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Enzi Request 7/16/98 - Not Public - [Climate Change] [2]

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These documents were hand-delivered to Chad Calvert of Senator Enzi's staff on Thursday, July 16, 1998 for his review.

They were picked up from his office the next week.

INDEX OF DOCUMENTS USED IN PREPARATION FOR CEA CHAIR JANET YELLEN'S TESTIMONY:

Materials that Implicate the President's Interest in the Confidentiality of White House Decision Making Processes and that Potentially Affect International Negotiations

1. Draft of paper from CEA staff to CEA Chair Janet Yellen that discusses various assumptions and estimates of the costs and benefits of the Kyoto Protocol. Paper includes an assessment of several alternative international trading scenarios.
   (20 pages)

2. Draft of paper from CEA staff to CEA Chair Janet Yellen that discusses the methodology for the cost analysis. Paper includes assumptions about the greenhouse gas emissions that are projected for 17 different countries and regions.
   (7 pages)

3. Various model runs done by CEA staff at the direction of CEA Chair Janet Yellen and CEA Member Jeff Frankel that reflect alternative assumptions regarding international trading, the impact of sinks, the impact of developing country participation, and other provisions of the Kyoto Protocol.
   (11 pages)

4. Table created by CEA staff for CEA Chair Janet Yellen that reflects early estimates of the costs of the Kyoto Protocol. Table reflects alternative assumptions about international trading.
   (1 page)

5. Draft of paper from CEA staff to CEA Chair Janet Yellen that presents an interpretation of the Kyoto Protocol and early estimates of the costs and benefits of Kyoto. Includes assumptions about international trading.
   (12 pages)

6. Table created by CEA and Treasury Department staff for CEA Chair Janet Yellen that shows energy prices under various scenarios and assumptions.
   (2 pages)

7. E-mail from Treasury Department economist to CEA economist regarding assumptions used in determining the effect on energy prices and expenditures.
(1 page)

8. Paper from CEA staff to CEA Chair Janet Yellen that summarizes the key elements of the Second Generation Model (SGM). Includes analytical comments on the limits of the model.
(2 pages)

9. Table created by CEA staff for CEA Chair Janet Yellen showing permit prices under various scenarios. Table reflects alternative assumptions about international trading.
(1 page)

10. Table created by EPA staff that shows results of a G-Cubed Model. Done at the request of CEA and reflects alternative assumptions about international trading.
(6 pages)

11. Paper from EPA staff describing G-Cubed analysis of the Impact of Carbon Emissions Reductions From the Kyoto Agreement. Paper reflects various assumptions about international trading and behavior of other countries.
(6 pages)

12. Charts created by CEA staff that reflect the impact of different policy approaches on coal consumption and carbon permit prices.
(1 page)

13. Paper prepared by the State Department that describes the Kyoto Protocol article-by-article. Reflects the State Department's confidential interpretation and analysis of the provisions.
(15 pages)

14. Table created by CEA staff for CEA Chair Janet Yellen that compares different model results. Reflects the effects of international permit trading on consumption losses by the OECD.
(1 page)

15. Draft paper from Treasury Department staff that describes one analyst's views on climate change policies. Includes an assessment of the accuracy of the analyst's assumptions.
(5 pages)

16. Memo from EPA officials to Assistant to the President Todd Stern regarding the role of the Climate Change Technology Initiative in Evaluating the Costs of Kyoto. Reflects administration policy deliberations and advice given to Senior White House official.
(3 pages)

17. Model runs done for CEA Chair Janet Yellen by CEA staff that show pre-Kyoto assessments of various climate change policy scenarios, including assumptions about international trading.
(10 pages)

18. Table created by CEA staff for CEA Chair Janet Yellen that summarizes different trading bloc scenarios.
(1 page)

19. Table created by CEA staff for CEA Chair Janet Yellen that summarizes the impact of alternative international trading scenarios under alternative assumptions.
(1 page)

20. Memo from Department of Energy staff person that provided CEA with a range of information and analysis used to calculate non-climate benefits.
(1 page)

21. Memo from Department of Transportation staff person to CEA that describes potential impacts of hypothetical fuel price increases.
(2 pages)

22. Charts regarding price and consumption of energy that were included in memos to the President.
(5 pages)

#1

draft; close hold, 1/23/98

CEA-Treasury

Costs and benefits of a program to address Global Climate Change

Agenda

I. Costs:
How low can international trading bring costs down, under successively more ambitious assumptions?

II. Benefits:
(1) reducing air pollution
(2) reducing traffic congestion,
(3) reducing traffic accidents

III. How sensitive are the above results to alternative
(1) models?
(2) assumptions about how sinks are accounted for?
(3) a more optimistic assumption about technology (AEEI)?

Answer: very sensitive. Nevertheless, the general result is as follows: Optimistic assumptions about trading are sufficient to bring costs down a lot, but not enough to bring them below benefits.

IV. To close the gap between costs and benefits, one needs *either:*
(1) to include the cost savings of a federal electricity restructuring bill, *or*
(2) to assume that permits are auctioned to raise revenues used to cut taxes on capital, *or*
(3) simply to argue that the future benefits of mitigating global climate change, while difficult to quantify in a single monetary number, should be large enough to merit the net costs that emerge from parts I and II above.

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The Costs of Climate Change Policy: Assumptions

Modeling. For this analysis, we calculated the costs of abatement for all six categories of greenhouse gases by merging two modeling efforts:

- *SGM*: Outputs of carbon dioxide emissions reductions and costs from the Second Generation Model (SGM) were used. SGM is used in Energy Modeling Forum exercises, and in EMF-14 it yielded cost estimates that ranged from being second most expensive for no trading to least expensive under worldwide trading.

- *EPA Bottom-Up Analysis*: Estimates of emissions reductions and costs for the other greenhouse gases were derived through a bottom-up analysis by EPA.

Trading Assumptions. We assessed several different trading scenarios:

- *Full Annex I Trading*: All Annex I countries participate in international trading.

- *Umbrellas*: Two "umbrellas" were assessed. One excludes the EU from Annex I trading, while the other excludes the EU and Eastern European countries from Annex I trading.

- *Joint Implementation*: We also assessed joint implementation with all developing countries and trading with key developing countries (China, India, Mexico, and Korea).

Sinks Assumptions. Given the uncertainty about the impacts of the sinks definition in the Protocol on commitments, we assessed the trading regimes under 3 sinks assumptions:

- *No Sinks*: All countries are assumed to have no emissions reductions through sinks.

- *Reported Sinks*: All countries are assumed to have emissions reductions through sinks equal to their reported sinks estimates in their national communications. For the U.S., above ground sinks are 104 MMTCE in 2010.

- *Half of Reported Sinks*: These are half of the above (52 MMTCE for U.S.).

Technology Assumptions. Given the uncertainty in projecting rates of technological improvement, we analyzed the above scenarios under two assumptions:

- *1.0 AEEI*: Annual energy efficiency improvement is assumed to increase 1% (base case).

- *1.25 AEEI*: Annual energy efficiency improvement is assumed to increase 1.25% (optimist case).

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Costs and Non-Climate Benefits without Sinks

Table 1. U.S. Costs and Non-Climate Benefits Summary (assuming 1.0 AEEI)

Scenario (no sinks)	**2010 Permit Price**	**2010 Resource Cost**	**2010 Monetized Benefits**[1]
10/97 Administration Position (6 gases, net-net sinks, 1990 by 2010, updated baseline)	$148/ton	$41 billion	$13 - 25 billion
Kyoto: No International Trading[2]	$171/ton	$51 billion	$15 - 29 billion
Full Annex I Trading	$48/ton	$22 billion	$4 - 8 billion
Umbrella excluding EU and Eastern Europe	$43/ton	$20 billion	$4 - 7 billion
Umbrella excluding EU	$26/ton	$13 billion	$2 - 4 billion
Annex I Trading + JI (JI = 20% worldwide trading)	$36/ton	$17 billion	$3 - 6 billion
Annex I Trading + Participation by Key Developing Countries	$20/ton	$10 billion	$2 - 3 billion
Annex I Trading + Full Worldwide Trading	$19/ton	$10 billion	$2 - 3 billion
Umbrella excluding EU + Full Worldwide Trading	$10/ton	$6 billion	$1 - 2 billion

[1] Benefits include reductions in local air pollutants, traffic accidents, and congestion.
[2] All subsequent cases evaluate the Kyoto Protocol.

Table 2. With accounting for sinks (assuming full Annex I trading)

Sinks Assumption	**2010 Permit Price**	**2010 Resource Cost**	**2010 Monetized Benefits**
No Sinks (U.S.: 0 MMTCE)	$48/ton	$22 billion	$4 - 8 billion
Half of Land Use Change and Forestry Sinks (U.S.: 52 MMTCE)	$26/ton	$12 billion	$2 - 4 billion
All of Land Use Change and Forestry Sinks (U.S.: 104 MMTCE)	$11/ton	$5 billion	$1 - 2 billion

Table 3. More Detailed Measures of Economic Effects of Various Trading Regimes[1]

2010	No International Trading	Full Annex I Trading	Umbrella excluding EU	Umbrella excluding EU + Full Worldwide Trading
Permit Price	$171/ton	$48/ton	$26/ton	$10/ton
Resource Cost	$51 billion	$22 billion	$13 billion	$6 billion
Percentage of Reductions Occurring in U.S.	100%	47%	31%	14%
Value of Transfers	$0	$15 billion	$11 billion	$5 billion
Change in Household Energy Expenditures Relative to BAU	+30%	+9%	+5%	+2%
Change in Household Energy Expenditures net of Administration's Electricity Restructuring Proposal	+26%	+5%	+1%	-2%
Change in Gasoline Price (per gallon)	+ $0.41	+ $0.12	+ $0.06	+ $0.02

[1] This analysis assumes no sinks and a technology improvement based on 1.0 AEEI.

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Non-Climate Benefits of U.S. Participation in the Kyoto Agreement

I. Percentage of total non-climate benefits expressible in dollars per year

Table 4. Distribution of Total Monetized Non-Climate Benefits

Category		Share of Total Non-Climate Benefits (Percentage)
Non-carbon Emissions reductions:	Utilities	27
	Vehicles	2
	Other	3
Highway fatalities		38
Highway accidents: injuries and other costs		22
Highway congestion		9
Increased fuel efficiency costs		-2
Total		100

II. Unquantifiable benefits

Inconvenience from highway congestion
Mercury emissions reductions
Sulfur dioxide emissions control cost savings
Energy independence

III. Caveat: The estimates are approximate and preliminary.

1) **A key uncertainty is the effect of lighter cars on highway safety. The ranges provided in the costs and benefits tables reflect this uncertainty.**
2) Estimates are generally proportional to fuel prices.
3) The estimated reductions in highway fatalities ignore effects of higher average speeds from reduced congestion.
4) The air emissions benefits estimates, while conservative, are uncertain and subjective, and based on control cost avoided.

Non-Monetized Benefits

Two very large categories of potential benefits have been left out of the foregoing list of costs and benefits: revenue recycling and climate change mitigation.

Revenue recycling If the emission permits to be issued in the budget period, 2008-2012, were to be auctioned off, rather than allocated for free, the resulting revenue for the government could provide major benefits. If the revenue were used to reduce taxes that fall on capital (i.e., to reduce the capital gains tax or corporate income tax, or to add an investment tax credit), then the result would be an increase in investment, and therefore an increase in growth. According to the Repetto-Austin meta-analysis of 16 leading models, the assumption of such revenue recycling together with several other assumptions (non-carbon backstop fuel, CGE model, increased energy and product substitution, and an idealized form of JI equivalent to global trading) is enough to turn what would otherwise be a negative effect of GDP into a positive one [2020]. Similarly, the IAT report estimated that under a policy of recycling revenues to business, the GDP effect would turn from negative to positive around 2010.[1] Using the revenue for deficit reduction is almost as good, because it lowers interest rates and again stimulates investment. Jorgenson, Shackleton, and other economists have similar findings.

However, returning the revenue to the general public through reductions in income taxes or payroll taxes, or through lump-sum redistribution, does not produce positive effects on GDP in these models. We suppose that cutting corporate taxes would be undesirable on political and income-distribution grounds, and that the government may want to use the revenue to ease the burden on those (e.g., displaced coal miners) who might be disadvantaged. For this reason, we have not as yet pursued the revenue recycling idea (also known as the double-dividend) any further.

Climate Change mitigation The goal of the entire exercise, of course, is to begin to move to an emissions path that implies lower levels of atmospheric concentrations of GHGs in future centuries, and thereby mitigate the likely extent of global climate change. Estimates of the economic damages from climate change (e.g., in the Integrated Assessment models of Nordhaus, Cline, and other economists) fall into the following areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, migration costs, human amenity, construction, leisure activities, urban infrastructure, and ecological damages such as forest loss and species loss). One must sympathize with those who critique the economists on the grounds that these costs are extremely difficult to quantify, particularly when it comes to possible catastrophe scenarios to which the scientists cannot assign

[1] (Figure 13 in IAT); this analysis assumes stabilization at 1990 levels by 2010, with 10-year phase-in; assuming a 1.25 % annual decrease in AEEI.

a reliable probability.

It turns out that the subject of perhaps the greatest uncertainty and sensitivity is the discount rate that is applied to the benefits of averting future climate change. Such a discount rate is needed, because the economic costs of the policies under discussion occur over the next few decades, whereas the prime benefits of averting climate change occur in coming centuries. Yet there is little agreement, even among economists, on the appropriate discount rate. Cline, for example, explicitly considers a low discount rate (and a high aversion to possible catastrophe) in getting his conclusion that the benefits of early and strong action outweigh the costs.

We take it as self-evident that the benefits of averting climate change are potentially enormous. But we have, so far, chosen not to try to quantify them in monetary terms, in light of the quantitative uncertainty, their timing (far outside the 2008-2012 window), and the need to make difficult decisions regarding the post 2012 path of emissions cuts in order to produce meaningful reductions in future concentrations. We are inclined to favor an attempt to add up the various possible costs and benefits of emissions policy excluding climate change. Thus a conclusion might be phrased along lines such as "the net benefits of our policies to reduce emissions [under the following conditions...] are likely to be positive, even before taking into account the benefits of averting climate change itself." Of course any testimony would also include an enumeration of the effects of climate change and the extent to which a mitigation program would help avert them; this would be partly *quantitative*, but would not include an estimate of *monetized* effects in the aggregate.

Technology Optimism Case

Table 5. U.S. Costs and Non-Climate Benefits (assuming 1.25 AEEI)

Scenario (no sinks)	2010 Permit Price	2010 Resource Cost	2010 Monetized Benefits[1]
10/97 Administration Position (6 gases, net-net sinks, 1990 by 2010)	$124/ton	$34 billion	$13 - $27 billion
Kyoto: No International Trading[2]	$145/ton	$44 billion	$14 - $30 billion
Full Annex I Trading	$36/ton	$16 billion	$4 - $8 billion
Umbrella excluding EU and Eastern Europe	$31/ton	$15 billion	$4 - $7 billion
Umbrella excluding EU	$18/ton	$9 billion	$2 - $4 billion
Annex I Trading + JI (JI = 20% worldwide trading)	$27/ton	$13 billion	$3 - $6 billion
Annex I Trading + Participation by Key Developing Countries	$16/ton	$8 billion	$2 - $4 billion
Annex I Trading + Full Worldwide Trading	$15/ton	$8 billion	$2 - $4 billion
Umbrella excluding EU + Full Worldwide Trading	$8/ton	$4 billion	$1 - $2 billion

[1] Benefits include reductions in local air pollutants, traffic accidents, and congestion.
[2] All subsequent cases evaluate the Kyoto Protocol.

Table 6. With accounting for sinks (assuming full Annex I trading)

Sinks Assumption	2010 Permit Price	2010 Resource Cost	2010 Monetized Benefits
No Sinks (U.S.: 0 MMTCE)	$36/ton	$16 billion	$4 - $8 billion
Half of Land Use Change and Forestry Sinks (U.S.: 52 MMTCE)	$17/ton	$8 billion	$2 - $4 billion
All of Land Use Change and Forestry Sinks (U.S.: 104 MMTCE)	$7/ton	$3 billion	$1 - $2 billion

Alternative Sinks Case

Table 7. U.S. Costs and Non-climate Benefits (assuming ½ of reported sinks, 1.0 AEEI)

Scenario (accounting for half of reported sinks)	**2010 Permit Price**	**2010 Resource Cost**	**2010 Monetized Benefits**
10/97 Administration Position (6 gases, net-net sinks, 1990 by 2010, updated baseline)	$148/ton	$41 billion	$14 - $31 billion
Kyoto: No International Trading[2]	$146/ton	$40 billion	$14 - $30 billion
Full Annex I Trading	$26/ton	$12 billion	$3 - $6 billion
Umbrella excluding EU and Eastern Europe	$20/ton	$9 billion	$2 - $4 billion
Umbrella excluding EU	$11/ton	$6 billion	$1 - $2 billion
Annex I Trading + JI (JI = 20% worldwide trading)	$21/ton	$10 billion	$2 - $5 billion
Annex I Trading + Participation by Key Developing Countries	$12/ton	$6 billion	$1 - $3 billion
Annex I Trading + Full Worldwide Trading	$12/ton	$6 billion	$1 - $3 billion
Umbrella excluding EU + Full Worldwide Trading	$4/ton	$2 billion	-$0.5 - $1 billion

[1] Benefits include reductions in local air pollutants, traffic accidents, and congestion.
[2] All subsequent cases evaluate the Kyoto Protocol.

Table 8. With accounting for sinks (full Annex I trading)

Sinks Assumption	**2010 Permit Price**	**2010 Resource Cost**	**2010 Monetized Benefits**
No Sinks (U.S.: 0 MMTCE)	$48/ton	$22 billion	$6 - $11 billion
Half of Land Use Change and Forestry Sinks (U.S.: 52 MMTCE)	$26/ton	$12 billion	$3 - $6 billion
All of Land Use Change and Forestry Sinks (U.S.: 104 MMTCE)	$11/ton	$5 billion	$1 - $2 billion

Appendix 1
Non-carbon Emissions Reductions

The Kyoto agreement will lead to ancillary reductions in emissions that contribute to local air pollution, e.g., NOx, and VOCs. NOx, for example, is a combustion by-product that contributes to ground-level ozone and fine particulate formation. Thus to the extent that carbon emissions are reduced through reductions in fuel use, NOx emissions will also fall. In addition, NOx emissions per unit energy are also greater from coal, a carbon-intensive fuel, so that substitution of natural gas for coal, as well as reductions in fuel use, will also result in reductions in NOx.

We here treat the ancillary reductions in emissions of these gases as reducing the costs of meeting the new national ambient air quality standards (NAAQS). EPA estimated the costs of meeting the new NAAQS in 2010 to be $9.6 billion per year for ozone, and $37 billion per year for particulate matter. (These cost estimates may not be additive.)

Although we treat these emission reductions as providing cost-savings, they may be better viewed as providing ancillary environmental and health benefits. An approach that uses ancillary benefits instead of ancillary cost-savings would be

1) more direct (and more easily understood),
2) potentially less arbitrary, as there is no clear analytic basis for any single cost/ton figure,
3) more valid to the extent that the avoided costs wouldn't be incurred anyway, as would be the case if nonattainment continues beyond 2010, as many observers expect.

However, the ancillary benefits approach would likely lead to lower estimates because EPA's incremental monetized benefits of full attainment relative to partial attainment are $1.6 to $10 billion annually, of which $1 to $6 billion is from the particulate matter standard. I will continue to pursue a benefits estimate, but this work will not be feasible to complete in the next few days.

A key question in estimating cost savings is whether carbon emissions reductions would avoid NAAQS related control measures. NAAQS related control costs would be avoided only if carbon-reduction strategies also reduced emissions that contribute to ozone and PM, *and* these ancillary emissions reductions were included in State Implementation Plans (SIPs) in lieu of reductions from specific new control measures. SIPs that "demonstrate attainment" with the new NAAQS will be due around 2002 for ozone and approximately 2005 for particulate matter. To date EPA has accepted in SIPs only those emission reductions that result from legally enforceable State actions. Thus EPA acceptance of emissions reductions from lower vehicle use resulting from higher fuel prices would be precedent setting, although it is apparently within the Agency's discretion. Since most of the control measures associated with attainment of the NAAQS entail sunk costs, cost savings may be reduced if controls to reduce carbon emissions occurred after, say, 2005, as may well be the case.

This note addresses ancillary reductions resulting from both reductions in fuel use and fuel switching based on the (incomplete) existing literature. Using conservative assumptions, it concludes that these ancillary benefits would range into the billions of dollars per year, given a carbon price of about $100/ton. In particular, fuel switching might reduce NOx emission control costs by $1.1 to $3.3 billion per year. Reduced vehicle use might reduce NOx and VOC emission control costs by $.15 billion in the short run to $.5 billion in the long run. Emissions cuts from other sectors may reduce control costs by between $.38 and $1.1 billion per year.

I. Utilities.

Electric utilities are expected to reduce carbon emissions through both reductions in fuel use and fuel switching. EIA has provided us with an estimate of NOx emissions reductions from electric utilities as a result of a $100/ton carbon tax and a $200/ton carbon tax. EIA estimate is 3 million tons of NOx emissions per year nation-wide from both fuel use and fuel switching. This estimate is an overstatement because it neglects both the recent PM/ozone standards and EPA's recently proposed OTAG SIP call to reduce NOx. EIA believes this overstatement is a "little" but not "substantial". In addition, the estimate includes emissions reductions in areas where NOx reductions would not otherwise be required, and where NOx does not contribute to significant pollution problems. EIA also estimates slight SO2 emissions reductions, and very large SO2 permit price reductions. In the case of a $100/ton carbon price, the SO2 price would fall from $189 to zero, presumably because utilities would switch to natural gas to such an extent that they would no longer operate existing scrubbers. In such a scenario, the cost savings from no longer having to control SO2 are likely to be in the range of several hundred million dollars per year. These estimates are summarized below.

Annual Ancillary Utilities Emission Reductions: Tons and Cost Avoided
Table 1

Carbon Permit Prices	SO_2 Cost Savings (billions)	NOX		Total Savings (billions)
		Million Tons	Savings (billions)	
$50/ton	<$0.5	1.5[2]	$1.5 to $4.5	forthcoming

[2]Based on a linear interpolation that EIA suggests may be inaccurate. New data may be available in the next few days.

$100/ton	"	3	$3 to $9	forthcoming
$200/ton	"	3.5	$3.5 to $10	forthcoming

For nationwide NOx reductions, we use $1000/ton, and $3000/ton. The EPA's Regulatory Impact Assessment for the NAAQS, uses $3,200/ton of NOx as an estimate of average control cost for specified measures in this full attainment scenario (see p. 9-15). The EPA also used a figure of $10,000/ton that for the incremental cost of the emissions reductions needed to reach full attainment of the new NAAQS, from a baseline of partial attainment. As the values in the NAAQS RIA may be too high for NOx to the extent that ancillary NOx reductions occur in areas that do not significantly contribute to ozone and particulate matter nonattainment, we use lower estimates, which may be conservative. For SO2, which is subject to a national cap, this concern does not apply.

EIA will later provide estimates of reductions in emissions of mercury.

Thus NOx and SO2 emission reductions valued at billions of dollars per year are likely to result from the utilities emissions reductions under the Kyoto accord. In particular a $100/ton carbon price might yield NOx cost savings of $3 to $9 billion per year.

II. Vehicles

NOx and VOC emission reductions from motor vehicles may come from more fuel efficient engines, reduced use, or changes in fleet composition. EPA estimates that 2010 Clean Air Act baseline NOx emissions from mobile sources (including motor vehicles and nonroad emissions sources) in ozone nonattainment areas will be 970 million tons; motor vehicle emissions nation-wide will be 7637 million tons.

Annual Ancillary Emission Reductions: Tons and Cost Avoided
Mobile Sources
Table 2

Area	Thousand tons/year					Cost Avoided per year (billions)	
	NOx	VOCs	Total Emissions	Emissions Reduced		Short Run	Long Run
				SR	LR		
Nation-wide[3]	7,637	5,834	13,400	270	940	$.3 [4] to $.8	$.9 to $2.8
Nonattainment areas[5]	1,433	841	2,300	50	160	$.15[6]	$.5

Note: Short run (SR) and long run (LR) emissions reductions reflect different price elasticities of demand; the long-run presumes vehicle fleet turn-over.

One recent study suggests that fuel price increases lead to reductions in carbon that are much larger than reductions in other emissions.[7] Several estimates for four metropolitan areas in California indicate that fuel taxes of $0.50 per gallon lead to NOx emissions reductions about 40 percent as large as carbon emission reductions. Reductions in VOCs are slightly larger, but for simplicity we ignore this difference. Given these relationships, we can posit a fuel price increase necessary to achieve a carbon emissions reduction, and then scale the NOx and VOC emissions reductions accordingly.

Our point of departure is the price hike needed to meet the Kyoto agreement. If the Kyoto agreement led to a cap and trade system for carbon it might raise gasoline prices by $100/ ton of carbon, or $0.26 / gallon of refined petroleum products. This is approximately a 20 percent

[3]Reflects Clean Air Act Baseline, and so does not exclude emission reductions to meet the NAAQS. Sum of nonroad and motor vehicle emissions.

[4] At $1000/ton and $3,000/ton.

[5]Reflects Partial Attainment Scenario baseline. Sum of mobile and non-road emissions.

[6]These reductions are valued at $3,200/ ton because they are exclusively in nonattainment areas.

[7]See *Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy and Equity Impacts*, California Environmental Protection Agency, November 1996

price increase. Given a demand elasticity (short-run estimates are around .25, long run estimates as high as .9) consumption should fall by 5 percent in the short run and 18 percent in the long-run. Using the scaling factor of .4 from the California study, NOx and VOC emissions reductions would be 2 percent in the short run and 7 percent in the long run. Applying these percentages to the baseline emissions reported in Table 2 above, the reductions in the short run are 270 and 50 thousand tons per year nationally and in nonattainment areas respectively. Reductions in the long-run are 940 and 160 thousand tons per year nationally and in nonattainment areas respectively.

For simplicity we do not distinguish between the control costs avoided for VOCs and NOx. VOC emissions in EPA's NAAQS RIA were assumed to be controllable at an average marginal cost of $10,000/ton, but identified measures had an average incremental cost of $4000/ton, i.e., above the comparable figure of $3,200 for NOx. We ignore this difference and value both VOCs and NOx at $3200/ton in nonattainment areas and $1000 to $3000 in attainment areas. This range of values is likely to be conservative for nonattainment areas; the extent of conservatism for nation-wide reductions is not clear. Thus the cost avoided from mobile source emissions reductions may be about a half billion dollars per year.

III. Other Sectors

Emissions from sectors other than utilities and mobile sources are summarized below.

Other Sector Emissions
Thousands of tons per year
Table 3

Pollutant	Industrial Point Sources	Area Sources
VOC	2164	7533
NOX	1958	2932
SO2	5990	1518
PM2.5	745	8931
Total	10857	20914
Grand Total	31771	

These emission estimates are not broken down by non-attainment area. However, EPA has argued in the development of it particulate matter NAAQS that fine particulates and their precursors move over large distances. In this case as a rough approximation, one might suppose, following the earlier discussion, a 12 percent reduction in all these emissions, i.e., a reduction of about 3800 thousand tons per year. Valuing these at $1000/ton would give ancillary benefits from these sources nation-wide of $380 million per year. At a higher value of $3,000/ton these ancillary benefits would be $1.1 billion per year.

Appendix 2
Congestion Related Benefits From Fuel Price Increases

The Kyoto agreement will reduce emissions from carbon by about 27 percent (100/137=.73). To the extent that these emissions reductions are achieved through fuel price increases, there will be a reduction in the use of motor vehicles, and there may be resulting increases in traffic congestion.

One recent study suggests that fuel price increases would lead to significant reductions in traffic delays.[8] Several estimates for four metropolitan areas in California indicate that fuel taxes of $0.50 per gallon in 1991 would have led to reductions in delay of about 7 percent.

A recent report funded by the Department of Transportation put the costs of congestion, relative to free-flowing traffic, at nearly $60 billion in 1994, up from less than $40 billion in 1986.[9] These costs reflect both the dollar value of delays to motorists, and the additional fuel consumption from congestion, although only about a tenth of the total estimated costs are fuel-related.

Thus a $100/ton carbon tax would lead to a $0.25/gal fuel tax, and reductions in congestion related delays of about 3.5 percent in the four California cities. If extrapolated nation-wide, reductions in congestion related delays, including the fuel savings, would be worth about $2 billion per year.

These estimates exclude the reductions in inconvenience that travelers would experience as a result of being able to begin trips closer to their preferred travel time. Such reduced inconvenience may be as valuable as the reductions in delay.

[8] See *Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy and Equity Impacts*, California Environmental Protection Agency, November 1996

[9] *Urban Roadway Congestion --1982 to 1994* Texas Transportation Institute, Texas Department of Transportation, and the Federal Highway Administration, August 1997

Appendix 3
Improvements in Highway Safety From Fuel Price Increases

Higher fuel prices may improve highway safety. One effect on highway safety is through fewer vehicle miles traveled, although this may be offset somewhat by higher speeds associated with reduced congestion. Another effect is through lighter and potentially less safe vehicles. A third effect is through accelerated fleet turnover. The first effect is likely to be much larger than the other two effects, and forms the basis for our quantitative estimate. We consider each in turn and calculate illustrative magnitudes assuming a $100/ton carbon price.

I. Vehicle miles traveled.

As higher fuel prices induce people to drive less, the reduction in driving reduces the losses from traffic accidents. To calculate the reduction in driving recall that total vehicle miles traveled (VMT) is identical to gasoline consumption times average miles per gallon (mpg). Thus the elasticity of VMT with respect to price equals the elasticity of gasoline consumption with respect to price *plus* the elasticity of miles per gallon with respect to price. Estimates of these elasticities are presented below:

Estimates of the Elasticity of Vehicle Miles Traveled With Respect to Fuel Price
Table 1

Run	price elasticity of gasoline consumption	price elasticity of miles per gallon	implied price elasticity of VMT
Short Run	-.26	0[10] to .1 to .12	~-.14 to ~-.26
Long Run	-.9	.08 to .21	~-.8 to ~-.7

Source: Dahl and Sterner, "Analysing Gasoline Demand Elasticities: A Survey", Energy Economics, July 1991 for fuel price elasticities. For fuel-efficiency elasticities, see Dahl "Demand for Transportation Fuels: A Survey of Demand Elasticities and Their Components", Division of Economics and Business, Colorado School of Mines, (September), as cited in Khazzoom.

We develop estimates using elasticities of .2 and .7 for the short-run and the long-run.

Thus fuel price increases of $0.26 /gallon, given a base of $1.30 / gallon imply VMT declines of nearly 4 percent in the short run. Assuming that fatal accidents are proportional to VMTs, we estimate that such a fuel price increase might prevent about 1700 highway fatalities per year in the short run, or 6000 in the long-run. If these were valued at $5 million per statistical life, this would amount to savings of $8.5 billion per year in the short-run or $30 billion per year in the

[10]Price hikes should affect fleet efficiency only to the extent that people buy new cars. Thus in the very short run, the elasticity must be zero.

long-run, when the vehicle fleet has changed. Higher estimates result could result in different assumptions about the likelihood of two-car collisions. A physical model of vehicles as random particles would suggest that 2-vehicle accidents might fall in proportion to the square of the percentage reduction in VMT. In this case the number of fatalities avoided would more than double, to about 3800.

Total private passenger and commercial insurance claims equaled $83.67 billion dollars in 1996. Of that, $2.8 billion dollars equaled the liability insurance cost of auto fatalities. Thus the insurance cost of accidents apart from fatalities was $80.9 billion. If these fell by an amount proportional to VMT, savings in the short run would be about $3.1 billion per year; in the long run they could reach $10 billion.

Another estimate of the savings in insurance costs can be derived. A paper by the California Energy Commission estimated that the marginal insurance cost per mile driven, including the fatality cost is $0.04/mile, on the basis of a simple regression of five years of data for all California counties. The short-run declines in VMT of four percent that are expected to result from a fuel price increase of $0.26/gallon, correspond to about 88 billion vehicle miles traveled, given the baseline of the 2.3 trillion vehicles miles traveled in 1993. If the marginal cost of 4¢/mile is applied to these miles, the result is about $3.5 billion per year. This estimate corresponds fairly closely to the $3.1 billion estimate that assumes that insurance costs are proportional to VMT. (This estimate may be too high because it assumes insurance costs in the rest of the country are as high as in California.)

These estimates should use a baseline of 2010, which will be different because vehicle miles traveled are projected to grow at an annual rate of nearly 2 percent over the next decade. If this growth rate is applied to 15 years, e.g., from 1993 through 2008, then the incremental insurance related cost is $4.8 billion in the short-run.

One complication in the relationship between VMT and safety is that with less VMT, roads will be less congested and vehicle speeds greater. Higher speeds lead to more severe crashes, given that crashes occur, and since a large share of the economic losses from traffic accidents is fatalities, there may be an offset due to greater fatalities at higher speeds. A California study indicates that a $.50 /gallon tax lowers travel times (and hence raises average speeds) by about 5 percent, an increase slightly larger than the estimated decrease in VMT from the same tax. To control for these effects requires information about average speed on fatality risk holding road conditions constant. For simplicity we ignore these offsetting effects. (We are pursuing these estimates.)

II. Vehicle weight.

The claim that more efficient vehicles, e.g., those adopted as a result of fuel efficiency standards, tend to be lighter, less crash-worthy, and therefore less safe, is contentious. We develop alternative estimates that reflect this effect and sketch arguments to justify ignoring it.

An article by Crandall and Graham has quantified the effect of weight on safety; they estimate elasticities of fatalities to vehicle weight of 1 to 2. We can not apply this estimate without knowing the effect of higher fuel prices on weight. We have no direct estimates of this relationship, so we use instead an indirect approach based on the relationship between fuel efficiency and prices, and fuel efficiency and vehicle weight. As mentioned above, Dahl reports average estimated elasticities of fuel efficiency with respect to fuel prices of .1 to .12. Crandall *et. al.*, (Regulating the Automobile, 1986), report elasticities of miles per gallon with respect to weight of .7 to .8. We assume that the elasticity of weight with respect to fuel price is thus .13 [.13=.1/.75]. Thus an increase in fuel price of $0.26/gallon or 20 percent leads to a .026 percent reduction in weight, and an increase in fatalities of 2.6 percent to 5.2 percent. These amount to between 1100 and 2300 of the 44400 highway fatalities that occurred in 1993(?). Valuing these at $5 million each provides for an offset to the ancillary benefits of $5.5 billion to $12 billion annually.

More recent research, however, has drawn a different conclusion, which is also pursued here. For example, Dan Khazzoom of RFF[11] is quite critical of claims that lighter vehicles are less safe. He argues

- The underlying econometric models of fatalities as a function of vehicle weight neglect vehicle size. This neglect introduces omitted variable bias so that weight appears to have a beneficial effect, although it is size that in fact matters. Models that have included size and weight gave no support for the claim that weight enhances safety, at least in single vehicle crashes.

- The National Research Council, in a study of two car crashes, concluded that the total number of injuries when both cars are made lighter could rise, fall or remain unchanged.
  --Although the weight of loaded trucks would not decrease with higher energy prices, passenger cars and light trucks would generally become lighter as a result of higher fuel prices, so this result seems applicable.

- Down-weighting without down-sizing is a plausible response to higher fuel prices and according to Khazzoom, "the more recent evidence does not support the theory that reducing car weight is a detriment to safety." (p.115)

[11] J. Daniel Khazzoom, "Impact of Pay at the Pump on Safety through Enhanced Vehicle Fuel Safety", *The Energy Journal*, Vol. 18, No.3, 1997, pp.115-133.

III. Fleet composition.

Higher fuel prices will accelerate the scrapping of older fuel-inefficient vehicles. Newer cars are generally safer than older cars, however, due to air-bags, automatic braking systems, etc. Khazzoom finds that "given these additional characteristics contribute to safety, the inducement to advance replacement brought about by [higher fuel prices] leads to higher levels of fleet safety. This will always be the case, so long as these other characteristics contribute more to safety than the increase fuel efficiency detracts from it, which is very unlikely to be the case in light of our findings above", (p.123). Even if fuel-efficiency gains did come at the expense of safety, these would be offset by the greater safety of a newer vehicle fleet.

IV. Social cost of greater fuel efficiency.

Increases in fuel efficiency are typically costly, holding performance constant. Crandall and Graham estimate that the cost of each mile per gallon improvement is $1 billion. Given our price increase of $0.26 and our elasticity of efficiency with respect to price of .1, the projected improvement in miles per gallon is about two percent in the short run. Thus if 23 mpg were taken as the baseline efficiency, and a two percent gain were projected, then the absolute gain in mpg would be about .4 mpg. This gain would cost about $.4 billion, taking Crandall's estimate of $1 billion/mpg as given.

#2

Summary of Cost Analysis Methodology

Since no model exists to handle all of the key parameters of the Kyoto Protocol (sinks, 6 gases, international trading, clean development mechanism), CEA assessed the economic implications of the Protocol by drawing on several available tools. To develop cost estimates, CEA completed four actions:

- **Constructed cost curves**: CEA drew from results from 60+ model runs from the Second Generation Model to develop country- and region-specific cost curves for carbon dioxide abatement. Further, CEA employed an EPA-developed bottom-up analysis for non-CO2 greenhouse gases for the United States. Integrating these two sets of data generated cost curves for all 6 gases under the Kyoto Protocol.

- **Constructed baselines**: While estimates of 1990 emissions and 2010 projected emissions for carbon dioxide are widely available for most Annex I countries, CEA had to draw from 25+ submitted National Communications to the Framework Convention, official reports of the Framework Convention, and EPA and DOE analyses to construct the appropriate 6 gas baselines. In some cases, extrapolations were made from one country to another based on common characteristics (e.g., GDP, size, etc.). These baseline estimates were used to identify the magnitude of necessary cuts (or paper tons) required of Annex I countries under the Protocol.

- **Identifying market clearing prices for trading blocs**: After developing the baselines and cost curves, CEA identified the market clearing prices for umbrella trading blocs. This required an analysis of different countries' and regions' cost curves to find where abatement costs would be minimized. The cost-effective price then serves as the estimated permit price.

- **Estimating effects on energy prices**: The permit prices were converted to estimated energy price effects based on an analysis available from Treasury.

METHODOLOGY

Trading

Abatement Cost Curves in Industrialized Countries: Marginal cost curves in countries derived from SGM for CO2 hold for all six gases and sinks for all countries except for the United States (this likely overstates costs of abatement under international trading). The U.S. cost curves are derived from SGM outputs for CO2 and from EPA/OAR for the other gases and sinks. The cost curve for the other gases and sinks ends at $70/ton -- we assume that no other reductions are available beyond those achievable at that price.

Intergas Trading: Trading is assumed to occur across all gases and sinks based on 100-year global warming potential.

Trading Blocs: We assessed three different industrialized country trading blocs.

- Annex I implies trading between all Annex I countries (note that in model, some small countries, e.g., New Zealand, Norway, Iceland, are not included).
- Umbrella with Eastern Europe implies trading among all Annex I countries except for the EU.
- Umbrella without Eastern Europe implies trading among all Annex I countries except for the EU and Eastern Europe.

Abatement Cost Curves in Developing Countries: Marginal abatement cost curves for developing countries only include opportunities to reduce carbon dioxide released through energy consumption. Given that numerous options for sequestration projects in these countries exist, these curves overestimate the costs of developing country participation.

AEEI: All of the SGM derived marginal abatement cost curves are based on model outputs assuming an AEEI of 1.0.

Electricity Restructuring: Interagency staff analysis on the Administration's electricity restructuring proposal indicates that carbon reductions resulting from RPS, PBF, and green marketing could range between 13 and 33 MMTCE. For this analysis, we assume the upper end of this range.

Baseline Construction

Carbon Dioxide Emissions: For projections of carbon dioxide, we used the business as usual projections in SGM, with the exception of the U.S., where we employed the more recent AEO98 estimate of 2010 BAU for energy-based CO2 and the Climate Action Report (U.S. National Communication) projection for non-energy-based CO2. For the EU, an adjustment was made to the Western Europe value in SGM to reflect the non-participation of Iceland, Norway, Switzerland, and Turkey in the EU bubble. Based on CO2 emissions estimates from Oak Ridge National Lab, 66.1 MMTCE were deducted from the Western Europe estimate to derive the EU 1990 baseline CO2 emissions value. For 2010 BAU, 85 MMTCE were deducted (this increase assumes that the four non-participating countries increase their BAU emissions at the same rate as the EU).

Emissions of Other GHG: For projections of the other five categories of greenhouse gases, we used the information provided in the national communications to the Framework Convention on Climate Change.

- Australia: Non-CO2 GHG comprise 33% of all GHG emissions in 1990. These are assumed to be 25% of all GHG emissions in 2010 based on the trends projected in the U.S. and the EU. The 1990/95 baseline excludes SF6 and HFCs.

- Austria: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2000 level using the average annual growth rate over the 1990-2000 period. For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Belgium: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Canada: For non-CO2 gases, Canada is assumed to have the same non-CO2 emissions/total GHG emissions ratio as the US (.17 in 1990/95 and .13 in 2010). Total GHG emissions are then calculated based on historical and projected CO2 emissions.

- Denmark: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2005 level using the average annual growth rate over the 2000-2005 period.

- Eastern Europe: For non-CO2 gases, Eastern European countries are assumed to have the same non-CO2 emissions/total GHG emissions ratio as the Former Soviet Union (.25 in 1990/95 and .19 in 2010). Total GHG emissions are then calculated based on historical and projected CO2 emissions.

- Finland: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Former Soviet Union: Non-CO2 GHG comprise 25% of all GHG emissions in 1990. These are assumed to be 19% of all GHG emissions in 2010 based on the trends projected in the U.S. and the EU. The 1990/95 baseline excludes SF6, PFCs and HFCs.

- France: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Germany: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2005 level using the average annual growth rate over the 1990-2005 period. For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Greece: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Ireland: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Italy: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Japan: Non-CO2 GHG comprise 4% of all GHG emissions in 1990. These are assumed to be 3% of all GHG emissions in 2010 based on the trends projected in the U.S. and the EU. The 1990/95 baseline excludes SF6, PFCs, and HFCs.

- Luxembourg: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2000 level using the average annual growth rate over the 1990-2000 period.

- Portugal: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Spain: The United Nations has not posted a national communication for Spain on the FCCC webpage. Estimates of the methane and nitrous oxide emissions are based on the average methane/GDP(1995) and nitrous oxide/GDP(1995) ratios for the other 14 EU countries multiplied by Spain's 1995 GDP. Similar calculations were done for the three minor gases, but only based on the average of the Netherlands, Sweden, and the UK's emissions.

Converting to Carbon Equivalence: In all cases where data are provided in tons of gas, or tons of carbon dioxide equivalent, the data were converted to tons of carbon equivalence based on their 100 year time horizon global warming potential (IPCC 1996, p. 121). Some countries aggregated all HFCs into one value (and in some cases, all PFCs into one value). We constructed an HFC weight and a PFC weight based on specific HFC and PFC emissions in the U.S. in 1995. For HFCs, I used the following weight:

$$[2 * GWP(HFC\text{-}134a) + GWP(HFC\text{-}23)]/3 = 1300$$

HFC-134a was 52% and HFC-23 was 21% of all U.S. HFC emissions in 1995. For PFCs, I used the following weight:

$$[2 * GWP(CF_4) + GWP(C_6F_{14})]/3 = 1854$$

CF_4 was about 60% and C_6F_{14} was about 25% of all U.S. PFC emissions in 1995.

Sinks: Sink estimates are subject to significant uncertainty due to ambiguities in the Protocol definition of carbon sinks. The UN webpage provides a data set on carbon sequestration due to land use change and forestry activities. In addition, the compilation and synthesis of national communications document includes projections for some countries. In cases where only 1990 or 2000 data are available, it is assumed that the sequestration will be the same in 2010 for that country. Carbon sink data were available for the following countries: Australia (2000), Austria (1990), Belgium (2010), Bulgaria (2000), Czech Republic (2010), Denmark (2000), Estonia (1990), Finland (2010), France (2000), Germany (2000), Hungary (1990), Ireland (2010), Italy (2000), Japan (2000), Latvia (2000), Liechtenstein (1990), the Netherlands (2010), New Zealand (2010), Norway (2010), Poland (1988), Romania (1989), Russian Federation (1990), Slovakia (2010), Spain (2000), Sweden (2010), Switzerland (2010), United Kingdom (2000), and the U.S. (2010 – 1997 Climate Action Report).

Given the uncertainties regarding the definition of sinks in the protocol, we are using these estimates without modification. Upon receiving more guidance from State and Agriculture, we may undertake some revisions to appropriately account for the three designated sink categories of afforestation, reforestation, and deforestation.

- EU Bubble Countries: Twelve of the fifteen EU bubble countries provide estimates of carbon sinks for at least some year between 1990 and 2010. The total for these twelve countries was scaled up proportional to the land area under forest cover in the fifteen countries (forest area from FAO statistical webpage).

- Canada: Since Canada has not provided a sinks estimate, we used the sink estimate from Climate Change 1995, Volume II (p. 777). The value of 80 MMTCE is based on the carbon flux estimated during the 1990s for Canada, and reflects sequestration in forest vegetation and forest soils.

- Eastern Europe: All but two countries in Eastern Europe provided carbon sink estimates. Again, we used the scaling procedure employed with the EU to estimate a total for all of Eastern Europe.

- Japan: The national communication estimated removal of carbon through managed forests is approximately 25 MMTCE. The provided data point was not modified for soil sinks, since the communication appears to exclude soils in its sequestration estimate.

- Former Soviet Union: All but two countries of the Former Soviet Union in Annex I provided carbon sink estimates. Again, we used the scaling procedure employed with the EU to estimate a total for all of FSU.

- United States: Three estimates of U.S. sinks in 2010 are used. First, a very conservative estimate of 0 is used simply for the purposes of establishing an upper bound on control costs. Second, 52 MMTCE refers to half of the amount of above ground sequestration and wood in use and landfill sinks estimated in the 1997 Climate Action Report. Third, all of the sequestration in these sink categories is used.

Kyoto Targets: The targets for countries were from the Kyoto Protocol. For the Former Soviet Union, the Russian Federation and Ukraine target of 1990/95 levels was used. For the Eastern Europe region, a target of 1990/95 - 2% was used, because it is roughly the average target for Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, Slovakia, and Slovenia. While several of the Eastern European countries have selected a year or period or years other than 1990 as their base year/period, we continue to use the 1990 SGM estimate for carbon dioxide.

Sources:

IPCC. 1996. Climate Change 1995: The Science of Climate Change. Cambridge, UK: CUP.
First National Communication from Australia
First National Communication from Austria

Second National Communication from Belgium
First National Communication from Denmark
First National Communication from Finland
First National Communication from France
First National Communication from Germany
First National Communication from Greece
First National Communication from Ireland
First National Communication from Italy
First National Communication from Japan
First National Communication from Luxembourg
Second National Communication from the Netherlands
First National Communication from Portugal
First National Communication from the Russian Federation
Second National Communication from Sweden
First National Communication from the United Kingdom
Second National Communication from the United States (Climate Action Report 1997)
Communications from Parties Included in Annex I to the Convention, Addendum
Annual Energy Outlook 1998
Emissions of Greenhouse Gases in the United States 1996
Food and Agriculture Organization Statistical Webpage
Unpublished Cost Curve on Non-CO2 GHG from EPA

Required Cut Under Kyoto	Sinks	Elect Res	Scenario	Permit Price (92$)	Domestic Reductions (MMTCE)	Permits Purchased Abroad	US Abatement Cost	US Capital Outflow	US TC ($b)	TC/GDP
600	0	0	Umb - EU, EE w/ Key LDC	16	130	470	1.0	7.5	8.6	0.000932
600	52	0	Umb - EU, EE w/ Key LDC	9	72	476	0.3	4.3	4.6	0.000502
600	104	0	Umb - EU, EE w/ Key LDC	2	27	469	0.0	0.9	1.0	0.000105
600	0	0	A1 + 20% JI	36	229	371	4.1	13.4	17.5	0.001903
600	52	0	A1 + 20% JI	21	164	384	1.7	8.1	9.8	0.001065
600	104	0	A1 + 20% JI	9	72	424	0.3	3.8	4.1	0.000451
600	0	0	Umb - EU + 20% JI	20	157	443	1.6	8.9	10.4	0.001136
600	52	0	Umb - EU + 20% JI	9	72	476	0.3	4.3	4.6	0.000502
600	104	0	Umb - EU + 20% JI	0	0	496	0.0	0.0	0.0	0
600	0	0	Umb - EU, EE + 20% JI	30	204	396	3.1	11.9	14.9	0.001627
600	52	0	Umb - EU, EE + 20% JI	16	130	418	1.0	6.7	7.7	0.000841
600	104	0	Umb - EU, EE + 20% JI	4	45	451	0.1	1.8	1.9	0.000206
600	0	0	A1 w/ Key LDC + 20% JI	20	157	443	1.6	8.9	10.4	0.001136
600	52	0	A1 w/ Key LDC + 20% JI	12	102	446	0.6	5.4	6.0	0.000649
600	104	0	A1 w/ Key LDC + 20% JI	5	51	445	0.1	2.2	2.4	0.000256
600	0	0	Umb - EU w/ Key LDC + 20% JI	11	95	505	0.5	5.6	6.1	0.000662
600	52	0	Umb - EU w/ Key LDC + 20% JI	5	51	497	0.1	2.5	2.6	0.000284
600	104	0	Umb - EU w/ Key LDC + 20% JI	0	0	496	0.0	0.0	0.0	0
600	0	0	Umb - EU, EE w/ Key LDC + 20% JI	15	123	477	0.9	7.2	8.1	0.000879
600	52	0	Umb - EU, EE w/ Key LDC + 20% JI	9	72	476	0.3	4.3	4.6	0.000502
600	104	0	Umb - EU, EE w/ Key LDC + 20% JI	2	27	469	0.0	0.9	1.0	0.000105

US Required Cut Under Kyoto	Sinks	Elect Res	Scenario	Permit Price (92$)	Domestic Reductions (MMTCE)	Permits Purchased Abroad	US Abatement Cost	US Capital Outflow	2010 GDP US TC ($b)	9185 TC/GDP
600	0	0	Dom Only	171	600	0	51.3	0.0	51.3	0.005585
600	52	0	Dom Only	146	548	0	40.0	0.0	40.0	0.004355
600	52	33	Dom Only	130	515	0	33.5	0.0	33.5	0.003645
600	104	33	Dom Only	105	463	0	24.3	0.0	24.3	0.002646
600	0	33	Dom Only	155	567	0	43.9	0.0	43.9	0.004784
497	-55	0	10/97 position	148	552	0	40.8	0.0	40.8	0.004447
600	104	0	Dom Only	121	496	0	30.0	0.0	30.0	0.003267
600	0	0	Annex I	48	281	319	6.7	15.3	22.1	0.002401
600	52	0	Annex I	26	187	361	2.4	9.4	11.8	0.001287
600	104	0	Annex I	11	95	401	0.5	4.4	4.9	0.000537
600	0	0	Umb - EU	26	187	413	2.4	10.7	13.2	0.001434
600	52	0	Umb - EU	11	95	453	0.5	5.0	5.5	0.000599
600	104	0	Umb - EU	0	0	496	0.0	0.0	0.0	0
600	0	0	Umb - EU, EE	43	258	342	5.5	14.7	20.3	0.002205
600	52	0	Umb - EU, EE	20	157	391	1.6	7.8	9.4	0.001022
600	104	0	Umb - EU, EE	5	51	445	0.1	2.2	2.4	0.000256
600	0	0	A1 + JI	19	150	450	1.4	8.6	10.0	0.001086
600	52	0	A1 + JI	12	102	446	0.6	5.4	6.0	0.000649
600	104	0	A1 + JI	5	51	445	0.1	2.2	2.4	0.000256
600	0	0	Umb - EU + JI	10	84	516	0.4	5.2	5.6	0.000608
600	52	0	Umb - EU + JI	4	45	503	0.1	2.0	2.1	0.000229
600	104	0	Umb - EU + JI	0	0	496	0.0	0.0	0.0	0
600	0	0	Umb - EU, EE + JI	14	116	484	0.8	6.8	7.6	0.000826
600	52	0	Umb - EU, EE + JI	8	66	482	0.3	3.9	4.1	0.000449
600	104	0	Umb - EU, EE + JI	2	27	469	0.0	0.9	1.0	0.000105
600	0	0	A1 w/ Key LDC	20	150	450	1.5	9.0	10.5	0.001143
600	52	0	A1 w/ Key LDC	12	102	446	0.6	5.4	6.0	0.000649
600	104	0	A1 w/ Key LDC	5	51	445	0.1	2.2	2.4	0.000256
600	0	0	Umb - EU w/ Key LDC	12	102	498	0.6	6.0	6.6	0.000717
600	52	0	Umb - EU w/ Key LDC	5	51	497	0.1	2.5	2.6	0.000284
600	104	0	Umb - EU w/ Key LDC	0	0	496	0.0	0.0	0.0	0

US									2010 GDP (b92$)	9185
AEEI	Kyoto	Sinks (US)	Scenario	US Permit Price	Domestic Reductions	Permits Purchased Abroad	US Abatement Cost	US Capital Outflow	US TC (billions 92$)	TC/GDP
1	600	50	A1	44	312	288	5.76	12.67	18.44	0.0020
1	600	50	U-EU	23	222	378	1.98	8.69	10.67	0.0012
1	600	50	U-EU,EE	36	282	318	4.18	11.45	15.62	0.0017
1	600	50	U-EU, 20%JI	17	186	414	1.16	7.04	8.19	0.0009
1	600	50	U-EU, EE 20%JI	25	234	366	2.30	9.15	11.45	0.0012
1	600	50	U-EU + Key LDC	10	134	466	0.42	4.66	5.08	0.0006
1	600	50	U-EU,EE + Key LDC	14	166	434	0.81	6.08	6.89	0.0007
1	600	50	A1 + 20%JI	33	267	333	3.58	10.99	14.57	0.0016
1.25	600	50	A1	31	318	282	4.15	8.74	12.90	0.0014
1.25	600	50	U-EU	15	228	372	1.34	5.58	6.92	0.0008
1.25	600	50	U-EU,EE	26	294	306	3.17	7.96	11.13	0.0012
1.25	600	50	U-EU, 20%JI	12	204	396	0.92	4.75	5.68	0.0006
1.25	600	50	U-EU, EE 20%JI	19	264	336	2.03	6.38	8.42	0.0009
1.25	600	50	U-EU + Key LDC	7	146	454	0.34	3.18	3.51	0.0004
1.25	600	50	U-EU,EE + Key LDC	10	185	415	0.68	4.15	4.83	0.0005
1.25	600	50	A1 + 20%JI	24	286	314	2.83	7.54	10.37	0.0011

No sinks assumed for other countries

Trading Bloc	LDC Part	sinks (MMTCE)	Required Emissions Cut (MMTCE)	**Permit Price (92$)**	US Red (MMTCE)	domestic abatement TC ($b)	permits from abroad (MMTCE)	capital transfer ($b)	**TC to US ($b)**	TC/GDP	2010 GDP ($b)
Domestic	none	0	600	**145**	600	43.5	0	0.0	**43.5**	0.47%	9185
		52	600	**122**	548	33.5	0	0.0	**33.5**	0.36%	9185
		104	600	**99**	496	24.7	0	0.0	**24.7**	0.27%	9185
Annex I	none	0	600	**36**	285	5.1	315	11.3	**16.3**	0.18%	9185
		52	600	**17**	199	1.7	349	6.1	**7.8**	0.08%	9185
		104	600	**7**	91	0.3	405	2.7	**3.0**	0.03%	9185
Umb - EU	none	0	600	**18**	204	1.8	396	7.1	**9.0**	0.10%	9185
		52	600	**7**	95	0.3	453	3.1	**3.5**	0.04%	9185
		104	600	**0**	0	0.0	496	0.0	**0.0**	0.00%	9185
Umb - EU, EE	none	0	600	**31**	268	4.2	332	10.4	**14.6**	0.16%	9185
		52	600	**14**	166	1.1	382	5.2	**6.3**	0.07%	9185
		104	600	**4**	56	0.1	440	1.8	**1.9**	0.02%	9185
Annex I	JI	0	600	**15**	175	1.3	425	6.2	**7.5**	0.08%	9185
		52	600	**8**	115	0.5	433	3.6	**4.1**	0.04%	9185
		104	600	**4**	54	0.1	442	1.8	**1.9**	0.02%	9185
Umb - EU	JI	0	600	**8**	111	0.5	489	4.0	**4.4**	0.05%	9185
		52	600	**4**	53	0.1	495	1.9	**2.0**	0.02%	9185
		104	600	**0**	0	0.0	496	0.0	**0.0**	0.00%	9185
Annex I	20% JI	0	600	**27**	249	3.4	351	9.5	**12.8**	0.14%	9185
		52	600	**14**	172	1.2	376	5.3	**6.6**	0.07%	9185
		104	600	**6**	80	0.2	416	2.4	**2.7**	0.03%	9185

	Cuts include paper tons					Cuts include paper tons		
	Cut1	Cut2	Cut3			Cut1	Cut2	Cut3
US	600	548	496		US	600	548	496
EU	277	247	218		EU	277	247	218
FSU	-318	-421	-523		FSU	-318	-421	-523
EE	-108	-112	-116		EE	-108	-112	-116
Aus	21	38	54		Aus	21	38	54
Jap	113	100	88		Jap	113	100	88
Can	62	22	-18		Can	62	22	-18
Annex I	647	422	199		Annex I	647	422	199
Umb-EU	370	175	-19		Umb-EU	370	175	-19
Umb-EU,EE	478	287	97		Umb-EU,EE	478	287	97

Emissions Cuts Under Various Sinks and Scenarios				
	No Sink	Sink1	Sink2	Sink3
US	600	0	52	104
EU	277	0	30	59
FSU	-318	0	103	205
EE	-108	0	4	8
Aus	21	0	-17	-33
Jap	113	0	13	25
Can	62	0	40	80

US MAC includes non-CO2 gas curves, EEFSU include paper tons in non-CO2																	
						Japan		Aus		Canada		FSU				Umb - EU, EE	
US						emissio	price	emissio	price	emissio	price	emissio	price			emissio	price
emissio	price											215	0	318	0	318	0
												318	0	318	0	318	0
												318	0	318	0	318	0
		10	0	10	0							318	0	318	0	328	0
16	4	29	4	45	4	2	4	2	4	2	4	237	4	340	4	391	4
25	7	35	7	60	7	4	7	3	7	3	7	255	7	358	7	428	7
33	9	36	9	69	9	5	9	3	9	3	9	262	9	365	9	445	9
41	11	52	11	93	11	6	11	4	11	4	11	271	11	374	11	481	11
67	16	62	16	129	16	9	16	5	16	6	16	294	16	397	16	546	16
72	17	63	17	135	17	9	17	6	17	7	17	306	17	409	17	566	17
92	21	72	21	164	21	12	21	7	21	8	21	325	21	428	21	619	21
99	23	72	23	171	23	12	23	7	23	8	23	321	23	424	23	622	23
113	26	72	26	185	26	14	26	8	26	9	26	342	26	445	26	661	26
115	26	72	26	187	26	14	26	8	26	10	26	344	26	447	26	666	26
140	32	72	32	212	32	17	32	9	32	11	32	359	32	462	32	711	32
165	38	72	38	237	38	20	38	10	38	13	38	383	38	486	38	766	38
177	41	73	41	250	41	21	41	11	41	13	41	382	41	485	41	780	41
234	57	88	57	322	57	28	57	14	57	18	57	432	57	535	57	917	57
277	70	91	70	368	70	34	70	16	70	21	70	462	70	565	70	1004	70
282	72	91	72	373	72	34	72	16	72	22	72	465	72	568	72	1013	72
330	89	91	89	421	89	41	89	19	89	24	89	494	89	597	89	1102	89
380	109	91	109	471	109	47	109	22	109	29	109	529	109	632	109	1201	109
514	173	91	173	605	173												

	Umb - EU			WEur		EEur					EuropeOnly			ANnex I			China
	emissio	price		emissio	price	emissio	price				emissio	price		emissio	price		emissio
	426	0				78	0	108	0		108	0		426	0		
	426	0				108	0	108	0		108	0		426	0		
	426	0				108	0	108	0		108	0		426	0		
	436	0				108	0	108	0		108	0		436	0		
	502	4		9	4	81	4	111	4		120	4		511	4		64
	541	7		15	7	83	7	113	7		128	7		556	7		102
	559	9		19	9	84	9	114	9		133	9		578	9		129
	597	11		23	11	86	11	116	11		139	11		620	11		
	665	16		34	16	89	16	119	16		153	16		699	16		207
	686	17		39	17	90	17	120	17		159	17		725	17		
	742	21		48	21	93	21	123	21		171	21		790	21		
	745	23		48	23	93	23	123	23		171	23		793	23		
	787	26		58	26	96	26	126	26		184	26		845	26		
	792	26		58	26	96	26	126	26		184	26		850	26		304
	841	32		68	32	100	32	130	32		198	32		909	32		343
	900	38		82	38	104	38	134	38		216	38		982	38		386
	915	41		83	41	105	41	135	41		218	41		998	41		409
	1063	57		116	57	116	57	146	57		262	57		1179	57		516
	1159	70		138	70	125	70	155	70		293	70		1297	70		
	1169	72		140	72	126	72	156	72		296	72		1309	72		
	1268	89		160	89	136	89	166	89		326	89		1428	89		
	1381	109		190	109	150	109	180	109		370	109		1571	109		

India	Korea	Mexico	ROW		Umbrella (no EU) + JI			Umbrella (no EU, no EE)			Annex I + JI			Annex I + Key LDC		
s					emission	price		emission	price		emission	price		emissions	price	
					426	0		318	0		426	0		426	0	
					426	0		318	0		426	0		426	0	
					426	0		318	0		426	0		426	0	
					436	0		328	0		436	0		436	0	
8	1	4	11		599	4		479	4		599	4		588	4	
14	1	6	18		697	7		569	7		697	7		679	7	
17	1	8	22		755	9		622	9		755	9		733	9	
29	2	14	38		989	16		836	16		989	16		951	16	
46	4	23	62		1289	26		1105	26		1289	26		1227	26	
53	4	26	73		1408	32		1210	32		1408	32		1335	32	
61	5	30	86			38		1334	38		1550	38		1464	38	
65	6	32	93													
85	8	42	125													

Umb - EU + Key LDC		Umb - EU, EE + Key LDC		A1 + 20%JI		Umb - EU +20% JI		Umb - EU, EE +20% JI		A1, Key LDC +20% JI	
emissions	price	emissions	price	emissions	price	emissions	price	emissions	price	emissions	price
426	0	318	0	426	0	426	0	318	0	426	0
426	0	318	0	426	0	426	0	318	0	426	0
426	0	318	0	426	0	426	0	318	0	426	0
436	0	328	0	436	0	436	0	328	0	436	0
579	4	468	4	529	4	520	4	409	4	590	4
664	7	551	7	584	7	569	7	456	7	683	7
714	9	600	9	613	9	594	9	480	9	737	9
917	16	798	16	757	16	723	16	604	16	959	16
1169	26	1043	26	938	26	880	26	754	26	1239	26
1267	32	1137	32	1009	32	941	32	811	32	1350	32
1382	38	1248	38	1096	38	1014	38	880	38	1481	38

Umb - EU, Key LDC +2			Umb - EU, EE, Key LDC +20%				A1 + China			A1 + India			A1 + Mexico	
emissions	price		emissio	price			emission	price		emission	price		emission	price
426	0		318	0			426	0		426	0		426	0
426	0		318	0			426	0		426	0		426	0
426	0		318	0			426	0		426	0		426	0
436	0		328	0			436	0		436	0		436	0
581	4		470	4			575	4		519	4		515	4
668	7		555	7			658	7		570	7		562	7
718	9		604	9			707	9		595	9		586	9
925	16		806	16			906	16		728	16		713	16
1181	26		1055	26			1154	26		896	26		873	26
1282	32		1152	32			1252	32		962	32		935	32
1399	38		1265	38			1368	38		1043	38		1012	38
							1407	41		1063	41		1030	41
							1695	57		1264	57		1221	57

Sinks

Year	Country	MMTCO2	MMTCE	
2000	Australia	121.9	33.24545	
1990	Austria	-13.3	-3.62727	
2010	Belgium	-2.1	-0.57273	
2000	Bulgaria	-5.8	-1.58182	
	Canada		0	
	Croatia		0	
2010	Czech Rep	-5	-1.36364	
2000	Denmark	-2.6	-0.70909	
1990	Estonia	1.8	0.490909	
2010	Finland	-15	-4.09091	
2000	France	-39	-10.6364	
2000	Germany	-20	-5.45455	
	Greece		0	
1990	Hungary	-4.5	-1.22727	
	Iceland		0	
2010	Ireland	-9.7	-2.64545	
2000	Italy	-46.7	-12.7364	
2000	Japan	-92	-25.0909	
2000	Latvia	-8.9	-2.42727	
1990	Lichtenstein	-0.022	-0.006	
	Lithuania		0	
	Luxembourg		0	
	Monaco		0	
2010	Netherland	-1.7	-0.46364	
2010	New Zealan	-21.2	-5.78182	
2010	Norway	-14.8	-4.03636	
1988	Poland	-1.4	-0.38182	
	Portugal		0	
1989	Romania	-2.9	-0.79091	
1990	Russian Fe	-734	-200.182	
2010	Slovakia	-8	-2.18182	
	Slovenia		0	
2000	Spain	-25.7	-7.00909	
2010	Sweden	-22	-6	
2010	Switzerland	-5.1	-1.39091	
	Ukraine		0	
2000	United King	-9.2	-2.50909	
	USA		0	
	EC15		-56.4545	-59.2773
	FSU		-202.118	-204.948
	EEur		-7.52727	-7.83664
	Australia			33.24545
	Japan			-25.0909
	Canada			-118.508

> 1AT because 97 EU rep has higher baseline

Assumes 104 mm from sinks
June says should get less credit from sinks, 85 mmT

June 1

#4

The Costs of Kyoto

case	permit price	domestic reductions	domestic TC	permits purchased abroad	capital transfer	TC to US	TC/GDP
no trading	$161	490	$39.4b	0	0	$39.4b	0.43%
Annex I	$25	110	$1.4b	380	$9.5b	$10.9b	0.12%
Umbrella w/ Ern Europe	$12	48	$0.3b	442	$5.3b	$5.6b	0.06%
Umbrella w/o Ern Europe	$19	82	$0.8b	408	$7.8b	$8.6b	0.09%

Trading Assumptions:

- Marginal cost curves in countries derived from SGM for CO2 hold for all six gases (this likely overstates costs of abatement).
- Trading is assumed to occur across gases based on GWP.
- EEFSU countries can sell a lot more than their differential in 1990/95 GHG emissions and their 2010 projected emissions because of substantial sequestration.
- Annex I implies trading between all Annex I countries (note that in model, some small countries, e.g., New Zealand, Norway, Iceland, are not included).
- Umbrella with Eastern Europe implies trading among all Annex I countries except for the EU.
- Umbrella without Eastern Europe implies trading among all Annex I countries except for the EU and Eastern Europe.

85 mmT off net deforestation
over budget period 2008-2012

#5

Preliminary Draft, Jan 13, 1998 (2:38pm)

INTERPRETATION OF KYOTO PROTOCOL

U.S.

Kyoto mandates that the U.S. reduces its emissions (through domestic abatement, international trading, and joint implementation) to -7% of its 1990 levels for six categories of gases, net of the effects of certain sinks. Not accounting for carbon sinks, the U.S. may need to abate about 600 MMTCE relative to its 2010 BAU over the 2008-2012 commitment period. The following chart illustrates this target relative to business as usual.

Table 1. U.S. Greenhouse Gas Emissions, 1990/95 Baseline and 2010 BAU (MMTCE)

Gas/Sinks	1990/95 Emissions	-7% of 1990/95	2010 BAU Emissions
CO_2	1374		1838
CH_4	181		152
N_2O	38		34
HFCs, PFCs, SF_6	36		91
Kyoto Sinks	n/a		?
Total	1629	1515	2115

Sources: AEO98, 1997 Climate Action Report

Annex I

Most Annex I countries must undertake substantial cuts from their BAU greenhouse gas emissions projection over the 2008-2012 period to comply with their Kyoto targets. Several countries undergoing economic transition will have paper tons available to sell to other countries.

Table 2. Required Greenhouse Gas Emissions Reductions Under Kyoto (MMTCE)

Country/ Region	Kyoto Target	2010 BAU Projection	Required Emissions Cut without Sinks
U.S.	1515	2115	600
EU	940	1217	277
FSU	1313	995	-318 (PT)[1]
EE	511	403	-108 (PT)
Australia	89	110	21
Japan	266	379	113
Canada	129	191	62

[1] PT refers to paper tons.
Source: CEA

Sinks

The Protocol states that the effects of carbon sinks, defined as "direct human-induced land-use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks", should be used by Annex I countries to meet their commitments. The State Department is working on a legal interpretation of the sinks provision, and the Department of Agriculture will make an estimate of the size of the U.S. sinks in 2010 in the near future. For this analysis, we employ an estimate of U.S. sinks from the 1997 Climate Action Report, and we assume that BAU sinks do not affect the target, but should be considered as "free" tons deducted from the projected BAU for estimating the control costs of meeting the U.S. target. We use estimates of carbon sinks for other countries based on data in National Communications, FAO statistical website, and the IPCC (see appendix for discussion of methodology).

Given the uncertainty in the sinks, we use three measures in our calculations. First, we consider the costs of complying with Kyoto by scoring sinks as 0 for all countries. This presumably makes the target more stringent for most Annex I countries (Australia is a significant exception because of their deforestation rate). Then we consider sinks based on the estimates for land use change and forestry provided in the national communications or in Climate Change 1995 (IPCC, WG-II). Given that the Protocol definition appears to be more constrained than this, we halve the sequestration in each country and assess those values as well. The no sinks and full sinks definitions serve as reasonable bounds, and the half of sinks could lie close to actual sink estimates.

Table 3. Annex I Sinks (MMTCE)

Country/Region	No Sinks	Half of Sinks	Full Sinks
U.S.	0	52	104
EU	0	30	60
Japan	0	13	25
Australia	0	-17	-33
Canada	0	40	80
Former Soviet Union	0	103	205
EE	0	4	8
Total	0	225	449

Sources: national communications, U.S. Climate Action Report 1997, CEA

Note that the sinks could significantly increase paper tons for FSU countries, and could possibly provide Canada with paper tons. Indeed, under the definition of full sinks, paper tons on an Annex I market could total nearly 700 MMTCE, which if sold to other Annex I countries, would account for nearly 80% of all required emissions reductions in the buying countries. Further, in the case where an umbrella trading bloc is formed without EU participation, the paper tons available would exceed the demand for emissions rights (which in the model would result in a $0 permit price).

THE COSTS OF KYOTO

Domestic Only Abatement

If the U.S. had to meet its Kyoto target exclusively through domestic emissions abatement, the costs would likely be quite high. To provide some context of what Kyoto means, recall that domestic only abatement to get CO2 to 1990 level in 2010 would cost $108/ton (SGM: 380 MMTCE of abatement). By including the other gases and net-net sinks in the U.S. position and using the updated carbon dioxide projection in AEO98, our 1990 in 2010 proposal would likely cost about $148/ton (SGM and EPA cost curves for other gases and expanding sinks: 552 MMTCE of abatement; total abatement cost: $40.8 billion, 0.4% of GDP).[1] Note that the cost

[1] Dropping sinks entirely, the U.S. 6 gas position with AEO98 data would result in a permit price of $121/ton.

curves for the other gases can significantly influence the permit price. If the sinks provision in Kyoto results in the U.S. having 48 MMTCE of carbon sequestration credits, then Kyoto will be comparable to the original U.S. position. Sinks that exceed this value would result in Kyoto being less stringent than the Administration's position.

The following chart provides estimates of permit prices and total costs to the U.S. with domestic abatement with several different assumptions about the size of the carbon sinks. Further, we consider the effects of the Administration's electricity restructuring proposal on carbon emissions. The last row provides an estimate of Annex I trading, but it assumes that the abatement cost curves in other countries for all six gases and sinks are the same as their cost curves for carbon dioxide (this assumption biases upward the permit price and the extent the U.S. purchases emissions rights from abroad).

Table 4. U.S. Domestic Only Abatement Costs in 2010 for U.S. to Meet Kyoto Target

sinks	elect. res.	permit price	domestic reductions	domestic abatement TC	permits from abroad	capital transfer	TC to US	TC/ GDP
0	0	$171	600	$51.3 b	0	0	$51.3 b	0.6%
52	0	$146	548	$40.0 b	0	0	$40.0 b	0.4%
52	33	$130	515	$33.5 b	0	0	$33.5 b	0.4%
104	0	$121	496	$30.0 b	0	0	$30.0 b	0.3%
104	33	$105	463	$24.3 b	0	0	$24.3 b	0.3%
0	33	$155	567	$43.9 b	0	0	$43.9 b	0.5%
0*	0	$48	202	$4.8 b	398	$19.1 b	$24.0 b	0.3%

* Annex I trading
Source: CEA

Annex I Trading

We assess a number of scenarios. In the first set we consider variations of Annex I trading regimes without joint implementation or trading with key developing countries.

Table 5. Annex I Trading, Abatement Costs in 2010 for U.S. to Meet Kyoto Target

case	sinks	permit price	domestic reductions	domestic abatement TC	permits from abroad	capital transfer	TC to US	TC/ GDP
Annex I	none	$48	281	$6.7 b	319	$15.3 b	$22.0 b	0.2%
Annex I	half	$26	187	$2.4 b	361	$9.4 b	$11.8 b	0.1 %
Annex I	full	$11	95	$0.5 b	401	$4.4 b	$4.9 b	0.1%
Umbrella w/o EU	none	$26	187	$2.4 b	413	$10.7 b	$13.1 b	0.1%
Umbrella w/o EU	half	$11	95	$0.5 b	453	$5.0 b	$5.5 b	0.1%
Umbrella w/o EU	full	$0	0	0	496	0	0	0
Umbrella w/o EU, EE	none	$43	258	$5.5 b	342	$14.7 b	$20.2 b	0.2%
Umbrella w/o EU, EE	half	$20	157	$1.6 b	391	$7.8 b	$9.4 b	0.1%
Umbrella w/o EU, EE	full	$5	51	$0.1 b	445	$2.2 b	$2.3 b	0.03%

Source: CEA

International Trading (Annex I plus Developing Countries)

Table 6. Summary Table on U.S. Permit Prices (Total Cost) for Different Sinks and Trading Scenarios

Scenario	No Sinks	Half of Sinks	Full Sinks
Domestic Only	$171/ ton ($51.3 b)	$146/ton ($40.0 b)	$121/ton ($30.0 b)
Annex I	$48/ton ($22.1 b)	$26/ton ($11.8 b)	$11/ton ($4.9 b)
Umbrella w/o EU	$26/ton ($13.2 b)	$11/ton ($5.5 b)	$0/ton
Umbrella w/o EU, EE	$43/ton ($20.2 b)	$20/ton ($9.4 b)	$5/ton ($2.4 b)
Annex I + 100% JI (worldwide trading)	$19/ton ($10.0 b)	$12/ton ($6.0 b)	$5/ton ($2.4 b)
Umbrella w/o EU + 100% JI	$10/ton ($5.6 b)	$4/ton ($2.1 b)	$0/ton
Umbrella w/o EU, EE + 100% JI	$14/ton ($7.6 b)	$8/ton ($4.1 b)	$2/ton ($1.0 b)
Annex I + Key LDC	$20/ton ($10.5 b)	$12/ton ($6.0 b)	$5/ton ($2.4 b)
Umbrella w/o EU + Key LDC	$12/ton ($6.6 b)	$5/ton ($2.6)	$0/ton
Umbrella w/o EU, EE + Key LDC	$16/ton ($8.6 b)	$9/ton ($4.6 b)	$2/ton ($1.0 b)
Annex I + 20% JI	$36/ton ($17.5 b)	$21/ton ($9.8 b)	$9/ton ($4.1 b)
Umbrella w/o EU + 20% JI	$20/ton ($10.4 b)	$9/ton ($4.6 b)	$0/ton
Umbrella w/o EU, EE + 20% JI	$30/ton ($14.9 b)	$16/ton ($7.7 b)	$4/ton ($1.9 b)
Annex I + Key LDC + 20% JI in ROW	$20/ton ($10.4 b)	$12/ton ($6.0 b)	$5/ton ($2.4 b)
Umbrella w/o EU + Key LDC + 20% JI in ROW	$11/ton ($6.1 b)	$5/ton ($2.6)	$0/ton
Umbrella w/o EU, EE + Key LDC + 20% JI in ROW	$15/ton ($8.1 b)	$9/ton ($4.6 b)	$2/ton ($1.0 b)

Source: CEA

METHODOLOGY

Trading

Abatement Cost Curves in Industrialized Countries: Marginal cost curves in countries derived from SGM for CO2 hold for all six gases and sinks for all countries except for the United States (this likely overstates costs of abatement under international trading). The U.S. cost curves are derived from SGM outputs for CO2 and from EPA/OAR for the other gases and sinks. The cost curve for the other gases and sinks ends at $70/ton -- we assume that no other reductions are available beyond those achievable at that price.

Intergas Trading: Trading is assumed to occur across all gases and sinks based on 100-year global warming potential.

Trading Blocs: We assessed three different industrialized country trading blocs.

- Annex I implies trading between all Annex I countries (note that in model, some small countries, e.g., New Zealand, Norway, Iceland, are not included).
- Umbrella with Eastern Europe implies trading among all Annex I countries except for the EU.
- Umbrella without Eastern Europe implies trading among all Annex I countries except for the EU and Eastern Europe.

Abatement Cost Curves in Developing Countries: Marginal abatement cost curves for developing countries only include opportunities to reduce carbon dioxide released through energy consumption. Given that numerous options for sequestration projects in these countries exist, these curves overestimate the costs of developing country participation.

AEEI: All of the SGM derived marginal abatement cost curves are based on model outputs assuming an AEEI of 1.0.

Electricity Restructuring: Interagency staff analysis on the Administration's electricity restructuring proposal indicates that carbon reductions resulting from RPS, PBF, and green marketing could range between 13 and 33 MMTCE. For this analysis, we assume the upper end of this range.

Baseline Construction

Carbon Dioxide Emissions: For projections of carbon dioxide, we used the business as usual projections in SGM, with the exception of the U.S., where we employed the more recent AEO98 estimate of 2010 BAU for energy-based CO_2 and the Climate Action Report (U.S. National Communication) projection for non-energy-based CO_2. For the EU, an adjustment was made to the Western Europe value in SGM to reflect the non-participation of Iceland, Norway, Switzerland, and Turkey in the EU bubble. Based on CO_2 emissions estimates from Oak Ridge National Lab, 66.1 MMTCE were deducted from the Western Europe estimate to derive the EU 1990 baseline CO_2 emissions value. For 2010 BAU, 85 MMTCE were deducted (this increase assumes that the four non-participating countries increase their BAU emissions at the same rate as the EU).

Emissions of Other GHG: For projections of the other five categories of greenhouse gases, we used the information provided in the national communications to the Framework Convention on Climate Change.

- Australia: Non-CO_2 GHG comprise 33% of all GHG emissions in 1990. These are assumed to be 25% of all GHG emissions in 2010 based on the trends projected in the U.S. and the EU. The 1990/95 baseline excludes SF_6 and HFCs.

- Austria: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2000 level using the average annual growth rate over the 1990-2000 period. For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Belgium: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Canada: For non-CO_2 gases, Canada is assumed to have the same non-CO_2 emissions/total GHG emissions ratio as the US (.17 in 1990/95 and .13 in 2010). Total GHG emissions are then calculated based on historical and projected CO_2 emissions.

- Denmark: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2005 level using the average annual growth rate over the 2000-2005 period.

- Eastern Europe: For non-CO_2 gases, Eastern European countries are assumed to have the same non-CO_2 emissions/total GHG emissions ratio as the Former Soviet Union (.25 in 1990/95 and .19 in 2010). Total GHG emissions are then calculated based on historical and projected CO_2 emissions.

- Finland: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Former Soviet Union: Non-CO2 GHG comprise 25% of all GHG emissions in 1990. These are assumed to be 19% of all GHG emissions in 2010 based on the trends projected in the U.S. and the EU. The 1990/95 baseline excludes SF6, PFCs and HFCs.

- France: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Germany: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2005 level using the average annual growth rate over the 1990-2005 period. For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Greece: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Ireland: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Italy: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Japan: Non-CO2 GHG comprise 4% of all GHG emissions in 1990. These are assumed to be 3% of all GHG emissions in 2010 based on the trends projected in the U.S. and the EU. The 1990/95 baseline excludes SF6, PFCs, and HFCs.

- Luxembourg: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2000 level using the average annual growth rate over the 1990-2000 period.

- Portugal: For the three minor gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the UK.

- Spain: The United Nations has not posted a national communication for Spain on the FCCC webpage. Estimates of the methane and nitrous oxide emissions are based on the average methane/GDP(1995) and nitrous oxide/GDP(1995) ratios for the other 14 EU countries multiplied by Spain's 1995 GDP. Similar calculations were done for the three minor gases, but only based on the average of the Netherlands, Sweden, and the UK's emissions.

Converting to Carbon Equivalence: In all cases where data are provided in tons of gas, or tons of carbon dioxide equivalent, the data were converted to tons of carbon equivalence based on their 100 year time horizon global warming potential (IPCC 1996, p. 121). Some countries aggregated all HFCs into one value (and in some cases, all PFCs into one value). We constructed an HFC weight and a PFC weight based on specific HFC and PFC emissions in the U.S. in 1995. For HFCs, I used the following weight:

$$[2*GWP(HFC\text{-}134a) + GWP(HFC\text{-}23)]/3 = 1300$$

HFC-134a was 52% and HFC-23 was 21% of all U.S. HFC emissions in 1995. For PFCs, I used the following weight:

$$[2*GWP(CF_4) + GWP(C_6F_{14})]/3 = 1854$$

CF_4 was about 60% and C_6F_{14} was about 25% of all U.S. PFC emissions in 1995.

Sinks: Sink estimates are subject to significant uncertainty due to ambiguities in the Protocol definition of carbon sinks. The UN webpage provides a data set on carbon sequestration due to land use change and forestry activities. In addition, the compilation and synthesis of national communications document includes projections for some countries. In cases where only 1990 or 2000 data are available, it is assumed that the sequestration will be the same in 2010 for that country. Carbon sink data were available for the following countries: Australia (2000), Austria (1990), Belgium (2010), Bulgaria (2000), Czech Republic (2010), Denmark (2000), Estonia (1990), Finland (2010), France (2000), Germany (2000), Hungary (1990), Ireland (2010), Italy (2000), Japan (2000), Latvia (2000), Liechtenstein (1990), the Netherlands (2010), New Zealand (2010), Norway (2010), Poland (1988), Romania (1989), Russian Federation (1990), Slovakia (2010), Spain (2000), Sweden (2010), Switzerland (2010), United Kingdom (2000), and the U.S. (2010 -- 1997 Climate Action Report).

Given the uncertainties regarding the definition of sinks in the protocol, we are using these estimates without modification. Upon receiving more guidance from State and Agriculture, we may undertake some revisions to appropriately account for the three designated sink categories of afforestation, reforestation, and deforestation.

- EU Bubble Countries: Twelve of the fifteen EU bubble countries provide estimates of carbon sinks for at least some year between 1990 and 2010. The total for these twelve countries was scaled up proportional to the land area under forest cover in the fifteen countries (forest area from FAO statistical webpage).

- Canada: Since Canada has not provided a sinks estimate, we used the sink estimate from Climate Change 1995, Volume II (p. 777). The value of 80 MMTCE is based on the carbon flux estimated during the 1990s for Canada, and reflects sequestration in forest vegetation and forest soils.

- Eastern Europe: All but two countries in Eastern Europe provided carbon sink estimates. Again, we used the scaling procedure employed with the EU to estimate a total for all of Eastern Europe.

- Japan: The national communication estimated removal of carbon through managed forests is approximately 25 MMTCE. The provided data point was not modified for soil sinks, since the communication appears to exclude soils in its sequestration estimate.

- Former Soviet Union: All but two countries of the Former Soviet Union in Annex I provided carbon sink estimates. Again, we used the scaling procedure employed with the EU to estimate a total for all of FSU.

- United States: Three estimates of U.S. sinks in 2010 are used. First, a very conservative estimate of 0 is used simply for the purposes of establishing an upper bound on control costs. Second, 52 MMTCE refers to half of the amount of above ground sequestration and wood in use and landfill sinks estimated in the 1997 Climate Action Report. Third, all of the sequestration in these sink categories is used.

Kyoto Targets: The targets for countries were from the Kyoto Protocol. For the Former Soviet Union, the Russian Federation and Ukraine target of 1990/95 levels was used. For the Eastern Europe region, a target of 1990/95 - 2% was used, because it is roughly the average target for Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, Slovakia, and Slovenia. While several of the Eastern European countries have selected a year or period or years other than 1990 as their base year/period, we continue to use the 1990 SGM estimate for carbon dioxide.

Sources:
IPCC. 1996. Climate Change 1995: The Science of Climate Change. Cambridge, UK: CUP.
First National Communication from Australia
First National Communication from Austria
Second National Communication from Belgium

First National Communication from Denmark
First National Communication from Finland
First National Communication from France
First National Communication from Germany
First National Communication from Greece
First National Communication from Ireland
First National Communication from Italy
First National Communication from Japan
First National Communication from Luxembourg
Second National Communication from the Netherlands
First National Communication from Portugal
First National Communication from the Russian Federation
Second National Communication from Sweden
First National Communication from the United Kingdom
Second National Communication from the United States (Climate Action Report 1997)
Communications from Parties Included in Annex I to the Convention, Addendum
Annual Energy Outlook 1998
Emissions of Greenhouse Gases in the United States 1996
Food and Agriculture Organization Statistical Webpage
Unpublished Cost Curve on Non-CO2 GHG from EPA

		household level					end-user level				
Aldy scenario #	permit price	ch, en exp household	ch, en exp d(elast)	index	adj for elec restruct	net of elec restruct			index	adj for elec restruct	net of elec restruct
1	148	0.299	0.263	126	4.5	122	0.414	0.365	136	5.5	131
2	171	0.345	0.304	130	4.7	126	0.479	0.421	142	5.8	138
3	48	0.097	0.085	109	3.9	105	0.134	0.118	112	4.5	108
4	43	0.087	0.076	108	3.9	104	0.120	0.106	111	4.5	107
5	26	0.053	0.046	105	3.8	101	0.073	0.064	106	4.3	102
6	36	0.073	0.064	106	3.8	103	0.101	0.089	109	4.4	105
7	20	0.040	0.036	104	3.7	100	0.056	0.049	105	4.3	101
8	19	0.038	0.034	103	3.7	100	0.053	0.047	105	4.2	101
9	10	0.020	0.018	102	3.7	98	0.028	0.025	102	4.2	98
1990 expen				100					100		
ch, expend @$100/ton		0.202					0.280				

Notes:

1. energy expenditure calculations based on an exercise of 10/97, which calculated that $100/ton carbon tax implies 76% increase in energy expenditure at primary fuel level, 28% at end-use level, 20.2% at hhld level.

2. Change in energy expenditure calculated by multiplying (residential expenditure on elec, nat gas, fuel oil, and LPG = $124b in 1993 + expenditure on gasoline = $100.7b in 1993) by the % change in energy sector expenditure, calculated above for each scenario.

3. Index number reflects per capita energy expenditure.
EIA projects primary energy consumption to grow at 1.0%/yr.
Census Bureau middle series population projection rises at 1.0%/yr until 2010, so per capita energy consumption is flat.
EIA projects energy prices, aggregated over all fuels, to be flat, as calculated in attached spreadsheet.

4. ch en exp d(elast) means change in energy expenditure taking account of price elasticity. Offline calculation indicates for a given expenditure calculated as "ch en exp" price elasticity effect offsets about 12% of the calculated total, averaged across household fuels
Thus, "ch en exp" multiplied by 88% to get "ch en exp d(elast)"

5. elec restructuring savings: 1993 exp, residential sector: $81 b.
2010 exp = $81 b x (index of hhld en exp for 2010). Demoninator is 1993 exp on all energy, hhld sector = $124b
+ $100b gasoline = $224b, which is the basis of the base year index = 100. At end-use level, we assume $20 b/yr savings, growing with index of energy exp growth,
out of $493 b total for all fuels (Stat Abstract Table 919)

6

#6

	(1) share: tot e	(2) price per phys unit	(3) %incr for $100/ton	(4) (3/2)	(5) (4) * (1)	(6) elast(price)	(7) delta q	(8) p*deltaq	(9) del p*del q	(10) ch expen (8)+(9)	(11) q(p+del p)	(12) %ch expen	(13) price growt 1996-2020	(14) (1) x (12)
gasoline	0.46	1.24	0.24	0.194	0.089	0.75	0.067	0.083	0.016	0.098826	0.6808	0.145161	0.004	0.00184
elec	0.37	8.40	1.50	0.179	0.066	0.4	0.026	0.222	0.040	0.261643	3.663	0.071429	-0.01	-0.0037
n gas	0.15	6.07	1.45	0.239	0.036	0.5	0.018	0.109	0.026	0.134728	1.128	0.11944	0.005	0.00075
fuel oil	0:03	0.90	0.34	0.378	0.011	0.5	0.006	0.005	0.002	0.007027	0.0372	0.188889	0.004	0.00012
sum: delta	1.01				0.202									-0.00099
														wgt price ch

	incr at				
	$100	$171	$48	$26	$10
gasoline	0.24	0.4104	0.1152	0.0624	0.024
elec	1.50	2.565	0.72	0.39	0.15
n gas	1.45	2.4795	0.696	0.377	0.145
fuel oil	0.34	0.5814	0.1632	0.0884	0.034

#7

Randall W. Lutter
02/23/98 05:52:27 PM

Record Type: Record

To: Janet L. Yellen/CEA/EOP

cc:
Subject: Here is Ray Squitieri's e-mail on prices and expenditures.

I am forwarding this as I promised. I think that it needs work and that you should give me til tomorrow morning to make it presentable before you spend time on it.

-RL

---------------------- Forwarded by Randall W. Lutter/CEA/EOP on 02/23/98 05:48 PM ---------------------------

Ray.R.S.Squitieri @ MS01.DO.treas.sprint.com
02/23/98 03:04:00 PM

Record Type: Record

To: Randall W. Lutter

cc:
Subject: fact check

Date: 02/23/1998 03:50 pm (Monday)
From: Ray Squitieri
To: randy
Subject: fact check

Janet Yellin testimony on climate change
Notes on effect on average family

Treasury 10/97 calculation (spreadsheet attached) found that $100/ton carbon tax implies 20.2% increase in direct energy expenditure at hhld level. Thus $14 to $23/ton carbon tax implies 3.8% increase before adjusting for price elasticity effect, or 3.4% increase after adjusting for price elasticity effect (which is about 12%).

Approximate agreement with earlier Treasury calculation done differently:
In 9/97 calculations, Treasury calculated the effect of $100/ton carbon at $514/hhld ($1992) for direct energy expenditures. Yellen testimony cites permit price of $14 to $23/ton. So 18.5/100 x 514 = $95 per hhld. In 1993, the average hhld had $1282 in direct expenditures for energy (Stat Abstract, table 920) not including gasoline, and bought about 1000 gallons of gasoline at an average price of $1.16 per gallon. Total direct energy expenditures were thus $2442. Then 95/2442 = 3.9%.

#8

The Second Generation Model (SGM)
Summary and Comments

Structure

Sectors:
- 7 energy sectors
  - (crude oil extraction, natural gas extraction, coal mining, uranium mining and processing, electicity, oil refining, and gas transmission and distribution)
- Agriculture,
- Other products

Subsectors for the energy sectors:
- 3 different grades of oil and gas, differing by extraction cost.
- 6 different electricity generation subsectors, differing by energy source,

Inputs: land, labor and capital of a various vintages, (e.g., 4 for capital lasting 20 years)
Capital is fixed factor, specific to sector or subsector, and of constant productivity until average lifetime is reached.

Accounting for reserves of depletable resources by resource by vintage

Technology:
- Separate CES production functions for each vintage capital
- Hick's neutral technological change by sector
  - Historical values range from 0 in agriculture to 2 percent in coal.
    - Other products is 0.5 percent.

Demand: 3 sectors:

--government (education, national defense and general government) the government maximizes utility defined over the 3 government services, and finances deficits net of domestic borrowing through foreign borrowing.

--households, savings assumed to vary directly with the real interest rate, interest elasticity of savings of .4, households can demand land and labor as well as final products, price and income elasticities taken from existing literature.

--trade: SGM assumes zero trade for all goods except crude oil

Firm behavior:

Profit maximization under adaptive expectations,

Accelerator-based investment, a sector's share of total investment depends on its relative expected future profitability, given macro investment demand function.

Implementation

--Calibration chooses model parameters to exactly reproduce observations in a given base year.

--Assumes base-year data reflect equilibrium, and "normal" growth path.

Issues:

Ability to replicate historical data is uncertain.

Behavior ignores uncertainty / risk.

EMF-14 MODEL COMPARISONS

Model	WGI-450	WGI-550	WGI-650
SGM (Battelle)	$80	$48	$24
Minicam (Battelle)	$160	$115	$77
CETA (Peck & Teisberg)	$145	$88	$37
CPBRIVM (Dutch Team)	$30	$19	$12
CRTM (Montgomery & Rutherford)	$242	$127	$92

Full Global Trading: 2010 Permit Prices

KYOTO PROTOCOL ANALYSIS

Model	No Trading	Annex 1	Umbrella - EU	Annex 1 + Ideal JI
SGM (Battelle)	$171	$48	$26	$19
G^3 (Shackleton)	$55	$32	$16	$11
MRT (Montgomery & Rutherford)	$279	$97	NA	$34

G³ 1/98 results #10

Kyoto, U.S. Only, Lump-Sum	2010	2015	2020
U.S.			
Gross National Product ($90, % Change f/ Base)	-0.6%	-0.5%	-0.4%
Gross Domestic Product ($90, % Change f/ Base)	-0.6%	-0.5%	-0.5%
Permit Price ($90)	49	52	56
Emission Reductions (MMTC)	-514	-652	-811
Real Effective Exchange Rate (% Change from Base)	2%	3%	4%
Exports ($90, % Change From Base)	-2%	-3%	-4%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-60	2	62
Japan			
Gross National Product ($90, % Change f/ Base)	0.0%	0.0%	0.1%
Gross Domestic Product ($90, % Change f/ Base)	-0.1%	-0.1%	-0.1%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	-1	-1	-2
Real Effective Exchange Rate (% Change from Base)	-4%	-5%	-5%
Exports ($90, % Change From Base)	2%	2%	2%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	13	10	1
Australia			
Gross National Product ($90, % Change f/ Base)	0.0%	0.0%	0.1%
Gross Domestic Product ($90, % Change f/ Base)	0.3%	0.3%	0.2%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	2	2	2
Real Effective Exchange Rate (% Change from Base)	2%	2%	2%
Exports ($90, % Change From Base)	0%	0%	0%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-9	-12	-14
Other OECD			
Gross National Product ($90, % Change f/ Base)	-0.1%	-0.1%	-0.1%
Gross Domestic Product ($90, % Change f/ Base)	-0.1%	-0.1%	-0.1%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	0	-1	-1
Real Effective Exchange Rate (% Change from Base)	-4%	-5%	-5%
Exports ($90, % Change From Base)	2%	2%	2%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	68	56	35
China			
Gross National Product ($90, % Change f/ Base)	0.0%	0.0%	0.0%
Gross Domestic Product ($90, % Change f/ Base)	0.0%	0.0%	0.0%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	0	2	2
Real Effective Exchange Rate (% Change from Base)	0%	0%	0%
Exports ($90, % Change From Base)	0%	0%	0%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	8	10	12
LDC's			
Gross National Product ($90, % Change f/ Base)	0.4%	0.4%	0.4%
Gross Domestic Product ($90, % Change f/ Base)	0.3%	0.3%	0.2%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	22	23	25
Real Effective Exchange Rate (% Change from Base)	7%	6%	6%
Exports ($90, % Change From Base)	-7%	-6%	-5%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	6	-9	-22
OPEC Oil Exports ($90, % Change from Base)	-2%	-2%	-2%
OPEC Oil Price (% Change from Base)	-4%	-5%	-5%

Kyoto, No Trading, Lump-Sum, OOECD Target = 300 MMTC	2010	2015	2020
U.S.			
Gross National Product ($90, % Change f/ Base)	-0.3%	-0.3%	-0.2%
Gross Domestic Product ($90, % Change f/ Base)	0.0%	0.0%	0.1%
Permit Price ($90)	54	57	60
Emission Reductions (MMTC)	-516	-662	-804
Real Effective Exchange Rate (% Change from Base)	12%	13%	14%
Exports ($90, % Change From Base)	-14%	-16%	-18%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-528	-578	-572
Japan			
Gross National Product ($90, % Change f/ Base)	-0.9%	-0.7%	-0.4%
Gross Domestic Product ($90, % Change f/ Base)	-1.5%	-1.5%	-1.5%
Permit Price ($90)	222	230	237
Emission Reductions (MMTC)	-96	-122	-146
Real Effective Exchange Rate (% Change from Base)	-23%	-22%	-22%
Exports ($90, % Change From Base)	13%	12%	12%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	28	44	30
Australia			
Gross National Product ($90, % Change f/ Base)	-2.4%	-3.6%	-4.5%
Gross Domestic Product ($90, % Change f/ Base)	-0.1%	-0.7%	-1.2%
Permit Price ($90)	49	66	84
Emission Reductions (MMTC)	-27	-44	-65
Real Effective Exchange Rate (% Change from Base)	16%	13%	10%
Exports ($90, % Change From Base)	-10%	-8%	-7%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-68	-116	-165
Other OECD			
Gross National Product ($90, % Change f/ Base)	-1.1%	-1.4%	-1.6%
Gross Domestic Product ($90, % Change f/ Base)	-1.2%	-1.4%	-1.5%
Permit Price ($90)	111	148	184
Emission Reductions (MMTC)	-301	-473	-673
Real Effective Exchange Rate (% Change from Base)	-23%	-23%	-23%
Exports ($90, % Change From Base)	15%	14%	14%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	460	604	688
China			
Gross National Product ($90, % Change f/ Base)	0.0%	0.1%	0.1%
Gross Domestic Product ($90, % Change f/ Base)	-0.1%	-0.1%	-0.1%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	1	4	4
Real Effective Exchange Rate (% Change from Base)	-1%	-1%	-1%
Exports ($90, % Change From Base)	1%	0%	0%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	34	46	57
LDC's			
Gross National Product ($90, % Change f/ Base)	2.4%	2.4%	2.2%
Gross Domestic Product ($90, % Change f/ Base)	1.4%	1.4%	1.2%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	83	88	95
Real Effective Exchange Rate (% Change from Base)	47%	45%	44%
Exports ($90, % Change From Base)	-34%	-30%	-25%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	124	117	115
OPEC Oil Exports ($90, % Change from Base)	-9%	-9%	-9%
OPEC Oil Price (% Change from Base)	-14%	-15%	-17%

Kyoto, No Trading, Lump-Sum, OOECD Target = 400 MMTC	2010	2015	2020
U.S.			
Gross National Product ($90, % Change f/ Base)	-0.3%	-0.2%	-0.2%
Gross Domestic Product ($90, % Change f/ Base)	0.1%	0.1%	0.2%
Permit Price ($90)	55	58	62
Emission Reductions (MMTC)	-520	-673	-824
Real Effective Exchange Rate (% Change from Base)	13%	14%	15%
Exports ($90, % Change From Base)	-16%	-18%	-20%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-581	-628	-626
Japan			
Gross National Product ($90, % Change f/ Base)	-0.8%	-0.6%	-0.3%
Gross Domestic Product ($90, % Change f/ Base)	-1.6%	-1.6%	-1.5%
Permit Price ($90)	219	226	233
Emission Reductions (MMTC)	-96	-121	-144
Real Effective Exchange Rate (% Change from Base)	-24%	-24%	-24%
Exports ($90, % Change From Base)	14%	13%	13%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	22	35	22
Australia			
Gross National Product ($90, % Change f/ Base)	-2.5%	-3.7%	-4.6%
Gross Domestic Product ($90, % Change f/ Base)	-0.1%	-0.7%	-1.2%
Permit Price ($90)	49	67	84
Emission Reductions (MMTC)	-27	-44	-65
Real Effective Exchange Rate (% Change from Base)	17%	13%	10%
Exports ($90, % Change From Base)	-10%	-8%	-7%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-68	-117	-166
Other OECD			
Gross National Product ($90, % Change f/ Base)	-1.4%	-1.6%	-1.8%
Gross Domestic Product ($90, % Change f/ Base)	-1.5%	-1.6%	-1.7%
Permit Price ($90)	146	179	212
Emission Reductions (MMTC)	-391	-574	-780
Real Effective Exchange Rate (% Change from Base)	-26%	-25%	-25%
Exports ($90, % Change From Base)	17%	15%	16%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	508	654	739
China			
Gross National Product ($90, % Change f/ Base)	0.0%	0.1%	0.1%
Gross Domestic Product ($90, % Change f/ Base)	-0.1%	-0.1%	-0.1%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	1	4	5
Real Effective Exchange Rate (% Change from Base)	-1%	-1%	-1%
Exports ($90, % Change From Base)	1%	0%	0%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	37	49	61
LDC's			
Gross National Product ($90, % Change f/ Base)	2.7%	2.6%	2.5%
Gross Domestic Product ($90, % Change f/ Base)	1.6%	1.5%	1.3%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	91	96	103
Real Effective Exchange Rate (% Change from Base)	53%	51%	49%
Exports ($90, % Change From Base)	-38%	-33%	-28%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	141	137	133
OPEC Oil Exports ($90, % Change from Base)	-10%	-10%	-10%
OPEC Oil Price (% Change from Base)	-16%	-17%	-19%

Kyoto, Annex I Trading, Lump-Sum, OOECD Target = 400 MMTC	2010	2015	2020
U.S.			
Gross National Product ($90, % Change f/ Base)	-0.2%	-0.5%	-0.7%
Gross Domestic Product ($90, % Change f/ Base)	-0.1%	-0.3%	-0.4%
Permit Price ($90)	32	52	67
Emission Reductions (MMTC)	-321	-625	-935
Real Effective Exchange Rate (% Change from Base)	5%	6%	7%
Exports ($90, % Change From Base)	-6%	-8%	-9%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-238	-302	-265
Japan			
Gross National Product ($90, % Change f/ Base)	-0.2%	-0.2%	-0.1%
Gross Domestic Product ($90, % Change f/ Base)	-0.5%	-0.6%	-0.6%
Permit Price ($90)	32	52	67
Emission Reductions (MMTC)	-19	-31	-43
Real Effective Exchange Rate (% Change from Base)	-14%	-14%	-14%
Exports ($90, % Change From Base)	8%	7%	7%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	50	88	95
Australia			
Gross National Product ($90, % Change f/ Base)	-2.0%	-3.3%	-4.1%
Gross Domestic Product ($90, % Change f/ Base)	0.1%	-0.5%	-0.9%
Permit Price ($90)	32	52	67
Emission Reductions (MMTC)	-17	-34	-51
Real Effective Exchange Rate (% Change from Base)	13%	11%	9%
Exports ($90, % Change From Base)	-7%	-6%	-4%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-61	-104	-147
Other OECD			
Gross National Product ($90, % Change f/ Base)	-0.5%	-0.7%	-0.9%
Gross Domestic Product ($90, % Change f/ Base)	-0.5%	-0.7%	-0.7%
Permit Price ($90)	32	52	67
Emission Reductions (MMTC)	-98	-173	-250
Real Effective Exchange Rate (% Change from Base)	-16%	-16%	-16%
Exports ($90, % Change From Base)	11%	10%	10%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	402	550	603
China			
Gross National Product ($90, % Change f/ Base)	0.0%	0.1%	0.1%
Gross Domestic Product ($90, % Change f/ Base)	-0.1%	0.0%	0.0%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	-1	1	3
Real Effective Exchange Rate (% Change from Base)	0%	0%	0%
Exports ($90, % Change From Base)	0%	0%	0%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	21	30	38
LDC's			
Gross National Product ($90, % Change f/ Base)	1.4%	1.4%	1.3%
Gross Domestic Product ($90, % Change f/ Base)	0.9%	0.8%	0.7%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	44	53	62
Real Effective Exchange Rate (% Change from Base)	26%	26%	25%
Exports ($90, % Change From Base)	-20%	-18%	-15%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	63	53	38
OPEC Oil Exports ($90, % Change from Base)	-4%	-5%	-5%
OPEC Oil Price (% Change from Base)	-3%	-6%	-9%

Kyoto, "Umbrella", Lump-Sum, OOECD Target = 400 MMTC	2010	2015	2020
U.S.			
Gross National Product ($90, % Change f/ Base)	0.1%	0.0%	-0.1%
Gross Domestic Product ($90, % Change f/ Base)	0.3%	0.1%	0.0%
Permit Price ($90)	16	30	40
Emission Reductions (MMTC)	-127	-325	-519
Real Effective Exchange Rate (% Change from Base)	8%	8%	8%
Exports ($90, % Change From Base)	-10%	-11%	-12%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-344	-396	-362
Japan			
Gross National Product ($90, % Change f/ Base)	-0.1%	0.0%	0.1%
Gross Domestic Product ($90, % Change f/ Base)	-0.5%	-0.5%	-0.6%
Permit Price ($90)	16	30	40
Emission Reductions (MMTC)	-13	-21	-29
Real Effective Exchange Rate (% Change from Base)	-16%	-15%	-15%
Exports ($90, % Change From Base)	8%	8%	8%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	29	73	97
Australia			
Gross National Product ($90, % Change f/ Base)	-1.3%	-2.1%	-2.6%
Gross Domestic Product ($90, % Change f/ Base)	0.1%	-0.3%	-0.6%
Permit Price ($90)	16	30	40
Emission Reductions (MMTC)	-8	-19	-30
Real Effective Exchange Rate (% Change from Base)	7%	6%	4%
Exports ($90, % Change From Base)	-4%	-4%	-3%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-21	-41	-62
Other OECD			
Gross National Product ($90, % Change f/ Base)	-1.2%	-1.4%	-1.5%
Gross Domestic Product ($90, % Change f/ Base)	-1.3%	-1.5%	-1.6%
Permit Price ($90)	146	179	212
Emission Reductions (MMTC)	-388	-568	-772
Real Effective Exchange Rate (% Change from Base)	-19%	-18%	-17%
Exports ($90, % Change From Base)	13%	11%	11%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	426	576	653
China			
Gross National Product ($90, % Change f/ Base)	0.0%	0.1%	0.1%
Gross Domestic Product ($90, % Change f/ Base)	-0.1%	0.0%	0.0%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	0	2	4
Real Effective Exchange Rate (% Change from Base)	0%	0%	0%
Exports ($90, % Change From Base)	0%	0%	0%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	23	32	40
LDC's			
Gross National Product ($90, % Change f/ Base)	1.8%	1.8%	1.7%
Gross Domestic Product ($90, % Change f/ Base)	1.0%	1.0%	0.8%
Permit Price ($90)	0	0	0
Emission Reductions (MMTC)	53	61	69
Real Effective Exchange Rate (% Change from Base)	32%	31%	30%
Exports ($90, % Change From Base)	-24%	-21%	-18%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	102	106	104
OPEC Oil Exports ($90, % Change from Base)	-6%	-6%	-7%
OPEC Oil Price (% Change from Base)	-8%	-10%	-12%

Kyoto, Full "JI", Lump-Sum, OOECD Target = 400 MMTC	2010	2015	2020
U.S.			
Gross National Product ($90, % Change f/ Base)	0.0%	0.0%	0.0%
Gross Domestic Product ($90, % Change f/ Base)	0.0%	0.0%	-0.1%
Permit Price ($90)	11	16	20
Emission Reductions (MMTC)	-102	-177	-267
Real Effective Exchange Rate (% Change from Base)	3%	3%	3%
Exports ($90, % Change From Base)	-3%	-3%	-4%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-78	-86	-47
Japan			
Gross National Product ($90, % Change f/ Base)	0.0%	0.0%	0.0%
Gross Domestic Product ($90, % Change f/ Base)	-0.2%	-0.2%	-0.2%
Permit Price ($90)	11	16	20
Emission Reductions (MMTC)	-6	-9	-12
Real Effective Exchange Rate (% Change from Base)	-5%	-6%	-6%
Exports ($90, % Change From Base)	3%	3%	3%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	25	44	38
Australia			
Gross National Product ($90, % Change f/ Base)	-0.7%	-1.1%	-1.3%
Gross Domestic Product ($90, % Change f/ Base)	-0.1%	-0.2%	-0.3%
Permit Price ($90)	11	16	20
Emission Reductions (MMTC)	-6	-10	-15
Real Effective Exchange Rate (% Change from Base)	3%	2%	2%
Exports ($90, % Change From Base)	-2%	-1%	-1%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-9	-17	-27
Other OECD			
Gross National Product ($90, % Change f/ Base)	-0.2%	-0.2%	-0.3%
Gross Domestic Product ($90, % Change f/ Base)	-0.2%	-0.2%	-0.2%
Permit Price ($90)	11	16	20
Emission Reductions (MMTC)	-33	-52	-74
Real Effective Exchange Rate (% Change from Base)	-6%	-6%	-6%
Exports ($90, % Change From Base)	4%	4%	4%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	183	259	311
China			
Gross National Product ($90, % Change f/ Base)	-0.5%	-0.1%	0.3%
Gross Domestic Product ($90, % Change f/ Base)	-0.6%	-0.5%	-0.7%
Permit Price ($90)	11	16	20
Emission Reductions (MMTC)	-278	-471	-697
Real Effective Exchange Rate (% Change from Base)	7%	11%	14%
Exports ($90, % Change From Base)	-5%	-7%	-8%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	-41	-46	-36
LDC's			
Gross National Product ($90, % Change f/ Base)	0.2%	0.1%	0.1%
Gross Domestic Product ($90, % Change f/ Base)	-0.1%	-0.2%	-0.3%
Permit Price ($90)	11	16	20
Emission Reductions (MMTC)	-118	-205	-308
Real Effective Exchange Rate (% Change from Base)	7%	6%	6%
Exports ($90, % Change From Base)	-5%	-5%	-4%
Net Int'l Invest. Pos. (Change from Base, $90 Billion)	51	50	40
OPEC Oil Exports ($90, % Change from Base)	-1%	-1%	-1%
OPEC Oil Price (% Change from Base)	-4%	-5%	-6%

#11

G-Cubed Analysis of the Impact of Carbon Emissions Reductions From the Kyoto Agreement

A simulation of the Kyoto agreement was carried out using version V31L2 of the G-Cubed model, an 8-region, 14-sector general equilibrium model of the global economy developed by McKibbin and Wilcoxen. (A brief description of the model is attached.) The simulation required two simplifying assumptions:

- Since the model covers only energy-related carbon emissions, the analysis assumed that 88% of required reductions are undertaken from carbon in the energy sector.
- The analysis has a significantly different emissions baseline than the CEA baseline, mainly because it does not capture the effects of reduced coal use in the UK and Germany, or the merger of East and West Germany. To accommodate this limitation, the required reductions were assumed to be proportional to those required in the CEA baseline.

For instance, since the "Other OECD" region reduces carbon emissions 26% below baseline in 2010, the region reduces emissions 26% below baseline in the G-Cubed analysis. This increases the reductions required of the Other OECD region; however, requiring higher reductions is likely to yield a more realistic characterization of the costs of meeting the commitment than requiring emissions of only 298 MMTC, since the model's reductions are taken from a higher stock of emissions than is likely to be the case.

	(1) CEA 2010 Carbon Emissions	(2) CEA 2010 Total GHG Commitment	(3) CEA Commitment * 0.88	(4) (3) / (1)	(5) GCubed 2010 Carbon Emissions	(6) GCubed 2010 Commitment (5)*(4)
U.S.	1838	600	528	-29%	1822	-523
Japan	368	113	99	-27%	358	-97
Australia	88	21	18	-21%	133	-28
Other OECD	1158	339	298	-26%	1560	-401

G-Cubed is a general equilibrium model, and thus represents each region as a competitive market economy in dynamic equilibrium with other regions. As a consequence, the representation of the former Soviet Bloc does not capture the shock associated with the institutional collapse of the formerly planned economy, the consequent dramatic decrease in emissions, or the consequent stock of "paper tons" that is likely to be available in the region in 2010. However, since the region has relatively little interaction with the rest of the world in the model (as a consequence of the calibration that renders it in equilibrium in the base year), the analysis treats the former Soviet Bloc exogenously, and assumes both the "paper tons" and the "supply curve" of additional reductions available from the SGM analysis. Thus the analysis assumes 426 MMTC of paper tons available in 2010, declining to about 350 MMTC in 2015 and 290 MMTC in 2020, and roughly an additional 140 MMTC available at a cost of $25/MTC ($92).[1]

[1] The SGM numbers, in turn, are based on the results of a joint project between the OECD, the World Bank and the Office of Policy Development at US EPA (see OECD document OECD/GD(97)154 "Environmental Implications of Energy and Transport Subsidies" or Chapter 6 of OECD publication "Reforming Energy and Transport Subsidies."

The analysis included the following scenarios:

1. **U.S. Only.** U.S. meets its commitment alone (this scenario illustrates the importance of trade and capital flows in the absence of any action by other countries).
2. **Annex I No Trading, OOECD = 300 MMTC.** The Annex I countries meet their commitments with no international permit trading (by implication, however, the countries of the "Other OECD," which includes the EU, Canada and New Zealand, are assumed to be trading amongst themselves). The "Other OECD" target is assumed to be 300 MMTC.
3. **Annex I No Trading, OOECD = 400 MMTC.** The Annex I countries meet their commitments with no international permit trading, and the "Other OECD" target is assumed to be 400 MMTC.
4. **Annex I Trading.** The Annex I countries meet their commitments with full international permit trading amongst the Annex I countries. In this and all of the following scenarios, the "Other OECD" target is assumed to be 400 MMTC.
5. **"Umbrella."** The Annex I countries meet their commitments with international permit trading amongst all Annex I countries except those in the "Other OECD" region. This is the model's nearest approximation of an "Umbrella, no EU" scenario.
6. **Full "JI".** The Annex I countries meet their commitments with full international permit trading and full "joint implementation," where it is assumed that developing countries have agreed to emissions rights equivalent to their modeled baseline, and have agreed to make those permits available on international markets.
7. **"JI" 20% of Reductions.** The Annex I countries meet their commitments with full international permit trading and "joint implementation," where "JI" tons are constrained to be only 20% of total emission reductions.
8. **20% of "JI."** The Annex I countries meet their commitments with full international permit trading and "joint implementation," where "JI" tons are constrained to be only 20% of the total "JI" tons in the Full "JI" scenario (6).

The analysis includes two versions of each of the above scenarios. The first simulates a system of freely distributed permits as a carbon tax with the revenues recycled through lump-sum reductions in personal income taxes (there are no distributional implications because there is only one representative agent per region). The second simulates a system of auctioned permits through a carbon tax with revenues used to reduce budget deficits in each region. The two versions of each scenario provide a reasonable bound of the impacts of different fiscal approaches to carbon controls.

Appendix: G-Cubed Model Description

This analysis was carried out using the G-Cubed model, a general equilibrium model of the global economy with 8 regions (the United States, Japan, Australia, Other OECD, China, non-oil exporting developing countries, former Soviet Bloc, and OPEC) and 13 sectors, including 5 energy sectors (electric and gas utilities, petroleum refining, coal mining, and crude oil and gas extraction) and 8 non-energy sectors (other mining, agriculture, forestry and wood products, durable manufacturing, non-durable manufacturing, transportation, services, and a sector producing investment goods). This model combines the international detail of the McKibbin-Sachs Global (MSG) global dynamic macroeconomic framework with the detailed, econometrically-based framework of the Jorgenson-Wilcoxen general equilibrium model of the U.S. economy. In this framework, carbon emissions are related to a variety of economic activities, while intertemporal behavior such as saving, investment and exchange rate arbitrage is modeled as forward-looking optimization by infinitely-lived "representative agents" (with 30% forward-looking, 70% adaptive expectations) and forward-looking firms "firms" all subject to appropriate intertemporal budget constraints. The model treats international trade and capital flows in a consistent general equilibrium framework, so that international trade and payments balances and exchange rates are simultaneously determined in the context of long-run growth and gradual convergence of developing economies' production possibilities to those of the developed countries. Using such a framework, we can show that consideration of all of these effects in a consistent manner greatly clarifies the likely effects of emission controls, particularly of differential commitments in different regions. We can also show that capital flows are likely to play a significant role in determining overall effects of differential commitments.

Consumer demand. Consumer behavior is represented by a two-tier system of nested constant elasticity of substitution (CES) utility functions. At the top tier, the household allocates spending between household capital services, labor services, energy and materials. In the current version of the model, the elasticity of substitution between these inputs is set to unity, rendering this tier Cobb-Douglas and probably overstating the ability of households to substitute away from energy toward other inputs. At the second tier, spending on energy and spending on materials are allocated among individual goods. The elasticity of substitution between energy goods is 0.8 and the elasticity of substitution among materials is 1.0. Both of these values were determined by econometric estimation.

Producer behavior. Similarly, production possibilities are represented by sector-specific nested factor demand equations. A top tier of equations specifies demand for capital, labor, energy and materials aggregates; while equations in lower tiers specify demand for specific energy inputs and materials inputs. The top tier substitution elasticities used in this analysis – most of them estimated from historical data for the U.S., but a few imposed exogenously to limit the limit the degree of fuel input substitution in the energy conversion sectors – range from 0.2 for most of the energy sectors to nearly 1.3 in Agriculture; while the substitution elasticities among energy inputs range from less than 0.2 in Coal Mining to over 1.1 in Other Mining; and those among materials inputs range from 0.2 for most energy sectors to 3.0 for Services.

Saving and investment. As noted above, 70% of households are assumed to be liquidity constrained and consume all of their income in each period. The remaining 30% are assumed to be full intertemporal optimizers who choose current consumption to maximize an intertemporal utility function. (The key parameters of the utility function are the intertemporal elasticity of substitution, imposed to be unity, and the rate of time preference, imposed to be 2.5%) The difference between the consumption of the intertemporal optimizers and their income determines total private domestic saving. Private domestic saving is augmented by public saving (or dissaving, as the case may be) and capital inflows from abroad (discussed below). This total is then allocated to investment in sector-specific capital goods according to a set of q-theoretic investment models. There is one capital good for each industry, plus one for capital used in producing capital goods themselves, plus one more for household capital, for a total of 14. Once installed in a particular sector, physical capital is completely immobile – it cannot move between sectors or from one country to another. Capital is not vintaged and depreciates geometrically.

G-Cubed Model V.31 CES Substitution Elasticities

Sector	Top Tier		Energy Tier	Materials Tier
	(Estimated)	(Imposed in this analysis)	(Estimated)	(Estimated)
Electricity	0.763	0.200	0.200	1.000
Natural Gas	0.810	0.200	0.932	0.200
Petroleum Refining	0.543	0.200	0.200	0.200
Coal Mining	1.703	0.493	0.159	0.529
Crude Oil & Gas	0.493	0.493	0.137	0.200
Other Mining	1.001	1.001	1.147	2.765
Agriculture	1.283	1.283	0.628	1.732
Forestry/Wood Products	0.935	0.935	0.939	0.176
Durables	0.410	0.410	0.804	0.200
Non-Durables	1.004	1.004	1.000	0.057
Transportation	0.537	0.537	0.200	0.200
Services	0.256	0.256	0.321	3.006
Investment Goods		1.000	1.000	1.000

Technological change. Technological change is represented primarily as exogenous labor-augmenting productivity growth, but the model also provides for total factor productivity (TFP) growth and energy-saving technological change (sometimes referred to as autonomous energy efficiency improvement, or AEEI). In the current version of the model, there is no endogenous technology response to changes in relative prices (apart from substitution).

Taxes. The model includes taxes on household income, corporate income, sales of goods and services and tariffs. It also includes a number of potential taxes that are zero in the base case but can be made nonzero for policy analysis: carbon and BTU taxes on primary fossil fuels, an investment tax credit, and a second lump-sum tax. It does not include a value added tax. Tax rates are generally set exogenously.

Fiscal policy. Government spending is set exogenously. Because spending and taxes are both exogenous, the government fiscal surplus or deficit will be endogenous. Government deficits accumulate into a stock of debt on which interest payments must be made in each period. The government's long term budget constraint is imposed by requiring that in each period the government levy a lump sum tax large enough to pay for that year's interest obligation. (That is, the government is not allowed to borrow to finance interest payments.) In essence this means that all government borrowing takes the form of consols backed by the revenue from an earmarked tax. Because some of the agents are not full intertemporal optimizers, the model does not yield Ricardian equivalence: government budget deficits do not lead to equivalent increases in savings, and so can influence real output.

Money, nominal wages and monetary policy. Money is supplied exogenously by each country's central bank and is demanded for transactions. The demand for real money balances depends positively on the volume of transactions (measured by total value of industry output) and negatively on the interest rate. The interest elasticity of money demand is -0.6. In the long run the model reaches full employment and the size of the labor force is determined by the exogenous rate of population growth. In the short run, however, wages are set in nominal terms and adjust slowly to changes in employment and to changes in current and expected inflation rates. As a result, monetary shocks have real short term effects because they change the real wage.

Trade. International trade is modeled as a set of bilateral flows of all twelve commodities between all eight regions. Within each country the demand for imports of each commodity is determined by imperfect substitution between the domestic good and imports from each of the other countries (the Armington approach). In the current version of the model, the elasticity of substitution between each domestic good and competing imports from all other countries is set to unity. For most of the goods in the model, this is likely to overstate the substitutability of foreign and domestic products. The model's sectors are highly aggregated and each includes a large variety of products that are at best, only very poor substitutes for each other. (That is, the product mix in imported durable goods does not look very much like the domestic product mix.) As a consequence, unitary Armington elasticities probably yields rather elastic responses to changes in exchange rates and relative prices, relative to empirical estimates. For petroleum products, on the other hand, the model may understate the substitutability of foreign and domestic varieties. (Empirical evidence on this point is mixed, however, in part because the history of regulation and institutions in the world oil market makes it difficult to estimate substitutability.)

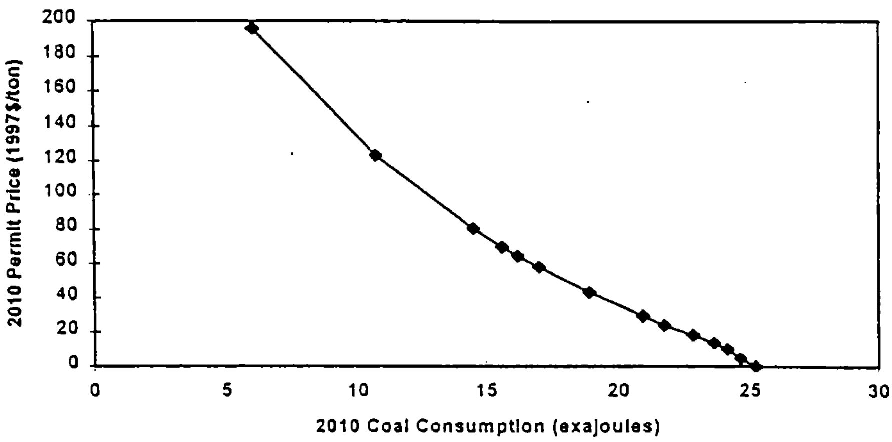
The model also includes full integration of international capital flows. All trade imbalances must be financed by offsetting flows of financial capital. Capital inflows accumulate into stocks of debt that must be serviced by future trade surpluses. At the same time, financial capital is fully mobile and flows to regions offering the highest rates of return after adjusting for expected changes in exchange rates. Together, these two mechanisms (trade imbalances and forward-looking interest rate arbitrage) determine exchange rates.

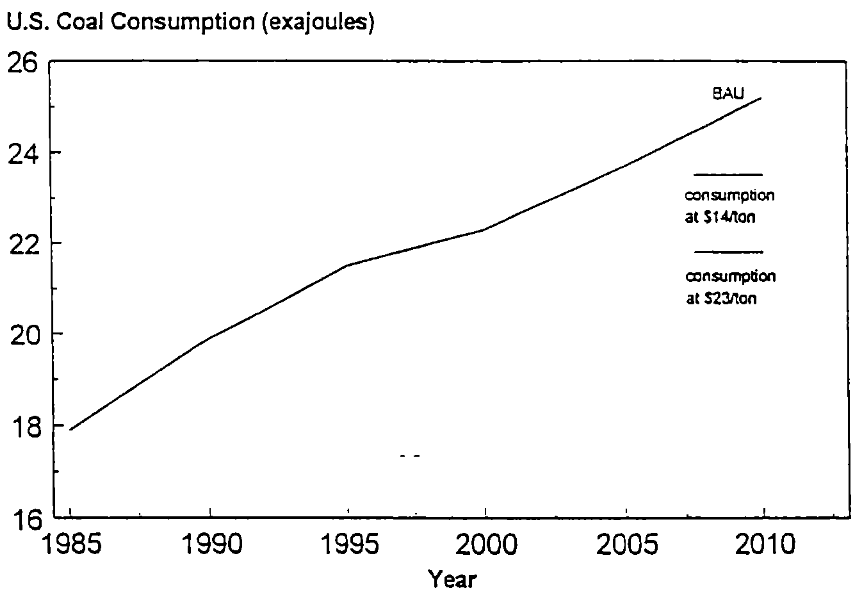
Model solution. The model has a large number of forward-looking variables: within each country there are 14 *q* variables corresponding to the 14 capital stocks, wealth, and the exchange rate. Adding up across countries brings the total to over 100. In addition, there are about 6,000 equations that must hold within each period. At the moment, the only feasible methods for solving a model of this size are based on linearization. G-Cubed uses a hybrid form of linearization in which price equations are linearized in logs and other equations are linearized in differences. All linearization is done about the model's benchmark year data set, which at the moment is for 1987. Once the linearization is complete, the resulting model is algebraically compressed into its minimal dynamic representation and solved numerically to obtain an expression relating the model's dynamic variables to current and future values of the exogenous variables (the model's "stable manifold"). Finally, this expression is then used to compute solutions to the model. Linearization has both benefits and costs. The principal cost is that the solutions will involve truncation error (and hence will be somewhat inaccurate) when simulating large shocks. The benefit, however, is that a large model with considerable detail in agents' expectations and intertemporal optimization decisions can be solved, and generally solved very quickly.

Baseline Projections. In order to solve the model, projections must be provided on the future course of key exogenous variables. These include: population growth by region, productivity growth by sector and region, energy efficiency improvements by sector and region, and tax rates, fiscal spending patterns and monetary policy by region. Unfortunately, few of these can be projected with any precision. The most important for climate policy are population and productivity growth. The base population assumption in G-Cubed is that regional population growth rates follow the paths projected by the United Nations. It is straightforward, however, to impose other population projections. For productivity, the base assumption in G-Cubed is that the pattern of technical change at the sector level is similar to the historical record for the United States (where data is available). In regions other than the United States, however, the sector-level rates of technical change are scaled up or down in order to match the region's observed rate of aggregate productivity growth. This approach attempts to capture the fact that the rate of technical change varies considerably across industries while reconciling it with regional differences in overall growth. It is, at best, a rough approximation: it would be better to estimate productivity growth for each sector in each region but the necessary data is largely unavailable. As with population projections, it is straightforward to impose other assumptions about future productivity growth. The default specification is that productivity is labor-augmenting but it can also be given as total factor productivity growth, or as a combination of the two. Energy-augmenting technical change can also be imposed.

#12

Coal Consumption and the Carbon Permit Price in SGM, 2010





Source: SGM

- SGM simulations project coal consumption to amount to approximately 25 exajoules in 2010 under business as usual. With a permit price of $14/ton, coal consumption would decline about 7% below the BAU level. At $23/ton of carbon, coal consumption would be about 13% below BAU. If all emissions reductions occurred at home, coal consumption would be about 75% below BAU.

- Under BAU, the average minemouth coal price is projected to be $15.32 per short ton (1997$, AEO98). At a $14/ton permit, coal would cost $22.89/short ton (~50% above BAU), and at a $23/ton permit, coal would cost $27.76/short ton (~80% above BAU).

#13

DRAFT

Kyoto Protocol:
Article-by-Article Review

Preamble

- The preamble is self-explanatory, containing nothing of particular interpretive significance.

Article 1 (Definitions)

- The definitions are technical and not of policy significance.

Article 2 (Policies/Measures)

- This Article obligates Annex I Parties, in achieving their target commitments, to implement policies and measures in accordance with their national circumstances.
- The list of policies and measures in this Article (e.g., "enhancement of energy efficiency in relevant sectors of the national economy") is illustrative, not mandatory.
- In order to avoid inconsistent national approaches in two areas where international coordination is desirable, the Article obligates Annex I Parties to pursue limitation or reduction of emissions from aviation and marine bunker fuels, working through the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO). (It should be noted that, through a separate methodological decision, it is made clear that bunker fuels do not count again national emissions totals.)
- In lieu of the G-77's unacceptable call for a compensation fund, the Article calls upon Annex I Parties, collectively rather than individually, to "strive" to implement policies and measures in such a way as to "minimize" adverse effects (both environmental and economic) on other Parties, including developing country Parties. The Conference of the Parties serving as the meeting of the Parties (hereinafter "COP/MOP") make take further action to implement this paragraph.
  - -- It should be noted that a similar provision appears in Article 3.14, discussed below.

-- It should be noted that COP 3 Decision L.9 requests the Subsidiary Body for Implementation, at its 8th session, to determine actions necessary to implement the corresponding provision in the Framework Convention (i.e., Article 4(8) and (9) relating to the specific needs of developing country Parties particularly affected by either climate change or by response measures to climate change) and further requests COP 4 to take a decision on actions.

o Finally, the Article provides for the COP/MOP, if it decides it would be beneficial to coordinate any policies and measures (i.e., on a strictly voluntary basis), then it is to consider ways to elaborate such coordination.

Article 3 (Annex I Target)

o Paragraph 1 contains two important features:

-- First, it sets forth the obligation of Annex I Parties to ensure that their emissions do not exceed their commitments, as set forth in Annex B (which contains the relevant percentage for each Party) and the rest of Article 3 (which contains time periods, base years, accounting rules, etc.). In order to make clear that the obligation, even though written in the plural ("The Parties included in Annex I shall..."), is not a collective obligation under which each Party would be responsible for another, the phrase "individually or jointly" was included.

-- Second, the end of the sentence containing the obligation states "with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012." There are three reasons why this phrase was written in non-legally binding terms:

o The point of the statement is more political than legal, i.e., it was considered that it more make it more palatable to have certain Annex I Parties increasing their emissions over 1990 levels (such as Australia) if it were pointed out that, as a group, the Annex I Parties will actually be reducing below 1990 levels.

o The figure of 5% below 1990 levels does not take account of the ability of Annex I Parties to increase their allowed emissions through the Clean Development Mechanism, described below. In other words, emissions trading and joint implementation among Annex I Parties would not change the 5% figure; however, additional emissions allowances through the CDM from outside of Annex I could theoretically even put the Annex

- o If legally binding, the provision might imply a collective responsibility to meet the group target, which would not have been acceptable to us.

- o It should also be noted, with respect to paragraph 1, that there has been a lack of clarity under the Convention as to which emissions count against a Party. In part to address this issue, and in part to address the U.S. national security issue, COP 3 adopted Decision L.5, which provides, <u>inter alia</u>:

  -- that emissions based upon fuel sold to ships or aircraft engaged in international transport are not included in national totals; and

  -- that emissions resulting from multilateral operations pursuant to the UN Charter are not included in national totals; and

  -- that other emissions related to the operations noted above (such as from training in a foreign country) are to be included in the national totals of one or more of the Parties involved, but it leaves to those Parties to figure out which. (In this way, it allows Parties to reallocate emissions without going through emissions trading.)

- o Paragraph 2, in order to respond to calls for an obligation before the 2008-2012 commitment period, calls for each Annex I Party to have made "demonstrable progress" in achieving its commitments. The U.S. took the position that, for example, having in place the necessary implementing legislation would fulful this obligation.

- o Paragraph 3 relates to sinks, specifically their treatment during the commitment period. (One must look to paragraph 7 of this Article to see that sinks are not included in the baseline.) The significant features include:

  -- that <u>net</u> changes in the specified categories are to be used in meeting the target commitment; in other words, a Party does not get to count only the positive.

  -- that the net changes in the specified categories <u>must</u> be counted; in other words, counting sinks is not optional.

  -- that the categories are currently limited to afforestation, reforestation, and deforestation, and, further, that these activities only count since 1990; in other words, the net changes in emissions from trees planted before 1990 would not count.

- Paragraph 4 contains two elements:

  -- First, each Annex I Party is to provides data to SBSTA to establish its level of carbon stocks in 1990.

  -- Second, the COP/MOP is authorized to decide upon the rules for how sink activities are to be counted, as well as for which additional activities are to be counted. (In order to avoid a situation where the addition of a new activity would make it more difficult for a Party to reach its target, any additions apply automatically only to subsequent commitment periods; a Party may, however, take advantage of an additional activity by opting to count it for purposes of the first commitment period.)

    - (Pursuant to COP 3 Decision L.7, this issue is on the agenda for COP 4.)

- Paragraphs 5 and 6 deal with countries with economies in transition. They provide:

  -- that the countries whose base years were decided under the Convention (e.g., 1987 for Russia) are to use those base years;

  -- other countries with economies in transition may use a base year other than 1990, provided the COP/MOP approves such base year; and

  -- the COP/MOP is to provide countries with economies in transition "a certain degree of flexibility" in the implementation of obligations under the Protocol other than under Article 3, i.e., such countries may not be accorded flexibility with respect to any other aspect of the target obligation other than the base year.

- Paragraph 7 defines the initial "assigned amount" for the first commitment period of 2008-2012, i.e., the amount that may be emitted during that period.

  -- It is derived from taking a Party's emissions of the six gases listed in Annex A in 1990 (except that economies in transition may be using a different base year and that Parties may elect 1995 for three of the gases, see below), multiplying that number by the percentage inscribed in Annex B (i.e., 93% for the United States), and multiplying that total by 5 (the number of years in the commitment period).

-- To accommodate Australia, this paragraph also provides that Parties for whom land use change and forestry constituted a net source of emissions in 1990 are to include the net change amount in their assigned amount.

o Paragraph 8 allows a Party to elect to use 1995 as its base year for HFCs, PFCs, and SF6.

o Paragraph 9 provides that commitments for subsequent commitment periods are to be established through amendment of Annex B. The amendment procedure that would apply would require affirmative ratification, approval, etc., i.e., the quicker opt-out procedure that might otherwise apply to annex amendments would not apply.

o Paragraphs 10, 11, 12 are accounting paragraphs. They provide for assigned amounts to be increased or decreased based on amounts received or transferred under emissions trading, joint implementation, or the Clean Development Mechanism.

o Paragraph 13 incorporates the U.S. "banking" proposal, namely it allows a Party that emits less than its assigned amount during a commitment period to add that amount to a subsequent commitment period's assigned amount.

o As noted above, paragraph 4 is similar to paragraph 3 of Article 2, except that:

-- it applies to each Annex I Party, rather to Annex I Parties collectively; and

-- it specifically notes that the COP/MOP is to consider the establishment of funding, insurance, and transfer of technology.

Article 4 ("Bubble")

o This Article allows Annex I Parties to prospectively reallocate their emissions targets, provided their total emissions do not exceed their combined assigned amounts.

-- If the Parties failed to achieve the total level of emissions reductions, each Party would be responsible for its own level of emissions set out in the reallocation agreement.

o Any reallocation agreement must be notified upon ratification and remains in operation for the commitment period in question. In other words, it may not be changed for that commitment period.

- If a regional economic integration organization (such as the EU) is involved, any change in the composition of the organization after adoption does not affect existing commitments. In other words, if an Eastern European country were to join the EU next week, it could not join the EU bubble; that country would only be part of the bubble for purposes of subsequent commitments.

Article 5 (Measurement)

- Under this Article, each Annex I Party must have in place, no later than 2007, a national system for the estimation of anthropogenic emissions by sources and removals by sinks of greenhouse gases.

- Guidelines for national measurement systems are to be decided by the COP/MOP and are to incorporate the IPCC methodologies, which were agreed upon at COP 3.

- Where a Party does not use the accepted methodologies, appropriate adjustments (e.g., discounting) are to be applied according to methodologies agreed by the COP/MOP.

- The COP/MOP is to regularly review methodologies and revise them as needed; importantly, revisions would only apply prospectively to subsequent commitments.

- This Article also provides that the global warming potentials (GWPs) used to calculate carbon dioxide equivalence (note that the target commitment is written in terms of carbon dioxide equivalence) are those accepted by the IPCC and agreed by COP 3. As with methodologies, the COP/MOP may revise GWPs; however, any revisions would only apply to subsequent commitments.

Article 6 (JI with Annex I)

- This Article is largely the joint implementation provision that the U.S. sought, except limited to Annex I Parties.

- The key elements include:

  -- Unlike under emissions trading (see Article 16 bis below) and the Clean Development Mechanism (see Article 12 below), the COP/MOP is not commanded to set rules; rather, it is authorized ("may") to further elaborate guidelines. This implies that JI could go forward without further COP/MOP action. (It should be noted, however, that the elaboration of guidelines is on the COP 4 agenda.)

- -- JI applies to emission reduction units resulting not only from mitigation projects, but also from projects "enhancing anthropogenic removals by sinks."
- -- Projects must have the approval of the Parties involved.
- -- A project must provide a reduction that is "additional" to any that would otherwise occur.
- -- A Party cannot acquire units if it is not in compliance with its measurement/reporting obligations; if a compliance issue is raised, units can continue to be exchanged; however, units may not be used to meet the target until any compliance issue is resolved.
- -- As under emissions trading (<u>see</u> Article 16 <u>bis</u> below), JI is to be "supplemental" to domestic actions for meeting the target.
- -- Parties may authorize legal entities (which could include the private sector) to participate.

<u>Article 7 (Reporting)</u>

- o Under this Article, each Annex I Party must incorporate in its annual inventory of emissions/removals and its national communication under the Convention the additional information that is necessary to ensure compliance with the target obligation.
- o The COP/MOP is to adopt guidelines for the submission of such additional information.

<u>Article 8 (Review)</u>

- o This Article provides that the information submitted by Annex I Parties under the previous Article is to be reviewed by expert teams, which are to be coordinated by the Secretariat and to be composed of experts selected from those nominated by Parties and, as appropriate, by intergovernmental organizations.
- o Expert teams are to prepare a report to the COP/MOP assessing implementation of all commitments (not just the target), including identifying potential problems in fulfilling commitments.

- The COP/MOP is to consider:

  -- information submitted under Article 7;

  -- the reports prepared by the expert teams; and

  -- any questions of implementation raised by the reports, as well as any questions raised by Parties;

  and take decisions.

Article 9 (Review of Protocol)

- This Article provides for the COP/MOP to review the Protocol periodically, in coordination with relevant reviews under the Convention; the first review is to take place at the second session of the COP/MOP.

- Significantly, the review under this Article is not (as had been proposed by some) limited to reviewing the commitments of Annex I Parties

Article 10 (Advancing Implementation of Commitments)

- Pursuant to the Berlin Mandate, this Article advances the implementation of existing commitments under Article 4.1 of the Convention.

- It applies to all Parties.

- With various qualifiers, it calls upon Parties to:

  -- formulate cost-effective programs to improve the quality of local emission factors;

  -- implement programs containing measures to mitigate climate change and facilitate adaptation to climate change;

  -- cooperate in promoting effective modalities for development, application, diffusion, and transfer of environmentally sound technologies pertinent to climate change; (significantly, the provision refers to the creation of an "enabling environment for the private sector");

  -- cooperate in scientific and technical research and promote systematic observation systems; and

  -- cooperate in development and implementation of education and training programs.

Article 11 (Financial Resources)

- This Article essentially restates the financial provisions of the Convention; it does not create new financial obligations.

- First, it provides that the operating entity of the financial mechanism of the Convention (i.e., the GEF) shall apply.

- Second, under the Convention, developed country Parties are obligated to provide new and additional financial resources to meet:

  - the agreed full costs incurred by developing country Parties in meeting certain commitments, such as reporting; and

  - the agreed full incremental costs of meeting other commitments.

  This Article makes clear which provisions of the previous Article (which advances the implementation of existing commitments under the Convention) qualify for full cost funding and which qualify for incremental cost funding.

Article 12 (Clean Development Mechanism)

- This Article provides for the functional equivalent of joint implementation with developing countries.

- It provides for Annex I Parties to be able to get credit towards "part" of their target (to be defined by the COP/MOP) for emissions reductions from project activities in non-Annex I countries.

- Emission reductions are to be certified by operational entities to be designated by the COP/MOP, based on:

  - voluntary participation by each involved Party;

  - real, measurable, and long-term benefits related to mitigation of climate change (which would appear to include sink projects);

  - reductions in emissions that are "additional" to any that would occur in the absence of the activity.

- The COP/MOP is to ensure that a share of proceeds from certified activities is used to cover administrative expenses, as well as assist developing country Parties (such as small island states) to adapt to climate change.

- As in Article 6 on JI, it is clear that the private sector may participate; participation may involve either investing in project activities that yield emission reductions or acquiring certified emission reductions without such an investment.

- Significantly, the Article provides for early credit in that certified reductions obtained from 2000 up to 2008 can be used to meet the target.

  - COP 3 Decision L.7 calls for COP 4 to analyze the implications of this provision.

<u>Article 13 (COP/MOP)</u>

- As a compromise between those wanting the Convention's Conference of the Parties (COP) to be the institution for the Protocol and those seeking a new, separate institution, Article 13 provides that the Convention COP will serve as the "meeting of the Parties" to the Protocol. While leaving ambiguous whether the COP/MOP is a new institution, the Article does make clear that decisions under the Protocol may only be taken by those that are Parties to the Protocol.

- The COP/MOP has basically the same functions with respect to the Protocol that the COP has with respect to the Convention.

- Significantly, the Article provides that the Convention's rules of procedure and financial rules will apply under the Protocol, except as otherwise decided by consensus by the COP/MOP. The implications of this provision are:

  - that, in the absence of agreed rules of procedure under the Convention (the current situation), the default decision-making rule under the Protocol would be consensus; and

  - the Convention's rules of procedure now need to be approached from the point of view that, absent consensus to the contrary, they will also apply to the Protocol.

<u>Article 14 (Secretariat)</u>

- This Article provides for the Convention Secretariat to serve as the Protocol Secretariat.

Article 15 (Subsidiary Bodies)

- This Article provides for the Convention's subsidiary bodies, namely the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation, to serve as the subsidiary bodies under the Protocol.

Article 16 (Multilateral Consultative Process)

- Article 13 of the Convention provides for the COP to

  > "consider the establishment of a multilateral consultative process, available to Parties on their request, for the resolution of questions regarding the implementation of the Convention."

- The intent was to create a forum for implementation questions that, in contrast to traditional dispute-settlement, was: multilateral; friendly; and able to take up issues that were necessarily alleged treaty violations.

- Numerous, inconclusive discussions have taken place under the Convention concerning the establishment of such a process.

- This Article of the Protocol presupposes the existence of a process under the Convention. It provides for the COP/MOP to consider the application to the Protocol of such a process, making modifications as appropriate.

Article 16 bis (Emissions Trading)

- This Article establishes emissions trading for purposes of meeting target commitments.

- Its significant features include:

  -- It provides for the COP (as opposed to the COP/MOP, so that decisions can be made in advance of the Protocol's entry into force) to define the relevant rules for trading. (The rules are on the agenda for COP 4.)

  -- There is a free-standing sentence providing for the ability to participate in emissions trading; unlike the penultimate version of the text, it is not explicitly preconditioned on the establishment of rules.

-- In contrast to proposals to put a percentage limit on the amount of the target that Party could satisfy through trading (either through a number or by providing that domestic actions had to be the "main" means of meeting the target), the Article simply provides that trading is to be "supplemental" to domestic actions.

-- Unlike other provisions in Article 3, which refer to Parties "included in Annex I," this Article provides for trading among "Parties included in Annex B." This is a result of a technical fix that was made when Article 10 (voluntary opt-in) was still in the text; that Article provided that, if a developing country took on a target, it would be inscribed in Annex B. In order to make clear that such countries could then trade, the emissions trading article then had to say that trading was possible among "Annex B" Parties. Even in the absence of Article 10, this Article can be read to allow trading among Parties, provided they are listed with a target in Annex B. As such, a developing country could presumably propose an amendment to Annex B with its target; if it were adopted and entered into force, it would seem to be able to trade.

<u>Article 17 (Non-Compliance)</u>

o This Article provides for the COP/MOP to approve appropriate and effective procedures and mechanisms to determine and address cases of non-compliance. Pursuant to a U.S. proposal, the task includes development of an indicative list of consequences for non-compliance, taking into account the cause, type, degree and frequency of non-compliance.

o It also provides that any <u>binding</u> consequences need to be adopted through an amendment.

-- This provision was a compromise between two views. Some considered that the COP/MOP ought to be authorized to establish binding penalties through decision. Our view was that binding consequences of non-compliance should be spelled out in the Protocol itself (such as our borrowing proposal) and that it was not appropriate (or likely to be acceptable to the Senate) to establish binding penalties through decisions. The compromise provides for the option of binding penalties, but makes clear that they would need to go through the normal amendment procedure.

Article 18 (Dispute Settlement)

o This Article incorporates by reference the Convention's provisions on dispute settlement. Technically, this Article was not necessary, given that Article 14 of the Convention provides that

> "the provisions of this Article shall apply to any related legal instrument which the Conference of the Parties may adopt, unless the instrument provides otherwise."

o Article 14 of the Convention (and this Article, by reference) provides for Parties to settle disputes through negotiation or other peaceful means. Parties may further opt to settle disputes through binding arbitration and/or the International Court of Justice. In the case of Parties that have not settled a dispute and have not opted for other settlement means, the dispute is to be submitted to non-binding conciliation.

Article 19 (Amendments)

o Amendments may be adopted by a three-fourths majority of Parties present and voting and enter into force for those Parties having accepted it ninety days after instruments of acceptance have been received from at least three-fourths of the Parties.

Article 20 (Annexes)

o Consistent with numerous other international agreements, this Article provides for a special, quicker procedure for adding/amending annexes. In sum, in exchange for being restricted to material that is "scientific, technical, procedural or administrative," such annexes may be added/amended without going through ratification; a Party that does not want to be bound simply "opts out."

o The original Annexes to the Protocol (Annex A on gases and Annex B on targets) are not, however, scientific, technical, etc. They are extremely substantive. Thus, this Article makes clear that the simplied procedure does not apply to them. Any amendment to these Annexes would need to go through the normal amendment procedure under Article 19.

Article 21 (Voting)

o This Article reflects the standard voting provision -- each Party has one vote, except that regional economic integration organizations (such as the EU) do not get an extra vote.

Article 22 (Depositary)

- The UN Secretary-General will be the Depositary.

Article 23 (Signature)

- The Protocol will be open for signature at UN Headquarters in New York from March 16, 1998, to March 15, 1999. It is only open for signature and ratification by States and regional economic integration organizations that are Parties to the Convention.

Article 24 (Entry into Force)

- This Article provides that there are two requirements for entry into force:

  -- at least 55 Parties to the Convention must have submitted their instruments of ratification, acceptance, etc.; and

  -- those having ratified, etc., must include Annex I Parties that accounted in total for at least 55% of total CO_2 emissions for 1990 of Annex I Parties (to be determined in accordance with the first national communications of such Parties submitted under the Convention).

Article 25 (Reservations)

- This Article provides that no reservations may be made to the Protocol. The United States opposed this Article, but did not prevail.

Article 26 (Withdrawal)

- A Party may withdraw three years after the Protocol entered into force for it; such withdrawal becomes effective one year after notification of withdrawal.

Article 27 (Languages)

- The six official UN languages are equally authentic.

Annex A (Gases)

- This Annex (which is referred to in Article 3 in describing the target obligation) contains the six major greenhouse gases, as well as the sectors/source categories that are covered.

Annex B (Target Commitments)

- This Annex lists Parties with target commitments, as well as the percentage of the base year to which they have committed.

- Initially, the list contains only Annex I Parties (minus Turkey), but could be amended to include Parties that are not Annex I Parties.

#14

The Effects of Full Worldwide Permit Trading on Consumption Losses by OECD Countries

Model	Pathway	Trading	No Trading	Trading/No Trading
CETA	WRE	1.86	1.83	1.02
CPBRIVM	WRE	0.17	0.64	0.27
FUND	WRE	1.47	9.82	0.15
MERGE	WRE	0.60	0.85	0.71
MiniCAM	WRE	0.54	1.58	0.34
SGM	WRE	0.13	1.84	0.07
CETA	WG-1	4.03	5.94	0.68
CPBRIVM	WG-1	0.99	3.25	0.30
FUND	WG-1	4.97	11.71	0.42
MERGE	WG-1	3.24	6.12	0.53
MiniCAM	WG-1	3.44	6.51	0.53
SGM	WG-1	1.48	6.17	0.24
			Average:	0.44

Trading and No Trading Values are in trillions of 1990 US$

#15

MEMORANDUM

DRAFT

TO: Distribution

SUBJECT: Nordhaus's arguments against strict action.

Executive Summary and Key Findings

- Nordhaus finds that the optimal policy, given the current state of knowledge and ignoring uncertainty, is to do very little in the short term (a $6/ton tax in 2005) and only marginally more in the long term. While his mild long-term policy suggestion helps to inform the basis of his short term recommendations, Nordhaus only intends to propose a short-term strategy and emphasizes that policies should change as we learn more.

- Recognizing wide-ranging uncertainties and the possibility of calamity, Nordhaus investigates optimal policy choices over a reasonable distribution of possible states of the world. He shows that while the median optimal carbon tax is on the order of $6/ton in 2005, the mean optimal carbon tax is somewhat larger, at $18/ton in 2005.

- His conclusions are viewed with skepticism by some critics, who believe some or all of the following: he overstates control costs, he understates control benefits, and his choice of a positive pure rate of time preference is indefensible. Others find his results and methodology more robust.

Introduction

In a 1994 book[1], Nordhaus calculates an optimal policy response to the problem of climate change. A distinguishing feature of this work is that it aims to uncover a truly optimal policy — that is, one that maximizes *net* benefit as opposed to one that merely minimizes the cost of achieving an *ad hoc* CO2 concentration target.

Basic Results

Ignoring uncertainty and with a best guess of costs and benefits (based on a wide purview of existing studies) Nordhaus finds that the optimal policy is to do close to nothing. With the optimal policy, carbon taxes rise from $6 per ton in 2005 to $20 per ton (1989 dollars) in 2100. Global average temperature under this policy increases 3.2°C — only 0.2°C less than in the baseline case. On net, the world economy under this scenario enjoys a small net benefit relative to the baseline case. See Table 1.

Restricting emissions of greenhouse gases to 1990 levels, on the other hand, inflicts relatively large net costs. Carbon taxes rise to $400/ton in 2100, and the increase in global average

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[1]"Managing the Global Commons," which presents analysis based on Nordhaus's DICE model. It is the culmination of arguments made in earlier papers.

temperature is limited to only 2.4°C — a full degree less than in the baseline.

Given that the optimal policy is much closer to doing nothing than to restricting to 1990 levels, it appears that literally doing nothing in the short term is superior to current proposals oriented on 1990 emissions levels.

Table 1[2]

	Global Net Benefit[3]			Carbon Tax ($/ton)		
	NPV ($billions)	Annualized ($billions)	NPV as % of PV of baseline output	2005	2055	2105
Optimal Policy (no uncertainty)	271	11	0.04	6	15	21
Restrict to 1990 levels	- 7,069	- 283	- 0.98	50	230	400
Stabilize at 1.5°C increase	- 40,980	- 1,639	- 5.94	200	700	800

It is worth emphasizing that Nordhaus's result is not simply a matter of delaying controls. While the typical *cost-minimization* exercise also shows that carbon emissions should be allowed to follow a near-baseline path at first, Nordhaus's result goes further: he finds that relatively little should be done even over the long term. In his optimal scenario, carbon concentrations are allowed to grow without apparent bound.

Incorporating uncertainty, Nordhaus's results change though the basic message of modest short-term measures does not.

- Nordhaus examines how the optimal policy changes when key parameter values vary from his best guess and finds that the mean optimal policy calls for higher carbon taxes than he finds for the best-guess case. The mean optimal policy calls for a carbon tax of $18/ton in 2005 and $53/ton in 2045.

- The "mean" result differs from the "best guess" result because the distribution of outcomes is skewed so that favorable climate change scenarios are similar to the best-guess case and occur with high probability while extremely unfavorable scenarios occur with low probability.

- Nordhaus finds that only 2% of possible scenarios -- the least favorable -- would call for a carbon tax in 1995 of over $100/ton.

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[2]Source for Tables 1 and 2: Nordhaus, "Managing the Global Commons", 1994. These data come from the DICE model.

[3]Net benefits are measured relative to the base case of taking no action.

Basis for Results

Nordhaus's results derive from three key assumptions:

- that the *costs* of reducing carbon emissions are relatively high;
- that the *benefits* of carbon control (in the form of averted damages) are relatively low; and
- that the social rate of discount is greater than zero.

Critics have attacked Nordhaus on all three points, and it is worth examining each point in greater detail.

1. Costs

The cost of reducing carbon emissions is determined by the responsiveness of the economy to a given level of carbon-control effort. For example, if a $10 carbon fee elicits a large response in terms of lower carbon emissions, the cost of carbon control will be low. Conversely, if a $10 carbon fee elicits a small response, program cost will be high.

The impact on the economy of a carbon-control program in Nordhaus's model is determined by two key assumptions — one concerning the "static" response, given current technologies and carbon use, the other concerning the "dynamic" response, reflecting induced changes in carbon use and advances in technology.

- Nordhaus bases his assumption about static responses on existing empirical studies. His assumptions here are not particularly contentious.
- Nordhaus attempts to capture dynamic responses by assuming that technology will improve at about the same rate in the future as it has done in the past. Importantly, the trend rate of improvement is not allowed to vary depending on the price of carbon permits or the level of a carbon tax. Critics find fault with this approach, since his model thus assumes that carbon taxes will in no way accelerate the development of non-carbon technologies — in stark contrast to the "technologist" view.

Nordhaus notes that his results are sensitive to assumptions about technology, but he does not document the extent of that sensitivity in isolation from other uncertainties.

2. Benefits

The benefits of carbon control are determined by the magnitude of damages averted -- that is, damages that would have occurred in the absence of a control program. Nordhaus calculates that these damages would be relatively modest. For example, he estimates that a 3°C temperature increase results in only a 1.3 percent loss of output per year.

Some critics feel that damages averted will be greater than Nordhaus assumes. They note that SO2 and particulate emissions will be reduced, biodiversity will be better maintained, and negative health effects will be avoided.

In a survey of experts, Nordhaus finds that the median cost prediction for a 3°C rise in temperature is 1.9 percent of output annually -- 40% higher than his own. The mean prediction is much higher, at 3.6 percent.

3. The social rate of discount

Given that costs are borne up front and benefits accrue mainly in the distant future, assumptions about the social rate of discount are crucial. Nordhaus assumes that the social rate of discount is 3 percent per year; this rate is sufficiently large as to significantly reduce the present value of the distant and already modest benefits.

Many critics (mainly non-economists) feel that a social rate of discount greater than zero is indefensible on ethical grounds. However, mainstream economists strongly endorse the approach to discounting which Nordhaus uses and find it difficult to understand very low rates of time preference in the context of observed behavior.

Nordhaus re-evaluates the optimal policy when the pure rate of time preference is only 1 percent and finds that the optimal carbon tax in this case is considerably greater (see Table 2).

Table 2

	Optimal Carbon Tax ($/ton)		
Rate of Time Preference	1995	2045	2095
3%	5.3	13.7	21.0
1%	23.6	52.6	77.5

Conclusion

Nordhaus's analysis implies that little should be done either in the short term or in the long term. His results hinge on assumptions about technology improvements, appropriate discount rates, and the size of potential damages. Critics feel that Nordhaus may be:

- overestimating mitigation costs because he ignores the possible influence of higher energy prices in spurring the development of new technology; and
- underestimating damages from climate change.

While both would tend to cause Nordhaus to be too lax in his policy recommendations, it is not clear that such criticisms can be sustained far enough to overturn Nordhaus's basic point that strict action is inappropriate in the short term. The discount rate issue, while crucial, is difficult to settle.

02/04/98 WED 19:02 FAX

#16

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US ENVIRONMENTAL PROTECTION AGENCY
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TO: ① Gene Sperling ② Jon Gruber ③ Katie McGinty ⑤ Stu Eizenstat ③ Jeff Frankel	FAX#: 4567132, 4562710, 3956947, 622 2633, 6479763
	PHONE#: 2607400
FROM: David Doniger / David Gardiner	PHONE#:

COMMENTS:

We've already moved just a bit in their direction, in last night's version. Joe can we do a run with AEEI of 1.5 or 1.6, just in case it is required?

DF

cc: JY
JA
RL
AM

page 1 of 3 (including cover sheet)

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MEMORANDUM FOR TODD STERN

FROM: David Doniger, EPA
David Gardiner, EPA

SUBJECT: The Role of the Climate Change Technology Initiative in Evaluating the Costs of Kyoto

DATE: February 4, 1998

We are concerned that the economic analysis now being prepared underestimates the impact of the tax incentives and program investments contained in the President's Climate Change Technology Initiative (CCTI) and the broader technology transformation that these proposals are intended to trigger. While we are not directly involved in preparation of the economic analysis, it is our understanding that the current draft analysis uses a range of 1.0% to 1.25% to represent the annual rate of improvement in energy efficiency across the economy (e/gdp). EPA believes this range significantly understates the potential of the Administration's expanded climate proposals. As explained below, we recommend extending the range examined in the analysis upward, at a minimum, to 1.5%.

The Administration's climate policy follows two paths to reduce the costs of meeting the Kyoto targets. The first path, represented by the CCTI proposals, seeks to lower the cost of purely domestic action by accelerating deployment and R&D incentives for energy-efficient and low-polluting technologies. The second path seeks to obtain low cost reductions from abroad through international market mechanisms (emissions trading, JI, and the CDM). Following both paths simultaneously gives us better prospects of achieving a reasonable cost result than following one or the other path alone.

We are concerned that the 1.0%-1.25% range of rates of change currently being modeled does not reflect the impact of the CCTI and associated policies. Thus, while the analysis is strong on the cost-reducing potential of the international trading path, it appears to sell short the Administration's commitment to reducing costs through accelerated technology change. This will hamper our efforts to gain Congressional support for the CCTI proposals and for our overall post-Kyoto policy.

The draft IAT analysis released last summer concluded that "higher rates of technological progress can cut dramatically the implicit price of carbon and the associated transitional GDP losses." The IAT analysis took 1.25% as a central case, not an upper limit. In the 1997 U.S. National Communication submitted under the climate convention, the Administration projected levels of energy savings from the Climate Change Action Plan programs, at their current funding level of about $1 billion over five years, that translate into a 1.25% annual improvement in e/gdp

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(approximately 1.2% if measured against the higher baseline of AEO 98). The IAT analysis also reported that carbon emissions and control costs would be significantly reduced if the annual e/gdp improvement rate could be increased to 1.75%.

The proposed CCTI program, at $6.3 billion in new funding over five years, significantly enlarges the CCAP effort. Funding for EPA and DOE programs to accelerate deployment of existing technologies is to be more than doubled. R&D funding is also substantially increased. These efforts are to be matched by $3.5 billion in tax incentives for technology deployment. EPA conservatively estimates that the CCTI (including the base CCAP programs) can increase the annual improvement in e/gdp in the energy sector to at least 1.5%.

Expanding the range of efficiency improvement rates being modeled to 1.0%-1.5% would, at the upper end, roughly double the expected impact of the Administration's climate programs. Working from the AEO 98 baseline, a 1.5% e/gdp improvement rate is equivalent to a reduction of about 180 mmtce, or about 10% of the baseline emissions in the energy sector. This is also about 35% of the 2010 "gap" in the energy sector.

A range extending to 1.5% would also be a conservative way to incorporate the results of the DOE 5 Lab study. Last year EPA undertook an analysis that built technological assumptions consistent with the DOE 5 Lab study into the Markal-Macro model. These assumptions led to an annual e/gdp improvement rate of about 1.6%. That analysis suggested that the price of carbon in 2010 could be lowered by more than 40% with net *positive* gains in GDP.

In sum, EPA believes it is essential that new analysis of the costs of Kyoto include adequate consideration of the potential for the CCTI and our related policies to lower costs by accelerating technological change. The analysis needs to fairly represent the Administration's two-path approach — pursuing lower costs through domestic technology change as well as international market mechanisms — towards reasonable economic outcomes. To understate the value of one path would weaken our prospects for defending both the new budget proposals and the overall economics of the Kyoto agreement.

We recognize that little time remains for preparation of next week's Congressional testimony. We will be happy to contribute in any way.

cc: Gene Sperling
Jeff Frankel
Katie McGinty
Jon Gruber
Stuart Eisenstat

4/18/97 (17)

ID	Scenario	Model	Modelers	Target	Timetable	Trading	Permit Allocation	Revenue Recycling	Burden Sharing	BAU Emissions Path Assumption	Paper Tons or Corresponding Reductions	AEEI	Ramp-up	Time Path	Outputs PDV (5%; 2000-2050) Foregone Consumption	GDP in 2010 (deviation from BAU)
SGM1	BAU	SGM, MAGICC	Battelle	n/a	n/a	n/a	n/a	n/a	n/a	IAT	n/a	1.0	n/a	-->2050, -->2100 (climate)	$121,650 billion (BAU consumption)	$9,185 billion (BAU GDP)
SGM9	-10% of 1990 in 2010	SGM, MAGICC	Battelle	-10% 1990 emissions level	stabilize in 2010	Annex I	auction	lump-sum	no LDC part.	IAT	PT	1.0	no	-->2050, -->2100 (climate)	$485 billion	$9,155 billion (-$30 billion)
SGM8	-10% of 1990 in 2010	SGM, MAGICC	Battelle	-10% 1990 emissions level	stabilize in 2010	domestic only	auction	lump-sum	no LDC part.	IAT	PT	1.0	no	-->2050, -->2100 (climate)	$980 billion	$9,149 billion (-$36 billion)
SGM10	-10% of 1990 in 2010	SGM, MAGICC	Battelle	-10% 1990 emissions level	stabilize in 2010	worldwide	auction	lump-sum	no LDC part.	IAT	PT	1.0	no	-->2050, -->2100 (climate)	$50 billion	$9,171 billion (-$14 billion)
SGM18	1990 in 2010	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2010	Annex I	auction	lump-sum	LDC stabilizes at 2030 in 2030	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$255 billion	$9,172 billion (-$13 billion)
SGM21	1990 in 2010	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2010	Annex I	auction	lump-sum	LDC BAU to 2030, equal per capita in 2050	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$260 billion	$9,172 billion (-$13 billion)
SGM3	1990 in 2010	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2010	Annex I	auction	lump-sum	no LDC part.	IAT	PT	1.0	no	-->2050, -->2100 (climate)	$225 billion	$9,172 billion (-$13 billion)
SGM20	1990 in 2010	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2010	domestic only	auction	lump-sum	LDC BAU to 2030, equal per capita in 2050	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$740 billion	$9,164 billion (-$21 billion)
SGM17	1990 in 2010	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2010	domestic only	auction	lump-sum	LDC stabilizes at 2030 in 2030	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$740 billion	$9,164 billion (-$21 billion)
SGM2	1990 in 2010	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2010	domestic only	auction	lump-sum	no LDC part.	IAT	PT	1.0	no	-->2050, -->2100 (climate)	$665 billion	$9,165 billion (-$20 billion)
SGM22	1990 in 2010	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2010	worldwide	auction	lump-sum	LDC BAU to 2030, equal per capita in 2050	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$25 billion	$9,180 billion (-$5 billion)
SGM19	1990 in 2010	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2010	worldwide	auction	lump-sum	LDC stabilizes at 2030 in 2030	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$20 billion	$9,180 billion (-$5 billion)
SGM4	1990 in 2010	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2010	worldwide	auction	lump-sum	no LDC part.	IAT	PT	1.0	no	-->2050, -->2100 (climate)	$5 billion	$9,180 billion (-$5 billion)

#3

ID	Permit Prices: 2010	Permit Prices: 2025	Permit Prices: 2050	Conc. (ppmv) in 2050 (Deviation from BAU)	Conc. (ppmv) in 2100 (Deviation from BAU)	Year Conc. (550 ppmv) Reaches 2x Pre-Ind. Level (Deviation from BAU)	Change in Temp. (deg. C) from 1990 in 2050 (Deviation from BAU)	Change in Temp. (deg. C) from 1990 in 2100 (Deviation from BAU)	Emissions Peak, mmtce (year)	Year Returns to 1990	Intl. Trade of Permits, U.S., 2010 (MMTCE), ($)	Intl. Trade of Permits, U.S., 2050 (MMTCE), ($)	Date Received Run	File (h:\jaldy\)
SGM1	$0	$0	$0	502	711	2065	1.06	2.36	no peak: 2245 (2050)	n/a	n/a	n/a	08/21/97	cea90_~1.xls
SGM9	$91	$137	$238	481 (-21)	645 (-66)	2074 (+9)	0.97 (-0.09)	2.11 (-0.25)	1637 (2005)	never returns	-180, (-$16.4 billion)	-332, (-$79.0 billion)	08/21/97	cea90m_~1.xls
SGM8	$175	$304	$924	481 (-21)	645 (-66)	2074 (+9)	0.97 (-0.09)	2.11 (-0.25)	1637 (2005)	2010	n/a	n/a	08/21/97	cea90m_~1.xls
SGM10	$33	$37	$45	481 (-21)	645 (-66)	2074 (+9)	0.97 (-0.09)	2.11 (-0.25)	no peak: 2060 (2050)	never returns	-332, (-$11.0 billion)	-845, (-$38.0 billion)	08/21/97	cea90m_~1.xls
SGM18	$39	$83	$150	478 (-24)	565 (-146)	2091 (+26)	0.96 (-0.10)	1.82 (-0.54)	no peak: 1712 (2050)	never returns	-209, (-$8.2 billion)	-362, (-$54.3 billion)	08/27/97	case2.xls, 9/4/97 fax
SGM21	$39	$83	$150	n/a	n/a	n/a	n/a	n/a	no peak: 1712 (2050)	never returns	-209, (-$8.2 billion)	-362, (-$54.3 billion)	08/27/97	case3.xls
SGM3	$42	$84	$149	486 (-16)	655 (-56)	2072 (+7)	0.99 (-0.07)	2.15 (-0.21)	no peak: 1714 (2050)	never returns	-202, (-$8.5 billion)	-364, (-$54.2 billion)	08/21/97	cea90_~2.xls
SGM20	$108	$188	$582	n/a	n/a	n/a	n/a	n/a	1550 (2000)	2010	n/a	n/a	08/27/97	case3.xls
SGM17	$108	$188	$582	476 (-26)	564 (-147)	2092 (+27)	0.95 (-0.11)	1.82 (-0.54)	1550 (2000)	2010	n/a	n/a	08/27/97	case2.xls, 9/4/97 fax
SGM2	$110	$191	$582	485 (-17)	658 (-53)	2072 (+7)	0.99 (-0.07)	2.16 (-0.20)	1637 (2005)	2010	n/a	n/a	08/21/97	cea90_~2.xls
SGM22	$15	$23	$0	n/a	n/a	n/a	n/a	n/a	no peak: 2239 (2050)	never returns	n/a	n/a	08/27/97	case3.xls
SGM19	$15	$23	$110	478 (-24)	565 (-146)	2091 (+26)	0.96 (-0.10)	1.82 (-0.54)	1883 (2040)	never returns	-316, (-$4.7 billion)	-500, (-$55.0 billion)	08/27/97	case2.xls, 9/4/97 fax
SGM4	$16	$23	$32	486 (-16)	655 (-56)	2072 (+7)	0.99 (-0.07)	2.15 (-0.21)	no peak: 2102 (2050)	never returns	-313, (-$5.0 billion)	-752, (-$24.1 billion)	08/21/97	cea90_~2.xls

ID	Scenario	Model	Modelers	Target	Timetable	Trading	Permit Allocation	Revenue Recycling	Burden Sharing	BAU Emissions Path Assumption	Paper Tons or Corre-sponding Reductions	AEEI	Ramp-up	Time Path	PDV (5%; 2000-2050) Foregone Consumption	GDP in 2010 (deviation from BAU)
SGM36	1990 in 2020	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2020	Annex I	auction	lump-sum	no LDC part.	IAT	PT	1.0	yes	-->2050, -->2100 (climate)	$195 billion	$9,179 billion (-$6 billion)
SGM35	1990 in 2020	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2020	domestic only	auction	lump-sum	no LDC part.	IAT	PT	1.0	yes	-->2050, -->2100 (climate)	$660 billion	$9,172 billion (-$13 billion)
SGM37	1990 in 2020	SGM, MAGICC	Battelle	1990 emissions level	stabilize in 2020	worldwide	auction	lump-sum	no LDC part.	IAT	PT	1.0	yes	-->2050, -->2100 (climate)	-$1 billion	$9,183 billion (-$2 billion)
SGM6	1995 in 2010	SGM, MAGICC	Battelle	1995 emissions level	stabilize in 2010	Annex I	auction	lump-sum	no LDC part.	IAT	CR	1.0	no	-->2050, -->2100 (climate)	$380 billion	$9,175 billion (-$10 billion)
SGM5	1995 in 2010	SGM, MAGICC	Battelle	1995 emissions level	stabilize in 2010	domestic only	auction	lump-sum	no LDC part.	IAT	CR	1.0	no	-->2050, -->2100 (climate)	$425 billion	$9,174 billion (-$11 billion)
SGM7	1995 in 2010	SGM, MAGICC	Battelle	1995 emissions level	stabilize in 2010	worldwide	auction	lump-sum	no LDC part.	IAT	CR	1.0	no	-->2050, -->2100 (climate)	$30 billion	$9,179 billion (-$6 billion)
SGM33	1995 in 2020	SGM, MAGICC	Battelle	1995 emissions level	stabilize in 2020	Annex I	auction	lump-sum	no LDC part.	IAT	CR	1.0	yes	-->2050, -->2100 (climate)	$410 billion	$9,176 billion (-$9 billion)
SGM32	1995 in 2020	SGM, MAGICC	Battelle	1995 emissions level	stabilize in 2020	domestic only	auction	lump-sum	no LDC part.	IAT	CR	1.0	yes	-->2050, -->2100 (climate)	$445 billion	$9,176 billion (-$9 billion)
SGM34	1995 in 2020	SGM, MAGICC	Battelle	1995 emissions level	stabilize in 2020	worldwide	auction	lump-sum	no LDC part.	IAT	CR	1.0	yes	-->2050, -->2100 (climate)	-$40 billion	$9,180 billion (-$5 billion)
SGM27	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	Annex I	auction	lump-sum	LDC BAU to 2030, equal per capita in 2050	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$75 billion	$9,185 billion (0 billion)
SGM24	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	Annex I	auction	lump-sum	LDC stabilizes at 2030 in 2030	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$75 billion	$9,185 billion (0 billion)
SGM12	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	Annex I	auction	lump-sum	no LDC part.	IAT	PT	1.0	no	-->2050, -->2100 (climate)	$55 billion	$9,185 billion ($0 billion)
SGM30	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	Annex I	auction	lump-sum	no LDC part.	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$75 billion	$9,185 billion (0 billion)
SGM11	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	domestic only	auction	lump-sum	no LDC part.	IAT	PT	1.0	no	-->2050, -->2100 (climate)	$235 billion	$9,185 billion ($0 billion)

ID	Permit Prices: 2010	Permit Prices: 2025	Permit Prices: 2050	Conc. (ppmv) in 2050 (Deviation from BAU)	Conc. (ppmv) in 2100 (Deviation from BAU)	Year Conc. (550 ppmv) Reaches 2x Pre-Ind. Level (Deviation from BAU)	Change in Temp. (deg. C) from 1990 in 2050 (Deviation from BAU)	Change in Temp. (deg. C) from 1990 in 2100 (Deviation from BAU)	Emissions Peak, mmtce (year)	Year Returns to 1990	Intl. Trade of Permits, U.S., 2010 (MMTCE), ($)	Intl. Trade of Permits, U.S., 2050 (MMTCE), ($)	Date Received Run	File (h:\jaldy\)
SGM36	$23	$86	$150	486 (-16)	656 (-55)	2072 (+7)	0.99 (-0.07)	2.16 (-0.20)	no peak: 1714 (2050)	n/a	-180 (-$4.14 billion)	-364 (-$54.6 billion)	09/10/97	case20~1.xls
SGM35	$71	$192	$582	484 (-18)	656 (-55)	2073 (+8)	0.98 (-0.08)	2.15 (-0.21)	1550 (2000)	2020	n/a	n/a	09/10/97	case20~1.xls
SGM37	$9	$24	$33	486 (-16)	656 (-55)	2072 (+7)	0.99 (-0.07)	2.16 (-0.20)	no peak: 2101 (2050)	n/a	-246 (-$2.21 billion)	-751 (-$24.78 billion)	09/10/97	case20~1.xls
SGM6	$74	$119	$202	483 (-19)	648 (-63)	2074 (+9)	0.98 (-0.08)	2.12 (-0.24)	1637 (2005)	never returns	36, (+$2.7 billion)	-122, (-$24.6 billion)	08/21/97	cea95_~1.xls
SGM5	$62	$131	$317	483 (-19)	648 (-63)	2074 (+9)	0.98 (-0.08)	2.12 (-0.24)	1637 (2005)	never returns	n/a	n/a	08/21/97	cea95_~1.xls
SGM7	$27	$32	$41	483 (-19)	648 (-63)	2074 (+9)	0.98 (-0.08)	2.12 (-0.24)	no peak: 2073 (2050)	never returns	-131, (-$3.5 billion)	-593, (-$24.3 billion)	08/21/97	cea95_~1.xls
SGM33	$57	$120	$203	482 (-20)	648 (-63)	2074 (+9)	0.97 (-0.09)	2.12 (-0.24)	no peak: 1599 (2050)	n/a	20 ($1.14 billion)	-119, (-$24.16 billion)	09/10/97	case20~2.xls
SGM32	$51	$131	$318	482 (-20)	648 (-63)	2074 (+9)	0.97 (-0.09)	2.12 (-0.24)	1550 (2000)	n/a	n/a	n/a	09/10/97	case20~2.xls
SGM34	$21	$33	$41	482 (-20)	648 (-63)	2074 (+9)	0.97 (-0.09)	2.12 (-0.24)	no peak: 2072 (2050)	n/a	-122 (-$2.56 billion)	-592 (-$24.27 billion)	09/10/97	case20~2.xls
SGM27	$11	$56	$153	n/a	n/a	n/a	n/a	n/a	1755 (2015)	never returns	-5, (-$0.06 billion)	-367, (-$56.2 billion)	08/27/97	case5.xls
SGM24	$11	$56	$153	481 (-21)	568 (-143)	2089 (+24)	0.98 (-0.08)	1.84 (-0.52)	1755 (2015)	never returns	-5, (-$0.06 billion)	-367, (-$56.2 billion)	08/27/97	case4.xls, 9/4/97 fax
SGM12	$0	$47	$155	491 (-11)	n/a	n/a	1.02 (-0.04)	n/a	1807 (2015)	never returns	0, (n/a)	-367, (-$56.9 billion)	08/21/97	cea90_~1.xls
SGM30	$11	$56	$153	489 (-13)	658 (-53)	2071 (+6)	1.00 (-0.06)	2.17 (-0.19)	1755 (2015)	never returns	-5, (-$0.06 billion)	-367, (-$56.2 billion)	08/27/97	case6.xls, 9/4/97 fax
SGM11	$0	$84	$559	489 (-13)	n/a	n/a	1.01 (-0.05)	n/a	1807 (2015)	2040	n/a	n/a	08/21/97	cea90_~1.xls

ID	Scenario	Model	Modelers	Target	Timetable	Trading	Permit Allocation	Revenue Recycling	Burden Sharing	BAU Emissions Path Assumption	Paper Tons or Corre-sponding Reductions	AEEI	Ramp-up	Time Path	PDV (5%; 2000-2050) Foregone Consumption	GDP in 2010 (deviation from BAU)
SGM26	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	domestic only	auction	lump-sum	LDC BAU to 2030, equal per capita in 2050	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$270 billion	$9,184 billion (-$1 billion)
SGM23	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	domestic only	auction	lump-sum	LDC stabilizes at 2030 in 2030	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$270 billion	$9,184 billion (-$1 billion)
SGM29	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	domestic only	auction	lump-sum	no LDC part.	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$270 billion	$9,184 billion (-$1 billion)
SGM25	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	worldwide	auction	lump-sum	LDC stabilizes at 2030 in 2030	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	-$3 billion	$9,185 billion (0 billion)
SGM31	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	worldwide	auction	lump-sum	no LDC part.	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	-$5 billion	$9,185 billion (0 billion)
SGM28	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	worldwide	auction	lump-sum	LDC BAU to 2030, equal per capita in 2050	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$1 billion	$9,185 billion (0 billion)
SGM13	Peak in 2015	SGM, MAGICC	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	worldwide	auction	lump-sum	no LDC part.	IAT	PT	1.0	no	-->2050, -->2100 (climate)	-$8 billion	$9,185 billion ($0 billion)
SGM15	+10% of 1990 in 2010	SGM, MAGICC	Battelle	+10% 1990 emissions level	stabilize in 2010	Annex I	auction	lump-sum	no LDC part.	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$95 billion	$9,181 billion (-$4 billion)
SGM14	+10% of 1990 in 2010	SGM, MAGICC	Battelle	+10% 1990 emissions level	stabilize in 2010	domestic only	auction	lump-sum	no LDC part.	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$460 billion	$9,174 billion (-$11 billion)
SGM16	+10% of 1990 in 2010	SGM, MAGICC	Battelle	+10% 1990 emissions level	stabilize in 2010	worldwide	auction	lump-sum	no LDC part.	IAT	PT	1.0	in 2005	-->2050, -->2100 (climate)	$1 billion	$9,184 billion (-$1 billion)

ID	Permit Prices: 2010	Permit Prices: 2025	Permit Prices: 2050	Conc. (ppmv) in 2050 (Deviation from BAU)	Conc. (ppmv) in 2100 (Deviation from BAU)	Year Conc. (550 ppmv) Reaches 2x Pre-Ind. Level (Deviation from BAU)	Change in Temp. (deg. C) from 1990 in 2050 (Deviation from BAU)	Change in Temp. (deg. C) from 1990 in 2100 (Deviation from BAU)	Emissions Peak, mmtce (year)	Year Returns to 1990	Intl. Trade of Permits, U.S., 2010 (MMTCE), ($)	Intl. Trade of Permits, U.S., 2050 (MMTCE), ($)	Date Received Run	File (h:\jaldy\)
SGM26	$12	$99	$563	n/a	n/a	n/a	n/a	n/a	1729 (2015)	2040	n/a	n/a	08/27/97	case5.xls
SGM23	$12	$99	$563	481 (-21)	568 (-143)	2089 (+24)	0.98 (-0.08)	1.84 (-0.52)	1729 (2015)	2040	n/a	n/a	08/27/97	case4.xls, 9/4/97 fax
SGM29	$12	$99	$563	489 (-13)	658 (-53)	2071 (+6)	1.00 (-0.06)	2.17 (-0.19)	1729 (2015)	2040	n/a	n/a	08/27/97	case6.xls, 9/4/97 fax
SGM25	$4	$16	$111	481 (-21)	568 (-143)	2089 (+24)	0.98 (-0.08)	1.84 (-0.52)	1893 (2030)	never returns	-30, (-$0.1 billion)	-500, (-$55.5 billion)	08/27/97	case4.xls, 9/4/97 fax
SGM31	$4	$16	$33	489 (-13)	658 (-53)	2071 (+6)	1.00 (-0.06)	2.17 (-0.19)	no peak: 2101 (2050)	never returns	-30, (-$0.12 billion)	-751, (-$24.8 billion)	08/27/97	case6.xls, 9/4/97 fax
SGM28	$4	$16	$0	n/a	n/a	n/a	n/a	n/a	no peak: 2241 (2050)	never returns	n/a	n/a	08/27/97	case5.xls
SGM13	$0	$14	$33	491 (-11)	n/a	n/a	1.02 (-0.04)	n/a	no peak: 2102 (2050)	never returns	0, (n/a)	-752, (-$24.8 billion)	08/21/97	cea90_~1.xls
SGM15	$17	$56	$113	489 (-13)	662 (-49)	2071 (+6)	1.00 (-0.06)	2.18 (-0.18)	no peak: 1824 (2050)	never returns	-172, (-$2.9 billion)	-339, (-$38.3 billion)	08/27/97	case1.xls
SGM14	$60	$128	$310	488 (-14)	664 (-47)	2071 (+6)	0.99 (-0.07)	2.18 (-0.18)	1550 (2000)	never returns	n/a	n/a	08/27/97	case1.xls
SGM16	$7	$16	$25	489 (-13)	662 (-49)	2071 (+6)	1.00 (-0.06)	2.18 (-0.18)	no peak: 2128 (2050)	never returns	-219, (-$1.5 billion)	-643, (-$16.1 billion)	08/27/97	case1.xls

ID	Scenario	Model	Modelers	Target	Timetable	Trading	Permit Allocation	Revenue Recycling	Burden Sharing	BAU Emissions Path Assumption	Paper Tons or Corresponding Reductions	AEEI	Ramp-up	Time Path	PDV (5%; 2000-2050) Foregone Consumption	GDP in 2010 (deviation from BAU)
MM1	BAU	Markal	DOE	n/a	n/a	n/a	n/a	n/a	n/a	IAT	n/a	~1.0	n/a	-->2025	n/a	$9,205 billion (BAU GDP)
MM2	1990 in 2010	Markal	DOE	1990 emissions level	stabilize in 2010	domestic only	auction	lump-sum	no LDC part.	IAT	n/a	~1.0	n/a	-->2025	n/a	$9,137 billion (-$68 billion)
MM3	1995 in 2010	Markal	DOE	1995 emissions level	stabilize in 2010	domestic only	auction	lump-sum	no LDC part.	IAT	n/a	~1.0	n/a	-->2025	n/a	$9,152 billion (-$53 billion)
MM4	1990 in 2020	Markal	DOE	1990 emissions level	stabilize in 2020	domestic only	auction	lump-sum	no LDC part.	IAT	n/a	~1.0	n/a	-->2025	n/a	$9,197 billion (-$8 billion)
MM5	Peak in 2015	Markal	DOE	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	domestic only	auction	lump-sum	no LDC part.	IAT	n/a	~1.0	n/a	-->2025	n/a	$9,201 billion (-$4 billion)

ID	Permit Prices: 2010	Permit Prices: 2025	Permit Prices: 2050	Conc. (ppmv) in 2050 (Deviation from BAU)	Conc. (ppmv) in 2100 (Deviation from BAU)	Year Conc. (550 ppmv) Reaches 2x Pre-Ind. Level (Deviation from BAU)	Change in Temp. (deg. C) from 1990 in 2050 (Deviation from BAU)	Change in Temp. (deg. C) from 1990 in 2100 (Deviation from BAU)	Emissions Peak, mmtce (year)	Year Returns to 1990	Intl. Trade of Permits, U.S., 2010 (MMTCE), ($)	Intl. Trade of Permits, U.S., 2050 (MMTCE), ($)	Date Received Run	File
MM1	$0	$0	n/a	n/a	n/a	n/a	n/a	n/a	no peak: 2066 (2025)	n/a	n/a	n/a	08/26/97	8_26run1.wk4
MM2	$148	$192	n/a	n/a	n/a	n/a	n/a	n/a	1586 (2005)	2010	n/a	n/a	08/26/97	8_26run1.wk4
MM3	$136	$146	n/a	n/a	n/a	n/a	n/a	n/a	1600 (2005)	n/a	n/a	n/a	08/26/97	8_26run1.wk4
MM4	$0	$198	n/a	n/a	n/a	n/a	n/a	n/a	1749 (2010)	2020	n/a	n/a	08/26/97	8_26run1.wk4
MM5	$0	$99	n/a	n/a	n/a	n/a	n/a	n/a	1767 (2015)	2040*	n/a	n/a	08/26/97	8_26run1.wk4

ID	Scenario	Model	Modelers	Target	Timetable	Trading	Permit Allocation	Revenue Recycling	Burden Sharing	BAU Emissions Path Assumption	AEEI	Ramp-up	Time Path	Outputs PDV (3%; 2000-2050) Foregone Consumption	Permit Prices: 2010	Permit Prices: 2025	Permit Prices: 2050	Electricity Prices: 2010, 2025, 2050
SGM1	BAU	SGM	Battelle	n/a	n/a	n/a	n/a	n/a	n/a	IAT	1.0	n/a	-->2050, -->2100 (climate)	$183,155 billion (BAU consumption)	$0	$0	$0	
SGM2	1990 in 2010	SGM	Battelle	1990 emissions level	stabilize in 2010	domestic only	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	$1126 billion	$110	$191	$582	
SGM3	1990 in 2010	SGM	Battelle	1990 emissions level	stabilize in 2010	Annex I	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	384 billion	$42	$84	$149	
SGM4	1990 in 2010	SGM	Battelle	1990 emissions level	stabilize in 2010	worldwide	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	$5 billion	$16	$23	$32	
SGM5	1995 in 2010	SGM	Battelle	1995 emissions level	stabilize in 2010	domestic only	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	$737 billion	$62	$131	$317	
SGM6	1995 in 2010	SGM	Battelle	1995 emissions level	stabilize in 2010	Annex I	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	$645 billion	$74	$119	$201	
SGM7	1995 in 2010	SGM	Battelle	1995 emissions level	stabilize in 2010	worldwide	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	$38 billion	$27	$32	$41	
SGM8	-10% if 1990 in 2010	SGM	Battelle	-10% 1990 emissions level	stabilize in 2010	domestic only	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	$1630 billion	$175	$304	$924	
SGM9	-10% if 1990 in 2010	SGM	Battelle	-10% 1990 emissions level	stabilize in 2010	Annex I	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	$808billion	$91	$137	$238	
SGM10	-10% if 1990 in 2010	SGM	Battelle	-10% 1990 emissions level	stabilize in 2010	worldwide	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	$63 billion	$33	$37	$45	
SGM11	[illegible] 2015	SGM	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	domestic only	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	$498 billion	$0	$84	$559	
SGM12	Peak in 2015	SGM	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	Annex I	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	$125 billion	$0	$47	$155	
SGM13	Peak in 2015	SGM	Battelle	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	worldwide	auction	lump-sum	no LDC part.	IAT	1.0	no	-->2050, -->2100 (climate)	-$16 billion	$0	$14	$33	
MM1	BAU	Markal	DOE	n/a	n/a	n/a	n/a	n/a	n/a	IAT	~1.0	n/a	-->2025	n/a	$0	$0	n/a	
MM2	1990 in 2010	Markal	DOE	1990 emissions level	stabilize in 2010	domestic only	auction	lump-sum	no LDC part.	IAT	~1.0	n/a	-->2025		$148	$192	n/a	
MM3	1995 in 2010	Markal	DOE	1995 emissions level	stabilize in 2010	domestic only	auction	lump-sum	no LDC part.	IAT	~1.0	n/a	-->2025		$136	$146	n/a	
MM4	1990 in 2020	Markal	DOE	1990 emissions level	stabilize in 2020	domestic only	auction	lump-sum	no LDC part.	IAT	~1.0	n/a	-->2025		$0	$198	n/a	
MM5	Peak in 2015	Markal	DOE	2010 BAU emissions in 2015; 1990 level in 2040	stabilize in 2040	domestic only	auction	lump-sum	no LDC part.	IAT	~1.0	n/a	-->2025		$0	$99	n/a	
	550ppm Least-Cost	MERGE	Richels	550ppm concentration														

Oil Prices: 2010, 2025, 2050	Conc. (ppmv) in 2050 (Deviation from BAU)	Conc. (ppmv) in 2100 (Deviation from BAU)	Year Conc. (550 ppmv) Reaches 2x Pre-Ind. Level (Deviation from BAU)	Change in Temp. (deg. C) from 1990 in 2050 (Deviation from BAU)	Change in Temp. (deg. C) from 1990 in 2100 (Deviation from BAU)	Emissions Peak, mmtce (year)	Year Returns to 1990	Intl. Trade of Permits, 2010, 2050 (mmtce)	Date Received Run	File	
	502	711	2065	1.06	2.36	no peak: 2245 (2050)	n/a	n/a	08/21/97	aldy/sgmruns/cca90_~1.xls	
	485 (-17)	658 (-53)	2072 (+7)	0.99 (-0.07)	2.16 (-0.20)	1637 (2005)	2010	n/a	08/21/97	aldy/sgmruns/cca90_~2.xls	
	485 (-17)	658 (-53)	2072 (+7)	0.99 (-0.07)	2.16 (-0.20)	no peak: 1714 (2050)	never returns	-202, -364	08/21/97	aldy/sgmruns/cca90_~2.xls	
	485 (-17)	658 (-53)	2072 (+7)	0.99 (-0.07)	2.16 (-0.20)	no peak: 2102 (2050)	never returns	-313, -752	08/21/97	aldy/sgmruns/cca90_~2.xls	
	481 (-21)	648 (-63)	2074 (+9)	0.98 (-0.08)	2.12 (-0.24)	1637 (2005)	never returns	n/a	08/21/97	aldy/sgmruns/cca95_~1.xls	
	481 (-21)	648 (-63)	2074 (+9)	0.98 (-0.08)	2.12 (-0.24)	1637 (200	never returns	36, -122	08/21/97	aldy/sgmruns/cca95_~1.xls	
	481 (-21)	648 (-63)	2074 (+9)	0.98 (-0.08)	2.12 (-0.24)	no peak: 2073 (2050)	never returns	-131, -593	08/21/97	aldy/sgmruns/cca95_~1.xls	
	481 (-21)	653 (-58)	2074 (+9)	0.97 (-0.09)	2.11 (-0.25)	1637 (2005)	2010	n/a	08/21/97	aldy/sgmruns/cca90m_~1.xls	
	481 (-21)	653 (-58)	2074 (+9)	0.97 (-0.09)	2.11 (-0.25)	1637 (2005)	never returns	-180, -332	08/21/97	aldy/sgmruns/cca90m_~1.xls	
	481 (-21)	653 (-58)	2074 (+9)	0.97 (-0.09)	2.11 (-0.25)	no peak: 2060 (2050)	never returns	-332, -845	08/21/97	aldy/sgmruns/cca90m_~1.xls	
	489 (-13)	653 (-58)	2072 (+7)	1.01 (-0.05)	2.15 (-0.21)	1807 (2015)	2040	n/a	08/21/97	aldy/sgmruns/cca90_~1.xls	
	489 (-13)	653 (-58)	2072 (+7)	1.01 (-0.05)	2.15 (-0.21)	1807 (2015)	never returns	0, -367	08/21/97	aldy/sgmruns/cca90_~1.xls	
	489 (-13)	653 (-58)	2072 (+7)	1.01 (-0.05)	2.15 (-0.21)	no peak: 2102 (2050)	never returns	0, -752	08/21/97	aldy/sgmruns/cca90_~1.xls	
	n/a	n/a	n/a	n/a	n/a	no peak: 2066 (2025)	n/a	n/a	08/26/97	aldy/markal~1/8_26run1.wk4	
	n/a	n/a	n/a	n/a	n/a	1580 (2005)	2010	n/a	08/26/97	aldy/markal~1/8_26run1.wk4	
	n/a	n/a	n/a	n/a	n/a	1600 (2005)	n/a	n/a	08/26/97	aldy/markal~1/8_26run1.wk4	
	n/a	n/a	n/a	n/a	n/a	1749 (2010)	2020	n/a	08/26/97	aldy/markal~1/8_26run1.wk4	
	n/a	n/a	n/a	n/a	n/a	1767 (2015)	2040			aldy/markal~1/8_26run1.wk4	

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Preliminary Draft, 2/3/98

Summary of Trading Bloc Scenarios, U.S. Sinks = 50 MMTCE, AEEI = 1.0

Scenario	Permit Price	% Reduced at Home	Total Cost (Capital Transfer)
Annex I	$44/ton	52%	$18.4 b ($12.7 b)
Umbrella (no EU)	$23/ton	37%	$10.7 b ($8.7 b)
Umbrella (no EU, EE)	$36/ton	47%	$15.6 b ($11.4 b)
Umbrella (no EU) + 20% JI	$17/ton	31%	$8.2 b ($7.0 b)
Umbrella (no EU, EE) + 20% JI	$25/ton	39%	$11.4 b ($9.1 b)

Summary of Trading Bloc Scenarios, U.S. Sinks = 50 MMTCE, AEEI = 1.25

Scenario	Permit Price	% Reduced at Home	Total Cost (Capital Transfer)
Annex I	$31/ton	53%	$12.9 b ($8.7 b)
Umbrella (no EU)	$15/ton	38%	$6.9 b ($5.6 b)
Umbrella (no EU, EE)	$26/ton	49%	$11.1 b ($8.0 b)
Umbrella (no EU) + 20% JI	$12/ton	34%	$5.7 b ($4.8 b)
Umbrella (no EU, EE) + 20% JI	$19/ton	44%	$8.4 b ($6.4 b)

- All scenarios assume that the U.S. achieves 8.3% of its domestic reductions through sinks (50 MMTCE), while no other countries reduce through sinks.

- 20% JI scenarios assume that joint implementation is equal to 20% of the gains from ideal worldwide trade.

- The U.S. marginal abatement curve is such that the slope increases after a certain price (that price varies by AEEI) because there are very few inexpensive abatement opportunities among non-CO2 gases above $20 (actually, there is a step in the non-CO2 supply curve, where the next large gain in emissions reductions is at $50/ton). Thus, the percent abated per $/ton is higher at lower permit prices than it is at higher permit prices.

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#19

Draft; Close Hold, 1/26/98

Table 1. Summary of Trading Scenarios with Permit Prices around $15/ton

Trading Scenario	Tech	Sinks	Permit Price	Resource Cost	Value of Transfers	% Reductions in U.S.	Change in Gas Price	Change in Electricity Price
Annex I	1.0	100% reported	$11/ton	$5 billion	$4 billion	19%	+$0.03/gal	+$0.002/kWh
Umbrella - EU, EE + 100% JI	1.0	no sinks	$14/ton	$8 billion	$7 billion	19%	+$0.03/gal	+$0.002/kWh
Umbrella - EU, EE + key LDCs	1.0	no sinks	$16/ton	$9 billion	$7 billion	22%	+$0.04/gal	+$0.002/kWh
Umbrella - EU, EE + Key LDC + 20% JI	1.0	no sinks	$15/ton	$8 billion	$7 billion	20%	+$0.04/gal	+$0.002/kWh
Annex I + 20% JI	1.25	50% reported	$14/ton	$7 billion	$5 billion	31%	+$0.03/gal	+$0.002/kWh

Table 2. Summary of Trading Scenarios with Permit Prices around $30/ton

Trading Scenario	Tech	Sinks	Permit Price	Resource Cost	Value of Transfers	% Reductions in U.S.	Change in Gas Price	Change in Electricity Price
Annex I	1.0	50% reported	$26/ton	$12 billion	$9 billion	34%	+$0.06/gal	+$0.004/kWh
Umbrella - EU	1.0	no sinks	$26/ton	$13 billion	$11 billion	31%	+$0.06/gal	+$0.004/kWh
Annex I + 20% JI	1.0	no sinks	$36/ton	$17 billion	$13 billion	38%	+$0.09/gal	+$0.005/kWh
Umbrella - EU, EE + 20% JI	1.0	no sinks	$30/ton	$15 billion	$12 billion	34%	+$0.07/gal	+$0.004/kWh
Umbrella - EU, EE	1.25	no sinks	$31/ton	$15 billion	$10 billion	45%	+$0.07/gal	+$0.005/kWh

From The Desk Of

ANDY S. KYDES

To: Ray Squitieri Date: January 8, 1998

Re: Outputs requested for the $ 100/ton case

Attached is a summary table relating the NO_x emissions for the AEO98 reference case versus a case that represents what might occur with a $ 100/ton carbon permit fee (fee100). You should be aware of certain caveats and assumptions that go with these runs when you consider the analysis.

- The reference case in AEO98 does not incorporate the new NO_x standards and consequently the path of NO_x emissions in the reference case, if they were incorporated, would probably be a little but not substantially lower than indicated.

- The sensitivity case that we ran with the $100/ton carbon fee makes the following assumptions: (a) the $100/ton fee is ramped up over three years reaching and retaining a plateau of $100/ton in 2010, (b) that a carbon fee of $100/ton will trigger the development and availability of advanced menu of end-use technologies as defined in the AEO98 advanced cost reduction technology cases, (c) supply side technologies remain defined as in the AEO98 reference case, (d) an advanced ethanol technology as an oxygenate and for gasohol is made available by 2010, (e) economic overbuilding in excess of required reserve margins on a year-to-year basis *is allowed* to reach 7 percent of the existing generation base in the utility sector.

A cursory observation of the runs reveals the following:

- The availability and penetration of advanced end-use technologies is projected to reduce primary energy consumption by about 4 Quads (3.7%) in 2010.
- Natural gas use for generation increases substantially at the expense of coal generation. In 2010, steam coal generation is about 5.5 Quads lower and natural gas generation is over 3 Quads higher, resulting in a NO_x reduction of about 1.1 million tons from generation.
- Non-hydropower renewable generation is projected to be over 25% higher in the $100/ton fee case than in the reference case in 2010.
- The $ 100/ton carbon fee increases electricity prices by about 33 percent in 2010 relative to the reference case in 2010. Relative to the 1996 price of electricity, the $100/ton fee case raises electricity prices in 2010 by about 14 percent.
- Primary energy intensity in the reference case declines by 0.9 percent annually between 1996-2020. Energy intensity in the $100/ton case declines by 1.2 percent annually.

I hopes this helps.

Andy

January 15, 1998

NOTE

TO: Randy Lutter, President's Council of Economic Advisors

FROM: John Berg, FHWA

SUBJECT: Potential Impacts of hypothetical fuel price increases

Randy, Since we haven't been able to connect by phone, I thought I'd send you over a few thoughts via fax. Since the effects you are interested in (investment req'ts. and traffic congestion) stem from the effect on overall travel, I'll start by speculating on possible effects of tax-induced price increases on fuel consumption. Most models relating fuel consumption to price use short-run elasticities in the range of -0.1 to -0.15 or -0.2. I've seen longer-run elasticities of -0.4, and sometimes higher. However, even with these higher long-run fuel price elasticities, the effect on travel has been much reduced because, once consumers perceive that the fuel price increase is long lasting, they tend to upgrade the fuel efficiency of their vehicles, so travel elasticities are much lower.

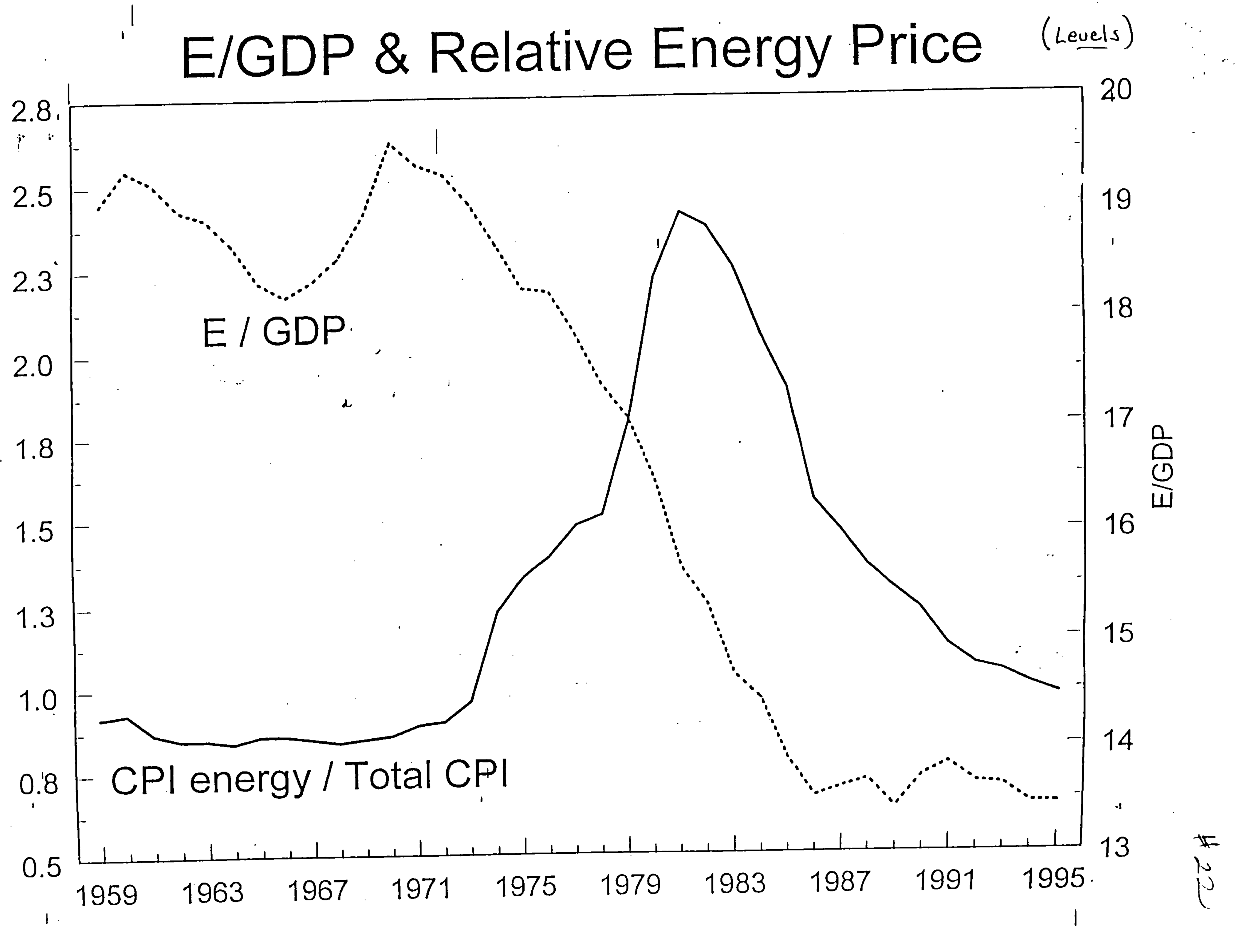
I don't have recent DOE estimates of these relationships, but a 1991 report, "Studies of Energy Taxes," provides some relevant information. The estimates DOE calculated for a 50-cent tax increase in 1991 indicate a 2.5 percent reduction (from the no-tax baseline) in fuel consumption in 1991, and a 7.5 percent reduction in 2000. Although I can't tell from the report, I would assume that they kept the price of fuel 50 cents higher than the baseline in real terms over the 1991 to 2000 period (that is, with further increases in fuel price in nominal terms over the intervening years).

The estimates of the effects of this tax increase on travel are quite revealing. Here, you see a 2.8 percent reduction in vehicle miles traveled in 1991, but by 2000, travel is only 1.1 percent below the baseline. From these figures I calculate a compound rate of growth of vmt of .008 percent per year in the base case (very low estimate compared to historical trends), and .007 percent per year in the case of the 50 cent tax. A 50 cent tax in 2010 would of course have a much reduced real effect than the tax examined in the 1991 study. While I'm sure DOE has updated these estimates, I think they make the point that, for your purposes, a 50-cent tax would not be likely to have a perceptible affect on overall travel, much less urban travel or congestion, and would not be likely to have a noticeable effect on investment requirements.

I guess we could speculate further on how these travel reductions would be reflected in urban travel and congestion. My guess is that urban congestion would be less effected by the fuel price increase than would longer non-urban trips, but that is only speculation. I personally think that the only way a price increase is going to significantly effect congestion, is if the price increase is in the form of a congestion fee (place and time specific), unless you're talking about a very substantial price increase (one that would substantially shut down economic activity). In a paper included in the National Academy of Sciences study of urban transportation pricing (Curbing Gridlock, 1994), the late Greig Harvey shows estimates of the effects of a gasoline tax increase of $2.00 per gallon resulting in reductions in vmt of 8.1 percent, and 7.6 percent in trips (the years aren't clear here).

In sum, I guess my advice is that a gas tax in the range of 50 cents per gallon would not be expected to have much effect on either congestion or investment requirements. Another thing to keep in mind is that a major part of the Administration's current Global Climate Change initiative is on improvements to the energy efficiency of vehicles and fuels. This would imply even a lesser affect of a fuel tax increase on travel.

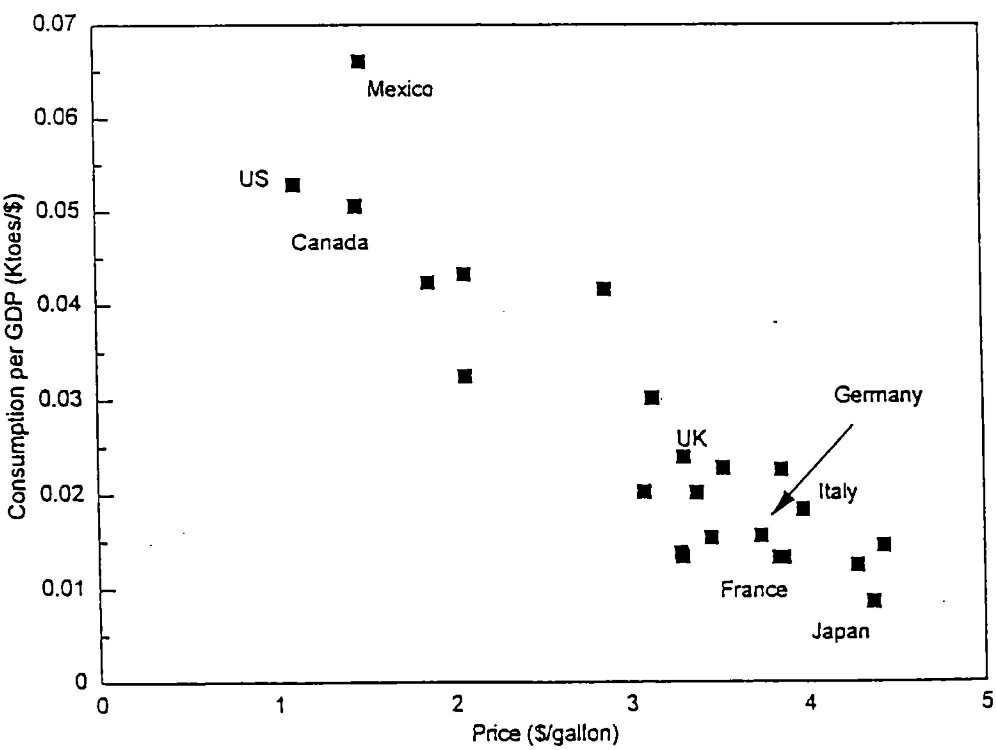
I suggest you touch base with the Department of Energy, Energy Information Administration for their latest estimates of fuel tax policies on consumption and travel. The name and number included in the 1991 report is Gerald Peabody, Distributional and Energy Demand Analysis, 202-586-6160. Another excellent contact is Dave Greene, with the Oak Ridge National Labs. David has been doing a considerable amount of work in the area of energy and transportation demand in the context of the current global climate change discussions. The number I have for him is 615-574-5963. I hope this information is helpful to you and I would be glad to discuss this with you further.


E/GDP & Relative Energy Price
(Levels)
E / GDP
CPI energy / Total CPI
E/GDP
2.8
2.5
2.3
2.0
1.8
1.5
1.3
1.0
0.8
0.5
20
19
18
17
16
15
14
13
1959
1963
1967
1971
1975
1979
1983
1987
1991
1995
#22

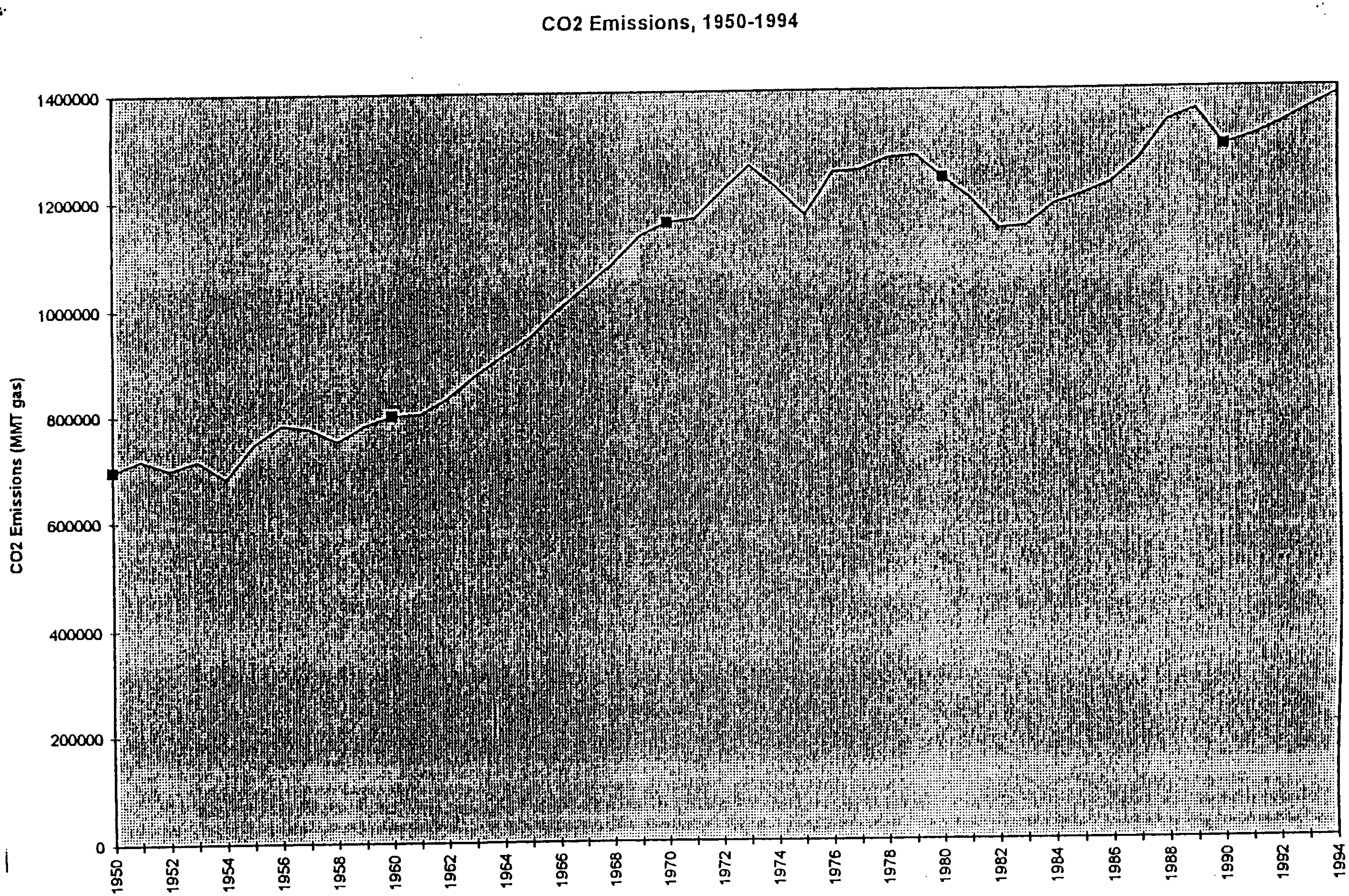
Price and Consumption of Energy in The Ten Largest OECD Countries (1994)

	Gasoline			Other Energy	
	Tax (per gallon)	Price (per gallon)	Consumption/GDP (Ktoe per $)	Price of Electricity: Households (per toe)	Total Energy Consumption/GDP (Ktoe per $)
Netherlands	$3.25	$4.28	0.0529	$1,744	0.1193
France	$3.09	$3.83	0.0156	$2,072	0.1184
Italy	$3.02	$3.97	0.0184	$1,907	0.1180
Germany	$2.89	$3.73	0.0240	$1,428	0.1547
UK	$2.50	$3.30	0.0086	$2,901	0.0733
Japan	$2.11	$4.37	0.0125	$1,343	0.1645
Spain	$2.11	$3.08	0.0203	$2,023	0.1394
Canada	$0.73	$1.45	0.0529	$977	0.2068
U.S.	$0.38	$1.11	0.0661	$788	0.2690
Mexico	$0.14	$1.48	0.0506	$692	0.3175

Consumption of Gasoline vs Price in OECD Countries



Sources: Energy Prices and Taxes: Second Quarter 1996; International Energy Agency (IEA); OECD
Energy Statistics of OECD Countries: 1993-1994; IEA; OECD
OECD in Figures: Statistics of the Member Countries (1996 Edition)


CO2 Emissions, 1950-1994
CO2 Emissions (MMT gas)
1400000
1200000
1000000
800000
600000
400000
200000
0
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994

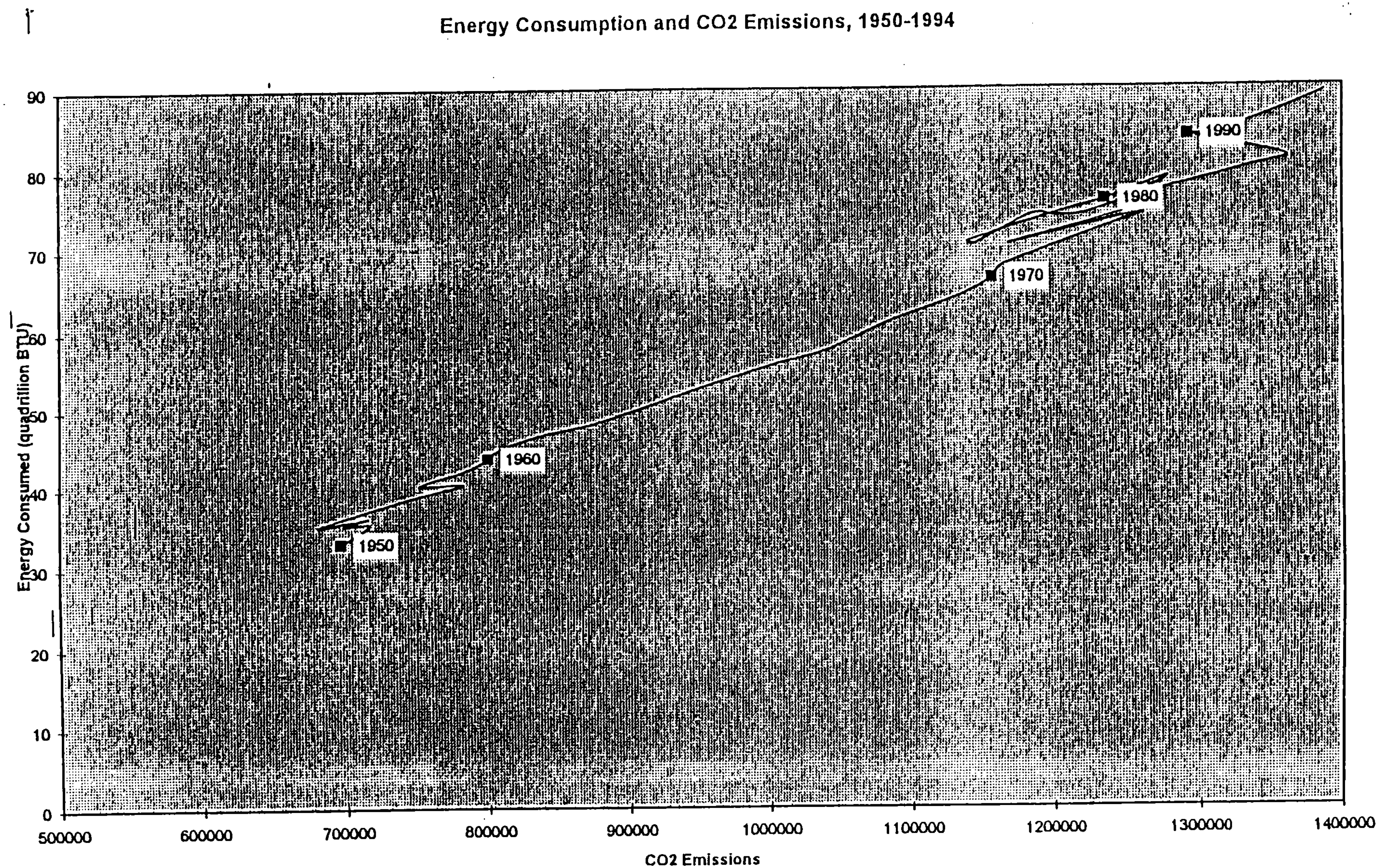
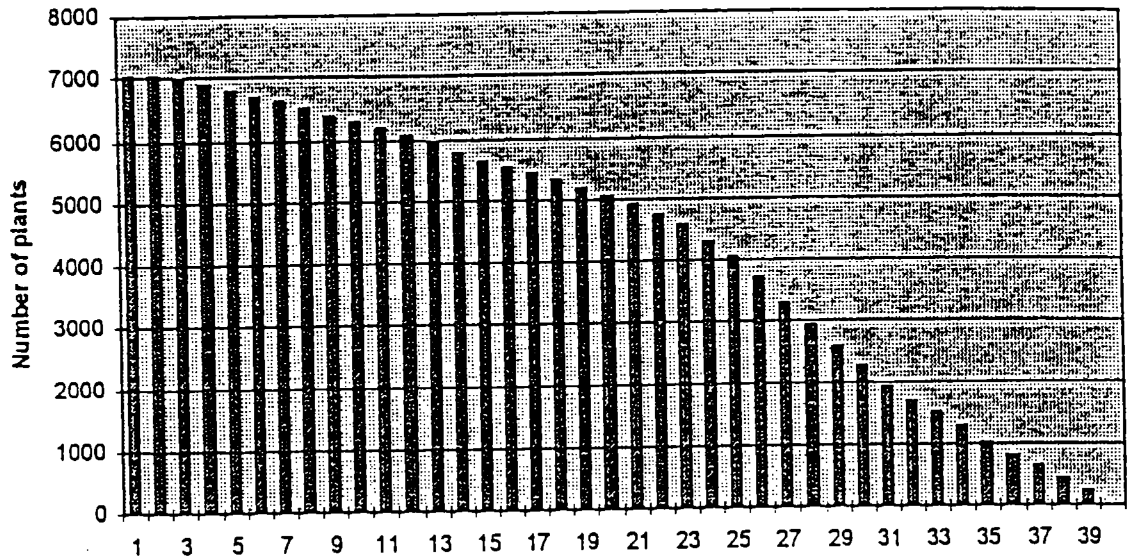

Energy Consumption and CO2 Emissions, 1950-1994
Energy Consumed (quadrillion BTU)
90
80
70
60
50
40
30
20
10
0
500000
600000
700000
800000
900000
1000000
1100000
1200000
1300000
1400000
CO2 Emissions
1950
1960
1970
1980
1990

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