising CAFE standards, however, can entail substantial -- albeit hidden -- costs. First, consumers have revealed their preference to use technology for improved features rather than fuel efficiency -- and forcing them to reverse this preference would be both unpopular and costly. For example, several studies have estimated the cost of reducing carbon emissions with CAFE standards. One estimated the implied cost of carbon reductions from increasing the CAFE standard to 37.5 miles per gallon at \$106 per ton of carbon reduced; another estimated that raising CAFE standards to 40 miles per gallon would be equivalent to a carbon price of \$104 per ton. Second, improving fuel efficiency doesn't necessarily reduce total fuel consumption, since it *reduces* the cost per mile travelled and thus encourages people to drive more. Third, because standards apply only to new cars and vehicles, an increase in CAFE takes a decade or more to work its way fully through the vehicle fleet -- so the impact of any CAFE increase would not be fully effective by 2010. Furthermore, increasing CAFE standards would be politically difficult. Auto-makers will resist efforts to increase standards, especially for sport-utility vehicles -- where the Big 3 make much of their profits (up to \$10,000 per vehicle).

The SO₂ Example: How Much Can We Learn From It?

The United States has more experience than any other country with emissions trading programs. The leading example is probably the sulphur dioxide (SO₂) emissions allowance trading program, part of the Clean Air Amendments of 1990. This statute required a 50 percent reduction in SO₂ emissions from electric-utility boilers. To accomplish this goal, a fixed number of emission allowances were allocated to electric utilities based on historical fuel use. (In addition, a small number of allowances are auctioned every year.) A natural question is whether the experience under the SO₂ programs provides insight into a carbon emissions trading system.

The SO₂ experience demonstrates three things:

- First, a tradeable permit system is an attractive system for reducing the cost of meeting some environmental problems. Especially relative to the previous command-and-control

approach to reducing SO₂ emissions, the tradeable permits program is widely hailed as a success in producing cost-effective environmental protection.

- Second, the cost estimates before the trading system began operations were too high. Around the time that the 1990 Amendments were enacted, a commonly held view was that achieving the targeted reduction in SO₂ would require the price of emissions to rise above \$400 per ton, and possibly as high as \$1,000 per ton. Today, the price of SO₂ allowances ranges between \$90 and \$120 per ton -- despite the fact that SO₂ emissions from utilities in 1995 and 1996 were 3 million tons lower than required.
- Third, a grandfathered permit program may not be viewed as a tax -- even if it raises energy prices. We are not aware of anyone who has charged that the tradeable SO₂ permits represent a tax.

There are several important caveats, however, that may raise questions about the applicability of the lessons from the SO₂ program:

- A carbon emissions program would be *substantially* larger than the SO₂ program: The annual stock of permits under the SO₂ program is worth less than \$1 billion; the annual stock of permits under a carbon trading program might be worth between \$30 billion and \$150 billion. And a significant reduction in carbon emissions will require much more fundamental changes in the structure of the American economy than the SO₂ program. Treasury and CEA argue that any emissions trading system for carbon will be substantially more difficult -- and perhaps even impossible -- to administer than is the case for SO₂, while EPA does not believe that the difference in scale would make much difference in administering the program.
- Simple price comparisons -- showing that the actual permit prices are much lower than predicted -- are somewhat misleading. Most of the early price estimates conflated the two phases of the program (we're still in the first phase), and were based on inaccurate guesses as to the provisions of the final bill. The last pre-enactment estimate -- the one with the best information about the legislation that would actually be passed -- projected that the permit price would be between \$170 and \$200 per ton. The degree of true prediction error was thus significantly smaller than some have suggested.
- The remaining discrepancy between predicted and actual permit prices under the SO₂ program partially reflects the deregulation of the freight-carrying railroads -- a development that had nothing to do with the SO₂ program -- which facilitated increased use of low-sulphur coal. By definition, it is impossible to know whether similar unexpected future policy actions will affect a carbon trading program.

Direct Allocation Versus Auctioning-With-Revenue Recycling

Another issue related to a permit system, and one we touched upon in our meeting, is whether the permits should be auctioned or allocated (that is distributed by the government to designated recipients). One approach to allocating permits would be to “grandfather” them to existing emitters. It is essential to recognize that regardless of whether the permits are auctioned or allocated, consumers are likely to bear most of the costs involved in reducing emissions (through higher energy prices). Thus the choice between auctioning and allocating does not in any way avoid the role of higher energy prices in reducing carbon emissions.

To summarize the pros and cons:

DIRECT ALLOCATION

PROS

- Not characterized as a tax: An allocation program does not involve directly raising revenue. Previous allocation programs -- such as the SO₂ program -- have not been viewed as a tax, although that could be because they were sufficiently small to avoid being a target for demagoguery.
- Corporate support: Our outreach effort suggests that an allocation system could be crucial to generating corporate support -- or at least minimizing opposition -- for the effort to reduce greenhouse gas emissions.
- Historical precedent: The SO₂ program would serve as a precedent for a grandfathered permit system.

CONS

- Regressivity: Even with allocated permits, companies are likely to pass most of the higher energy costs on to consumers. Any program that involves direct allocation to businesses thus protects corporations even though they do not need protection, and gives away the funds that could protect consumers, who will bear most of the costs from adjusting to the emissions reduction scheme.
- Corporate welfare: One way to think about the difference between direct allocation and auctioning is to recognize that allocation is functionally equivalent to auctioning the permits, and then giving the proceeds of the auctions back to the recipients of the permits. If permits are “grandfathered,” this wealth would go directly to existing emitters. The optics of “giving away” to companies as much as \$50 to \$100 billion per year, which represents about 10 to 20 percent of total after-tax corporate profits, may

be difficult.

- Inefficiency: Treasury and CEA have grave reservations about the efficiency -- and indeed even the feasibility -- of an allocation system, especially if the permit requirement is imposed downstream (e.g., on electric utilities). First, any downstream option must settle for only partial coverage of emissions to limit administrative burden. Second, the typical downstream system creates obvious incentives for evasion (e.g., cheating or building units that fall just the cutoff level).

AUCTIONS

PROS

- Auctioning would raise revenue -- potentially more than \$100 billion a year -- that could be used to reduce other taxes, fund the adjustment programs favored by the labor unions, offset the regressivity of the emissions reduction scheme, or raise national saving. As some rough examples of what could be done under a revenue-neutral auction approach, \$50 billion raised from auctioning permits could be used for one of the following:
 - Exclude over \$3,000 of payroll from both parts of the 12.4 percent OASDI tax;
 - Cut the employees' OASDI payroll tax (currently 6.2 percent) by 25 percent; or
 - Reduce the 15 percent income tax rate in the lowest bracket to 12.7 percent.

CONS

- Business groups are likely strongly to oppose an auction. The theoretical benefits of auctions as a means of distributing the permits will be much less salient to the CEO of a large corporation than the necessity of having to purchase permits to continue operations. Businesses will view an auction as an obligation to pay for something they currently do for free -- even if they are able to pass the higher costs on to consumers.
- An auction would be more easily characterized as a tax than an allocation program. Although we could emphasize the differences between an auction and a tax, the auction would be scored by budget experts as a revenue flow to the Treasury.

III. THE COSTS AND BENEFITS OF A GRADUAL APPROACH

Absent policy interventions, atmospheric greenhouse gas concentrations will increase during the next century to levels unknown on this planet for 50 million years. Some of your advisers argue that, to avoid such extraordinary increases, *global* greenhouse gas emissions must begin to decline from projected levels early in the next century. For *global* emissions to begin to

decline in this time frame, developed countries must move quickly to reduce their emissions, followed rapidly by action by developing countries.

For the world realistically to avoid a doubling of pre-industrial greenhouse gas concentrations (to 550 ppm) in the next century, global emissions must deflect from a "business-as-usual" path by about 2010.² The heart of the debate among your advisers is over the degree of deflection from the business-as-usual path: whether it is better to start small and grow over time, or whether it is crucial to begin with a more "front-loaded" reduction. The sections below briefly summarize the relevant arguments, which will be presented in more detail in the decision memorandum we submit to you next week.

The case for a front-loaded approach

Those in favor of a more "front-loaded" approach -- such as implied by reaching 1990 levels by 2010 -- argue that if the United States delays emissions reductions, it seems likely that other developed countries will do so too. It will be much longer, as well, before developing countries take any steps to reduce emissions. A slow start on our part therefore increases the carbon emitted into the atmosphere, and forces more dramatic emissions reductions later to achieve the same ultimate CO₂ concentration.

- **Effect of delay on later emissions reductions.** For example, if our goal were to stay below 550 ppm of CO₂ in the atmosphere, a ten-year delay in starting emissions reductions would require emissions reductions to proceed twice as fast in later decades. Even assuming steep reductions in greenhouse gas emissions in distant decades (which our children and grandchildren may or may not be able to achieve), reductions must begin soon to avoid serious environmental damage.

The case for a gradual approach

Other advisers are extremely concerned that a target anywhere close to 1990 emissions levels by 2010 would be excessively costly, mirroring the oil shocks of the 1970s and imposing a reduction in the living standards of the average family of about \$1,000 -- equivalent to a tax on consumers at least five times as large as the Administration's 1993 BTU tax proposal. These advisers argue that the same environmental goals can be achieved at substantially lower

²At a doubling of pre-industrial concentrations, projected impacts average global temperature increase of 2-6.5 degrees F., sea-level rise of 6-38 inches, more intense droughts and floods, and an additional 50-80 million cases of malaria worldwide. According to a NOAA study, this would mean increases in July temperatures in Washington, D.C. of 5-15 degrees F. by the end of the next century. For the world realistically to avoid a near-tripling of greenhouse gas concentrations (750 ppm), global emissions must deflect from this "business-as-usual" path by 2020.

economic cost by adopting a more gradual approach -- one that allows the economy to adjust slowly over time to the new constraints being imposed. There are two major reasons that a more rapid approach raises overall costs:

- **Capital stock.** It is very expensive to scrap capital stock while it is still in the prime of its useful life, and replace it with new plant and equipment that is more energy-efficient. But over the course of twenty to forty years, much of our existing plant and equipment will be ready for replacement anyway. Making efficiency improvements when the plants would have been replaced in any case significantly reduces the costs of such improvements because there are no additional costs to scrapping otherwise productive plant. Thus a more gradual approach is substantially less costly -- because it allows the capital stock to turn over naturally with the improved technology.
- **Lead time for technologies.** A second motivation for a slow takeoff in curbing greenhouse gases emissions is that it takes considerable time before emerging carbon-free or carbon-lean technologies are developed. Waiting until these new technologies are available before making expensive emissions-saving investments offers the potential of both lower economic costs and higher environmental payoffs. A rapid timetable forces long-term investments to be made before superior technologies have been developed and refined.

Responding to the concern that a more gradual approach may delay the pace of emissions reductions in the developing countries, Treasury and CEA argue that even if the more aggressive U.S. policy moves the developing countries from stabilizing emissions in 2050 to stabilizing emissions in 2020, the effect on the temperature in 2100 is less than 0.3 degrees.

On the other hand, the comparison of 1990 to 2010 to the oil shocks may be misleading because the oil shocks were sudden and unanticipated, whereas businesses would have a decade or more to plan for a climate change regime. There would be no climate change "shock," in the sense that term is used to describe the experience of the 1970's -- since markets would have many years for orderly adjustment.

IV. ESCAPE CLAUSE

One way to address the uncertainties associated with the cost of climate change policies would be an "escape clause." Such a mechanism could provide insurance that the costs of meeting our target and timetable do not become excessive.

Under an escape clause, the U.S. Government would stand ready to sell permits at a given price (say \$X per ton). If the market price threatened to exceed \$X, firms would begin purchasing from the government -- thus expanding the supply of permits and driving down the price. The government's promise to sell at \$X ensures that the economic cost of the overall policy is capped at \$X per ton. *It is crucial to recognize, however, that if the escape clause is*

triggered we will not meet our target and timetable, because the government will be selling additional permits.

The value of \$X is important to the design of any escape clause. If \$X is set at a high level, the probability of triggering the escape clause would be low. If \$X is set at a lower level, the escape clause is more likely to be triggered, and the target and timetable is therefore less likely to be met.

More complicated versions of the escape clause could include increases in the real value of \$X over calendar years (e.g., \$X for 2010-2020, \$X+\$15 for 2020-2030, etc.). The mechanism could also provisions to raise \$X as more permits are sold (e.g., \$X for the first 100,000 tons through the escape clause, \$X+\$5 for the next 100,000 tons, etc.). If the price per ton rises as more permits are sold, the price increase will exert more pressure on emissions to return to the original target and timetable glidepath.

An escape clause could protect against high economic costs, and help reduce corporate opposition to a greenhouse gas control program. Technology optimists could believe that we will meet the target and timetable without triggering the escape clause. But, if we set the escape clause at too low a level, we face a substantial risk of appearing disingenuous to domestic constituencies and the international community, since we will be forced to admit that we do not intend to meet our stated target and timetable

International ramifications

An escape clause denominated as such would not be negotiable internationally, and a U.S. proposal in this regard would provoke significant international criticism. Furthermore, it is not clear how an escape clause of the type described above would function internationally, in the absence of an international permit-issuing entity.

However, the U.S. position already includes a provision -- known as "borrowing" -- that operates in a manner similar to an escape clause. Under our borrowing proposal, countries could exceed their targets and timetables for a given period, and have the overage charged to subsequent periods. An escape clause under domestic law could in theory be shaped in a manner consonant with a borrowing provision under the treaty.

Targets and Timetables : Executive Summary

A consideration of targets and timetables raises the question as to how ambitious to be in seeking to ameliorate global climate change. But it also raises the question as to whether it is advisable to reduce emissions of greenhouse gases (GHG) early and rapidly, or more gradually. This paper reviews the academic literature and other relevant information and analysis. It concludes that a given environmental goal, expressed in terms of the level at which atmospheric GHG concentrations are induced to level off, can be attained at far lower economic costs if emission reductions are phased in gradually rather than suddenly. More specifically, it concludes that a moderate path such as "eliminate emissions growth by 2010-2020, and return emissions to 1990 levels by 2040," is to be preferred to the more aggressive alternative "return emissions to 1990 levels by 2010."

1. The factors at work

It is easy to state the basic forces at work in the trade-off between front-loaded and back-loaded emissions reductions. Four factors work in favor of back-loading:

- the time-value of money (resources not spent on emission reductions early on can be invested at a positive return, so as to purchase more emission reductions later),
- allowing for uncertainty to be resolved,
- giving more lead time to develop and implement new technologies.
- allowing time for the capital stock to turn over. By way of stylized illustration, scrapping all coal-fired power plants by 2010 would mean writing off 88% of the capital stock in this sector; waiting until 2020 would necessitate scrapping only 49% of the plants before the end of their normal useful life.

The most important argument in favor of front-loading concerns political credibility:

- an announcement by the world's governments that they are committing to a serious agreement -- but that stringent policy measures will not be taken until 50 years or more into the future -- will not be credible. Only early concrete measures will send the signal necessary to move patterns of research, investment, and consumption onto the new path.

2. The costs of "1990 levels by 2010"

The costs of reducing emissions to 1990 levels by 2010, as the cost of any path, depend heavily on what is assumed about the international regime and domestic implementation. "We can do it smart or we can do it dumb." But any effective program will have to raise the cost of GHG emissions, particularly the cost of using fossil fuels that put carbon dioxide into the air. A broad range of models place the carbon permit price required to achieve this target in the range of \$70 - \$200 per ton. This surcharge translates into an increase in the price of gasoline between 18 and 50 cents per gallon and an increase in the price of coal between 250 and 500 per cent. Averaging over fuels, it is nine times greater than the BTU tax that was proposed in 1993, and as great as the oil shocks of the 1970s. (The necessary increase in price could be cut if we are able to pay Russia, developing countries, or others to reduce emissions in our place. But the remaining price increase

would nevertheless be substantial.)

These increases in the price of energy might or might not have substantial negative effects on output as did the 1970s oil shocks. The answer depends on many things, such as whether the policy is implemented efficiently (e.g., by auctioning emissions permits or a carbon tax) or inefficiently (e.g., by command-and-control style regulation), and whether any revenues that may be generated are redistributed by means of tax cuts that lower the cost of capital to firms. In any case, the policy will have substantial negative effects on consumption, in order to free up resources for investment in new low-carbon plant and equipment.

3. The effects of peaking in 2010-2020

A more moderate path would:

- (i) begin to reduce the rate of growth of emissions in the near-term (2000-2010)
- (ii) eliminate emissions growth in the medium term (so that emissions at the end of the decade 2010-2020 were the same as at the beginning), and
- (iii) return emissions to the 1990 level in the longer term (e.g., 2040).

The overall cost of this approach is much less than that of the more aggressive timetable. Estimates suggest that the price of carbon would be between \$5/ton and \$12/ton in 2010. (It would have to continue to rise thereafter, as is also true under the first approach.) Gas prices would rise by an estimated 2 to 3 cents, and coal prices by 25%-35%. Effects on the economy are scaled down accordingly. Estimates of the loss in consumption are roughly 1/10-1/3 the size of the more aggressive approach.

4. A comparison of paths assuming the same eventual emission levels

The natural question to ask is: what is the environmental loss that the planet must bear in exchange for this economic gain? The answer depends entirely on what is assumed about emissions during the remainder of the 21st century (and thereafter). Differences in emissions in the early years of the century are virtually negligible in their direct implications for the cumulative concentration levels. But "even the longest journey begins with a single step." Differences in that first step are important to the extent that they begin the journey down different pathways.

Let us first consider what happens if, after re-attaining 1990 emission levels -- whether in 2010 under the aggressive approach or 2040 under the moderate approach -- emissions remain at that same level for the remainder of the century. This assumption, on the one hand, implies a growing gap with the business-as-usual growth path while, on the other hand, entailing insufficient cuts to stabilize concentrations in the atmosphere. The "1990 by 2010" path only reduces the warming by an estimated 0.08 degrees centigrade in 2050 and 0.21 degrees in 2100. (Even a more aggressive path of 10 percent emission cuts by 2010 has virtually the same small effect, to one decimal place. This is relative to a warming of 1.06 and 2.36 degrees, respectively, under business as usual.) The date at which concentrations reach double pre-industrial levels is postponed by an estimated 9 years. How much of these environmental benefits are achieved by the moderate path? Warming is mitigated by 0.06 degrees in 2050 and 0.19 in 2100. No difference, to one decimal place.

5. A comparison of paths assuming the same eventual emission levels

Concentrations and temperatures continue to rise in subsequent centuries, under any of the paths just discussed. In order to put a bound on the magnitude of eventual climate disruption, one

has to put a bound on the magnitude of concentrations. Doing so requires reducing emissions below 1990 levels.

Perhaps the strongest case against an aggressive path like "1990 in 2010" is that *the same ultimate goal in terms of concentrations* can be achieved far more cheaply by imposing aggressive cuts in emissions later in the 21st century rather than earlier. It is possible to compute the path that minimizes the total economic costs of attaining a given ultimate concentration target. An estimate of the least-cost path, of those that eventually cause concentrations to level off at twice industrial levels (i.e., to 550 ppmv), is relatively gradual in the early years. The least cost mitigation path has emissions from Annex I countries peaking in the decade 2020-2030. The peak of emissions is 29 percent above 1990 levels. Annex I emissions do not return to their 1990 levels until after 2050. This experiment assumes that developing countries are successfully brought in to the agreement, with their participation phased in between 2030 and 2050. Emissions from developing countries peak in 2050. (Without the participation of the developing countries, attaining the target of 550 ppmv concentrations is virtually impossible, since they are such a rapidly growing share of world emissions.) This least cost mitigation path generates quite low values for carbon emissions rights in the early years. The permit price is only \$2/ton in 2010, and slowly rises thereafter. Only in the latter part of the century does it rise significantly, to \$156/ton in 2100. The least cost mitigation path costs the U.S. \$0.124 trillion in terms of lost consumption (present discounted value), as compared to \$0.303 trillion under the "1990 in 2010" path. Thus the least cost mitigation path generates savings of 60 percent from the 1990 in 2010 path. Assuming that environmental effects depend on concentrations, there is no little or no environmental cost to be weighed against the large economic benefits of going more slowly.

It is important to keep in mind that all these cost estimates are "best case" scenarios, in the sense that they assume efficient market implementation, international trading, and full international participation and enforcement. Actual costs could be much higher if less efficient command-and-control mechanisms of implementation are used, if there is not effective international trading, or if some countries do not accede to or abide by a treaty.

6. Political credibility

A path under which emissions peak in the decade 2020-2030 is far more conservative than the paths that have been discussed in international negotiations. The strong argument for moving the timetable forward is the one mentioned above: political credibility. The year 2020 is more than twenty years in the future. A path under which emissions peak in the decade 2010-2020 represents early commitment to a tangible target ("eliminate emissions growth"), while estimates suggest that it is almost as beneficial as the least-cost path. The political credibility of the path could be further boosted by commitments at earlier dates such as 2000-2010 ("reduce emissions growth"). Credibility would be particularly enhanced by a specific proposal to raise the price of energy, even if by only a small amount, if domestic political opposition was not overwhelming.

More aggressive paths are likely to arouse greater political opposition, in correspondence to their greater economic cost. Where domestic opposition is sufficiently great to kill a proposal politically, the set-back will be to international political credibility -- and to environmental progress. The last section of the paper, however, discusses one possible option for helping to limit the economic cost and corresponding domestic opposition, for any given target/timetable: an escape clause triggered by the price of carbon emissions.

Predecisional draft. Very preliminary. Close hold. Do not distribute

Targets and Timetables

A U.S. proposal for "targets and timetables" for reducing countries' emissions of greenhouse gases (GHG) must be made soon. The U.N. Framework Convention on Climate Change has called for economically cost-effective remedies to the problem [cite? From JY]. Tradeoffs have to be made -- both with respect to the ultimate target and with respect to the timetable under which it is achieved. The subject of this paper is how to do them. (The paper does not directly focus on two other key sets of policy decisions -- domestic implementation and proposals for developing country participation and other sorts of "when-and-where flexibility".)

It is futile to search for a single comprehensive econometric model within which these questions can be appropriately raised and definitively answered. Even within a given model, answers depend critically on the precise nature of the question asked (e.g., the extent of global participation and international trading, whether and how any revenue is recycled, what is assumed about technological progress, etc.) Furthermore, each model has strengths and weaknesses; each has questions to which it is better or worse suited to answer. Some, for example, model the energy sector in detail. Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that runs on natural gas. Some have enough tax policy detail to distinguish alternative ways of redistributing tax revenues. Some are capable of showing short-term macroeconomic disequilibria. Some include a long-term "carbon cycle" model that can keep track of the accumulation of GHG concentrations in the atmosphere and their climatological effects. Some break down the rest of the world into regions and so can model international trade. No one model does everything.

The existence of modeling difficulties does not mean that we can abandon rigorous economic analysis. Rather, we must employ a broad set of economic tools to analyze the policy options. The tools employed in this paper include results from models of the energy sector and economy over the next 25 years, including but not limited to the models that were used by the Interagency Analytical Team (IAT) earlier in this year. The survey also includes models that are designed to operate on the longer time frame that is relevant for thinking about climatological effects. Other tools include simple relevant statistics, "meta-analyses" of existing models, historical and sectoral examples, and basic economic reasoning. Drawing on this broad array of analytical tools allows an intelligent evaluation of the policy alternatives.

1. Why do economists estimate high costs to early reductions in emissions?

The large economic impact of aggressive action

The measures necessary to implement serious reductions in GHG emissions would inevitably have very major effects on the U.S. economy. One path that has been widely discussed in the U.S. is to return to 1990 levels in 2010. (Still more aggressive paths seek to cut emissions 10 percent or more below 1990 levels by 2010. Intermediate paths are to return to 1990 levels by 2020, or to 10 percent above 1990 levels by 2010.) Estimates suggest that to reduce 2010 emissions to the level of 1990, it would be necessary to increase the price of energy on the order of \$100 per ton of carbon.

This is a rough midpoint, around which there is a great range of uncertainty. The range of

estimates in the IAT exercise was \$80-\$140, for the case without international trading. Some agencies believe that the necessary increase in price would be less than this, others that it would be more. [These estimates are representative of the broad economic literature. References.¹] It is anticipated that prices would have to continue to increase after 2010, even if emissions were not brought down any further, because of the widening gap vis-a-vis the business-as-usual case. Energy modelers often make the assumption that, once the price of carbon goes high enough, some sort of unidentified "back-stop technology" will eventually be developed, thereby putting a limit on how high the price ultimately goes.

The estimate of \$100/ton in 2010 represents an increase in the price of oil of \$11/barrel (52%), an increase in the price of gasoline of 26 cents/gallon, and an increase in the price of coal of 273%. One standard of comparison is the BTU tax that the Administration proposed in 1993. The increase contemplated here is 9 times larger. (This is for a weighted average of fuels. The multiple for coal is greater than this, and for oil is less.)

These large price changes signal major changes in the allocation of resources across activities and sectors. Need they require a reduction in the rate of growth of aggregate income and output? This depends, in particular, on two things. First, adjustment costs can impose a negative effect on GDP and employment, especially in the short term. (Model estimates of GDP losses from "1990 by 2010" reached ___ in the IAT exercise under some pessimistic assumptions, and are higher in some other estimates. ____.) Second, if measures to raise the price of energy result in the generation of revenues for the government, and they are used to reduce the cost of capital to firms (e.g., by means of an investment tax credit), then negative effects on economic growth can in the long run be moderated, eliminated, or possibly even reversed. The meta-analysis of 162 simulations derived from 16 leading models by Repetto and Austin (1997, p.13) concludes that the negative effect on national income can be offset or reversed *if*:

- (I) tax revenues are recycled in the optimal way,
- (ii) developing countries participate in the agreement, *and*
- (iii) optimistic assumptions are made regarding the availability of non-carbon backstop technologies, efficient economic responses, and increased energy and product substitution.

However, the best single measure of aggregate economic costs is the appropriate summation over time -- the present discounted value -- of foregone consumption. Even in a case so optimistic that there might be no effect on output, early action to address climate change requires a diversion of resources from consumption to investment. Thus the present discounted value of consumption is likely to fall. By way of analogy, defense build-ups have appreciable economic costs, in terms of foregone consumption, even though there is often little or no negative effect on aggregate GDP.

Analogy with the oil shocks of the 1970s

A standard of comparison for judging the magnitude of the price increases entailed in climate change policy is the oil shocks of the 1970s. The energy price increase now contemplated [an estimated 88 percent], for stabilization by 2010 is on the same order of magnitude as either the 1973-74 or 1979-80 oil price increases. Again, this is for a weighted average of primary fuels. Fossil fuel

¹ The range of variation across models reported by the Energy Modeling Forum, based in Stanford, is at least as large. Gaskins and Weyant (1993) and EMF (1994).

prices net of inflation doubled between 1972 and 1975, and doubled again by 1981. Gasoline prices rose by 30 percent between 1972 and 1974 and by nearly another 50 percent from 1974 to 1981. Coal, as a substitute for oil, also experienced a price increase in the earlier episode, but by much less.

One can check independently how the price increase necessary in the present context compares to those of the oil shock decade. Carbon emissions in the year 2000 will be about 15%__ (?) percent above 1990 levels. Between 1973 and 1984, U.S. energy use departed from its usual growth trend, and was essentially unchanged in absolute terms. U.S. emissions fell by only 6.2%. This comparison suggests that to return emissions to 1990 levels between 2000 and 2010, a decline of 15%, would require much greater increases in energy prices than took place over the decade of the oil shocks.

Those price increases, which are designated "supply shocks," are widely believed to have led to high levels of inflation that were eventually reversed only by means of high interest rates and very large losses in output over time. More specifically, they are believed to have led directly to the recessions of 1974 and 1980. (Indeed, the contraction in output, as much as the fall in the energy/output ratio, was a prime force reducing energy use below its long-run trend.) Some economists also believe that the oil shocks may have played a role in the abrupt slowdown in the long-term trend of productivity growth evidenced in the U.S. and other industrialized countries after 1973; but that is much less certain.

The large models that have been used to examine climate change policy tend to exclude supply-shock effects. [Only the DRI model is a macro model capable of addressing these effects; and it shows a loss of only 150,000 to 400,000 jobs in 2010.] The idea is that a path of gradual increases in energy prices will be fully built into the expectations of firms and workers, because of clear commitments to future policies. Thus they will be able to plan ahead and avoid serious microeconomic dislocation and macroeconomic disturbance. Furthermore, the 70s oil shocks entailed large transfers from the U.S. and other oil-importing countries to OPEC, thus depressing real income and spending in the former; a self-imposed energy price increase to address global climate change need not entail such a transfer of purchasing power. Still, if it is contemplated to introduce large increases in energy prices over a period as short as a single decade, it is worth remembering the experience of 1972-81. [Some further details are available in a separate memo.]

The role of turnover of the capital stock

Why do economic models consistently find that the cost of major reductions in emissions is much higher if they are implemented by 2010 than if they are stretched out for another decade or more? There are several arguments for waiting. They include

- (1) the time-value of money (resources not spent on emission reductions early on can be invested at a positive return, so as to purchase more emission reductions later²),
- (2) allowing for uncertainty to be resolved, and
- (3) giving more lead time to develop and implement new technologies. (There are also a number of reasons for wanting to go fast, listed in bullet form in the Section on cost-benefit analysis below.)

² Meanwhile, a higher fraction of carbon emissions will have been naturally removed from the atmosphere by a fixed date, e.g., into the oceans, the earlier those emissions occur.

But the most important reason for waiting is :

(4) to allow time for the capital stock to turn over.

The basic point is that it would be very expensive to scrap the entire capital stock, to replace it with more carbon-free plant and equipment, while it is still in the prime of its useful life. But 20 to 40 years out into the future, much of our existing plant and equipment will be ready for replacement anyway, whether because the plant and equipment have depreciated gradually or because they have more suddenly come to the end of their useful life.

[FIGURE 1 GOES HERE]

The effect of the turnover of the capital stock is built into some of the models used to address climate change [e.g., Markal Macro; though not into most “bottom-up” engineering studies, like the Department of Energy’s Five-Labs study]. But it may be useful to look at a simple illustration of the point, for the case of the capital stock in power generation.

Figure 1 shows the effects of an accelerated replacement schedule for all of the 7,900 electric power plants built during the last 40 years. [One could skip directly to coal-fired plants, to save space.] Imagine, to take an extreme case, that all power plants had to be shut down within ten years (by 2007), and replaced with less-polluting technology. This would imply replacing 6,330 plants before the end of their normal lifespan, or 80 per cent of the total. Now imagine a policy that required replacement of all power plants in 20 years. This would constitute an accelerated replacement of 4,600 plants, or 58 per cent of the total. If one could wait 30 years, the complete replacement would mean an accelerated replacement of 2,000 plants, 26 per cent of the total. If one waited forty years, under the stylized assumption of a 40-year life there would be no additional cost to replacing them. [We have truncated the distribution at 40 years, the average lifespan of existing electric power plants. There are other plants that are still in use 50, 60, or even 90 years after they were built. But their numbers are small, and by the end of 40 years the cost of shutting them down would in any case be much-reduced, particularly as technology will have advanced in the meantime.]

Figure 2a does the same exercise for the set of power plants that are coal-fired. This is the class of generators that produce the most carbon and that would thus have to be replaced even under a moderate plan to address climate change. If a complete change-over of coal plants were to be accomplished in 10 years, 799 of the 1,122 coal-fired plants (71 per cent) would have to be replaced before the end of their expected lifespan. If replacement occurs over 20 years, 488 plants would be affected, or 43 percent of the total. If one could wait 30 years, 227 plants would be closed prematurely, or 20 per cent of the total.

Perhaps a comparison between 2010 and 2020 would be most relevant, as these two years figure prominently in the targets-and-timetables debate. In our stylized hypothetical experiment, imagine that all power plants had to be shut down by 2010 (i.e., within 13 years). This would imply replacing 88 percent of the plants before the end of their normal lifespan. Now imagine that all power plants had to be replaced by 2020 (23 years). This would constitute an accelerated replacement of only half the plants.

[FIGURES 2a AND 2b GO HERE]

Figure 2b repeats the exercise on the basis of coal plant capacity. Since newer plants tend to have larger capacity, the effects of a rapid replacement schedule are magnified. Closing all plants within 10 years implies that 289 million KW of capacity would be prematurely shut down, or 90 per cent of the total. If one could wait 20 years, 235 million KW of capacity would be affected, or 73 per cent. For 30 years, the capacity that would have to be replaced falls to 116 million KW, or 36 per cent of the total.

This exercise is not intended to be an estimate of the costs of different time-tables, even within this one sector. Rather, the point has been to illustrate concretely the importance of allowing time for the capital stock to turn over, and to illustrate it in a transparent framework that is independent of modeling assumptions over which analysts might differ.

One can pose the question regarding effects of alternative paths in three ways. (I) How do the economic and environmental effects of "1990 by 2010" compare to those of more moderate paths, e.g., in which that level is attained at some later date? (ii) What are the economic effects of alternative paths toward the same ultimate environmental objective, e.g., eventual stabilization of concentrations at twice pre-industrial levels? (iii) What is the optimal unconstrained path to balance estimates of economic costs and environmental benefits? We will consider each question in turn, though in reverse order.

[or would it be better to do it in order (I) (ii) (iii): 1990-LEVEL RESULTS, THEN 550PPM CONSTRAINT, THEN IA MODELS?]

2. Cost-benefit analysis in the Integrated Assessment models

It is difficult to put economic costs and climate benefits into the same unified analytical framework. This is in part because the effects are so uncertain, especially with regard to climate, and in part because the climate effects take place on a very long time scale. So-called Integrated Assessment models attempt to put everything into one framework. They attempt to quantify the benefits of averted climate change in the distant future, as well as the economic costs of programs to address emissions, and to compare the two.

Integrated Assessment models began with Nordhaus (1989, 1994). By now many of these models exist. An Appendix I to this paper elaborates. The literature is surveyed by Manne (1996). Those models that can be used for cost-benefit analysis tend to give a similar result: a plan that optimally balances costs and benefits calls for relatively small actions at the beginning, with the result that GHG emissions continue to rise, although at a reduced pace, for at least a century. Concentrations reach ___ ppmv by 21___. In the simplest case, damage from warming is assumed to rise linearly with temperature. But it is plausible that the costs in fact begin to rise more sharply, e.g., when concentrations and temperature go above a threshold level. Findings by Peck-Tiesberg (1992), using the CETA model and the case of a non-linear damage function (allowing the damage to rise increasingly sharply with the temperature), call for emissions peaking in 2080-2090.

Some of the authors have characterized in a striking way the gap between the optimal paths that their models produce and the frequently heard proposal to return emissions to 1990 levels by 2010: In their models, the economic costs of such a strong early response are so great that, if that were the only alternative, we would be better off doing nothing at all [Jorgenson testimony? Can't find it in there. It's _____ of Stanford?]. In other words, the economic costs of "1990 levels by 2010" outweigh the benefits.

Arguments for earlier action

This conclusion, and the methodology that produced it, have been criticized on a number of grounds.

- Some claim that it gives insufficient weight to the (small, but nonetheless alarming) probability of a discontinuously-large and essentially irreversible catastrophe, such as the melting of the West Antarctic ice sheet [which might raise ocean levels by 5 to 6 meters], a runaway "positive-feedback" greenhouse effect (e.g., from methane release), or structural changes in ocean currents such as the Gulf Stream. [references: Cline (1992, p.34-35, Revelle, 1983, p.442, IPCC 1996a; Schelling AER 1995?)]
- Some claim that it gives insufficient weight to the welfare of future generations that will bear the costs of climate change (that is, the discount rate is too high). [references: Cline (1992) and Howarth (199_).]
- Some claim that it neglects basic uncertainty about all parameters -- the economic effects, the climate effects, and the discount rate necessary to compare the two. [reference: Pizer (1996)]
- Some claim that it omits a basic point about political credibility: an announcement by the world's governments that they are committing to a serious agreement -- but that stringent policy measures will not be taken until 50 years or more into the future -- will not be credible, and understandably so. The arguments for postponing sharp cuts in emissions ten years only work if people use the intervening period to begin adjusting. If they are skeptical of the need to adjust, then ten years later nothing will have been accomplished, and the economy at that point will face the same high costs to early reductions as before. Only early concrete measures will send the signal necessary to move people's patterns of research, investment, and consumption onto the new path.³

3. Estimates of least-cost paths to stabilize concentration levels

Much of the debate about GHG stabilization takes as given that simply allowing emissions to continue to grow for a long period, albeit more slowly, puts the biosphere at too much risk and is not credible politically. An alternative strategy is to reason that the probability of catastrophe may rise to unacceptable levels unless GHG concentrations are capped at some particular level. Such an approach has the disadvantage that the choice of any specific concentration cap is arbitrary, and is inconsistent with the spirit of cost-benefit analysis. But it has the advantage of being analytically tractable, and offers a meaningful focal point for negotiation..

Stabilization of concentrations at 550 ppmv

³ An opposing credibility point is also made: A proposed agreement that demonstrably imposes much higher costs than an alternative more measured approach, and thereby invites substantial domestic political opposition, will also suffer from credibility problems both here and abroad.

We will consider the question of the optimal path subject to the constraint that concentrations be stabilized at 550 ppmv (approximately double the pre-industrial level of 275 ppmv⁴). One might ask why we need accept a level of concentrations, and corresponding probability of catastrophe, as high as this. Indeed, why accept any probability of catastrophe? It is important to recognize that it is already too late to keep this probability at zero (even if one were to accept that it would have been worth the cost to do so, had we known at the beginning of the Industrial Revolution what we know now). Concentrations are already at 365 ppmv, and it is impossible to prevent them rising further in the short run; one would have to reduce emissions almost to zero to do so.

[It would be useful to quantify the implicit gap between this strategy and the strategies resulting from the unconstrained optimization by the Integrated Assessment models. The difference represents the role being accorded to the four bullet points above. In addition, some sensitivity analysis with respect to the level of the concentration constraint would be desirable.]

Results for a less aggressive path

Wigley, Richels and Edmonds (1996) [WRE] examined alternative paths to reach 550 ppmv and other concentration levels. They considered a path where global emissions peaked in 2030 and did not return to 1990 levels until some date past 2100. Manne-Richels (1997) use the MERGE model to examine the implications of the WRE path in more detail.⁵ In their model, emissions from OECD countries as well as from other Annex I countries (most of the former Soviet Union and Eastern Europe) peak in the decade 2010-2020. (Annex I emissions do not return to their 1990 levels until sometime early in the decade 2030-2040. The price of crude oil peaks in 2040.) The reason that the peak in worldwide emissions lags two decades behind the peak in Annex I emissions is that the developing countries do not peak until 2050.

WRE argue that this path has much lower economic costs than proposed paths that are more aggressive in terms of timing, while producing the same terminal effects on concentration. The more aggressive path they examine is the IPCC Working Group path 1 [WG1], which entails Annex I fossil fuel emissions peaking in 1990, and falling 24 percent worldwide below 1990 levels by 2010.⁶ (Of course, it is too late for this scenario to be realized. Seven years have passed during which emissions manifestly have not in fact begun to fall in the overwhelming majority of OECD

⁴ The concentration figure refers only to CO₂. Emission of other greenhouse gases will raise the warming potential, or carbon-equivalent, above this level.

⁵ MERGE's results regarding the comparison of the WRE and WG1 paths apparently fall in the middle of the results of 10 or so models that participate in the Energy Modeling Forum (EMF-14, Oslo, Aug. 1997).

⁶ *Worldwide* emissions rise 8 percent by 2010 [from 5.885 to 6.351]. These numbers come from 8/28 personal communication with Richels. (Earlier communication had worldwide emissions rising 13.64% by 2010 under the IPCC path [to 7.798 PgC]. Evidently the former statistic refers only to fossil fuel emissions and the latter to all carbon emissions.)

countries. Below, we will also consider other alternative proposals that, while sufficiently ambitious as to be expensive to achieve, at least have the virtue of not having been ruled out by history.)

As noted earlier, the best single measure of aggregate economic costs is the present discounted value, i.e., the appropriate summation over time, of foregone consumption. The IPCC Working Group path shows a total worldwide consumption loss of \$8.6 trillion. (The loss would be lower if costless international trading were allowed -- \$3.3 trillion. On the other hand, the cost would be higher if the developing countries do not agree to the targets envisioned. Indeed, if the developing countries do not participate at all, then the goal would be impossible to attain at any cost.) The more moderate WRE path toward the same concentration goal entails far smaller costs: a total worldwide cost of \$1.57 trillion. (With costless global trading, it is \$0.77 trillion. The difference illustrates the great benefits of "where flexibility," assuming that international trading can be successfully implemented.) Thus the saving from letting emissions continue to rise as late as 2010 is more than three-quarters of the cost.

WRE did not attempt to compute the least-cost path for reaching the same goal.

The least-cost mitigation path, compared to 2010 constraints

Manne and Richels (1997) is believed to be virtually the first paper to compute the path that minimizes costs (again, using the MERGE model), subject to the constraint of stabilizing concentrations at a level such as 550 ppmv.⁷ They must necessarily make some assumption about international burden-sharing. The particular question is as follows: how much can we insist that developing countries (who are poor, but in many cases rapidly growing) reduce their emissions, relative to their (low, but often rapidly growing) paths? For the case of 550 ppmv concentrations, they assume that non-Annex I countries can plausibly be expected to begin to limit emissions in 2030, and to complete a transition to a regime under which their per-capita emission rights are equal to those of the industrialized countries by 2050.⁸

The global numbers that Manne and Richels reported in their paper need to be broken down by region. In addition, they were asked to constrain the year 2000 emission levels to the BAU level, under the theory that a treaty that reduces emissions beginning in 1990 has already been ruled out by history, and that even a start in 1998 is extremely unlikely. Their model implies that the least cost mitigation path has emissions from OECD countries, as well as from other Annex I countries in general, peaking in the decade 2020-2030, a bit behind the WRE path. The peak of Annex I emissions is 29 percent above 1990 levels. [Source: personal communication from Richels, 8/21 and

⁷ Also Manne and Richels (1995). Kosobud, et al (1994) examine alternative paths to achieve a given temperature target in 2100. All three papers find that a return to 1990 emission levels early in the 21st century is a needlessly costly way to attain the 2100 goals for concentration and climate.

⁸ Based on 1990 populations. This formula could imply large transfers from OECD countries to developing countries. We consider an alternative scenario in the next section -- that the developing countries do not participate at all. It would also be desirable to look at the implications of a plan under which a small number of middle-income countries (particularly Korea and Mexico) begin to limit emissions by 2010. Without China and India, however, the emissions of the middle-income countries are a small fraction of the world total, so that their involvement would be important only in order to point the way for other emerging economies, rather than to reduce emissions perceptibly in their own right.

8/28/97.] Emissions do not return to their 1990 levels until after 2050. Emissions from developing countries peak in 2050. The sum of the two, total worldwide emissions, also peaks in 2050. (By mid-century, developing countries are such an important source of emissions that they dominate the global peaking date and the date of return to 1990 levels.) Worldwide emissions return to their 1990 levels shortly before the end of the 21st century.

This least cost mitigation path generates quite low values for carbon emissions rights after implementation in 2000. The permit price is only \$2/ton in 2010, and slowly rises to \$3/ton in 2020. Only in the latter part of the century does it rise significantly, to \$156/ton in 2100.

In contrast to the least cost path, the following table demonstrates the effect of constraining Annex I emissions relative to 1990 levels in 2010. The constraint is imposed over the period 2010-2030. After 2030, further reductions in Annex I emissions occur in order to meet the constraint of concentrations at 550 ppmv. Developing countries again participate, consistent with the burden sharing formula described above. Thus the permit price estimates presuppose full global participation and trading ("where flexibility") but not intertemporal trading ("when flexibility").

Change in emissions relative to 1990 in 2010	Permit Price in 2010 (\$/ton)	Permit Price in 2020 (\$/ton)	Consumption Losses (trillions of dollars) ⁹		
			U.S.	Annex I	World
+10%	4	65	0.293	0.564	0.782
0%	67	88	0.303	0.619	0.939
-10%	120	112	0.429	1.054	1.276

According to Manne and Richels, their least cost mitigation path costs the U.S. \$0.124 trillion in terms of lost consumption (present discounted value), as compared to \$1.28 trillion under the IPCC Working Group path and as compared to \$0.303 trillion under the "1990 in 2010" path. Thus the least cost mitigation path generates savings of 90 percent from WG1 and 60 percent from the 1990 in 2010 path.¹⁰

It is important to keep in mind that all these cost estimates are "best case" (almost utopian) scenarios, in the sense that they assume efficient market implementation, international trading, and full international participation and enforcement. Actual costs could be much higher if less efficient command-and-control mechanisms of implementation are used, if there is not effective international trading, or if some countries do not accede to or abide by a treaty.

What if there is no international trading?

⁹ The present discounted value of consumption assumes a 5% discount rate and a time horizon of 1990-2100.

¹⁰ Most of this gain is also reflected in the WRE path, as described above.

It is important to keep in mind that the permit price estimates cited above assume perfect global trading. Under this assumption, emission reductions occur where it is cheapest to do so regardless of geographic location (including in developing countries). What if there is no opportunity to buy emission reductions from lower-cost countries? The following table shows permit prices in 2010 when Annex I emissions are constrained to 1990 levels under alternative assumptions about where flexibility. If the U.S. must attain its target by domestic emission cuts entirely, because developing countries do not participate and there is not trading even among Annex I countries, then the cost rises steeply. These conditions triple the price of the "1990 by 2010" target, in terms of the marginal cost of abatement, from \$67/ton to \$204.

U.S. Permit Prices in 2010, 1990 Level in 2010 Scenario

Where Flexibility	Global Trading	Annex I Only Trading	Domestic Only Trading
Permit Price in 2010 (\$/ton)	67	132	204

What if the developing countries do not agree to go along?

It is difficult to imagine that the industrialized countries will be able to extract commitments from developing countries much more serious than those assumed in the preceding section, the Manne-Richels burden-sharing schedule. (Or that U.S. taxpayers will agree to transfers to developing countries larger than those implicit in that schedule.) What if, as is more likely, the commitments extracted from developing countries are less strong than this, rather than more? On the one hand, as a matter of arithmetic, meeting the 550ppmv concentration constraint would require more aggressive targets and timetables on the part of the Annex I countries, if indeed it would be possible at all. On the other hand, as a matter of politics, the absence of the developing countries would probably lead the peoples of the Annex I countries to choose a less aggressive path, even though it would produce a higher terminal concentration level.¹¹ (An analytical balancing of costs and benefits would give the same answer -- a less aggressive path -- once the concentration constraint is relaxed.)

To consider the possibility that developing countries might decline to participate, or decide to participate only to a lesser degree than the Manne-Richels burden-sharing formula, we ask what would be the effects, both economic and environmental, if the Annex I countries were constrained to the WRE path, but developing countries do not participate (i.e., developing countries remain on their BAU path). The welfare losses (in terms of present discounted value) will depend upon whether there is trading in emission rights among Annex I countries. If Annex I trading occurs, then Annex I countries' losses increase from \$0.62 trillion to \$0.91 trillion, or 47%. If emission trading among Annex I countries does not occur, then losses rise to \$1.00 trillion, or 61%. For the U.S., in

¹¹ Conversely, the developing countries are less likely to agree to participate if the Annex I countries have not already taken serious action.

the absence of developing country participation, welfare losses rise from \$0.28 to \$0.36 trillion, or 29%, assuming Annex I trading. Without Annex I trading, U.S. losses rise to \$0.41 trillion or 46%.¹² Meanwhile, the non-participation of the developing countries means a clear failure to meet the goal of capping global emissions at 550 ppmv.

Even if the Annex I countries choose an aggressive path of reducing emissions 10% below 1990 levels by 2010 (and stay at that level thereafter), the effect is to reduce global concentrations only 7 % below BAU levels in the year 2100. This is less than a third of the reductions achieved when the developing countries participate [22%; conversation 8/28] This result illustrates the problem of free riding. Moreover, the estimate does not include an allowance for "leakage" of carbon savings from participating to non-participating countries (e.g., reduced oil demand in the former, via a lower world price of oil, raises oil consumption in the latter). Once leakage effects are added to the free-riding problem, the difficulty of accomplishing meaningful reductions without the help of developing countries are even greater. The savings is only 5 percent in this case. In other words, of the 22 percent reductions achieved when the developing countries participate, 15 percentage points are lost to free-riding, and another 2 points to carbon leakage. [conversation 8/29.] This estimate captures only some of the possible leakage channels; it omits, for example, the relocation of production in polluting industries to non-participating countries. Indeed, no model measures this effect with much precision or accuracy.

**

4. What is the trade-off between the paths currently under discussion?

As we have seen, the Manne-Richels results suggest that the optimal path has Annex I emissions peaking in the decade 2020-2030 and returning to 1990 levels after 2050. The paths for emission reductions that have been discussed in the international negotiations are more aggressive.

What are the additional economic costs, and climatological benefits, of moving from the optimal path to "1990 levels by 2010"? Table 4, "Climate and Economic Variables under Alternative Emissions Paths," which reports results from the SGM model, is designed to answer this question. The economic costs of the more aggressive path can be measured in several ways. The price of gasoline in 2010 would rise by 26 cents a gallon and coal prices by 273 percent, as compared to only 3 cents per gallon on the less ambitious path, and an increase in coal prices of only 53 percent. The total economic loss, in the present discounted value of foregone consumption, \$206 billion, as compared to only \$95 billion on the less ambitious path. [These figures cumulate lost consumption out only to 2050, and thus are not comparable with the figures cited in the preceding section.] What is accomplished by the more aggressive strategy? The date at which concentrations are doubled is postponed by a mere 3 years (beyond the nine-year postponement achieved by the less aggressive path). The estimated warming in 2100 (2.45 degrees under the business as usual case)

¹² For purposes of this comparison, we assume that if developing countries do participate, there will be full global trading.

is reduced by a mere .03 degrees.. While different observers will weigh the economic costs and climate benefits in different ways, the percentage increase in costs from early action seems greater than the percentage reduction in concentrations and warming.

This conclusion omits that concentrations continue to rise in subsequent centuries. The way to address such concerns is by means of models (such as Integrated Assessment models) that keep track of economic and environmental effects on a longer time frame. The section of the paper on "Least-cost Paths to Stabilize Concentration Levels" explains how more moderate paths can attain the identical objective, in terms of terminal concentration levels, with lower economic costs than "1990 in 2010." But all these results leave out the major argument for early action mentioned elsewhere: the need for political credibility of an announced long-term plan. This argument suggests that a moderate path should be accompanied by early and specific announcement of serious domestic measures of implementation.

Table 4

Climate and Economic Variables under Alternative Emissions Paths *

		<u>Concentration Level (ppmv)</u>		<u>Year at Which Concentration Reaches 2x Pre-Industrial Level **</u>	<u>Change in Temperature from 1990 Level (Celsius)</u>	
		<u>2050</u>	<u>2100</u>		<u>2050</u>	<u>2100</u>
Business As Usual (BAU)		502	711	2064	1.06	2.36
<i>Deviation from BAU:</i>						
Annex I Participation Only	1990 -10% beginning in 2010	-21	-66	+10	-0.09	-0.25
	1990 beginning in 2010	-18	-55	+9	-0.08	-0.21
	peak in 2015, 1990 in 2040	-13	-52	+7	-0.06	-0.19
	1990 +10% beginning in 2010	-14	-47	+7	-0.07	-0.18
		<u>Carbon Permit Price (\$ per ton)</u>		<u>Consumption *** (billions of \$)</u>		
		<u>Domestic Trading</u>		<u>Annex I Trading</u>		
		<u>2010</u>	<u>2050</u>	<u>2010</u>	<u>2050</u>	
Business As Usual (BAU)		0.00		0.00		121,650
<i>Deviation from BAU:</i>						
Annex I Participation Only	1990 -10% beginning in 2010	+175	+924	+91	+238	-980
	1990 beginning in 2010	+109	+582	+41	+149	-740
	peak in 2015, 1990 in 2040	+12	+563	+11	+153	-270
	1990 +10% beginning in 2010	+60	+310	+17	+113	-460

Summary description

A plan to return carbon emissions to their 1990 levels by 2010 postpones by 9 years the date at which CO₂ concentrations reach twice pre-industrial levels. Global warming would be reduced by 0.21 degrees by the year 2100 versus an estimated 2.36 degrees under BAU. Under this emissions path the value of the estimated foregone consumption is \$740 billion.

A less ambitious path -- "eliminate emissions growth by 2010-2020" -- would postpone the doubling date by 2 years less, and would lead to another 0.02 degrees of warming. But, the economics would become much easier: The value of foregone consumption would be only \$270 billion.

* Preliminary CEA projections. The origin of these preliminary numbers is described on the accompanying page.

** Pre-industrial concentrations of CO₂ were approximately 275 ppmv.

*** Assumes domestic trading only. Annex I or worldwide trading may substantially reduce these costs.

Deviations are foregone consumption assuming a 5% discount rate for the time horizon 2000-2050.

September 10, 1997

Sources and Explanations

Sources

Business As Usual (BAU) emissions projections are based on the assumptions employed in the IAT process. These projections incorporate the Annual Energy Outlook and International Energy Outlook projections, and closely mirror the IPCC IS92a emissions profiles with modifications made for the economic decline in the Former Soviet Union and Eastern Europe. BAU concentration and temperature projections are from the MAGICC model. Carbon permit price estimates and foregone consumption figures are from the SGM model. All these results were provided by Jae Edmonds, Marshall Wise, and Chris MacCracken at Battelle, Washington, DC.

Participation Cases

Annex I Participation Only: Assumes full compliance of stated targets and timetables by countries in Annex I; rest of the world behaves as in BAU.

Targets and Timetables

1990 (+/-10%) in 2010: Emissions follow BAU through 2000, reduce to 1990 (+/-10%) levels by 2010, and remain at 1990 (+/-10%) levels thereafter.

Peak in 2015, 1990 in 2040: Emissions follow BAU through 2005, peak at 2010 BAU levels in 2015, and stabilize at 1990 levels in 2040 and into the future. Because of linear interpolation in emissions profile between 2015 and 2040, this scenario may slightly overestimate the deviation of concentration from BAU.

Trading Scenarios

Domestic Trading: Trading only within each country.

Annex I Trading: Permits are grandfathered to Annex I nations based on 1990 emissions levels. All Annex I countries participate in the trading of permits.

Price Assumptions

Carbon: U.S. permit prices for the four policy options are from SGM, which assumes that all revenues are returned to the economy through a lump-sum redistribution.

Consumption: Deviations are present discounted value of foregone consumption differences for United States in billions of dollars between BAU and scenarios. The present discounted value assumes a discount rate of 5% and a time horizon of 2000-2050.

5. Escape clauses and other flexibility provisions

In addition to the question of the stringency of targets and timetables, there are a number of other important determinants of the economic costs of a program encompassed in the term “flexibility”. The U.S. has proposed both “when flexibility” and “where flexibility.”

Examples of “when flexibility” are our proposals for targets that are multi-year averages, for multiple target periods, and for banking and borrowing. An example of “where flexibility” is international trading, especially with the participation of developing countries. All of these proposals could substantially reduce the cost of a given level of emissions, and are crucial elements of our ability to attain moderate targets, let alone more ambitious targets. Costs would be far higher without them.

Another possibility that has recently received attention in the inter-agency process is to add one or more escape clauses. The main idea is to safeguard against unexpectedly large economic costs of emissions reductions. These are costs that could turn out to be unexpectedly large if the economic growth rate turned out higher than expected, or if unrealistic estimates regarding the ease of reducing emissions were built into treaty targets. One possible escape clause would focus on the price of energy per ton of carbon.

Nordhaus (1997) and McKibbin and Wilcoxon (1997) have proposed plans under which there is a cap on how much the price of carbon can rise. The proposal is that above a certain level, governments (or perhaps a supranational authority) could make available an indefinite quantity of emission permits at the predetermined price. While the academic proposals tend to call for common policies and measures to be negotiated worldwide, the idea could usefully be integrated into the U.S. proposal for targets and timetables regarding emission quantities, in the form of a conditional escape clause. The effect would be to convert the quantity limit into a price instrument under circumstances when the burden would otherwise be too burdensome.

Escape clauses could also serve other purposes as well. Possibilities include:

- An escape clause that would be triggered in the future if continued **scientific research** determined that the dangers from GHG concentrations and climate change were much less than previously feared. Presumably the treaty would be renegotiated in such a case anyway. But the arguments for putting this language in now are three: (1) to facilitate the change, should this come to pass, (2) so that we don't look foolish in the eyes of history if this should come to pass, and most importantly, (3) to help allay the fears of today's skeptics.
- An escape clause that would be triggered in the future if **developing country accession** turned out to be less than we expect after Kyoto.
- An escape clause that would be triggered by other Annex I countries' **failure to abide** by their commitments.

Each of these proposals, might be useful in avoiding economic costs that otherwise might be incurred needlessly.

6. Conclusions and Summary

[SEE EXECUTIVE SUMMARY AT THE BEGINNING]

Appendix I: Integrated Assessment Models (M. Toman)

Integrated Assessment (IA) analyses try to bring together assessments of the physical, ecological, economic, and social impacts of climate change with assessments of policies for responding to climate change and their socioeconomic consequences. Generally speaking, the models can be described schematically as linking economic decisions in the energy (and agriculture) sectors that give rise to GHG emissions (and changes in carbon sequestration), models of atmospheric composition, climatic change, and changes in oceans, and models that describe the potential impacts of climate change on health, natural resources, coastal areas, and other factors of socioeconomic interest. Different components of various IA frameworks are represented in differing degrees of detail and sophistication. A few models contain the capacity to be used for a benefit-cost analysis, in which it is possible to evaluate changes in the long-term path of GHG emissions that maximizes the net benefits of GHG control (these benefits are the avoided damages of climate change less the costs of control). A larger number of IA models can evaluate the benefits and costs of specified policies but are unable to indicate what emissions reductions maximize net benefits. IA frameworks are inherently more “top-down” in their characterization of economic decisionmaking, though some models contain a fair amount of energy sector detail.

A very striking feature of IA models is that they tend to indicate the desirability – from the perspective of maximizing net benefits over time -- of emissions continuing to rise well into the next century, if not beyond. (For a recent comparison of IA model results, see Manne 1996.) By 2100, the models indicate only small deviations downward from a business as usual (BAU) path (see also IPCC 1996b, Chapter 10). In some cases the emissions do stabilize toward the middle of the next century, but in other cases they continue rising (though more slowly than with business as usual) even beyond 2100. These emissions paths clearly imply increases in atmospheric concentrations of GHGs well beyond the kinds of targets that have been considered in current policy debates (e.g., 550 ppm). One important consequence is that the models indicate costs of near-term emissions stabilization well in excess of the avoided damage costs.

As noted in the text, a number of criticisms have been levelled at these IA results. These criticisms include:

Failure to consider the possibility of unlikely but catastrophic events that could result from climate change (e.g., catastrophic sea level rise from melting of the Antarctic ice sheet, runaway global warming from frozen methane releases, or relocation of the Gulf Stream – see IPCC 1996a, Chapter ____).

Failure to give adequate consideration to the scale of potential damages, even in the absence of catastrophe. Cline (1992), for example, argues that damages are much higher than is incorporated in most IA models (see also IPCC 1996a, Chapter 6 for various estimates). One specific concern that has been raised is that the IA models do not account adequately for the costs of a less stable climatic and ecological systems in the face of GHG accumulations.

Failure to consider the adverse consequences of less aggressive abatement policies for future generations – in the context of IA models themselves, the criticism is that discounting of future generations' well-being is excessive. Cline (1992) also raises this concern, as does Howarth (199__).

Failure to consider how uncertainty about all these effects affects the “optimal” decision (Pizer 1997).

Failure to consider how lack of early action will jeopardize the achievement of any longer-term mitigation by signalling a lack of political will ([NEED CITE]), or how lack of early action will retard induced technical progress that is needed to make mitigation affordable (Grubb 1995).

Sensitivity analyses carried out with IA models suggest that at least some of these criticisms are not major concerns; others may be serious concerns, but empirical judgments are not possible given the current state of knowledge. The Manne (1996) survey referred to above considered scenarios in which the climate's sensitivity to accumulating GHGs was greater than is typically assumed, or the damages are larger (by a factor of almost 8) for a given change in the atmosphere. In either case emissions should (from the perspective of maximizing net benefits) be lower, but the extra degree of emissions reductions required by 2010 is significant (on the order of 25 percent or more) only if climate damages are much higher than expected (the sensitivity of the atmosphere to GHG emissions seems much less important in these analyses). And even in this case, emissions still will be higher than 1990 levels unless the atmosphere and the ecological-economic systems both are quite sensitive. (Broadly similar conclusions follow if, instead of looking at higher damages, one looked at damages that grew proportionately faster as atmospheric GHG concentrations grew [CETA cite]). Thus, the IA models give little support for a policy of near-term emissions stabilization unless damages turn out to be much higher than at least some experts expect.

As noted, one of the criticisms of many integrated assessments (IAs) is that they do not incorporate the possibility of catastrophe. Recent extensions of

the IA literature include the possibility of a major, discontinuous jump in the damages caused by climate change. For example, a European paper by Gjerde et al (1997) incorporates the risk that climate change will suddenly cause damages equal to a significant share of global GDP. The risk is assumed to rise with an increase in temperature from global warming; following Nordhaus (1994b), the benchmark risk scenario assumes a 12% chance of a loss equal to 25% of GDP (the scale of the great depression) in 2090 if climate has warmed by 3 degrees C. Incorporating this risk into the IA framework causes the optimal path for global emissions to be reduced, but not by that much in the early years. By 2060, optimal emissions are only somewhat over half what they would have been without the risk of catastrophe, but the reduction by 2020 is on the order of 15% below the no-catastrophe case and still above emissions in 1990.¹³ Even sharper emissions reductions are implied if the catastrophe is truly shattering (on the order of the entire GDP), or if the discount rate is extremely low (high intergenerational egalitarianism.)

It is also true that the results of IA models are sensitive to the choice of discount rate used to compare consumption today and in the future. A very low discount rate will imply greater weight on damages accruing over time to future generations, and thus the need for a more aggressive abatement strategy. This tradeoff is influenced by the rate of economic growth, since growth will make future generations better off and thus better able to afford and respond to the damages of climate change (Schelling 1995). However, there are numerous economic and ethical controversies surrounding the appropriate way to discount future damages in IA models, and no clear consensus has emerged. One important point that is often ignored in this debate is how much *today's* generation is willing to sacrifice to provide for the increased protection of future generations through GHG abatement; this is a critical unknown since it is today's generation that must necessarily decide to pay the bill. All that can be said analytically, therefore, is that intergenerational equity *might* be an argument for more aggressive abatement.

Uncertainty about future damages or other influences on the costs and benefits of abatement can make a difference. However, Pizer's (1997) analysis suggests that the most important source of uncertainty concerns the nature of our preferences for consumption and environmental protection. (Unlike the Manne (1996) analysis, Pizer considers the possibility that damages may be lower as well as larger.) A recent paper by Gjerde et al (1997) considers the risk of a sudden loss of economic output and well-being on the scale of the Great Depression from climate change. While their analysis indicates more aggressive abatement than other IA analyses without this risk, the introduction of the

¹³ The no-catastrophe optimal path is substantially below BAU in this analysis, an artifact of the assumptions of low abatement cost and high damage cost.

risk has little relative effect on the desirable level of emissions reduction by 2010, and little effect for a number of years thereafter (unless the loss is much larger even than the Depression).

This leaves the issues of political credibility and induced technical change. As for the latter, it is true that sending a less strong signal to energy markets will slow up technical progress. However, there is great uncertainty about how much of a loss this would be in practice, and the loss would have to be greater than most models seem to indicate before the substantial costs of near-term stabilization could be justified. This does *not* mean, however, that *no* actions are justified on cost-benefit grounds to reduce emissions or stimulate technical progress. Aside from initial steps to curb emissions growth, which signal the need for technical change, longer-term measures to promote the development of new technology are warranted. Political credibility is a more complicated issue.

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Targets and Timetables

The Framework Convention on Climate Change signed at the 1992 earth summit in Rio de Janeiro called for carbon dioxide emissions in 2000 at 1990 levels. Given the likely failure of most countries, including the United States, to achieve these emission reductions, most quantitative proposals that have been advanced in the runup to Kyoto focus on variants of the target and timetable agreed to at Rio. Such proposals thus represent the deferred fulfillment of a previously negotiated goal. Consequently, a proposal to "stabilize CO₂ emissions at 1990 levels by 2010" (and variants thereof, including a more stringent proposal by the EU to stabilize at 10% below 1990 levels by 2010) has received considerable attention.

This memo provides a preliminary evaluation of the likely economic consequences for the United States of a program to attain 1990 CO₂ emissions levels by 2010. It compares the costs and benefits of this baseline proposal with those associated with alternative targets and timetables that entail a less rapid initial reduction in CO₂ emission levels. The conclusions described here rely on the substantial body of economic analysis that has been conducted by researchers worldwide, including the Intergovernmental Panel on Climate Change (IPCC), and Administration economists.

Summary of Conclusions:

- **The economic consequences of a "1990 by 2010" program:** A program to attain 1990 greenhouse gas emission levels by 2010 *through domestic emissions reductions alone* entails a reduction in CO₂ emissions of about 29% relative to projected 2010 emissions in the absence of policy intervention.
 - To meet a timetable of 1990 emissions by 2010 it would likely be necessary to replace prematurely a significant fraction of the existing capital stock, and especially of coal-fired power plants. Premature obsolescence represents a significant cost of such a program. Moreover, early replacement of plants entails the use of currently available technologies rather than the new technologies that are likely to be developed in response to the incentives of the program.
 - The implied increase in the price of energy needed to reach 1990 emissions levels by 2010 would entail a significant inflationary shock with an associated rise in the CPI and decline in real wages, as in the oil shocks of the 1970s. Unless effective measures can be designed to offset the impact of the energy price hikes on labor's real income, it is likely that efforts by workers to recoup lost income and by the Federal Reserve to restrain inflation could cause a period of significantly higher unemployment.
- **The timing of emissions reductions in a cost-effective program.** A cost effective program to stabilize atmospheric concentrations of greenhouse gases entails emissions

reductions on a far less aggressive timetable than the "1990 by 2010" program. The "1990 by 2010" program is *inefficient* in the sense that it imposes burdens well in excess of those required to achieve the Framework Convention's ultimate goal, which is to "achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

- For example, a timetable designed to ultimately stabilize atmospheric concentrations at 550 ppmv whereby OECD emissions would *peak* by 2020, reach 1990 levels by 2030, and continue to decline even further is estimated to result in costs that are only one tenth to one third those of a program that attains the same goal along a path in which domestic emissions reach 1990 levels by 2010.
- Cost effective emission reductions strategies normally involve an initial phase in which actual emissions approximate the baseline or business-as-usual (BAU) path. (That period is longer the higher the ultimate concentration goal.) This more extended timetable for emissions reductions mitigates the costs associated with premature capital stock obsolescence and provides time for research and development to yield new, superior energy-savings technologies and low cost fossil-fuel substitutes. In addition, postponed costs are lower costs because, with a positive return on investment, fewer resources need to be set aside today to meet future costs.
- Cost-effective emissions strategies often entail serious policy actions from the outset. Although such strategies could be criticized as initially unaggressive from the standpoint of emissions, they need not be initially unaggressive from the standpoint of policy. In order to create appropriate incentives for emission reductions over time and the development and adoption of appropriate technologies, the price of carbon emissions must be increased at the outset of such a program. Gradual emissions price increases are also necessary over time. In comparison with the "1990 by 2010" program, however, the initial carbon emissions prices is apt to be substantially lower.
- The incremental benefit, measured in terms of average global temperature change, of an aggressive program to stabilize emissions at 1990 levels by 2010 is tiny in comparison with a program that approaches the same target more gradually. The difference in world temperatures is about .03 degrees Celsius.
- **International trading.** The carbon price increases required for the United States to attain any agreed upon target and timetable, along with the overall economic cost, would be substantially reduced through effective international emissions trading programs. The satisfaction of treaty obligations in this way would result, however, in substantial international transfers.

- From a worldwide standpoint, a cost-efficient program to reduce GHG emissions would implement abatement programs in those countries and sectors where they can be accomplished at least cost. As in the EPA's acid rain "cap and trade" system, high cost emitters could pay lower cost emitters to fulfill their own obligations. It is expected that developing countries that are rapidly increasing their capital stocks, especially for generation of electricity, can be induced to use low-carbon techniques at far lower expense than would be entailed by the replacement of current US capital stock by new capital stocks with low-carbon emissions. Among Annex I countries, the former Soviet Union and other Eastern European countries are thought to be high cost emitters.
- According to the results of the Administration modeling team, trading among Annex I countries would reduce the implied carbon permit price needed to achieve "1990 by 2010" by about 50%; and fully effective joint implementation with Non Annex I countries could lower the "price" by a further 50%.

1990 by 2010: The Scope of the Task

To appreciate the ambitiousness of a program to curb U.S. emissions levels to 1990 by 2010 it is necessary to recognize that such a target involves a cutback of about 29 percent in energy use in 2010 relative to baseline. Carbon emissions are now 12 percent above 1990 levels. Real growth in the economy over the next decade would further raise carbon emissions. Even under an optimistic assumption concerning the pace of improvement of energy efficiency (.9 percent per year) under constant relative energy prices, there would be further increases in carbon emissions by 2010 of 17 percent if we continue business as usual. The net required reductions to meet for 1990 emissions in 2010 would be 29 percent. Figure 1 shows the aggregate use of energy in the US economy and the price of energy relative to aggregate prices over the period 1970 to 1990. It shows that energy use was almost constant over the oil-shock period, 1972 to 1984, while the relative energy price index increased by more than 150 percent.

Cutbacks in energy use (relative to GDP) of this magnitude are at least comparable and arguably greater than those achieved in the decade of the two oil shocks--a period in which aggregate energy prices more than doubled. Between 1972 and 1982 energy use was essentially unchanged in absolute terms while GDP grew in real terms at about 2 percent per year. So we would need to accomplish a larger reduction in energy use than we witnessed over a decade in which energy prices more than doubled. The experience of the oil shock period suggests that the responsiveness of energy use to changes in the price of energy over periods as short as a decade are quite low--the elasticity is no higher than 0.2. (With a price elasticity of demand of, say, 0.2 over a decade, energy prices would have to rise by around 140 percent.) Figure 1 shows the aggregate use of energy in the US economy and the price of energy relative to aggregate prices over the period 1970 to 1990. It shows that energy use was almost constant over the oil-shock period, 1972 to 1984, while the relative energy price index increased by more than 150 percent.

The kind of logic just outlined is what is embodied in greater detail in the various models that have been used to assess the impact of the 1990 by 2010 plan. Those models differ a bit about the response of carbon emissions to price changes and technological trends, but a broad range of models place the carbon permit price in the range of \$80 and \$140 per ton with a gas price hike between 18¢ and 36¢ and a coal price increase between 150 percent and 300 percent. Relative to the BTU tax proposed by the Administration in 1993 this is 8 to 24 times as large. As these numbers suggest, an intervention of very large magnitude in the economy is required with substantial negative economic consequences. The typical family's spending on energy would rise by about \$1000 per year.

Why are the costs of early emissions reductions so high?

The previous section argued that large costs would be involved in meeting a "1990 by 2010" target. This section shows that the 1990 by 2010 program is actually so aggressive as to be inefficient-- in the sense of raising substantially the total projected cost of reaching a given environmental goal. Economists have tried to demonstrate this point by looking at how the total

costs of achieving a fixed environmental goal vary with the aggressiveness of the initial reductions. There are five reasons why a slower takeoff in curtailing emissions reduces overall costs: (1) it allows time for the capital stock to turn over, (2) it reduces short-term macroeconomic shock, (3) it provides more lead time to develop and implement new technologies, (4) it allows for the resolution of uncertainty, (5) it makes use of the time-value of money (resources not spent on emission reductions early on can be invested at a positive return which could purchase more emission reductions later).

The role of turnover of the capital stock. The most clear cut and easily quantifiable reason for the high price tag associated with rapid emissions reductions relates to the need for premature replacement of plant and equipment in response to large increases in the price of carbon emissions. A longer window in which to reduce carbon emissions would allow time for the capital stock to turn over. It would be very expensive to scrap the entire capital stock, to replace it with more carbon-free plant and equipment, while it is still in the prime of its useful life. But 20 to 40 years out into the future, much of our existing plant and equipment will be ready for replacement anyway, whether because the plant and equipment have depreciated gradually or because they have more suddenly come to the end of their useful life.

The intuition behind the large costs of very rapid reductions in carbon emissions can be illustrated by considering reductions in electrical power generation. The case of electrical generation is important in its own right since electrical generation is responsible for more than one third of all energy consumption in the United States, but the same principles apply universally to all other uses of energy. As reduced energy use in electrical generation entails the accelerated scrapping of power plants, reduced energy in residences entails the accelerated retrofitting of housing, in transportation the premature scrapping of vehicles, and in energy-intensive industry the premature scrapping of plant and equipment.

Figure 2 shows the effects of an accelerated replacement schedule for all of the 7,900 electric power plants built during the last 50 years. Imagine, to take an extreme case, that all power plants had to be shut down within ten years (by 2007), and replaced with less-polluting technology. This would imply replacing 6,330 plants before the end of their normal lifespan, or 80 per cent of the total. Now imagine that all power plants had to be replaced in 20 years. This would constitute an accelerated replacement of 4,600 plants, or 58 per cent of the total. If one could wait 30 years, the complete replacement would mean an accelerated replacement of 2,000 plants, 26 per cent of the total. If one waited fifty years, under the stylized assumption of a 50-year life there would be no additional cost to replacing them.^{1,2}

¹ The distribution has been truncated at 50 years, the average lifespan of existing electric power plants. A few plants are still in use 60, 70, or even 90 years after they were built.

² The same exercise can be done for coal-fired power plants. This is the class of generators that produce the most carbon and that would thus have to be replaced even under a moderate plan to address climate change. If a complete change-over of coal plants were to be

This exercise is not intended to provide an estimate of the costs of different time-tables, even within this one sector. Rather, it illustrates concretely the importance of allowing time for the capital stock to turn over.

Analogy with the oil shocks of the 1970s. From a macroeconomic perspective, an energy price increase is a supply shock and a shock of this magnitude constitutes a substantial stagflationary shock. Its impact will be to raise inflation, to lower real wages and to raise unemployment, as in the period following the two oil shocks. Unemployment in the four years after the first oil shock averaged 7.2 percent in comparison to 5.0 percent in the four years prior and unemployment rose further to an average of 8.7 percent in the four-year aftermath of the second. There remains debate about how much of this was due directly to the oil shock, because there was a simultaneous decline in productivity growth and transfers of real income to OPEC producers. Nevertheless, we should expect that the efforts of the Federal Reserve to contain inflation, coupled with likely efforts on the part of workers to recoup real wage losses will lead to a period of higher unemployment.

Furthermore, it is important to note that most of the estimates of the costs of large changes in energy prices--such as by large-scale long-term models--assume that resources are fully employed. These models therefore make no assessment of the consequent increases in unemployment.

Technology. Another important reason for a fairly slow short-term but an aggressive medium-term policy for curbing greenhouse gases is that it will take considerable time before emerging carbon-free or carbon-lean technologies are developed. In many cases it is useful to wait until the new technologies are available before making expensive emissions-saving investments.

The readiness of technology to ease abatement is one area where your advisers appear to be in sharpest disagreement. In fact this disagreement is less than meets the eye, but a misunderstanding as to its resolution could result in errors in judgment, particularly regarding what constitutes a realistic timetable for emissions abatement.

A report by five federal laboratories has catalogued emissions-savings technologies that are currently cost effective and that, if put in place now, could save as much as 30 to 50 percent

accomplished in 10 years, 799 of the 1,122 coal-fired plants (71 per cent) would have to be replaced before the end of their expected lifespan. If replacement occurs over 20 years, 488 plants would be affected, or 43 percent of the total. If one could wait 30 years, 227 plants would be closed prematurely, or 20 per cent of the total. Figure 2b repeats the exercise on the basis of coal plant capacity. Since newer plants tend to have larger capacity, the effects of a rapid replacement schedule are magnified. Closing all plants within 10 years implies that 289 million KW of capacity would be prematurely shut down, or 90 per cent of the total. If one could wait 20 years, 235 million KW of capacity would be affected, or 73 per cent. For 30 years, the capacity that would have to be replaced falls to 116 million KW, or 36 per cent of the total.

of US energy. They view this finding as reason for optimism. Your economic advisers, however, have a different perspective. While they also believe that there are many unused technological opportunities for emissions saving, they inquire why these opportunities remain idle. There may be subtle disadvantages of many of these technologies--for example significant energy and cost savings would result from the residential replacement of incandescent lights by fluorescent, but consumers dislike the difference in color of the light. In addition, even if the product were exactly the same, as well as less expensive, there still could be considerable inertia in its adoption. It may take time, or an added incentive for people to do what is good for them. Therefore rather than stressing the availability of alternative technologies, your economic advisers stress the necessity of economic incentives in terms of a higher implicit price of carbon to induce the use of these emissions saving devices. The scientists are probably not in disagreement about this point; for example even the optimistic five labs study projected an increase of \$50 in the implicit price of carbon would be needed to induce the use of these existing technologies. The major difference between these two groups lies in their focus: the mission of scientists is to provide the appropriate technologies, while the narrower mission of economists is to see that incentives are sufficient that those technologies will be developed as needed and also put into use. Thus the scientific reports mainly *emphasize* the availability of the technologies while the economic studies *emphasize* the responsiveness to changes in price.

Indeed your economic advisers see the role of a strong price signal in solving the problem of CO₂ emissions as central. They note that the economics of carbon emission, and of the development of lean carbon technologies is very different from the economics of the use or the technological development of a standard consumption commodity. The emission of CO₂ is a classic externality, since no individual has any economic incentive to use lean-carbon or carbon-free sources of energy. The global-warming costs of carbon emission have (almost) no effect on the individual user of a fossil fuel since the damage done by current carbon emissions are global, and for the most part will occur in the next century. In the absence of any price incentive such as a tax on the use of fossil fuels, because no individual stands to gain by curbing her emissions, there is no market-incentive for saving on current carbon emissions, and, further, there is even less incentive for the development of carbon-saving technologies which no one has an incentive to buy. The solution to curbing carbon emissions relative to baseline, and also to induce private research and development, involves changing the incentive structure to encourage reductions in emissions and also in the development of carbon-saving technologies.

~~There is considerable disagreement among your advisers about the emissions-saving investments that will be undertaken in the absence of price increases. Some of your advisers believe that there are significant energy saving (and therefore emissions saving) investments that can be undertaken with very high current returns, and that these investments will be undertaken even in the absence of any significant increase in the implicit price of carbon emission. How much can we reasonably expect of technological advances without the spur of a sharp price increase? Your economic advisers tend to stress the importance of market incentives for technological advances: they argue that technology will clearly be one of the conduits for meeting an emissions reduction target, but that significant energy price increases are necessary to induce the requisite technological~~

advances. They believe that emissions reductions with existing technologies will require significant price increases. They estimate quite a low price elasticity of demand for energy and therefore find it hard to believe that significant energy reductions beyond the long-term historical trend of 0.5 to 1.0 percent per year will be forthcoming in the absence of very large cost savings. As one indication of the reasons for such pessimism, the relatively small differences in energy use per dollar of GDP in the US and Europe despite the very large differences in energy prices suggests a *long run* elasticity of demand for energy that is fairly low. The *short run* elasticity will be an order of magnitude lower.

— Others believe that even without an increase in the price of energy, there are numerous opportunities for energy-saving technologies to be developed and applied. For example, a study conducted by five of the Department of Energy's national laboratories concluded that even without an increase in the price of carbon, "cost-effective energy efficiency alone can take the nation 30 to 50% of the way to 1990 levels" by 2010. The report, however, simply *assumes* the existence of government programs that would develop and disseminate pollution-reducing technologies—without explicitly examining the costs of such programs. It is thus a concise summary of the *potential* for increased efficiency without any increase in price, but provides little insight into how costly it would be to achieve (e.g., through government programs to spur technological advances) those potential reductions.

— The degree of disagreement should not, however, be exaggerated. Even the study mentioned above—which is considered extremely optimistic about the role of technology—concludes that it is not possible to reach a target of 1990 emissions levels by 2010 without a \$50 per ton increase in the price of carbon. As already discussed, this increase in price is roughly consistent—depending on whether international trading is allowed—with what economists believe is necessary to achieve the same goal. In summary, despite ongoing debates about the incentives needed to trigger the use and development of emissions-saving technology there is no debate that *a significant price signal is crucial to achieving emissions reductions* of the sort being considered in international fora. It is impossible to achieve 1990 emissions levels by 2010 without an increase in carbon prices substantial enough for people to notice. All your advisers are in further agreement that there is a great need for an increase in funds for research and development of emissions-saving technologies.

Quantifying the Costs of Slow versus Fast Take-off

The relative costs of slow versus fast takeoff in curbing CO₂ can also be analyzed by large-scale long-term energy models. All such models must make many approximations to describe the energy sector globally and for more than a century in scope. Therefore it is useful to interpret the results of the models qualitatively, not quantitatively, and also to view the outcomes of the simulations as giving a range of estimates rather than any single number. To enable such comparison of results, the Stanford Energy Modeling Forum ran different models with common benchmark assumptions. The Energy Modeling Forum ran alternative models with common

assumptions about benchmark parameters in describing the technology, resource availability, and the rate of discount. They compared the cost of two different paths for reducing carbon emissions from Business as Usual to an eventual stabilization of atmospheric CO₂ at double the pre industrial level--550 ppmv. The first of these paths was first suggested by the Working Group 1 of the Intergovernmental Panel on Climate Change, who proposed a set of paths that would stabilize atmospheric carbon at different levels in the year 2100; all of the Working Group 1 paths have quite early take-off in emission abatement. For example, on the 550-ppmv stabilization path reductions in OECD carbon emissions were 25 percent below Business as Usual in 2010. In contrast, Wigle, Reilly and Edmonds have suggested an alternative set of emission paths for reaching the corresponding long-term goal of stabilizing atmospheric carbon at different levels in 2100. They argued that their paths, with attenuated reductions in emissions, would have much lower costs than the original Working Group 1 paths. The appropriate economic measure of losses is the discounted value of losses in future consumption relative to Business as Usual.

Tables 1 and 2 show two robust conclusions from comparison of the fast take-off Working Group 1 (WG 1) 550-stabilization path and its Wigle-Reilly-Edmonds path (WRE) counterpart. Fast takeoff in emission reduction greatly increases the costs. A viable system of international permit trading would very much reduce costs. Table 1 shows the discounted value of consumption loss for the two paths--both with and without international trading of permits. In 11 out of 12 simulations--for six different models with and without permit trading--the costs on the slow-takeoff WRE path is less than a third of the cost on the corresponding fast take-off path. The average ratio of relative costs for the 12 comparisons was less than .3. Table 2 presents a permutation of the same cost estimates in order to assess the benefits from international permit trading. With one exception, all the ratios--of costs with permit trading relative to costs without--are considerably less than one; two thirds of the ratios are less than one half. The average ratio for the twelve simulation outcomes is .41.

For interpretation of the absolute level of the costs, it is important to note that these calculations assume the full utilization of resources and do not at all assess the costs from lost output and employment of such large changes in energy prices. Any losses resulting from less than a full utilization of resources must be added to obtain the full cost of emissions abatement. These qualifications notwithstanding, abatement costs are acutely sensitive in these simulations to the rate at which abatement begins.

It is also important to note what is probably the most important assumption in these simulation exercises--the assumption about the targets and timetables for developing countries. **Source: Manne and Richels. Contradicted by Holdren in Talk.** By the end of the next century--by 2100-- on the Business as Usual path--non Annex 1 countries will have more than 90 percent of CO₂ emissions. Developing country participation is absolutely necessary to any stabilization scheme. **CHECK: In the Energy Model Forum simulations developing countries follow business as usual until 2030. After 2050 they conform to emission target that are allocated globally on a per capita basis. Between 2030 and 2050 they are adjusting to these per capita targets.**

Timetable of Least-Cost and Low-Cost Paths

If reaching 1990 emissions by 2010 is unnecessarily costly, what paths of emission targets will be relatively efficient? What will those paths look like? Do they peak early? Do they peak late? Are they close or far from attaining 1990 by 2010 emissions?

The WRE paths give some indication of the nature of low-cost emissions paths. In contrast with the WG 1 paths, for some period of time they continue to have rising emissions, in the beginning departing relatively little from business as usual. The comparison is made in Figure 3, which plots the OECD WG 1 and the WRE emission paths for different levels of stabilization of atmospheric carbon concentrations. The OECD emissions path with 550 ppmv stabilization, and international permit trading, for example, peaks @@@ years after the implementation of an abatement program, returns to approximate parity with the initial levels @@@ years later, and then descends considerably more rapidly than the Working Group 1 paths. This gives some approximation of what a low-cost abatement path should look like.

Since neither the WG 1 nor the WRE paths are optimal--the WRE paths being only conjectured preferable alternatives--it is envisage an optimal target path would look like. Manne and Richels have computed the least cost path with 550-stabilization in 2100. Such paths are similar to WRE, but not quite the same. Figure 4 demonstrates the shape of the least cost paths and also allows comparison with the WG 1 paths at different levels of stabilization in 2100. The Manne-Richels least-cost path would peak between 2020 and 2030 and then gradually decline. Reaching 1990 emissions so comparatively late does not involve doing nothing now. On the contrary because of projected trend growth in GNP, it entails departing from Business as Usual at an accelerating rate. In order to attain these emissions levels it will return to 1990 emissions only after 2050. Meeting such targets does not imply doing nothing. For example on the 500ppmv stabilization path the implicit price of carbon should increase by \$@@@ @@@ years after implementation.

Benefits of slow versus fast takeoff

While the excess cost of fast takeoff compared to gradual takeoff in the restriction of carbon emissions has been projected to be large, the differences in projected global temperatures between the fast and the slow paths are, in fact, quite small--small both in absolute amount and relative to temperature changes expected from global warming. **CHECK: While global warming is expected to increase by 1.15 degrees Celsius by 2050 and 2.45 degrees Celsius by 2100 with business as usual, the differences in temperature between the WG 1 path and low cost paths--either WRE or the least-cost path--is uniformly less than .05 degrees.**

The limited climatological impact of even an extremely aggressive emissions reductions program measured in terms of temperature impacts during the next century results from extremely long lags involved in the underlying physical processes, and the dependence of temperature on the

total stock of carbon dioxide in the atmosphere, rather than the flow of emissions at a given time. Emissions reductions do matter to temperature, but over an extremely long horizon. The cumulative nature of the process points to a payoff from early action, but also suggests that there is little effect on global temperature from a slow rather than from a fast abatement takeoff. The addition to the total stock of carbon from a slow rather than from a fast start to abatement contributes a very small relative addition to total atmospheric CO₂ between now and 2100 for four separate reasons: the difference in carbon emissions between a slow and a fast start over the initial decades of abatement is only a small fraction of total emissions in that period; the stock of CO₂ in the atmosphere is itself the result of many decades of emissions; some of the CO₂ emissions of the early decades will have been re-absorbed; and the most serious build-up in CO₂ under Business as Usual occurs late in the next century, at that time being mainly the result of emissions from newly developed non-Annex I countries so that Annex I emissions will not dominate that build-up.

Other Considerations and Their Effects on the Timetable

Even the presence of major factors that have not been explicitly considered in our analysis, will not affect the basic trade-offs between the high costs of fast vs slow takeoff. These factors do however add, perhaps greatly, to the urgency of moderate long-term targets for greenhouse gases. They include:

- The possibility of a discontinuously-large catastrophe, such as the melting of the West Antarctic ice sheet, a runaway greenhouse effect (e.g., from release of trapped methane with the melting of the permafrost), or structural changes in ocean currents such as the Gulf Stream.
- The considerable uncertainty about parameter values in three dimensions: relative to economic effects, climate effects, and the discount rate. the two.

On the other hand, our analysis of the economic costs and benefits of a fast vs a slow takeoff does not take account of the effects of a fast takeoff on our ability to lock in other governments, especially from developing countries, into long-term agreements about future emissions.

International Trading of Permits

As has already been seen, the costs of limiting carbon emissions depends upon whether or not there is international trading of emission permits. Allowing emissions sources to contract with each other to implement required emissions reductions can substantially reduce the costs of achieving any over-all abatement target. With a system in which permits can be purchased or sold, either domestically or internationally, a facility that could reduce emissions at great cost can compensate another facility with expensive abatement to make the cuts for it. For example international joint implementation of CO₂ emission reductions would allow a utility in the United States to be credited with an emissions reduction if a corresponding factory in a foreign country

installed more fuel efficient furnaces. Since CO_2 has the same effect on climate wherever it is released, finding the lowest-cost abatement possibilities is cost-effective. Making such trades voluntary would insure both parties to the transaction gain from it.

An international plan for the eventual stabilization of atmospheric carbon eventually must entail limiting emissions from developing countries. The projected growth of these countries is greater than that of Annex I countries (OECD plus the former Soviet Bloc) and in addition these countries have much greater population and population growth than Annex 1. The IPCC IS92a Business-as-Usual scenario projects that these countries will produce more than 90 percent of world carbon emissions in 2100. The common assumption of the low cost paths was that non-Annex 1 countries will agree now to a target for emissions. This target will be Business as Usual until 2030, at which point countries must begin to limit their emissions, with a transition to equal per capita emission rights by 2050. It is important that developing countries agree now to future emissions abatement.

While the effectiveness of carbon emissions targets is extremely dependent on eventual developing country participation in an agreement to limit their own emissions, such agreement will have virtually no effect on the current cost to Annex I countries of current carbon abatement schemes. To consider the possibility that developing countries might decline to participate, or decide to participate only to a lesser degree than the least cost burden-sharing formula, we ask what would be the effects of developing countries nonparticipation on the economic costs of emission abatement to Annex 1 countries. **JLY has different number.** The increased discounted cost according to Manne and Richels would be \$25 billion. [This is the WRE path? Or the least-cost path?] Even this estimate is an upper bound since the model fails to take account of the migration of energy intensive industries to developing countries with no carbon taxes. Of course such trade effects will also make the abatement program correspondingly less effective.

While a system of international joint implementation of carbon abatement has considerable promise in reducing costs, there may be severe difficulties in establishing an effective system. Consider the example in which a utility in the United States purchased an emissions permit from a factory in a foreign country. This purchase will have an effect only if the sellers of the permit abate emissions that they would not do in the absence of their sale of the permit. It is easy to imagine that there are many jurisdictions in which it will be difficult to enforce such reductions. It is precisely in such jurisdictions that it will be most advantageous for firms to sell permits. Even if feasible, it is likely to take considerable time to establish a system of international permit trading with adequate enforcement.

Recycling of Revenues

The cost of emission abatement depends upon the use of the revenues from carbon taxes.. If the revenues from the taxes levied are used to replace the most inefficient existing taxes there will be welfare gains that will offset microefficiency losses from energy curtailment. According to Jorgenson and Wilcoxon GNP would actually increase if the revenues were used to reduce taxes

on capital. Elsewhere Jorgenson and Yun have estimated the efficiency loss from an extra dollar of tax revenue at 38 cents. Nordhaus' simulations give carbon taxes of about \$5 when recirculation of revenues have no incentive effects. However if the revenues are used to replace other taxes with an efficiency loss of 50 cents, the growth rate of the optimal carbon tax is extraordinarily large and within 10 years of an abatement program the implicit price of carbon is almost \$60. The simple lesson is that the costs of emission abatement are greatly reduced if the revenues from the taxes levied can be put to good use.

So far we have approached the recycling of revenues from the standpoint of microeconomic efficiency. There is also the potential for using the revenues to prevent a macroeconomic shock. Conceivably revenues from the sale of emission permits or from taxes on the emission of CO₂ could be used to reduce the size of the macroeconomic shock. The oil shock is believed by many economists to have resulted in increased unemployment because workers saw their real wages fall as energy prices increased. Their increased wage demands added inflationary pressures to the economy that could only be suppressed with tightening of fiscal and/or monetary policy. Some would argue that the effects of the real wage shock could be diminished by reduced tax payments to offset workers' losses of real wages.

But there is also reason for pessimism regarding the potential success of such an attempt to allay the macroeconomic consequences of the rising energy costs by such recycling. An experiment of this sort was carried out in the late 1970's with no success. In 1979 Margaret Thatcher increased the VAT tax and simultaneously decreased the income tax. The two changes should have had offsetting effects on real incomes, and therefore might be expected to have had no effect on inflation. However, the increase in the VAT tax resulted in an immediately noticeable increase in the CPI. A wage-price spiral ensued as workers attempted to maintain their *pre-tax* real wages.

5. Escape clauses and other flexibility provisions

In addition to the question of the stringency of targets and timetables, there are a number of other important determinants of the economic costs of a program encompassed in the term "flexibility". The U.S. has proposed both "when flexibility" and "where flexibility."

Examples of "when flexibility" are our proposals for targets that are multi-year averages, for multiple target periods, and for banking and borrowing. An example of "where flexibility" is international trading, especially with the participation of developing countries. All of these proposals could substantially reduce the cost of a given level of emissions, and are crucial elements of our ability to attain moderate targets, let alone more ambitious targets. Costs would be far higher without them.

Another possibility that has recently received attention in the inter-agency process is to add one or more escape clauses. The main idea is to safeguard against unexpectedly large economic costs of emissions reductions. These are costs that could turn out to be unexpectedly large if the economic growth rate turned out higher than expected, or if unrealistic estimates

regarding the ease of reducing emissions were built into treaty targets. One possible escape clause would focus on the price of energy per ton of carbon.

Nordhaus and McKibbin and Wilcoxon have proposed plans under which there is a cap on how much the price of carbon can rise. According to the proposal, above a certain level, governments (or perhaps a supranational authority) could issue an indefinite quantity of emission permits at the predetermined price. While the academic proposals tend to call for common policies and measures to be negotiated worldwide, the idea could usefully be integrated into the U.S. proposal for targets and timetables regarding emission quantities, in the form of a conditional escape clause. The effect would be to convert the quantity limit into a price instrument under circumstances when the burden would otherwise be too burdensome.

Escape clauses could also serve other purposes as well. Possibilities include:

- An escape clause that would be triggered in the future if continued **scientific research** determined that the dangers from GHG concentrations and climate change were much less than previously feared. Presumably the treaty would be renegotiated in such a case anyway. But the arguments for putting this language in now are three: (1) to facilitate the change, should this come to pass, (2) so that we don't look foolish in the eyes of history if this should come to pass, and most importantly, (3) to help allay the fears of today's skeptics.
- An escape clause that would be triggered in the future if **developing country accession** turned out to be less than we expect after Kyoto.
- An escape clause that would be triggered by other Annex I countries' **failure to abide by** their commitments.

Each of these proposals, might be useful in avoiding economic costs that otherwise might be incurred needlessly.

GAA: my addition
An alternative Option

What might be a compromise position on abatement? A compromise solution might be the enactment of a significant tax on the use of carbon that would be rising over time. This would be a good faith effort of the United States to begin an abatement program. At the same time it would not have the large scale macroeconomic consequences that would be expected from a policy of 1990 by 2010.

The IAT (InterAgent Taskforce) report has estimated that with international permit trading the increase in the implicit price of carbon necessary to meet a goal of 1990 emissions by 2010 would be \$50 per ton of carbon. This estimate is likely to be optimistic

since the models used to obtain this estimate do not capture the short-term inertia in energy and emissions saving. Also if the system of international permit trading does not work ideally as assumed, the implicit price increase of carbon emissions must be correspondingly greater. Nevertheless this estimate could be used to justify a US position of an initial carbon tax of \$25 per ton beginning within a year of implementation of the treaty and increasing at the rate of 8 percent per year so as to reach \$50 in the year 2010. A \$25 initial permit price for emitting carbon would increase energy prices by 25 percent. It would increase the price of natural gas by @@@ percent; the price of a barrel of oil by \$5.50, and the price of gasoline by about 6 ¢ per gallon. The price of coal would be seriously affected. Coal would increase in price by @@@ percent. This could be defended as a serious attempt to begin a United States program of carbon abatement.

The macroeconomic cost of this program might be significant, but it would be much smaller than that of the combined oil shocks of the 1970's. CHECK: The two oil shocks involved an increase of 160 percent in the producer price index of energy. A \$25 tax would involve an increase of 25 per cent. Therefore the maximum negative impact of such a strategy would be 1/6 of the effect of the oil shock. In the ten years aftermath of the first oil shock, which are inclusive of the second oil shock and its aftermath, unemployment was 2.7 percentage points higher than pre-shock levels. If all of the increase was due to the oil shocks, the increase in unemployment from such a carbon tax of \$25 would be less than .5 percent. If 1/3 of the change was due to the oil shock and 2/3 due to simultaneous change in trend productivity, then the expected unemployment increase would be in the range of .1 to .2 percent. Some significant fraction of the revenues from the tax would have to be used to help displaced coal miners who will of necessity be very seriously affected by any effective abatement program. While any loss on employment is extremely regrettable, a trade-off may need to be made between employment opportunities on the one hand and climate change on the other. It is absolutely essential that the policies that the government is adopting should minimize the losses in employment for the given objective.

PLAN

Rev.

9/25/97

1. Targets and timetables: A moderate path

- begin to reduce emissions growth in the short term
(e.g., the emissions rise in 2000-2010 < the rise in 1990-2000)
- *eliminate emissions growth 10-20 years after treaty is ratified*
(e.g., in 2010-2020, so emissions at the end of the decade = emissions at the beginning))
- subsequently return emissions to 1990 levels (by a date to be set at a future Conference of the Parties; perhaps 2040 for modeling purposes)
- aim for a path to stabilize concentrations in the longest term (550ppmv for modeling purposes)

2. Require full "when and where flexibility"

- Require developing country participation
- Insist on flexibility provisions of current U.S. position:
 - international trading
 - multiple multi-year targets
 - banking and borrowing
- Add *escape clauses*
 - *Economic trigger*: If carbon price goes as high as a pre-determined P (set substantially above expected price necessary to achieve targets), national governments or a supra-national body will sell additional emission permits to keep price from rising above P.
 - *Science trigger*: If the scientific community (IPCC) should decide in the future that the risks are not what was feared, the treaty shall be re-negotiated.

3. Unilateral actions (in the event that negotiations break down?)

- U.S. adopts a small carbon tax of \$15-\$25/ton phased in over

199_-20__, with the proceeds fully recycled so as to reduce other taxes. (If a tax is ruled out politically, then could do auctioned permits as a second-best.)

- U.S. leads movement toward global ban on fossil fuel subsidies
- R&D/diffusion subsidies up to \$3 billion/yr.
- a sensible version of Joint Implementation, e.g., subsidize non-carbon energy sources in developing countries through the World Bank.

Talking Points on Climate Change Scenarios

Scenario 1:

The economic consequences of 1990 by 2010:

- The attempt to achieve 1990 emission levels by 2010 through reductions in U.S. emissions involves an extraordinarily large cutbacks in energy use. Carbon emissions would need to fall about 10% from present levels and around 25% from projected 2010 levels. Cutbacks in energy use of this magnitude are comparable to those achieved in the decade of the two oil shocks--a period in which aggregate energy prices roughly doubled. The 1990 by 2010 plan is thus likely to entail energy price increases that are comparable in magnitude. This is consistent with the various model results.

- A broad range of models place the carbon permit price required to achieve such a cutback in the range of \$70 and \$200 per ton with a gas price hike between 18 and 50¢ and a coal price increase between x and y %. Relative to the BTU tax proposed by the Administration in 1993 this is 8 to 24 times as large. As these numbers suggest, an intervention of very large magnitude in the economy is required with substantial negative economic consequences. The typical family's spending on energy would rise by about \$x per year.

From a macroeconomic perspective, an energy price increase is a supply shock and a shock of this magnitude constitutes a substantial stagflationary shock. Its impact will be to raise inflation, to lower real wages and to raise unemployment, as in the period following the two oil shocks. We should expect that the efforts of the Federal Reserve to contain inflation, coupled with likely efforts on the part of workers to recoup real wage losses will lead to a period of higher unemployment.

In order to realize carbon emission reductions of the magnitude required to meet this target, it would be necessary to reduce the use of coal by electric utilities and, over a short time span of a decade, this would entail premature obsolescence of a large number of plants. Coal plants typically have a useful life of around 50 years. It will be extremely expensive to scrap these plants before the end of their normal lifespan. However, in 20-40 years they will large be ready for replacement. (If we had to shut down all 1,122 coal fired plants by 2010, to take an extreme case, we would be replacing 88% of them before the end of their normal lifespan.) In addition, replacing them now means replacing them with currently available technologies rather than the superior technologies that would become available over time.

This last point suggests that such a rapid path toward emission reduction is inefficient--it is imposing an unnecessarily costly adjustment on the economy. In fact, as I will elaborate when we come to Scenario 2, this choice of time path is so inefficient in comparison with a path that allows the same adjustment to be accomplished over a longer time, that the

1995: 8.1%
1996: 11.9%

Europe BAU in
2010 3 only
18.9% above
1990

28.7%

320/140 >

19

23

Assuming
complete
pass thru,
no Δ in
consumption

assumes
same
quantity

85 nat gas
23 fuel oil
150 elec
13 LPG
243 gasoline
516

→ adjust
E/CO2
= 1.2%

→ 450

Indirect

70
12%

500

950

90% of capacity
71% of plants

overall cost of achieving a given environmental goal with such a rapid takeoff rises by a factor between 3 and 10.

Indeed, not only does this path impose unnecessary costs; it also results in no significant environmental gains relative to a path that allows emissions to be contained less rapidly, as in Scenario 2. Under business as usual, temperatures are expected to rise by about 2.36 degrees by 2100. Stabilization at 1990 levels beginning in 2010 would reduce the temperature rise to 2.16 degrees--a .20 degree Celsius payoff. In contrast a path that peaks in 2015 and returns to 1990 levels by 2040 has a payoff of 0.19 degrees. So the payoff to the extra speed is .01 degrees.

4. If the price of energy increases by the amount contemplated there will be serious sectoral effects--industries like coal and electric utilities as well as energy intensive industries and their workers would be quite seriously affected and there would also be significant regional effects.

5. Finally, there is the issue of carbon leakage. Even if the failure to include developing countries in the proposal does not lead U.S. firms to move operations abroad carbon emission reductions in the U.S. could be offset partially by increased emissions abroad through a number of channels including international shifts in the location of production (lower oil prices, less efficient production of goods abroad) Estimates range from 3.5% to 70%.

Impact of Annex I trading:

- Annex I trading--assuming that it can be effectively implemented (which is questionable unless all Annex I countries adopt tradeable permit systems)--would permit the United to satisfy a portion of its emission reduction requirements by purchasing permits from other countries that can reduce emissions at lower costs and are willing to sell us permits. As indicated in the handout, the permit price and other price impacts needed to satisfy 1990 by 2010 would be roughly halved.
- Such trading will result in substantial international transfers. It is likely that we would purchase permits from the FSU and Eastern European countries resulting in substantial international transfers--on the order of \$5 billion by 2010 according to IAT simulations.
- The choice of 1990 as a baseline for emissions reduction rather than a later year is inequitable for the United States vis a vis Europe because we are currently x% above 1990 level whereas Europe is y% above 1990 levels.

Scenario 2. Under Scenario 2 the U.S. would commit to eliminate emissions growth by ten years after the treaty is implemented. There would be a later negotiation to determine appropriate next steps including longer term emissions reductions. This plan could be achieved through an auction permit system or through a carbon tax.

- This plan could be achieved with an increase in the price of carbon emissions probably in the range of \$5-25 in 2010. The price increase would initially be small and would rise

over time. As indicated, gas prices would rise by on the order of 1-3 cents initially.

- The effect on families would be noticeable (\$50 per year from increased energy costs) but substantially less than under the first scenario.
- This plan sets a goal that can be obtained with a defensible and prudent level of intervention in the economy.
- This plan sacrifices nothing on the environmental front and results in enormous cost reductions relative to the first plan: Many environmentalists would argue that what ultimately matters to the environment is concentration levels and not emission levels--that to stabilize the temperature we ultimately have to stabilize the concentration of CO₂ in the atmosphere which could, depending on the ultimate concentration desired, entail emissions cutbacks below or even substantially below 1990 levels. Suppose that were our goal, and we tried to work back from that goal and ask what would be a cost-effective way of achieving that goal. What targets would we initially set for emissions to move us toward that goal in the most cost effective way. That issue has been studied. A large number of modelers have addressed it and what they find is that a path designed to minimize costs allows emissions to grow for a time before leveling them off and then ultimately lowering them further. The reasons are to avoid the premature obsolescence of the capital stock I mentioned earlier and to take advantage of new technologies that will become available over time. 1990 by 2010 is like trying to ask an ocean liner to change course abruptly. It is virtually impossible because it has too much momentum. It is capable of changing course, but it can't turn on a dime. As I mentioned, the total aggregate costs of achieving a given long term concentration with or without trading range, in most models, from 10% to 50% and come without any sacrifice of benefits with respect to ultimate temperature increase. To give a sense of magnitudes, a number of models place the cost to the OECD of stabilizing concentrations at 550 ppm along a path that begins by "1990 by 2010" at around 6 trillion dollars with no trade. (the present value of lost consumption) whereas a path that peaks in 2010 and declines gradually thereafter costs only 14% of that--\$.85 trillion.

this is WGI, not
1990-2010
2 pts on foregone consumption
1 + 3 are the same
2 is 1/3 of these

JA: please check. Source: Manne and Richels

① The Framework Convention on Climate Change signed at the 1992 earth summit in Rio de Janeiro called for carbon dioxide emissions in 2000 at 1990 levels.

Source: unknown JLY added this

Consequently, a proposal to "stabilize CO₂ emissions at 1990 levels by 2010" (and variants thereof, including a more stringent proposal by the EU to stabilize at 10% below 1990 levels by 2010) has received considerable attention

A & R: Source: see calculations below that were fact-checked in earlier JLY memo

✓ ② A program to attain 1990 greenhouse gas emission levels by 2010 *through domestic emissions reductions alone* entails a reduction in CO₂ emissions of about 29% relative to projected 2010 emissions in the absence of policy intervention.

28%

JA:

③ Check that this description of the path accords with the description of the optimal path in the later detailed section. Change the wording here to fit accordingly. I think that the years in which it peaks are not correct as well as the years in which it reaches 1990 levels. We need to word this more felicitously.

For example, a timetable designed to ultimately stabilize atmospheric concentrations at 550 ppmv whereby OECD emissions would *peak* by 2020, reach 1990 levels by 2030, and continue to decline even further is estimated to result in costs that are only one tenth to one third those of a program that attains the same goal along a path in which domestic emissions reach 1990 levels by 2010.

Do you want WRE or least-cost?

wrong
→ this is the comparison w/ WGI, not 1990 = 2010

See that this statement is true for WRE and Manne Richels paths.

✓ Cost effective emission reductions strategies normally involve an initial phase in which actual emissions approximate the baseline or business-as-usual (BAU) path. (That period is longer the higher the ultimate concentration goal.) This more extended timetable for emissions reductions mitigates the costs associated with premature capital stock obsolescence and provides time for research and development to yield new, superior energy-savings technologies and low cost fossil-fuel substitutes. In addition, postponed costs are lower costs because, with a positive return on investment, fewer resources need to be set aside today to meet future costs.

See that this description of the change in global warming is consistent with the later statement. Probably a better statement would be less than .1 degree Fahrenheit.

The incremental benefit, measured in terms of average global temperature change, of an

aggressive program to stabilize emissions at 1990 levels by 2010 is tiny in comparison with a program that approaches the same target more gradually. The difference in world temperatures is about .03 degrees Celsius.

See that this is correct. Source: IAT report. Could infer this from change in the implicit price of carbon. In one case in the range of 80 to 140, or about 110, in the other case about 50.

A & R: These numbers were fact checked earlier. Look them over to see that they are still OK. They are important.

To appreciate the ambitiousness of a program to curb U.S. emissions levels to 1990 by 2010 it is necessary to recognize that such a target involves a cutback of about 29 percent in energy use in 2010 relative to baseline. Carbon emissions are now 12 percent above 1990 levels. Real growth in the economy over the next decade would further raise carbon emissions. Even under an optimistic assumption concerning the pace of improvement of energy efficiency (.9 percent per year) under constant relative energy prices, there would be further increases in carbon emissions by 2010 of 17 percent if we continue business as usual. The net required reductions to meet for 1990 emissions in 2010 would be about 29 percent.

We need this figure. Suggestion: Total energy in BTU. The PPI-energy index relative to the PPI.

Figure 1 shows the aggregate use of energy in the US economy and the price of energy relative to aggregate prices over the period 1970 to 1990. It shows that energy use was almost constant over the oil-shock period, 1972 to 1984, while the relative energy price index increased by more than 150 percent.

RL: We need to check these numbers. Source your earlier estimate that \$100 per ton would be doubling energy prices. We also need to check IAT report of 80 to 140. I think it may be 70 to 140. Joe probably has the IAT report. I think he is checking this number.

The kind of logic just outlined is what is embodied in greater detail in the various models that have been used to assess the impact of the 1990 by 2010 plan. Those models differ a bit about the response of carbon emissions to price changes and technological trends, but a broad range of models place the carbon permit price in the range of \$80 and \$140 per ton with a gas price hike between 18¢ and 36¢ and a coal price increase between 150 percent and 300 percent. Relative to the BTU tax proposed by the Administration in 1993 this is 8 to 24 times as large. As these numbers suggest, an intervention of very large magnitude in the economy is required with substantial negative economic consequences. The typical family's spending on energy would rise by about \$1000 per year.

KF: Could you please check these numbers that you originally gave to JF?

Figure 2: WE NEED FIGURE ON SEPARATE PAGE--perhaps to be inserted here in text-- shows the effects of an accelerated replacement schedule for all of the 7,900 electric power plants built during the last 50 years. Imagine, to take an extreme case, that all power plants had to be shut down within ten years (by 2007), and replaced with less-polluting technology. This would imply replacing 6,330 plants before the end of their normal lifespan, or 80 per cent of the total. Now imagine that all power plants had to be replaced in 20 years. This would constitute an accelerated replacement of 4,600 plants, or 58 per cent of the total. If one could wait 30 years, the complete replacement would mean an accelerated replacement of 2,000 plants, 26 per cent of the total. If one waited fifty years, under the stylized assumption of a 50-year life there would be no additional cost to replacing them.

From Footnotes:

The same exercise can be done for coal-fired power plants. This is the class of generators that produce the most carbon and that would thus have to be replaced even under a moderate plan to address climate change. If a complete change-over of coal plants were to be accomplished in 10 years, 799 of the 1,122 coal-fired plants (71 per cent) would have to be replaced before the end of their expected lifespan. If replacement occurs over 20 years, 488 plants would be affected, or 43 percent of the total. If one could wait 30 years, 227 plants would be closed prematurely, or 20 per cent of the total. Since newer plants tend to have larger capacity, the effects of a rapid replacement schedule are magnified. Closing all plants within 10 years implies that 289 million KW of capacity would be prematurely shut down, or 90 per cent of the total. If one could wait 20 years, 235 million KW of capacity would be affected, or 73 per cent. For 30 years, the capacity that would have to be replaced falls to 116 million KW, or 36 per cent of the total.

A & R: Check these unemployment numbers. Source: ERP.

From a macroeconomic perspective, an energy price increase is a supply shock and a shock of this magnitude constitutes a substantial stagflationary shock. Its impact will be to raise inflation, to lower real wages and to raise unemployment, as in the period following the two oil shocks. Unemployment in the four years after the first oil shock averaged 7.2 percent in comparison to 5.0 percent in the four years prior and unemployment rose further to an average of 8.7 percent in the four-year aftermath of the second. There remains debate about how much of this was due directly to the oil shock, because there was a simultaneous decline in productivity growth and transfers of real income to OPEC producers. Nevertheless, we should expect that the efforts of the Federal Reserve to contain inflation, coupled with likely efforts on the part of workers to recoup real wage losses will lead to a period of higher unemployment.

JA: See whether this statement is true

(S) A report by five ^{Department of Energy research} federal laboratories has catalogued emissions-savings technologies that ^{account for} are it claims are currently cost effective and that, if put in place now, could ~~save~~ ^{reduce emissions 7-10%} as much as 30 to 50 percent of

We obviously need to be careful about what we say on this issue.

the ~~new~~ carbon ~~reductions~~ necessary to stabilize emissions at 1990 level in 2010.
US energy. They view this finding as reason for optimism.

We need to fact check this number. It was originally inserted by Peter O.

See above
A report by five federal laboratories has catalogued emissions-savings technologies that are currently cost effective and that, if put in place now, could save as much as 30 to 50 percent of US energy. They view this finding as reason for optimism.

JA: I think this needs a bit of checking. We need to know exactly what the assumptions are underlying the EMF simulations.

6 The Energy Modeling Forum ran alternative models with common assumptions about benchmark parameters in describing the technology, resource availability, and the rate of discount. They compared the cost of two different paths for reducing carbon emissions from Business as Usual to an eventual stabilization of atmospheric CO₂ at double the pre industrial level--550 ppmv. The first of these paths was first suggested by the Working Group 1 of the Intergovernmental Panel on Climate Change, who proposed a set of paths that would stabilize atmospheric carbon at different levels in the year 2100; all of the Working Group 1 paths have quite early take-off in emission abatement. For example, on the 550-ppmv stabilization path reductions in OECD carbon emissions were 25 percent below Business as Usual in 2010. In contrast, Wigley, Reilly and Edmonds have suggested an alternative set of emission paths for reaching the corresponding long-term goal of stabilizing atmospheric carbon at different levels in 2100. They argued that their paths, with attenuated reductions in emissions, would have much lower costs than the original Working Group 1 paths. The appropriate economic measure of costs is the discounted value of losses in future consumption relative to Business as Usual.

model specific - pathways are just global, use model to make split.

Wigley,
Richels

OECD 2010
BAU
3.915

W/o trading
2.2

W/trading
3.0

full intl.

↓
W/trading
24% below
BAU

W/o trading
44% below
BAU

7 We have one of these tables. The other table is easy to compute it is just a permutation of the first table.

Wigley, Richels

Tables 1 and 2 show two robust conclusions from comparison of the fast take-off Working Group 1 (WG 1) 550-stabilization path and its Wigley-Reilly-Edmonds path (WRE) counterpart. Fast takeoff in emission reduction greatly increases the costs. A viable system of international permit trading would very much reduce costs. Table 1 shows the discounted value of consumption loss for the two paths--both with and without international trading of permits. In 11 out of 12 simulations--for six different models with and without permit trading--the costs on the slow-takeoff WRE path is less than a third of the cost on the corresponding fast take-off path. The average ratio of relative costs for the 12 comparisons was less than 1/3. Table 2 presents a permutation of the same cost estimates in order to assess the benefits from international permit trading. With one exception, all the ratios--of costs with permit trading relative to costs without--are considerably less than one; two thirds of the ratios are less than one half. The average ratio for the twelve simulation outcomes is .41.

7/12

.44

10

insert "by OECD countries"

JA: Check this statement about the models. I am pretty sure they are correct.

- ⑦ *For interpretation of the absolute level of the costs, it is important to note that these calculations assume the full utilization of resources and do not at all assess the costs from lost output and employment of such large changes in energy prices. Any losses resulting from less than a full utilization of resources must be added to obtain the full cost of emissions abatement. These qualifications notwithstanding, abatement costs are acutely sensitive in these simulations to the rate at which abatement begins.*

Chris M,
Weyant

- ⑧ JA: These are the Manne and Richels assumptions. Are these also the EMF assumptions?

It is also important to note what is probably the most important assumption in these simulation exercises--the assumption about the targets and timetables for developing countries. **Source: Manne and Richels. Contradicted by Holdren in Talk.** By the end of the next century--by 2100-- on the Business as Usual path--non Annex I countries will have more than 90 percent of CO₂ emissions. Developing country participation is absolutely necessary to any stabilization scheme. **CHECK: In the Energy Model Forum simulations developing countries follow business as usual until 2030. After 2030 they conform to emission target that are allocated globally on a per capita basis. Between 2030 and 2050 they are adjusting to these per capita targets.**

check IPCC

Weyant
email

⑨ JA: We need figure of the WRE paths and also the M & R least cost emissions paths. WE also need some indication, not too low of the necessity of a significant carbon tax. All the numbers in this section were guesses to be filled in more accurately.

The WRE paths give some indication of the nature of low-cost emissions paths. In contrast with the WG 1 paths, for some period of time they continue to have rising emissions, in the beginning departing relatively little from business as usual. The OECD emissions path with 550 ppmv stabilization, and international permit trading, for example, peaks @@@@ years after the implementation of an abatement program, returns to approximate parity with the initial levels @@@@ years later, and then descends considerably more rapidly than the Working Group 1 paths. This gives some approximation of what a low-cost abatement path should look like.

Since neither the WG 1 nor the WRE paths are optimal--the WRE paths being only conjectured preferable alternatives--it is envisage an optimal target path would look like. Manne and Richels have computed the least cost path with 550-stabilization in 2100. Such paths are similar to WRE, but not quite the same. The Manne-Richels least-cost path would peak between 2020 and 2030 and then gradually decline. Reaching 1990 emissions so comparatively late does not involve doing nothing now. On the contrary because of projected trend growth in GNP, it entails departing from Business as Usual at an accelerating rate. In order to attain these emissions levels it will, returning to 1990 emissions only after 2050. Meeting such targets does not imply doing nothing. For example on the 500 ppmv stabilization path the implicit price of carbon should increase by \$@@@ @@@@ years after implementation.

].?awk.

awk

2010 \$2
2020 \$3
2030 \$6
2040 \$10
2050 \$20
2100 \$156

check MERGE chart

what do you want here?

regime

550

2.36

1.06

6

note: the climate
outputs are from
the MAGICC model

(10)

JA: we need to check this fact. Source--from the SGM model runs.

While the excess cost of fast takeoff compared to gradual takeoff in the restriction of carbon emissions has been projected to be large, the differences in projected global temperatures between the fast and the slow paths are, in fact, quite small--small both in absolute amount and relative to temperature changes expected from global warming. **CHECK: While global warming is expected to increase by 1.15 degrees Celsius by 2050 and 2.45 degrees Celsius by 2100 with business as usual, the differences in temperature between the WG 1 path and low cost paths--either WRE or the least-cost path--is uniformly less than .05 degrees.**

we have
never
asked
for this
info from
Richels

(X1)

JA: Could you check these facts. Source is probably Manne and Richels.

w/ -10'1.

The IPCC IS92a Business-as-Usual scenario projects that these countries will produce more than 90 percent of world carbon emissions in 2100. The common assumption of the low cost paths was that non-Annex I countries will agree now to a target for emissions. This target will be Business as Usual until 2030, at which point countries must begin to limit their emissions, with a transition to equal per capita emission rights by 2050. It is important that developing countries agree now to future emissions abatement.

(12)

JA: Original source was JF's table of Batelle results.

While the effectiveness of carbon emissions targets is extremely dependent on eventual developing country participation, such agreement will have virtually no effect on the current cost to Annex 1 countries of current carbon abatement schemes. To consider the possibility that developing countries might decline to participate, or decide to participate only to a lesser degree than the least cost burden-sharing formula, we ask what would be the effects of developing countries nonparticipation on the economic costs of emission abatement to Annex 1 countries. **JLY has different number.** The increased discounted cost according to Manne and Richels would be \$25 billion. [This is the WRE path? Or the least-cost path?] Even this estimate is an upper bound since the model fails to take account of the migration of energy intensive industries to developing countries with no carbon taxes. Of course such trade effects will also make the abatement program correspondingly less effective.

See
photo
copy

AM: Could you check these. The sources are in the reader or in Cline.

According to Jorgenson and Wilcoxon GNP would actually increase if the revenues were used to reduce taxes on capital.

I think the source is Cline.

Elsewhere Jorgenson and Yun have estimated the efficiency loss from an extra dollar of tax revenue at 38 cents.

The source is Nordhaus' book--section on recycling of revenues.

Nordhaus' simulations give carbon taxes of about \$5 when recirculation of revenues have no incentive effects. However if the revenues are used to replace other taxes with an efficiency loss of 50 cents, the growth rate of the optimal carbon tax is extraordinarily large and within 10 years of an abatement program the implicit price of carbon is almost \$60.

AM: A good source is the AER of perhaps QJE article by Poterba, Summers and Rotemberg. I guess that the date of publication is about 1985.

But there is also reason for pessimism regarding the potential success of such an attempt to allay the macroeconomic consequences of the rising energy costs by such recycling. An experiment of this sort was carried out in the late 1970's with no success. In 1979 Margaret Thatcher increased the VAT tax and simultaneously decreased the income tax. The two changes should have had offsetting effects on real incomes, and therefore might be expected to have had no effect on inflation. However, the increase in the VAT tax resulted in an immediately noticeable increase in the CPI. A wage-price spiral ensued as workers attempted to maintain their *pre-tax* real wages.

RL: We need to check these prices. They come from your memo to Jeff.

JA: Could you check the figure of \$50 in the interagency task force report.

Interagency Analytical Team

Annex I
56 w/ CR
25 w/o CR

JI
20 w/ CR
9 w/o CR

The IAT (InterAgency Taskforce) report has estimated that with international permit trading the increase in the implicit price of carbon necessary to meet a goal of 1990 emissions by 2010 would be \$50 per ton of carbon. [This estimate is likely to be optimistic since the models used to obtain this estimate do not capture the short-term inertia in energy and emissions saving.] Also if the system of international permit trading does not work ideally as assumed, the implicit price increase of carbon emissions must be correspondingly greater. Nevertheless this estimate could be used to justify a US position of an initial carbon tax of \$25 per ton beginning within a year of implementation of the treaty and increasing at the rate of 8 percent per year so as to reach \$50 in the year 2010. [A \$25 initial permit price for emitting carbon would increase energy prices by 25 percent. It would increase the price of natural gas by @@@ percent; the price of a barrel of oil by \$5.50, and the price of gasoline by about 6 ¢ per gallon. The price of coal would be seriously affected. Coal would increase in price by @@@ percent. This could be defended as a serious attempt to begin a United States program of carbon abatement.]

- is this necessary? if so, it should occur in the very first discussion on permit prices, not embedded in this with trade price issue

A & R: Could you check these macro numbers.

Also is there any way to estimate the effect on coal miners. How many coal miners are there? How much attrition has there been in the last few years? What are the most impacted industries? Is any other industry comparable to coal?

The macroeconomic cost of this program might be significant, but it would be much smaller than that of the combined oil shocks of the 1970's. CHECK: The two oil shocks involved an increase of 160 percent in the producer price index of energy. A \$25 tax would involve an increase of 25 per cent. Therefore the maximum negative impact of such a strategy would be $1/6$ of the effect of the oil shock. In the ten years aftermath of the first oil shock, which are inclusive of the second oil shock and its aftermath, unemployment was 2.7 percentage points higher than pre-shock levels. If all of the increase was due to the oil shocks, the increase in unemployment from such a carbon tax of \$25 would be less than .5 percent. If $1/3$ of the change was due to the oil shock and $2/3$ due to simultaneous change in trend productivity, then the expected unemployment increase would be in the range of .1 to .2 percent. Some significant fraction of the revenues from the tax would have to be used to help displaced coal miners who will of necessity be very seriously affected by any effective abatement program. While any loss on employment is extremely regrettable, a trade-off may need to be made between employment opportunities on the one hand and climate change on the other. It is absolutely essential that the policies that the government is adopting should minimize the losses in employment for the given objective.

Comments on pages 9, 10:

Comparative Costs of Slow Versus Fast Take-Off

Insert "In addition," to beginning of last sentence of first paragraph on p. 9.

Change "signed" to "implemented" in third sentence of second paragraph on p. 9 (since, presumably, a treaty will be signed in December, but it will take a couple of years to ratify and implement it).

Insert "Modeling" after "Energy" at beginning of first sentence of third paragraph on p. 9. Alternatively, we could employ the acronym, "EMF" to refer to the Forum throughout the paper.

Change "energy" to "carbon" before "permits" in the first sentence of the third paragraph on p. 9.

Change "energy" to either "permit" or "carbon" before "trading system" in the second sentence of the third paragraph on p. 9.

Insert footnote at end of third paragraph on p. 9:

The Annex I trading permit price assumes that all permit sellers undertake corresponding reductions. For example, Russia could not sell "paper tons" based on the collapse of its economy after 1990. Instead, for every permit that it sells, Russia would have to abate that quantity of carbon emissions.

Change first two full sentences of top paragraph on p. 10 to:

"With full global permit trading, they find that any path that cannot exceed 1990 emissions levels by 2010 will have 2 ½ times the cost of the least-cost abatement path without any near term constraint on emissions. Without full global trading, the costs increase considerably."

Delete the following sentence in this same paragraph (beginning "But again the 1990...") and the last sentence in the paragraph (beginning "International permit trading...").

Timetable of Least-Cost and Low-Cost Paths

Change beginning of third full sentence of first paragraph of this section to "Wigley, Richels, and Edmonds (WRE)"

Insert a footnote at the end of the fifth sentence of this paragraph (after "ppmv"):

These concentrations stabilizations are assumed to occur over several hundred years, and begin to converge on their target levels during the first half of the 22nd century.

Insert "WG1" after "pathways" in the following sentence.

Change "Wigley, Reilly, and Edmonds (WRE)" to "WRE" in the sentence beginning "In response, ...".

Change "Working Group 1" to "WG1" at end of the following sentence.

Change "The" to "They" in the next sentence.

Rewrite the next sentence to:

With 550 ppmv stabilization and no international trading, the discounted consumption loss to the U.S. is \$2.17 trillion with the WG1 path and \$0.41 trillion with the WRE path.

Insert a footnote at the end of the previous sentence:

The present discounted value of consumption is calculated using a 5% discount rate and a time horizon of 1990-2100.

In the last sentence of this paragraph, insert "2%" in place of "@@@".

confirm trading in all charter figures, this

9

Focus on U.S. costs
- would costs only if
no U.S. costs

Comparative Costs of Slow versus Fast Take-off

Another way to analyze the relative costs of different timetables for curbing CO₂ is by large-scale long-term energy models. All such models must make many approximations to cover a topic that is global in nature and also more than a century in scope. Therefore it is useful to interpret the results of the models qualitatively, not quantitatively, and also to view the outcomes of the simulations as giving a range of estimates rather than any single number. To enable such comparison of results, the Stanford Energy Modeling Forum ran different models with common benchmark assumptions. These simulations show two robust conclusions: Fast takeoff in emission reduction greatly increases the costs. This lower cost with longer timetable reflects increases in the price elasticity of energy demand over longer periods of time; it also reflects the lower costs of replacing capital stock and greater ability to adapt technologies over a longer time period. A viable system of international permit trading very much reduces the costs of meeting any given emissions target.

In addition, implemented

Table 1 shows that losses are very much dependent on the schedule of emissions reductions. For each and every model the losses from achieving 1990 by 2010 were a fraction of the losses from achieving the less ambitious goal of emissions which are 10 percent higher. For interpretation of the absolute level of the costs, it is important to note that these simulations were run early in the 1990's on the assumption that the abatement program had begun in 1990, with a 20 year window for accomplishment, rather than begun in 2000 with a 10 year window, as will occur if a Treaty is signed in 2000. *It is also important to note that these models assume the full utilization of resources and do not at all assess the costs from lost output and employment of such large changes in energy prices. Any losses resulting from less than a full utilization of resources must be added to obtain the full cost of emissions abatement.* These qualifications notwithstanding, abatement costs are acutely sensitive in these simulations to the rate at which abatement begins. There are very large differences in abatement costs with a goal of 1990 plus 10 percent in comparisons to a goal of 1990.

The Stanford Energy Modeling Forum simulations also demonstrate that participation in trading of energy permits will greatly reduce the costs. Table 2 shows worldwide losses with and without such an energy trading system and a variety of such comparisons for the United States, with a bit less between-model comparability than in the Stanford Energy Forum, as reported in the IPCC report *Climate Change*. There are no exceptions to the large gains obtainable from a system of international trading of permits. The IAT report similarly projected that permit trading would reduce the implicit price increase on carbon emissions from a range of \$80 to \$140 to about \$50.

Manne and Richels have made comparisons of different paths of emission targets, which yet again, verify the sensitivity of costs to the rate of takeoff in curbing carbon emissions. They

For: The Annex I trading permit price assumes that all permit sellers undertake ~~equivalent~~ corresponding reductions equivalent to the quantity of

US losses vs world - SGMM or MERGE
make more specific

Annex I
SGMM-81
DIRE-95
MM-145

SGMM-56

Table 1
for
Werant
EMF-12

permit

Carbon

Modeling

which chart
in Climate
Change
table 9, 25?

least cost (assumes full global trading)
 US PDV foreign consumption:
 \$1.12 trillion
 World PDV foreign consumption
 \$5.56 trillion

1990 = 2010, domestic only, trading
 US PDV foreign consumption:
 \$4.3 trillion → 3.58
 World PDV foreign consumption:
 \$2.4 trillion → 4.3
 3 1/2 times

10

examine emissions paths which all stabilize atmospheric concentrations of CO₂ at the same level in the year 2100, and they compute the discounted consumption losses from not doing business as usual. (This is the economically correct measure of loss). Without permit trading they find that any path that cannot exceed 1990 emissions levels by 2010 will have six times the cost of the optimal abatement path without any near term constraint on emissions. International trading reduces the cost considerably. But again the 1990 by 2010 constraint raises the total cost by a multiple. Again the message is that 1990 by 2010 constitutes a very fast takeoff in emissions abatement. Slower takeoff will result in much lower costs. International permit trading is also important.

check, make more specific → least cost always assumes full global trading

(WG1) Timetable of Least-Cost and Low-Cost Paths

Richels

(WRE)

over several hundred years → FN

If reaching 1990 emissions by 2010 is unnecessarily costly, what paths of emission targets will lead be relatively efficient? Two exercises have especially aimed at discovering the nature of these paths. Wigley, Reilly and Edmonds proposed a path to the stabilization of greenhouse gases with a slower take-off. The brief history goes as follows. In 1992 the Working Group 1 of the Intergovernmental Panel on Climate Change published a set of concentration profiles for stabilizing atmospheric CO₂ at various levels--350, 450, 550, 650 and 750 ppmv. The Working Group 1 pathways all have the property of stabilizing world emissions quite early. They assume rapidly declining OECD emissions from the very beginning, declining by 25 percent 20 years after initiation of emissions targets. In response Wigley, Reilly and Edmonds (WRE) proposed alternative pathways that would also stabilize emissions but with continued rising emissions for some period of time. The OECD emissions path with 550 ppmv stabilization, for example, peaked 20 years after the beginning of abatement, reached approximate parity with the initial levels 40 years later and then descended considerably more rapidly than the Working Group 1 paths. The estimated difference in the loss of the present discounted value of consumption between the WG 1 and the WRE paths and have verified the qualitative argument of WRE that the costs of the attenuated abatement paths was very much lower. With 550 ppmv-stabilization the discounted consumption loss to the OECD get US number @@@ is @@@ with the WG 1 path and, @@@ with the WRE path. Neither the WG 1 Nor the WRE paths is optimal. An alternative methodology would be to explicitly compute the path with the smallest discounted loss to consumption with a stabilization target in 2100. According to calculations by Manne and Richels, for Annex 1 countries emissions would reach a peak for Annex 1 countries between 2020 and 2030. That peak would be 29 percent above 1990 levels and @@@ percent below the business as usual paths.

WRE
 .28
 .36
 .41

WG1
 1.29
 2.17

on the optimal path with lower discounted losses, OECD 2%

Again we should emphasize that these models fail to take account of the macroeconomic impact of the relative change in the cost of energy. The desirability of spreading the macroeconomic impact gives added reason for such a comparatively long timetable in returning to 1990 emissions levels. There is a further dimension lacking in most of the long-term energy models. Most of these models fail to take into account how the revenues from carbon taxes or the sale of permits will be utilized. The net costs of emission abatement depends upon whether or not these revenues are used well or badly. This problem will be discussed below.

chart
 shapes of
 different
 paths
 WG1
 least-cost
 550

They

DRAFT #2

September 14, 1997

MEMORANDUM FOR THE PRESIDENT

FROM: GENE SPERLING
KATIE McGINTY
DANIEL TARULLO

SUBJECT: Climate change scenarios

I. INTRODUCTION

This memorandum is the first of several that we will be submitting to you over the next several weeks on the substance of climate change issues. As you know, this issue provides an opportunity for you to address what many consider to be the premier environmental challenge of the next century. As the world's largest emitter of greenhouse gasses, our country's actions will send a key signal to the rest of the world that steps can be taken to reduce emissions over the long term without undue adverse effects on economic growth. But the issue is particularly difficult -- both analytically and politically -- because the environmental and economic consequences are potentially momentous and yet highly uncertain.

The purpose of this memorandum is to frame the decision-making process by presenting three scenarios illustrating possible strategies for the Kyoto negotiations in December and beyond. Subsequent decision memoranda will discuss various aspects of our negotiating position in more detail.

II. AREAS OF DISAGREEMENT

Before considering the three scenarios, however, we want to highlight several key issues upon which there is significant disagreement among your advisers:

- How to implement a carbon emissions reduction scheme;
- How much we can reasonably expect from technological advances without a significant price signal;
- How effective joint implementation will prove; and

- How the environmental effects *differ* from policy actions within the range being considered.

We will undoubtedly discuss these critical issues in more detail over the coming weeks; our purpose here is merely to summarize some of the different views to inform your evaluation of the scenarios examined below.

A. Domestic implementation

Under the system to be negotiated in Kyoto, each participating country would be able to choose its own method for ensuring emissions reductions. The potential “domestic implementation” methods differ markedly in terms of their economic efficiency and political feasibility. Market-based structures for domestic enforcement fall into two categories: (1) tradeable permits and (2) a carbon emissions tax. Our focus here is on the first approach.

Tradeable Permits

Under this approach, the Federal government would issue a limited supply of permits for emissions, and these permits would be tradeable. *One key issue with permits is the allocation mechanism.* There are two approaches to allocation: auctioning, or an administrative allocation of permits. Your economic advisers have grave concerns about the cost -- and even the feasibility -- of an administrative allocation system. Others dispute this claim, arguing that administrative allocations mechanisms are both feasible and crucial for garnering corporate support.

1. An auction-based approach

The United States and most other countries have long used auctions to sell government securities, and governments have also used auctions to allocate other resources -- such as oil leases, timber, and portions of the spectrum. The auction mechanism for distributing carbon permits has two main advantages:

- First, it would ensure that permits are placed directly into the hands of those who value them most highly.
- Second, it would raise revenue that could be used to reduce other taxes (e.g., to offset the regressivity of the emissions reduction scheme), raise national saving, or fund adjustment programs. Depending on the stringency of the control regime and other factors, the auction revenue could amount to relatively small amounts of money or as much as \$150 billion per year. If those funds were used to reduce extant distortionary taxes, the so-called double dividend may result: improved environmental protection *and* less distortionary overall taxation.

The main disadvantage to an auction approach is the effect it would have on corporate support and on the likelihood that the program is characterized as a “tax”:

- Auctions would force most businesses to pay large costs simply for the right to maintain

their business-as-usual operations. Despite the fact that these firms would likely pass most of the cost through to consumers, a firestorm of opposition will arise from these businesses.

- Corporate opponents would undoubtedly attack the auctions as a tax, even if the revenues were recycled to reduce other taxes. The success of the auction approach would depend critically on building constituencies for the tax reductions made possible by the auction revenues.

2. An administrative allocation approach

Instead of forcing emitters to pay for permits at an auction, the government could allocate them administratively, based on a pre-determined formula. The most likely system would involve granting permits to existing emitters based on historical fuel use or emissions; permits are allocated in this manner in the SO₂ trading program.

This approach has significant political advantages over an auction:

- The prospects for support from key businesses -- such as those you met with last month -- are much higher with an allocation scheme than an auction. The theoretical benefits of auctions as a means of distributing the permits will be much less salient to the CEO of a large corporation than the necessity of having to purchase permits to continue operations.

This significant advantage brings with it several disadvantages, however.

- An administrative system would confer a substantial amount of wealth on those to whom the permits are awarded. Such an approach would reward those who were biggest polluters in the past.
- The value of the permits would attract many claimants. Deciding which claimants deserve the permits and avoiding double-counting at different levels of the energy system (miners, refiners, utilities, end-users, etc.) could prove very difficult. Treasury and CEA have grave concerns that the rent-seeking behavior inherent in attempts to capture the permit wealth will make the entire system grossly inefficient. For example, there may be pressure to issue the permits downstream (e.g., to auto manufacturers, washing-machine manufacturers, and air-conditioner manufacturers) even though it would be significantly more efficient to issue them further upstream (e.g., to oil refiners and coal processors).
- Administrative allocation schemes forgo the opportunity to raise revenues -- and thus to use the revenues to cut other taxes.

It may be possible to combine an auction and an administrative allocation approach -- for example, by auctioning some percentage of the permits, and administratively allocating the rest.

↳ Note - you still need to set up a trading system so that businesses have an incentive to reduce emissions & so there can be an efficient secondary mkt.

B. The role of technology

Your advisers also have sharp disagreements about how much we can reasonably expect of technological advances without the spur of a price increase.

- Some of your advisers believe that the cost estimates presented below are too high because even without an increase in the price of energy, there are numerous opportunities for energy-saving technologies to be developed and applied. For example, one controversial study conducted by five of the Department of Energy's national laboratories concluded that even without an increase in the price of carbon, "cost-effective energy efficiency alone can take the nation 30 to 50% of the way to 1990 levels" by 2010.
- Your economic advisers raise a series of significant methodological objections to the study mentioned above. They also tend to stress the importance of market incentives for technological advances. They argue that technology will clearly be one of the conduits for meeting an emissions reduction target, but that both theoretically and historically, the most rapid technological advances come in response to significant increases in the relative price of energy.

For instance, over the entire postwar period, the fossil-fuel efficiency of the U. S. economy has improved at slightly more than one percent per year. Between 1970 and 1986, during which time the economy suffered two oil-price shocks, fossil-fuel efficiency grew by more than 2½ percent per year. The pace of efficiency improvement has slowed down, but not stopped, since the late 1980s, as the relative price of energy has fallen.

The degree of disagreement on this crucial topic, however, can easily be exaggerated. Despite ongoing debates over the precise role of technology, therefore, there is broad technical agreement that *a significant price signal is crucial to achieving emissions reductions* of the sort being considered in international fora. In other words, it is impossible to achieve 1990 emissions levels by 2010 without a substantial increase in carbon prices.

C. Joint implementation

Another source of disagreement among your advisers is the role of joint implementation (JI). JI is a mechanism by which a private entity in the United States could invest in greenhouse gas mitigation projects in developing countries without emissions budgets. In exchange, the investor (and the U.S.) would receive credit towards its emission budget. Some of your advisers believe that JI is crucial to reducing the cost of reaching a given target and timetable, and for building corporate support. Others are concerned that the program has been oversold — and in particular, that it does not guarantee that our overall efforts will succeed in reducing global emissions.

In principle, JI provides a very low cost mechanism for reducing emissions, by "trading" emissions here for emissions abroad, where the cost of reduction is much

lower. In practice, however, JI requires a mechanism for guaranteeing that emission reductions that qualify for credits are "additional" to – above and beyond – reductions that would have happened anyway in the baseline case. How can we tell whether the low emissions power generation plant built in a developing country would have been built in the absence of JI incentives? If credit is given for investments that would have happened anyway, then the use of these credits to meet developed country obligations will result in higher global emissions. On the other hand, if the standard of "additionality" is set too high, or if projects are choked off by transaction costs associated with resolving baseline and additionality questions, then the large potential savings associated with JI will be lost.

The JI issue is just one aspect of the role of developing countries in worldwide efforts to reduce greenhouse gas emissions. There is a vast gulf between the dialogue abroad (where previous U.S. proposals on developing country participation are almost uniformly considered too aggressive) and at home (where Senator Byrd's resolution, calling for even tougher demands on developing countries than previous U.S. proposals, passed the Senate 95-0). *[[Your advisers have decided to adopt a much tougher line on developing countries, even if that necessitates a two-step approach to the international negotiations: reach agreement among the developed countries, but do not submit the agreement for domestic ratification until key developing countries commit to binding targets.]]*

D. Environmental effects

A final source of uncertainty and disagreement is over the size of the environmental effects from different government policies. Our best models suggest that under business-as-usual (BAU), concentration levels of carbon are expected to rise from approximately 360 parts per million by volume (ppmv) today to over 500 ppmv in 2050 and over 700 ppmv by 2100 – the highest in more than 50 million years. Pre-industrial concentrations were approximately 250 ppmv, and concentrations are expected to reach twice these pre-industrial levels in about 2060. The increase in carbon concentrations is expected to produce an increase in mean global temperature of between 2 and 6.5 degrees Fahrenheit.

The relevant question in evaluating our policy choices, however, is not the baseline. Rather, we must compare the likely environmental costs averted under one set of our actions to the likely costs averted under some other set of actions.

- Some of your advisers believe that although there is substantial uncertainty involved, the best models available suggest that differences in the targets and timetables of the type discussed in this memo have relatively little effect on the ultimate concentration of carbon and therefore on climate change. For example, models predict that the difference between the most aggressive and least aggressive paths discussed below produce differences in temperature increases by 2100 of less than 0.1 degrees Fahrenheit. In other words, they argue that by changing the shape of the emissions path to a given ultimate concentration, it is possible to achieve the same environmental benefit at a much lower economic cost.

- Others believe that such comparisons are fundamentally misleading because they assume that our actions have little influence on developing country behavior, and do not account for the (admittedly small) probability that the different emissions paths will interact with potential non-linearities in the climate system. They thus argue that the environmental differences among the scenarios (particularly Scenario 1 and Scenario 2) are potentially momentous.

III. THREE SCENARIOS

The climate change issue involves so many different parts (the target and timetable for our emissions, whether to use a tradeable permits system to reach that target, whether to auction the permits, etc.) that it is easy to become enmeshed in the details while losing sight of larger strategic considerations. The purpose of this section is to present scenarios that try to present some of the trade-offs on that higher strategic plane; subsequent memoranda and meetings will allow us to examine many of the component pieces in more detail.

The three scenarios we consider are:

- Scenario 1: Adopt most attractive policies currently acceptable in international sphere, fight for domestic ratification;
- Scenario 2: Devise more economically efficient domestic policy, even if not internationally acceptable; and
- Scenario 3: Trying to bridge the gap

It is crucial to emphasize that the scenarios are meant to be illustrative, to provide a way of thinking about our policy proposals. Similarly, the economic figures presented along with each scenario are highly uncertain. They reflect educated guesses based on economic models. The issues of disagreement discussed above, along with many others, could have a substantial effect on the precise outcomes.

SCENARIO 1

ADOPT POLICIES CURRENTLY ACCEPTABLE IN INTERNATIONAL SPHERE

Overall strategy

- Reach the most advantageous but internationally feasible full agreement in Kyoto
- Fight to sell and ratify agreement domestically over the next few years

Components

Target and timetable	1990 emissions levels by 2010
Domestic implementation	Tradeable permits. R&D and Federal energy efficiency programs.
Developing country participation	Agreement in principle on joint implementation. Unlikely to get international agreement -- even in principle -- on Annex B (voluntary limits for developing economies) or evolution (a mandatory graduation system for adopting quantified targets).
International trading	Agreement in principle on a trading regime within Annex I (developed economies).

Energy price effects

The cutbacks in energy use (relative to GDP) required to meet this target are at least comparable to -- and arguably greater -- than those achieved in the decade of the two oil shocks, a period in which aggregate energy prices roughly doubled. Not surprisingly, therefore, the implied increase in energy prices needed to reach 1990 emissions levels by 2010 would entail a significant inflationary shock, with an associated rise in the CPI and decline in real wages.

With Annex I (developed economy) trading

- Permit price. Carbon prices in 2010 up between \$50 and \$90 per ton.
- Gas prices. Gas prices in 2010 would rise by between 10 and 25 cents.
- Coal prices. Coal prices in 2010 would rise by between \$30 and \$70 per ton, relative to the current price of about \$20 per ton.
- BTU-equivalent. In terms of coal prices, the energy price increase is equivalent to a tax of between \$1.50 and \$3 per million BTUs in 2010. (In 1993, the Administration proposed a

tax of \$0.26 per million BTUs plus a \$0.34 per million BTUs tax on oil.)

- Effects on families. Some critics might charge that the average family would either have to reduce consumption or pay as much as \$500 to \$1,000 more in 2010 from the increase in energy prices. The increase in expenditures as a percentage of income for the lowest decile is approximately six times the percentage increase for the highest decile.
- International transfers. There is substantial uncertainty over the size and even the direction of net international transfers. However, under some scenarios, purchases of permits from other countries in 2010 could amount to \$5-\$10 billion.

No Annex I trading

- Permit price. A carbon price increase of between \$80 and \$140 per ton in 2010.
- Gas prices. Prices in 2010 would rise by between 20 and 30 cents per gallon.
- Coal prices. Coal prices in 2010 would rise by between \$50 and \$100 per ton, relative to a current price of \$20 per ton.
- BTU-equivalent. In terms of coal prices, the energy price increase is equivalent to a tax of between \$2 and \$4 per million BTUs in 2010.
- Effects on families. Some critics might charge that higher expenditures of as much as \$900 to \$1,500 more in 2010 from the increase in energy prices.

International reaction

- Kyoto agreement feasible, albeit not guaranteed.
- Some criticism from Europeans and other countries.

Domestic reaction

- Hill. Kyoto agreement *extremely* unlikely to be ratified (Byrd resolution); attacked as massive energy tax hike. Even without ratification vote, Congressional anger could manifest itself in many ways.
- Corporations. Major concerns over costs imposed on the economy, as well as developing country stance. Firms in energy-intensive industries will argue (regardless of the evidence) that their operations will flee the United States for other countries. Strong support from renewable energy and energy-efficiency firms.
- Environmental groups. Many environmental groups will support a 1990 by 2010 target, but would prefer a more aggressive path.

- Labor. Strong opposition, driven particularly by coal workers
- Elite media. Likely to support Administration for tackling critical issue
- Outside critics. Many economists who have studied climate change are likely to be extremely critical of the 1990 by 2010 target, as will be discussed under Scenario 2.

SCENARIO 2

DEVISE MORE ECONOMICALLY EFFICIENT DOMESTIC POLICY

Overall strategy

- Devise more economically efficient domestic policy with same ultimate carbon concentration as Scenario 1.
- Allow more time for capital stock to turn over naturally, while providing signal for technological development and dissemination.
- Since this scenario will not be remotely acceptable in the international sphere, it is provided more as a benchmark than a true scenario *for Kyoto.*

Components

Target and timetable	Reduce emissions <i>growth</i> to zero ten years after ratification. Then, determine when emissions would return to 1990 or other base year level.
Domestic implementation	Tradeable permits (auctioned), or equivalent measures (e.g., \$5 per ton initially, rising over time). R&D and Federal energy efficiency programs.
Developing country participation	U.S. would insist on mandatory, binding targets for developing economies with relatively large total emissions or relatively high per capita incomes. Extremely difficult to get developing countries to agree on such targets.
International trading	U.S. would seek international trading system among all participating countries. Little prospect for success in near term.

Energy price effects

The overall cost of this approach is approximately 1/10 to 1/3 as expensive as under Scenario 1, even for a given ultimate concentration of carbon.

- Permit price. A carbon price increase of between \$5 and \$10 per ton by 2010, scheduled to increase further over time.
- Gas prices. Gas prices in 2010 would rise by an estimated 2 to 3 cents.
- Coal prices. Coal prices in 2010 would rise by between \$5 and \$7 per ton, relative to the current price of about \$20 per ton.
- BTU-equivalent. In terms of coal prices, the energy price increase is equivalent to a tax of

about \$0.05 to \$0.30 per million BTUs.

- Effects on families. Some critics might charge that the average family would either have to reduce consumption or pay as much as \$10 to \$100 more in 2010 from the increase in energy prices.

International reaction

- Kyoto agreement impossible.
- The U.S. will be blamed for undermining the current round of international negotiations (Rio II).

Domestic reaction

- Hill. Less chance of intense attack.
- Corporations. Many firms could decide that the gradual approach to emissions reductions is the best they will be able to achieve.
- Environmental groups. Environmental groups sharply criticize.
- Labor. The AFL-CIO does not object
- Elite media. Criticism from many editorial boards. More criticism likely if severe weather events raise prominence of issue.

SCENARIO 3: TRYING TO BRIDGE THE GAP

Overall strategy

The difficulties with Scenarios 1 and 2 are clear: Scenario 1 represents a strong and credible commitment to address the climate change problem, but only at a significant -- and politically infeasible -- cost to the U.S. economy. Scenario 2 substantially mitigates the economic costs, but will be met by immense criticism abroad and among environmental groups at home as insufficiently responsive to the scale of the climate change challenge.

The central question is whether a strategy can be found for bridging the gap between these approaches, providing a credible commitment to taking the environmental problem seriously without imposing untenable costs on the U.S. economy. We suggest three directions for bridging the gap between these two extremes:

- Delaying the 1990 base year;
- Delaying the 2010 year; and
- Softening the 1990 by 2010 commitment by building in an escape clause likely to be triggered

These directions should not be taken as mutually exclusive; they may be used separately or in combination in finding the common ground between the first two scenarios. In each case, we take as our reference point Scenario 1, with a target and timetable of 1990 emissions levels by 2010.

All the alternatives below could be predicated on binding commitments from key developing countries. One possible way to address the developing country issue is a two-step approach: we could try to reach an agreement among the developed economies, but no such international agreement would be submitted for ratification before the key developing economies agreed to their commitments.

Approach A: Moving the Target Base Year (1990)

- The first approach to bridging the gap would maintain the 2010 deadline, but change the base year from 1990 to same later year. Possibilities include the year of ratification or 2000.
- The target year 1990 is a particularly disadvantageous one from the perspective of the United States. Between 1990 and 1995, our emissions grew xxx% while those in ... grew by only yyy%. projections of 2000.... Thus, the choice of 1990 instead of a later year essentially amounts to a large transfer from the U.S. to the rest of the world, a transfer made explicit in the case of Annex I trading. As a result, we could greatly mitigate the costs to the U.S. economy by moving the target from 1990 to a later year.

- Alternatively, the 1990 base year could be maintained, but the target could be set above 1990 levels -- for example, we could commit to reaching 1990 emissions levels plus 15 or 20 percent by 2010. This commitment would be roughly equivalent, in terms of domestic emissions, to a 2000 by 2010 commitment.

Economic Effects

- The advantage of this approach is that it would greatly mitigate the economic effects. With developed country trading, reaching 1990 levels plus 15 to 20 percent by 2010 implies a permit price in 2010 of about \$10, rather than the \$50 price implied by trying to reach 1990 levels by 2010. Without developed country trading, the permit price would be between \$15 and \$25 -- relative to \$80 to \$140 under the 1990 by 2010 commitment.

Environmental and International Political Ramifications

- The disadvantage of this approach is that there is much negotiating history invested in the 1990 target. A move off of that target by the U.S. would be criticized internationally, since there would be relatively little gain for any country other than the U.S., and even some loss in countries such as Germany and Russia. There would probably be less international censure for an increase in the 1990 target, even at the same economic cost to the U.S.
- Either approach would be met with some disappointment from the environmental community -- but we would receive some credit for taking a concrete step over a relatively short horizon.

Approach B: Moving the Timetable (1990 by some year later than 2010)

- Alternatively, 1990 could be maintained as a base year, and the timetable could be lengthened from 2010. Under Scenario 2, it was lengthened indefinitely to approximately 2040. Alternatives could be to lengthen it more modestly, say to 2025.
- Concerns about appearing insufficiently attentive to the problem could be addressed by taking action immediately upon ratification: for example, raising the price on carbon by \$10 or \$15 per ton, either through a tax or a tradeable permit scheme.
- Another twist on this scheme would be that it could combined with the approach above: for example, we could commit to 1990 levels by 2025, *and* 2000 levels by 2010. Such an approach would also help to address the charge that our proposal was too backloaded.

Economic Effects

- This would once again mitigate the economic costs of the program. But it requires a substantial lengthening of the timetable to induce substantial reductions in costs. For

example, a target and timetable of 1990 by 2020 still forces us to bear 90 percent of the economic costs of a 1990 by 2010 commitment. Because of the slow turnover of the capital stock, economic costs are not dramatically reduced without an even longer lengthening of the timetable.

Environmental and International Political Ramifications

- This approach would also be met by increased dissatisfaction from the environmental community, since we would be seen as pushing our commitment off sufficiently far that we have no intention of meeting it. It is unclear how successful any initial carbon price increase would be in mollifying these concerns.
- The international community would similarly be worried about our long run commitment, and it is once again unclear whether these concerns could be reduced by an initial carbon price in this range. In particular, many of your advisers worry that the delays embodied in this approach would undermine U.S. leadership on a critical issue, and make it even more difficult for us to convince developing countries to participate.

Approach C: Adopt 1990 by 2010, with "escape clause" to minimize domestic costs

- This approach bridges the gap by adopting a 1990 by 2010 target and timetable, but insisting on an "escape clause": the U.S. government would stand ready to sell unlimited permits at \$10 to \$20 per ton.
- The approach allows technology optimists to believe that we will meet the 1990 by 2010 target and timetable, but provides an upper bound on the economic costs imposed (even if that means the target and timetable is not met).
- The economic cost is capped -- if the cap binds, it's functionally equivalent to a tax of that amount per ton. Revenue neutral, but still "tax cut" if funds from selling permits are used to reduce other taxes.

Economic effects

- Some environmentalists and technology optimists believe that it is possible to reduce emissions to 1990 levels by 2010 with a relatively low permit price -- low enough so that the escape clause is irrelevant. But the economic models generally suggest that the escape clause will be triggered -- so that the permit price would be as set in the escape clause (\$10 to \$20), not the higher amount that would be necessary to succeed in fully reducing emissions to their 1990 levels by 2010.
- In essence, this provides a guarantee. If our projections are too pessimistic, and we can achieve the target and timetable with a permit price in the \$10 to \$20 range, then there will be no need to invoke the escape clause. But if the costs turn out to be much higher, they will be capped and the economic exposure of the nation limited.

Environmental and International Political Ramifications

- The escape clause is likely to be criticized by other countries, who may argue that it makes it extremely unlikely that we will meet our ostensible target and timetable. Such criticism could damage our credibility worse than either of the other two approaches, since we will not be viewed as taking the process sufficiently seriously. Nonetheless, even if the escape clause is triggered and we fail to meet the target and timetable, we will still have made an important first step: a \$10 to \$20 charge per ton of carbon.
- Domestic environmental constituencies may exert pressure to retain the target and timetable, but remove the escape clause. If the escape clause is stripped away during the debate, the economic costs skyrocket.
- The approach does, however, have the important advantage of taking seriously the claims of the technology "optimists": if the promised benefits of technology do emerge, then this may be a credible plan for meeting our goal.