FOIA Number: 2017-1095-F

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Documents Protected by Executive Privilege Subject: Climate Change [2]

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SCENARIO 1
ADOPT BEST POLICIES CURRENTLY ACCEPTABLE IN INTERNATIONAL SPHERE, FIGHT FOR DOMESTIC RATIFICATION

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

No Annex I trading

- Permit price. A carbon price increase of between $70 and $120 per ton in 2010.

- Gas prices. Gas prices in 2010 would rise by between 18 and 30 cents per gallon.

- Coal prices. Coal prices in 2010 would rise by between $50 and $90 per ton, increases of between 150 and 350 percent 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 $2 and $4 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. The average family would pay between [$XX] more per year in direct (e.g., air conditioning bills) and indirect (e.g., airline tickets) costs from the increase in energy prices. The percentage increase in expenditures for the lowest decile is approximately six times the percentage increase for the highest decile.

With Annex I (developed economy) trading

- Permit price. Carbon prices in 2010 are expected to increase between $40 and $100 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.

- Effects on families. The average family would pay between [$XX and $XX] more per year in direct and indirect energy costs.

International reaction

- Kyoto agreement feasible, albeit not guaranteed. Developing economy issue addressed only by agreement in principle to have further discussions.

- Some criticism from Europeans and other countries may occur, for failing to propose a more aggressive target than 1990 levels by 2010.

Domestic reaction

- Hill. Kyoto agreement *extremely* unlikely to be ratified and will be attacked as massive energy tax hike. Given the clear instructions in the Byrd mandate, Congress is likely to be particularly irritated by the agreement reached. 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 economy stance. Firms in energy-intensive industries will be particularly opposed, and argue (regardless of the evidence) that their operations will flee the United States for other countries. Strong support is likely 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 (the environmental community has explicitly asked for 1990 by 2005).

- Labor. Significant concerns over costs imposed on industries such as steel and cement. Also, strong opposition from union workers in the coal industry and perhaps in the oil industry. The AFL-CIO indicated that to have its support, "every nation has to be in the regime, abiding by mutually agreed upon reduction regimes."

- 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, FIGHT FOR INTERNATIONAL ACCEPTANCE

Overall strategy

- Devise more economically efficient domestic policy, and then fight for international agreement
- Shifts focus from reducing *emissions* to stabilizing *concentrations*
- Makes agreement in December impossible
- Try to build strong domestic support for the most "sensible" approach -- which would reduce costs by allowing more natural turnover of the capital stock and include binding targets on developing countries, which would boost the environmental benefits.

Components

Target and timetable	Stabilize concentrations at twice pre-industrial levels (550 ppmv). U.S. emissions peak sometime between 2010 and 2020.
Domestic implementation	Tradeable permits (auctioned), or small tax (e.g., $5 per ton initially, rising over time). R&D and Federal energy efficiency programs
Developing country participation	Mandatory, binding targets for developing economies with relatively large total emissions or relatively high per capita incomes
International trading	International trading system among all participating countries

Energy price effects

- 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 would rise by an estimated 2 to 3 cents.

- Coal prices. Coal prices 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. The average family would spend between [$20 and $100] more per year from increased energy costs.

International reaction

- Kyoto agreement impossible: U.S. developing country stance tightened substantially (and our current stance is already unacceptable internationally), and target and timetable significantly less aggressive than European proposals.

- The U.S. is very likely to be blamed for undermining the current round of international negotiations (Rio II).

- Over time, we could try to build international support for our approach. Then any agreement that is ultimately reached internationally would have a chance at being ratified domestically.

Domestic reaction

- Hill. Failure of immediate international agreement may make domestic implementation package less of a political issue. Potentially some criticism for undermining current round of negotiations.

- Corporations. Many firms could decide that the focus on concentrations and the gradual approach to emissions reductions is the best they will be able to achieve. But most -- particularly in industries with large current emissions -- are likely to oppose strongly the auctioning or tax provisions.

- Environmental groups.
  [OPTION 1: Environmental groups criticize the failure of reaching an agreement in December.]

  [OPTION 2: Environmental groups support the focus on stabilizing concentrations, rather than emissions. They criticize the Administration for not adopting a more aggressive path toward that stabilized concentration level, but are generally supportive of the effort.]

- Labor. The AFL-CIO has indicated that, "If it takes another round of conversation and negotiations to find the right solution mix with our global partners -- the right balance, the right equitable mix -- then take the time to find the best solution."
- Elite media. Likely to criticize Administration for failing to tackle critical

policy challenge -- especially if severe weather events raise prominence of issue. But overall response probably depends on attitude of environmental groups; if the environmental groups accept the focus on concentrations despite a less aggressive emissions reduction path, it is unlikely that the issue will generate enough controversy to be of interest to the media.

- Think tanks and specialists. Economists likely to be supportive, although some dissidents will remain.

SCENARIO 3
ADOPT AGREEMENT IN KYOTO BUT DO NOT SUBMIT IMMEDIATELY FOR RATIFICATION, CONTINUE INTERNATIONAL NEGOTIATING PROCESS OVER DEVELOPING ECONOMIES

Overall strategy

- Recognizes the magnitude of the decisions involved in climate change policies, and that solution requires a series of steps over an extended period.
- Maintain balance between momentum in the international negotiations and crucial concerns over the participation of developing economies are addressed.
- Aims to achieve in Kyoto an interim agreement covering the developed economies, and an agreement on the next stage of negotiations -- which would involve mandatory, binding commitments for some developing economies.
- Ratification of the Kyoto agreement would be delayed until the developing economy negotiations are completed.

Components

Target and timetable	1990 levels by 2010 to 2020
Domestic implementation	Tradeable permits. R&D and Federal energy efficiency programs.
Developing country participation	Do not submit for ratification until mandatory, binding targets for developing economies with relatively large total emissions or relatively high per capita incomes
International trading	International trading system among all participating countries

Energy price effects

- Permit price.
- Gas prices.
- Coal prices.
- BTU-equivalent.
- Effects on families.

Reactions

International reaction

- Likely to be criticized by other countries for insisting on a stronger developing economy package before ratifying the putative Kyoto agreement. The U.S. target and timetable is also likely to be criticized as too weak,

- It is likely to prove quite difficult to get the crucial developing economies -- China, India, Mexico, Korea, etc. -- to agree to binding quantified targets. Concessions in other areas of our relationships with the developing economies may be necessary.

Domestic reaction

- Hill. The Hill may attack the Administration's acceptance of a binding target before locking in commitments from the developing economies. The period in between Kyoto and the second round of negotiations -- when developing economy commitments would be clarified -- may be particularly difficult.

- Corporations. Most corporations are likely to support the insistence on developing economy participation, but will nonetheless strongly attack the target and timetable as being overly aggressive. Indeed, the attack is likely to be nearly as strong as under Scenario 1, since the costs are similar. And we may be most vulnerable in between the stages of this strategy.

- Environmental groups. Environmental groups are likely to blame the President and Vice President for failing to submit a full agreement for ratification. It may falsely appear that we are playing games with the process.

- Labor. Labor is unlikely to oppose taking more time to reach an agreement. As noted above, Rich Trumka has indicated that it's worth waiting if necessary. But labor may still oppose the ultimate agreement, even if it includes a set of credible developing economy commitments, because of concerns over employment in specific heavily-affected industries (coal, steel, aluminum, etc.).

- Elite media. The elite media reaction is likely to be mixed. There may be some support for insisting on developing economy participation, but the potentially long delay in submitting the agreement for ratification may be criticized as reflecting a lack of political courage.

- Think tanks and specialists. Economists are likely to sharply critical of the 1990 by 2020 target.

SCENARIO 3

ADOPT AGREEMENT IN KYOTO BUT DO NOT SUBMIT IMMEDIATELY FOR RATIFICATION, CONTINUE INTERNATIONAL NEGOTIATING PROCESS OVER DEVELOPING ECONOMIES

Overall strategy

- Recognizes the magnitude of the decisions involved in climate change policies, and that solution requires a series of steps over an extended period

- Maintain balance between momentum in the international negotiations and concerns over the participation of developing economies

- Aims to achieve an interim agreement covering the developed economies, and a commitment to the next stage of negotiations -- which would involve mandatory, binding commitments for some developing economies.

- Ratification of the Kyoto agreement would be delayed until the developing economy negotiations are completed.

Components

Target and timetable	1990 levels by 2010 to 2020
Domestic implementation	Tradeable permits. R&D and Federal energy efficiency programs.
Developing country participation	Do not submit for ratification until mandatory, binding targets for developing economies with relatively large total emissions or relatively high per capita incomes
International trading	International trading system among all participating countries

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SGM
An I,
2020
2020 permit price
$22.0

Energy price effects

Annex I.
2010 or 2020

- Permit price. The permit price in 2010 would be somewhere between $25 and $100.

  seems high if we assume Annex I trading

- Gas prices. Gas prices would rise between 5 cents and 25 cents per gallon in 2010.

  6.8 cents w/ complete pass thru

  -26 in IAF

  $25/ton C => $13.52 w/ complete pass thru

  IAF indicates $52.52

- Coal prices. Coal prices would rise between $20 and $70 per ton in 2010.

  complete pass thru => $4.0

- BTU-equivalent. The coal price increase is equivalent to a BTU tax of between $0.75 and $3 per million BTU.

- Effects on families. Whether it's true or not, some critics might charge that the average family would face [$1,000] more per year in costs from the increase in energy prices.

9/5/97

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

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 level is arbitrary, and is inconsistent with the spirit of cost-benefit analysis. But it has the advantage of being analytically tractable.

Stabilization of concentrations at 550 ppmv

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 ppmv[1]). One might ask why we need accept a level of concentrations, and corresponding probability of catastrophe, as high as this. Indeed, why accept <u>any</u> 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 virtually 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. 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 [WGI], which entails Annex I fossil fuel emissions peaking in 1990, and falling 24 percent worldwide below 1990 levels by 2010.[2] (Of course, it is too late for this scenario to be realized. Below, we will also consider

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

[2] Worldwide emissions are up 8 percent in 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

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 the passage of seven years during which emissions manifestly have not in fact begun to fall in the overwhelming majority of countries.)

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 number would be lower if 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 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

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.[3] 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.[4]

The global numbers that Manne and Richels reported in their paper need to be broken down by region. In addition, we asked them 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 so 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

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emissions and the latter to all carbon emissions.)

[3] Also Manne and Richels (1995). Kosobud, et al (1994) examine alternative paths to achieve a given <u>temperature</u> 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.

[4] Based on 1990 populations. We consider alternative scenarios in Appendix _.. One alternative is 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.

Richels, 8/21 and 8/28/97.] Emissions do not return to their 1990 levels until after 2050. Emissions from developing countries peak in 2050. As noted, the sum of the two, total worldwide emissions, also peaks in 2050. Worldwide emissions return to their 1990 levels shortly before the end of the 21st century. 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.

The least cost mitigation path generates quite low values for carbon emissions rights after implementation in 2000. In 2010, the permit price is $2/ton 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 consistent with the burden sharing formula described earlier. The permit price estimates presuppose full global trading (where flexibility) but not intertemporal trading (when flexibility).

Change in emissions relative to 1990	Permit Price in 2010 ($/ton)	Permit Price in 2020 ($/ton)	Consumption Losses (trillions of dollars)[5]		
			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

It is important to keep in mind that the permit price estimates assume perfect global trading. Under this assumption, emission reductions occur where it is cheapest to do so regardless of geographic location. The following table permit prices in 2010 when Annex I emissions are constrained to 1990 levels under alternative assumptions about where flexibility.

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

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

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

2010" path. Thus the least cost mitigation path generates savings of 90 percent from WGI and 60 percent from the 1990 in 2010 path. (Most of this gain is also reflected in the WRE path, as described above.) 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.

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. 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.[6] (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 climatological, if the Annex I countries were constrained to the WRE path and 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 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%.[7]

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. 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

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

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

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.]

[The difference for concentrations can be crudely translated into an estimate of the effect on temperature in 2050 or 2100 by means of simple interpolation of IPCC estimates...]

Predecisional draft. Very preliminary. Close hold. Do not distribute. 8/29/97

Targets and Timetables

A U.S proposal for "targets and timetables" for reducing countries' emissions of greenhouse gases (GHG) must be made soon. No matter what the choice, the decision will inevitably be a tradeoff between costs and benefits. [The U.N. Framework Convention on Climate Change calls for cost-effective remedies to the problem.] A path of very aggressive reductions, relative to the business as usual path (BAU), is likely to entail higher economic costs, but also higher benefits in terms of averted GHG concentrations in the atmosphere and disruption to the climate. A less aggressive path is likely to entail lower economic costs, and lower climate benefits. The 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.

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. 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.[1] 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 "back-stop technology" will eventually be developed, thereby putting a limit on how 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 now contemplated 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.)

Analogy with the oil shocks of the 1970s

Another standard of comparison 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 the 1973-74 and 1979-80 oil price increases combined. Again, this is for a weighted average of primary fuels. Fossil fuel prices net of inflation doubled between 1972 and 1975, and

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[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).

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.

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. (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 that are announced well ahead of time will be fully built into the expectations of firms and workers. Thus they will be able to plan ahead and avoid serious microeconomic dislocation and macroeconomic disturbance. 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.]

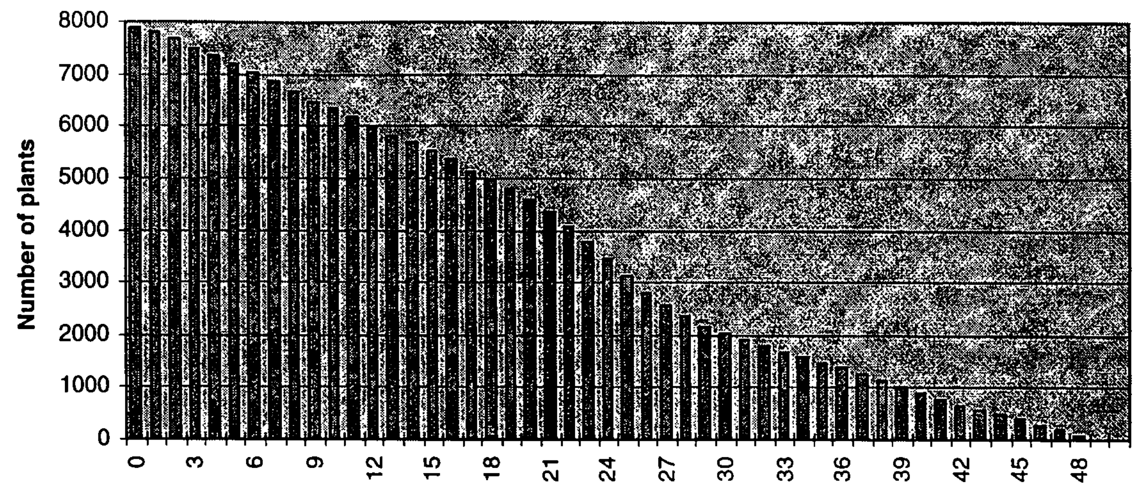
The role of turnover of the capital stock

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 later), (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 Section 2 below.) But the most important reason for waiting is 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.

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 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 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

Figure 1: Accelerated Replacement of Electric Power Plants



Bar height shows number of plants to replace (beyond normal replacement schedule) if complete change-over occurs within number of years shown on axis

a 50-year life there would be no additional cost to replacing them. [We have truncated the distribution at 50 years, the average lifespan of existing electric power plants. There are other plants that are still in use 60, 70, or even 90 years after they were built. But their numbers are small, and by the end of 50 years the cost of shutting them down would in any case be much-reduced.]

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. 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.

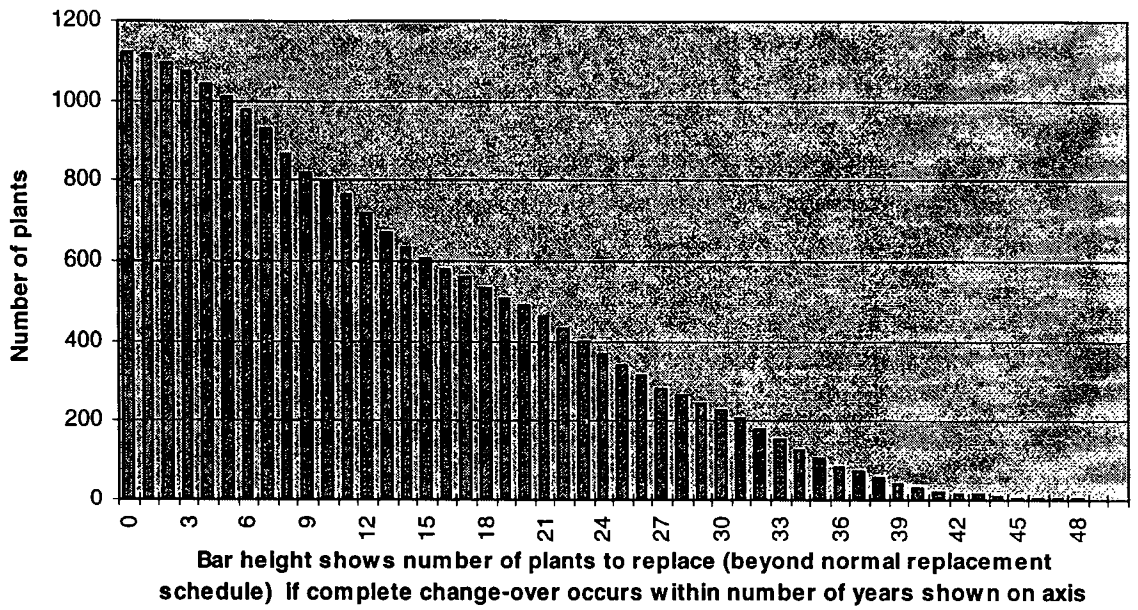


Figure 2a: Accelerated Replacement of Coal Plants

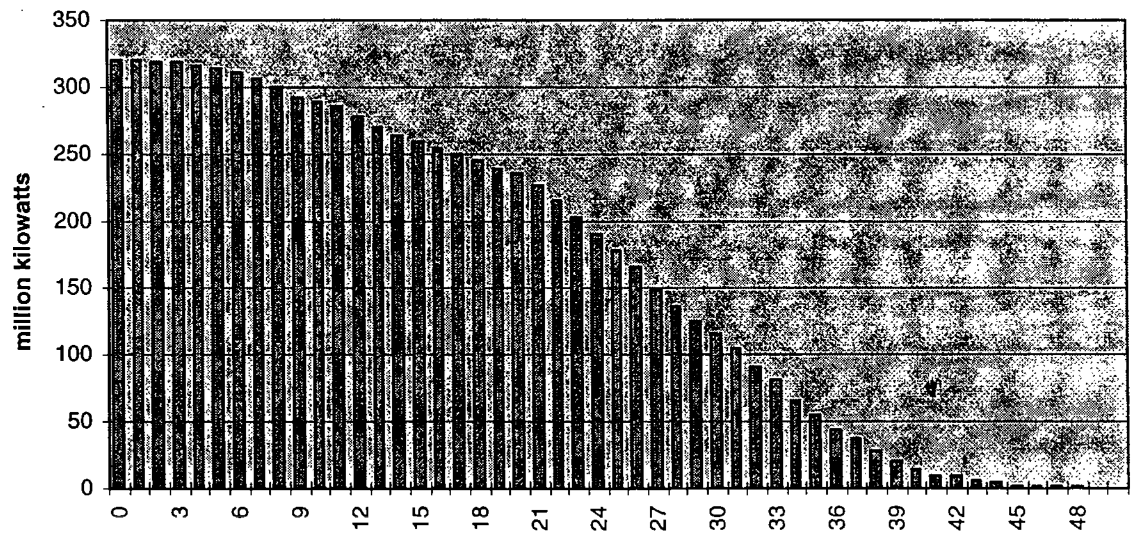
2. Cost-benefit analysis in the Integrated Assessment models

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 costs of climate change in the distant future, as well as the economic costs of programs to address emissions, and to compare the two.

By now many of these models exist. They tend all 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. [a bit of elaboration on Nordhaus (1994), etc., e.g. from IPCC summary.] 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 the 22nd century.

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____]. In other words, the economic costs of "1990 levels by 2010" outweigh the

Figure 2b: Accelerated Replacement of Coal Plant Capacity



Bar height shows coal capacity to replace (beyond normal replacement schedule) if complete change-over occurs within number of years shown on axis

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 catastrophe, such as the melting of the West Antarctic ice sheet [which might raise ocean levels by __], a runaway greenhouse effect (e.g., from methane release), or structural changes in ocean currents such as the Gulf Stream. [references: Schelling AER ___; __]
- 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). [reference : Cline...]
- 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. [ref.: Pizer..]
- 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. Only early concrete measures will send the signal necessary to move people's patterns of research, investment, and consumption onto the new path.

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

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 level is arbitrary, and is inconsistent with the spirit of cost-benefit analysis. But it has the advantage of being analytically tractable.

Stabilization of concentrations at 550 ppmv

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 ppmv[2]). One might ask why we need accept a level of concentrations, and corresponding probability of catastrophe, as high as this. Indeed, why accept <u>any</u> 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 virtually 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.

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

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. 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 [ ], which entails Annex I fossil fuel emissions peaking in 1990, and falling 24 percent worldwide below 1990 levels by 2010.[3] (Of course, it is too late for this scenario to be realized. 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 the passage of seven years during which emissions manifestly have not in fact begun to fall in the overwhelming majority of countries.)

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 consumption loss of $8.6 trillion. (The number would be lower if 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 cost of ~~$1.78~~ trillion. (With 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.

1.57 adjustment made for Sov Un

The least-cost mitigation path

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.[4] They must necessarily make some assumption about international burden-sharing. The particular question is as follows: how much can we insist that

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[3] Worldwide emissions are up 8 percent in 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.)

[4] Also Manne and Richels (1995). Kosobud, et al (1994) examine alternative paths to achieve a given <u>temperature</u> 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.

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.[5]

The global numbers that Manne and Richels reported in their paper need to be broken down by region. In addition, we asked them 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 so unlikely. Their model implies that the optimal 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 8/28/97.] Emissions do not return to their 1990 levels until after 2050. Emissions from developing countries peak in 2050. As noted, the sum of the two, total worldwide emissions, also peaks in 2050. Worldwide emissions return to their 1990 levels shortly before the end of the 21st century. 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.

$156

Do these values assume intl (WW) trade?

The optimal path shows the ~~value~~ of carbon emission rights starting ~~at~~ quite low levels ~~after~~ implementation in 2000, a mere $2.~~00~~/ton in 2010, and rising only gradually through ~~the~~ first half of the 21st century. Only in the ~~latter~~ part of the century does it rise strongly, to $1~~28~~ ton. This is a sharp contrast to what happens if one imposes an arbitrary constraint on the level of emissions in 2010.[6] If emissions are constrained to 10% above 1990 levels, the price jumps to $15/ton in 2010, rising to $28 by 2020. If the constraint is the much-discussed target of 1990 levels by 2010, the price rises more steeply, to $37/ton in 2010 and $70/ton in 2020. If the constraint is a still more ambitious target of cutting emissions 10%, the price goes to $54/ton in 2010 and $102 in 2020. Under these alternatives, if no constraints are imposed for the remainder of the century, other than the constraint of terminal concentrations at 550 ppmv, then the price of carbon {and the level of emissions?} snaps back almost to the same low level as under the optimal path. This reflects that the 2010 emission constraints -- any of the three possibilities -- are sharp deviations from the economically efficient least-cost path.

See table in fax

Do we want this assumption?

least-cost mitigation .556 global, not US

According to Manne and Richels, their ~~optimal~~ path costs $0.54~~5~~ trillion in terms of lost consumption (present discounted value), as compared to $3.3 trillion under the IPCC Working Group path [and as compared to _ trillion under the "1990 in 2010" path]. Thus the optimal path generates

.939 US: .303 US: 1.28 US: .124

assumes full global trading

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[5] Based on 1990 populations. We consider alternative scenarios in Appendix _.. One alternative is 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.

expand w/ US, Annex I

[6] This constraint is maintained through 2030, at which time the transition to full developing-country participation with equal per capital emission levels results in a reduction in Annex I countries.

savings of 83 percent from WG1 [and __ % from the 1990 in 2010 path]. (Most of this gain is also reflected in the WRE path, as described above. These paths allow emissions in 2000 to fall below BAU.) 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.

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. 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.[7] (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 climatological, if the Annex I countries remained on the same path (peaking in 2020-2030). The economic effects are not very different from the case where developing countries do participate. The world price of oil is presumably higher, because the developing countries do not curb their consumption. But the adverse economic effects on the Annex I countries is very small. The loss in welfare (present discounted value of consumption) is $.795 trillion, not much worse than the $.77 trillion cost that we saw when the developing countries were in. [This is the WRE path? Or the least-cost path?] Overall, concerns about adverse effects on the competitiveness of energy-intensive manufactures do not show up at the aggregate level...

replace w/ text

The effects on concentrations of omitting the developing countries, however, are large. Global emissions continue to grow at... Global concentrations go to __ in 2050 and __ in 2100.

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 ~~emissions~~ concentrations only 7 % below BAU levels in the year 2100. This is less than a third of the ~~emission~~ reductions achieved when the developing countries participate [22%; conversation 8/28] This result illustrates the problem of free riding. 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,

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

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.]

[The difference for concentrations can be crudely translated into an estimate of the effect on temperature in 2050 or 2100 by means of simple interpolation of IPCC estimates...]

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. One 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.

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," 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 per cent. 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) is reduced by a mere .03 degrees.. While different observers will weight the economic costs and climate benefits in different ways, the percentage increase in costs from early action seems far greater than the percentage reduction in concentrations and warming. (This conclusion omits that concentrations continue to rise in subsequent centuries. It also leaves out the major argument for early action mentioned earlier: political credibility of an announced long-term plan.)

Table 4

Climate and Economic Variables under Alternative Emissions Paths *

		Concentration Level (ppmv)		Year at Which Concentration Reaches 2x Pre-Industrial Level **	Change in Temperature from 1990 Level (Celsius)	
	Year	2050	2100		2050	2100
	Business As Usual (BAU)	522.1	729.8	2058	1.15	2.45
Deviation from BAU:						
Annex I Participation Only	1990 -10% beginning in 2010	-30.3	-95.0	+15	-0.13	-0.36
	1990 beginning in 2010	-24.8	-83.4	+12	-0.10	-0.31
	peak in 2015, 1990 in 2040	-17.6	-77.6	+9	-0.06	-0.28

		Carbon Permit Price ($ per ton): Domestic Trading		Carbon Permit Price ($ per ton): Annex I Trading		Consumption *** (billions of $)
		2010	2050	2010	2050	
	Business As Usual (BAU)	0.00		0.00		183,155
Deviation from BAU:						
Annex I Participation Only	1990 -10% beginning in 2010	+175	+924	+91	+238	-1630
	1990 beginning in 2010	+110	+582	+42	+149	-1126
	peak in 2015, 1990 in 2040	+0	+559	+0	+155	-498

Summary description

A plan to return carbon emissions to their 1990 levels by 2010 postpones by 12 years the date at which CO2 concentrations reach twice pre-industrial levels. Global warming would be reduced by 0.31 degrees by the year 2100 versus an estimated 2.45 degrees under BAU. Under this emissions path the value of the estimated foregone consumption is $1.126 trillion.

A less ambitious path -- "eliminate emissions growth by 2010-2020" -- would postpone the doubling date by 3 years less, and would lead to another 0.03 degrees of warming. But, the economics would become much easier: The value of foregone consumption would be only $498 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.
*** Domestic Trading Only. Annex I or worldwide Trading may substantially reduce these costs. Deviations are foregone consumption assuming a 3% discount rate.

August 29, 1997

Sources and Explanations

Sources

Business As Usual (BAU) emissions projections are based on published IPCC IS92a emissions profiles. BAU concentration and temperature projections are from the MiniCAM model. Carbon permit price estimates and foregone consumption figures are from SGM model. All these 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.

Worldwide Participation: All nations including developing countries are assumed to comply fully with the same targets and timetables.

Targets and Timetables

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

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

Price Assumptions

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

Consumption: Deviations are 1995 present value of foregone consumption differences for United States in millions of dollars between BAU and scenarios. Consumption estimates go only to the year 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 Wilcoxen (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

[to be added]

References

Cline, William, 1992, The Economics of Global Warming, Institute for International Economics: Washington, DC.

Energy Modeling Forum, 1994, Reducing Global Carbon Dioxide Emissions: Costs and Policy Options, EMF Report 12, Stanford University, November 8.

Gaskins, Darius, and John Weyant, 1993 (?), "Model Comparisons of the Costs of Reducing CO2 Emissions," American Economic Review 83, no. 2, 318-323.

IPCC Working Group 3, 1995.

Jorgenson?

Kosobud, R., T. Daly, D.South and K. Quinn, 1994, "Tradable Cumulative CO2 permits and Global Warming Control," Energy Journal 15, no.2, 213-232.

Manne, Alan, and Richels, Richard, 1997, On Stabilizing CO2 Concentrations--Cost-Effective Emission Reduction Strategies, Workshop on Design of International Emissions Trading Systems, Aug 12-14. Forthcoming, Environmental Modeling and Assessment, The Netherlands.

Manne, Alan, and Richels, Richard, 1995, "The Greenhouse Debate: Economic Efficiency, Burden Sharing and Hedging Strategies," Energy Journal 16, no.4, 1-37.

McKibbin, Warwick, and Peter Wilcoxen, 1997, "A Better Way to Slow Global Climate Change," The Brookings Institution, Washington, DC, March.

Nordhaus, William, 1994, Managing the Global Commons: The Economics of Climate Change. MIT Press, Cambridge, MA

Nordhaus, Bill, 1997, "Climate Allowances Protocol (CAP): Comparison of Alternative Global Tradable Emissions Regimes," Yale University, June 17.

Peck, S. And T. Teisberg, 1992, "CETA: A Model for Carbon Emissions Trajectory Assessment," The Energy Journal 13, no. 1, 55-77.

Pizer, William A, Optimal Choice of Policy Instrument and Stringency Under Uncertainty: The Case of Climate Change, Resources for the Future, Discussion Paper 97-17, Dec 96

Repetto, Robert, and Austin, Duncan, The Costs of Climate Protection: A Guide for the Perplexed, World Resources Institute, 1997.

Wigley, T.M.L., Richels, R, and Edmonds, J.A., Economic and Environmental Choices in the Stabilization of Atmospheric CO2 Concentrations, Nature, Vol 379, Jan 18, 96

Spell check

Predecisional draft. Very preliminary. Close hold. Do not distribute. 8/29/97

Targets and Timetables

A U.S proposal for "targets and timetables" for reducing countries' emissions of greenhouse gases (GHG) must be made soon. No matter what the choice, the decision will inevitably be a tradeoff between costs and benefits. A path of very aggressive reductions, relative to the business as usual path (BAU), is likely to entail higher economic costs, but also higher benefits in terms of averted GHG concentrations in the atmosphere and disruption to the climate. A less aggressive path is likely to entail lower economic costs, and lower climate benefits. The 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.

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. 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.[1] 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 "back-stop technology" will eventually be developed, thereby putting a limt on how 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 now contemplated 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.)

Analogy with the oil shocks of the 1970s

Another standard of comparison 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 the 1973-74 and 1979-80 oil price increases combined. Again, this is for a weighted average of primary fuels. Fossil fuel 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

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[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).

percent from 1974 to 1981. Coal, as a substitute for oil, also experienced a price increase in the earlier episode, but by much less.

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. (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 that are announced well ahead of time will be fully built into the expectations of firms and workers. Thus they will be able to plan ahead and avoid serious microeconomic dislocation and macroeconomic disturbance. 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.]

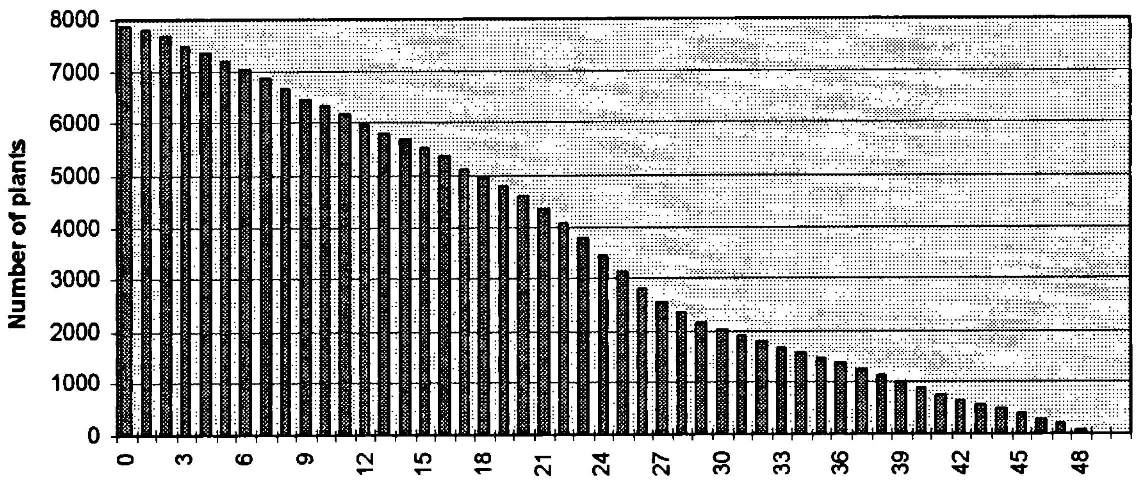
The role of turnover of the capital stock

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 allowing for uncertainty to be resolved, and 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 Section 2 below.) But the most important reason for waiting is 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 plantsand 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 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 Five-Labs study]. But it may be useful to look at a simple illustration of the point, for the case of the capital stock inpower generation. Figure 1 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. [We have truncated the distribution at 50 years, the average lifespan of existing electric power plants. There are other plants that are still in use 60, 70, or even 90 years after they were built. But their numbers are small, and by the end of 50 years the

Figure 1: Accelerated Replacement of Electric Power Plants



Bar height shows number of plants to replace (beyond normal replacement schedule) if complete change-over occurs within number of years shown on axis

cost of shutting them down would in any case be much-reduced.]

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. 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.

how much of this is of the total electricity output of the sector

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.

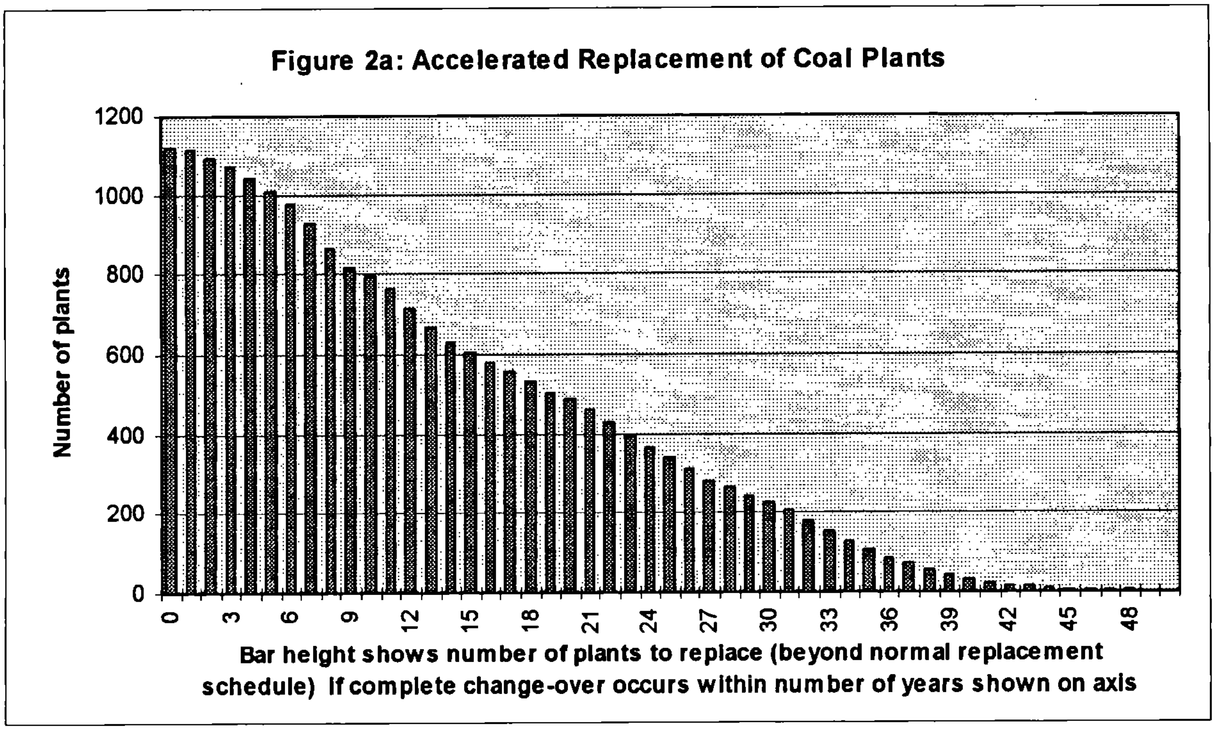


Figure 2a: Accelerated Replacement of Coal Plants
Number of plants
1200
1000
800
600
400
200
0
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Bar height shows number of plants to replace (beyond normal replacement schedule) if complete change-over occurs within number of years shown on axis

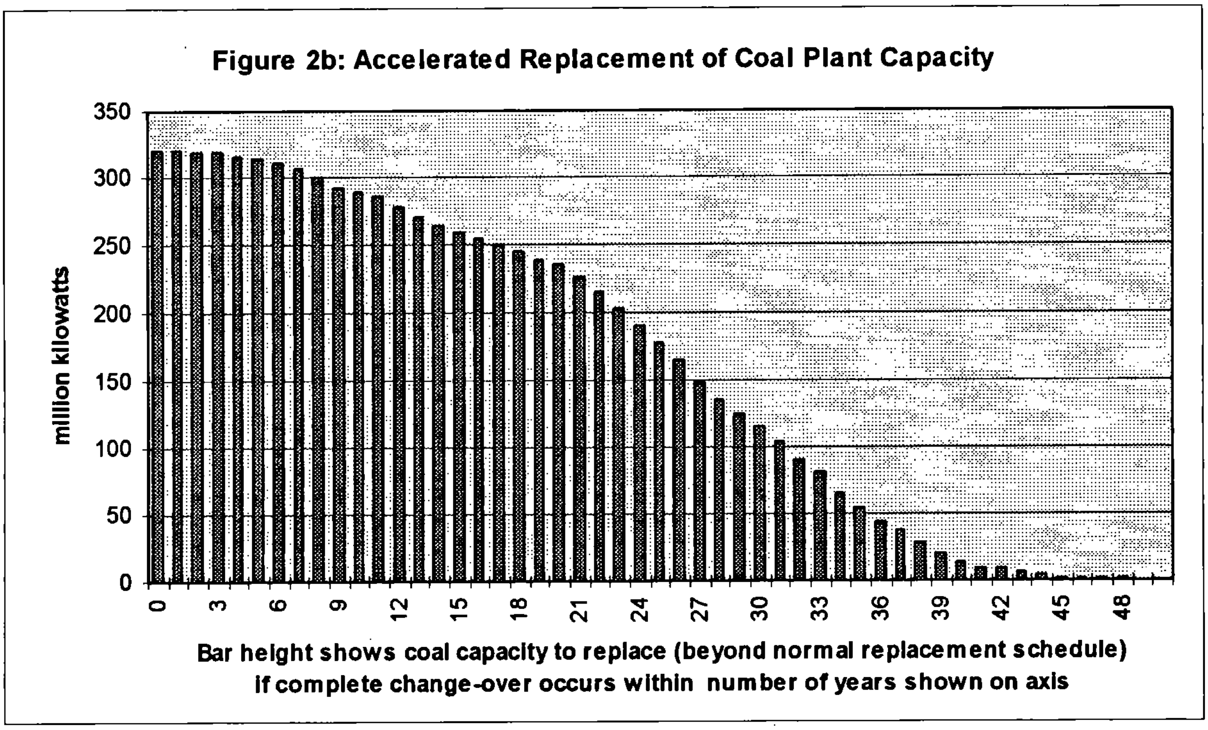
2. Cost-benefit analysis in the Integrated Assessment models

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 costs of climate change in the distant future, as well as the economic costs of programs to address emissions, and to compare the two.

By now many of these models exist. They tend all 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. [a bit of elaboration on Nordhaus, IPCC summary, Peck-Tiesberg (CETA) and others, with footnotes. Do any call for emissions peaking, e.g., in the 22nd century?] fill in

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____]. In other words, the economic costs of "1990 levels by 2010" outweigh the benefits. — explicit in Nordhaus paper fill in

move to p. 4



fill in

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 catastrophe, such as the melting of the West Antarctic ice sheet [which might raise ocean levels by __], a runaway greenhouse effect (e.g., from methane release), or structural changes in ocean currents such as the Gulf Stream. [references: Schelling AER ___; __]
- 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). [reference : Cline...]
- 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. [ref.: Pizer..]
- 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. Only early concrete measures will send the signal necessary to move people's patterns of research, investment, and consumption onto the new path.

3. Estimates of optimal paths to stabilize concentration levels

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 level is arbitrary, and is inconsistent with the spirit of cost-benefit analysis. But it has the advantage of being analytically tractable.

Stabilization of concentrations at 550 ppmv

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 ppmv[2]). One might ask why we need accept a level of concentrations, and corresponding probability of catastrophe, as high as this. Indeed, why accept <u>any</u> 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 virtually 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.

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

sq.

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. 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 and climate. The proposed path they examine is the IPCC Working Group path 1 [ ], which entails Annex I fossil fuel emissions peaking in 1990, and falling 2% worldwide below 1990 levels by 2010.[3] (Of course, it is too late for this scenario to be realized. 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 the passage of seven years during which emissions manifestly have not in fact begun to fall.)

WG I

disc rate + time horizon

fn: note

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 consumption loss of $8.6 trillion. (The number would be lower if international trading were allowed -- $3.3 trillion. On the other had, 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 cost of $1.776 trillion. (With global trading, it is $0.77 trillion.) Thus the saving from letting emissions continue to rise as late as 2010 is more than three-quarters of the cost.

need consistent sig figs

WRE do not consider whether other paths might reach the same goals at still lower costs.

The optimal path

Manne and Richels (1997) is believed to be the first paper to compute the economically-optimal path (again, using the MERGE model) subject to the constraint of stabilizing concentrations at a level such as 550 ppmv. 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

[3] Worldwide emissions are up 8 percent in 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.)

this needs clarification → is it BAU

↳ is this all C or all CE

industrialized countries by 2050. [4]

The global numbers that Manne and Richels reported in their paper need to be broken down by region. In addition, we asked them 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 so unlikely. Their model implies that the optimal path has emissions from OECD countries, as well as from other Annex I countries, 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 8/28/97.] Emissions do not return to their 1990 levels until after 2050. Emissions from developing countries peak in 2050. As noted, the sum of the two, total worldwide emissions, also peaks in 2050. Worldwide emissions return to their 1990 levels shortly before the end of the 21st century. 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.

The optimal path shows the value of carbon emission rights starting at quite low levels after implementation in 2000, a mere $2.00/ton in 2010, and rising only gradually through the first half of the 21st century. Only in the latter part of the century does it rise strongly, to $128 ton. This is a sharp contrast to what happens if one imposes an arbitrary constraint on the level of emissions in 2010. If emissions are constrained to 10% above 1990 levels, the price jumps to $36/ton. If the constraint is the much-discussed target of 1990 levels by 2010, the price rises more steeply, to $91/ton. If the constraint is a still more ambitious target of cutting emissions 10%, the price goes to $161/ton. Under these alternatives, if no constraints are imposed for the remainder of the century, other than the constraint of terminal concentrations at 550 ppmv, then the price of carbon {and the level of emissions?} snaps back almost to the same low level as under the optimal path. This reflects that the 2010 emission constraints -- any of the three possibilities -- are sharp deviations from the economically efficient least-cost path.

According to Manne and Richels, their optimal path costs $0.545 trillion in terms of lost consumption (present discounted value), as compared to $3.3 trillion under the IPCC Working Group path. (Thus the saving under the optimal path is 83 percent. (Most of this gain is also reflected in the WRE path, as described above. These paths allow emissions in 2000 to fall below BAU.) 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.

We should make comparisons directly to 1990 in 2010 variants, not WGI

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[4] We consider alternative scenarios in Appendix _.. One alternative is 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.

and $X trillion under the 1990 in 2010 path

Thus the optimal path generates savings of 83% + X% from WGI + 1990 in 2010 paths.

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. 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.[5] (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 climatological, if the Annex I countries remained on the same path (peaking in 2020-2030). The economic effects are not very different from the case where developing countries do participate. The world price of oil is higher [by __], because the developing countries do not curb their consumption. This affects the Annex I countries as follows ... Overall, concerns about adverse effects on the competitiveness of energy-intensive manufactures do not show up at the aggregate level...

The effects on concentrations of omitting the developing countries, however, are large. Global emissions continue to grow at... Global concentrations go to __ in 2050 and __ in 2100. 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 emissions only 7 % below BAU levels in the year 2100. This is less than a third of the emission reductions achieved when the developing countries participate [22% or 26%, depending the definition of emissions; conversation 8/28] This result illustrates the problem of free riding. 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 would be even greater. [The difference for concentrations can be crudely translated into an estimate of the effect on temperature in 2050 or 2100 by means of simple interpolation of IPCC estimates...]

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. One 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.

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

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," 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 per cent. 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) is reduced by a mere .03 degrees.. While different observers will weight the economic costs and climate benefits in different ways, the percentage increase in costs from early action seems far greater than the percentage reduction in concentrations and warming. (This conclusion leaves out the major argument for early action mentioned earlier: political credibility of an announced long-term plan.)

Table 4

Climate and Economic Variables under Alternative Emissions Paths *

		Concentration Level (ppmv)		Year at Which Concentration Reaches 2x Pre-Industrial Level **	Change in Temperature from 1990 Level (Celsius)	
	Year	2050	2100		2050	2100
	Business As Usual (BAU)	522.1	729.8	2058	1.15	2.45
Deviation from BAU:						
Annex I Participation Only	1990 -10% beginning in 2010	-30.3	-95.0	+15	-0.13	-0.36
	1990 beginning in 2010	-24.8	-83.4	+12	-0.10	-0.31
	peak in 2015, 1990 in 2040	-17.6	-77.6	+9	-0.06	-0.28

		Carbon Permit Price ($ per ton): Domestic Trading		Carbon Permit Price ($ per ton): Annex I Trading		Consumption *** (billions of $)
		2010	2050	2010	2050	
		0.00		0.00		39,422
Annex I Participation Only	1990 -10% beginning in 2010	+175	+924	+91	+238	-299.2
	1990 beginning in 2010	+110	+582	+50	+149	-205.7
	peak in 2015, 1990 in 2040	+0	+560	+0	+155	-94.7

Summary description

A plan to return carbon emissions to their 1990 levels by 2010 postpones by 12 years the date at which CO2 concentrations reach twice pre-industrial levels. Global warming would be reduced by 0.31 degrees by the year 2100 versus an estimated 2.45 degrees under BAU. Under this emissions path the value of the estimated foregone consumption is $205.7 billion.

A less ambitious path -- "eliminate emissions growth by 2010-2020" -- would postpone the doubling date by 3 years less, and would lead to another 0.03 degrees of warming. But, the economics would become much easier: The value of foregone consumption would be only $94.7 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.

*** Domestic Trading Only. Annex I or WorldWide Trading may substantially reduce these costs. Deviations are foregone consumption up to 2050 assuming a 3% discount rate.

Sources and Explanations

Sources

Business As Usual (BAU) emissions projections are based on IAT emissions profiles. BAU concentration and temperature projections are from the MAGICC model. Carbon permit price estimates and foregone consumption figures are from SGM model. All these 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.

Worldwide Participation: All nations including developing countries are assumed to comply fully with the same targets and timetables.

Targets and Timetables

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

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

Price Assumptions

Carbon: U.S. permit prices for the policy options to attain 1990 emissions level in 2010 and 10% below 1990 emissions level in 2010 are from the DRI model used by EPA, which assumes that all revenues are used to improve the federal budget. The estimated permit price necessary under the policy option that peaks in 2015 is a linear interpolations based on these models.

Consumption: Deviations are 1995 present value of foregone consumption differences for U S in millions of dollars between BAU and scenarios. Consumption estimates go only to the year 2050.

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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. Examples 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.

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 Wilcoxen ( ) 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) can 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 wee incurred

References

Cline, William, 1992, The Economics of Global Warming, Institute for International Economics: Washington, DC.

Energy Modeling Forum, 1994, Reducing Global Carbon Dioxide Emissions: Costs and Policy Options, EMF Report 12, Stanford University, November 8.

Gaskins, Darius, and John Weyant, 1993 (?), "Model Comparisons of the Costs of Reducing CO2 Emissions," American Economic Review 83, no. 2, 318-323.

IPCC Working Group 3, 1995.

Jorgenson?

Manne, Alan, and Richels, Richard, On Stabilizing CO2 Concentrations--Cost-Effective Emission Reduction Strategies, Workshop on Design of International Emissions Trading Systems, Aug 12-14, 97

McKibbin, Warwick, and Peter Wilcoxen, 1997, "A Better Way to Slow Global Climate Change," The Brookings Institution, Washington, DC, March.

Nordhaus

Nordhaus, Bill, 1997, "Climate Allowances Protocl (CAP): Comparison of Alternative Global Tradable Emissions Regimes," Yale University, June 17.

Pizer, William A, Optimal Choice of Policy Instrument and Stringency Under Uncertainty: The Case of Climate Change, Resources for the Future, Discussion Paper 97-17, Dec 96

Repetto, Robert, and Austin, Duncan, The Costs of Climate Protection: A Guide for the Perplexed, World Resources Institute, 1997.

Wigley, T.M.L., Richels, R, and Edmonds, J.A., Economic and Environmental Choices in the Stabilization of Atmospheric CO2 Concentrations, Nature, Vol 379, Jan 18, 96

Targets and Timetables

A U.S. proposal for "targets and timetables" for reducing countries' emissions of greenhouse gases (GHG) must be made soon. No matter what the choice, the decision will inevitably be a tradeoff between costs and benefits. A path of very early and aggressive reductions, relative to the business as usual path (BAU), is likely to entail higher economic costs, but also higher benefits in terms of averted GHG concentrations in the atmosphere and disruption to the climate. A less aggressive path is likely to entail lower economic costs, and lower climate benefits. The tradeoff has to be made. The subject of this paper is how to do it.

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. 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 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. 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.]

This 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 now contemplated 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.)

Analogy with the oil shocks of the 1970s

Another standard of comparison 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 the 1973-74 and 1979-80 oil price increases combined. Again, this is for a weighted average of primary fuels. Fossil fuel 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.

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. (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 that are announced well ahead of time will be fully built into the expectations of firms and workers. Thus they will be able to plan ahead and avoid serious microeconomic dislocation and macroeconomic disturbance. 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.]

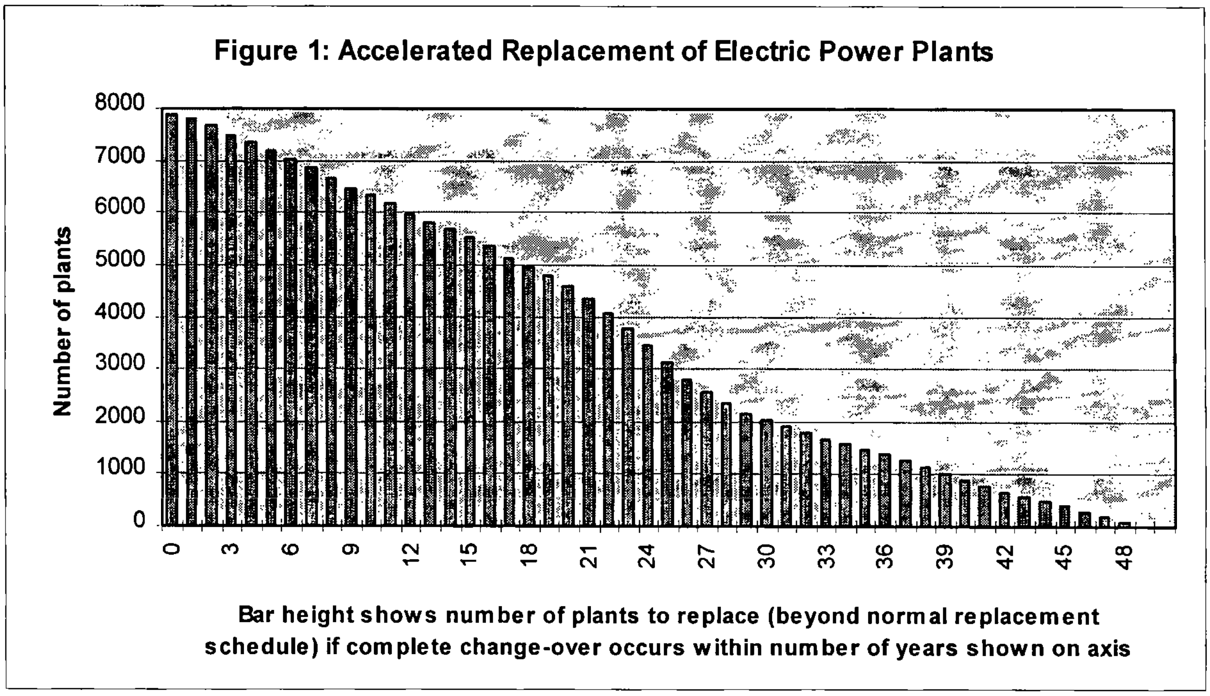
The role of turnover of the capital stock

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 allowing for uncertainty to be resolved, and 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 Section 2 below.) But the most important reason for waiting is 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.

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; but not into most "bottom-up" engineering studies, like the 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 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. [We have truncated the distribution at 50 years, the average lifespan of existing electric power plants. There are other plants that are still in use 60, 70, or even 90 years after they were built. But their numbers are small, and by the end of 50 years the cost of shutting them down would in any case be much-reduced.]

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. 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.

Figure 2a: Accelerated Replacement of Coal Plants

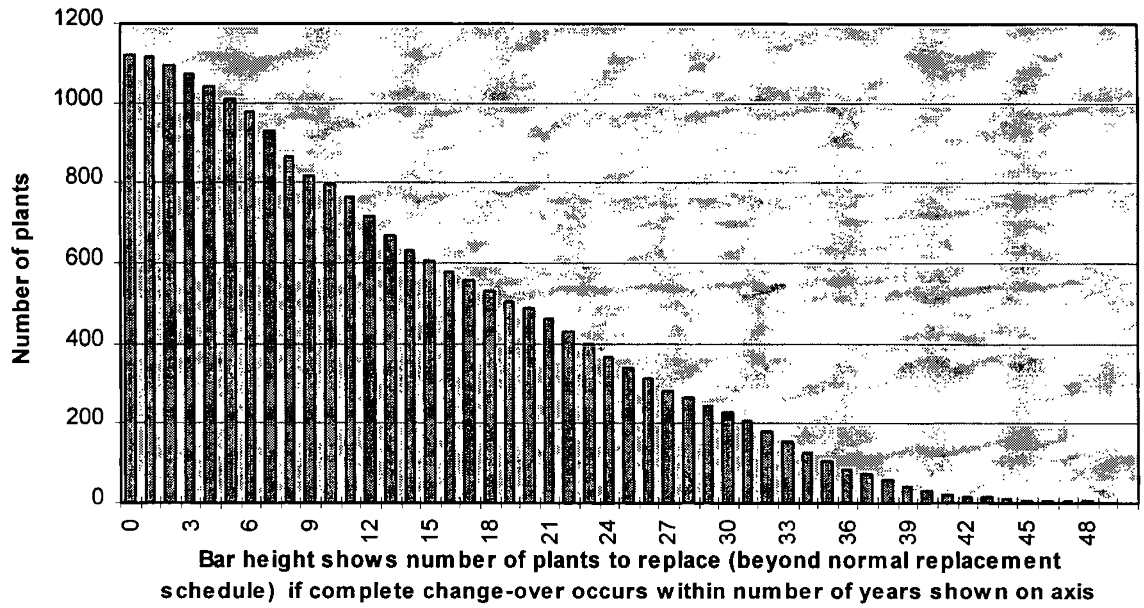
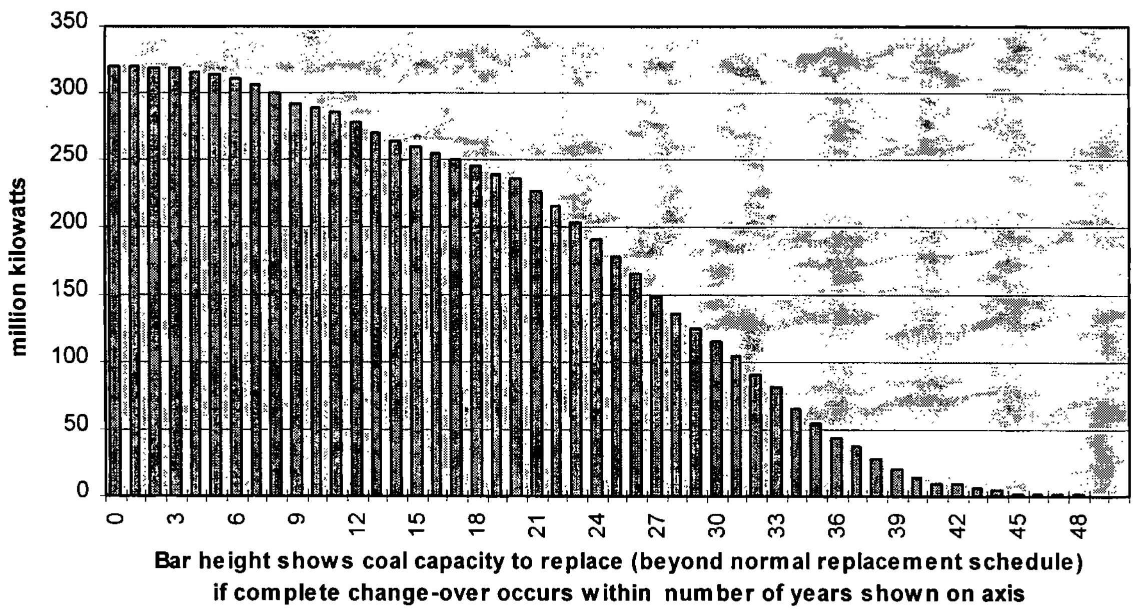


Figure 2b: Accelerated Replacement of Coal Plant Capacity



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 it all into one framework.

By now many of these models exist. They tend all 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. [a bit of elaboration on Nordhaus, IPCC summary, Peck-Tiesberg (CETA) and others, with footnotes. Do any call for emissions peaking, e.g., in the 22nd century?]

Some of the authors have characterized the gap between the optimal paths that their models produce and the frequently heard proposal to return emissions to 1990 levels by 2010 in a striking way: 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 ____]. 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 catastrophe, such as the melting of the West Antarctic ice sheet [which might raise ocean levels by __], a runaway greenhouse effect (e.g., from methane release), or structural changes in ocean currents such as the Gulf Stream. [references: Schelling AER ___; __]
- Some claim that it gives insufficient weight to the welfare of future generations (that is, the discount rate is too high). [reference : Cline...]
- 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. [ref.: Pizer..]
- 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. Only early concrete measures will send the signal necessary to move people's patterns of research, investment, and consumption onto the new path.

3. Estimates of optimal paths to stabilize concentration levels

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 level is arbitrary, and is inconsistent with the spirit of cost-benefit analysis. But it has the advantage of being analytically tractable.

Stabilization of concentrations at 550 ppmv

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 ppmv). One might ask why we need accept a level of concentrations, and corresponding probability of catastrophe, as high as this. Indeed, why accept <u>any</u> 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 virtually 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.

Published results from the MERGE model

Wigley, Richels and Edmonds (1996) [WRE] examined the costs associated with some plausible 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 2100. 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. (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. [This description of the breakdown of the WRE results comes from Manne-Richels (1997).]

WRE argue that this path has much lower economic costs than paths -- such as the IPCC Working Group path [ ] or "1990 levels by 2010" -- that are more aggressive in terms of timing, while producing the same terminal effects on concentration and climate. The IPCC Working Group path shows a total loss (present dicounted value of consumption) of $8.6 trillion. (The number would be lower if international trading were allowed -- $3.3 trillion -- but higher if the developing countries do not participate.) The more moderate WRE path toward the same concentration goal entails far smaller costs: a total loss of $1.776 trillion. (With global trading, it is $0.77 trillion.) Thus the saving is more than three-quarters.

WG 1

WRE do not consider whether other paths might reach the same goals at still lower costs.

The optimal path

Manne and Richels (1997) is believed to be the first paper to compute the economically-optimal path (again, using the MERGE model) subject to the constraint of stabilizing concentrations at a level such as 550 ppmv. 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. [We consider alternative scenarios in Appendix _.. One is that a small number of middle-income countries begin to limit emissions by 2010. Another is that the developing countries do not participate at all.]

The Manne and Richels global numbers need to be broken down by region. Their model implies that the optimal path has emissions from OECD countries, as well as from other Annex I countries, peaking in 2020 (similar to WRE). [Source: personal communication from Richels, 8/21/97.] Emissions do not return to their 1990 levels until the decade ___. Emissions from developing countries peak in 2050. (As noted, the sum of the two, total worldwide emissions, also peak in 2050. By mid-century, developing countries are such an important source of emissions that they dominate the global peaking date.)

The best single measure of aggregate economic costs is the present discounted value (i.e, the appropriate summation over time) of foregone consumption. According to Manne and Richels, their optimal path costs $0.545 trillion in terms of lost consumption, as compared to $3.3 trillion under the IPCC Working Group path. Thus the saving under the optimal path is 83 percent. (Most of this gain is also reflected in the WRE path, as described above.)

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 these. What if, as is more likely, the commitments extracted from developing countries are less strong than the Manne-Richels burden-sharing schedule, 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. 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. (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 climatological, if the Annex I countries remained on the same path (peaking in 2010-2020 [?]). The economic effects are not very different from the case where developing countries do participate. The world price of oil is higher [by __], because the developing countries do not curb their consumption. This affects the Annex I countries as follows ... Overall, concerns about adverse effects on the competitiveness of energy-intensive manufactures do not show up at the aggregate level...

The effects on concentrations of omitting the developing countries, however, are large... (These are the effects of leakage and free-riding.) The difference for concentrations can be crudely translated into an estimate of the effect on temperature in 2050 or 2100 by means of simple interpolation of IPCC estimates...

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 2010-2020 [?] and returning to 1990 levels in 20__. The paths for emission reductions that have been discussed in the international negotiations are more aggressive. One that has been widely discussed in the U.S. is to return to 1990 levels in 2010. What are the additional economic costs, and climatological benefits, of moving from the first path to the second one? Table 4, "Climate and Economic Variables under Alternative Emissions Paths," 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 per cent. 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 20__, 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) is reduced by a mere .03 degrees.. While different observers will wait the economic costs and climate benefits in different ways, the percentage increase in costs seems far greater than the percentage reduction in concentrations and warming.

how far is 2015 peak from 2015 BAU

Table 4

Climate and Economic Variables under Alternative Emissions Paths *

		Concentration Level (ppmv)		Year at Which Concentration Reaches 2x Pre-Industrial Level **	Change in Temperature from 1990 Level (Celsius)	
	Year	2050	2100		2050	2100
	Business As Usual (BAU)	522.1	729.8	2058	1.15	2.45
Deviation from BAU:						
Annex I Participation Only	1990 -10% beginning in 2010	-30.3	-95.0	+15	-0.13	-0.36
	1990 beginning in 2010	-24.8	-83.4	+12	-0.10	-0.31
	peak in 2015, 1990 in 2040	-17.6	-77.6	+9	-0.06	-0.28

		Carbon Permit Price ($ per ton) Domestic Trading		Worldwide Trading		Consumption *** (billions of $)
	Year	2010	2050	2010	2050	
	Business As Usual (BAU)	0.00		0.00		39,422
Deviation from BAU:						
Annex I Participation Only	1990 -10% beginning in 2010	+175	+924	+33	+45	-299.2
	1990 beginning in 2010	+110	+582	+16	+32	-205.7
	peak in 2015, 1990 in 2040	+0	+560	+0	+33	-94.7

Summary description

A plan to return carbon emissions to their 1990 levels by 2010 postpones by 12 years the date at which CO2 concentrations reach twice pre-industrial levels. Global warming would be reduced by 0.31 degrees by the year 2100 versus an estimated 2.45 degrees under BAU. Under this emissions path the value of the estimated foregone consumption is $205.7 billion.

A less ambitious path -- "eliminate emissions growth by 2010-2020" -- would postpone the doubling date by 3 years less, and would lead to another 0.03 degrees of warming. But, the economics would become much easier: The value of foregone consumption would be only $94.7 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.
*** Domestic Trading Only. Annex I or WorldWide Trading may substantially reduce these costs. Deviations are foregone consumption assuming a 3% discount rate.

August 21, 1997

Sources and Explanations

Sources

Business As Usual (BAU) emissions projections are based on published IPCC IS92a emissions profiles. BAU concentration and temperature projections are from the MiniCAM model. Carbon permit price estimates and foregone consumption figures are from SGM model. All these 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.

Worldwide Participation: All nations including developing countries are assumed to comply fully with the same targets and timetables.

Targets and Timetables

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

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

Price Assumptions

Carbon: U.S. permit prices for the policy options to attain 1990 emissions level in 2010 and 10% below 1990 emissions level in 2010 are from the DRI model used by EPA, which assumes that all revenues are used to improve the federal budget. The estimated permit price necessary under the policy option that peaks in 2015 is a linear interpolations based on these models.

Consumption: Deviations are 1995 present value of foregone consumption differences for United States in millions of dollars between BAU and scenarios. Consumption estimates go only to the year 2050.

5. Escape clauses and other flexibility provisions

References

Cline

IPCC

Jorgenson

Manne, Alan, and Richels, Richard, On Stabilizing CO2 Concentrations--Cost-Effective Emission Reduction Strategies, Workshop on Design of International Emissions Trading Systems, Aug 12-14, 97

Nordhaus

Pizer, William A, Optimal Choice of Policy Instrument and Stringency Under Uncertainty: The Case of Climate Change, Resources for the Future, Discussion Paper 97-17, Dec 96

Repetto, Robert, and Austin, Duncan, The Costs of Climate Protection: A Guide for the Perplexed, World Resources Institute, 1997.

Wigley, T.M.L., Richels, R, and Edmonds, J.A., Economic and Environmental Choices in the Stabilization of Atmospheric CO2 Concentrations, Nature, Vol 379, Jan 18, 96

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

Targets and Timetables

No matter what the "targets and timetables" that are set for reducing countries' emissions of greenhouse gases (GHG), the decision will inevitably be a tradeoff between costs and benefits. A path of very early and aggressive reductions, relative to the business as usual path (BAU), is likely to entail higher economic costs, but also higher benefits in terms of averted GHG concentrations in the atmosphere and disruption to the climate. A less aggressive path is likely to entail lower economic costs, and lower climate benefits. The tradeoff has to be made. The subject of this paper is how to do it.

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

[Turnover of capital stock. The example of the power generation plants.]

[The 1970s oil shock.]

2. 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 both are so uncertain (especially the climate effects), and in part because the climate effects take place on a very long time scale. So-called Integrated Assessment models attempt to put it all into one framework.

By now there are many of these models. They tend all 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. [a bit of elaboration on Nordhaus and others, with footnotes.]

Some of the authors have characterized the gap between the targets and timetables that their models produce and the frequently heard proposal to return emissions to 1990 levels by 2010 in a striking way: In their models, the economic costs of such a strong early response are so great that, if that were the only alternative, <u>we would be better off doing nothing at all.</u> In other words, the economic costs of "1990 levels by 2010" outweigh the benefits. reference Jorgenson testimony

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 catastrophe, such as the melting of the Antarctic ice shelf or the reversal of the Gulf Stream. [references:]
- Some claim that it gives insufficient weight to the welfare of future generations (that is, the discount rate is too high). [reference : Cline...]
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to move people's patterns of research, investment, and consumption on to the new path.

3. Estimates of optimal paths to stabilize concentration levels

An alternative strategy is to reason that the probability of catastrophe is likely to 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 level is arbitrary, and is inconsistent with the spirit of cost-benefit analysis. But it has the advantage of being analytically tractable.

We will consider the question of the optimal path subject to the constraint that concentrations be stabilized at 550 ppm (approximately double the pre-industrial level). 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 and it is impossible to prevent them rising further in the short run; one would have to reduce emissions virtually to zero to do so.

It will be useful to quantify the implicit gap between this strategy and the strategies resulting from the unconstrained optimization by the Integrated Assessment models [Jay?...]. 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.

Wigley, Richels and Edmonds (1996) examined the costs associated with some plausible paths to reach 550 ppm and other concentration levels. They considered a path where [global] emissions peaked in 2030 and did not return to 1990 levels until 2100. 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. (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. [This description of the breakdown of the WGE results comes from Manne-Richels (1997).] WG I

They argue that this path has much lower economic costs than paths -- such as the IPCC Working Group path [ ] or "1990 levels by 2010" -- that were more aggressive in terms of timing, but produced the same terminal effects on concentration and climate. However they do not consider whether other paths might reach the same goals at still lower costs.

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concentrate on optimal path

appears to be 2010

of 2030 — 10 20 — 2050

Manne and Richels find that the optimal path has emissions from OECD countries as well as from other Annex I countries peaking in the decade 20__-20__. Emissions do not return to their 1990 levels until the decade __. Emissions from developing countries peak in __. Thus total worldwide emissions peak in ~~2050.~~ 2030 -2040

The best single measure of aggregate economic costs is the present discounted value (i.e, the appropriate summation over time) of foregone consumption. According to Manne and Richels, their optimal path costs __ in lost consumption, as compared to __ under the IPCC Working Group path. (Most of this gain is also reflected in the WRE path, which shows a loss of __.) ~.87 ~3.5T ~.6T

It is difficult to imagine that the industrialized countries will be able to extract commitments from developing countries much more serious than these. What if, as is more likely, the commitments extracted from developing countries are less than this, rather than more? On the one hand, as a matter of arithmetic, meeting the 550ppm concentration constraint would require more aggressive targets and timetables for the Annex I countries. 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. (An analytical balancing of costs and benefits would give the same answer, once the concentration constraint is relaxed.)

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Foregone Consumption

.545 LC — WG I w/o trading 8.6

.77 WRE w/ trading — w/ trading 3.3

1.776 WRE w/o trading

5. Escape clauses and other flexibility provisions