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First Schaefer Request 4/17/98 - [Climate Change] [1]

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1st Request.

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

THE CHAIRMAN

April 17, 1998

Dear Chairman Schaefer:

Enclosed find documents relied upon in the preparation of my testimony on the economics of the Kyoto Protocol before the House Commerce Committee's Subcommittee on Energy and Power. I apologize for not forwarding these materials sooner. CEA is a small agency with large responsibilities, and we have gathered these documents as quickly as our resources allowed.

In addition to the documents provided today, your request calls for materials that implicate the President's interest in the confidentiality of White House decision making processes. That interest is particularly acute here because of ongoing interactions with foreign governments and because we are continuing to consider, formulate and effectuate new policies in this area.

Pursuant to standard procedures of the Executive Branch, we have consulted with the Office of Counsel to the President to determine how to accommodate the Subcommittee's oversight needs regarding these materials, without undermining the interest of the Executive Branch in the confidentiality of its decision making. As part of that accommodation, the White House is prepared to make available for review, but not copying, by Members and Subcommittee staff, confidential documents you have requested which were relied upon in the preparation of my testimony on the economics of the Kyoto Protocol before the Subcommittee.

Please call me to discuss arrangements for such review, or to address any questions you might have.

Sincerely,

Janet L. Yellen

Janet L. Yellen

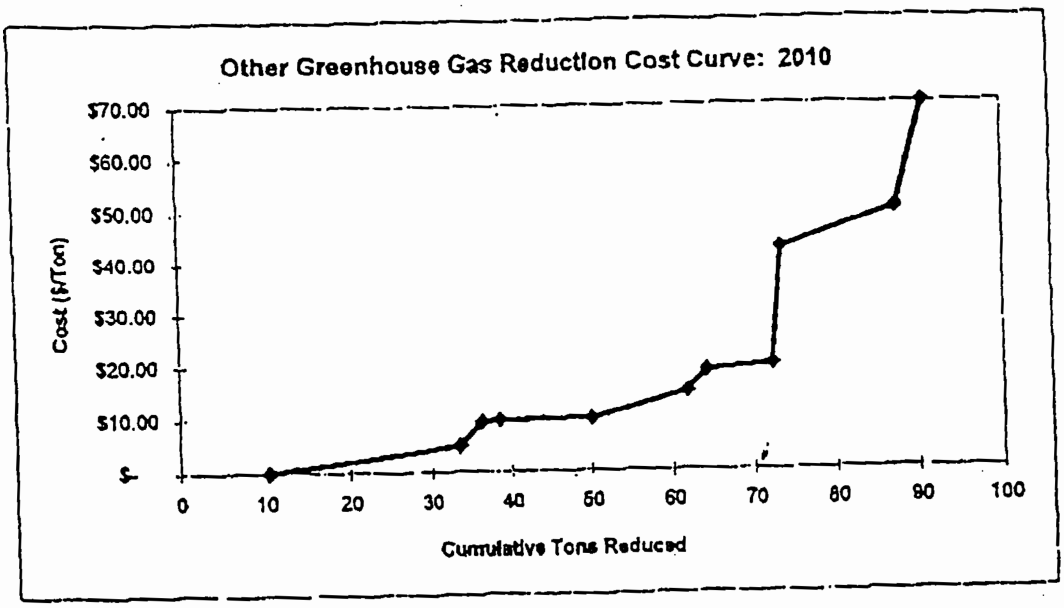
The Honorable Dan Schaefer
Chairman, Subcommittee on Energy & Power
House Commerce Committee
2125 Rayburn House Office Building
Washington, D.C. 20515-6115

Enclosures

Costs of Reducing Non-energy Greenhouse Gas Emissions in 2010

| Cumulative Tons Reduced | Cost ($/ton) | MMTCE $CH_4$ | MMTCE HFC/PFC | MMTCE Sinks | MMTCE $NO_x$ $N_2O$ | Total Tons Reduced |
|---|---|---|---|---|---|---|
| 10 | $ - | 6.1 | | | 4.3 | 10.4 |
| 34 | $ 5.00 | 1.4 | 21.8 | | | 23.2 |
| 36 | $ 9.51 | | | 2.7 | | 2.7 |
| 38 | $ 9.86 | | | 2.2 | | 2.2 |
| 50 | $ 10.00 | 2.5 | 9.0 | | | 11.5 |
| 62 | $ 15.00 | 3.6 | 8.1 | | | 11.7 |
| 64 | $ 18.98 | | | 2.5 | | 2.5 |
| 72 | $ 20.00 | 2.4 | 5.6 | | | 8.0 |
| 73 | $ 42.47 | | | 1.2 | | 1.2 |
| 87 | $ 50.00 | 7.8 | 6.2 | | | 14.0 |
| 91 | $ 70.00 | 3.4 | | | | 3.4 |
| Total by Gas | | 27.1 | 50.6 | 8.7 | 4.3 | |

**Average Cost = $18 Per Ton**
**Total Cost = $1.650 Billion**
**Total Reduction = 91 MMTCE**




Note: $70/ton was selected as the cutoff because it was the average value from EMF-12

OPTIONAL FORM 99 (7-90)

**FAX TRANSMITTAL** # of pages ▶ 1

| | |
|---|---|
| To Reid Harvey | From Bill Hohenstein |
| Dept./Agency OAR | Phone # 260-7019 |
| Fax # 233-9569 | Fax # 260-6405 |
| NSN 7540-01-317-7368 5099-101 | GENERAL SERVICES ADMINISTRATION |

## Table 62. Nitrogen Oxide Emissions from Electricity Generators by Region (million tons)

| Supply and Demand | 2000 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t | 5.34 | 5.50 | 5.55 | 5.57 | 5.56 | 5.60 | 5.63 | 5.62 | 5.65 | 5.67 | 5.69 | 5.69 | 5.68 | 5.70 | 5.77 | 5.82 | 5.85 | 5.88 |
| Area Reliability Coordination Agreement | 1.35 | 1.37 | 1.37 | 1.37 | 1.38 | 1.39 | 1.39 | 1.38 | 1.38 | 1.37 | 1.38 | 1.37 | 1.36 | 1.36 | 1.41 | 1.44 | 1.44 | 1.46 |
| ability Council of Texas | .42 | .38 | .38 | .37 | .34 | .33 | .33 | .32 | .33 | .33 | .33 | .33 | .33 | .33 | .33 | .34 | .35 | .35 |
| Area Council | .26 | .24 | .24 | .24 | .25 | .25 | .26 | .25 | .26 | .26 | .26 | .26 | .26 | .26 | .27 | .27 | .27 | .28 |
| Interconnected Network* | .47 | .45 | .45 | .46 | .46 | .47 | .47 | .47 | .47 | .48 | .48 | .48 | .48 | .48 | .48 | .49 | .49 | .50 |
| : Area Power Pool | .36 | .38 | .38 | .38 | .38 | .39 | .39 | .39 | .39 | .39 | .39 | .39 | .39 | .39 | .40 | .40 | .40 | .40 |
| er Coordinating Council/New York | .10 | .07 | .07 | .07 | .07 | .07 | .07 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .09 |
| er Coordinating Council/New England | .09 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .08 | .09 | .09 |
| Electric Reliability Council/Florida | .26 | .27 | .28 | .28 | .27 | .27 | .27 | .28 | .28 | .28 | .28 | .29 | 29 | .30 | .31 | .31 | .31 | .31 |
| Electric Reliability Council/Excl. Florida | .95 | .97 | .98 | .99 | .99 | 1.00 | 1.01 | 1.02 | 1.02 | 1.03 | 1.04 | 1.03 | 1.03 | 1.03 | 1.01 | 1.02 | 1.02 | 1.02 |
| er Pool | .62 | .63 | .63 | .63 | .63 | .63 | .63 | .64 | .63 | .63 | .62 | .62 | .61 | .61 | .61 | .61 | .61 | .61 |
| ms Coordinating Council/NWP | .21 | .22 | .22 | .22 | .22 | .23 | .22 | .23 | .23 | .23 | .23 | .23 | .23 | .23 | .23 | 23 | .23 | .23 |
| ms Coordinating Council/RA | .27 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .29 | .29 | .29 |
| ms Coordinating Council/CNV | .17 | .15 | .16 | .17 | .17 | .18 | .18 | .19 | .19 | .20 | .20 | .24 | .24 | .24 | .25 | .25 | .26 | .26 |

0698a run in /store2 on Tue Jan 6 16:11:25 EST 1998

## Table 62. Nitrogen Oxide Emissions from Electricity Generators by Region (Million tons)

| Supply and Demand | 2000 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.54 | 5.38 | 5.43 | 5.45 | 5.45 | 5.09 | 4.76 | 4.48 | 4.38 | 4.41 | 4.33 | 4.43 | 4.42 | 4.35 | 4.41 | 4.48 | 4.52 | 4.49 |
| Area Reliability Coordination Agreement | 1.33 | 1.33 | 1.33 | 1.34 | 1.36 | 1.24 | 1.13 | 1.05 | .97 | .93 | .84 | .85 | .88 | .87 | .91 | .94 | .95 | .95 |
| bility Council of Texas | .42 | .38 | .39 | .37 | .34 | .32 | .27 | .22 | .20 | .20 | .20 | .23 | .22 | .22 | .23 | .23 | .24 | .24 |
| rea Council | .27 | .25 | .25 | .25 | .25 | .24 | .24 | .24 | .24 | .24 | .23 | .24 | .24 | .22 | .26 | .24 | .24 | .24 |
| terconnected Network | .48 | .41 | .41 | .42 | .42 | .39 | .35 | .33 | .33 | .35 | .33 | .35 | .35 | .34 | .34 | 34 | .34 | .35 |
| Area Power Pool | .35 | .37 | .37 | .38 | .39 | .35 | .34 | .31 | .32 | .33 | .32 | .33 | .34 | .33 | .33 | .33 | .33 | .33 |
| r Coordinating Council/New York | .10 | .07 | .07 | .07 | .07 | .05 | .05 | .06 | .06 | .06 | .07 | .06 | .07 | .06 | .06 | .06 | .06 | .06 |
| r Coordinating Council/New England | .09 | .10 | .10 | .10 | .09 | .08 | .07 | .06 | .06 | .07 | .06 | .06 | .06 | .07 | .07 | 07 | .07 | .07 |
| lectric Reliability Council/Florida | .26 | .26 | .26 | .26 | .25 | .23 | .22 | .22 | .21 | .22 | .23 | .24 | .22 | .22 | .24 | .24 | .24 | .24 |
| lectric Reliability Council/Excl. Florida | .97 | .99 | 1.01 | 1.02 | 1.02 | .98 | .96 | .93 | .93 | .93 | .94 | .96 | .95 | .94 | .95 | .95 | .96 | .95 |
| r Pool | .61 | .60 | .60 | .59 | .59 | .56 | .51 | .48 | .47 | .49 | .50 | .51 | .50 | .47 | .47 | .47 | .43 | .48 |
| s Coordinating Council/NWP | .17 | .15 | .15 | .16 | .17 | .17 | .17 | .17 | .17 | .17 | .17 | 19 | .19 | .19 | .19 | .20 | .20 | .20 |
| s Coordinating Council/RA | .21 | .22 | .22 | .22 | .22 | .22 | .20 | .20 | .19 | .19 | .19 | .20 | .19 | .19 | .19 | .19 | .19 | .19 |
| s Coordinating Council/CNV | .27 | 26 | .27 | .27 | .27 | .26 | .24 | .22 | .21 | .23 | .24 | .23 | .23 | .22 | .22 | .21 | .21 | .21 |

96a run in /store2 on Tue Jan 6 16:11:25 EST 1998

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| Fax # 395-6870 | Fax # |

5:00 pm 1/7/98

| Post-it® Fax Note 7671 | Date 1-15-98 | # of pages ▶ 14 |
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| Fax # 260-6870 | Fax # 622-1294 | |

# U. S. Department of Energy

# TELEFAX TRANSMISSION

FROM

ENERGY INFORMATION ADMINISTRATION
Office of Integrated Analysis and Forecasting (EI-80)
1000 Independence Avenue, S.W.
Washington, D.C. 20585

DATE: 1/14/98

TO: Ray Squitieri

FAX NUMBER: 202-622-~~1294~~ 2633
301 913 0252

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FROM: Andy Kydes

1000 INDEPENDENCE AVE FAX NUMBER: (202) 586-3045

MESSAGE:

From The Desk Of

# ANDY S. KYDES

To: Ray Squitieri, Treasury Date: January 14, 1998

Re: Summary Tables of Carbon Permit Impacts

Attached please find a copy of NEMS summary tables in response to your request for information on the impact of alternative carbon fees on NOx and SOx emissions. A complete set of printouts are available as in the AEO98 reference case in the event you want them. In these tables, the results are derived as follows:

Column 1: AEO98 results

Column 2: New base: Advanced AEO98 demand technologies case with some further adjustments. The sensitivity cases that we ran with the various carbon fees make the following assumptions: (a) the fees are ramped up over three years reach and retain a plateau in 2010, (b) that a carbon fee greater than or equal to $100/ton will trigger the development and availability of an 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.

Column 3: New Base with a $100/ton carbon fee
Column 4: New Base with a $200/ton carbon fee
Column 5: New Base with a $300/ton carbon fee

- potentially mislabeled. 7/28/97

Table 62 is the table with the national and regional level Sox, Nox, and Carbon emissions.

Please let me know if you need anything else or want any explanation or further analysis.

cc Mary J. Hutzler
Scott Sitzer
Art Andersen

Andy

NATIONAL ENERGY MODELING SYSTEM

Table 1. Total Energy Supply and Disposition Summary

(Quadrillion Btu per Year, Unless Otherwise Noted)

| Supply, Disposition, and Prices | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2000 (5) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2010 (5) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2015 (5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Production** | | | | | | | | | | | | | | | |
| Crude Oil & Lease Condensate | 13.06 | 13.06 | 13.06 | 13.06 | 13.06 | 11.79 | 11.62 | 11.56 | 11.51 | 11.50 | 11.09 | 10.85 | 10.44 | 10.55 | 10.29 |
| Natural Gas Plant Liquids | 2.39 | 2.36 | 2.35 | 2.37 | 2.36 | 2.95 | 2.78 | 3.22 | 3.34 | 3.39 | 3.12 | 2.98 | 3.48 | 3.24 | 3.22 |
| Dry Natural Gas | 20.84 | 20.66 | 20.58 | 20.69 | 20.64 | 25.39 | 24.03 | 27.63 | 28.55 | 28.97 | 24.85 | 25.75 | 28.14 | 27.67 | 27.50 |
| Coal | 24.34 | 24.20 | 24.06 | 23.98 | 24.02 | 26.62 | 25.35 | 13.32 | 11.40 | 9.70 | 27.73 | 25.60 | 9.58 | 8.47 | 7.40 |
| Nuclear Power | 7.36 | 7.36 | 7.36 | 7.36 | 7.36 | 6.36 | 6.36 | 6.36 | 6.36 | 6.36 | 5.12 | 5.12 | 5.12 | 5.12 | 5.13 |
| Renewable Energy | 6.82 | 6.80 | 6.92 | 6.96 | 7.82 | 7.41 | 7.31 | 10.15 | 10.74 | 11.27 | 7.59 | 7.61 | 15.35 | 14.17 | 14.57 |
| Other | .56 | .55 | .56 | .54 | .56 | .48 | .48 | .46 | .60 | .60 | .47 | .63 | 1.16 | 1.13 | 1.11 |
| Total | 75.37 | 74.99 | 74.89 | 74.97 | 75.01 | 81.00 | 77.92 | 72.69 | 72.70 | 71.80 | 81.97 | 78.45 | 71.24 | 70.13 | 69.30 |
| **Imports** | | | | | | | | | | | | | | | |
| Crude Oil | 19.10 | 19.10 | 19.08 | 19.07 | 19.07 | 23.17 | 23.37 | 22.12 | 21.20 | 20.57 | 24.36 | 24.49 | 22.99 | 22.59 | 21.98 |
| Petroleum Products | 4.25 | 4.39 | 4.27 | 4.25 | 4.27 | 7.61 | 6.89 | 5.02 | 4.89 | 5.07 | 9.01 | 7.83 | 5.07 | 5.03 | 5.12 |
| Natural Gas | 4.20 | 4.21 | 4.23 | 4.22 | 4.22 | 4.66 | 4.55 | 4.69 | 4.60 | 4.60 | 5.04 | 4.81 | 5.71 | 5.82 | 5.08 |
| Other Imports | .62 | .63 | .63 | .63 | .63 | .57 | .59 | 1.08 | 1.20 | 1.41 | .54 | .58 | 1.06 | 1.26 | 1.39 |
| Total | 28.26 | 28.33 | 28.21 | 28.17 | 28.19 | 36.02 | 35.80 | 32.91 | 32.05 | 31.74 | 38.96 | 37.41 | 34.82 | 34.70 | 34.37 |
| **Exports** | | | | | | | | | | | | | | | |
| Petroleum | 1.71 | 1.72 | 1.71 | 1.71 | 1.71 | 1.80 | 1.76 | 1.48 | 1.44 | 1.32 | 1.89 | 1.83 | 1.59 | 1.55 | 1.63 |
| Natural Gas | .28 | .28 | .28 | .28 | .28 | .29 | .29 | .29 | .29 | .29 | .30 | .30 | .30 | .30 | .30 |
| Coal | 2.41 | 2.41 | 2.41 | 2.41 | 2.41 | 2.84 | 2.84 | 2.84 | 2.84 | 2.84 | 3.03 | 3.03 | 3.03 | 3.03 | 3.03 |
| Total | 4.39 | 4.40 | 4.40 | 4.40 | 4.40 | 4.93 | 4.90 | 4.61 | 4.58 | 4.45 | 5.21 | 5.15 | 4.91 | 4.87 | 4.96 |
| **Discrepancy** | .58 | .40 | .62 | .60 | .63 | .08 | -.39 | .02 | -.39 | -.37 | .00 | -.24 | -.15 | -.21 | -.17 |
| **Consumption** | | | | | | | | | | | | | | | |
| Petroleum Products | 38.35 | 38.26 | 38.26 | 38.25 | 38.26 | 44.53 | 43.05 | 40.68 | 39.95 | 39.60 | 46.20 | 44.45 | 41.46 | 40.66 | 40.03 |
| Natural Gas | 24.74 | 24.57 | 24.51 | 24.61 | 24.55 | 29.63 | 28.13 | 31.78 | 32.69 | 33.23 | 31.44 | 30.12 | 33.35 | 32.99 | 32.89 |
| Coal | 22.14 | 21.99 | 21.87 | 21.76 | 21.62 | 24.03 | 22.75 | 11.15 | 8.94 | 7.01 | 24.95 | 22.74 | 6.82 | 5.71 | 4.70 |
| Nuclear Power | 7.36 | 7.36 | 7.36 | 7.36 | 7.36 | 6.36 | 6.36 | 6.36 | 6.36 | 6.36 | 5.12 | 5.12 | 5.12 | 5.12 | 5.13 |
| Renewable Energy | 6.82 | 6.81 | 6.92 | 6.96 | 7.82 | 7.42 | 7.33 | 10.17 | 10.75 | 11.20 | 7.62 | 7.64 | 15.37 | 14.19 | 14.59 |
| Other | .41 | .41 | .41 | .41 | .41 | .40 | .39 | .88 | 1.08 | 1.22 | .40 | .41 | .87 | 1.07 | 1.20 |
| Total | 99.8 | 99.6 | 99.3 | 99.3 | 99.4 | 112.2 | 108.0 | 101.0 | 99.8 | 98.71 | 115.7 | 110.5 | 101.0 | 99.7 | 98.54 |
| **Net Imports - Petroleum** | 21.72 | 21.70 | 21.64 | 21.62 | 21.63 | 28.99 | 28.50 | 25.66 | 24.64 | 24.32 | 31.48 | 30.19 | 26.47 | 26.08 | 25.46 |
| **Prices (1996 dollars per unit)** | | | | | | | | | | | | | | | |
| World Oil Price ($ per bbl) | 19.11 | 19.07 | 19.07 | 19.07 | 19.06 | 20.81 | 20.21 | 18.85 | 18.42 | 18.26 | 21.40 | 20.48 | 17.88 | 17.61 | 17.36 |
| Gas Wellhead Price($ / Mcf) | 2.11 | 2.12 | 2.11 | 2.13 | 2.11 | 2.31 | 1.92 | 2.44 | 2.59 | 2.61 | 2.30 | 1.92 | 2.94 | 2.89 | 2.91 |
| Coal Minemouth Price ($ / ton) | 17.45 | 17.30 | 17.37 | 17.35 | 17.35 | 15.05 | 14.99 | 17.93 | 18.24 | 18.95 | 13.99 | 14.65 | 17.95 | 18.40 | 18.74 |
| Aver. Electricity (cents / Kwh) | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 | 5.9 | 5.9 | 9.4 | 10.1 | 10.6 | 5.6 | 5.6 | 9.1 | 9.6 | 10.2 |

neo98b.d100197a - AEO98 Reference Case, newbase.d011398a - Carbon Reference (1), fem100.d011398a (2), fem200.d011498a (3), fem300.d011598b (4

NATIONAL ENERGY MODELING SYSTEM

Table 17. Carbon Emissions by Sector and Source

(Million Metric Tons per Year, Unless Otherwise Noted)

| d Source | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2000 (5) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2010 (5) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2015 (5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| al | | | | | | | | | | | | | | | |
| um | 25.8 | 25.7 | 25.7 | 25.7 | 25.7 | 24.8 | 24.3 | 21.8 | 21.2 | 20.6 | 24.5 | 23.9 | 21.5 | 20.9 | 20.4 |
| Gas | 77.0 | 76.8 | 76.0 | 76.8 | 76.8 | 81.1 | 81.1 | 70.5 | 68.4 | 66.8 | 83.8 | 83.2 | 70.8 | 68.9 | 67.2 |
| | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.4 | 1.3 | 1.3 | 1.2 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 |
| city | 201.3 | 199.6 | 198.2 | 197.6 | 198.8 | 230.9 | 214.0 | 134.7 | 121.6 | 109.8 | 248.8 | 225.5 | 108.1 | 98.7 | 91.4 |
| | 305.6 | 303.5 | 302.1 | 301.5 | 301.9 | 338.1 | 320.8 | 228.2 | 212.5 | 198.5 | 358.3 | 334.0 | 201.6 | 189.7 | 180.2 |
| l | | | | | | | | | | | | | | | |
| um | 12.8 | 12.8 | 12.8 | 12.8 | 12.8 | 12.8 | 12.7 | 12.3 | 12.1 | 12.0 | 12.7 | 12.6 | 12.2 | 12.0 | 11.9 |
| Gas | 49.9 | 49.7 | 49.7 | 49.7 | 49.7 | 54.0 | 52.7 | 49.4 | 48.6 | 47.9 | 55.4 | 53.4 | 49.3 | 48.6 | 47.9 |
| | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| city | 182.2 | 181.3 | 180.1 | 179.5 | 179.9 | 205.1 | 196.3 | 122.3 | 109.8 | 99.0 | 217.8 | 203.6 | 95.7 | 87.1 | 80.4 |
| | 247.1 | 246.0 | 244.8 | 244.2 | 244.6 | 274.4 | 264.2 | 186.4 | 173.0 | 161.4 | 288.4 | 272.1 | 159.7 | 150.2 | 142.0 |
| l .. | | | | | | | | | | | | | | | |
| um | 103.3 | 102.7 | 102.6 | 102.6 | 102.7 | 115.6 | 112.4 | 104.5 | 98.4 | 98.1 | 119.3 | 114.5 | 107.5 | 105.2 | 103.3 |
| Gas | 155.5 | 154.4 | 154.4 | 154.4 | 154.3 | 165.8 | 158.6 | 150.5 | 151.0 | 150.4 | 167.1 | 158.9 | 146.7 | 145.2 | 141.2 |
| | 60.7 | 59.4 | 59.4 | 59.4 | 59.4 | 62.8 | 55.9 | 47.7 | 47.0 | 46.5 | 61.7 | 53.3 | 45.7 | 45.1 | 44.7 |
| city | 187.3 | 185.9 | 184.4 | 183.9 | 184.3 | 219.1 | 205.3 | 141.3 | 126.2 | 115.6 | 230.6 | 210.4 | 112.0 | 102.3 | 94.4 |
| | 506.7 | 502.3 | 500.7 | 500.3 | 500.7 | 563.3 | 532.1 | 444.0 | 423.5 | 408.6 | 578.7 | 537.1 | 412.0 | 396.7 | 385.5 |
| ation | | | | | | | | | | | | | | | |
| um | 502.4 | 502.4 | 502.2 | 502.2 | 502.2 | 601.0 | 591.1 | 557.1 | 545.7 | 538.6 | 632.3 | 615.0 | 552.3 | 542.2 | 533.2 |
| Gas | 12.2 | 12.1 | 12.0 | 12.1 | 12.0 | 17.2 | 16.4 | 17.4 | 17.9 | 17.9 | 18.6 | 17.9 | 10.4 | 10.1 | 10.1 |
| | .1 | .1 | .1 | .1 | .1 | 1.5 | 1.5 | 1.3 | 1.3 | 1.2 | 2.2 | 2.3 | 1.9 | 1.9 | 1.8 |
| city | 3.2 | 3.3 | 3.2 | 3.2 | 3.2 | 7.3 | 8.7 | 5.5 | 5.0 | 4.5 | 9.5 | 10.6 | 5.1 | 4.7 | 4.3 |
| | 517.9 | 517.7 | 517.5 | 517.6 | 517.5 | 627.5 | 617.7 | 581.4 | 569.9 | 562.3 | 662.7 | 644.6 | 577.0 | 566.9 | 557.4 |
| bon Emissions .. | | | | | | | | | | | | | | | |
| um | 644.4 | 643.6 | 643.3 | 643.4 | 643.3 | 754.2 | 748.5 | 695.6 | 677.5 | 669.4 | 788.9 | 764.9 | 693.5 | 680.4 | 668.0 |
| Gas | 294.6 | 292.9 | 292.8 | 293.0 | 292.8 | 318.1 | 308.8 | 287.8 | 286.7 | 282.9 | 324.9 | 313.4 | 285.3 | 278.9 | 274.3 |
| | 64.3 | 63.0 | 63.0 | 63.0 | 63.1 | 66.6 | 59.7 | 51.4 | 50.7 | 50.2 | 65.6 | 57.1 | 49.5 | 48.8 | 48.4 |
| | .1 | .1 | .1 | .1 | .1 | 1.5 | 1.5 | 1.3 | 1.3 | 1.2 | 2.2 | 2.3 | 1.9 | 1.9 | 1.8 |
| city | 574.0 | 570.1 | 565.9 | 564.2 | 565.4 | 662.9 | 624.4 | 403.8 | 362.6 | 327.0 | 706.8 | 650.1 | 320.9 | 292.6 | 270.5 |
| | 1577 | 1570 | 1565 | 1564 | 1565 | 1803 | 1735 | 1440 | 1379 | 1331 | 1888 | 1788 | 1351 | 1303 | 1264 |
| Generators .. | | | | | | | | | | | | | | | |
| um | 11.4 | 10.6 | 10.8 | 10.5 | 10.7 | 7.4 | 7.2 | 4.6 | 5.3 | 6.0 | 6.8 | 6.2 | 6.3 | 4.8 | 4.6 |
| Gas | 59.6 | 58.0 | 57.9 | 59.3 | 58.6 | 106.3 | 94.5 | 167.9 | 182.1 | 193.0 | 125.4 | 118.5 | 193.1 | 194.5 | 197.4 |
| | 503.0 | 500.6 | 497.2 | 494.3 | 496.1 | 549.3 | 522.8 | 231.3 | 175.2 | 126.4 | 574.5 | 525.4 | 121.5 | 93.9 | 68.6 |
| | 574.0 | 570.1 | 565.9 | 564.2 | 565.4 | 662.9 | 624.4 | 403.8 | 362.6 | 327.0 | 706.8 | 650.1 | 320.9 | 292.6 | 270.5 |
| bon Emissions .. | | | | | | | | | | | | | | | |
| um | 655.8 | 654.2 | 654.0 | 653.8 | 654.1 | 761.5 | 747.7 | 700.2 | 682.8 | 676.3 | 795.7 | 771.1 | 699.7 | 684.9 | 673.4 |
| Gas | 354.2 | 351.7 | 350.8 | 352.2 | 351.4 | 424.4 | 403.2 | 455.7 | 468.8 | 476.7 | 450.3 | 431.9 | 478.4 | 473.1 | 471.8 |
| | 567.3 | 563.7 | 560.2 | 557.5 | 559.1 | 615.9 | 582.4 | 282.7 | 225.9 | 176.6 | 640.1 | 582.5 | 171.0 | 142.7 | 116.9 |
| | .1 | .1 | .1 | .1 | .1 | 1.5 | 1.5 | 1.3 | 1.3 | 1.2 | 2.2 | 2.3 | 1.9 | 1.9 | 1.8 |
| | 1577 | 1570 | 1565 | 1564 | 1565 | 1803 | 1735 | 1440 | 1379 | 1331 | 1888 | 1788 | 1351 | 1303 | 1264 |
| issions of person) | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 6.0 | 5.8 | 4.8 | 4.6 | 4.5 | 6.1 | 5.7 | 4.3 | 4.2 | 4.1 |

100197a - AEO98 Reference Case, nmbase.d011398a - Carbon Reference (1), fos100.d011398a (2), fos200.d011698a (3), fos300.d011398b (4)

1

NATIONAL ENERGY MODELING SYSTEM

Table 62. Emissions by NERC Region (million short tons) except Carbon and Carbon Dioxide (million metric tons)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2000 (5) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2010 (5) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2015 (5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emissions | | | | | | | | | | | | | | | |
| United States | | | | | | | | | | | | | | | |
| Total Carbon | 574.0 | 570.1 | 565.9 | 564.2 | 565.4 | 662.9 | 624.4 | 403.0 | 362.6 | 327.0 | 706.0 | 650.1 | 320.9 | 292.6 | 270.3 |
| Carbon Dioxide | 2104 | 2090 | 2075 | 2069 | 2073 | 2431 | 2289 | 1481 | 1330 | 1199 | 2591 | 2384 | 1177 | 1075 | 991.9 |
| Sulfur Dioxide | 10.29 | 10.19 | 10.42 | 10.44 | 10.43 | 9.22 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| Nitrogen Oxide | 6.14 | 6.11 | 6.06 | 6.03 | 6.05 | 6.51 | 6.19 | 3.52 | 2.97 | 2.45 | 6.75 | 6.29 | 2.13 | 1.84 | 1.54 |
| | | | | | | 6.51 | | 3.52 | 2.17 | 2.45 | | | | | |
| East Central Area Reliability | | | | | | | | | | | | | | | |
| Total Carbon | 128.8 | 128.1 | 125.8 | 125.7 | 126.0 | 144.3 | 136.0 | 100.0 | 90.46 | 80.31 | 148.5 | 137.6 | 76.82 | 69.74 | 64.18 |
| Carbon Dioxide | 472.4 | 469.6 | 461.3 | 461.0 | 462.0 | 529.1 | 498.6 | 366.7 | 331.7 | 294.5 | 544.5 | 504.4 | 281.7 | 255.7 | 235.3 |
| Sulfur Dioxide | 3.43 | 3.38 | 3.54 | 3.61 | 3.58 | 3.07 | 2.93 | 4.16 | 3.94 | 4.04 | 2.86 | 2.70 | 5.06 | 5.45 | 5.83 |
| Nitrogen Oxide | 1.50 | 1.49 | 1.47 | 1.46 | 1.47 | 1.62 | 1.53 | 1.01 | .80 | .65 | 1.64 | 1.51 | .69 | .63 | .53 |
| Electric Reliability Council Tx | | | | | | | | | | | | | | | |
| Total Carbon | 45.89 | 45.75 | 45.73 | 45.73 | 45.75 | 51.05 | 47.25 | 27.01 | 25.81 | 24.19 | 52.53 | 48.62 | 21.91 | 21.43 | 19.64 |
| Carbon Dioxide | 168.3 | 167.7 | 167.7 | 167.7 | 167.7 | 187.2 | 173.3 | 99.0 | 94.61 | 90.53 | 192.6 | 178.3 | 80.35 | 78.59 | 72.00 |
| Sulfur Dioxide | .35 | .35 | .35 | .35 | .35 | .34 | .32 | .06 | .07 | .09 | .33 | .30 | .12 | .14 | .19 |
| Nitrogen Oxide | .47 | .47 | .47 | .47 | .47 | .40 | .36 | .23 | .21 | .20 | .38 | .36 | .11 | .10 | .10 |
| Mid-Atlantic Area Council | | | | | | | | | | | | | | | |
| Total Carbon | 34.52 | 34.10 | 33.33 | 33.75 | 33.76 | 40.01 | 37.60 | 29.90 | 25.50 | 24.34 | 42.05 | 38.99 | 21.99 | 20.32 | 19.57 |
| Carbon Dioxide | 126.6 | 125.0 | 122.2 | 123.8 | 123.8 | 146.7 | 137.9 | 109.6 | 93.50 | 89.23 | 154.2 | 143.0 | 80.64 | 74.51 | 71.74 |
| Sulfur Dioxide | .56 | .54 | 1.09 | 1.09 | 1.10 | .53 | .40 | 1.04 | .90 | 1.10 | .51 | .44 | .62 | .48 | .43 |
| Nitrogen Oxide | .29 | .29 | .28 | .29 | .29 | .31 | .28 | .21 | .15 | .15 | .31 | .29 | .11 | .09 | .08 |
| Mid-America Interconnected Netw | | | | | | | | | | | | | | | |
| Total Carbon | 40.82 | 40.56 | 40.26 | 40.37 | 40.61 | 47.77 | 45.08 | 25.64 | 23.07 | 21.14 | 50.52 | 46.37 | 25.05 | 22.67 | 21.09 |
| Carbon Dioxide | 149.7 | 148.7 | 147.6 | 148.0 | 148.9 | 175.2 | 165.3 | 94.01 | 84.57 | 77.52 | 185.2 | 170.0 | 91.86 | 83.12 | 77.33 |
| Sulfur Dioxide | .93 | .87 | .96 | .99 | .99 | .65 | .63 | .40 | .39 | .33 | .61 | .58 | .46 | .33 | .32 |
| Nitrogen Oxide | .52 | .52 | .52 | .52 | .52 | .54 | .52 | .19 | .16 | .12 | .56 | .52 | .13 | .13 | .09 |
| Mid-Continent Area Power Pool | | | | | | | | | | | | | | | |
| Total Carbon | 32.66 | 32.45 | 31.80 | 31.71 | 31.92 | 38.87 | 36.67 | 20.54 | 17.37 | 13.92 | 41.28 | 38.41 | 10.43 | 8.98 | 8.43 |
| Carbon Dioxide | 119.7 | 119.0 | 116.6 | 116.3 | 117.0 | 142.5 | 134.5 | 75.31 | 63.70 | 51.03 | 151.3 | 140.0 | 38.23 | 32.62 | 31.63 |
| Sulfur Dioxide | .42 | .41 | .39 | .40 | .39 | .43 | .41 | .27 | .29 | .25 | .42 | .39 | .08 | .06 | .13 |
| Nitrogen Oxide | .39 | .39 | .38 | .38 | .38 | .45 | .43 | .20 | .16 | .13 | .46 | .43 | .05 | .05 | .05 |
| Northeast Power Council/New York | | | | | | | | | | | | | | | |
| Total Carbon | 13.50 | 13.53 | 13.39 | 13.32 | 13.32 | 14.13 | 13.01 | 10.31 | 9.96 | 9.97 | 15.31 | 14.22 | 10.03 | 9.93 | 8.8[illegible] |
| Carbon Dioxide | 49.50 | 49.60 | 49.11 | 48.83 | 48.83 | 51.82 | 47.71 | 37.81 | 36.51 | 36.57 | 56.15 | 52.12 | 34.78 | 36.41 | 32.5[illegible] |
| Sulfur Dioxide | .24 | .24 | .26 | .26 | .26 | .19 | .18 | .13 | .10 | .07 | .17 | .16 | .15 | .17 | .1[illegible] |
| Nitrogen Oxide | .11 | .11 | .11 | .11 | .11 | .09 | .08 | .05 | .04 | .04 | .09 | .09 | .04 | .04 | .0[illegible] |
| Northeast Power Council/New Engl | | | | | | | | | | | | | | | |
| Total Carbon | 11.59 | 11.45 | 11.59 | 11.57 | 11.62 | 14.09 | 14.47 | 8.92 | 8.74 | 7.98 | 14.32 | 13.98 | 8.01 | 7.97 | 7.6[illegible] |
| Carbon Dioxide | 42.48 | 41.97 | 42.51 | 42.43 | 42.60 | 51.67 | 53.04 | 32.72 | 32.05 | 28.95 | 52.49 | 51.27 | 29.38 | 29.22 | 28.0[illegible] |
| Sulfur Dioxide | .18 | .18 | .16 | .16 | .17 | .14 | .17 | .04 | .06 | .06 | .13 | .14 | .06 | .07 | .0[illegible] |

aeo98b.d100197a - AEO98 Reference Case, nobase.d011398a - Carbon Reference (1), fee100.d011398a (2), fee200.d011498a

ENERGY INFORMATION ADMINISTRATION

Table 62. Emissions by NERC Region (million short tons) (Continued)
except Carbon and Carbon Dioxide (million metric tons)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2000 (5) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2010 (5) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2015 (5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Southeastern Electric/Florida | | | | | | | | | | | | | | | |
| Total Carbon | 26.44 | 26.18 | 25.82 | 25.82 | 25.74 | 32.84 | 30.37 | 20.30 | 19.43 | 18.36 | 38.16 | 33.04 | 19.23 | 18.69 | 17.46 |
| Carbon Dioxide | 96.93 | 96.01 | 94.66 | 94.65 | 94.37 | 120.4 | 111.4 | 74.45 | 71.26 | 67.33 | 139.9 | 121.1 | 70.50 | 68.51 | 64.02 |
| Sulfur Dioxide | .39 | .40 | .32 | .32 | .32 | .37 | .34 | .16 | .17 | .16 | .37 | .37 | .19 | .21 | .18 |
| Nitrogen Oxide | .29 | .29 | .28 | .28 | .28 | .33 | .30 | .16 | .18 | .13 | .38 | .32 | .12 | .12 | .10 |
| Southeastern Electric/Excl Fla | | | | | | | | | | | | | | | |
| Total Carbon | 104.2 | 103.1 | 104.1 | 101.9 | 102.5 | 122.0 | 113.8 | 80.93 | 74.00 | 65.59 | 131.5 | 121.1 | 63.22 | 57.66 | 51.04 |
| Carbon Dioxide | 382.1 | 378.1 | 381.8 | 373.7 | 375.6 | 447.3 | 417.2 | 296.6 | 271.3 | 240.5 | 482.0 | 444.1 | 231.8 | 211.4 | 187.1 |
| Sulfur Dioxide | 2.56 | 2.70 | 2.21 | 2.12 | 2.19 | 2.48 | 2.52 | 2.38 | 2.74 | 2.65 | 2.63 | 2.95 | 1.83 | 1.73 | 1.39 |
| Nitrogen Oxide | 1.06 | 1.05 | 1.06 | 1.03 | 1.04 | 1.18 | 1.12 | .77 | .70 | .57 | 1.23 | 1.13 | .44 | .37 | .28 |
| Southwest Power Pool | | | | | | | | | | | | | | | |
| Total Carbon | 59.86 | 59.67 | 59.02 | 59.33 | 59.26 | 68.26 | 65.90 | 35.12 | 32.20 | 29.35 | 70.37 | 66.71 | 26.57 | 24.39 | 23.59 |
| Carbon Dioxide | 219.5 | 218.8 | 216.4 | 217.6 | 217.3 | 250.3 | 241.6 | 128.8 | 118.1 | 107.6 | 258.0 | 244.6 | 97.41 | 89.41 | 86.50 |
| Sulfur Dioxide | .68 | .67 | .68 | .68 | .68 | .62 | .62 | .21 | .20 | .10 | .59 | .59 | .23 | .19 | .17 |
| Nitrogen Oxide | .69 | .68 | .67 | .68 | .68 | .71 | .70 | .33 | .32 | .26 | .69 | .67 | .16 | .14 | .12 |
| Western Systems Council/NWP | | | | | | | | | | | | | | | |
| Total Carbon | 24.83 | 24.76 | 24.70 | 24.72 | 24.66 | 29.61 | 28.71 | 15.01 | 10.85 | 10.23 | 30.44 | 29.53 | 12.09 | 10.09 | 9.14 |
| Carbon Dioxide | 91.05 | 90.78 | 90.56 | 90.64 | 90.41 | 108.6 | 105.3 | 55.03 | 39.78 | 37.50 | 111.6 | 108.3 | 44.32 | 37.00 | 33.50 |
| Sulfur Dioxide | .16 | .16 | .16 | .16 | .16 | .14 | .14 | .03 | .02 | .01 | .13 | .13 | .02 | .01 | .01 |
| Nitrogen Oxide | .24 | .24 | .23 | .24 | .23 | .25 | .25 | .09 | .05 | .04 | .25 | .25 | .05 | .04 | .03 |
| Western Systems Council/RA | | | | | | | | | | | | | | | |
| Total Carbon | 27.94 | 27.99 | 27.94 | 28.04 | 28.04 | 31.83 | 30.92 | 17.13 | 15.52 | 13.47 | 33.15 | 31.91 | 15.72 | 13.36 | 12.10 |
| Carbon Dioxide | 102.5 | 102.6 | 102.4 | 102.8 | 102.8 | 116.7 | 113.4 | 62.79 | 56.91 | 49.39 | 121.6 | 117.0 | 57.64 | 48.97 | 44.37 |
| Sulfur Dioxide | .21 | .21 | .21 | .21 | .21 | .18 | .18 | .13 | .12 | .12 | .16 | .16 | .16 | .15 | .17 |
| Nitrogen Oxide | .30 | .30 | .30 | .29 | .29 | .31 | .31 | .14 | .12 | .09 | .32 | .31 | .11 | .08 | .08 |
| Western Systems Council/CNV | | | | | | | | | | | | | | | |
| Total Carbon | 22.87 | 22.43 | 22.39 | 22.27 | 22.32 | 28.16 | 24.67 | 13.03 | 9.73 | 7.69 | 38.66 | 29.63 | 9.87 | 7.50 | 7.35 |
| Carbon Dioxide | 83.84 | 82.25 | 82.10 | 81.66 | 81.85 | 103.3 | 90.46 | 47.79 | 35.67 | 28.21 | 141.7 | 108.6 | 36.18 | 27.48 | 26.96 |
| Sulfur Dioxide | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .01 | .01 | .01 | .08 | .08 | .02 | .01 | .01 |
| Nitrogen Oxide | .18 | .19 | .19 | .19 | .19 | .22 | .21 | .10 | .06 | .05 | .33 | .26 | .06 | .03 | .03 |

aeo98b.d100197a - AEO98 Reference Case, newbase.d011398a - Carbon Reference (1), fea100.d011398a (2), fea201.d011498a (3), fea3[illegible]

NATIONAL ENERGY MODELING SYSTEM

Table 117. National Impacts of the Clean Air Act Amendments of 1990 (CAAA90)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2000 (5) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2010 (5) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2015 (5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scrubber Retrofits (gigawatts).. | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Interregional SO2 Allowances Traded (thousand tons)........ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| SO2 Allowance Price ............ | 120.9 | 137.3 | 76.25 | 75.11 | 73.70 | 189.4 | 186.5 | .00 | .00 | .00 | 181.0 | 177.7 | .00 | .00 | .00 |
| SO2 Emissions (million tons).... | 10.19 | 10.19 | 10.42 | 10.44 | 10.43 | 9.22 | 9.00 | 9.00 | 9.01 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| Coal Production by Sulfur Categ. (million tons) | | | | | | | | | | | | | | | |
| Low Sulfur (< .61 lbs s/mmBtu).. | 466.1 | 473.8 | 453.9 | 450.9 | 451.3 | 594.1 | 569.1 | 167.7 | 132.9 | 97.83 | 660.9 | 595.0 | 101.0 | 86.78 | 69.53 |
| Med.Sulfur(.61-1.67 lbs.S/mmBtu) | 498.7 | 492.9 | 484.5 | 482.8 | 484.6 | 478.1 | 454.3 | 294.5 | 266.5 | 234.9 | 464.9 | 440.9 | 225.7 | 289.5 | 193.8 |
| High Sulfur (> 1.67 lbs.S/mmBtu) | 177.9 | 173.5 | 194.7 | 195.9 | 195.4 | 192.9 | 181.3 | 121.3 | 100.5 | 84.10 | 200.3 | 179.1 | 87.39 | 72.51 | 55.65 |
| Gasoline Prices | | | | | | | | | | | | | | | |
| Traditional Gasoline........... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Oxygenated Gasoline............ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Reformulated Gasoline.......... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| High-Oxygen Reformulated Gas... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Average........................ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Gasoline Quantities | | | | | | | | | | | | | | | |
| Traditional Gasoline........... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Oxygenated Gasoline............ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Reformulated Gasoline.......... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| High-Oxygen Reformulated Gas... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Total.......................... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Distillate Prices | | | | | | | | | | | | | | | |
| Distillate <= 0.05% Sulfur..... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Distillate > 0.05% Sulfur...... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Average........................ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Distillate Quantities | | | | | | | | | | | | | | | |
| Distillate <= 0.05% Sulfur..... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Distillate > 0.05% Sulfur...... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Total.......................... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

aeo98b.d100197a - AEO98 Reference Case: nmbase.d011398a - Carbon Reference (1), fma101.d011398a (2), fma201.d011498a (3), fma301.d[illegible]

ENERGY INFORMATION ADMINISTRATION

# U. S. Department of Energy

# TELEFAX TRANSMISSION

FROM

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**MESSAGE:**

From The Desk Of

# ANDY S. KYDES

To: Ray Squitieri, Treasury Date: January 14, 1998

Re: Summary Tables of Carbon Permit Impacts

Attached please find a copy of NEMS summary tables in response to your request for information on the impact of alternative carbon fees on NOx and SOx emissions. A complete set of printouts are available as in the AEO98 reference case in the event you want them. In these tables, the results are derived as follows:

Column 1: AEO98 results

Column 2: New base: Advanced AEO98 demand technologies case with some further adjustments. The sensitivity cases that we ran with the various carbon fees make the following assumptions: (a) the fees are ramped up over three years reach and retain a plateau in 2010, (b) that a carbon fee greater than or equal to $100/ton will trigger the development and availability of an 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.

Column 3: New Base with a $100/ton carbon fee

Column 4: New Base with a $200/ton carbon fee

Column 5: New Base with a $300/ton carbon fee

Table 62 is the table with the national and regional level Sox, Nox, and Carbon emissions.

Please let me know if you need anything else or want any explanation or further analysis.

Andy

cc Mary J. Hutzler
Scott Sitzer
Art Andersen

NATIONAL ENERGY MODELING SYSTEM

Table 1. Total Energy Supply and Disposition Summary

(Quadrillion Btu per Year, Unless Otherwise Noted)

| Supply, Disposition, and Prices | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2000 (5) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2010 (5) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2015 (5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Production** | | | | | | | | | | | | | | | |
| Crude Oil & Lease Condensate | 13.06 | 13.06 | 13.04 | 13.06 | 13.06 | 11.79 | 11.62 | 11.56 | 11.51 | 11.50 | 11.09 | 10.85 | 10.44 | 10.31 | 10.29 |
| Natural Gas Plant Liquids | 2.39 | 2.36 | 2.35 | 2.37 | 2.36 | 2.95 | 2.78 | 3.22 | 3.34 | 3.39 | 3.12 | 2.98 | 3.48 | 3.24 | 3.22 |
| Dry Natural Gas | 20.64 | 20.66 | 20.58 | 20.69 | 20.64 | 25.39 | 24.03 | 27.63 | 28.55 | 28.97 | 26.85 | 25.75 | 28.14 | 27.67 | 27.58 |
| Coal | 24.34 | 24.20 | 24.06 | 23.98 | 24.02 | 26.62 | 25.35 | 13.32 | 11.10 | 9.70 | 27.73 | 25.50 | 9.50 | 8.97 | 7.40 |
| Nuclear Power | 7.36 | 7.36 | 7.36 | 7.36 | 7.36 | 6.36 | 6.36 | 6.36 | 6.36 | 6.36 | 5.12 | 5.12 | 5.12 | 5.12 | 5.13 |
| Renewable Energy | 6.82 | 6.88 | 6.92 | 6.96 | 7.02 | 7.41 | 7.31 | 10.15 | 10.74 | 11.27 | 7.59 | 7.61 | 13.35 | 14.17 | 14.57 |
| Other | .56 | .55 | .56 | .56 | .56 | .48 | .48 | .46 | .68 | .60 | .47 | .63 | 1.16 | 1.15 | 1.11 |
| Total | 75.37 | 74.99 | 74.89 | 74.97 | 75.01 | 81.80 | 77.92 | 72.69 | 72.70 | 71.08 | 81.97 | 78.45 | 71.24 | 70.13 | 69.30 |
| **Imports** | | | | | | | | | | | | | | | |
| Crude Oil | 19.18 | 19.10 | 19.08 | 19.07 | 19.07 | 23.17 | 23.37 | 22.12 | 21.20 | 20.57 | 24.36 | 24.49 | 22.99 | 22.59 | 21.90 |
| Petroleum Products | 4.25 | 4.39 | 4.27 | 4.25 | 4.27 | 7.61 | 6.89 | 5.02 | 4.89 | 5.07 | 9.01 | 7.53 | 5.07 | 5.03 | 5.12 |
| Natural Gas | 4.20 | 4.21 | 4.23 | 4.22 | 4.22 | 4.66 | 4.53 | 4.69 | 4.60 | 4.60 | 5.64 | 4.81 | 5.71 | 5.82 | 5.80 |
| Other Imports | .62 | .63 | .63 | .63 | .63 | .67 | .59 | 1.08 | 1.20 | 1.41 | .84 | .84 | 1.06 | 1.26 | 1.39 |
| Total | 28.26 | 28.33 | 28.21 | 28.17 | 28.19 | 36.02 | 35.38 | 32.91 | 32.05 | 31.74 | 38.96 | 37.41 | 34.82 | 34.70 | 34.37 |
| **Exports** | | | | | | | | | | | | | | | |
| Petroleum | 1.71 | 1.72 | 1.71 | 1.71 | 1.71 | 1.80 | 1.76 | 1.48 | 1.44 | 1.32 | 1.89 | 1.83 | 1.59 | 1.55 | 1.63 |
| Natural Gas | .28 | .28 | .28 | .28 | .28 | .29 | .29 | .29 | .29 | .29 | .30 | .30 | .30 | .31 | .30 |
| Coal | 2.41 | 2.41 | 2.41 | 2.41 | 2.41 | 2.84 | 2.84 | 2.84 | 2.84 | 2.84 | 3.03 | 3.03 | 3.03 | 3.05 | 3.03 |
| Total | 4.39 | 4.40 | 4.40 | 4.40 | 4.40 | 4.93 | 4.90 | 4.61 | 4.58 | 4.45 | 5.21 | 5.15 | 4.91 | 4.87 | 4.96 |
| **Discrepancy** | .58 | .48 | .62 | .60 | .63 | .08 | -.39 | .02 | -.59 | -.37 | .08 | -.24 | -.15 | -.21 | -.17 |
| **Consumption** | | | | | | | | | | | | | | | |
| Petroleum Products | 38.35 | 38.26 | 38.26 | 38.25 | 38.26 | 44.33 | 43.05 | 40.68 | 39.95 | 39.60 | 46.20 | 44.43 | 41.46 | 40.64 | 41.03 |
| Natural Gas | 24.74 | 24.57 | 24.51 | 24.61 | 24.55 | 29.63 | 28.13 | 31.78 | 32.69 | 33.23 | 31.44 | 30.12 | 33.35 | 32.99 | 32.89 |
| Coal | 22.14 | 21.99 | 21.87 | 21.76 | 21.82 | 24.03 | 22.75 | 11.15 | 8.94 | 7.01 | 24.95 | 22.74 | 6.82 | 5.71 | 4.70 |
| Nuclear Power | 7.36 | 7.36 | 7.36 | 7.36 | 7.36 | 6.36 | 6.36 | 6.36 | 6.36 | 6.36 | 5.12 | 5.12 | 5.12 | 5.12 | 5.15 |
| Renewable Energy | 6.82 | 6.81 | 6.92 | 6.94 | 7.02 | 7.42 | 7.33 | 10.17 | 10.75 | 11.28 | 7.62 | 7.64 | 15.37 | 14.19 | 14.59 |
| Other | .41 | .41 | .41 | .41 | .41 | .40 | .39 | .80 | 1.08 | 1.22 | .40 | .41 | .87 | 1.07 | 1.20 |
| Total | 99.8 | 99.4 | 99.3 | 99.3 | 99.4 | 112.2 | 108.0 | 101.8 | 99.8 | 98.71 | 115.7 | 110.5 | 101.0 | 99.7 | 98.54 |
| **Net Imports - Petroleum** | 21.72 | 21.78 | 21.64 | 21.62 | 21.63 | 28.99 | 28.60 | 25.66 | 24.64 | 24.32 | 31.40 | 30.19 | 26.47 | 26.08 | 25.46 |
| **Prices (1996 dollars per unit)** | | | | | | | | | | | | | | | |
| World Oil Price ($ per bbl) | 19.11 | 19.07 | 19.07 | 19.07 | 19.06 | 20.01 | 20.21 | 18.85 | 18.42 | 18.26 | 21.48 | 20.40 | 17.88 | 17.61 | 17.36 |
| Gas Wellhead Price($ / Mcf) | 2.11 | 2.12 | 2.11 | 2.13 | 2.11 | 2.31 | 1.92 | 2.64 | 2.59 | 2.61 | 2.38 | 1.92 | 2.94 | 2.89 | 2.91 |
| Coal Minemouth Price ($ / ton) | 17.45 | 17.30 | 17.37 | 17.35 | 17.35 | 15.05 | 14.99 | 17.93 | 18.24 | 18.95 | 13.99 | 14.03 | 17.95 | 18.48 | 18.74 |
| Aver. Electricity (cents / Kwh) | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 | 5.9 | 5.9 | 9.4 | 10.1 | 10.6 | 5.6 | 5.6 | 9.1 | 9.6 | 10.2 |

aeo98b.d110197a - AEO98 Reference Case, [illegible].d011398a - Carbon Reference (1), fem160.d011398a (2), fem[illegible].d011498a (3), fem300.d011598b (4)

ENERGY INFORMATION ADMINISTRATION

| | (1) | (2) | (3) | (4) | (5) | (1) | (2) | (3) | (4) | (5) | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | | | | | | | | |
| Petroleum | 25.8 | 25.7 | 25.7 | 25.7 | 25.7 | 24.8 | 24.3 | 21.8 | 21.2 | 20.6 | 24.5 | 23.9 | 21.5 | 20.9 | 20.4 |
| Natural Gas | 77.0 | 76.8 | 76.8 | 76.8 | 76.8 | 81.1 | 81.1 | 70.5 | 68.4 | 66.0 | 83.8 | 83.2 | 70.0 | 68.9 | 67.2 |
| Coal | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.4 | 1.3 | 1.3 | 1.2 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 |
| Electricity | 201.5 | 199.6 | 198.2 | 197.6 | 198.0 | 230.9 | 214.0 | 134.7 | 121.6 | 109.0 | 248.8 | 225.5 | 108.1 | 98.7 | 91.4 |
| Total | 305.6 | 303.5 | 302.1 | 301.5 | 301.9 | 338.1 | 320.8 | 228.2 | 212.6 | 198.8 | 358.5 | 334.0 | 201.6 | 189.7 | 180.2 |
| **Commercial** | | | | | | | | | | | | | | | |
| Petroleum | 12.8 | 12.8 | 12.8 | 12.8 | 12.8 | 12.8 | 12.7 | 12.3 | 12.1 | 12.0 | 12.7 | 12.6 | 12.2 | 12.0 | 11.9 |
| Natural Gas | 49.9 | 49.7 | 49.7 | 49.7 | 49.7 | 54.0 | 52.7 | 49.4 | 48.6 | 47.9 | 55.4 | 53.4 | 49.3 | 48.6 | 47.9 |
| Coal | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Electricity | 182.2 | 181.3 | 180.1 | 179.3 | 179.9 | 205.1 | 196.3 | 122.3 | 109.8 | 99.0 | 217.0 | 205.6 | 95.7 | 87.1 | 80.4 |
| Total | 247.1 | 246.0 | 244.8 | 244.2 | 244.6 | 274.4 | 264.2 | 186.4 | 173.0 | 161.4 | 288.4 | 278.1 | 159.7 | 150.2 | 142.8 |
| **Industrial** | | | | | | | | | | | | | | | |
| Petroleum | 103.3 | 102.7 | 102.6 | 102.6 | 102.7 | 115.6 | 112.4 | 104.5 | 98.4 | 98.1 | 119.3 | 114.5 | 107.5 | 103.2 | 103.3 |
| Natural Gas | 155.5 | 154.4 | 154.4 | 154.4 | 154.3 | 163.8 | 158.6 | 150.5 | 151.0 | 151.4 | 167.1 | 158.9 | 146.7 | 143.2 | 141.2 |
| Coal | 60.7 | 59.4 | 59.4 | 59.4 | 59.4 | 62.8 | 55.9 | 47.7 | 47.8 | 46.5 | 61.7 | 53.3 | 45.7 | 43.1 | 44.7 |
| Electricity | 187.3 | 185.9 | 184.4 | 183.9 | 184.3 | 219.1 | 205.3 | 141.3 | 126.2 | 115.6 | 230.6 | 218.4 | 112.0 | 102.3 | 94.4 |
| Total | 506.7 | 502.3 | 500.7 | 500.3 | 500.7 | 563.3 | 532.1 | 444.0 | 423.5 | 408.6 | 578.7 | 537.1 | 412.0 | 398.7 | 383.5 |
| **Transportation** | | | | | | | | | | | | | | | |
| Petroleum | 502.4 | 502.4 | 502.2 | 502.2 | 502.2 | 601.0 | 591.1 | 557.1 | 545.7 | 538.6 | 632.3 | 615.8 | 552.8 | 542.2 | 538.2 |
| Natural Gas | 12.2 | 12.1 | 12.0 | 12.1 | 12.0 | 17.2 | 16.4 | 17.4 | 17.9 | 17.9 | 18.6 | 17.9 | 18.4 | 18.1 | 18.1 |
| Other | .1 | .1 | .1 | .1 | .1 | 1.5 | 1.5 | 1.8 | 1.3 | 1.2 | 2.2 | 2.3 | 1.9 | 1.9 | 1.8 |
| Electricity | 3.2 | 3.3 | 3.2 | 3.2 | 3.2 | 7.3 | 6.7 | 5.5 | 5.0 | 4.5 | 9.5 | 10.6 | 5.1 | 4.7 | 4.3 |
| Total | 517.9 | 517.7 | 517.5 | 517.6 | 517.5 | 627.5 | 617.7 | 581.4 | 569.9 | 562.3 | 662.7 | 646.6 | 577.8 | 566.9 | 557.4 |
| **Total Carbon Emissions** | | | | | | | | | | | | | | | |
| Petroleum | 644.4 | 643.6 | 643.3 | 643.4 | 643.3 | 754.2 | 740.5 | 695.6 | 677.5 | 669.4 | 788.9 | 764.9 | 693.5 | 680.4 | 668.8 |
| Natural Gas | 294.6 | 292.9 | 292.8 | 293.0 | 292.8 | 318.1 | 308.8 | 287.8 | 286.7 | 282.9 | 324.9 | 313.4 | 285.3 | 278.9 | 274.3 |
| Coal | 64.3 | 63.0 | 63.0 | 63.0 | 63.1 | 66.6 | 59.7 | 51.4 | 51.7 | 50.2 | 65.6 | 57.1 | 49.5 | 48.8 | 48.4 |
| Other | .1 | .1 | .1 | .1 | .1 | 1.5 | 1.5 | 1.3 | 1.3 | 1.2 | 2.2 | 2.3 | 1.9 | 1.9 | 1.8 |
| Electricity | 574.0 | 570.1 | 565.9 | 564.2 | 565.4 | 662.9 | 624.4 | 403.5 | 362.6 | 327.0 | 706.8 | 650.1 | 320.9 | 292.6 | 270.5 |
| Total | 1577 | 1570 | 1565 | 1564 | 1565 | 1803 | 1735 | 1440 | 1379 | 1331 | 1888 | 1788 | 1351 | 1303 | 1264 |
| **Electric Generators** | | | | | | | | | | | | | | | |
| Petroleum | 11.4 | 10.6 | 10.8 | 10.5 | 10.7 | 7.4 | 7.2 | 4.6 | 5.3 | 6.0 | 6.8 | 6.2 | 6.3 | 4.5 | 4.6 |
| Natural Gas | 59.6 | 58.6 | 57.9 | 59.3 | 58.6 | 106.3 | 94.3 | 167.9 | 182.1 | 193.0 | 125.4 | 118.5 | 193.1 | 194.3 | 197.4 |
| Coal | 503.0 | 500.6 | 497.2 | 494.5 | 496.1 | 549.3 | 522.8 | 231.3 | 175.2 | 126.4 | 574.5 | 525.4 | 121.5 | 93.9 | 68.6 |
| Total | 574.0 | 570.1 | 565.9 | 564.2 | 565.4 | 662.9 | 624.4 | 403.8 | 362.6 | 327.0 | 706.8 | 650.1 | 320.9 | 292.6 | 270.5 |
| **Total Carbon Emissions** | | | | | | | | | | | | | | | |
| Petroleum | 655.8 | 654.2 | 654.0 | 653.8 | 654.1 | 761.5 | 747.7 | 700.2 | 682.8 | 676.3 | 795.7 | 771.1 | 699.7 | 684.9 | 673.4 |
| Natural Gas | 354.2 | 351.7 | 350.8 | 352.2 | 351.4 | 424.4 | 403.2 | 455.7 | 468.8 | 476.7 | 450.3 | 431.9 | 478.4 | 473.1 | 471.8 |
| Coal | 567.3 | 563.7 | 560.2 | 557.5 | 559.1 | 615.9 | 582.4 | 282.7 | 226.9 | 176.6 | 640.1 | 582.5 | 171.0 | 142.7 | 116.9 |
| Other | .1 | .1 | .1 | .1 | .1 | 1.5 | 1.5 | 1.5 | 1.3 | 1.2 | 2.2 | 2.3 | 1.9 | 1.9 | 1.8 |
| Total | 1577 | 1570 | 1565 | 1564 | 1565 | 1803 | 1735 | 1440 | 1379 | 1331 | 1888 | 1788 | 1351 | 1393 | 1264 |
| **Carbon Emissions** | | | | | | | | | | | | | | | |
| (tons per person) | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 6.0 | 5.8 | 4.8 | 4.6 | 4.5 | 6.1 | 5.7 | 4.3 | 4.2 | 4.1 |

aeo98b.d101197a - AEO98 Reference Case, nmbase.d011398a - Carbon Reference (1), fea100.d011398a (2), fea200.d011498a (3), fea300.d011398b (4)

[redacted]



Table 62. Emissions by NERC Region (million short tons)
except Carbon and Carbon Dioxide (million metric tons)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2000 (5) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2010 (5) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2015 (5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emissions | | | | | | | | | | | | | | | |
| United States | | | | | | | | | | | | | | | |
| Total Carbon | 574.0 | 570.1 | 565.9 | 564.2 | 565.4 | 662.9 | 624.4 | 403.8 | 362.6 | 327.0 | 786.8 | 650.1 | 320.9 | 292.6 | 278. |
| Carbon Dioxide | 2104 | 2090 | 2075 | 2069 | 2073 | 2431 | 2289 | 1481 | 1330 | 1199 | 2591 | 2384 | 1177 | 1073 | 991. |
| Sulfur Dioxide | 10.19 | 10.19 | 10.42 | 10.44 | 10.45 | 9.22 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.0 |
| Nitrogen Oxide | 6.14 | 6.11 | 6.06 | 6.03 | 6.03 | 6.51 | 6.19 | 3.52 | 2.97 | 2.45 | 6.75 | 6.29 | 2.23 | 1.84 | 1.5 |
| East Central Area Reliability | | | | | | | | | | | | | | | |
| Total Carbon | 128.8 | 128.1 | 125.8 | 125.7 | 126.0 | 144.3 | 136.0 | 100.8 | 90.46 | 80.31 | 148.5 | 137.6 | 76.02 | 69.74 | 64.1 |
| Carbon Dioxide | 472.4 | 469.6 | 461.3 | 461.0 | 462.0 | 529.1 | 498.6 | 354.7 | 331.7 | 294.5 | 544.5 | 514.4 | 283.7 | 255.7 | 235. |
| Sulfur Dioxide | 3.43 | 3.36 | 3.54 | 3.61 | 3.58 | 3.07 | 2.93 | 4.16 | 3.94 | 4.04 | 2.86 | 2.78 | 5.06 | 5.45 | 5.8 |
| Nitrogen Oxide | 1.50 | 1.49 | 1.47 | 1.46 | 1.47 | 1.62 | 1.53 | 1.01 | .80 | .65 | 1.64 | 1.51 | .69 | .63 | .5 |
| Electric Reliability Council Tx | | | | | | | | | | | | | | | |
| Total Carbon | 45.89 | 45.75 | 45.75 | 45.73 | 45.75 | 51.05 | 47.25 | 27.01 | 25.61 | 24.69 | 52.53 | 48.62 | 21.91 | 21.43 | 19.6 |
| Carbon Dioxide | 168.3 | 167.7 | 167.7 | 167.7 | 167.7 | 187.2 | 173.3 | 99.0 | 94.61 | 90.55 | 192.6 | 178.3 | 80.35 | 78.59 | 72.0 |
| Sulfur Dioxide | .35 | .35 | .36 | .35 | .35 | .34 | .32 | .06 | .07 | .09 | .33 | .30 | .12 | .14 | .1 |
| Nitrogen Oxide | .47 | .47 | .47 | .47 | .47 | .40 | .36 | .23 | .21 | .28 | .38 | .34 | .11 | .10 | .1 |
| Mid-Atlantic Area Council | | | | | | | | | | | | | | | |
| Total Carbon | 34.52 | 34.10 | 33.33 | 33.75 | 33.76 | 40.01 | 37.60 | 29.90 | 23.56 | 24.34 | 42.05 | 38.99 | 21.99 | 20.32 | 19.5 |
| Carbon Dioxide | 126.6 | 125.0 | 122.2 | 123.8 | 123.8 | 146.7 | 137.9 | 109.6 | 93.50 | 89.23 | 154.2 | 143.0 | 80.64 | 74.51 | 71.7 |
| Sulfur Dioxide | .54 | .54 | 1.09 | 1.09 | 1.10 | .53 | .48 | 1.04 | .98 | 1.10 | .51 | .44 | .62 | .48 | .4 |
| Nitrogen Oxide | .29 | .29 | .28 | .29 | .29 | .31 | .28 | .21 | .15 | .15 | .31 | .29 | .11 | .09 | .0 |
| Mid-America Interconnected Netw | | | | | | | | | | | | | | | |
| Total Carbon | 40.82 | 40.56 | 40.26 | 40.37 | 40.61 | 47.77 | 45.08 | 25.64 | 23.07 | 21.14 | 50.52 | 46.57 | 25.05 | 22.67 | 21.0 |
| Carbon Dioxide | 149.7 | 148.7 | 147.6 | 148.0 | 148.9 | 175.2 | 165.3 | 94.01 | 84.57 | 77.52 | 185.2 | 170.0 | 91.86 | 83.12 | 77.3 |
| Sulfur Dioxide | .95 | .87 | .96 | .99 | .99 | .65 | .63 | .40 | .39 | .33 | .61 | .58 | .46 | .33 | .3 |
| Nitrogen Oxide | .52 | .52 | .52 | .52 | .52 | .54 | .52 | .19 | .16 | .12 | .54 | .52 | .13 | .13 | .0 |
| Mid-Continent Area Power Pool | | | | | | | | | | | | | | | |
| Total Carbon | 32.64 | 32.45 | 31.89 | 31.71 | 31.92 | 38.87 | 36.67 | 20.54 | 17.37 | 13.92 | 41.28 | 38.41 | 10.43 | 8.90 | 8.63 |
| Carbon Dioxide | 119.7 | 119.0 | 116.6 | 116.3 | 117.0 | 142.5 | 134.5 | 75.31 | 63.70 | 51.03 | 151.3 | 140.8 | 38.23 | 32.62 | 31.63 |
| Sulfur Dioxide | .42 | .41 | .39 | .40 | .39 | .43 | .41 | .27 | .29 | .25 | .42 | .39 | .08 | .06 | .13 |
| Nitrogen Oxide | .39 | .39 | .38 | .38 | .38 | .45 | .43 | .20 | .16 | .13 | .46 | .43 | .15 | .05 | .05 |
| Northeast Power Council/New York | | | | | | | | | | | | | | | |
| Total Carbon | 13.50 | 13.53 | 13.39 | 13.32 | 13.32 | 14.13 | 13.01 | 10.31 | 9.96 | 9.97 | 15.31 | 14.22 | 10.13 | 9.93 | 8.89 |
| Carbon Dioxide | 49.50 | 49.60 | 49.13 | 48.83 | 48.83 | 51.82 | 47.71 | 37.81 | 36.51 | 36.57 | 56.15 | 52.12 | 36.78 | 36.41 | 32.58 |
| Sulfur Dioxide | .24 | .24 | .26 | .26 | .26 | .19 | .18 | .13 | .10 | .07 | .17 | .16 | .15 | .17 | .10 |
| Nitrogen Oxide | .11 | .11 | .11 | .11 | .11 | .09 | .08 | .05 | .04 | .04 | .09 | .09 | .04 | .04 | .03 |
| Northeast Power Council/New Engl | | | | | | | | | | | | | | | |
| Total Carbon | 11.59 | 11.45 | 11.59 | 11.57 | 11.62 | 14.09 | 14.47 | 8.92 | 8.74 | 7.98 | 14.32 | 13.98 | 8.01 | 7.97 | 7.65 |
| Carbon Dioxide | 42.48 | 41.97 | 42.51 | 42.43 | 42.60 | 51.67 | 53.04 | 32.72 | 32.05 | 28.95 | 52.49 | 51.27 | 29.36 | 29.22 | 28.05 |
| Sulfur Dioxide | .18 | .18 | .16 | .16 | .17 | .14 | .17 | .04 | .06 | .06 | .13 | .14 | .06 | .07 | .09 |

aeo98b.d100197a - AEO98 Reference Case, nodbase.d011398a - Carbon Reference (1), 1mo10[illegible].d011398a (2); 1mo21[illegible].d011398a (

NATIONAL ENERGY MODELING SYSTEM

Table 62. Emissions by NERC Region (million short tons) (Continued)
except Carbon and Carbon Dioxide (million metric tons)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2000 (5) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2010 (5) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2015 (5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Southeastern Electric/Florida | | | | | | | | | | | | | | | |
| Total Carbon | 26.44 | 26.28 | 25.62 | 25.82 | 25.74 | 32.84 | 30.37 | 20.30 | 19.43 | 18.36 | 38.16 | 33.04 | 19.23 | 18.69 | 17.44 |
| Carbon Dioxide | 96.93 | 96.01 | 94.66 | 94.65 | 94.37 | 120.4 | 111.4 | 74.45 | 71.26 | 67.33 | 139.9 | 121.1 | 70.50 | 68.81 | 64.02 |
| Sulfur Dioxide | .39 | .40 | .32 | .32 | .32 | .37 | .34 | .16 | .17 | .16 | .37 | .37 | .19 | .21 | .18 |
| Nitrogen Oxide | .29 | .29 | .28 | .28 | .28 | .33 | .30 | .16 | .18 | .13 | .30 | .32 | .12 | .12 | .10 |
| Southeastern Electric/Excl Fla | | | | | | | | | | | | | | | |
| Total Carbon | 104.2 | 103.1 | 104.1 | 101.9 | 102.5 | 122.0 | 113.8 | 80.91 | 74.03 | 65.59 | 131.5 | 121.1 | 63.22 | 57.66 | 51.04 |
| Carbon Dioxide | 382.1 | 378.1 | 381.8 | 373.7 | 375.6 | 447.3 | 417.2 | 296.4 | 271.3 | 240.5 | 482.0 | 444.1 | 231.8 | 211.4 | 187.1 |
| Sulfur Dioxide | 2.56 | 2.70 | 2.21 | 2.12 | 2.14 | 2.48 | 2.52 | 2.38 | 2.74 | 2.65 | 2.63 | 2.93 | 1.83 | 1.73 | 1.59 |
| Nitrogen Oxide | 1.06 | 1.03 | 1.06 | 1.03 | 1.04 | 1.16 | 1.12 | .77 | .78 | .57 | 1.23 | 1.13 | .44 | .37 | .28 |
| Southwest Power Pool | | | | | | | | | | | | | | | |
| Total Carbon | 59.86 | 59.67 | 59.02 | 59.33 | 59.26 | 68.26 | 65.90 | 35.12 | 32.20 | 29.35 | 70.37 | 66.71 | 26.57 | 24.39 | 23.59 |
| Carbon Dioxide | 219.5 | 218.8 | 216.4 | 217.6 | 217.3 | 250.3 | 241.6 | 128.8 | 118.1 | 107.6 | 258.0 | 244.6 | 97.41 | 89.41 | 86.50 |
| Sulfur Dioxide | .68 | .67 | .66 | .68 | .66 | .62 | .62 | .21 | .20 | .10 | .59 | .59 | .23 | .19 | .17 |
| Nitrogen Oxide | .69 | .68 | .67 | .68 | .68 | .71 | .70 | .33 | .32 | .26 | .69 | .67 | .16 | .14 | .12 |
| Western Systems Council/NWP | | | | | | | | | | | | | | | |
| Total Carbon | 24.83 | 24.76 | 24.70 | 24.72 | 24.66 | 29.61 | 28.71 | 15.01 | 10.85 | 10.23 | 30.44 | 29.53 | 12.09 | 10.39 | 9.14 |
| Carbon Dioxide | 91.05 | 90.78 | 90.56 | 90.64 | 90.41 | 108.6 | 105.3 | 55.03 | 39.78 | 37.50 | 111.6 | 108.3 | 44.32 | 37.80 | 33.50 |
| Sulfur Dioxide | .16 | .16 | .16 | .16 | .16 | .14 | .14 | .03 | .02 | .01 | .13 | .13 | .02 | .01 | .01 |
| Nitrogen Oxide | .24 | .24 | .23 | .24 | .23 | .25 | .25 | .09 | .05 | .04 | .25 | .23 | .05 | .04 | .03 |
| Western Systems Council/RA | | | | | | | | | | | | | | | |
| Total Carbon | 27.94 | 27.99 | 27.94 | 28.04 | 28.04 | 31.83 | 30.92 | 17.13 | 15.52 | 13.47 | 33.15 | 31.91 | 15.72 | 13.36 | 12.10 |
| Carbon Dioxide | 102.5 | 102.6 | 102.4 | 102.8 | 102.8 | 116.7 | 113.4 | 62.79 | 56.91 | 49.39 | 121.6 | 117.0 | 57.64 | 48.97 | 44.37 |
| Sulfur Dioxide | .21 | .21 | .21 | .21 | .21 | .18 | .18 | .15 | .12 | .12 | .16 | .16 | .16 | .13 | .17 |
| Nitrogen Oxide | .30 | .30 | .31 | .29 | .29 | .31 | .31 | .19 | .12 | .09 | .32 | .31 | .11 | .10 | .08 |
| Western Systems Council/CNV | | | | | | | | | | | | | | | |
| Total Carbon | 22.87 | 22.43 | 22.39 | 22.27 | 22.32 | 28.16 | 24.67 | 13.03 | 9.73 | 7.69 | 38.64 | 29.65 | 9.87 | 7.50 | 7.35 |
| Carbon Dioxide | 83.84 | 82.25 | 82.10 | 81.66 | 81.85 | 103.3 | 90.46 | 47.79 | 35.67 | 28.21 | 141.7 | 108.6 | 36.18 | 27.48 | 26.96 |
| Sulfur Dioxide | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .02 | .01 | .01 | .08 | .06 | .02 | .01 | .01 |
| Nitrogen Oxide | .18 | .19 | .19 | .19 | .19 | .22 | .21 | .10 | .06 | .05 | .33 | .26 | .06 | .05 | .03 |

aeo98b.d100197a - AEO98 Reference Case, combase.d111398a - Carbon Reference (1), fee101.d111598a (2), fee201.d111498a (3), fee300

ENERGY INFORMATION ADMINISTRATION

NATIONAL ENERGY MODELING SYSTEM

Table 117. National Impacts of the Clean Air Act Amendments of 1990 (CAAA90)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2000 (5) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2010 (5) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2015 (5) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scrubber Retrofits (gigawatts) | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Interregional SO2 Allowances Traded (thousand tons) | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| SO2 Allowance Price | 120.9 | 137.3 | 76.25 | 75.11 | 73.78 | 189.4 | 186.5 | .00 | .00 | .00 | 181.0 | 177.7 | .00 | .00 | .00 |
| SO2 Emissions (million tons) | 10.19 | 10.19 | 10.42 | 10.44 | 10.43 | 9.22 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| Coal Production by Sulfur Categ. (million tons) | | | | | | | | | | | | | | | |
| Low Sulfur (< .61 lbs S/mmBtu) | 466.1 | 473.8 | 453.9 | 460.9 | 461.3 | 594.1 | 549.1 | 167.7 | 137.9 | 97.83 | 616.9 | 593.6 | 101.8 | 66.70 | 69.53 |
| Med.Sulfur(.61-1.67 lbs.S/mmBtu) | 498.7 | 492.9 | 484.5 | 482.8 | 484.6 | 478.1 | 454.3 | 294.5 | 266.3 | 234.9 | 464.9 | 448.9 | 225.7 | 209.5 | 195.8 |
| High Sulfur (> 1.67 lbs.S/mmBtu) | 177.9 | 173.9 | 194.7 | 196.9 | 195.4 | 192.9 | 181.3 | 121.3 | 108.5 | 84.10 | 208.3 | 179.1 | 87.30 | 72.81 | 55.63 |
| Gasoline Prices | | | | | | | | | | | | | | | |
| Traditional Gasoline | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Oxygenated Gasoline | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Reformulated Gasoline | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| High-Oxygen Reformulated Gas | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Average | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Gasoline Quantities | | | | | | | | | | | | | | | |
| Traditional Gasoline | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Oxygenated Gasoline | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Reformulated Gasoline | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| High-Oxygen Reformulated Gas | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Total | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Distillate Prices | | | | | | | | | | | | | | | |
| Distillate <= 0.05% Sulfur | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Distillate > 0.05% Sulfur | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Average | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Distillate Quantities | | | | | | | | | | | | | | | |
| Distillate <= 0.05% Sulfur | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Distillate > 0.05% Sulfur | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Total | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

aeo98b.d101197a - AEO98 Reference Case, nexbase.d011598a - Carbon Reference (1), fao101.d011398a (2), fao202.d012498a (3), fao310.d01...

ENERGY INFORMATION ADMINISTRATION

Table 62. Nitrogen Oxide Emissions from Electricity Generators by Region (million tons)

| Electricity Supply and Demand | 2000 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| United States | 5.54 | 5.50 | 5.55 | 5.57 | 5.56 | 5.60 | 5.63 | 5.62 | 5.65 | 5.67 | 5.69 | 5.69 | 5.68 | 5.70 | 5.77 | 5.82 | 5.85 | 5.88 |
| East Central Area Reliability Coordination Agreement | 1.35 | 1.37 | 1.37 | 1.37 | 1.38 | 1.39 | 1.39 | 1.38 | 1.38 | 1.37 | 1.38 | 1.37 | 1.36 | 1.36 | 1.41 | 1.44 | 1.44 | 1.46 |
| Electric Reliability Council of Texas | .42 | .38 | .38 | .37 | .34 | .33 | .33 | .32 | .33 | .33 | .33 | .33 | .33 | .33 | .33 | .34 | .35 | .35 |
| Mid-Atlantic Area Council | .26 | .24 | .24 | .24 | .25 | .25 | .26 | .25 | .26 | .26 | .26 | .26 | .26 | .26 | .27 | .27 | .27 | .28 |
| Mid-America Interconnected Network | .47 | .45 | .45 | .46 | .46 | .47 | .47 | .47 | .47 | .48 | .48 | .48 | .48 | .48 | .48 | .49 | .49 | .50 |
| Mid-Continent Area Power Pool | .36 | .38 | .38 | .38 | .38 | .39 | .39 | .39 | .39 | .39 | .39 | .39 | .39 | .39 | .40 | .40 | .40 | .40 |
| Northeast Power Coordinating Council/New York | .10 | .07 | .07 | .07 | .07 | .07 | .07 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .09 |
| Northeast Power Coordinating Council/New England | .09 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .08 | .09 | .09 |
| Southeastern Electric Reliability Council/Florida | .26 | .27 | .28 | .28 | .27 | .27 | .27 | .28 | .28 | .28 | .28 | .29 | .29 | .30 | .31 | .31 | .31 | .31 |
| Southeastern Electric Reliability Council/Excl. Florida | .95 | .97 | .98 | .99 | .99 | 1.00 | 1.01 | 1.02 | 1.02 | 1.03 | 1.04 | 1.05 | 1.05 | 1.05 | 1.01 | 1.02 | 1.02 | 1.02 |
| Southwest Power Pool | .62 | .63 | .63 | .63 | .63 | .63 | .63 | .64 | .63 | .63 | .62 | .62 | .61 | .61 | .61 | .61 | .61 | .61 |
| Western Systems Coordinating Council/NWP | .21 | .22 | .22 | .22 | .22 | .23 | .22 | .23 | .23 | .23 | .23 | .23 | .23 | .23 | .23 | .23 | .23 | .23 |
| Western Systems Coordinating Council/RA | .27 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .29 | .29 | .29 |
| Western Systems Coordinating Council/CNV | .17 | .15 | .16 | .17 | .17 | .18 | .18 | .19 | .19 | .20 | .20 | .24 | .24 | .24 | .25 | .25 | .26 | .26 |

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Table 62. Nitrogen Oxide Emissions from Electricity Generators by Region (million tons)

| Electricity Supply and Demand | 2000 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| United States | 5.53 | 5.37 | 5.44 | 5.46 | 5.46 | 5.48 | 5.46 | 4.53 | 4.51 | 4.41 | 4.26 | 4.29 | 4.35 | 4.29 | 4.33 | 4.38 | 4.45 | 4.44 |
| East Central Area Reliability Coordination Agreement | 1.34 | 1.33 | 1.34 | 1.34 | 1.36 | 1.37 | 1.37 | 1.13 | 1.14 | 1.06 | .97 | .91 | .89 | .84 | .87 | .90 | .91 | .92 |
| Electric Reliability Council of Texas | .42 | .38 | .38 | .37 | .35 | .32 | .32 | .26 | .23 | .21 | .18 | .19 | .20 | .20 | .21 | .22 | .22 | .23 |
| Mid-Atlantic Area Council | .26 | .24 | .25 | .25 | .25 | .26 | .26 | .22 | .23 | .23 | .23 | .23 | .23 | .22 | .23 | .23 | .24 | .24 |
| Mid-America Interconnected Network | .47 | .41 | .42 | .42 | .42 | .43 | .43 | .31 | .32 | .33 | .34 | .33 | .34 | .34 | .34 | .34 | .34 | .34 |
| Mid-Continent Area Power Pool | .36 | .36 | .37 | .38 | .38 | .39 | .39 | .30 | .31 | .31 | .29 | .30 | .33 | .32 | .32 | .32 | .32 | .32 |
| Northeast Power Coordinating Council/New York | .10 | .07 | .07 | .07 | .07 | .08 | .08 | .06 | .06 | .06 | .06 | .06 | .06 | .06 | .06 | .06 | .06 | .06 |
| Northeast Power Coordinating Council/New England | .09 | .10 | .10 | .10 | .10 | .10 | .09 | .07 | .07 | .07 | .07 | .06 | .06 | .07 | .07 | .07 | .07 | .07 |
| Southeastern Electric Reliability Council/Florida | .26 | .26 | .26 | .26 | .25 | .25 | .26 | .21 | .21 | .20 | .20 | .21 | .22 | .23 | .24 | .24 | .24 | .24 |
| Southeastern Electric Reliability Council/Excl. Florida | .97 | .99 | 1.01 | 1.02 | 1.02 | 1.03 | 1.04 | .92 | .92 | .89 | .89 | .91 | .94 | .94 | .94 | .94 | .95 | .95 |
| Southwest Power Pool | .62 | .60 | .60 | .59 | .59 | .59 | .58 | .44 | .44 | .45 | .45 | .46 | .46 | .47 | .46 | .46 | .48 | .47 |
| Western Systems Coordinating Council/NWP | .21 | .22 | .22 | .22 | .22 | .22 | .22 | .19 | .19 | .19 | .19 | .19 | .19 | .19 | .19 | .19 | .20 | .19 |
| Western Systems Coordinating Council/RA | .27 | .27 | .27 | .27 | .27 | .27 | .27 | .22 | .22 | .22 | .22 | .23 | .23 | .22 | .22 | .21 | .21 | .21 |
| Western Systems Coordinating Council/CNV | .17 | .15 | .15 | .16 | .17 | .17 | .17 | .17 | .17 | .17 | .17 | .19 | .19 | .19 | .19 | .20 | .20 | .20 |

fee100.d010698a run in /store2 on Tue Jan 6 16:11:25 EST 1998

Ray: This is preliminary 1/7/97 1pm; It will probably change a little.

- No ramp on carbon fee. $100/ton carbon beginning in 2010
- 1st begins in 2010 and remains flat
- advanced demand technologies; ref. supply technologies

Will rerun w/ 3 year ramp beginning in 2008

Andy

01/23/98 17:32 DOE/EIA/OIAF → 202 395 6870 NO.825 001

# U. S. Department of Energy

# TELEFAX TRANSMISSION

FROM

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Office of Integrated Analysis and Forecasting (EI-80)
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Carbon fee tables requested from Andy Kydes

640 of 710.

NATIONAL ENERGY MODELING SYSTEM

Table 1. Total Energy Supply and Disposition Summary
(Quadrillion Btu per Year, Unless Otherwise Noted)

| Disposition, and Prices | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2005 (1) | 2005 (2) | 2005 (3) | 2005 (4) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2020 (1) | 2020 (2) | 2020 (3) | 2020 (4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| n | | | | | | | | | | | | | | | | | | | | |
| Oil & Lease Condensate. | 13.06 | 13.06 | 13.07 | 13.07 | 12.33 | 12.33 | 12.33 | 12.26 | 11.60 | 11.80 | 11.77 | 11.56 | 11.07 | 11.05 | 10.97 | 10.61 | 10.33 | 10.31 | 10.15 | 9.76 |
| l Gas Plant Liquids.... | 2.39 | 2.36 | 2.37 | 2.36 | 2.63 | 2.64 | 2.66 | 2.56 | 2.93 | 2.94 | 3.02 | 3.04 | 3.28 | 3.13 | 3.24 | 3.17 | 3.30 | 3.29 | 3.40 | 3.25 |
| tural Gas............. | 20.85 | 20.76 | 20.75 | 20.60 | 22.83 | 22.90 | 23.10 | 22.25 | 25.30 | 25.35 | 26.09 | 26.19 | 26.72 | 26.88 | 27.86 | 27.16 | 28.12 | 28.05 | 28.92 | 27.72 |
| ...................... | 24.33 | 24.42 | 24.42 | 24.21 | 25.52 | 25.52 | 24.99 | 24.22 | 26.50 | 26.33 | 23.52 | 19.25 | 27.64 | 27.18 | 23.54 | 18.96 | 28.37 | 28.06 | 24.25 | 19.42 |
| r Power............... | 7.36 | 7.36 | 7.36 | 7.36 | 6.87 | 6.87 | 6.87 | 6.87 | 6.36 | 6.36 | 6.36 | 6.36 | 5.12 | 5.12 | 5.12 | 5.12 | 4.09 | 4.09 | 4.09 | 4.09 |
| ble Energy ........... | 6.82 | 6.82 | 6.84 | 6.83 | 7.11 | 7.11 | 7.17 | 7.34 | 7.41 | 7.42 | 7.97 | 8.05 | 7.86 | 8.00 | 8.89 | 9.06 | 8.19 | 8.48 | 9.32 | 9.83 |
| ...................... | .56 | .56 | .56 | .56 | .55 | .54 | .54 | .54 | .48 | .48 | .55 | .60 | .64 | .83 | 1.01 | .92 | .89 | .98 | 1.25 | 1.37 |
| tal................... | 75.36 | 75.35 | 75.37 | 74.95 | 77.84 | 77.90 | 77.65 | 76.04 | 80.79 | 80.67 | 79.28 | 75.04 | 82.32 | 82.19 | 80.63 | 74.98 | 83.29 | 83.25 | 81.37 | 75.44 |
| | | | | | | | | | | | | | | | | | | | | |
| Oil .................. | 19.18 | 19.19 | 19.15 | 19.11 | 21.98 | 22.09 | 22.10 | 21.91 | 23.18 | 23.31 | 23.16 | 22.96 | 24.35 | 24.65 | 24.34 | 24.09 | 25.40 | 25.71 | 25.34 | 24.97 |
| eum Products ......... | 4.39 | 4.26 | 4.27 | 4.40 | 5.55 | 5.51 | 5.52 | 5.19 | 7.56 | 7.30 | 7.10 | 5.62 | 8.81 | 8.21 | 7.60 | 5.89 | 9.50 | 9.02 | 8.24 | 6.19 |
| l Gas ................ | 4.21 | 4.23 | 4.22 | 4.21 | 4.44 | 4.43 | 4.52 | 4.42 | 4.70 | 4.72 | 4.87 | 4.85 | 5.06 | 5.10 | 5.38 | 5.28 | 5.36 | 5.35 | 5.74 | 5.53 |
| Imports .............. | .62 | .62 | .62 | .63 | .58 | .58 | .58 | .60 | .57 | .57 | .59 | .66 | .54 | .54 | .57 | .64 | .56 | .56 | .58 | .66 |
| tal................... | 28.40 | 28.31 | 28.27 | 28.35 | 32.55 | 32.61 | 32.73 | 32.12 | 36.01 | 35.90 | 35.72 | 34.08 | 38.77 | 38.51 | 37.89 | 35.91 | 40.82 | 40.67 | 39.90 | 37.35 |
| | | | | | | | | | | | | | | | | | | | | |
| leum ................. | 1.73 | 1.73 | 1.74 | 1.73 | 1.73 | 1.73 | 1.73 | 1.72 | 1.78 | 1.70 | 1.70 | 1.70 | 1.86 | 1.82 | 1.82 | 1.80 | 1.64 | 1.53 | 1.59 | 1.66 |
| l Gas................. | .26 | .28 | .28 | .28 | .28 | .28 | .26 | .28 | .29 | .29 | .29 | .29 | .30 | .30 | .30 | .30 | .32 | .32 | .32 | .32 |
| ...................... | 2.41 | 2.41 | 2.41 | 2.41 | 2.64 | 2.64 | 2.64 | 2.64 | 2.84 | 2.84 | 2.84 | 2.84 | 3.03 | 3.03 | 3.03 | 3.03 | 3.23 | 3.23 | 3.23 | 3.23 |
| tal................... | 4.41 | 4.41 | 4.42 | 4.41 | 4.65 | 4.65 | 4.66 | 4.65 | 4.91 | 4.84 | 4.83 | 4.83 | 5.19 | 5.14 | 5.15 | 5.13 | 5.20 | 5.05 | 5.15 | 5.21 |
| | | | | | | | | | | | | | | | | | | | | |
| ncy .................. | .49 | .63 | .63 | .46 | .05 | .01 | .03 | -.07 | .14 | .19 | -.27 | -.31 | -.09 | .13 | .05 | .00 | -.07 | -.08 | .00 | -.05 |
| | | | | | | | | | | | | | | | | | | | | |
| ion | | | | | | | | | | | | | | | | | | | | |
| leum Products ........ | 38.37 | 38.38 | 38.35 | 38.26 | 41.38 | 41.41 | 41.43 | 40.69 | 44.37 | 44.37 | 43.72 | 41.82 | 46.21 | 46.20 | 45.42 | 42.87 | 47.65 | 47.70 | 46.82 | 43.85 |
| al Gas................ | 24.76 | 24.69 | 24.68 | 24.51 | 26.93 | 27.00 | 27.28 | 26.34 | 29.57 | 29.63 | 30.51 | 30.56 | 31.32 | 31.53 | 32.76 | 31.97 | 33.00 | 32.99 | 34.16 | 32.75 |
| ...................... | 22.13 | 22.22 | 22.21 | 22.01 | 23.11 | 23.10 | 22.63 | 21.83 | 23.91 | 23.73 | 20.91 | 16.71 | 24.87 | 24.41 | 20.78 | 16.28 | 25.40 | 25.09 | 21.26 | 16.49 |
| ar Power.............. | 7.36 | 7.36 | 7.36 | 7.36 | 6.87 | 6.87 | 6.87 | 6.67 | 6.36 | 6.36 | 6.36 | 6.36 | 5.12 | 5.12 | 5.42 | 5.12 | 4.09 | 4.09 | 4.09 | 4.09 |
| able Energy .......... | 6.82 | 6.82 | 6.84 | 6.84 | 7.12 | 7.12 | 7.17 | 7.35 | 7.43 | 7.43 | 7.99 | 8.07 | 7.88 | 8.02 | 8.92 | 9.06 | 8.22 | 8.51 | 9.35 | 9.86 |
| ...................... | .41 | .41 | .41 | .41 | .37 | .37 | .37 | .37 | .40 | .39 | .42 | .46 | .41 | .41 | .43 | .46 | .43 | .43 | .45 | .49 |
| al.................... | 99.8 | 99.9 | 99.9 | 99.4 | 105.8 | 105.9 | 105.8 | 103.4 | 112.0 | 111.9 | 109.9 | 104.0 | 115.8 | 115.7 | 113.4 | 105.8 | 118.8 | 118.8 | 116.1 | 107.5 |
| | | | | | | | | | | | | | | | | | | | | |
| ts - Petroleum........ | 21.84 | 21.73 | 21.69 | 21.79 | 25.80 | 25.87 | 25.89 | 25.37 | 28.97 | 28.91 | 28.56 | 26.88 | 31.30 | 31.04 | 30.12 | 28.18 | 33.26 | 33.20 | 31.99 | 29.50 |
| | | | | | | | | | | | | | | | | | | | | |
| 1996 dollars per unit) | | | | | | | | | | | | | | | | | | | | |
| il Price ($ per bbl) ... | 19.12 | 19.11 | 19.11 | 19.06 | 20.25 | 20.27 | 20.25 | 19.76 | 20.60 | 20.77 | 20.36 | 19.17 | 21.17 | 21.08 | 20.35 | 19.12 | 21.82 | 21.81 | 21.06 | 19.95 |
| lhead Price($ / Mcf)... | 2.13 | 2.12 | 2.13 | 2.13 | 2.15 | 2.15 | 2.19 | 2.08 | 2.26 | 2.29 | 2.49 | 2.36 | 2.32 | 2.37 | 2.67 | 2.58 | 2.49 | 2.56 | 2.85 | 2.64 |
| nemouth Price ($ / ton). | 17.36 | 17.44 | 17.46 | 17.40 | 16.00 | 16.26 | 16.26 | 16.17 | 14.87 | 15.15 | 15.50 | 15.82 | 13.88 | 14.24 | 14.61 | 14.58 | 13.26 | 13.50 | 13.74 | 14.26 |
| lectricity (cents / Kwh) | 6.5 | 6.5 | 6.5 | 6.5 | 6.2 | 6.2 | 6.3 | 6.2 | 6.0 | 6.2 | 7.1 | 7.9 | 5.6 | 5.8 | 6.8 | 7.6 | 5.5 | 5.6 | 5.7 | 7.6 |

e.d012198a - 0 Tax, Reference Demand Technology (1), fee005.d012298a (2), fee050.d012298a (3), fee100.d012298a (4)

ENERGY INFORMATION ADMINISTRATION

NATIONAL ENERGY MODELING SYSTEM

Table 17. Carbon Emissions by Sector and Source

(Million Metric Tons per Year, Unless Otherwise Noted)

| d Source | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2005 (1) | 2005 (2) | 2005 (3) | 2005 (4) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2020 (1) | 2020 (2) | 2020 (3) | 2020 (4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| al | | | | | | | | | | | | | | | | | | | | |
| um | 25.8 | 25.8 | 25.8 | 25.7 | 25.0 | 25.0 | 25.0 | 24.8 | 24.8 | 24.7 | 24.1 | 23.1 | 24.6 | 24.5 | 24.0 | 22.7 | 24.3 | 24.2 | 23.8 | 22.2 |
| Gas | 77.0 | 76.9 | 76.9 | 76.8 | 78.7 | 78.7 | 78.5 | 78.2 | 81.3 | 80.8 | 77.8 | 74.7 | 84.0 | 83.3 | 79.8 | 75.7 | 86.1 | 85.4 | 82.1 | 77.4 |
| | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| city | 201.3 | 201.8 | 201.6 | 199.4 | 215.6 | 215.6 | 212.7 | 202.4 | 229.8 | 228.5 | 209.1 | 174.0 | 247.9 | 244.5 | 219.4 | 179.9 | 265.8 | 262.9 | 235.5 | 190.4 |
| | 305.5 | 306.0 | 305.8 | 303.3 | 320.7 | 320.7 | 317.6 | 306.8 | 337.3 | 335.4 | 312.3 | 273.1 | 357.9 | 353.6 | 324.5 | 279.6 | 377.5 | 373.8 | 342.6 | 291.3 |
| l | | | | | | | | | | | | | | | | | | | | |
| um | 12.9 | 12.9 | 12.9 | 12.8 | 12.9 | 12.9 | 12.9 | 12.6 | 12.8 | 12.8 | 12.7 | 12.5 | 12.7 | 12.7 | 12.6 | 12.4 | 12.5 | 12.4 | 12.3 | 12.1 |
| Gas | 49.9 | 49.9 | 49.9 | 49.7 | 52.1 | 52.0 | 52.0 | 51.2 | 54.1 | 53.9 | 53.0 | 50.8 | 55.5 | 55.3 | 54.2 | 51.1 | 55.6 | 55.3 | 54.3 | 50.7 |
| | 2.2 | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| city | 182.1 | 182.6 | 182.4 | 181.1 | 192.8 | 192.8 | 190.3 | 184.9 | 204.1 | 202.9 | 185.1 | 158.6 | 216.9 | 213.8 | 190.7 | 160.5 | 223.9 | 221.3 | 196.5 | 162.9 |
| | 247.1 | 247.5 | 247.4 | 245.8 | 260.1 | 260.1 | 257.5 | 251.3 | 273.5 | 272.1 | 253.2 | 224.3 | 287.7 | 284.3 | 260.0 | 226.5 | 294.4 | 291.6 | 265.7 | 228.3 |
| l .. | | | | | | | | | | | | | | | | | | | | |
| um | 103.3 | 103.2 | 103.1 | 102.6 | 109.6 | 109.9 | 109.9 | 107.9 | 115.4 | 116.0 | 113.4 | 109.7 | 118.6 | 119.5 | 117.1 | 110.4 | 119.3 | 120.0 | 117.4 | 110.6 |
| Gas | 155.5 | 155.5 | 155.5 | 154.4 | 158.6 | 158.6 | 158.7 | 153.4 | 166.0 | 165.3 | 163.1 | 153.9 | 167.2 | 166.6 | 164.4 | 152.3 | 167.9 | 166.8 | 164.4 | 151.4 |
| | 60.6 | 60.6 | 60.6 | 59.4 | 62.3 | 62.3 | 62.4 | 57.9 | 62.7 | 62.2 | 57.3 | 49.3 | 61.6 | 61.1 | 56.5 | 47.0 | 60.6 | 60.1 | 55.3 | 44.6 |
| city | 187.5 | 188.0 | 187.6 | 185.6 | 203.0 | 203.5 | 201.3 | 193.2 | 217.0 | 217.5 | 207.2 | 182.5 | 228.5 | 227.8 | 213.8 | 184.7 | 237.4 | 237.3 | 221.4 | 187.8 |
| | 506.8 | 507.2 | 506.8 | 502.0 | 533.5 | 534.3 | 532.2 | 512.5 | 561.2 | 561.0 | 541.2 | 495.4 | 575.9 | 575.0 | 551.7 | 494.5 | 585.3 | 584.3 | 558.5 | 494.4 |
| ation | | | | | | | | | | | | | | | | | | | | |
| um | 502.7 | 502.8 | 502.8 | 502.3 | 552.7 | 553.1 | 553.2 | 549.6 | 600.6 | 599.8 | 589.3 | 569.5 | 628.1 | 622.6 | 607.4 | 580.8 | 649.0 | 646.1 | 627.0 | 591.3 |
| l Gas | 12.1 | 12.1 | 12.1 | 12.0 | 14.5 | 14.4 | 14.6 | 14.3 | 17.2 | 17.2 | 17.1 | 17.0 | 18.3 | 18.3 | 18.6 | 18.3 | 19.7 | 19.7 | 19.9 | 19.1 |
| | .1 | .1 | .1 | .1 | .5 | .5 | .5 | .5 | 1.4 | 1.4 | 1.4 | 1.4 | 2.2 | 2.2 | 2.2 | 2.1 | 2.7 | 2.7 | 2.6 | 2.5 |
| icity | 3.3 | 3.3 | 3.3 | 3.3 | 5.9 | 5.9 | 5.8 | 5.8 | 8.7 | 8.7 | 8.0 | 7.2 | 10.7 | 10.6 | 9.5 | 8.5 | 12.2 | 12.1 | 10.9 | 9.7 |
| l | 518.2 | 518.2 | 518.2 | 517.7 | 573.6 | 574.0 | 574.1 | 570.2 | 627.9 | 627.1 | 615.8 | 595.0 | 659.4 | 653.7 | 637.7 | 609.7 | 683.6 | 680.6 | 660.3 | 622.6 |
| bon Emissions .. | | | | | | | | | | | | | | | | | | | | |
| eum | 644.7 | 644.6 | 644.6 | 643.4 | 700.1 | 700.9 | 701.0 | 695.1 | 753.6 | 753.4 | 739.6 | 714.8 | 784.0 | 779.3 | 761.1 | 726.3 | 805.1 | 802.9 | 780.5 | 736.2 |
| l Gas | 294.5 | 294.3 | 294.5 | 292.8 | 303.9 | 303.7 | 303.7 | 297.1 | 318.6 | 317.2 | 311.0 | 296.4 | 325.0 | 323.5 | 316.9 | 297.4 | 329.3 | 327.2 | 320.6 | 298.6 |
| | 64.2 | 64.2 | 64.2 | 63.0 | 66.0 | 66.1 | 66.2 | 61.6 | 66.5 | 65.9 | 61.1 | 53.0 | 65.5 | 65.0 | 60.3 | 50.8 | 64.5 | 63.9 | 59.1 | 48.4 |
| | .1 | .1 | .1 | .1 | .5 | .5 | .5 | .5 | 1.4 | 1.4 | 1.4 | 1.4 | 2.2 | 2.2 | 2.2 | 2.1 | 2.7 | 2.7 | 2.6 | 2.5 |
| icity | 574.1 | 575.7 | 574.9 | 569.4 | 617.3 | 617.9 | 610.1 | 586.4 | 659.7 | 657.7 | 609.4 | 522.3 | 704.0 | 696.7 | 633.4 | 533.6 | 739.2 | 733.5 | 664.3 | 550.8 |
| l | 1578 | 1579 | 1578 | 1569 | 1688 | 1689 | 1681 | 1641 | 1800 | 1796 | 1722 | 1588 | 1881 | 1867 | 1774 | 1610 | 1961 | 1930 | 1827 | 1637 |
| Generators .. | | | | | | | | | | | | | | | | | | | | |
| eum | 11.2 | 11.6 | 11.1 | 10.6 | 9.2 | 9.3 | 9.5 | 9.1 | 8.2 | 8.2 | 9.1 | 6.5 | 7.6 | 7.7 | 9.1 | 7.8 | 7.8 | 8.3 | 9.3 | 7.3 |
| l Gas | 60.0 | 59.1 | 58.7 | 57.9 | 81.8 | 82.9 | 87.1 | 80.4 | 104.9 | 107.3 | 126.1 | 141.9 | 123.7 | 128.2 | 152.5 | 161.1 | 143.6 | 145.4 | 168.7 | 171.1 |
| | 502.9 | 505.1 | 505.0 | 500.8 | 526.3 | 525.7 | 513.5 | 497.0 | 546.7 | 542.2 | 474.3 | 373.4 | 572.7 | 560.8 | 471.8 | 364.7 | 587.9 | 579.8 | 486.4 | 372.4 |
| l | 574.1 | 575.7 | 574.9 | 569.4 | 617.3 | 617.9 | 610.1 | 586.4 | 659.7 | 657.7 | 609.4 | 522.3 | 704.0 | 696.7 | 633.4 | 533.6 | 739.2 | 733.5 | 664.3 | 550.8 |
| rbon Emissions .. | | | | | | | | | | | | | | | | | | | | |
| eum | 655.9 | 656.2 | 655.7 | 654.1 | 709.3 | 710.2 | 710.5 | 704.2 | 761.8 | 761.6 | 748.6 | 721.7 | 791.7 | 787.0 | 770.2 | 734.2 | 812.9 | 811.2 | 789.7 | 743.5 |
| l Gas | 354.5 | 353.4 | 353.2 | 350.8 | 385.7 | 396.6 | 390.8 | 377.5 | 423.5 | 424.4 | 437.1 | 438.3 | 448.7 | 451.7 | 469.4 | 458.5 | 472.8 | 472.6 | 489.3 | 469.7 |
| | 567.1 | 569.3 | 569.2 | 563.9 | 592.3 | 591.8 | 579.7 | 558.6 | 613.2 | 608.1 | 535.4 | 426.4 | 638.2 | 625.7 | 532.1 | 415.5 | 652.4 | 643.8 | 545.5 | 420.9 |
| | .1 | .1 | .1 | .1 | .5 | .5 | .5 | .5 | 1.4 | 1.4 | 1.4 | 1.4 | 2.2 | 2.2 | 2.2 | 2.1 | 2.7 | 2.7 | 2.6 | 2.5 |
| al | 1578 | 1579 | 1578 | 1569 | 1688 | 1689 | 1681 | 1641 | 1800 | 1796 | 1722 | 1580 | 1881 | 1867 | 1774 | 1610 | 1941 | 1930 | 1827 | 1637 |
| Emissions (per person) | 5.7 | 5.7 | 5.7 | 5.7 | 5.9 | 5.9 | 5.9 | 5.7 | 6.0 | 6.0 | 5.8 | 5.3 | 6.0 | 6.0 | 5.7 | 5.2 | 6.0 | 6.0 | 5.6 | 5.1 |

s.d012198a - 0 Tax, Reference Demand Technology (1), fee005.d012298a (2), fee050.d012298a (3), fee100.d012298a (4)

NATIONAL ENERGY MODELING SYSTEM

Table 62. Emissions by NERC Region (million short tons) except Carbon and Carbon Dioxide (million metric tons)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2005 (1) | 2005 (2) | 2005 (3) | 2005 (4) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2020 (1) | 2020 (2) | 2020 (3) | 2020 (4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| s...... | | | | | | | | | | | | | | | | | | | | |
| tates | | | | | | | | | | | | | | | | | | | | |
| Carbon | 574.1 | 575.7 | 574.9 | 569.4 | 617.3 | 617.9 | 610.1 | 586.4 | 659.7 | 657.7 | 609.4 | 522.3 | 704.0 | 696.7 | 633.4 | 533.6 | 739.2 | 733.5 | 664.3 | 550.8 |
| Dioxide | 2105 | 2111 | 2108 | 2088 | 2263 | 2265 | 2237 | 2150 | 2419 | 2411 | 2234 | 1915 | 2581 | 2555 | 2322 | 1957 | 2711 | 2690 | 2436 | 2020 |
| Dioxide | 10.19 | 10.19 | 10.19 | 10.19 | 9.69 | 9.63 | 9.69 | 9.69 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| en Oxide | 6.15 | 6.17 | 6.16 | 6.10 | 6.29 | 6.28 | 6.18 | 5.96 | 6.48 | 6.44 | 5.81 | 4.86 | 6.75 | 6.64 | 5.81 | 4.74 | 6.94 | 6.86 | 5.99 | 4.83 |
| tral Area Reliability | | | | | | | | | | | | | | | | | | | | |
| Carbon | 129.0 | 129.1 | 129.1 | 127.0 | 135.7 | 136.8 | 134.4 | 129.4 | 143.8 | 143.7 | 130.1 | 106.5 | 149.2 | 148.6 | 134.4 | 99.0 | 155.3 | 155.5 | 139.6 | 105.9 |
| Dioxide | 472.9 | 473.5 | 473.4 | 465.7 | 497.6 | 501.6 | 492.9 | 474.5 | 527.3 | 527.0 | 476.9 | 390.6 | 547.0 | 544.9 | 492.8 | 363.1 | 569.6 | 570.0 | 511.9 | 388.3 |
| Dioxide | 3.39 | 3.61 | 3.61 | 3.60 | 3.33 | 3.53 | 3.48 | 3.41 | 2.98 | 3.10 | 3.11 | 3.28 | 2.94 | 3.10 | 3.22 | 3.01 | 2.80 | 3.10 | 3.02 | 3.11 |
| en Oxide | 1.50 | 1.50 | 1.50 | 1.48 | 1.55 | 1.57 | 1.52 | 1.47 | 1.61 | 1.61 | 1.41 | 1.04 | 1.64 | 1.63 | 1.42 | .88 | 1.68 | 1.68 | 1.45 | .95 |
| Reliability Council Tx | | | | | | | | | | | | | | | | | | | | |
| Carbon | 45.92 | 45.91 | 45.89 | 45.74 | 47.40 | 47.40 | 47.28 | 46.27 | 50.00 | 49.80 | 45.62 | 33.86 | 52.61 | 51.91 | 47.59 | 36.42 | 54.64 | 54.40 | 50.01 | 38.41 |
| Dioxide | 168.4 | 168.3 | 168.3 | 167.7 | 173.8 | 173.8 | 173.4 | 169.7 | 183.3 | 182.6 | 167.3 | 124.2 | 192.9 | 190.3 | 174.5 | 133.5 | 200.3 | 199.5 | 183.3 | 140.8 |
| Dioxide | .35 | .35 | .35 | .35 | .34 | .34 | .35 | .35 | .36 | .34 | .31 | .15 | .33 | .33 | .30 | .19 | .32 | .32 | .29 | .22 |
| en Oxide | .47 | .47 | .47 | .47 | .43 | .43 | .43 | .42 | .38 | .37 | .33 | .25 | .38 | .38 | .33 | .26 | .39 | .39 | .35 | .27 |
| antic Area Council | | | | | | | | | | | | | | | | | | | | |
| Carbon | 34.48 | 34.36 | 34.37 | 34.04 | 35.70 | 35.62 | 35.24 | 34.30 | 39.69 | 39.72 | 38.37 | 35.19 | 41.62 | 41.76 | 39.66 | 35.46 | 45.23 | 44.36 | 42.49 | 37.84 |
| Dioxide | 126.4 | 125.0 | 126.0 | 124.8 | 130.9 | 130.6 | 129.2 | 125.8 | 145.5 | 145.6 | 140.7 | 129.0 | 152.6 | 153.1 | 145.4 | 130.0 | 165.8 | 162.7 | 155.8 | 138.7 |
| Dioxide | .55 | .63 | .63 | .72 | .54 | .63 | .63 | .71 | .50 | .60 | .57 | .64 | .50 | .56 | .49 | .57 | .52 | .56 | .49 | .57 |
| gen Oxide | .29 | .29 | .29 | .29 | .28 | .28 | .28 | .27 | .30 | .30 | .28 | .26 | .31 | .31 | .28 | .25 | .33 | .33 | .30 | .27 |
| rica Interconnected Netw | | | | | | | | | | | | | | | | | | | | |
| Carbon | 40.87 | 41.08 | 40.99 | 40.77 | 44.56 | 42.61 | 41.35 | 38.37 | 47.70 | 45.45 | 41.88 | 35.31 | 50.20 | 48.18 | 42.72 | 36.21 | 52.30 | 50.53 | 44.22 | 37.36 |
| n Dioxide | 149.8 | 150.6 | 150.3 | 149.5 | 163.4 | 156.2 | 151.6 | 140.7 | 174.9 | 166.6 | 153.6 | 129.5 | 184.1 | 176.7 | 156.6 | 132.8 | 191.8 | 185.3 | 162.1 | 137.0 |
| r Dioxide | .88 | 1.00 | 1.01 | .98 | .70 | .72 | .74 | .75 | .65 | .65 | .64 | .71 | .61 | .62 | .78 | .82 | .57 | .58 | .86 | .99 |
| gen Oxide | .52 | .53 | .53 | .52 | .52 | .50 | .48 | .45 | .54 | .52 | .45 | .36 | .56 | .54 | .46 | .36 | .59 | .57 | .48 | .37 |
| tinent Area Power Pool | | | | | | | | | | | | | | | | | | | | |
| Carbon | 32.68 | 32.66 | 32.63 | 32.19 | 37.10 | 37.19 | 37.45 | 35.14 | 38.85 | 38.54 | 36.79 | 32.04 | 41.10 | 40.98 | 38.39 | 34.25 | 42.13 | 42.06 | 39.06 | 34.28 |
| n Dioxide | 119.8 | 119.8 | 119.6 | 118.0 | 136.0 | 136.4 | 137.3 | 128.8 | 142.5 | 141.3 | 134.9 | 117.5 | 150.7 | 150.2 | 140.8 | 125.6 | 154.5 | 154.2 | 143.2 | 125.7 |
| r Dioxide | .42 | .42 | .43 | .41 | .44 | .45 | .46 | .41 | .43 | .43 | .41 | .37 | .42 | .42 | .39 | .37 | .40 | .40 | .38 | .35 |
| gen Oxide | .39 | .39 | .39 | .39 | .43 | .44 | .44 | .41 | .45 | .44 | .41 | .34 | .45 | .45 | .41 | .36 | .46 | .46 | .41 | .35 |
| ast Power Council/New York | | | | | | | | | | | | | | | | | | | | |
| Carbon | 13.60 | 13.56 | 13.54 | 13.46 | 13.11 | 13.09 | 13.19 | 12.55 | 14.04 | 13.97 | 13.07 | 11.86 | 15.26 | 15.33 | 14.18 | 12.84 | 16.16 | 16.33 | 15.94 | 11.99 |
| n Dioxide | 49.51 | 49.73 | 49.64 | 49.36 | 48.06 | 48.00 | 48.36 | 46.01 | 51.48 | 51.21 | 47.91 | 43.48 | 55.97 | 56.22 | 51.98 | 47.09 | 59.26 | 59.87 | 58.44 | 43.95 |
| r Dioxide | .24 | .24 | .24 | .24 | .20 | .20 | .21 | .20 | .19 | .19 | .14 | .14 | .17 | .16 | .13 | .14 | .16 | .16 | .15 | .12 |
| gen Oxide | .11 | .11 | .11 | .11 | .09 | .09 | .09 | .08 | .09 | .09 | .07 | .06 | .09 | .09 | .07 | .07 | .09 | .10 | .09 | .06 |
| ast Power Council/New Engl | | | | | | | | | | | | | | | | | | | | |
| l Carbon | 11.59 | 11.59 | 11.59 | 11.50 | 14.59 | 14.58 | 14.58 | 14.19 | 14.97 | 15.00 | 14.61 | 11.76 | 14.95 | 14.95 | 13.88 | 11.53 | 15.50 | 15.45 | 14.25 | 12.34 |
| n Dioxide | 42.50 | 42.51 | 42.49 | 42.16 | 53.48 | 53.47 | 53.46 | 52.03 | 54.90 | 54.99 | 53.57 | 43.12 | 54.82 | 54.81 | 50.91 | 42.28 | 56.85 | 56.64 | 52.25 | 45.26 |
| ur Dioxide | .18 | .18 | .19 | .18 | .20 | .20 | .20 | .19 | .17 | .18 | .17 | .10 | .16 | .16 | .15 | .09 | .14 | .19 | .15 | .10 |
| ogen Oxide | .10 | .10 | .10 | .10 | .11 | .11 | .11 | .11 | .11 | .11 | .11 | .07 | .11 | .11 | .10 | .07 | .11 | .11 | .09 | .08 |

ase.d012198a - 0 Tax, Reference Demand Technology (1), fee005.d012298a (2), fee050.d012298a (3), fee100.d012298a (4)

ENERGY INFORMATION ADMINISTRATION

$5 $50 $100

5 year ramp 22006

N A T I O N A L   E N E R G Y   M O D E L I N G   S Y S T E M

Table 62. Emissions by NERC Region (million short tons) (Continued)
except Carbon and Carbon Dioxide (million metric tons)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2005 (1) | 2005 (2) | 2005 (3) | 2005 (4) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2020 (1) | 2020 (2) | 2020 (3) | 2020 (4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ern Electric/Florida | | | | | | | | | | | | | | | | | | | | |
| arbon | 26.48 | 26.33 | 26.25 | 26.12 | 30.55 | 29.97 | 28.09 | 27.22 | 32.60 | 32.13 | 29.05 | 25.19 | 37.72 | 36.06 | 31.43 | 27.04 | 43.57 | 41.44 | 33.27 | 28.85 |
| Dioxide | 97.09 | 96.55 | 96.24 | 95.76 | 112.0 | 109.9 | 103.0 | 99.8 | 120.2 | 117.8 | 106.5 | 92.37 | 138.3 | 132.2 | 115.2 | 99.1 | 159.7 | 151.9 | 122.0 | 105.8 |
| Dioxide | .40 | .39 | .36 | .35 | .35 | .37 | .34 | .34 | .33 | .37 | .31 | .27 | .36 | .38 | .32 | .26 | .43 | .42 | .34 | .27 |
| n Oxide | .29 | .29 | .29 | .28 | .32 | .31 | .29 | .28 | .33 | .32 | .28 | .24 | .37 | .35 | .29 | .25 | .43 | .40 | .30 | .26 |
| ern Electric/Excl Fla | | | | | | | | | | | | | | | | | | | | |
| arbon | 104.0 | 105.6 | 105.1 | 104.1 | 112.5 | 114.8 | 115.9 | 111.3 | 120.6 | 122.1 | 114.4 | 103.5 | 130.9 | 130.6 | 120.4 | 108.1 | 135.8 | 138.0 | 126.0 | 112.2 |
| Dioxide | 381.3 | 387.0 | 385.3 | 381.8 | 412.4 | 421.0 | 425.0 | 408.1 | 442.3 | 447.8 | 419.6 | 379.3 | 480.0 | 478.7 | 441.4 | 396.3 | 497.8 | 506.0 | 461.9 | 411.2 |
| Dioxide | 2.64 | 2.24 | 2.24 | 2.21 | 2.51 | 2.19 | 2.21 | 2.25 | 2.39 | 2.12 | 2.38 | 2.52 | 2.66 | 2.30 | 2.34 | 2.74 | 2.74 | 2.36 | 2.45 | 2.47 |
| n Oxide | 1.06 | 1.07 | 1.07 | 1.07 | 1.12 | 1.13 | 1.14 | 1.11 | 1.17 | 1.17 | 1.11 | 1.04 | 1.24 | 1.21 | 1.10 | 1.04 | 1.22 | 1.24 | 1.11 | 1.05 |
| Power Pool | | | | | | | | | | | | | | | | | | | | |
| arbon | 59.92 | 59.75 | 59.73 | 59.35 | 65.03 | 64.95 | 62.68 | 61.37 | 68.41 | 67.94 | 62.74 | 54.33 | 70.22 | 69.59 | 62.25 | 56.89 | 72.96 | 71.73 | 66.18 | 56.29 |
| Dioxide | 219.7 | 219.1 | 219.0 | 217.6 | 238.4 | 238.1 | 229.8 | 225.0 | 250.8 | 249.1 | 230.0 | 199.2 | 257.5 | 255.2 | 228.2 | 208.6 | 267.5 | 263.0 | 242.6 | 206.4 |
| Dioxide | .68 | .68 | .68 | .68 | .64 | .64 | .65 | .65 | .62 | .61 | .58 | .46 | .59 | .59 | .51 | .50 | .56 | .56 | .54 | .48 |
| n Oxide | .69 | .69 | .68 | .68 | .70 | .70 | .67 | .66 | .71 | .70 | .62 | .54 | .69 | .68 | .57 | .54 | .70 | .68 | .61 | .52 |
| ystems Council/NWP | | | | | | | | | | | | | | | | | | | | |
| arbon | 24.84 | 24.73 | 24.76 | 24.71 | 28.20 | 28.10 | 27.87 | 28.92 | 29.74 | 29.85 | 28.91 | 25.77 | 31.31 | 31.11 | 30.42 | 26.77 | 32.57 | 32.40 | 31.05 | 26.23 |
| Dioxide | 91.07 | 90.69 | 90.79 | 90.61 | 103.4 | 103.0 | 102.2 | 106.0 | 109.1 | 109.5 | 106.0 | 94.50 | 114.8 | 114.1 | 111.5 | 98.17 | 119.4 | 118.8 | 113.8 | 96.18 |
| Dioxide | .16 | .16 | .16 | .16 | .15 | .16 | .15 | .15 | .14 | .14 | .14 | .11 | .13 | .13 | .12 | .10 | .12 | .12 | .12 | .09 |
| n Oxide | .24 | .24 | .24 | .24 | .24 | .24 | .24 | .25 | .25 | .25 | .24 | .21 | .26 | .26 | .25 | .22 | .26 | .25 | .25 | .21 |
| ystems Council/RA | | | | | | | | | | | | | | | | | | | | |
| arbon | 27.99 | 28.16 | 27.98 | 27.91 | 30.32 | 30.22 | 29.45 | 28.60 | 31.98 | 31.81 | 30.00 | 25.89 | 33.10 | 32.57 | 30.42 | 26.08 | 34.21 | 33.77 | 30.35 | 24.95 |
| Dioxide | 102.6 | 103.2 | 102.6 | 102.3 | 111.2 | 110.8 | 108.0 | 104.9 | 117.3 | 116.6 | 110.0 | 94.91 | 121.4 | 119.4 | 111.5 | 95.63 | 125.4 | 123.8 | 111.3 | 91.48 |
| Dioxide | .21 | .21 | .21 | .21 | .20 | .20 | .20 | .20 | .18 | .18 | .18 | .17 | .16 | .16 | .16 | .15 | .16 | .16 | .15 | .14 |
| n Oxide | .30 | .30 | .30 | .30 | .31 | .31 | .30 | .29 | .31 | .31 | .29 | .25 | .32 | .31 | .29 | .24 | .32 | .32 | .28 | .22 |
| ystems Council/CNV | | | | | | | | | | | | | | | | | | | | |
| arbon | 22.87 | 22.90 | 22.97 | 22.47 | 22.53 | 22.52 | 22.59 | 18.72 | 27.12 | 27.63 | 23.88 | 21.07 | 35.82 | 35.09 | 27.65 | 23.03 | 38.87 | 37.58 | 31.95 | 24.23 |
| Dioxide | 83.85 | 83.97 | 84.24 | 82.40 | 82.52 | 82.56 | 82.82 | 68.64 | 99.4 | 101.3 | 87.54 | 77.24 | 131.4 | 128.7 | 101.4 | 84.44 | 142.5 | 137.8 | 117.1 | 88.83 |
| Dioxide | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .07 | .08 | .08 | .08 | .07 | .08 | .08 | .08 | .07 |
| n Oxide | .19 | .19 | .19 | .19 | .18 | .18 | .18 | .15 | .23 | .24 | .20 | .18 | .32 | .31 | .23 | .20 | .35 | .34 | .28 | .21 |

.d012198a - 0 Tax, Reference Demand Technology (1), fee005.d012298a (2), fee050.d012298a (3), fee100.d012298a (4)

E N E R G Y   I N F O R M A T I O N   A D M I N I S T R A T I O N

N A T I O N A L   E N E R G Y   M O D E L I N G   S Y S T E M

Table 117. National Impacts of the Clean Air Act Amendments of 1990 (CAAA90)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2005 (1) | 2005 (2) | 2005 (3) | 2005 (4) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2020 (1) | 2020 (2) | 2020 (3) | 2020 (4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| r Retrofits (gigawatts).. | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| gional SO2 Allowances (thousand tons)......... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| owance Price ............ | 133.7 | 82.24 | 79.59 | 79.91 | 181.4 | 163.7 | 139.0 | 129.5 | 224.4 | 184.3 | 114.5 | 31.53 | 181.9 | 149.2 | 106.5 | 18.52 | 166.9 | 113.4 | 101.4 | 35.86 |
| ssions (million tons).... | 10.19 | 10.19 | 10.19 | 10.19 | 9.69 | 9.69 | 9.69 | 9.69 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| oduction by Sulfur Categ. | | | | | | | | | | | | | | | | | | | | |
| n tons) | | | | | | | | | | | | | | | | | | | | |
| fur (< .61 lbs S/mmBtu).. | 474.6 | 459.1 | 458.3 | 455.8 | 538.1 | 512.5 | 501.3 | 482.8 | 608.4 | 572.3 | 476.8 | 352.2 | 667.5 | 625.4 | 500.0 | 374.9 | 697.6 | 668.9 | 552.7 | 385.5 |
| fur(.61-1.67 lbs.S/mmBtu) | 493.2 | 494.5 | 494.4 | 490.0 | 482.7 | 489.2 | 486.0 | 471.3 | 467.1 | 472.1 | 450.5 | 375.5 | 459.8 | 456.4 | 422.4 | 331.2 | 454.4 | 451.2 | 411.9 | 336.0 |
| lfur (> 1.67 lbs.S/mmBtu) | 178.4 | 194.0 | 194.2 | 192.8 | 185.9 | 197.1 | 185.1 | 184.7 | 188.1 | 201.3 | 174.3 | 163.2 | 196.6 | 207.8 | 183.6 | 180.6 | 214.6 | 222.7 | 186.5 | 184.2 |
| e Prices | | | | | | | | | | | | | | | | | | | | |
| ional Gasoline........... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ated Gasoline............ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ulated Gasoline.......... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| xygen Reformulated Gas... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ........................ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| e Quantities | | | | | | | | | | | | | | | | | | | | |
| ional Gasoline........... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ated Gasoline............ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ulated Gasoline.......... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| xygen Reformulated Gas... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ........................ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| late Prices | | | | | | | | | | | | | | | | | | | | |
| llate <= 0.05% Sulfur..... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| llate > 0.05% Sulfur...... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ........................ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| late Quantities | | | | | | | | | | | | | | | | | | | | |
| llate <= 0.05% Sulfur..... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| llate > 0.05% Sulfur...... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ........................ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

ase.d012198a - 0 Tax, Reference Demand Technology (1), fee005.d012298a (2), fee050.d012298a (3), fee100.d012298a (4)

E N E R G Y   I N F O R M A T I O N   A D M I N I S T R A T I O N

N A T I O N A L   E N E R G Y   M O D E L I N G   S Y S T E M

Table 1. Total Energy Supply and Disposition Summary
(Quadrillion Btu per Year, Unless Otherwise Noted)

| , Disposition, and Prices | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2005 (1) | 2005 (2) | 2005 (3) | 2005 (4) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2020 (1) | 2020 (2) | 2020 (3) | 2020 (4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ion | | | | | | | | | | | | | | | | | | | | |
| e Oil & Lease Condensate. | 13.06 | 13.07 | 13.07 | 13.06 | 12.33 | 12.26 | 12.26 | 12.26 | 11.80 | 11.51 | 11.47 | 11.42 | 11.07 | 10.49 | 10.37 | 10.29 | 10.33 | 9.60 | 9.45 | 9.39 |
| ral Gas Plant Liquids.... | 2.39 | 2.35 | 2.36 | 2.36 | 2.63 | 2.55 | 2.55 | 2.52 | 2.93 | 3.16 | 3.13 | 3.13 | 3.28 | 3.25 | 3.30 | 3.35 | 3.30 | 3.37 | 3.47 | 3.46 |
| Natural Gas.............. | 20.85 | 20.57 | 20.65 | 20.64 | 22.83 | 22.21 | 22.15 | 21.95 | 25.30 | 27.18 | 26.94 | 26.80 | 26.72 | 27.75 | 28.15 | 28.53 | 28.12 | 28.73 | 29.62 | 29.44 |
| ......................... | 24.33 | 24.11 | 23.98 | 24.02 | 25.52 | 24.15 | 24.00 | 23.93 | 26.50 | 15.13 | 12.83 | 11.11 | 27.64 | 13.78 | 9.30 | 7.62 | 28.37 | 13.26 | 8.64 | 6.36 |
| ear Power.............. | 7.36 | 7.36 | 7.36 | 7.36 | 6.87 | 6.87 | 6.87 | 6.87 | 6.36 | 6.36 | 6.36 | 6.36 | 5.12 | 5.12 | 5.12 | 5.12 | 4.09 | 4.09 | 4.09 | 4.09 |
| wable Energy ............ | 6.82 | 6.86 | 6.94 | 6.97 | 7.11 | 7.56 | 7.60 | 8.29 | 7.41 | 9.38 | 10.40 | 11.27 | 7.86 | 11.17 | 13.50 | 14.47 | 8.19 | 12.79 | 14.76 | 16.46 |
| r ....................... | .56 | .56 | .56 | .56 | .55 | .54 | .54 | .54 | .46 | .54 | .43 | .60 | .64 | 1.20 | 1.15 | 1.13 | .89 | 1.32 | 1.22 | 1.14 |
| Total.................... | 75.36 | 74.89 | 74.92 | 74.98 | 77.84 | 76.14 | 76.16 | 76.35 | 80.79 | 73.25 | 71.56 | 70.69 | 82.32 | 72.77 | 70.88 | 70.50 | 83.29 | 73.14 | 71.24 | 70.33 |
| e Oil ................... | 19.18 | 19.10 | 19.08 | 19.08 | 21.98 | 21.94 | 21.76 | 21.60 | 23.18 | 22.38 | 21.84 | 21.20 | 24.35 | 23.68 | 22.80 | 21.95 | 25.40 | 24.79 | 24.07 | 22.90 |
| oleum Products .......... | 4.39 | 4.40 | 4.40 | 4.41 | 5.55 | 5.16 | 5.27 | 5.43 | 7.56 | 5.37 | 5.33 | 5.15 | 8.81 | 5.10 | 5.15 | 5.24 | 9.50 | 5.41 | 5.26 | 5.73 |
| ral Gas ................. | 4.21 | 4.22 | 4.23 | 4.24 | 4.44 | 4.41 | 4.42 | 4.42 | 4.70 | 5.10 | 5.18 | 5.27 | 5.06 | 5.61 | 5.72 | 5.64 | 5.36 | 5.85 | 5.98 | 6.11 |
| r Imports ............... | .62 | .63 | .63 | .63 | .58 | .60 | .60 | .60 | .57 | .85 | 1.08 | 1.28 | .54 | .87 | 1.06 | 1.26 | .56 | .88 | 1.07 | 1.27 |
| Total.................... | 28.40 | 28.35 | 28.33 | 28.35 | 32.55 | 32.12 | 32.05 | 32.06 | 36.01 | 33.70 | 33.43 | 32.90 | 38.77 | 35.25 | 34.72 | 34.09 | 40.82 | 36.93 | 36.39 | 36.01 |
| ; | | | | | | | | | | | | | | | | | | | | |
| oleum ................... | 1.73 | 1.73 | 1.72 | 1.71 | 1.73 | 1.72 | 1.72 | 1.72 | 1.78 | 1.68 | 1.46 | 1.37 | 1.66 | 1.68 | 1.55 | 1.69 | 1.64 | 1.54 | 1.42 | 1.31 |
| ral Gas.................. | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .28 | .29 | .29 | .29 | .29 | .30 | .30 | .30 | .30 | .32 | .32 | .32 | .32 |
| l........................ | 2.41 | 2.41 | 2.41 | 2.41 | 2.64 | 2.64 | 2.64 | 2.64 | 2.84 | 2.84 | 2.84 | 2.84 | 3.03 | 3.03 | 3.03 | 3.03 | 3.23 | 3.23 | 3.23 | 3.23 |
| Total.................... | 4.41 | 4.41 | 4.40 | 4.40 | 4.65 | 4.64 | 4.64 | 4.64 | 4.91 | 4.81 | 4.59 | 4.50 | 5.19 | 5.00 | 4.87 | 4.82 | 5.20 | 5.09 | 4.97 | 4.86 |
| pancy ................... | .49 | .48 | .46 | .46 | .05 | -.11 | -.03 | -.04 | .14 | -.27 | -.36 | -.28 | -.09 | -.04 | .01 | .05 | -.07 | -.15 | -.13 | -.12 |
| ption | | | | | | | | | | | | | | | | | | | | |
| roleum Products ......... | 38.37 | 38.25 | 38.25 | 38.26 | 41.38 | 40.67 | 40.62 | 40.61 | 44.37 | 41.10 | 40.48 | 40.05 | 46.21 | 42.07 | 41.34 | 40.72 | 47.69 | 42.87 | 41.99 | 41.37 |
| ural Gas................. | 24.76 | 24.49 | 24.58 | 24.58 | 26.93 | 26.29 | 26.24 | 26.04 | 29.57 | 31.83 | 31.65 | 31.55 | 31.32 | 32.88 | 33.38 | 33.66 | 33.00 | 34.06 | 35.08 | 35.01 |
| l........................ | 22.13 | 21.93 | 21.78 | 21.80 | 23.11 | 21.75 | 21.63 | 21.55 | 23.91 | 12.54 | 10.26 | 8.49 | 24.87 | 11.03 | 6.51 | 4.76 | 25.40 | 10.30 | 5.70 | 3.32 |
| lear Power............... | 7.36 | 7.36 | 7.36 | 7.36 | 6.87 | 6.87 | 6.87 | 6.87 | 6.36 | 6.36 | 6.35 | 6.36 | 5.12 | 5.12 | 5.12 | 5.12 | 4.09 | 4.09 | 4.09 | 4.09 |
| evable Energy ........... | 6.82 | 6.86 | 6.94 | 6.97 | 7.12 | 7.56 | 7.81 | 8.29 | 7.43 | 9.40 | 10.42 | 11.28 | 7.88 | 11.20 | 13.52 | 14.49 | 8.22 | 12.82 | 14.79 | 16.49 |
| er ...................... | .41 | .41 | .41 | .41 | .37 | .37 | .37 | .37 | .40 | .65 | .88 | 1.08 | .41 | .69 | .87 | 1.07 | .43 | .71 | .89 | 1.09 |
| otal..................... | 99.0 | 99.3 | 99.3 | 99.4 | 105.8 | 103.5 | 103.5 | 103.7 | 112.0 | 101.9 | 100.0 | 98.81 | 115.8 | 103.0 | 100.7 | 99.8 | 118.8 | 104.9 | 102.5 | 101.4 |
| ports - Petroleum........ | 21.84 | 21.78 | 21.76 | 21.77 | 25.80 | 25.38 | 25.31 | 25.31 | 28.97 | 26.07 | 25.71 | 24.98 | 31.30 | 27.10 | 26.40 | 25.70 | 33.26 | 28.66 | 27.92 | 27.32 |
| ; (1996 dollars per unit) | | | | | | | | | | | | | | | | | | | | |
| l Oil Price ($ per bbl) ... | 19.12 | 19.08 | 19.08 | 19.06 | 20.25 | 19.75 | 19.75 | 19.76 | 20.80 | 18.73 | 18.49 | 18.18 | 21.17 | 18.30 | 17.95 | 17.81 | 21.82 | 19.56 | 19.24 | 19.17 |
| Wellhead Price($ / Mcf)... | 2.13 | 2.11 | 2.12 | 2.12 | 2.15 | 2.05 | 2.05 | 2.03 | 2.26 | 2.59 | 2.65 | 2.68 | 2.32 | 2.91 | 2.98 | 2.94 | 2.49 | 2.86 | 2.96 | 3.00 |
| Minemouth Price ($ / ton). | 17.36 | 17.39 | 17.34 | 17.38 | 16.00 | 16.18 | 16.14 | 16.17 | 14.87 | 16.79 | 17.86 | 18.41 | 13.88 | 15.65 | 17.75 | 18.54 | 13.26 | 15.52 | 17.03 | 18.33 |
| . Electricity (cents / Kwh) | 6.5 | 6.5 | 6.5 | 6.5 | 6.2 | 6.2 | 6.2 | 6.2 | 6.0 | 8.7 | 9.4 | 10.1 | 5.6 | 8.5 | 9.1 | 9.5 | 5.5 | 8.3 | 9.0 | 9.4 |

base.d012198a - 0 Tax, Reference Demand Technology (1), fee150.d012298a (2), fee200.d012298a (3), fee250.d012298a (4)

E N E R G Y   I N F O R M A T I O N   A D M I N I S T R A T I O N

NATIONAL ENERGY MODELING SYSTEM

Table 17. Carbon Emissions by Sector and Source

(Million Metric Tons per Year, Unless Otherwise Noted)

| nd Source | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2005 (1) | 2005 (2) | 2005 (3) | 2005 (4) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2020 (1) | 2020 (2) | 2020 (3) | 2020 (4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ial | | | | | | | | | | | | | | | | | | | | |
| eum | 25.8 | 25.7 | 25.7 | 25.7 | 25.0 | 24.8 | 24.8 | 24.8 | 24.8 | 22.4 | 21.8 | 21.2 | 24.6 | 22.2 | 21.5 | 20.9 | 24.3 | 21.7 | 21.1 | 20.4 |
| l Gas | 77.0 | 76.8 | 76.8 | 76.8 | 78.7 | 78.4 | 78.2 | 78.5 | 81.3 | 71.9 | 69.8 | 67.9 | 84.0 | 72.6 | 70.5 | 68.7 | 86.1 | 74.5 | 72.0 | 69.9 |
| .... | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 | 1.3 | 1.2 | 1.2 | 1.2 |
| icity | 201.3 | 198.7 | 197.8 | 197.9 | 215.6 | 201.4 | 200.1 | 198.5 | 229.8 | 145.1 | 127.3 | 114.5 | 247.9 | 140.8 | 105.9 | 93.6 | 265.8 | 142.9 | 108.1 | 90.1 |
| l | 305.5 | 302.6 | 301.7 | 301.8 | 320.7 | 305.9 | 304.5 | 303.2 | 337.3 | 240.7 | 220.2 | 204.9 | 357.9 | 236.9 | 199.1 | 184.4 | 377.5 | 240.3 | 202.6 | 181.7 |
| al | | | | | | | | | | | | | | | | | | | | |
| eum | 12.9 | 12.8 | 12.8 | 12.8 | 12.9 | 12.8 | 12.8 | 12.8 | 12.8 | 12.4 | 12.3 | 12.1 | 12.7 | 12.3 | 12.2 | 12.0 | 12.5 | 12.0 | 11.9 | 11.8 |
| l Gas | 49.9 | 49.7 | 49.7 | 49.6 | 52.1 | 51.2 | 51.2 | 51.3 | 54.1 | 49.8 | 49.1 | 48.3 | 55.5 | 50.1 | 49.3 | 48.6 | 55.6 | 49.8 | 48.9 | 48.1 |
| .... | 2.2 | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| ricity | 182.1 | 180.5 | 179.6 | 179.8 | 192.8 | 184.0 | 182.8 | 181.3 | 204.1 | 131.8 | 115.3 | 103.3 | 216.9 | 125.2 | 93.8 | 82.6 | 223.9 | 121.7 | 91.8 | 76.3 |
| l | 247.1 | 245.1 | 244.3 | 244.4 | 260.1 | 250.3 | 249.1 | 247.7 | 273.5 | 196.4 | 179.1 | 166.2 | 287.7 | 190.1 | 157.7 | 145.7 | 294.4 | 186.0 | 155.1 | 138.7 |
| ial .. | | | | | | | | | | | | | | | | | | | | |
| leum | 103.3 | 102.6 | 102.6 | 102.6 | 109.6 | 107.7 | 107.3 | 107.2 | 115.4 | 107.3 | 104.6 | 104.4 | 118.6 | 108.1 | 107.2 | 108.4 | 119.3 | 108.1 | 106.2 | 107.5 |
| al Gas | 155.5 | 154.3 | 154.4 | 154.4 | 158.6 | 153.4 | 153.7 | 153.7 | 166.0 | 151.4 | 148.3 | 145.4 | 167.2 | 148.0 | 146.0 | 142.5 | 167.9 | 148.8 | 148.0 | 141.1 |
| .... | 60.6 | 59.4 | 59.4 | 59.4 | 62.3 | 57.9 | 57.9 | 57.8 | 62.7 | 48.5 | 47.5 | 46.8 | 61.6 | 45.3 | 45.5 | 44.8 | 60.6 | 43.9 | 43.2 | 42.6 |
| ricity | 187.5 | 184.9 | 183.9 | 184.3 | 203.0 | 192.0 | 190.6 | 188.6 | 217.0 | 154.4 | 134.7 | 120.3 | 228.5 | 146.2 | 109.8 | 97.2 | 237.4 | 142.3 | 108.0 | 39.9 |
| al | 506.8 | 501.2 | 500.3 | 500.7 | 533.5 | 511.0 | 509.4 | 507.3 | 561.2 | 461.5 | 435.1 | 417.0 | 575.9 | 448.7 | 408.5 | 392.9 | 585.3 | 443.1 | 405.4 | 381.1 |
| rtation | | | | | | | | | | | | | | | | | | | | |
| leum | 502.7 | 502.2 | 502.2 | 502.2 | 552.7 | 549.6 | 549.3 | 549.2 | 600.6 | 561.1 | 552.9 | 541.0 | 628.1 | 562.3 | 550.6 | 540.9 | 649.0 | 577.9 | 565.6 | 554.8 |
| al Gas | 12.1 | 12.0 | 12.0 | 12.0 | 14.5 | 14.4 | 14.4 | 14.2 | 17.2 | 17.4 | 17.2 | 17.0 | 18.3 | 18.6 | 18.5 | 18.6 | 19.7 | 19.7 | 20.2 | 20.2 |
| .... | .1 | .1 | .1 | .1 | .5 | .5 | .5 | .5 | 1.4 | 1.3 | 1.3 | 1.2 | 2.2 | 2.0 | 1.9 | 1.8 | 2.7 | 2.5 | 2.6 | 2.3 |
| ricity | 3.3 | 3.2 | 3.2 | 3.2 | 5.9 | 5.8 | 5.7 | 5.7 | 8.7 | 6.0 | 5.2 | 4.7 | 10.7 | 6.7 | 5.0 | 4.4 | 12.2 | 7.2 | 5.4 | 4.5 |
| al | 518.2 | 517.5 | 517.5 | 517.6 | 573.6 | 570.3 | 570.0 | 569.6 | 627.9 | 585.8 | 576.7 | 563.9 | 659.4 | 589.7 | 576.1 | 565.8 | 683.6 | 607.3 | 593.6 | 581.8 |
| arbon Emissions .. | | | | | | | | | | | | | | | | | | | | |
| leum | 644.7 | 643.2 | 643.2 | 643.3 | 700.1 | 694.9 | 694.1 | 694.0 | 753.6 | 703.1 | 691.6 | 678.7 | 784.0 | 704.9 | 691.5 | 682.3 | 805.1 | 719.7 | 704.7 | 694.5 |
| al Gas | 294.5 | 292.8 | 292.9 | 292.8 | 303.9 | 297.4 | 297.6 | 297.6 | 318.6 | 290.5 | 284.4 | 278.6 | 325.0 | 289.3 | 284.3 | 278.4 | 329.3 | 292.8 | 289.1 | 279.4 |
| .... | 64.2 | 63.0 | 63.0 | 63.0 | 66.0 | 61.6 | 61.6 | 61.5 | 65.5 | 52.2 | 51.3 | 50.5 | 65.5 | 50.1 | 49.2 | 48.5 | 64.5 | 47.7 | 46.9 | 46.4 |
| : | .1 | .1 | .1 | .1 | .5 | .5 | .5 | .5 | 1.4 | 1.3 | 1.3 | 1.2 | 2.2 | 2.0 | 1.9 | 1.8 | 2.7 | 2.5 | 2.4 | 2.3 |
| ricity | 574.1 | 567.3 | 564.5 | 565.2 | 617.3 | 583.1 | 579.3 | 574.2 | 659.7 | 437.3 | 382.5 | 342.8 | 704.0 | 419.0 | 314.5 | 277.7 | 739.2 | 414.1 | 313.3 | 260.9 |
| al | 1578 | 1566 | 1564 | 1564 | 1688 | 1838 | 1633 | 1628 | 1800 | 1484 | 1411 | 1352 | 1881 | 1465 | 1341 | 1289 | 1941 | 1477 | 1356 | 1283 |
| ic Generators .. | | | | | | | | | | | | | | | | | | | | |
| oleum | 11.2 | 10.7 | 10.6 | 10.7 | 9.2 | 8.8 | 8.9 | 8.7 | 8.2 | 4.8 | 4.7 | 5.4 | 7.6 | 6.7 | 6.0 | 3.4 | 7.8 | 4.9 | 3.6 | 3.0 |
| ral Gas | 60.0 | 57.8 | 59.0 | 58.9 | 81.8 | 79.3 | 78.4 | 75.5 | 104.9 | 165.9 | 169.5 | 173.9 | 123.7 | 182.3 | 194.4 | 204.5 | 143.6 | 195.9 | 214.1 | 222.8 |
| .... | 502.9 | 498.8 | 495.0 | 495.5 | 526.3 | 494.9 | 492.0 | 490.0 | 546.7 | 266.5 | 208.3 | 163.5 | 572.7 | 230.0 | 114.1 | 69.8 | 587.9 | 213.4 | 95.6 | 35.1 |
| tal | 574.1 | 567.3 | 564.5 | 565.2 | 617.3 | 583.1 | 579.3 | 574.2 | 659.7 | 437.3 | 382.5 | 342.8 | 704.0 | 419.0 | 314.5 | 277.7 | 739.2 | 414.1 | 313.3 | 260.9 |
| Carbon Emissions .. | | | | | | | | | | | | | | | | | | | | |
| oleum | 655.9 | 653.9 | 653.8 | 654.0 | 709.3 | 703.7 | 702.9 | 702.7 | 761.8 | 707.9 | 696.3 | 684.1 | 791.7 | 711.6 | 697.4 | 685.7 | 812.9 | 724.6 | 708.4 | 697.5 |
| ral Gas | 354.5 | 350.5 | 351.8 | 351.8 | 385.7 | 376.8 | 376.0 | 373.1 | 423.5 | 456.4 | 454.0 | 452.5 | 448.7 | 471.6 | 478.7 | 482.9 | 472.8 | 488.6 | 503.3 | 502.2 |
| .... | 567.1 | 561.8 | 558.0 | 558.6 | 592.3 | 556.5 | 553.6 | 551.5 | 613.2 | 318.7 | 259.5 | 214.1 | 638.2 | 280.1 | 163.4 | 118.3 | 652.4 | 261.1 | 142.5 | 81.4 |
| r | .1 | .1 | .1 | .1 | .5 | .5 | .5 | .5 | 1.4 | 1.3 | 1.3 | 1.2 | 2.2 | 2.0 | 1.9 | 1.8 | 2.7 | 2.5 | 2.4 | 2.3 |
| otal | 1578 | 1566 | 1564 | 1564 | 1688 | 1638 | 1633 | 1628 | 1800 | 1484 | 1411 | 1352 | 1881 | 1465 | 1341 | 1289 | 1941 | 1477 | 1356 | 1283 |
| n Emissions | | | | | | | | | | | | | | | | | | | | |
| s per person) | 5.7 | 5.7 | 5.7 | 5.7 | 5.9 | 5.7 | 5.7 | 5.7 | 6.0 | 5.0 | 4.7 | 4.5 | 6.0 | 4.7 | 4.3 | 4.1 | 6.0 | 4.6 | 4.2 | 4.0 |

ase.d012198a - 0 Tax, Reference Demand Technology (1), fee150.d012298a (2), fee200.d012298a (3), fee250.d012298a (4)

NATIONAL ENERGY MODELING SYSTEM

Table 62. Emissions by NERC Region (million short tons) except Carbon and Carbon Dioxide (million metric tons)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2005 (1) | 2005 (2) | 2005 (3) | 2005 (4) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2020 (1) | 2020 (2) | 2020 (3) | 2020 (4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ........................ | | | | | | | | | | | | | | | | | | | | |
| ites | | | | | | | | | | | | | | | | | | | | |
| rbon........................ | 574.1 | 567.3 | 564.5 | 565.2 | 617.3 | 583.1 | 579.3 | 574.2 | 659.7 | 437.3 | 382.5 | 342.8 | 704.0 | 419.0 | 314.5 | 277.7 | 739.2 | 414.1 | 313.3 | 260.9 |
| Dioxide.................... | 2105 | 2080 | 2070 | 2072 | 2263 | 2138 | 2124 | 2105 | 2419 | 1603 | 1402 | 1257 | 2581 | 1536 | 1153 | 1018 | 2711 | 1518 | 1149 | 956.4 |
| Dioxide.................... | 10.19 | 10.19 | 10.42 | 10.33 | 9.69 | 9.69 | 9.69 | 9.69 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| Oxide...................... | 6.15 | 6.08 | 6.04 | 6.04 | 6.29 | 5.94 | 5.90 | 5.85 | 6.48 | 3.84 | 3.25 | 2.78 | 6.75 | 3.29 | 2.04 | 1.57 | 6.94 | 3.15 | 1.86 | 1.16 |
| al Area Reliability | | | | | | | | | | | | | | | | | | | | |
| rbon........................ | 129.0 | 126.2 | 125.7 | 126.1 | 135.7 | 128.8 | 128.4 | 128.1 | 143.8 | 99.5 | 93.60 | 86.31 | 149.2 | 80.15 | 71.04 | 64.17 | 155.3 | 74.49 | 58.55 | 52.28 |
| Dioxide.................... | 472.9 | 462.7 | 461.0 | 462.4 | 497.6 | 472.4 | 470.9 | 459.7 | 527.3 | 364.7 | 343.2 | 316.4 | 547.0 | 293.9 | 260.5 | 235.3 | 569.6 | 273.1 | 214.7 | 191.7 |
| Dioxide.................... | 3.39 | 3.68 | 3.57 | 3.51 | 3.33 | 3.43 | 3.33 | 3.33 | 2.98 | 4.07 | 4.43 | 4.76 | 2.84 | 3.10 | 4.73 | 5.89 | 2.80 | 2.31 | 1.95 | 3.18 |
| Oxide...................... | 1.50 | 1.47 | 1.46 | 1.47 | 1.55 | 1.46 | 1.46 | 1.46 | 1.61 | 1.00 | .96 | .89 | 1.64 | .63 | .59 | .53 | 1.68 | .48 | .29 | .23 |
| Reliability Council Tx | | | | | | | | | | | | | | | | | | | | |
| rbon........................ | 45.92 | 45.73 | 45.72 | 45.74 | 47.40 | 46.25 | 46.17 | 46.07 | 50.00 | 29.33 | 26.67 | 25.58 | 52.61 | 27.66 | 22.18 | 20.70 | 54.64 | 27.34 | 21.85 | 19.40 |
| Dioxide.................... | 168.4 | 167.7 | 167.6 | 167.7 | 173.8 | 169.6 | 169.3 | 168.9 | 183.3 | 107.6 | 97.80 | 93.77 | 192.9 | 101.4 | 81.32 | 75.89 | 200.3 | 100.2 | 80.11 | 71.14 |
| Dioxide.................... | .35 | .35 | .35 | .35 | .34 | .35 | .34 | .35 | .34 | .09 | .06 | .08 | .33 | .14 | .13 | .19 | .32 | .14 | .19 | .53 |
| Oxide...................... | .47 | .47 | .47 | .47 | .43 | .43 | .43 | .42 | .38 | .23 | .22 | .21 | .38 | .15 | .10 | .10 | .39 | .15 | .10 | .07 |
| tic Area Council | | | | | | | | | | | | | | | | | | | | |
| arbon....................... | 34.48 | 33.80 | 33.62 | 33.84 | 35.70 | 34.34 | 33.58 | 33.47 | 39.69 | 30.39 | 27.04 | 24.06 | 41.62 | 28.36 | 21.40 | 19.70 | 45.23 | 27.06 | 21.07 | 18.24 |
| Dioxide.................... | 126.4 | 123.9 | 123.3 | 124.1 | 130.9 | 125.9 | 123.1 | 122.7 | 145.5 | 111.4 | 99.2 | 88.20 | 152.6 | 104.0 | 78.48 | 72.23 | 165.8 | 99.2 | 77.24 | 66.86 |
| Dioxide.................... | .55 | .61 | 1.10 | 1.11 | .54 | .63 | 1.04 | 1.05 | .50 | .51 | .84 | .77 | .50 | .39 | .53 | .41 | .52 | .35 | .64 | .63 |
| n Oxide.................... | .29 | .29 | .29 | .29 | .28 | .27 | .26 | .26 | .30 | .19 | .16 | .13 | .31 | .16 | .10 | .08 | .33 | .15 | .09 | .07 |
| ca Interconnected Netw | | | | | | | | | | | | | | | | | | | | |
| arbon....................... | 40.87 | 40.78 | 40.53 | 40.27 | 44.56 | 37.66 | 37.83 | 37.94 | 47.70 | 30.30 | 24.88 | 22.86 | 50.20 | 32.12 | 24.39 | 22.00 | 52.30 | 31.30 | 24.46 | 20.00 |
| Dioxide.................... | 149.8 | 149.5 | 148.5 | 147.7 | 163.4 | 138.1 | 138.7 | 139.1 | 174.9 | 111.1 | 91.20 | 83.83 | 184.1 | 117.8 | 89.41 | 80.65 | 191.8 | 114.8 | 89.67 | 73.34 |
| Dioxide.................... | .88 | .99 | .99 | .97 | .70 | .75 | .73 | .73 | .55 | .68 | .37 | .31 | .61 | .90 | .50 | .38 | .57 | 1.14 | 1.00 | .67 |
| n Oxide.................... | .52 | .52 | .52 | .52 | .52 | .45 | .44 | .44 | .54 | .25 | .17 | .14 | .56 | .29 | .13 | .10 | .59 | .29 | .15 | .09 |
| nent Area Power Pool | | | | | | | | | | | | | | | | | | | | |
| arbon....................... | 32.68 | 31.54 | 31.76 | 31.78 | 37.10 | 34.89 | 34.04 | 33.53 | 38.85 | 24.95 | 17.58 | 15.30 | 41.10 | 21.08 | 10.00 | 9.41 | 42.13 | 14.62 | 9.21 | 8.18 |
| Dioxide.................... | 119.8 | 115.6 | 116.4 | 116.5 | 136.0 | 127.9 | 124.8 | 122.5 | 142.5 | 91.47 | 64.47 | 56.09 | 150.7 | 77.28 | 36.67 | 34.52 | 154.5 | 53.62 | 33.78 | 29.98 |
| Dioxide.................... | .42 | .40 | .40 | .40 | .44 | .41 | .38 | .38 | .43 | .32 | .23 | .23 | .42 | .28 | .02 | .03 | .40 | .17 | .01 | .02 |
| n Oxide.................... | .39 | .38 | .38 | .38 | .43 | .41 | .40 | .39 | .45 | .24 | .16 | .13 | .45 | .18 | .04 | .04 | .46 | .11 | .04 | .03 |
| Power Council/New York | | | | | | | | | | | | | | | | | | | | |
| Carbon...................... | 13.50 | 13.50 | 13.41 | 13.45 | 13.11 | 12.56 | 12.32 | 12.27 | 14.04 | 10.85 | 10.13 | 10.57 | 15.26 | 10.60 | 9.65 | 9.72 | 16.16 | 10.70 | 9.58 | 9.15 |
| Dioxide.................... | 49.51 | 49.50 | 49.17 | 49.32 | 48.06 | 46.06 | 45.19 | 45.00 | 51.48 | 39.79 | 37.13 | 38.75 | 55.97 | 38.88 | 35.40 | 35.64 | 59.26 | 39.23 | 35.13 | 33.55 |
| Dioxide.................... | .24 | .24 | .26 | .26 | .20 | .20 | .20 | .20 | .19 | .15 | .14 | .12 | .17 | .14 | .15 | .20 | .16 | .16 | .21 | .36 |
| en Oxide................... | .11 | .11 | .11 | .11 | .09 | .08 | .08 | .08 | .09 | .05 | .04 | .04 | .09 | .05 | .04 | .04 | .09 | .05 | .04 | .03 |
| Power Council/New Engl | | | | | | | | | | | | | | | | | | | | |
| Carbon...................... | 11.59 | 11.52 | 11.58 | 11.60 | 14.59 | 14.15 | 14.26 | 14.24 | 14.97 | 10.46 | 9.30 | 8.84 | 14.95 | 10.00 | 8.52 | 8.25 | 15.50 | 9.59 | 8.58 | 8.42 |
| Dioxide.................... | 42.50 | 42.25 | 42.44 | 42.53 | 53.48 | 51.90 | 52.28 | 52.23 | 54.90 | 38.34 | 34.10 | 32.77 | 54.82 | 36.68 | 31.23 | 30.24 | 56.85 | 35.15 | 31.47 | 30.86 |
| Dioxide.................... | .18 | .18 | .16 | .16 | .20 | .19 | .17 | .17 | .17 | .08 | .05 | .05 | .16 | .09 | .07 | .11 | .14 | .07 | .08 | .23 |
| en Oxide................... | .10 | .10 | .10 | .10 | .11 | .11 | .11 | .11 | .11 | .05 | .04 | .04 | .11 | .05 | .04 | .04 | .11 | .05 | .04 | .04 |

e.d012198a - 0 Tax, Reference Demand Technology (1), fee150.d012298a (2), fee200.d012298a (3), fee250.d012298a (4)

ENERGY INFORMATION ADMINISTRATION

N A T I O N A L   E N E R G Y   M O D E L I N G   S Y S T E M

Table 62. Emissions by NERC Region (million short tons) (Continued)
except Carbon and Carbon Dioxide (million metric tons)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2005 (1) | 2005 (2) | 2005 (3) | 2005 (4) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ern Electric/Florida | | | | | | | | | | | | |
| arbon | 26.48 | 25.97 | 25.66 | 25.75 | 30.55 | 26.56 | 26.65 | 26.52 | 32.80 | 21.34 | 20.35 | 19.53 |
| Dioxide | 97.09 | 95.23 | 94.10 | 94.41 | 112.0 | 97.38 | 97.73 | 97.23 | 120.2 | 78.25 | 74.63 | 71.59 |
| Dioxide | .40 | .35 | .32 | .32 | .35 | .34 | .31 | .31 | .33 | .21 | .19 | .21 |
| n Oxide | .29 | .28 | .28 | .28 | .32 | .28 | .28 | .28 | .33 | .18 | .17 | .16 |
| ern Electric/Excl Fla | | | | | | | | | | | | |
| arbon | 104.0 | 104.1 | 102.3 | 102.3 | 112.5 | 111.1 | 110.1 | 109.2 | 120.6 | 84.25 | 75.37 | 67.52 |
| Dioxide | 381.3 | 381.9 | 375.2 | 375.2 | 412.4 | 407.2 | 403.7 | 400.5 | 442.3 | 308.9 | 276.3 | 247.6 |
| Dioxide | 2.64 | 2.26 | 2.12 | 2.09 | 2.51 | 2.31 | 2.11 | 2.11 | 2.39 | 2.29 | 2.27 | 2.17 |
| n Oxide | 1.06 | 1.07 | 1.04 | 1.04 | 1.12 | 1.11 | 1.10 | 1.09 | 1.17 | .79 | .70 | .59 |
| : Power Pool | | | | | | | | | | | | |
| Carbon | 59.92 | 59.07 | 59.21 | 59.38 | 65.03 | 61.01 | 60.41 | 59.61 | 68.41 | 41.89 | 33.36 | 29.69 |
| Dioxide | 219.7 | 216.6 | 217.1 | 217.7 | 238.4 | 223.7 | 221.5 | 219.3 | 250.8 | 153.6 | 122.3 | 108.9 |
| Dioxide | .68 | .68 | .68 | .68 | .64 | .65 | .65 | .65 | .62 | .35 | .23 | .17 |
| en Oxide | .69 | .67 | .67 | .68 | .70 | .65 | .65 | .64 | .71 | .39 | .29 | .26 |
| Systems Council/NWP | | | | | | | | | | | | |
| Carbon | 24.84 | 24.74 | 24.72 | 24.82 | 28.20 | 27.92 | 27.67 | 28.65 | 29.74 | 18.00 | 15.47 | 10.95 |
| Dioxide | 91.07 | 90.70 | 90.64 | 91.01 | 103.4 | 102.4 | 101.4 | 105.0 | 109.1 | 66.00 | 56.73 | 40.16 |
| Dioxide | .16 | .16 | .16 | .16 | .15 | .16 | .15 | .15 | .14 | .04 | .04 | .01 |
| en Oxide | .24 | .24 | .23 | .24 | .24 | .24 | .24 | .24 | .25 | .12 | .10 | .04 |
| Systems Council/RA | | | | | | | | | | | | |
| Carbon | 27.99 | 27.90 | 27.92 | 28.09 | 30.32 | 28.58 | 28.23 | 27.35 | 31.98 | 21.09 | 16.59 | 14.59 |
| Dioxide | 102.6 | 102.3 | 102.4 | 103.0 | 111.2 | 104.8 | 103.5 | 100.3 | 117.3 | 77.32 | 60.85 | 53.49 |
| Dioxide | .21 | .21 | .21 | .22 | .20 | .20 | .20 | .19 | .18 | .18 | .13 | .11 |
| en Oxide | .30 | .30 | .30 | .29 | .31 | .29 | .29 | .28 | .31 | .19 | .13 | .11 |
| Systems Council/CNV | | | | | | | | | | | | |
| Carbon | 22.87 | 22.37 | 22.37 | 21.98 | 22.53 | 19.29 | 19.58 | 16.98 | 27.12 | 14.96 | 12.16 | 6.93 |
| Dioxide | 83.85 | 82.03 | 82.04 | 80.58 | 82.62 | 70.72 | 71.79 | 62.25 | 99.4 | 54.84 | 44.59 | 25.42 |
| Dioxide | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .08 | .04 | .01 | .01 |
| gen Oxide | .19 | .19 | .19 | .18 | .18 | .16 | .16 | .14 | .23 | .12 | .09 | .04 |

| | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2020 (1) | 2020 (2) | 2020 (3) | 2020 (4) |
|---|---|---|---|---|---|---|---|---|
| ern Electric/Florida | | | | | | | | |
| arbon | 37.72 | 22.49 | 19.55 | 18.03 | 43.57 | 26.13 | 22.37 | 18.36 |
| Dioxide | 138.3 | 82.45 | 71.67 | 66.11 | 159.7 | 95.80 | 82.01 | 67.32 |
| Dioxide | .36 | .22 | .24 | .24 | .43 | .32 | .35 | .38 |
| n Oxide | .37 | .17 | .13 | .11 | .43 | .22 | .16 | .10 |
| ern Electric/Excl Fla | | | | | | | | |
| arbon | 130.9 | 88.54 | 61.76 | 50.96 | 135.8 | 98.78 | 68.50 | 52.89 |
| Dioxide | 480.0 | 324.6 | 226.4 | 186.8 | 497.8 | 362.2 | 251.2 | 193.9 |
| Dioxide | 2.66 | 3.01 | 2.10 | 1.10 | 2.74 | 3.68 | 3.86 | 1.94 |
| n Oxide | 1.24 | .82 | .44 | .26 | 1.22 | .91 | .51 | .24 |
| : Power Pool | | | | | | | | |
| Carbon | 70.22 | 40.53 | 26.10 | 24.40 | 72.96 | 38.25 | 27.77 | 22.65 |
| Dioxide | 257.5 | 148.6 | 95.68 | 89.44 | 267.5 | 140.3 | 101.8 | 83.03 |
| Dioxide | .59 | .43 | .25 | .23 | .56 | .38 | .36 | .53 |
| en Oxide | .69 | .34 | .15 | .13 | .70 | .32 | .17 | .11 |
| Systems Council/NWP | | | | | | | | |
| Carbon | 31.31 | 20.72 | 12.23 | 9.97 | 32.57 | 20.00 | 13.84 | 9.13 |
| Dioxide | 114.8 | 75.99 | 44.83 | 36.56 | 119.4 | 73.32 | 50.73 | 33.47 |
| Dioxide | .13 | .08 | .03 | .02 | .12 | .07 | .05 | .01 |
| en Oxide | .26 | .15 | .06 | .04 | .26 | .14 | .08 | .03 |
| Systems Council/RA | | | | | | | | |
| Carbon | 33.10 | 21.89 | 16.89 | 12.91 | 34.21 | 21.98 | 16.86 | 14.81 |
| Dioxide | 121.4 | 80.25 | 61.93 | 47.34 | 125.4 | 80.60 | 61.83 | 54.30 |
| Dioxide | .16 | .19 | .22 | .18 | .16 | .19 | .24 | .49 |
| en Oxide | .32 | .20 | .13 | .08 | .32 | .20 | .13 | .10 |
| Systems Council/CNV | | | | | | | | |
| Carbon | 35.82 | 14.81 | 10.81 | 7.50 | 38.87 | 13.89 | 10.67 | 7.35 |
| Dioxide | 131.4 | 54.32 | 39.64 | 27.51 | 142.5 | 50.93 | 39.14 | 26.95 |
| Dioxide | .08 | .05 | .02 | .03 | .08 | .04 | .02 | .03 |
| gen Oxide | .32 | .11 | .07 | .03 | .35 | .09 | .06 | .02 |

se.d012198a - 0 Tax, Reference Demand Technology (1), fee150.d012298a (2), fee200.d012298a (3), fee250.d012298a (4)

E N E R G Y   I N F O R M A T I O N   A D M I N I S T R A T I O N

Table 117. National Impacts of the Clean Air Act Amendments of 1990 (CAAA90)

| | 2000 (1) | 2000 (2) | 2000 (3) | 2000 (4) | 2005 (1) | 2005 (2) | 2005 (3) | 2005 (4) | 2010 (1) | 2010 (2) | 2010 (3) | 2010 (4) | 2015 (1) | 2015 (2) | 2015 (3) | 2015 (4) | 2020 (1) | 2020 (2) | 2020 (3) | 2020 (4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofits (gigawatts).. | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ional SO2 Allowances (thousand tons)......... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| wance Price ............ | 133.7 | 62.63 | 77.26 | 88.93 | 181.4 | 119.0 | 145.1 | 134.7 | 224.4 | .00 | .00 | .00 | 181.9 | .00 | .00 | .00 | 166.9 | .00 | .00 | .00 |
| ssions (million tons).... | 10.19 | 10.19 | 10.42 | 10.33 | 9.69 | 9.69 | 9.69 | 9.69 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| oduction by Sulfur Categ. n tons) | | | | | | | | | | | | | | | | | | | | |
| fur (< .61 lbs S/mmBtu).. | 474.6 | 454.0 | 451.1 | 453.6 | 535.1 | 478.8 | 481.4 | 477.6 | 608.4 | 229.2 | 163.2 | 125.0 | 667.5 | 217.9 | 105.7 | 74.31 | 697.6 | 198.4 | 103.9 | 64.44 |
| fur(.61-1.67 lbs.S/mmBtu) | 453.2 | 484.2 | 482.1 | 486.3 | 482.7 | 471.3 | 465.6 | 465.6 | 467.1 | 317.1 | 285.0 | 258.7 | 459.6 | 279.6 | 219.8 | 197.0 | 454.4 | 270.8 | 208.7 | 176.8 |
| lfur (> 1.67 lbs.S/mmBtu) | 178.4 | 197.1 | 195.6 | 190.4 | 185.9 | 185.5 | 181.2 | 180.9 | 188.1 | 138.0 | 114.8 | 98.04 | 196.6 | 134.5 | 78.84 | 54.92 | 214.5 | 131.5 | 66.62 | 30.54 |
| e Prices | | | | | | | | | | | | | | | | | | | | |
| ional Gasoline........... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ated Gasoline............ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ulated Gasoline.......... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| xygen Reformulated Gas... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ......................... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| e Quantities | | | | | | | | | | | | | | | | | | | | |
| ional Gasoline........... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ated Gasoline............ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ulated Gasoline.......... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Oxygen Reformulated Gas... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ......................... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| late Prices | | | | | | | | | | | | | | | | | | | | |
| llate <= 0.05% Sulfur..... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| llate > 0.05% Sulfur...... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| e......................... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| late Quantities | | | | | | | | | | | | | | | | | | | | |
| llate <= 0.05% Sulfur..... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| llate > 0.05% Sulfur...... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ......................... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

ase.d012198a - 0 Tax, Reference Demand Technology (1), fee150.d012298a (2), fee200.d012298a (3), fee250.d012298a (4)

NATIONAL ENERGY MODELING SYSTEM

Table 1. Total Energy Supply and Disposition Summary
(Quadrillion Btu per Year, Unless Otherwise Noted)

| Disposition, and Prices | 2000 (1) | 2000 (2) | 2005 (1) | 2005 (2) | 2010 (1) | 2010 (2) | 2015 (1) | 2015 (2) | 2020 (1) | 2020 (2) |
|---|---|---|---|---|---|---|---|---|---|---|
| n | | | | | | | | | | |
| Oil & Lease Condensate. | 13.06 | 13.06 | 12.33 | 12.25 | 11.60 | 11.37 | 11.07 | 10.21 | 10.33 | 9.29 |
| l Gas Plant Liquids.... | 2.39 | 2.36 | 2.63 | 2.52 | 2.93 | 3.19 | 3.28 | 3.27 | 3.30 | 3.34 |
| tural Gas............. | 20.85 | 20.66 | 22.83 | 21.94 | 25.30 | 27.25 | 26.72 | 27.94 | 28.12 | 28.54 |
| ...................... | 24.33 | 23.98 | 25.52 | 23.88 | 26.50 | 9.35 | 27.64 | 6.98 | 28.37 | 5.81 |
| r Power................ | 7.36 | 7.36 | 6.87 | 6.87 | 6.36 | 6.36 | 5.12 | 5.12 | 4.09 | 4.20 |
| ble Energy ............ | 6.82 | 7.02 | 7.11 | 8.41 | 7.41 | 11.84 | 7.86 | 14.88 | 8.19 | 17.02 |
| ...................... | .56 | .55 | .55 | .54 | .48 | .60 | .64 | 1.10 | .89 | 1.12 |
| tal.................... | 75.36 | 74.99 | 77.84 | 76.40 | 80.79 | 69.95 | 82.32 | 69.49 | 83.29 | 69.33 |
| Oil ................... | 19.18 | 19.06 | 21.98 | 21.58 | 23.18 | 20.53 | 24.35 | 21.86 | 25.40 | 22.78 |
| eum Products .......... | 4.39 | 4.41 | 5.55 | 5.43 | 7.56 | 5.51 | 8.81 | 5.17 | 9.50 | 5.42 |
| l Gas ................. | 4.21 | 4.22 | 4.44 | 4.41 | 4.70 | 5.34 | 5.06 | 5.68 | 5.36 | 6.08 |
| Imports ............... | .62 | .63 | .58 | .60 | .57 | 1.40 | .54 | 1.39 | .56 | 1.41 |
| tal.................... | 28.40 | 28.32 | 32.55 | 32.02 | 36.01 | 32.77 | 38.77 | 34.09 | 40.82 | 35.69 |
| leum .................. | 1.73 | 1.70 | 1.73 | 1.71 | 1.78 | 1.31 | 1.86 | 1.55 | 1.64 | 1.32 |
| al Gas................. | .28 | .28 | .28 | .28 | .29 | .29 | .30 | .30 | .32 | .32 |
| ...................... | 2.41 | 2.41 | 2.64 | 2.64 | 2.84 | 2.84 | 3.03 | 3.03 | 3.23 | 3.23 |
| tal.................... | 4.41 | 4.39 | 4.65 | 4.64 | 4.91 | 4.44 | 5.19 | 4.68 | 5.20 | 4.87 |
| ncy ................... | .49 | .47 | .05 | -.14 | .14 | -.43 | -.09 | -.22 | -.07 | -.36 |
| ion | | | | | | | | | | |
| leum Products ......... | 38.37 | 38.24 | 41.38 | 40.58 | 44.37 | 39.56 | 46.21 | 39.94 | 47.69 | 40.41 |
| al Gas................. | 24.76 | 24.57 | 26.93 | 26.00 | 29.57 | 32.13 | 31.32 | 33.12 | 33.00 | 34.10 |
| ...................... | 22.13 | 21.79 | 23.11 | 21.40 | 23.91 | 6.77 | 24.87 | 4.20 | 25.60 | 2.82 |
| ar Power............... | 7.36 | 7.36 | 6.87 | 6.87 | 6.36 | 6.36 | 5.12 | 5.12 | 4.09 | 4.20 |
| able Energy ........... | 6.82 | 7.02 | 7.12 | 8.42 | 7.43 | 11.85 | 7.88 | 14.90 | 8.22 | 17.05 |
| ...................... | .41 | .41 | .37 | .37 | .40 | 1.19 | .41 | 1.20 | .43 | 1.22 |
| al..................... | 99.8 | 99.4 | 105.8 | 103.6 | 112.0 | 97.85 | 115.8 | 98.48 | 118.8 | 99.8 |
| rts - Petroleum........ | 21.84 | 21.77 | 25.80 | 25.29 | 28.97 | 24.73 | 31.30 | 25.47 | 33.26 | 26.89 |
| 1996 dollars per unit) | | | | | | | | | | |
| il Price ($ per bbl) ... | 19.12 | 19.04 | 20.25 | 19.76 | 20.80 | 17.82 | 21.17 | 17.51 | 21.82 | 18.92 |
| lhead Price($ / Mcf)... | 2.13 | 2.13 | 2.15 | 2.02 | 2.26 | 2.84 | 2.32 | 2.97 | 2.49 | 2.78 |
| nemouth Price ($ / ton). | 17.36 | 17.33 | 16.00 | 16.14 | 14.87 | 19.08 | 13.88 | 18.77 | 13.26 | 18.68 |
| lectricity (cents / Kwh) | 6.5 | 6.5 | 6.2 | 6.2 | 6.0 | 10.6 | 5.6 | 10.2 | 5.5 | 10.1 |

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ENERGY INFORMATION ADMINISTRATION

N A T I O N A L   E N E R G Y   M O D E L I N G   S Y S T E M

Table 17. Carbon Emissions by Sector and Source
(Million Metric Tons per Year, Unless Otherwise Noted)

| ınd Source | 2000 (1) | 2000 (2) | 2005 (1) | 2005 (2) | 2010 (1) | 2010 (2) | 2015 (1) | 2015 (2) | 2020 (1) | 2020 (2) |
|---|---|---|---|---|---|---|---|---|---|---|
| ial | | | | | | | | | | |
| leum | 25.8 | 25.7 | 25.0 | 24.8 | 24.8 | 20.6 | 24.6 | 20.3 | 24.3 | 19.9 |
| al Gas | 77.0 | 76.8 | 78.7 | 78.4 | 81.3 | 65.8 | 84.0 | 66.8 | 86.1 | 68.6 |
| | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.2 | 1.3 | 1.2 | 1.3 | 1.2 |
| ricity | 201.3 | 197.5 | 215.6 | 196.9 | 229.8 | 104.9 | 247.9 | 88.7 | 265.8 | 82.5 |
| al | 305.5 | 301.4 | 320.7 | 301.5 | 337.3 | 192.6 | 357.9 | 177.0 | 377.5 | 172.2 |
| ial | | | | | | | | | | |
| leum | 12.9 | 12.8 | 12.9 | 12.8 | 12.8 | 12.0 | 12.7 | 11.9 | 12.5 | 11.7 |
| al Gas | 49.9 | 49.6 | 52.1 | 51.2 | 54.1 | 47.4 | 55.5 | 47.8 | 55.6 | 47.6 |
| | 2.2 | 2.2 | 2.3 | 2.3 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 |
| ricity | 182.1 | 179.4 | 192.8 | 179.8 | 204.1 | 94.3 | 216.9 | 78.0 | 223.9 | 69.6 |
| al | 247.1 | 244.1 | 260.1 | 246.2 | 273.5 | 156.2 | 287.7 | 140.3 | 294.4 | 131.4 |
| ial .. | | | | | | | | | | |
| leum | 103.3 | 102.7 | 109.6 | 107.2 | 115.4 | 102.0 | 118.6 | 103.7 | 119.3 | 101.4 |
| al Gas | 155.5 | 154.3 | 158.6 | 153.5 | 166.0 | 144.0 | 167.2 | 139.8 | 167.9 | 141.2 |
| | 60.6 | 59.4 | 62.3 | 57.8 | 62.7 | 46.3 | 61.6 | 44.3 | 60.6 | 42.1 |
| ricity | 187.5 | 186.1 | 203.0 | 187.1 | 217.0 | 110.0 | 228.5 | 91.9 | 237.4 | 81.7 |
| al | 506.8 | 500.5 | 533.5 | 505.5 | 561.2 | 402.4 | 575.9 | 379.7 | 585.3 | 366.4 |
| ırtation | | | | | | | | | | |
| leum | 502.7 | 502.3 | 552.7 | 549.2 | 600.6 | 533.1 | 628.1 | 531.6 | 649.0 | 544.2 |
| al Gas | 12.1 | 12.0 | 14.5 | 14.3 | 17.2 | 17.2 | 18.3 | 18.1 | 19.7 | 19.5 |
| | .1 | .1 | .5 | .5 | 1.4 | 1.2 | 2.2 | 1.8 | 2.7 | 2.2 |
| ricity | 3.3 | 3.2 | 5.9 | 5.6 | 8.7 | 4.3 | 10.7 | 4.1 | 12.2 | 4.1 |
| al | 518.2 | 517.7 | 573.6 | 569.6 | 627.9 | 555.7 | 659.4 | 555.7 | 683.6 | 569.9 |
| Carbon Emissions .. | | | | | | | | | | |
| oleum | 644.7 | 643.5 | 700.1 | 693.9 | 753.6 | 567.8 | 784.0 | 667.6 | 805.1 | 677.1 |
| al Gas | 294.5 | 292.7 | 303.9 | 297.6 | 318.6 | 274.4 | 325.0 | 272.5 | 329.3 | 276.9 |
| | 64.2 | 63.1 | 66.0 | 61.5 | 66.5 | 50.0 | 65.5 | 48.0 | 64.5 | 45.9 |
| c | .1 | .1 | .5 | .5 | 1.4 | 1.2 | 2.2 | 1.8 | 2.7 | 2.2 |
| ricity | 574.1 | 564.2 | 617.3 | 569.4 | 659.7 | 313.5 | 704.0 | 262.8 | 739.2 | 238.0 |
| tal | 1578 | 1564 | 1688 | 1623 | 1800 | 1307 | 1881 | 1253 | 1941 | 1240 |
| ic Generators .. | | | | | | | | | | |
| oleum | 11.2 | 10.1 | 9.2 | 8.2 | 8.2 | 7.1 | 7.6 | 4.0 | 7.8 | 2.8 |
| ral Gas | 60.0 | 59.0 | 81.8 | 75.2 | 104.9 | 186.3 | 123.7 | 202.6 | 143.6 | 212.2 |
| | 502.9 | 495.1 | 526.3 | 486.1 | 546.7 | 120.1 | 572.7 | 56.2 | 587.9 | 22.9 |
| tal | 574.1 | 564.2 | 617.3 | 569.4 | 659.7 | 313.5 | 704.0 | 262.8 | 739.2 | 238.0 |
| Carbon Emissions .. | | | | | | | | | | |
| olcum | 655.9 | 653.7 | 709.3 | 702.0 | 761.8 | 674.9 | 791.7 | 671.6 | 812.9 | 679.9 |
| ıral Gas | 354.5 | 351.7 | 385.7 | 372.6 | 423.5 | 460.8 | 448.7 | 475.1 | 472.8 | 489.1 |
| | 567.1 | 558.2 | 592.3 | 547.6 | 613.2 | 170.1 | 638.2 | 104.2 | 652.4 | 68.7 |
| er | .1 | .1 | .5 | .5 | 1.4 | 1.2 | 2.2 | 1.8 | 2.7 | 2.2 |
| otal | 1578 | 1564 | 1688 | 1623 | 1800 | 1307 | 1881 | 1253 | 1941 | 1240 |
| n Emissions | | | | | | | | | | |
| s per person) | 5.7 | 5.7 | 5.9 | 5.7 | 6.0 | 4.4 | 6.0 | 4.0 | 6.0 | 3.0 |

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N A T I O N A L   E N E R G Y   M O D E L I N G   S Y S T E M

Table 52. Emissions by NERC Region (million short tons) except Carbon and Carbon Dioxide (million metric tons)

| | 2000 (1) | 2000 (2) | 2005 (1) | 2005 (2) | 2010 (1) | 2010 (2) | 2015 (1) | 2015 (2) | 2020 (1) | 2020 (2) |
|---|---|---|---|---|---|---|---|---|---|---|
| ns | | | | | | | | | | |
| States | | | | | | | | | | |
| Carbon | 574.1 | 564.2 | 617.3 | 569.4 | 659.7 | 313.5 | 704.0 | 262.8 | 739.2 | 238.0 |
| n Dioxide | 2105 | 2069 | 2263 | 2088 | 2419 | 1149 | 2581 | 963.5 | 2711 | 872.5 |
| r Dioxide | 10.19 | 10.45 | 9.69 | 9.69 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| gen Oxide | 6.15 | 6.03 | 6.29 | 5.78 | 6.48 | 2.30 | 6.75 | 1.41 | 6.94 | .98 |
| ntral Area Reliability | | | | | | | | | | |
| Carbon | 129.0 | 125.5 | 135.7 | 127.0 | 143.8 | 76.76 | 149.2 | 55.23 | 155.3 | 49.44 |
| n Dioxide | 472.9 | 460.0 | 497.6 | 465.8 | 527.3 | 281.4 | 547.0 | 217.2 | 569.6 | 181.3 |
| r Dioxide | 3.39 | 3.58 | 3.33 | 3.28 | 2.98 | 4.57 | 2.84 | 5.95 | 2.60 | 3.50 |
| gen Oxide | 1.50 | 1.46 | 1.55 | 1.44 | 1.61 | .67 | 1.64 | .46 | 1.68 | .20 |
| c Reliability Council Tx | | | | | | | | | | |
| Carbon | 45.92 | 45.76 | 47.40 | 45.52 | 50.00 | 24.48 | 52.61 | 20.01 | 54.64 | 17.05 |
| n Dioxide | 168.4 | 167.8 | 173.8 | 166.9 | 183.3 | 89.74 | 192.9 | 73.35 | 200.3 | 62.50 |
| r Dioxide | .35 | .35 | .34 | .35 | .34 | .10 | .33 | .24 | .32 | .75 |
| gen Oxide | .47 | .47 | .43 | .41 | .38 | .20 | .38 | .10 | .39 | .06 |
| lantic Area Council | | | | | | | | | | |
| l Carbon | 34.48 | 33.40 | 35.70 | 33.18 | 39.69 | 23.12 | 41.62 | 19.32 | 45.23 | 16.89 |
| on Dioxide | 126.4 | 122.5 | 130.9 | 121.6 | 145.5 | 84.75 | 152.6 | 70.82 | 165.8 | 61.91 |
| ur Dioxide | .55 | 1.09 | .54 | 1.05 | .50 | .85 | .50 | .41 | .52 | .65 |
| ogen Oxide | .29 | .29 | .28 | .26 | .30 | .12 | .31 | .08 | .33 | .06 |
| erica Interconnected Netw | | | | | | | | | | |
| l Carbon | 40.87 | 40.78 | 44.56 | 37.75 | 47.70 | 21.65 | 50.20 | 21.04 | 52.30 | 18.61 |
| on Dioxide | 149.8 | 149.5 | 163.4 | 138.4 | 174.9 | 79.39 | 184.1 | 77.15 | 191.8 | 68.23 |
| ur Dioxide | .68 | .96 | .70 | .73 | .65 | .32 | .61 | .37 | .57 | .69 |
| ogen Oxide | .52 | .53 | .52 | .44 | .54 | .12 | .56 | .09 | .59 | .07 |
| ntinent Area Power Pool | | | | | | | | | | |
| l Carbon | 32.68 | 31.80 | 37.10 | 32.95 | 38.85 | 11.85 | 41.10 | 8.78 | 42.13 | 6.73 |
| on Dioxide | 119.8 | 116.6 | 136.0 | 120.8 | 142.5 | 43.47 | 150.7 | 32.21 | 154.5 | 24.66 |
| ur Dioxide | .42 | .39 | .44 | .36 | .43 | .19 | .42 | .12 | .40 | .02 |
| ogen Oxide | .39 | .38 | .43 | .39 | .45 | .10 | .45 | .04 | .46 | .03 |
| ast Power Council/New York | | | | | | | | | | |
| l Carbon | 13.50 | 13.43 | 13.11 | 12.32 | 14.04 | 9.25 | 15.26 | 8.98 | 16.16 | 8.24 |
| on Dioxide | 49.51 | 49.25 | 48.06 | 45.17 | 51.48 | 33.93 | 55.97 | 32.93 | 59.26 | 30.20 |
| fur Dioxide | .24 | .26 | .20 | .19 | .19 | .09 | .17 | .19 | .16 | .28 |
| ogen Oxide | .11 | .11 | .09 | .08 | .09 | .03 | .09 | .03 | .09 | .03 |
| ast Power Council/New Engl | | | | | | | | | | |
| l Carbon | 11.59 | 11.54 | 14.59 | 14.11 | 14.97 | 8.59 | 14.95 | 7.56 | 15.50 | 6.74 |
| on Dioxide | 42.50 | 42.31 | 53.48 | 51.73 | 54.90 | 31.49 | 54.82 | 27.73 | 56.85 | 24.73 |
| fur Dioxide | .18 | .19 | .20 | .19 | .17 | .06 | .16 | .09 | .14 | .33 |
| rogen Oxide | .10 | .10 | .11 | .11 | .11 | .04 | .11 | .04 | .11 | .03 |

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N A T I O N A L   E N E R G Y   M O D E L I N G   S Y S T E M

Table 62. Emissions by NERC Region (million short tons) (Continued)
except Carbon and Carbon Dioxide (million metric tons)

| | 2000 (1) | 2000 (2) | 2005 (1) | 2005 (2) | 2010 (1) | 2010 (2) | 2015 (1) | 2015 (2) | 2020 (1) | 2020 (2) |
|---|---|---|---|---|---|---|---|---|---|---|
| tern Electric/Florida | | | | | | | | | | |
| Carbon | 26.48 | 25.19 | 30.55 | 26.33 | 32.80 | 18.52 | 37.72 | 16.57 | 43.57 | 16.60 |
| n Dioxide | 97.09 | 52.36 | 112.0 | 96.54 | 120.2 | 67.91 | 138.3 | 60.74 | 159.7 | 60.86 |
| r Dioxide | .40 | .34 | .35 | .33 | .33 | .23 | .36 | .20 | .43 | .22 |
| gen Oxide | .29 | .27 | .32 | .27 | .33 | .14 | .37 | .09 | .43 | .07 |
| stern Electric/Excl Fla | | | | | | | | | | |
| Carbon | 104.0 | 102.9 | 112.5 | 108.5 | 120.6 | 62.65 | 130.9 | 49.71 | 135.8 | 49.44 |
| n Dioxide | 381.3 | 377.1 | 412.4 | 397.8 | 442.3 | 229.7 | 480.0 | 182.2 | 497.8 | 181.3 |
| r Dioxide | 2.64 | 2.14 | 2.51 | 2.11 | 2.39 | 2.31 | 2.66 | 1.00 | 2.74 | 1.44 |
| gen Oxide | 1.06 | 1.04 | 1.12 | 1.08 | 1.17 | .52 | 1.26 | .24 | 1.22 | .19 |
| st Power Pool | | | | | | | | | | |
| Carbon | 59.92 | 59.11 | 65.03 | 59.89 | 68.41 | 28.08 | 70.22 | 22.71 | 72.96 | 18.20 |
| n Dioxide | 219.7 | 216.7 | 238.4 | 219.6 | 250.8 | 102.9 | 257.5 | 83.27 | 267.5 | 66.73 |
| r Dioxide | .68 | .68 | .64 | .65 | .62 | .16 | .59 | .21 | .56 | .43 |
| gen Oxide | .69 | .67 | .70 | .64 | .71 | .23 | .69 | .11 | .70 | .07 |
| Systems Council/NWP | | | | | | | | | | |
| Carbon | 24.84 | 24.65 | 28.20 | 29.60 | 29.74 | 9.73 | 31.31 | 9.04 | 32.57 | 8.84 |
| n Dioxide | 91.07 | 90.39 | 103.4 | 108.5 | 109.1 | 35.66 | 114.8 | 33.16 | 119.4 | 32.42 |
| r Dioxide | .16 | .16 | .15 | .15 | .14 | .00 | .13 | .01 | .12 | .02 |
| gen Oxide | .24 | .23 | .24 | .25 | .25 | .03 | .26 | .03 | .26 | .03 |
| Systems Council/RA | | | | | | | | | | |
| Carbon | 27.99 | 28.01 | 30.32 | 26.88 | 31.98 | 12.17 | 33.10 | 12.50 | 34.21 | 14.67 |
| n Dioxide | 102.6 | 102.7 | 111.2 | 98.55 | 117.3 | 44.63 | 121.4 | 45.82 | 125.4 | 53.78 |
| r Dioxide | .21 | .21 | .20 | .20 | .18 | .10 | .16 | .22 | .16 | .61 |
| gen Oxide | .30 | .29 | .31 | .28 | .31 | .07 | .32 | .08 | .32 | .10 |
| Systems Council/CNV | | | | | | | | | | |
| Carbon | 22.87 | 22.23 | 22.53 | 15.39 | 27.12 | 6.65 | 35.82 | 7.33 | 38.87 | 6.52 |
| on Dioxide | 83.85 | 81.52 | 82.62 | 56.42 | 99.4 | 24.39 | 131.4 | 26.87 | 142.5 | 23.92 |
| ur Dioxide | .08 | .08 | .05 | .08 | .08 | .01 | .08 | .02 | .08 | .04 |
| ogen Oxide | .19 | .19 | .18 | .12 | .23 | .03 | .32 | .02 | .35 | .02 |

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E N E R G Y   I N F O R M A T I O N   A D M I N I S T R A T I O N

NATIONAL ENERGY MODELING SYSTEM

Table 117. National Impacts of the Clean Air Act Amendments of 1990 (CAAA90)

| | 2000 (1) | 2000 (2) | 2005 (1) | 2005 (2) | 2010 (1) | 2010 (2) | 2015 (1) | 2015 (2) | 2020 (1) | 2020 (2) |
|---|---|---|---|---|---|---|---|---|---|---|
| er Retrofits (gigawatts).. | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| egional SO2 Allowances | | | | | | | | | | |
| i (thousand tons)......... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| lowance Price ........... | 133.7 | 71.72 | 181.4 | 155.1 | 224.4 | .00 | 181.9 | .00 | 166.9 | .00 |
| issions (million tons).... | 10.19 | 10.45 | 9.69 | 9.69 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| roduction by Sulfur Categ. | | | | | | | | | | |
| on tons) | | | | | | | | | | |
| lfur (< .61 lbs s/mmBtu).. | 474.6 | 452.9 | 538.1 | 478.2 | 608.4 | 93.18 | 667.5 | 63.87 | 697.6 | 55.20 |
| lfur(.61-1.67 lbs.S/mmBtu) | 493.2 | 482.3 | 482.7 | 464.7 | 467.1 | 228.2 | 459.8 | 138.4 | 454.4 | 169.0 |
| ulfur (> 1.67 lbs.S/mmBtu) | 178.4 | 194.6 | 185.9 | 178.6 | 188.1 | 78.95 | 196.6 | 45.39 | 214.5 | 22.34 |
| ne Prices | | | | | | | | | | |
| tional Gasoline........... | .00 | .00 | .00 | .00 | -.00 | .00 | .00 | .00 | .00 | .00 |
| nated Gasoline............ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| mulated Gasoline.......... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Oxygen Reformulated Gas... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| e......................... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ne Quantities | | | | | | | | | | |
| tional Gasoline........... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| nated Gasoline............ | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| mulated Gasoline.......... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Oxygen Reformulated Gas... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ......................... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| late Prices | | | | | | | | | | |
| llate <= 0.05% Sulfur..... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| llate > 0.05% Sulfur...... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| e......................... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| late Quantities | | | | | | | | | | |
| llate <= 0.05% Sulfur..... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| llate > 0.05% Sulfur...... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| ......................... | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

ase.d012198a - 0 Tax, Reference Demand Technology (1), fee300.d012298a (2)

John Weyant

# The Design of Post-Kyoto EMF Scenarios

An Activity of the

Target and Burden Sharing Study Group of

EMF 16: Integrated Assessment of Climate Change - Post-Kyoto Analyses

# Outline

- Rationale for Post Kyoto EMF Scenarios
- Summary Description of New Scenarios
- Reporting Regions
- Variables to be Reported/Compared

# During the First Part of 1998 We Will ? rsue a Two-track Course of Action to the Design of Post-Kyoto EMF Scenarios

- Initially, parameterize the assumptions made about the potential for off-sets to the year 2010 carbon equivalents targets from sinks and non-carbon GHGs .
- Collect information and analysis on sinks and the non-carbon GHGs to enable the modeling teams to endogenize them in subsequent model comparison scenarios.

# Three Types of Scenarios

1 Modelers Reference Scenario

2 Kyoto Implementations

– Vary Assumptions About Sinks

– Vary Assumptions About Other GHGs

– Vary Assumptions About Emissions Trading

– Vary Post-Kyoto Objectives and Commitments

3 Alternatives to Kyoto Style Scenarios

# Maximum Sink Potentials

- United States: 300 MMT
- European Union/Western Europe: 150 MMT
- Japan: 0
- Canada/Australia/New Zealand: 300 MMT
- Eastern Europe/Former Soviet Union: 300 MMT
- China: 300 MMT
- India: 300 MMT
- Mexico & OPEC: 300 MMT
- Rest of World: 300 MMT

# Three Sets of Sink Assumptions

<u>Reference</u> 1/6 Maximum Potentials in 2010 & 1/3 in 2020-2100.

<u>Pessimistic</u> 0 in All Years

<u>Optimistic</u> 2/3 Maximum Potential in 2010 & Maximum Potential in 2020-2100.

# Three Sets of Assumptions About Reductions in Emissions of Other Greenhouse Gases

Reductions in other greenhouse gases covered by the protocol result in a

- –10%,
- 0%,
- or +10%

change in the carbon equivalents target for each Annex I countries specified in the protocol in 2010

# Three Different Levels of International Emissions Trading

No Trading Among Countries/Regions,

Annex I Trading,

- Annex I Country/regions Allowed to Satisfy No More Than 1/3 of Its Emission Reduction Requirements With Purchased Emissions Rights.
- Sinks Increase Non-Annex I Baselines by 10% and Each Non-Annex I Country is Permitted to Sell Emissions Rights via the Clean Development Mechanism up 15% of the Amount it Would Sell Under a Full Global Emissions Trading Regime.

Full Global Trading With No Restrictions.

# Two Options for the Required Emission Reduction Beyond 2010

- Freezing Commitments At The 2010 Level, Or
- Pursuing an Emissions Trajectory That Leads To Stabilization of the CO2 Concentration in the Atmosphere at 550 PPM Driven By:
  - Further Emission Reductions By Annex I Countries
  - A Graduation Clause Based On Income For The Non-Annex I Countries That Would Lead To Them Reduce Emissions As Well.

# Two Cost Minimizing Scenarios

- Follow the Kyoto protocol targets through 2010 and then minimize the cost of limiting the concentration of $CO_2$ in the atmosphere to no more than 550 PPM
- Minimize the cost of limiting the concentration of $CO_2$ in the atmosphere to 550 PPM without observing the targets proposed in the Kyoto protocol.

| Scenario | Offset Provided by Other GHGs | Contribution of Sinks | Emissions Trading | Post-2010 Objectives |
|---|---|---|---|---|
| 1. Modelers Reference | Run your normal emissions reference case (using your preferred set of population, economic, and energy inputs) assuming the Kyoto protocol is never implemented. | | | |
| 2. Kyoto Reference | 0% | 1/6 (1/3) of Max. Potentials In 2010 (2020-) | Annex I Only (See Specification Above) | Kyoto Forever |
| 3. Minimum Offsets | -10% | 0 | Annex I Only (See Specification Above) | Kyoto Forever |
| 4. Maximum Offsets | +10% | 2/3 (All) of Max. Potentials in 2010 (2020-) | Annex I Only (See Specification Above) | Kyoto Forever |
| 5. No Trading | 0% | 1/6 (1/3) of Max. Potentials In 2010 (2020-) | None | Kyoto Forever |
| 6. Global Trading | 0% | 1/6 (1/3) of Max. Potentials In 2010 (2020-) | Full Global Trading | Kyoto Forever |
| 7. 550 PPM CO2 Limit | 0% | 1/6 (1/3) of Max. Potentials In 2010 (2020-) | Annex I Only (See Specification Above) | Kyoto, Then Limit CO2 to 550 PPM |
| 8. Kyoto Plus Min. Cost 550 PPM | 0% | 1/6 (1/3) of Max. Potentials In 2010 (2020-) | Annex I Only (See Specification Above) | Kyoto, Then Min. Cost of 550 PPM |
| 9. Min. Cost 550 PPM Limit | 0% | 1/6 (1/3) of Max. Potentials In 2010 (2020-) | Annex I Only (See Specification Above) | Min. Cost of 550 PPM |

# Regions for Which Results Are to be Reported

- US
- OECD- Europe
- CANZ
- Japan
- OECD Total
- EEFSU
- non-OECD Annex 1
- Annex 1
- China
- India
- Mexico & OPEC
- ROW
- Non-Annex 1
- Non-OECD Total

# Variables for Which Results Are to Be Reported

Carbon Taxes/Emissions Rights Purchase Costs

Emissions

Total Primary Energy

Total Fossil Fuel Primary Energy

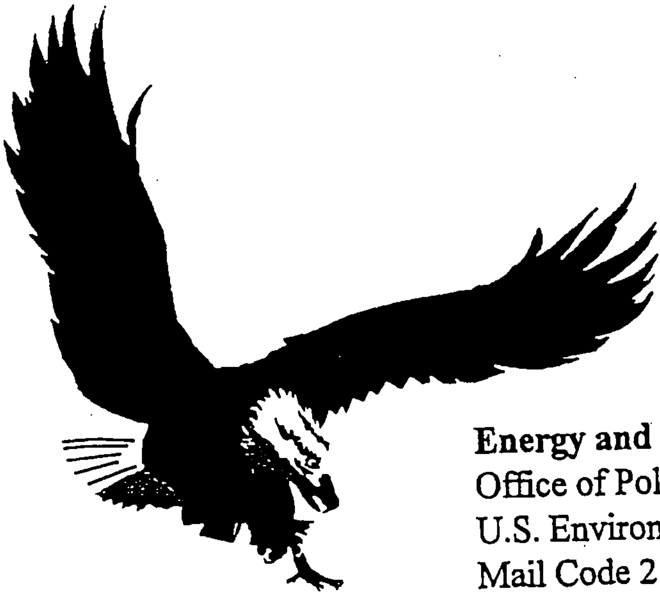
Emissions Rights Bought/Sold

GDP

Macroeconomic Consumption

Discounted Present Value of Loss in Macroeconomic Consumption

o E prices



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2

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Number of pages to follow: 5

Comments:

Standard & Poor's
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# Memorandum

**Date:** January 21, 1998

**To:** Heidi Nelson, ICF

**CC:** Tracy Terry, EPA

**From:** James Lin, DRI James

**Subject:** TD #18, WA #1-07, Contract # 68-W6-0029
**The Carbon Emissions Impacts of a Federal Gasoline Tax Reduction**

This memorandum summarizes the results from our simulation analysis of the carbon emissions impacts of eliminating the 4.3 cent federal gasoline tax enacted in 1993. The first section describes the basic structure of the Transportation Submodel of DRI's U.S. Energy Model which was used to forecast vehicle demand for oil. The second section reports the estimated impacts of the proposed gasoline tax reduction on transportation fuel demand and carbon emissions.

## DRI's Transportation Fuel Demand Model

DRI's Transportation Fuel Demand Model is a vintage capital model. It is premised on the notion that the demand for motor fuels is derived from the demand for travel and consumer's preferences toward particular vehicles. Consumers determine the level of travel as well as the vehicle stock composition through their purchase decisions. The stock composition, associated efficiency characteristics, and vehicle vintage patterns determine the level of fuel consumption. Both vehicle purchase patterns and travel decisions are derived within the model as functions of economic activity and fuel prices. The model is capable of examining dynamic adjustments to fiscal policies such as road pricing and fuel taxes, as well as policies directly affecting technological characteristics of the vehicle stock.

The process of determining fuel consumption begins with consumers' vehicle purchase decisions, particularly the timing of the purchase and the type of vehicle bought. Total sales of imported cars, domestic cars, light trucks, medium trucks, and heavy trucks are obtained from DRI's Automotive Service. The next step is to determine the vehicle stock in any given year, which is a function of past sales patterns and the technological characteristics of those sales, as embodied in the survival probabilities associated with specific vehicle age groups. The vehicle stock in a particular class in any given year depends upon the number of vehicles sold in each of the previous "N" years and the probabilities that these vehicles will still be on the road in that year.

The total number of miles traveled by the stock of vehicles of a particular class and fuel-using type is the product of the number of vehicles in that class' stock and the number of miles traveled per vehicle in that stock. The vehicle miles traveled is estimated econometrically. It varies across the class of vehicle and the age of the vehicles within that class (Generally, the older the vehicle, the fewer miles it is driven each year). It also changes with changes in the real cost per mile and real disposable income. The real cost per mile is defined by dividing fuel prices by the vehicle fuel efficiency.

Fuel consumption for a particular class and model year of vehicle is derived by multiplying each segment's vehicle stock by the miles traveled per vehicle and then dividing by the average fuel efficiency of the vehicle stock. The average fuel efficiency of the vehicle stock is calculated as a stock-weighted average of the vehicle fuel efficiencies by vintage. Overtime, new vehicles are purchased and old vehicles are retired. Since new fuel vehicle efficiencies are affected by fuel costs, real fuel prices increasingly influence the stock efficiency and hence gasoline consumption over time. Total fuel consumption is the sum of fuel consumption for each of the vehicle classes and model years.

**The Impacts of the Gasoline Tax Reduction**

In this study, we applied the Transportation Model to simulation the carbon emissions impacts of eliminating the 4.3 cent federal gasoline tax enacted in 1993. The DRI's Fall 1997 Energy Forecast was used as the baseline. As shown in the attached Excel workbook, the 4.3 cent reduction in federal gasoline tax reduces real gasoline prices by 3.40% in 1998, 2.31% in 2010, and 1.37% in 2020. Consequently, the total number of vehicle miles traveled (VMT) rises and new vehicle fuel efficiency falls. The VMT of passenger cars in 2020 increases by 0.68% from 1627 billion vehicle-miles in the baseline to 1638 billion vehicle-miles while that of light trucks increases by 0.67% from 1947 to 1955 billion vehicle-miles. The new vehicle fuel efficiency declines by about 0.1-0.2 miles per gallon (MPG) from the baseline, which in turn causes a reduction in vehicle stock fuel efficiency.

The higher VMT and lower MPG result in an increase in transportation oil demand and carbon emissions. Compared with the baseline, the annual highway gasoline consumption increases by 0.6%-1.7% and total transportation oil demand increases by no more than 1% for most years during the forecast period. The projected increase in total carbon emissions from the transportation sector is about 1.8 million tonnes (0.37% of the baseline) in 1998, 4.6 million tonnes (0.85% of the baseline) in 2010, and 3.5 million tonnes (0.60% of the baseline) in 2020.

Maryann -
For comparison purposes, we estimated that CMAQ would reduce carbon emissions by 3.5 to 5.3 mil. metric tons. Ken Adler

1/21/98

Transportation Sector Outlook
(Percent Change from the Baseline to GasTaxCH Case)

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| **CARBON EMISSIONS** | | | | | | | | | |
| Total Emissions (Million Tonnes) | 0.00 | 0.00 | 0.37 | 0.50 | 0.68 | 1.03 | 0.85 | 0.66 | 0.60 |
| **FUEL CONSUMPTION** | | | | | | | | | |
| Total Oil Demand (Trillion BTU) | 0.00 | 0.00 | 0.37 | 0.51 | 0.65 | 1.01 | 0.82 | 0.64 | 0.58 |
| Highway Gasoline (Billion Gallons) | 0.00 | 0.00 | 0.58 | 0.86 | 0.99 | 1.57 | 1.30 | 1.08 | 0.93 |
| **GASOLINE RETAIL PRICES ~~(Cents/Gallon)~~ %** | | | | | | | | | |
| 1996 Dollars | 0.00 | 0.00 | -3.40 | -3.36 | -3.21 | -2.72 | -2.31 | -1.82 | -1.37 |
| Nominal Dollars | 0.00 | 0.00 | -3.34 | -3.30 | -3.23 | -2.75 | -2.28 | -1.82 | -1.42 |
| Federal Tax | 0.00 | 0.00 | -23.50 | -23.50 | -23.50 | -23.50 | -23.50 | -19.28 | -14.19 |
| **PASSENGER CARS** | | | | | | | | | |
| VMT (Billion) | 0.00 | 0.00 | 0.58 | 0.72 | 0.93 | 1.34 | 1.09 | 0.91 | 0.68 |
| Miles/Car | 0.00 | 0.00 | 0.57 | 0.77 | 0.95 | 1.35 | 1.09 | 0.88 | 0.67 |
| Miles/Gallon (On-Road) | | | | | | | | | |
| New Car Avg | 0.00 | 0.00 | 0.00 | 0.00 | -0.45 | -0.43 | -0.40 | -0.38 | -0.74 |
| Stock Avg | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.43 | 0.00 | -0.39 |
| **LIGHT TRUCKS** | | | | | | | | | |
| VMT (Billion) | 0.00 | 0.00 | 0.54 | 0.81 | 0.96 | 1.38 | 1.09 | 0.85 | 0.67 |
| Miles/Truck | 0.00 | 0.00 | 0.57 | 0.77 | 0.95 | 1.36 | 1.09 | 0.89 | 0.66 |
| Miles/Gallon (On-Road) | | | | | | | | | |
| New Truck Avg | 0.00 | 0.00 | 0.00 | 0.00 | -0.60 | 0.00 | 0.00 | -0.48 | -0.45 |
| Stock Avg | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.60 | 0.00 | -0.53 | -0.50 |

2000 = 7 years out

price decline 3.21 ¢ ≈ 3.2 %

.9 % VMT ≈ 3.

⇒ growth = e 2.8

9/2

BASE

1/21/98

Transportation Sector Outlook
(DRI Fall 1997 Baseline Forecast)

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| **CARBON EMISSIONS** | | | | | | | | | |
| Total Emissions (Million Tonnes) | 445.3 | 453.4 | 464.8 | 476.8 | 487.4 | 523.6 | 553.1 | 573.2 | 587.3 |
| **FUEL CONSUMPTION** | | | | | | | | | |
| Total Oil Demand (Trillion BTU) | 23496.2 | 23895.2 | 24488.8 | 25119.1 | 25675 | 27606.6 | 29208.2 | 30296.4 | 31059.9 |
| Highway Gasoline (Billion Gallons) | 119.5 | 121.7 | 124.8 | 128.1 | 131 | 140.3 | 146.2 | 148.8 | 150.2 |
| **GASOLINE RETAIL PRICES (Cents/Gallon)** | | | | | | | | | |
| 1996 Dollars | 128.8 | 125.6 | 123.4 | 121.9 | 121.5 | 125 | 129.8 | 137.2 | 146 |
| Nominal Dollars | 128.8 | 128.2 | 128.8 | 130.2 | 133.1 | 156.4 | 189 | 236.7 | 301.9 |
| Federal Tax | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 18.3 | 22.3 | 30.3 |
| **PASSENGER CARS** | | | | | | | | | |
| VMT (Billion) | 1375 | 1375 | 1386 | 1398 | 1405 | 1423 | 1470 | 1541 | 1627 |
| Miles/Car | 11049 | 11090 | 11214 | 11353 | 11463 | 11921 | 12378 | 12772 | 13151 |
| Miles/Gallon (On-Road) | | | | | | | | | |
| New Car Avg | 21.3 | 21.5 | 21.7 | 21.8 | 22 | 23.2 | 25 | 26.2 | 27.1 |
| Stock Avg | 20.8 | 20.8 | 20.9 | 21 | 21.1 | 21.8 | 23.2 | 24.6 | 25.8 |
| **LIGHT TRUCKS** | | | | | | | | | |
| VMT (Billion) | 813 | 861 | 921 | 983 | 1044 | 1307 | 1558 | 1771 | 1942 |
| Miles/Truck | 11473 | 11525 | 11664 | 11819 | 11945 | 12472 | 12993 | 13434 | 13847 |
| Miles/Gallon (On-Road) | | | | | | | | | |
| New Truck Avg | 16 | 16.1 | 16.3 | 16.4 | 16.6 | 17.8 | 19.5 | 20.9 | 22 |
| Stock Avg | 15.5 | 15.6 | 15.7 | 15.8 | 15.9 | 16.7 | 17.7 | 19 | 20.2 |

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1/21/98

Transportation Sector Outlook
(Gasoline Tax Reduction Scenario)

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| CARBON EMISSIONS | | | | | | | | | |
| Total Emissions (Million Tonnes) | 445.3 | 453.4 | 468.5 | 479.2 | 490.7 | 529 | 557.8 | 577 | 590.8 |
| FUEL CONSUMPTION | | | | | | | | | |
| Total Oil Demand (Trillion BTU) | 23498.2 | 23895.2 | 24578.2 | 25246.8 | 25843 | 27886.8 | 29448.3 | 30491.4 | 31240.4 |
| Highway Gasoline (Billion Gallons) | 119.5 | 121.7 | 125.5 | 129.2 | 132.3 | 142.5 | 148.1 | 150.4 | 151.6 |
| GASOLINE RETAIL PRICES (Cents/Gallon) | | | | | | | | | |
| 1996 Dollars | 128.8 | 125.6 | 119.2 | 117.8 | 117.6 | 121.8 | 126.8 | 134.7 | 144 |
| Nominal Dollars | 128.8 | 128.2 | 124.5 | 125.9 | 128.8 | 152.1 | 184.7 | 232.4 | 297.8 |
| Federal Tax | 18.3 | 18.3 | 14 | 14 | 14 | 14 | 14 | 18 | 26 |
| PASSENGER CARS | | | | | | | | | |
| VMT (Billion) | 1375 | 1375 | 1394 | 1408 | 1418 | 1442 | 1488 | 1555 | 1638 |
| Miles/Car | 11049 | 11090 | 11278 | 11440 | 11572 | 12082 | 12513 | 12885 | 13239 |
| Miles/Gallon (On-Road) | | | | | | | | | |
| New Car Avg | 21.3 | 21.5 | 21.7 | 21.8 | 21.9 | 23.1 | 24.9 | 26.1 | 26.9 |
| Stock Avg | 20.8 | 20.8 | 20.9 | 21 | 21.1 | 21.8 | 23.1 | 24.6 | 25.7 |
| LIGHT TRUCKS | | | | | | | | | |
| VMT (Billion) | 813 | 861 | 926 | 991 | 1054 | 1325 | 1575 | 1786 | 1955 |
| Miles/Truck | 11473 | 11525 | 11730 | 11910 | 12059 | 12641 | 13135 | 13553 | 13939 |
| Miles/Gallon (On-Road) | | | | | | | | | |
| New Truck Avg | 18 | 16.1 | 16.3 | 16.4 | 16.5 | 17.8 | 19.5 | 20.8 | 21.9 |
| Stock Avg | 15.5 | 15.6 | 15.7 | 15.8 | 15.9 | 16.8 | 17.7 | 18.9 | 20.1 |

$CO_2$ only

energy-related $CO_2$

ANNEX 1 CARBON EMISSIONS (million metric tons)

| | 1990 emissions | 2010 emissions | |
|---|---|---|---|
| United States | 1,337 | 1,721 | → AEO98: 1803 |
| Former Soviet Union | 1,029 | 872 | |
| Western Europe | 1,016 | 1,208 | |
| Eastern Europe | 309 | 306 | |
| Japan | 308 | 466 | |
| Canada | 137 | 182 | |
| Australia/ New Zealand | 100 | 127 | Target 2010 |
| | 4236 | 4882 | 4024 AI |
| | | | 7942.overall |

DEVELOPING COUNTRIES (million metric tons)

| | 1990 emissions | 2010 emissions |
|---|---|---|
| All other | 904 | 1,811 |
| China | 625 | 1,523 |
| India | 159 | 421 |
| Mexico | 87 | 163 |
| | | 3918 |
| | 6011 | 8800 |

1997 Internal Energy Outlook
EIA

01/09/98 FRI 15:59 FAX 001

To: Randy Lutter
Phone: 395 - 3142
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From: Phillip Tseng
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## Converting carbon value to energy price increases

| Carbon "Value" | Natural Gas (mcf) | Gasoline (gallon) | Coal (ton) | Coal-fired* electricity ($/kwh) | Total* electricity ($/kwh) | Total** electricity ($/kwh) |
|---|---|---|---|---|---|---|
| $0.00 | $0.00 | $0.00 | $0.00 | $0.0000 | $0.0000 | $0.0000 |
| $10.00 | $0.15 | $0.02 | $5.46 | $0.0026 | $0.0016 | $0.0017 |
| $20.00 | $0.30 | $0.05 | $10.92 | $0.0053 | $0.0033 | $0.0034 |
| $30.00 | $0.45 | $0.07 | $16.38 | $0.0079 | $0.0049 | $0.0050 |
| $40.00 | $0.60 | $0.10 | $21.84 | $0.0106 | $0.0066 | $0.0067 |
| $50.00 | $0.75 | $0.12 | $27.30 | $0.0132 | $0.0082 | $0.0084 |
| $60.00 | $0.89 | $0.15 | $32.76 | $0.0158 | $0.0099 | $0.0101 |
| $70.00 | $1.04 | $0.17 | $38.22 | $0.0185 | $0.0115 | $0.0118 |
| $80.00 | $1.19 | $0.19 | $43.68 | $0.0211 | $0.0131 | $0.0135 |
| $90.00 | $1.34 | $0.22 | $49.14 | $0.0238 | $0.0148 | $0.0151 |
| $100.00 | $1.49 | $0.24 | $54.60 | $0.0264 | $0.0164 | $0.0168 |
| $110.00 | $1.64 | $0.27 | $60.06 | $0.0290 | $0.0181 | $0.0185 |
| $120.00 | $1.79 | $0.29 | $65.52 | $0.0317 | $0.0197 | $0.0202 |

* Calculation based on 1995 electricity generation, excluding Cogen.
** Calculation based on 1995 electricity Sales.

## 1995 Price and Consumption of Natural gas, Gasoline, Coal, and Electricity

| | Price | Quantity | P*Q ($billion) |
|---|---|---|---|
| Natural Gas ($/mcf at wellhead, tcf) | $1.61 | 22.2 | $35.71 |
| Gasoline ($/gallon, mmbd/day) | $1.15 | 7.8 | $137.45 |
| Coal($/ton at electric utilities, mil short ton) | $27.01 | 847.0 | $22.88 |
| Electricity($/kwh end-use, bkwh) | $0.07 | 3,008.0 | $213.57 |

October 9, 1997

# Why 7% below Kyoto's "1990 levels" is no more than 3% below the President's proposal: a calculation

This paper compares the carbon numbers associated with the United States emissions commitment under the Kyoto Protocol with the commitment the President made in his October speech. The Kyoto Protocol and the President's speech differ both in the emissions budget and in the emissions accounting system that will determine the emissions that must be below the budget for compliance with the treaty, *so the targets cannot be compared directly*. The most significant differences between the two commitments are1:

(1) Under the Kyoto Protocol, each party has its choice of 1990 or 1995 as a base year for emissions of three greenhouse gases: HFC, PFC, and SF6. The U.S. had 13 MMTCE more emissions of these gases in 1995 than in 1990, making the option of a 1995 base year less restrictive.

(2) Under the Kyoto Protocol, the emissions budget is based only on gross emissions, not counting the carbon sequestered by forests in the base year (1990), the "sinks." The effect of this difference is to make the Kyoto budget less strict than it would have been using the President's assumption that the budget would be based on net emissions.

(3) Under the Kyoto Protocol, the emissions accounting system includes only certain land use changes and forestry activities in its calculation of sinks, rather than the carbon activity in all U.S. forests. The effect of this provision relative to the President's plan depends on the methodology developed to account for sinks under the Kyoto agreement. 2

## The Kyoto Protocol

**(A) The Kyoto Target**

Emissions budget = 5 years × (1990 Emissions of $CO_2$, $CH_4$, $N_2O$ + 1995 Emissions of HFC, PFC, and $SF_6$) × 93%

1990 Emissions of $CO_2$, $CH_4$, $N_2O$ = 1559 MMTCE
1995 Emissions of HFC, PFC, and $SF_6$ = 37 MMTCE
Total baseline emissions = 1596 MMTCE

Kyoto Emissions Budget, total for first budget period = 5 years × (1596) × 93%
= 7421 MMTCE

**Annual Average Budget in 2008-2012 = 1484 MMTCE**

**(B) The Kyoto Accounting System**

2008-2012 emissions = [Total emissions of $CO_2$, $CH_4$, $N_2O$, HFC, PFC, $SF_6$]
- [net changes of carbon stocks "from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks in each commitment period" ]

## The President's Announcement

**(A) The President's October Target**

Under the President's October plan, the emissions target for the United States would be written:

Emissions Budget = 5 years × [(1990 Emissions of $CO_2$, $CH_4$, $N_2O$ <u>and</u> HFC, PFC, and $SF_6$) - (net changes carbon stocks from all forests, including forest soils]

Note that the budget equation includes sinks, which all else equal makes the budget tighter for the United States, which experienced positive sequestration in forests in 1990.

1990 Emissions of $CO_2$, $CH_4$, $N_2O$ = 1559 MMTCE
1990 Emissions of HFC, PFC, and $SF_6$ = 24 MMTCE
Carbon activity in forests (sequestration) = -282 MMTCE
Net emissions = 1301 MMTCE

President's Plan Emissions Budget = 5 years × (1301) = 6505 MMTCE

**Annual Average Budget in 2008-2012 = 1301 MMTCE**

(B) The President's October Accounting System

2008-2012 Emissions Calculation = [Total emissions of CO2, CH4, N2O, HFC, PFC, SF6 2] - [net changes of carbon stocks from all U.S. forests]

**Comparison: How much lower is the Kyoto target than the President's plan?**

Recall that the two plans entail different accounting systems for the emissions that must be within budget, *so the budgets of the two commitments (1484 and 1301) are not directly comparable.*

## The Kyoto commitment:

[Total emissions of all six gases] - [net changes of carbon stocks from certain activities ] < 1484

Since the sink accounting system under the Kyoto Protocol is not yet determined, we must make an assumption about the net changes of carbon stocks from the activities specified in the treaty. The U.S. has said that the accounting system for carbon sinks will not increase the emissions calculation under the Protocol, and may in fact offset our emissions. If we assume that sinks are zero, that is they neither offset U.S. emissions nor contribute to them, then the Kyoto commitment is:

[Total emissions of all six gases] - 0 < 1484

## President's plan:

[Total emissions of all six gases] - [net changes of carbon stocks from all U.S. forests] < 1301

The change in carbon stocks from all U.S. forests in 2010 is estimated by USDA and EPA to be about 227 MMTCE. If that figure is about average for the budget period, the President's commitment would be equivalent to:

[Total emissions of all six gases] - 227 < 1301, or equivalently,
[Total emissions of all six gases] < **1528** (the total of the budget plus offsets by sinks)

Then the comparison question is: **how much lower is 1484 than 1538?**

Algebraically, the percentage difference, x, can be expressed: 1484 = (1-x)1538
=> x = 1 - 1484/1538 = .03
=> **1484 is 3% below 1538.**

What if accounting for sinks under the Protocol offsets our emissions, as we expect they may do? Then the total emissions of all six gases can be *higher* than 1484 by the amount of carbon sequestered in the eligible land use activities. That makes the Kyoto Protocol even less than 3% more stringent than the President's plan.

**Conclusion: The Kyoto agreement is no more than 3% more stringent than the Presidents plan.**

# Trends in Energy-Related Carbon Dioxide Emissions

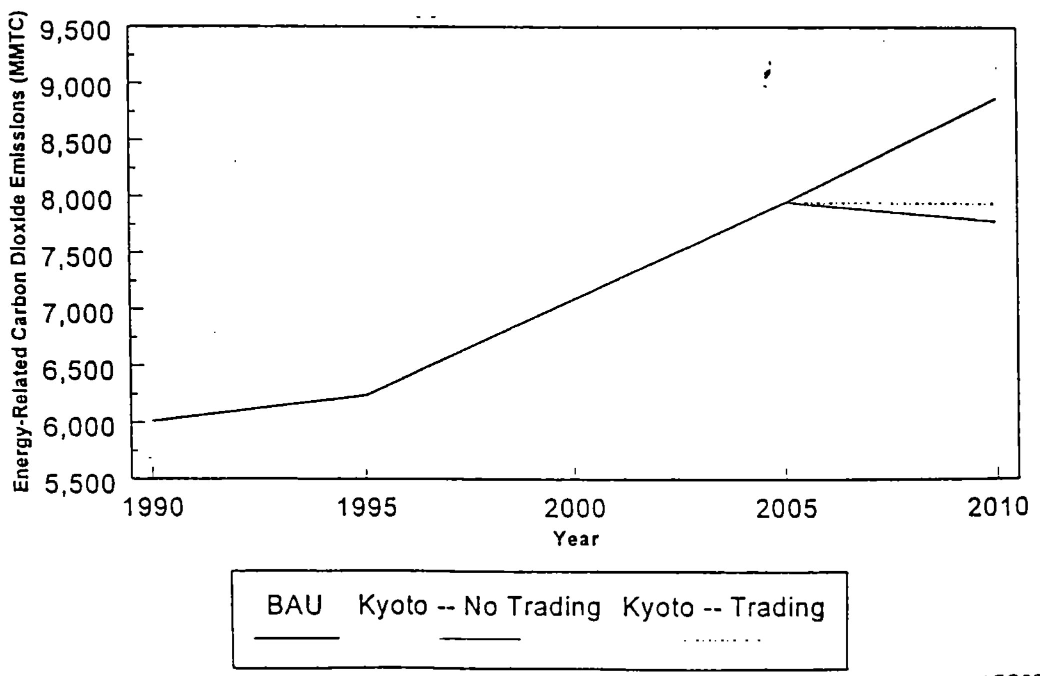
- To assess the implications of Kyoto on global greenhouse gas emissions, we had to make two simplifying assumptions because of data limitations. First, we assumed that energy-related carbon dioxide emissions could serve as an adequate proxy for greenhouse gas emissions (in the U.S., energy-related carbon dioxide emissions are more than 97% of all carbon dioxide emissions). Second, we assumed that Annex I countries will reduce their energy-related carbon dioxide emissions by the percentage cuts stipulated in Annex B of the Kyoto Protocol (in effect, we ignore any opportunities for what flexibility).

- Chart 1 illustrates the trend in world emissions under BAU and under two scenarios of Annex I emissions reductions. One scenario assumes no trading of emissions rights, which has lower total Annex I emissions because countries with paper tons would not be able to sell their excess rights. The other scenario assumes trading of emissions rights, so total Annex I emissions are higher.

- In 2010, both Kyoto scenarios have emissions slightly below 2005 BAU and a little more than 10% below global 2010 BAU. Because of the substantial growth in non-Annex I emissions, global emissions in 2010 under both Kyoto scenarios are approximately 30% above the global 1990 level.

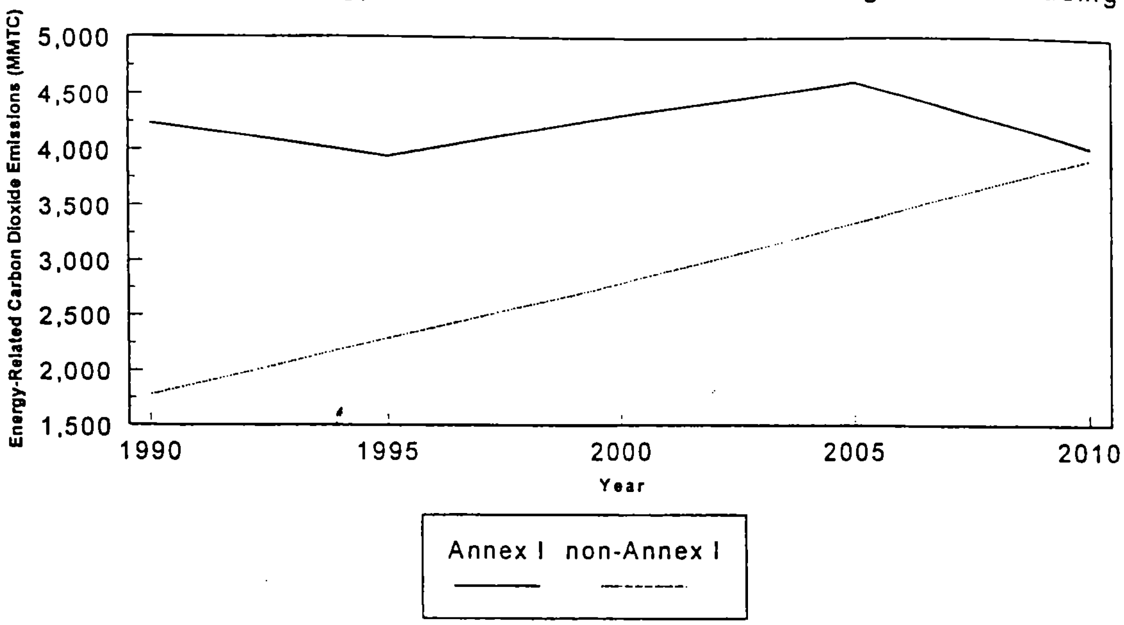
- Charts 2 and 3 illustrate the breakdown of emissions between Annex I and non-Annex I. Without international trading, non-Annex I emissions will surpass Annex I emissions in 2010. With international trading, non-Annex I emissions are slightly lower than Annex I emissions, but would likely pass Annex I emissions by the end of the first commitment period.

Chart 1: Trend in Global Energy-Related CO2 Emissions



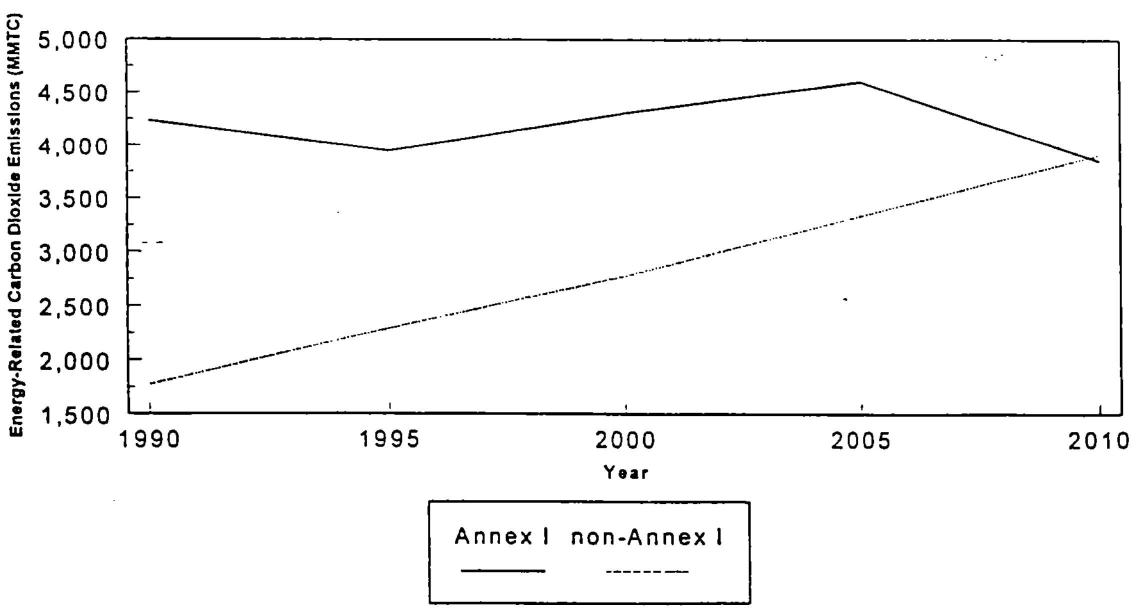

Sources: EIA IEO97 and AEO98

Chart 2: Trend in Energy-Related CO2 Emissions Assuming Annex I Trading




Sources: EIA IEO97 and AEO98

Chart 3: Trend in Energy-Related CO2 Emissions Assuming No Annex I Trading




Sources: EIA IEO97 and AEO98

Bill Hohenstein
1/98

## The Structure of the Kyoto Protocol: US Efforts Needed to Meet Commitments

In October 1997, President Clinton proposed to return greenhouse gas net emissions to 1990 levels in 2008-2012. This target was premised on the long-standing US position of comprehensive coverage of all greenhouse gases (CO2, CH4, N2O, PFCs, HFCs, and SF6) and all sectors (including land use and forestry systems). Although comprehensiveness increased the tonnes of US reductions required to meet a given numerical target, we have pushed for it because it provides greater cost-effectiveness and increases the industrial support for the agreement,. The EU or Japanese wanted to exclude the synthetic gases and land use and forestry, making their targets several percentage points "easier" to achieve than if their proposals had been comprehensive.

The Kyoto Protocol assigns the US a 7% reduction below base period emissions. The U.S. accepted changes in calculation of the obligation for synthetic gases, forests and land use change that allowed the US to deepen its numerical target for the same level of effort. These changes simultaneously increased the level of effort required by the EU and Japan.

The U.S. also agreed to increase the strength of its obligation. The total of the accounting changes and increased strength result in the change of target to 7% below base period levels. Despite the accounting changes, the U.S. gained virtually comprehensive coverage during the commitment period of 2008 to 2012.

### Synthetic Gases (HFC/PFC/SF6) → fastest growing gases

The President's proposal included the rapidly growing synthetic gases, using a base year of 1990. The US won inclusion of these gases, and accepted a 1995 base year for calculation of the commitment. The recalculation of base period emissions allowed the U.S. to adjust downward its numerical target by roughly 13 MMTCE, the amount by which the synthetic greenhouse gases grew between 1990 and 1995 (about 1% of the U.S. commitment). For the EU and Japan, which had not counted synthetic gases in their proposals, the broader coverage made their targets more difficult.

### Exclusion of Forest and Land Use Change Category.

Forest carbon sequestration is a large, but declining offset to US emissions. U.S. estimates, using 1996 IPCC guidelines adopted by the Parties, indicate that US forest carbon sequestration is expected to decline by 55 MMTCE between 1990 and 2010.[1] Unlike emissions from energy use, emissions or removals in the base period cannot be continued indefinitely; emissions decline as available land is exhausted and removals decline as forest systems mature. Therefore,

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[1] The US Climate Action Report estimated that US forest sinks would decline by 16 MMTCE. This estimate was updated to include soil carbon, to conform with the 1996 IPCC guidelines and the U.S. goal of comprehensive coverage.

including this sector in calculation of the GHG obligation penalizes those Parties with net removals in the base period and rewards Parties with net emissions. The Kyoto Protocol therefore, as standard practice, excludes LUCF from the base period emissions on which the GHG obligation is based, eliminating the "penalty" in the President's proposed target of 55 MMTCE of carbon (slightly more than 3% of our overall commitment). It had no effect on the EU or Japan, which had excluded the category from their target proposals.

In addition, the U.S. gained crediting of specific forest activities, limited to: afforestation, reforestation, and deforestation since 1990. While the U.S. was initially opposed to this approach due to its inherent accounting uncertainty, we believe that these credits may further reduce the level of effort needed for a given target by a significant but as yet unquantified amount.

**Additional Reductions**

The US accepted an additional -3 percentage points of real effort in order to get agreement with the European Union, Japan, and the G-77. The U.S. reached a target 7% below the base period emissions by combining the two changes in calculation of base period emissions, which made the President's proposal equivalent to -1 percentage points for synthetic gases plus -3 percentage points for forests and land use change, with the -3 percentage points of additional reductions.

Final Draft of Kyoto Protocol to U.N. Climate Change
Convention
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CONFERENCE OF THE PARTIES

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10 December 1997

ENGLISH ONLY

KYOTO PROTOCOL TO THE
UNITED NATIONS FRAMEWORK CONVENTION
ON CLIMATE CHANGE

Final draft by the Chairman of the Committee of the Whole

The Parties to this Protocol,

Being Parties to the United Nations Framework convention on Climate Change, hereinafter referred to as "the Convention",

In pursuit of the ultimate objective of the Convention as stated in its Article 2,

Recalling the provisions of the Convention,

Being guided by Article 3 of the Convention,

Pursuant to the Berlin Mandate adopted by decision 1/CP.1 of the Conference of the Parties to the Convention at its first session,

Have agreed as follows:

Article 1

For the purposes of this Protocol, the definitions contained in Article 1 of the convention shall apply. In addition:

1. "Conference of the Parties" means the Conference of the Parties to the Convention.

2. "Convention" means the United Nations Framework Convention on Climate Change, adopted in New York on 9 May 1992.

3. "Intergovernmental Panel on Climate Change" means the Intergovernmental Panel on Climate Change established in 1988 jointly by the World Meteorological Organization and the United Nations Environment Programme.

4. "Montreal Protocol" means the Montreal Protocol on Substances that Deplete the Ozone Layer, adopted in Montreal on 16 September 1987 and as subsequently adjusted and amended.

5. "Parties present and voting" means Parties present and casting an affirmative or negative vote.

6. "Party" means, unless the context otherwise indicates, a Party to this Protocol.

7. "Party included in Annex I" means a Party included in Annex I to the Convention, as may be amended, or a Party which has made a notification under Article 4, paragraph 2(g), of the Convention.

Article 2

1. Each Party included in Annex I in achieving its quantified emission limitation and reduction commitments under Article 3, in order to promote sustainable development, shall:

(a) Implement and/or further elaborate policies and measures in accordance with its national circumstances, such as:

(i) Enhancement of energy efficiency in relevant sectors of the national economy;

(ii) Protection and enhancement of sinks and reservoirs of greenhouse gases not controlled by the Montreal Protocol, taking into account its commitments under relevant international environmental agreements; promotion of sustainable forest management practices, afforestation and reforestation;

(iii) Promotion of sustainable forms of agriculture in light of climate change considerations;

(iv) Promotion, research, development and increased use of new and renewable forms of energy, of carbon dioxide sequestration technologies and of advanced and innovative environmentally sound technologies;

(v) Progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse gas emitting sectors that run counter to the objective of the Convention and apply market instruments;

(vi) Encouragement of appropriate reforms in relevant sectors aimed at promoting policies and measures which limit or reduce emissions of greenhouse gases not controlled by the Montreal Protocol;

(vii) Measures to limit and/or reduce emissions of greenhouse gases not controlled by the Montreal Protocol in the transport sector;

(viii) Limitation and/or reduction of methane through recovery and use in waste management, as well as in the production, transport and distribution of energy;

(b) Cooperate with other such Parties to enhance the individual and combined effectiveness of their policies and measures adopted under this Article, pursuant to Article 4, paragraph 2(e)(i), of the Convention. To this end, these Parties shall take steps to share their experience and exchange information on such policies and measures, including developing ways of improving their comparability, transparency and effectiveness. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soon as practicable thereafter, consider ways to facilitate such cooperation, taking into account all relevant information.

2. The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively.

3. The Parties included in Annex I shall strive to implement policies and measures under this Article in such a way as to minimize adverse effects, including the adverse effects of climate change, effects on international trade, and social, environmental and economic impacts on other Parties, especially developing country Parties and in particular those identified in Article 4, paragraphs 8 and 9 of the Convention, taking into account Article 3 of the Convention. The Conference of the Parties serving as the meeting of the Parties to this Protocol may take further action, as appropriate, to promote the implementation of the provisions of this paragraph.

4. The Conference of the Parties serving as the meeting of the Parties to this Protocol, if it decides that it would be beneficial to coordinate any of the policies and measures in paragraph 1(a) above, taking into account different national circumstances and potential effects, shall consider ways and means to elaborate the coordination of such policies and measures.

Article 3

1. The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant tO their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by six per cent below 1990 levels in the commitment period 2008 to 2012.

2. Each Party included in Annex I shall, by 2005, have made demonstrable progress in achieving its commitments under this Protocol.

3. The net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks in each commitment period shall be used to meet the commitments in this Article of each Party included in Annex I. The greenhouse gas emissions from sources and removals by sinks associated with those activities shall be reported in a transparent and verifiable manner and reviewed in accordance with Articles 7 and 8.

Δ since 90
or Δ in 2008-12 ?

4. Prior to the first session of the Conference of the Parties serving as the meeting of the Parties to this Protocol, each Party included in Annex I shall provide for consideration by the Subsidiary Body for Scientific and Technological Advice data to establish its level of carbon stocks in 1990 and to

enable an estimate to be made of its changes in carbon stocks in subsequent years. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soon as practicable thereafter, decide upon modalities, rules and guidelines as to how and which additional human-induced activities related to changes in greenhouse gas emissions and removals in the agricultural soil and land-use change and forestry categories, shall be added to, or subtracted from, the assigned amount for Parties included in Annex I, taking into account uncertainties, transparency in reporting, verifiability, the methodological work of the Intergovernmental Panel on Climate Change, the advice provided by the Subsidiary Body for Scientific and Technological Advice in accordance with Article 5 and the decisions of the Conference of the Parties. Such a decision shall apply in the second and subsequent commitment periods.

5. The Parties included in Annex I undergoing the process of transition to a market economy whose base year or period was established pursuant to decision 9/CP.2 of the Conference of the Parties at its second session, shall use that base year or period for the implementation of their commitments under this Article. Any other Party included in Annex I undergoing the process of transition to a market economy which has not yet submitted its first national communication under Article 12 of the Convention may also notify the Conference of the Parties serving as the meeting of the Parties to this Protocol that it intends to use a historical base year or period other than 1990 for the implementation of its commitments under this Article. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall decide on the acceptance of such notification.

6. Taking into account Article 4, paragraph 6, of the Convention, in the implementation of their commitments under this Protocol other than those in this Article, a certain degree of flexibility shall be allowed by the Conference of the Parties serving as the meeting of the Parties to this Protocol to the Parties included in Annex I undergoing the process of transition to a market economy.

QELROs
Average
2008-2012
vs. 1990

7. In the first quantified emission limitation and reduction commitment period, from 2008 to 2012, the assigned amount ~~for each Party included in~~ Annex I shall be equal to the percentage inscribed for it in Annex B of its aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A in 1990, or the base year or period determined in accordance with paragraph 5 above, multiplied by five.

HFCs... 1995

8. Any Party included in Annex I may use 1995 as its base year for hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride, for the purposes of the calculation referred to in paragraph 7 above.

9. Commitments for subsequent periods for Parties included in Annex I shall be established in amendments to Annex B to this Protocol, which shall be adopted in accordance with the provisions of Article 21. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall initiate the consideration of such commitments at least seven years before the end of the first commitment period mentioned in paragraph 7 above.

Trdg

10. For the purpose of meeting its commitments under this Article, any Party included in Annex I may participate in emissions trading. The Conference of the Parties shall define the relevant rules and guidelines for verification, reporting and accountability. Such trading shall be supplemental to domestic actions for

the purpose of meeting its commitments.

Trading

11. Any part of an assigned amount, or any emission reduction units, which a Party acquires from another Party in accordance with the provisions of paragraph 10 above or Article 6 shall be added to the assigned amount for that Party.

12. Any part of an assigned amount, or any emission reduction units, which a Party transfers to another Party in accordance with the provisions of paragraph 10 above or Article 6 shall be subtracted from the assigned amount for that Party.

13. Any certified emission reductions which a Party acquires from another Party in accordance with the provisions of Article 13 shall be added to the assigned amount for that Party.

Banking
(no interest rate)

14. If the emissions of a Party included in Annex I during a commitment period are less than its assigned amount under this Article, this difference shall, on request of that Party, be added to the assigned amount for that Party for subsequent commitment periods.

15. Each Party included in Annex I shall strive to implement the commitments mentioned in paragraph 1 above in such a way as to minimize adverse social, environment and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the Convention. In line with relevant decisions of the Conference of the Parties on the implementation of those paragraphs, the Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session, consider what actions are necessary to minimize the adverse effects of climate change and/or the impacts of response measures on Parties referred to in those paragraphs. Among the issues to be considered shall be the establishment of funding, insurance and transfer of technology.

Article 4

Bubble ?

1. Any Parties included in Annex I that have agreed to jointly fulfil their commitments under Article 3 shall be deemed to have met those commitments provided that their total combined aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of Article 3. The respective emission level allocated to each of the Parties to the agreement shall be set out in that agreement.

2. The Parties to any such agreement shall notify the secretariat of the terms of the agreement on the date of deposit of their instruments of ratification, acceptance, approval or accession. The secretariat shall in turn inform the Parties and signatories to the Convention of the terms of the agreement.

3. The agreement shall remain in operation for the duration of the commitment period specified in Article 3, paragraph 7.

4. If Parties acting jointly do so in the framework of, and together with, a regional economic integration organization, any alteration in the composition of the organization after adoption of this Protocol shall not affect existing new EU ?

commitments under this Protocol. Any alteration in the composition of the organization shall only apply for the purpose of those commitments under Article 3 that are adopted subsequent to that revision.

5. In the event of failure by the Parties to such an agreement to achieve their total combined level of emission reductions, each Party to such an agreement shall be responsible for its own level of emissions set out in the agreement.

6. If Parties acting jointly do so in the framework of, and together with, a regional economic integration organization which is itself a Party to this Protocol, each member State of that regional economic integration organization individually, and together with the regional economic integration organization acting in accordance with Article 24, shall, in the event of failure to achieve the total combined level of emission reductions, be responsible for its level of emissions as notified in accordance with this Article.

Article 5

1. Each Party included in Annex I shall have in place, no later than one year prior to the start of the first commitment period, a national system for the estimation of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. Guidelines for such national systems, which shall incorporate the methodologies specified in paragraph 2 below, shall be decided upon by the Conference of the Parties serving as the meeting of the Parties to his Protocol at is first session.

2. Methodologies for estimating anthropologic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol shall be those be those accepted by the Intergovernmental Panel on Climate Change and agreed upon by the Conference of the Parties at its third session. Where such methodologies are not used, appropriate adjustments shall be applied according to methodologies agreed upon by the Conference of the Parties serving as the meeting of the Parties to this Protocol at its first session. Based on the work of, inter alia, the Intergovernmental Panel on Climate Change and advice provided by the Subsidiary Body for Scientific and Technological Advice, the Conference of the Parties serving as the meeting of the parties to this Protocol shall regularly review and, as appropriate, revise such methodologies and adjustments, taking fully into account any relevant decisions by the Conference of the Parties. Any revision to methodologies or adjustments shall be used only for the purposes of ascertaining compliance with commitments under Article 3 in respect of any commitment period adopted subsequent to that revision

3. The global warming potentials used to calculate the carbon dioxide equivalence of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol listed in Annex A shall be those accepted by the Intergovernmental Panel on Climate Change and agreed upon by the Conference of the Parties at its third session. Based on the work of, inter alia, the Intergovernmental Panel on Climate Change and advice provided by the Subsidiary Body for Scientific and Technological Advice, the Conference of the Parties serving as the meeting of the Parties to this Protocol shall regularly review and, as appropriate, revise the global warming potential of each greenhouse gas, taking fully into account any relevant decisions by the Conference of the Parties. Any revision to a global warming potential shall apply only to those commitments under Article 3 in respect of

any commitment period adopted subsequent to that revision.

Article 6

Just among Annex I?

(LDCs are Article 13)

1. For the purpose of meeting its commitments under Article 3, any Party included in Annex I may transfer to, or acquire from, any other such Party emission reduction units ~~resulting from projects~~ aimed at reducing anthropogenic emissions by so or enhancing anthropogenic removals by sinks of greenhouse gases in any sector of the economy, provided that:

(a) Any such project has the approval of the Parties involved;

Additionality

(b) Any such project provides a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to any that would otherwise occur;

(c) It does not acquire any emission reduction units if it is not in compliance with its obligations under Articles 5 and 7; and

(d) The acquisition of omission reduction units shall be supplemental to domestic actions for the purposes of meeting commitments under Article 3.

2. The Conference of the Parties serving as the meeting of the Parties to this Protocol may, at its first session or as soon as practicable thereafter, further elaborate guidelines for the implementation of this Article for verification and reporting.

3. A Party included in Annex I may authorize legal entities to participate, under its responsibility, in actions leading to the generation, transfer or acquisition of this Article of emission reduction units.

4. If a question of implementation by a Party included in Annex I of the requirements referred to in this paragraph is identified in accordance with the relevant provisions of Article 8, transfers and acquisitions of emission reduction units may continue to be made after the question has been identified, provided that any such units may not be used by a Party to meet its commitments under Article 3 until any issue of compliance is resolved.

Article 7

1. Each Party included in Annex I shall incorporate in its annual inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol, submitted in accordance with the relevant decisions of the Conference of the Parties, the necessary supplementary information for the purposes of ensuring compliance with Article 3, to be determined in accordance with paragraph 4 below.

2. Each Party included in Annex I shall incorporate in its national communication, submitted under Article 12 of the Convention, the supplementary information necessary to demonstrate compliance with its commitments under this Protocol, to be determined in accordance with paragraph 4 below.

3. Each Party included in Annex I shall submit the information required under paragraph I above annually, beginning with the first inventory due under the

Convention for the first year of the commitment period after this Protocol has entered into force for it. Each such Party shall submit the information required under paragraph 2 above as part of the first national communication due under the Convention after this Protocol has entered into force for it and after the adoption of guidelines as provided for in paragraph 4 below. The frequency of subsequent submission of information required under this Article shall be determined by the Conference of the Parties serving as the meeting of the Parties to this Protocol, taking into account any timetable for the submission of national communications decided upon by the Conference of the Parties.

4. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall adopt at its first session, and review periodically thereafter, guidelines for the preparation of the information required under this Article, taking into account guidelines for the preparation of national communications by Parties included in Annex I adopted by the Conference of the Parties. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall also, prior to the first commitment period, decide upon modalities for the accounting of assigned amounts.

Article 8

1. The information submitted under Article 7 by each Party included in Annex I shall be reviewed by expert review teams pursuant to the relevant decisions of the Conference of the Parties serving as the meeting of the Parties to this Protocol under paragraph 4 below. The information submitted under Article 7, paragraph 1, by each Party included in Annex I shall be reviewed as part of the annual compilation and accounting of emissions inventories and assigned amounts. Additionally, the information submitted under Article 7, paragraph 2, by each Party included in Annex I shall be reviewed as part of the review of communications.

2. Expert review teams shall be coordinated by the secretariat and shall be composed of experts selected from those nominated by Parties to the Convention and, as appropriate, by intergovernmental organizations, in accordance with guidance provided for this purpose by the Conference of the Parties.

3. The review process shall provide a thorough and comprehensive technical assessment of all aspects of the implementation by a Party of this protocol. The expert review teams shall prepare a report to the Conference of the Parties serving as the meeting of the Parties to this Protocol, assessing the implementation of the commitments of the Party and identifying any potential problems in, and factors influencing, the fulfilment of commitments. Such reports shall be circulated by the secretariat to all Parties to the Convention. The secretariat shall list those questions of implementation indicated in such reports for further consideration by the Conference of the Parties serving as the meeting of the Parties to this Protocol.

4. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall adopt at its first session, and review periodically thereafter, guidelines for the review of implementation by expert review teams taking into account the relevant decisions of the Conference of the Parties.

5. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, with the assistance of the Subsidiary Body for Implementation

and, as appropriate, the Subsidiary Body for Scientific and Technological Advice, consider:

(a) The information submitted by the Parties under Article 7 and the reports of the expert reviews thereon conducted under this Article; and

(b) Those questions of implementation listed by the secretariat under paragraph 3 above, a well as any questions raised by Parties.

6. Pursuant to its consideration of the information referred to in paragraph 5 above, the Conference of the Parties serving as the meeting of the Parties to this Protocol shall take decisions on any matter required for the implementation of this Protocol.

Article 9

LDCs can voluntarily join later

1. Any signatory or Party to this Protocol not included in Annex I may, at any time, notify the Depositary that it has opted to be bound by this Article. The Depositary shall inform the other signatories and Parties of any such notification.

2. Such notification, supported by an inventory of emissions of greenhouse gases not controlled by the Montreal Protocol, including for the historical base year or period chosen under subparagraph (a) below, and a projection of future emissions, shall include a formal declaration on the following points:

(a) Its chosen historical base year or period for the implementation of subparagraph (b) below; and

(b) The level of limitation or reduction of anthropogenic emissions of greenhouse gases listed in Annex A, as a basket, it is ready to undertake.

3. Where a notification has been made pursuant to paragraphs 1 and 2 above, the secretariat shall include it in the agenda for the following session of the Conference of the Parties serving as the meeting of the Parties to this Protocol which shall decide on the acceptance of such notification.

4. After its acceptance by the Conference of the Parties serving as the meeting of the Parties to this Protocol, a notification by a signatory shall enter into force on the date of entry into force of this Protocol for that State, and a notification by a Party to this Protocol shall enter into force on the ninetieth day after the acceptance of such notification. The commitment under paragraph 2(b) above of Parties acting under this Article shall be inscribed in Annex B.

Article 10

reviews

1. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall periodically review this Protocol in the light of the best available scientific information and assessments on climate change and its impacts, as well as relevant technical, social and economic information. Such reviews shall be coordinated with pertinent reviews under the Convention, in particular those required by Article 4, paragraph 2(d), and Article 7, paragraph 2(a), of the Convention. Based on these reviews, the Conference of the Parties serving as the meeting of the Parties to this Protocol shall take appropriate action.

2. The first review shall take place at the second session of the Conference of the Parties serving as the meeting of the Parties to this Protocol. Further reviews shall take place at regular intervals and in a timely manner.

Article 11

All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, without introducing any new commitments for Parties not included in Annex I, but reaffirming existing commitments in Article 4, paragraph 1, of the Convention, and continuing to advance the implementation of these commitments in order to achieve sustainable development, taking into account Article 4, paragraphs 3, 5 and 7, of the Convention, shall:

(a) Formulate, where relevant and to the extent possible, cost-effective national, and where appropriate regional programmes to improve the quality of local emission factors, activity data and/or models which reflect the socio-economic conditions of each Party for the preparation and periodic updating of national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties, and consistent with the guidelines for national communications adopted by the Conference of the Parties;

Alternative A

Policies & measures

(b) Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change and measures to facilitate adequate adaptation to climate change;

(i) The programmes containing measures shall, inter alia, and to the extent possible and relevant, remove obstacles to the limitation or the abatement of increase of anthropogenic emissions by sources and to the enhancement of removals by sinks, enhance energy efficiency, emphasize market-oriented pricing, as appropriate encourage reforms in the energy sector and regulatory regimes, increase the use of renewable energy, make improvements in the transport and industrial sectors, promote the development and sustainable management of greenhouse gas sinks and reservoirs, improve the integration of climate change considerations into the agriculture and waste management sectors, promote voluntary arrangements with industry, and generally take actions to address climate change that, in the context of their national priorities, objectives and circumstances, are economically justified and can help address other environmental problems; and

(ii) The programmes containing measures shall, inter alia, and to the extent possible and relevant, deploy adaptation technologies and know-how, develop and implement integrated mountain area plans, develop and implement integrated coastal zone management plans, develop research on impacts of, and adaptation to, climate change, develop and implement related technical capacity building and awareness raising measures promote sustainable management plans for the conservation and enhancement of sinks and reservoirs and ecosystems and develop and implement plans for water resources and agriculture, particularly for countries affected by drought and desertification;

Alternative B

(b) Each developed country Party and each other developed Party included in Annex II to the Convention shall incorporate into its national programmes the quantified emission limitation and reduction objectives and related policies and measures under this Protocol, including details of measures undertaken by them to promote, facilitate and finance transfer of technology, provide new and additional financial resources and assist in meeting costs of adaptation in developing countries. Each developing country Party shall seek to include in its national communication, as appropriate, information on programmes which contain measures that the Party believes contribute to addressing climate change and its adverse impacts, including the abatement of increase in greenhouse gas emissions, and enhancement of and removals by sinks, capacity building and adaptation measures;

(c) Cooperate in the promotion of effective modalities for the development, application and diffusion of, and take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies, know-how, practices and processes pertinent to climate change, in particular to developing countries, including the formulation of policies and programmes for the effective transfer of environmentally sound technologies that are publicly owned or in the public domain and the creation of an enabling environment for the private sector, to promote and enhance access to, and transfer of, environmentally sound technologies;

(d) Cooperate in scientific and technical research and promote the maintenance and the development of systematic observation systems and development of data archives to reduce uncertainties related to the climate system, the adverse impacts of climate change and the economic and social consequences of various response strategies, and promote the development and strengthening of endogenous capacities and capabilities to participate in international and intergovernmental efforts, programmes and networks on research and systematic observation, taking into account Article 5 of the Convention;

(c) Cooperate in and promote at the international level, and, where appropriate, using existing bodies, the development and implementation of education and training programmes, including the strengthening of national capacity building, in particular human and institutional capacities and the exchange or secondment of personnel to train experts in this field, in particular for developing countries, and facilitate at the national level public awareness and public access to information on climate change. Suitable modalities should be developed to implement these activities through the relevant bodies of the Convention taking into account Article 6 of the Convention;

(f) Include in their national communications information on programmes and activities undertaken pursuant to this Article in accordance with relevant decisions of the Conference of the Parties; and

(g) Give full consideration, in implementing the commitments in this Article, to Article 4, paragraph 8, of the Convention.

Article 12

1. In the implementation of Article 11, Parties shall take into account the

provisions of Article 4, paragraphs 4, 5, 7, 8 and 9 of the Convention.

2. In the context of the implementation of Article 4, paragraph 1, of the Convention, in accordance with the provisions of Article 4, paragraph 3, and Article 11 of the Convention, and through the operating entity or entities of the financial mechanism of the Convention, the developed country Parties and other developed Parties included in Annex II to the Convention shall:

Money to LDCs

(a) Provide new and additional financial resources to meet the agreed full costs incurred by developing country Parties in advancing the implementation of existing commitments under Article 4, paragraph 1(a), of the Convention that are covered in Article 11, subparagraph (a); and

(b) Also provide such financial resources, including for the transfer of technology, needed by the developing country Parties to meet the agreed full incremental costs of advancing the implementation of existing commitments in Article 4, paragraph 1, of the Convention that are covered by Article 11 and that are agreed between a developing country Party and the international entity or entities referred to in Article 11 of the Convention, in accordance with that Article.

The implementation of these existing commitments shall take into account the need for adequacy and predictability in the flow of funds and the importance of appropriate burden sharing among developed country Parties. The guidance to the financial mechanism of the Convention in relevant decisions of the Conference of the Parties, including those agreed before the adoption of this Protocol, shall apply mutatis mutandis to the provisions of this paragraph.

3. The developed country Parties and other developed Parties in Annex II to the Convention may also provide, and developing country Parties avail themselves of, financial resources for the implementation of Article 11, through bilateral, regional and other multilateral channels.

Article 13

"Clean Dev. mech."

1. A clean development mechanism is hereby defined.

2. The purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.

3. Under the clean development mechanism:

(a) Parties not included in Annex I will benefit from project activities resulting in certified emission reductions; and

[illegible]

(b) Parties included in Annex I may use the certified emission reductions accruing from such project activities to contribute to compliance with part of their quantified emission limitation and reduction commitments under Article 3, as determined by the Conference of the Parties serving as the meeting of the Parties to this Protocol.

4. The clean development mechanism shall be subject to the authority and

guidance of the Conference of the Parties serving as the meeting of the Parties to this Protocol and be supervised by an executive board of the Parties.

5. Emission reductions resulting from each project activity shall be certified by operational entities to be designated by the Conference of the Parties serving as the meeting of the Parties to this Protocol, on the basis of:

(a) Voluntary participation approved by each Party involved;

(b) Real, measurable, and long-term benefits related to the mitigation of climate change; and

(c) Reductions in emissions that are additional to any that would occur in the absence of the certified project activity.

6. The clean development mechanism shall assist in arranging funding of certified project activities as necessary.

7. The Conference of Parties serving as the meeting of the Parties to this Protocol shall, at its first session, elaborate modalities and procedures with the objective of ensuring transparency, efficiency and accountability through independent auditing and verification of project activities.

8. A share of the proceeds from certified project activities shall be used to cover administrative expenses as well as assist developing country Parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation.

9. Participation under the clean development mechanism, including in activities mentioned in paragraph 3(a) above and acquisition of certified emission reductions, may involve private and/or public entities, and is to be subject to whatever guidance may be provided by the executive board of the clean development mechanism.

10. Certified emission reductions obtained during the period from the year 2000 up to the beginning of the first commitment period can be used to assist in achieving compliance in the first commitment period.

Article 14

1. The Conference of the Parties, the supreme body of the Convention, shall Serve as the meeting of the Parties to this Protocol.

2. Parties to the Convention that are not Parties to this Protocol may participate as observers in the proceedings of any session of the Conference of the Parties serving as the meeting of the Parties to this Protocol. When the Conference of the Parties serves as the meeting of the Parties to this Protocol, decisions under this Protocol shall be taken only by those that are Parties to it.

3. When the Conference of the Parties serves as the meeting of the Parties to this Protocol, any member of the Bureau of the Conference of the Parties representing a Party to the Convention but, at that time, not a Party to this Protocol, shall be substituted by an additional member to be elected by and from amongst the Parties to this Protocol.

4. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall keep under regular review the implementation of this Protocol and shall make, within its mandate, the decisions necessary to promote its effective implementation. It shall perform the functions assigned to it by this Protocol and shall:

(a) Assess, on the basis of all information made available to it in accordance with the provisions of this Protocol, the implementation of this Protocol by the Parties, the overall effects of the measures taken pursuant to this Protocol, in particular environmental, economic and social effects as well as their cumulative impacts and the extent to which progress towards the objective of the Convention is being achieved;

(b) Periodically examine the obligations of the Parties under this Protocol, giving due consideration to any reviews required by Article 4, paragraph 2(d), and Article 7, paragraph 2, of the Convention, in the light of the objective of the Convention, the experience gained in its implementation and the evolution of scientific and technological knowledge, and in this respect consider and adopt regular reports on the implementation of this Protocol;

(c) Promote and facilitate the exchange of information on measures adopted by the Parties to address climate change and its effects, taking into account the differing circumstances, responsibilities and capabilities of the Parties and their respective commitments under this Protocol;

(d) Facilitate, at the request of two or more Parties, the coordination of measures adopted by them to address climate change and its effects, taking into account the differing circumstances, responsibilities and capabilities of the Parties and their respective commitments under this Protocol;

(e) Promote and guide, in accordance with the objective of the Convention and the provisions of this Protocol, and taking fully into account the relevant decisions by the Conference of the Parties, the development and periodic refinement of comparable methodologies for the effective implementation of this Protocol, to be agreed on by the Conference of the Parties serving as the meeting of the Parties to this Protocol;

(f) Make recommendations on any matters necessary for the implementation of this Protocol;

(g) Seek to mobilize additional financial resources in accordance with Article 12, paragraph 2;

(h) Establish such subsidiary bodies as are deemed necessary for the implementation of this Protocol;

(i) Seek and utilize, where appropriate, the services and cooperation of, and information provided by, competent international organizations and intergovernmental and non-governmental bodies; and

(j) Exercise such other functions as may be required for the implementation of this Protocol, and consider any assignment resulting from a decision by the Conference of the Parties.

5. The rules of procedure of the Conference of the Parties and financial

procedures of the Convention shall be applied mutatis mutandis under this Protocol, except as may be otherwise decided by consensus by the Conference of the Parties serving as the meeting of the Parties to this Protocol.

6. The first session of the Conference of the Parties serving as the meeting of the Parties to this Protocol shall be convened by the secretariat in conjunction with the first session of the Conference of the Parties that is scheduled after the date of the entry into force of this Protocol. Subsequent ordinary sessions of the Conference of the Parties serving as the meeting of the Parties to this Protocol shall be held every year and in conjunction with ordinary sessions of the Conference of the Parties unless otherwise decided by the Conference of the Parties serving as the meeting of the Parties to this Protocol.

7. Extraordinary sessions of the Conference of the Parties serving as the meeting of the Parties to this Protocol shall be held at such other times as may be deemed necessary by the Conference of the Parties serving as the meeting of the Parties to this Protocol, or at the written request of any Party, provided that, within six months of the request being communicated to the Parties by the secretariat, it is supported by at least one third of the Parties.

8. The United Nations, its specialized agencies and the International Atomic Energy Agency, as well as any State member thereof of observers thereto not party to the Convention, may be represented at sessions of the Conference of the Parties serving as the meeting of the Parties to this Protocol as observers. Any body or agency, whether national or international, governmental or non-governmental, which is qualified in matters covered by this Protocol and which has informed the secretariat of its wish to be represented at a session of the Conference of the Parties serving as the meeting of the Parties to this Protocol as an observer, may be so admitted unless at least one third of the Parties present object. The admission and participation of observers shall be subject to the rules of procedure, as referred to in paragraph 5 above.

Article 15

1. The secretariat established by Article 8 of the Convention shall serve as the secretariat of this Protocol.

2. Article 8, paragraph 2, of the Convention on the functions of the secretariat, and Article 8, paragraph 3, of the Convention on arrangements made for the functioning of the secretariat, shall apply mutatis mutandis to this Protocol. The secretariat shall, in addition, exercise the functions assigned to it under this Protocol.

Article 16

1. The Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation established by Articles 9 and 10 of the Convention shall serve as, respectively, the Subsidiary Body for Scientific and Technologial Advice and the Subsidiary Body for Implementation of this Protocol. The provisions relating to the functioning of these two bodies under the Convention shall apply mutatis mutandis to this Protocol. Sessions of the meetings of the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation of this Protocol shall be held in conjunction with the meetings of, respectively, the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for

Implementation of this Convention.

2. Parties to the Convention that are not Parties to this Protocol may participate as observers in the proceedings of any session of the subsidiary bodies. When the subsidiary bodies serve as the subsidiary bodies of this Protocol, decisions under this Protocol shall be taken only by the Parties to this Protocol.

3. When the subsidiary bodies established by Articles 9 and 10 of the Convention exercise their functions with regard to matters concerning this Protocol, any member of the Bureaux of those subsidiary bodies representing a Party to the Convention but, at that time, not a party to this Protocol, shall be substituted by an additional member to be elected by and from amongst the Parties to this Protocol.

Article 17

The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, as soon as practicable, consider the application to this Protocol of, and modify as appropriate, the multilateral consultative process referred to in Article 13 of the Convention, in the light of any relevant decisions that may be taken by the Conference of the Parties. Any multilateral consultative process that may be applied to this Protocol shall operate without prejudice to the procedures and mechanisms established in accordance with Article 18.

Article 18

The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session, approve appropriate and effective procedures and mechanisms to determine and to address cases of non-compliance with the provisions of this Protocol, including through the development of an indicative list of consequences, taking into account the cause, type, degree and frequency of non-compliance. Any procedures and mechanisms under this Article entailing binding consequences shall be adopted by means of an amendment to this Protocol.

Article 19

The provision of Article 14 of the Convention on settlement of disputes shall apply mutatis mutandis to this Protocol.

Article 20

1. Any party may propose amendments to this Protocol.

2. Amendments to this Protocol shall be adopted at an ordinary session of the Conference of the Parties serving as the meeting of the Parties to this Protocol. The text of any proposed amendment to this Protocol shall be communicated to the Parties by the secretariat at least six months before the meeting at which it is proposed for adoption. The secretariat shall also communicate the text of any proposed amendments to the Parties and signatories to the Convention and, for information, to the Depositary.

3. The Parties shall make every effort to reach agreement on any proposed amendment to this Protocol by consensus. If all efforts at consensus have

been exhausted, and no agreement reached, the amendment shall as a last resort be adopted by a three-fourths majority vote of the Parties present and voting at the meeting. The adopted amendment shall be communicated by the secretariat to the Depositary, who shall circulate it to all Parties for their acceptance.

4. Instruments of acceptance in respect of an amendment shall be deposited with the Depositary. An amendment adopted in accordance with paragraph 3 above shall enter into force for those Parties having accepted it on the ninetieth day after the date of receipt by the Depositary of an instrument of acceptance by at least three fourths of the Parties to this Protocol.

5. The amendment shall enter into force for any other Party on the ninetieth day after the date on which that Party deposits with the Depositary its instrument of acceptance of the said amendment.

Article 21

1. Annexes to this Protocol shall form an integral part thereof and, unless otherwise expressly provided, a reference to this Protocol constitutes at the same time a reference to any annexes thereto. Any annexes adopted after the entry into force of this Protocol shall be restricted to lists, forms and any other material of a descriptive nature that is of a scientific, technical, procedural or administrative character.

2. Any Party may make proposals for an annex to this Protocol and may propose amendments to annexes to this Protocol.

3. Annexes to this Protocol and amendments to annexes to this Protocol shall be adopted at an ordinary session of the Conference of the Parties serving as the meeting of the Parties to this Protocol. The text of any proposed annex or amendment to an annex shall be communicated to the Parties by the secretariat at least six months before the meeting at which it is proposed for adoption. The secretariat shall also communicate the text of any proposed annex or amendment to an annex to the Parties and signatories to the Convention and, for information, to the Depositary.

4. The Parties shall make every effort to reach agreement on any proposed annex or amendment to an annex by consensus. If all efforts at consensus have been exhausted, and no agreement reached, the annex or amendment to an annex shall as a last resort be adopted by a three-fourths majority vote of the Parties present and voting at the meeting. The adopted annex or amendment to an annex shall be communicated by the secretariat to the Depositary, who shall circulate it to all Parties for their acceptance.

5. An annex, other than Annex A or B, that has been adopted or amended in accordance with paragraphs 3 and 4 above shall enter into force for all Parties to this Protocol six months after the date of the communication by the Depositary to such Parties of the adoption or amendment of the annex, except for those Parties that have notified the Depositary in writing within that period of their non-acceptance of the annex or amendment to the annex. The annex or amendment to an annex shall enter into force for Parties which withdraw their notification of non-acceptance on the ninetieth day after the date on which withdrawal of such notification has been received by the Depositary.

6. If the adoption of an annex or an amendment to an annex involves an amendment to this Protocol, that annex or amendment to an annex shall not enter into force until such time as the amendment to this Protocol enters into force.

7. Amendments to Annexes A and B to this Protocol shall be adopted and enter into force in accordance with the procedure set out in Article 20, provided that any amendments to Annex B shall be adopted only with the written consent of the Party concerned.

Article 22

1. Each Party shall have one vote, except as provided for in Paragraph 2 below.

2. Regional economic integration organizations, in matters within their competence, shall exercise their right to vote with a number of votes equal to the number of their member States which are Parties to this Protocol. Such an organization shall not exercise its right to vote if any of its member States exercises its right, and vice versa.

Article 23

The Secretary-Generl of the United Nations shall be the Depositary of this Protocol.

Article 24

1. This Protocol shall be open for signature and subject to ratification, acceptance or approval by States and regional economic integration organizations which are Parties to the Convention. It shall be open for signature at United Nations Headquarters in New York from 16 March 1998 to 15 March 1999. This Protocol shall be open for accession from the day after the date on which it is closed for signature. Instruments of ratification, acceptance, approval or accession shall be deposited with the Depositary.

2. Any regional economic integration organization which ~~becomes~~ a Party to this Protocol without any of its member States being a Party shall be bound by all the obligations under this Protocol. In the case of such organizations, one or more of whose member States is a Party to this Protocol, the organization and its member States shall decide on their respective responsibilities for the performance of their obligations under this Protocol. In such cases, the organization and the member States shall not be entitled to exercise rights under this Protocol concurrently.

3. In their instruments of ratification, acceptance, approval or accession, regional economic integration organizations shall declare the extent of their competence with respect to the matters governed by this Protocol. These organizations shall also inform the Depositary, who shall in turn inform the Parties, of any substantial modification in the extent of their competence.

Article 25

Entry into force

1. this Protocol shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Parties included in Annex I which accounted in total for at least 55 per cent of the total

carbon dioxide emissions for 1990 of the Parties included in Annex I, have deposited their instruments of ratification, acceptance, approval or accession.

2. For the purposes of this Article, "the total carbon dioxide emissions for 1990 of the Parties included in Annex I" means the amount communicated on or before the date of adoption of this Protocol by the Parties included in Annex I in their first national communications submitted in accordance with Article 12 of the Convention.

3. For each State or regional economic integration organization that ratifies, accepts or approves this Protocol or accedes thereto after the conditions set out in paragraph 1 above for the entry into force have been fulfilled, this Protocol shall enter into force on the ninetieth day following the date of deposit of its instrument of ratification, acceptance, approval or accession.

4. For the purposes of this Article, any instrument deposited by a regional economic integration organization shall not be counted as additional to those deposited by States members of the organization.

Article 26

No reservations may be made to this Protocol.

Article 27

1. At any time after three years from the date on which this Protocol has entered into force for a Party, that Party may withdraw from this Protocol by giving written notification to the Depositary.

2. Any such withdrawal shall take effect upon expiry of one year from the date of receipt by the Depositary of the notification of withdrawal, o on such later date as may be specified in the notification of withdrawal.

3. Any Party that withdraws from the Convention shall be considered as also having withdrawn from this Protocol.

Article 28

The original of this Protocol, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations.

Done at Kyoto this tenth day of December one thousand nine hundred and ninety-seven.

Annex A

Greenhouse gases

Carbon dioxide ($CO_2$)

Methane ($CH_4$)

Nitrous oxide ($N_2O$)

Hydrofluorocarbons (HFCs)

Perfluorocarbons (PFCs)

Sulphur hexafluoride (SF6)

Sectors/source categories

Energy

Fuel combustion

Energy industries

Manufacturing industries and construction

Transport

Other sectors

Other

Fugitive emissions from fuels

Solid fuels

Oil and natural gas

Other

Industrial processes

Mineral products

Chemical industry

Metal production

Other production

Production of halocarbons and sulphur hexafluoride

Consumption of halocarbons and sulphur hexafluoride

Other

Solvent and other product use

Agriculture

Enteric fermentation

Manure management

Rice cultivation

Agricultural soils

Prescribed burning of savannas

Field burning of agricultural residues

Other

Waste

Solid waste disposal on land

Wastewater handling

Waste incineration

Other

Annex B

| Party | Quantified emission limitation or reduction commitments (percentage change from 1990) |
| --- | --- |
| Australia | (to be completed) |
| Austria | |
| Belgium | |
| Bulgaria* | |
| Canada | |
| Croatia* | |
| Czech Republic* | |
| Denmark | |
| Estonia* | |
| European Community | |
| Finland | |
| France | |
| Germany | |
| Greece | |
| Hungary* | |
| Iceland | |
| Ireland | |
| Italy | |
| Japan | |
| Latvia* | |
| Liechtenstein | |
| Lithuania* | |
| Luxembourg | |
| Monaco | |
| Netherlands | |
| New Zealand | |
| Norway | |
| Poland* | |
| Portgual | |
| Romania* | |

Russian Federation*
Slovakia*
Slovenia*
Spain
Sweden
Switzerland
Ukraine*
United Kingdom of Great Britain and
Northern Ireland
United States of America
*Countries that are undergoing the process of transition to a market economy.

Back to top

# FAO PRODUCTION YEARBOOK

| | |
|---|---|
| LAND USE | Land Use Country Notes |
| IRRIGATION | Specific Country Notes |
| General Country Notes | |

**Land use (land cover)**

It should be borne in mind that definitions used by reporting countries vary considerably and items classified under the same category often relate to greatly differing kinds of land.

Definitions of land use (land cover) categories are as follows:

11 Total Area 1000ha:
the total area of the country, including area under inland water bodies. Data in this category are obtained mainly from the United Nations Statistical Division, New York. Possible variations in the data may be due to updating and revisions of the country data and not necessarily to any change of area.

31 Land Area 1000ha:
total area excluding area under inland water bodies. The definition of inland water bodies generally includes major rivers and lakes. Data in this category are obtained mainly from the United Nations Statistical Division, New York. Possible variations in the data may be due to updating and revisions of the country data and not necessarily to any change of area.

51 Agricultural Area 1000ha:
up to 1994, this element shows total of data under Elements 061 (Arable land and Permanent crops) and 131 (Permanent pastures).

61 Arable and Permanent Crops 1000ha:
Arable land and land under permanent crops shows the total of data in Elements 071 (Arable land) and 121 (Permanent crops).

71 Arable Land 1000ha:
land under temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included in this category. Data for "Arable land" are not meant to indicate the amount of land that is potentially cultivable.

121 Permanent Crops 1000ha:
land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee and rubber; this category includes land under flowering shrubs, fruit trees, nut trees and vines, but excludes land under trees grown for wood or timber.

131 Permanent Pasture 1000ha:
land used permanently (five years or more) for herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land). The dividing line between this category and the category "Forests and woodland"; is rather indefinite, especially in the case of shrubs, savannah, etc., which may have been reported under either of these two categories. In the year 1995 and onward there will be no data for this element.

141 Forests and Woodland 1000ha:
land under natural or planted stands of trees, whether productive or not. This category includes land from which forests have been cleared but that will be reforested in the foreseeable future, but it excludes woodland or forest used only for recreation purposes. The question of shrub land, savannah, etc. raises the same problem as in the category "Permanent meadows and pastures". In the year 1995 and onward there will be no data for this element.

181 All Other Land 1000ha:
up to 1994, this category includes any other land not specifically listed under elements 051

(Agricultural land) and 141 (Forests and Woodland). This element includes: built-on areas, roads, barren land, etc. for which no specific data are available.

191 Non arable and permanent crops 1000ha:

from 1995 this element includes any other land not specifically listed under elements 061 (Arable land and Permanent crops) i.e.: permanent pastures, forests and woodland, built on areas, roads, barren lands, etc.

## LAND USE COUNTRY NOTES

The following are specific country notes pertaining to land-use (land-cover) categories:

*Australia:* Data on arable land include about 27 million hectares of cultivated grassland.

*Greenland:* "Total area" refers to area free from ice.

*Mauritius:* Data on total area exclude dependencies.

*Russian Federation:* Data on total area exclude the portion of land under the White Sea and the Azov Sea.

*Switzerland:* Data from 1992, with the exception of "Total area" are not comparable with those of the previous years because of a new statistical method recently applied by the country.

*Ukraine:* Data on total area exclude the portion of land under the Azov Sea.

*USSR:* Data on total area include the White Sea (9 million hec tares) and the Azov Sea (3.73 million hectares). Data on arable land and land under permanent crops and on permanent meadows and pastures refer to the land being used by agricul tural undertakings and farms, i.e. excluding State land reserves and areas belonging to nonagricultural undertakings.

## Irrigation

051 Irrigated Area 1000ha:

Data on irrigation relate to areas equipped to provide water to the crops. These include areas equipped for full and partial control irrigation, spate irrigation areas, and equipped wetland or inland valley bottoms.

The following are specific country notes:

*Cuba:* Data refer to State sector only.

*Hungary:* Data exclude complementary farm plots and individual farms.

*Japan; Korea, Republic of; Sri Lanka:* Data refer to irrigated rice only.

## GENERAL COUNTRY NOTES

Anguilla

Data for Anguilla are included with those of Saint Kitts and Nevis.

China

Data for China generally include those for Taiwan (Province of China).

Cyprus

As a result of the present situation in Cyprus, data refer to the governmentcontrolled area only, except for total area and Population where data refer to all Cyprus.

Czech Republic, Slovakia

Starting in 1993, these independent republics, formerly Czecho slovakia, are shown separately.

East Timor

Most data for recent years are included in those of Indonesia.

Eritrea, Ethiopia

Starting in 1993, Eritrea and Ethiopia, formerly Ethiopia PDR, are shown separately.

Independent republics of the USSR

Starting in 1992, the independent republics Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan are shown separately in Asia, while Belarus, Estonia, Latvia, Lithuania, Moldova, the Russian Federation and Ukraine are shown separately in Europe. However, they are not included in the continental totals. Data before 1992 are shown under USSR.

Independent republics of Yugoslavia SFR

Starting in 1992, the independent republics Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Slovenia, and the Federal Republic of Yugoslavia (Serbia and Montenegro) are shown separately. Data for the years prior to 1992 are shown under Yugoslavia SFR.

India and Pakistan

Data relating to KashmirJammu, whose final status has not yet been determined, are generally included under India and excluded from figures for Pakistan. Data for Sikkim are included under India.

Pacific Islands

This heading includes data for the Republic of the Marshall Islands, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia and the Republic of Palau.

Saint Helena

Data for Saint Helena include those for Ascension and Tristan da Cunha.

Yemen

Data for the former Yemen Arab Republic and the former Yemen, Democratic, have been combined.

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| *LAND USE* | Year | | | | | |
|---|---|---|---|---|---|---|
| *LAND AREA (1000HA)* | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
| ALBANIA | 2,740 | 2,740 | 2,740 | 2,740 | 2,740 | 2,740 |
| AUSTRALIA | 768,230 | 768,230 | 768,230 | 768,230 | 768,230 | 768,230 |
| AUSTRIA | 8,273 | 8,273 | 8,273 | 8,273 | 8,273 | 8,273 |
| BEL-LUX | 3,282 | 3,282 | 3,282 | 3,282 | 3,282 | 3,282 |
| BULGARIA | 11,055 | 11,055 | 11,055 | 11,055 | 11,055 | 11,055 |
| CANADA | 922,097 | 922,097 | 922,097 | 922,097 | 922,097 | 922,097 |
| CZECHOSLOVAK | 12,536 | 12,536 | 12,536 | | | |
| DENMARK | 4,239 | 4,239 | 4,243 | 4,243 | 4,243 | 4,243 |
| ESTONIA | | | 4,227 | 4,227 | 4,227 | 4,227 |
| FINLAND | 30,459 | 30,459 | 30,459 | 30,459 | 30,459 | 30,459 |
| FRANCE | 55,010 | 55,010 | 55,010 | 55,010 | 55,010 | 55,010 |
| GERMANY | 34,927 | 34,927 | 34,927 | 34,927 | 34,927 | 34,927 |
| BOSNIA HERZG | | | 5,100 | 5,100 | 5,100 | 5,100 |
| GREECE | 12,890 | 12,890 | 12,890 | 12,890 | 12,890 | 12,890 |
| HUNGARY | 9,234 | 9,234 | 9,234 | 9,234 | 9,234 | 9,234 |
| CROATIA | | | 5,592 | 5,592 | 5,592 | 5,592 |
| ICELAND | 10,025 | 10,025 | 10,025 | 10,025 | 10,025 | 10,025 |
| IRELAND | 6,889 | 6,889 | 6,889 | 6,889 | 6,889 | 6,889 |
| ITALY | 29,406 | 29,406 | 29,406 | 29,406 | 29,406 | 29,406 |
| JAPAN | 37,652 | 37,652 | 37,652 | 37,652 | 37,652 | 37,652 |
| LATVIA | | | 6,205 | 6,205 | 6,205 | 6,205 |
| LIECHTENSTEN | 16 | 16 | 16 | 16 | 16 | 16 |
| LITHUANIA | | | 6,480 | 6,480 | 6,480 | 6,480 |
| NETHERLANDS | 3,392 | 3,392 | 3,392 | 3,392 | 3,392 | 3,392 |
| MACEDONIA | | | 2,543 | 2,543 | 2,543 | 2,543 |
| NEW ZEALAND | 26,799 | 26,799 | 26,799 | 26,799 | 26,799 | 26,799 |
| NORWAY | 30,683 | 30,683 | 30,683 | 30,683 | 30,683 | 30,683 |
| CZECH REP | | | | 7,728 | 7,728 | 7,728 |
| POLAND | 30,442 | 30,442 | 30,442 | 30,442 | 30,442 | 30,442 |
| PORTUGAL | 9,150 | 9,150 | 9,150 | 9,150 | 9,150 | 9,150 |
| ROMANIA | 23,034 | 23,034 | 23,034 | 23,034 | 23,034 | 23,034 |
| RUSSIAN FED | | | 1,688,850 | 1,688,850 | 1,688,850 | 1,688,850 |
| YUGOSLAVIA | | | 10,200 | 10,200 | 10,200 | 10,200 |
| SLOVENIA | | | 2,012 | 2,012 | 2,012 | 2,012 |
| SLOVAKIA | | | | 4,808 | 4,808 | 4,808 |
| SPAIN | 49,944 | 49,944 | 49,944 | 49,944 | 49,944 | 49,944 |
| SWEDEN | 41,162 | 41,162 | 41,162 | 41,162 | 41,162 | 41,162 |
| SWITZERLAND | 3,955 | 3,955 | 3,955 | 3,955 | 3,955 | 3,955 |
| UK | 24,160 | 24,160 | 24,160 | 24,160 | 24,160 | 24,160 |

| | | | | | | |
|---|---|---|---|---|---|---|
| UKRAINE | | | 57,935 | 57,935 | 57,935 | 57,935 |
| USA | 915,912 | 915,912 | 915,912 | 915,912 | 915,912 | 915,912 |
| YUGOSLAV SFR | 25,540 | 25,540 | | | | |
| EC (15) | 313,183 | 313,183 | 313,187 | 313,187 | 313,187 | 313,187 |
| E EUROPE | 114,581 | 114,581 | 114,488 | 114,488 | 114,488 | 114,488 |

| *LAND USE* | Year | | | | | |
|---|---|---|---|---|---|---|
| *FOREST&WOOD (1000HA)* | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
| ALBANIA | 1,045 | 1,050 | 1,051 | 1,048 | 1,048 | 0 |
| AUSTRALIA | 145,613 | 145,000 | 145,000 | 145,000 | 145,000 | 0 |
| AUSTRIA | 3,227 | 3,227 | 3,218 | 3,240 | 3,240 | 0 |
| BEL-LUX | 709 | 709 | 709 | 709 | 709 | 0 |
| BULGARIA | 3,345 | 3,348 | 3,348 | 3,348 | 3,348 | 0 |
| CANADA | 453,300 | 453,300 | 453,300 | 453,300 | 453,300 | 0 |
| CZECHOSLOVAK | 4,618 | 4,619 | 4,618 | | | |
| DENMARK | 417 | 417 | 417 | 417 | 417 | 0 |
| ESTONIA | | | 2,016 | 2,022 | 2,017 | 0 |
| FINLAND | 23,373 | 23,222 | 23,186 | 23,186 | 23,186 | 0 |
| FRANCE | 14,811 | 14,850 | 14,872 | 14,931 | 15,012 | 0 |
| GERMANY | 10,735 | 10,700 | 10,700 | 10,700 | 10,700 | 0 |
| BOSNIA HERZG | | | 2,100 | 2,000 | 2,000 | 0 |
| GREECE | 2,620 | 2,620 | 2,620 | 2,620 | 2,620 | 0 |
| HUNGARY | 1,675 | 1,701 | 1,712 | 1,719 | 1,719 | 0 |
| CROATIA | | | 2,074 | 2,076 | 2,076 | 0 |
| ICELAND | 123 | 120 | 120 | 120 | 120 | 0 |
| IRELAND | 500 | 570 | 570 | 570 | 570 | 0 |
| ITALY | 6,760 | 6,764 | 6,772 | 6,800 | 6,809 | 0 |
| JAPAN | 25,105 | 25,230 | 25,230 | 25,100 | 25,000 | 0 |
| LATVIA | | | 2,815 | 2,839 | 2,870 | 0 |
| LIECHTENSTEN | 3 | 3 | 3 | 3 | 3 | 0 |
| LITHUANIA | | | 1,983 | 1,983 | 1,983 | 0 |
| NETHERLANDS | 334 | 334 | 334 | 334 | 334 | 0 |
| MACEDONIA | | | 1,066 | 1,020 | 1,020 | 0 |
| NEW ZEALAND | 7,667 | 7,667 | 7,667 | 7,667 | 7,667 | 0 |
| NORWAY | 8,330 | 8,330 | 8,330 | 8,330 | 8,330 | 0 |
| CZECH REP | | | | 2,629 | 2,629 | 0 |
| POLAND | 8,672 | 8,732 | 8,732 | 8,732 | 8,732 | 0 |
| PORTUGAL | 3,102 | 3,102 | 3,102 | 3,102 | 3,102 | 0 |
| ROMANIA | 6,685 | 6,680 | 6,682 | 6,682 | 6,680 | 0 |
| RUSSIAN FED | | | 767,693 | 768,436 | 765,912 | 0 |
| YUGOSLAVIA | | | 1,769 | 1,769 | 1,769 | 0 |
| SLOVENIA | | | 1,077 | 1,077 | 1,077 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| SLOVAKIA | | | | 1,989 | 1,989 | 0 |
| SPAIN | 15,807 | 15,858 | 15,915 | 16,137 | 16,137 | 0 |
| SWEDEN | 28,025 | 28,025 | 28,025 | 28,025 | 28,025 | 0 |
| SWITZERLAND | 1,186 | 1,186 | 1,186 | 1,186 | 1,186 | 0 |
| UK | 2,326 | 2,390 | 2,390 | 2,390 | 2,390 | 0 |
| UKRAINE | | | 9,239 | 9,239 | 9,239 | 0 |
| USA | 295,990 | 295,990 | 295,990 | 295,990 | 295,990 | 0 |
| YUGOSLAV SFR | 9,118 | 9,120 | | | | |
| EC (15) | 112,746 | 112,788 | 112,830 | 113,161 | 113,251 | 0 |
| E EUROPE | 35,158 | 35,250 | 34,229 | 34,089 | 34,087 | 0 |

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# CALIBRATION OF THE SECOND GENERATION MODEL

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CALIBRATION OF THE SECOND GENERATION MODEL

Methods and tools used to calibrate specific computable general equilibrium models (CGEMs) have been extensively documented in recent years (e.g. Mansur and Whalley (1984), and Ballard et al. (1985)). Many embodiments of CGEMs have sufficiently similar properties that relatively standard techniques can be employed to implement them. When model design departs substantially from the norm, existing methods must be extended and new methods developed.

The second generation model (SGM) is a CGEM which was designed specifically to address issues associated with global change. As a consequence, the model embodies characters which are novel and interesting. A theoretical description of the model is contained in Edmonds et al (1993). Because the model must be capable of addressing major issues associated with both the emission of radiatively important gases and the potential consequences of atmosphere/-climate change, the model was designed to perform three tasks:

1. Provides estimates of environmentally important emissions associated with human activities,

2. Provides estimates of the consequences of global environmental change, with particular emphasis on human activities, and

3. Provides estimates of the economic consequences of actions to mitigate and adapt to global environmental change.

Further, the nature of the global change problem dictates that the SGM reflect the following characteristics:

1. The issue is **global**, emissions from all sources in all regions of the world determine total atmospheric change,

2. Anticipated changes in the greenhouse effect result from the emission of a **number of gases** including: $CO_2$, $CH_4$, CO, N2O, $NO_x$, $SO_2$, VOCs, CFCs, and CFC substitutes,

3. **Many human activities** are involved in both emissions and impacts including: Agriculture and Forestry, Energy Production and Consumption, Transportation, Manufacture, Services, Coastal Zone Settlement, Health Care, Water Use, and Land Use,

4. Emissions and impacts depend upon multiple **resources and technologies** including: Managed and Unmanaged Ecosystems, Capital Stocks, and Labor,

5. Emissions and impacts also depend on **international trade patterns**, and possibly, migration patterns,

6. Factors 3, 4, and 5 depend upon **institutional arrangements**,

7. Policy analysis requires both mid-term (5-year) and long-term (100 year) **time horizons**.

As a consequence, the SGM differs from other CGEMs in that it includes:

1. an energy/agriculture focus;
2. a putty-clay vintaged representation of capital;
3. land as a factor of production;
4. depletable natural resources;
5. competition among technologies; and
6. sector- and subsector-level investment decisions.

This paper provides a complete description of how the SGM was calibrated including the methods and tools from existing literature which were applied and the calibration methods which were developed to handle the unique features of the SGM. In addition, the important underlying assumptions and procedures used to produce a data set consistent with the general theoretic principles of the SGM are presented.

## I. CALIBRATION VS. MACROECONOMIC PRACTICE

An essential step in applying general equilibrium analysis is the construction of a benchmark data set for the base year of simulation. Contrary to standard macroeconomic models, which are estimated econometrically from time-series data, parameters for most computable general equilibrium models (CGEMs) are not estimated with econometric techniques[1]. From a practical standpoint, this can easily be explained by the number of parameters involved. More importantly, however, is the absence of input-output time series data with satisfactory levels of disaggregation which makes econometric estimations of some model parameters virtually impossible. Although Chipman [1991] demonstrates that the number of observations does not have to be greater than the number of parameters to be estimated in a CGEM, the number of parameters requiring estimation within the SGM is too large for econometric estimation to be a feasible option. This is largely due to the SGM's requirement of 6-digit input-output tables to describe the economy in appropriate detail when, as is the case with the U.S., such data requirements are only published every 5 years[2]. In addition to the problems of data availability, parameters estimated econometrically over 5, 10, or 20 years can be questionable when used for long-term projections[3]. As a result of these data constraints, the method of calibration, described as the process of choosing model parameters to exactly reproduce observations in a given base year, is widely used by developers of CGEMs.

As with econometric estimation, calibration also has its limitations. The method of calibration not only assumes that benchmark year data reflect an economy in equilibrium, it also assumes that the benchmark equilibrium is representative of a "normal" growth path. Input-output tables and national accounts are well suited for use in general equilibrium analysis since they reflect an economy where supply equals demand (including trade). Budget constraints for the government and household sectors, however, are not explicitly reflected in input-output tables, thus requiring some work to reconcile input-output observations with these constraints.

[1] The Jorgenson/Wilcoxen [1990] model is an exception to this rule.
[2] Chipman [1991] shows that to econometrically estimate a linear approximation of a CGEM with 10,000 parameters, a minimum of 8 years of quarterly observations (25 observations) are required.
[3] Reliability, however, can be enhanced with the use of elasticities given by the literature and a comprehensive sensitivity analysis.

## II. DATA REQUIREMENTS

The objective of calibration, as previously mentioned, is to choose model parameters so as to exactly reproduce data observations in the chosen base year. Essentially, the calibration process consists of translating available data into a problem-oriented data set which is used not only to reproduce observations in the benchmark years, but also to make long-term projections. A set of appropriate input-output tables (e.g., the 6-digit level 1982 benchmark tables for the US, published by the US Department of Commerce), and the national accounts are the basis for the calibration of the SGM. Other data sources include: 1) time series data on gross capital stocks and discards for each major industry and service, 2) energy data, and 3) input-output tables and national accounts for 1985, the actual benchmark year of the model. Key-parameters, such as elasticities of substitution in production, and income and price elasticities of final demand sectors, were obtained from existing literature.

### II.a. Intermediate Production

In order to acquire the model parameters necessary to estimate intermediate production by SGM industry, data are required on the use of factors by industry, and input-output transactions. The "use" and "make" tables of the input-output accounts published by the Bureau of Economic Analysis (Department of Commerce, BEA 1982) provide the necessary data on factor requirements, value-added, and final demand to develop most of these model parameters. The "use" table provides the value of (1) each industry's consumption of commodities as factors of production, (2) each industry's value-added components (i.e., labor expenditures, indirect business taxes, and other value-added components), and (3) final demands for commodities.

Each column in the interindustry portion of the "use" table describes production within a specific industry while the row values pertain to the amount consumed of each commodity as input to the industry's production process. Therefore, the "use" table dimensions of commodity-by-industry. Because of joint production (i.e., multiple commodities produced in a single industry), output by industry is different than output by commodity; hence, row sums do not equal column sums in the "use" table. This presents a problem when using these data to calibrate production functions within a CGE modeling framework where single commodity production is assumed.

In order to produce an "use" table where row sums equal column sums, the construction of a commodity-by-commodity or industry-by-industry "use" table is required. A commodity-by-commodity table was constructed for the SGM since the units of output pertain to actual commodity units and not to a mix of commodities as is the case with an industry-by-industry table. This commodity-by-commodity table was constructed by combining data from the "use" table with data from the "make" table. The "make" table provides a distribution of commodity production across industries. Each row in the "make" table pertains to a single industry and gives the amount produced of each commodity within that industry. Thus, the dimensions of the "make" table are industry-by-commodity. By normalizing this "make" table and post-multiplying it with the "use" table (i.e., "use" table X normalized "make" table), a commodity-by-commodity "use" table is obtained.

Before the "use" and "make" tables can be combined, however, translation of the more disaggregate BEA industry categories to SGM categories is required. The BEA publishes two types of input-output accounts; the "benchmark" I-O accounts and the annual I-O accounts. The benchmark I-O accounts are published for economic census years and therefore include more detailed data than are available on an annual basis. Annual I-O accounts, although published more frequently, include 85 industry categories while the benchmark I-O accounts include 500 industry categories. Although the base year of the SGM is 1985, data from the 1985 annual I-O accounts are not used directly to calibrate the SGM; rather these data are used to project observations of the 1982 benchmark I-O accounts to 1985 levels. This is due to the energy sector detail required in the SGM which is only available in benchmark years.

Table 1 provides a mapping of BEA's 1982 benchmark I-O industry categories to SGM categories. Although most SGM categories are aggregations of BEA categories, a few SGM categories are actually portions of more aggregate BEA categories. In particular, the SGM Crude Oil Extraction and Natural Gas Extraction categories were created by separating the two from the more aggregate BEA category, Crude Oil and Natural Gas Extraction. To separate the two industries, it was assumed that (1) all crude oil and natural gas demand from the Oil Refining industry is actually only crude oil, and (2) all crude oil and natural gas demand from the Gas Transmission and Distribution industry is actually natural gas.

The SGM industry "Uranium Mining and Processing" also required some manipulation of the I-O accounts data. Through discussions with BEA staff, values of uranium mining and uranium processing were determined and extracted from the more aggregate BEA categories of "Nonferrous Metal Ores Mining" and "Industrial Inorganic Chemicals n.e.c".

Table 1

| SGM Industry Category | BEA Category | Standard Industrial Classification | BEA Classification |
|---|---|---|---|
| Agriculture | Agriculture, Forestry and Fishing; Food and Kindred Products | 01 - 09,20 | 01 - 04,14 |
| Crude Oil Extraction | Crude Petroleum & Natural Gas* | 13 | 08 |
| Natural Gas Extraction | Crude Petroleum & Natural Gas* | 13 | 08 |
| Coal Mining | Coal Mining | 12 | 07 |
| Uranium Mining and Processing | Nonferrous Metal Ores Mining, except Copper* | 1094 | 0602 |

| | | | |
|---|---|---|---|
| | Industrial Inorganic Chemicals n.e.c* | 2819 | 270104 |
| Electricity Generation, Transmission & Distribution | Private Electric Services (Utilities) | 4911 | 6801 |
| | Federal Electric Utilities | | 7802 |
| | State & Local Electric Utilities | | 7902 |
| Oil Refining | Petroleum Refining | 2911 | 310101 |
| | Products of Petroleum & Coal n.e.c. | 2999 | 310103 |
| Gas Transmission & Distribution (utilities) | Private Gas Production | 492 | 6802 |
| Other Products | All other industries | | |

* Part of this industry category.

Upon completion of the commodity-by-commodity (CXC) "use" table, values are adjusted to 1985 levels by using data obtained from the 1985 input-output accounts. Industry output and intermediate consumption totals in 1985 for each of the SGM commodities are estimated using the 1985 I-O data. Using these totals, CXC table values are then adjusted using the RAS (row and column sum) adjustment procedure developed by Michael Bacharach [1971][4]. Other adjustments to the CXC table include industry-specific data reconciliation; for example, splitting crude oil from natural gas and ensuring that uranium is only consumed by the electric generation and defense industries.

### II.b. Industry Value Added

Once completed, this CXC table provides the necessary information on the use of produced commodities in the production of other commodities which will be used in the computation of each industry's production function coefficients. Before these coefficients can be estimated, however, information on the use of non-produced factors of production (i.e., land and labor) is required. Each industry's land and labor expenditures are included in the value added portion of the I-O accounts. For benchmark years (e.g., 1982), the value added portion of the I-O accounts included the following components: (1) "compensation of employees" (labor expenditures), (2) "indirect business taxes" (e.g., sales taxes, excise taxes, property taxes, import taxes (duties)), (3)

[4] This procedure adjusts the values within the matrix so that the row and column sums equal the 1985 estimated totals.

"other value added" (e.g., profits, land rents). In order to obtain information on land and labor expenditures in the form required by the SGM, some adjustments to the data provided in the I-O accounts are necessary.

### Land

In the I-O accounts, the real estate industry includes rents for buildings but not for land. Land rents paid by each industry is included in the "other value added" component of value added in the I-O accounts. A separate land component is imperative for the SGM to study the effects of greenhouse gas emissions on land use; particularly for the Agriculture sector. The land component for each SGM industry was separated from the "other value added" component by estimating each industry's expenditures on land. Land rents by SGM industry were estimated by applying an average cost of agricultural land (based on data obtained from the U.S. Department of Agriculture) to land use data from the "Statistical Abstract of the U.S." published by the Department of Commerce[5]. These estimates of land rents for each SGM industry are added as a separate component to each industry's value added and accounted for by subtracting an equal value from the "other value added" component of value added.

### Labor

Industry labor expenditures are given in the "use" table of the I-O accounts as a component of value added called "compensation of employees". These data are aggregated to SGM industries at the same time as intermediate production. The only adjustment to the industry labor component is the extraction of labor used for government services from the "Other Products" industry sector. Prior to SGM industry aggregation, the industrial production component of the I-O accounts includes a "Government Industry" which contains labor as its only input to production. (This industry was added to the "Other Products" industry during SGM industry aggregation). Since the calibration of the government services' utility function (discussed in Section III.d. below) is conducted separately from industrial production, government labor expenditures need to be included with other government expenditures in the final demand portion of the I-O accounts. Therefore, government services labor expenditures are extracted from the "Other Products" sector and added as another component of the government's final demand.

### Corporate Retained Earnings

Included in the total amount of savings available for investment is corporate retained earnings; the amount of corporate profits retained for investment purposes. The SGM estimates the corporate retained earnings rate (the percentage of corporate profits retained) for each sector as follows:

$$RE_i = \alpha_i (1 - e^{r \cdot \beta_i}) \qquad (1)$$

where

---

[5] An average agricultural land rental price was used on the assumption that (1) agricultural land makes up the majority of total usable land area and (2) the differential from urban land prices will be reflected in the constant term of the production function.

| | | |
|---|---|---|
| $RE_i$ | = | corporate retained earnings rate of sector i; |
| $\alpha_i$ | = | the maximum potential retained earnings rate; |
| r | = | the real market interest rate; and |
| $\beta_i$ | = | the retained earnings sensitivity to the real interest rate. |

Although separate retained earnings rates are defined for each sector, an average retained earnings rate over all sectors was applied to each. To calibrate equation (1) to the 1985 base year it is necessary to first calculate an actual retained earnings rate over all sectors for 1985 by dividing 1985 total corporate retained earnings by 1985 total corporate profits obtained from the "Economic Report of the President, 1992". Next, the maximum potential retained earnings rate was estimated from historical data to be 0.60 (i.e., the percentage of corporate profits retained would never expect to be higher than 60%). Last, assuming a real market interest rate of 3%, the sensitivity parameter (bi) can be directly calculated from equation (1).

## II.c. Capital Inputs

In addition to the factor inputs described in the I-O accounts, data on the underlying capital stock used in production are also required to compute each industry's production function coefficients. The SGM requires productive capital stock of each industry to be divided into "vintages" corresponding to the 5-year period in which the capital was initially purchased. "Vintaged" capital stock allows for improvements in production efficiency (e.g., as a result of technological change) within an industry. The SGM also assumes capital to be a fixed factor of production and to be completely productive until its average lifetime is reached[6]. The SGM assumes that at any period of time, an industry produces using capital stock from the number of vintages equal to the average lifetime of capital in that industry divided by 5 (length of a SGM time step (period)). For example, in period 1 (which includes the years 1986 to 1990) an industry with an average capital lifetime of 20 years would have four vintages of capital stock: (1) capital stock purchased during the period 1971-1975, (2) capital stock purchased during the period 1976-1980, (3) capital stock purchased during the period 1981-1985, and (4) capital stock purchased in the current period 1986-1990. Each of these capital stocks would be used to produce output in period 1.

Annual equipment and structures capital stock data were obtained from the "Fixed Reproducible Tangible Wealth in the United States" published by the BEA and are consistent with the national income and product accounts (NIPA). These data include annual values by BEA industry category for gross capital stock, capital inputs, net capital stock, depreciation, and discards. As with the I-O tables, these data require conversion from BEA industries to SGM industries.

To calculate capital stock by vintage for each SGM industry, it is necessary to first calculate annual investment by industry as the difference between the industry's current year's gross capital stock and last year's gross capital stock plus the current year's discards. Capital stock by vintage is calculated by taking the sum of investment over the vintage's corresponding 5-year period and subtracting the "vintage" discards which are calculated on the basis of lifetimes of equipment and structures, and annual investment numbers[7].

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[6] This differs from typical accounting methods in which capital is depreciated over time.

[7] Note: Since the BEA capital stock data includes actual discards which do not always occur at the exact end of the capital's lifetime (some capital could have been discarded before or after the capital's average

As discussed previously, the production function for each industry is the sum of separate CES production functions for each vintage. For example, an industry with an average capital lifetime of 20 years would have the following production function in Period 0:

$$Q_{0,s} = q_{0,s} + q_{-1,s} + q_{-2,s} + q_{-3,s} \tag{2}$$

where

| | | |
|---|---|---|
| $Q_{0,s}$ | = | total production of commodity s in period 0; and |
| $q_{v,s}$ | = | output of commodity s produced with vintage v capital stock (based on a CES production function). |

This specification allows for improvements in productivity (e.g., technological change) over time. This improvement in productivity is based on the Hicks-neutral technological change rate which consists of a percentage rate of change in production efficiency incorporated into the scale factor (a0) of each vintage's CES production function. Table 2 presents the average capital lifetimes and the historical rate of Hick's-neutral technological change assumption for each SGM sector. These rates were calculated based on historical data on the use of factor inputs in production, and are applied only to historical vintages in the SGM (i.e., vintages prior to period 0). Future productivity growth assumptions were determined separately and are documented in Fisher-Vanden, et. al. [1993].

Table 2

| SGM Industry Category | Average Capital Lifetime (in years) | Rate of Hick's-neutral Technological Change (in %)* | Elasticity of Substitution in Production |
|---|---|---|---|
| Agriculture | 20 | 0 | 0.4 |
| Crude Oil Extraction | 15 | 1.5 | 0.5 |
| Natural Gas Extraction | 15 | 1.5 | 0.5 |
| Coal Mining | 15 | 2.5 | 0.5 |
| Uranium Mining and Processing | 15 | 1.0 | 0.5 |

lifetime), adjustments to the capital stock data are needed to reflect the SGM assumption that discards occur at the time the capital's lifetime has been reached. This is done by summing annual investment values (the difference between the current year's gross capital stock and last year's gross capital stock plus the current year's annual discards value given by the BEA) over the 5-year vintage period and adding a "vintage" discards value which is calculated based on the SGM capital retirement assumption. By calculating vintage capital stock this way, the only discards taken into account are those based on the SGM assumption; BEA discards are not included. Since capital stock values include equipment and structures, "vintage" discards in these benchmark data will only exist in cases where either an industry's equipment or structure lifetime is less that the average lifetime for both equipment and structures. This is done only for benchmarking purposes only, and once in the SGM, equipment and structures are combined and retired at the average lifetime of both.

| | | | |
|---|---|---|---|
| Electricity Generation, Transmission, and Distribution | 35** | 1.0 | 0.2 |
| Oil Refining | 30 | 0.5 | 0.1 |
| Gas Transmission and Distribution | 30 | 0.5 | 0.15 |
| Everything Else | 20 | 0.5 | 0.5 |

* Applied to vintages prior to period 0.
** Except for hydroelectric power plants (65 years).

### II.d. Subsectors

In order to fully understand the effects of certain economic activities on potential greenhouse gas emissions and to adequately address the consequences of certain policy actions to reduce greenhouse gas emissions on these activities, some further disaggregation of SGM industries is necessary. In this version of the SGM, the following disaggregation of particular SGM industries was done: (1) the Crude Oil Extraction sector was disaggregated into three subsectors each representing a different "grade" of crude oil; (2) the Natural Gas Extraction sector was also disaggregated into three subsectors each representing a different "grade" of natural gas; and (3) the Electricity Generation sector was disaggregated into six subsectors each representing a different method of electricity generation (e.g., oil-fired electricity generation).

"Grades" of crude oil and natural gas pertain to different levels of extraction costs[8]. For example, grade 1 of crude oil has the lowest cost of extraction which could represent the process of extracting oil close to the earth's surface. Grade 3, on the other hand, would have the highest cost of extraction and could represent extraction which requires much more extensive drilling procedures. Due to the different method of extraction associated with each "grade", a different production function specification is required for each grade. Using assumptions based on the cost of extraction for each grade, the I-O accounts and capital stock data for both the Crude Oil Extraction sector and Natural Gas Extraction sector are partitioned into different grades. It is important to note that although each grade has an associated method of extraction, the output produced is assumed to be homogeneous; thus, unlike sectors within the SGM, each grade faces a common output price of either crude oil or natural gas. Therefore, the likely outcome of the model would be that more of the "cheapest" grade (i.e., the grade with the lowest cost of extraction) would be produced relative to other grades.

The Electricity Generation sector was disaggregated into the following six subsectors based on the method of generation: (1) oil-fired electricity generation; (2) natural gas-fired electricity generation; (3) coal-fired electricity generation; (4) biomass-fired electricity generation; (5) nuclear electricity generation; and (6) hydro or solar electricity generation[9]. Data on annual net electricity generation by energy source and associated costs in addition to assumptions on capital intensity were used to separate the I-O accounts and capital stock data of the Electricity

[8] In the SGM, "grades" do not refer to the quality of crude oil extracted, but rather to the cost of extraction.
[9] Capital purchased in this subsector prior to 1991 is assumed to be used in hydroelectric generation. Subsequent purchases of capital are assumed to be used in solar electricity generation. Different "vintage" production functions are used to reflect this separation.

Generation sector into these six subsectors. As with Crude Oil and Natural Gas Extraction, these data are used to create production functions for each subsector and each subsector faces a common price of output (i.e., the price of electricity).

### II.e. Elasticities of Substitution in Production

The final items necessary to estimate production function parameters for each sector (or subsector) are assumptions on the elasticities of substitution among factors of production. Although in most cases elasticities of substitution for each production function were obtained from existing literature (e.g., Ballard et al [1985]), some were estimated based on the underlying assumptions of the SGM. For instance, since activities at a lower level of aggregation are being described within the electricity sector, a lower level of substitutability among factors is implied. Therefore, a quasi-Leontif production function (i.e., a CES production function with an elasticity of substitution value close to 0) was assumed for the electricity subsectors. Table 2 provides the elasticity of substitution values chosen for each sector in the SGM.

## III. ESTIMATION OF MODEL PARAMETERS

### III.a. Calibration of the CES Production Functions

As previously discussed, each SGM sector and subsector has associated with it a unique production function in order to reflect differences in production processes. As shown in equation (2) above, total production in each sector and subsector is the sum of vintage production (i.e., output associated with each vintage capital stock). Each vintage production is described by the following CES production function:

$$q_{v,s} = \alpha_{0,s,v} \left( \sum_{i=1}^{N-1} \alpha_{i,s} X_{i,s,v}^{\rho} + \alpha_{N,s} X_{N,s,v}^{\rho} \right)^{\frac{1}{\rho}} \qquad (v = -V_s \ldots 0) \tag{3}$$

where

| | | |
|---|---|---|
| $q_{v,s}$ | = | output of commodity s produced with vintage v capital stock; |
| $\alpha_{0,s,v}$ | = | scale coefficient in vintage v's production of commodity s; |
| $\alpha_{i,s}$ | = | factor intensity of the ith input in the production of commodity s; |
| N-1 | = | number of variable inputs (N = total number of inputs; 1 refers to the number of fixed factors (i.e., capital) in Version 0.0); |
| $X_{i,s,v}$ | = | demand for input i in vintage v's production of commodity s; |
| $\alpha_{N,s}$ | = | factor intensity of the capital input (input N) in the production of commodity s; |
| $X_{N,s,v}$ | = | demand for the capital input (input N) in vintage v's production of commodity s; |
| $\rho$ | = | elasticity of substitution parameter; and |
| $-V_s$ | = | oldest vintage capital stock for industry s (equal to the negative of the average lifetime of capital for industry s divided by the length of a period (i.e., 5 years) plus 1) |

As evident from equations (2) and (3), Version 0.0 of the SGM assumes that relative production function factor intensities do not differ between vintages. The difference in production between vintages is due to the overall efficiency of all inputs; not to the efficiencies (or inefficiencies) of individual inputs to production. Therefore, Version 0.0 of the SGM assumes that the factor intensity parameters of each vintage production function (within a sector or subsector) differ only by a scalar (reflected in the scale parameter ($\alpha_{0,s,v}$)). This scalar comprises the Hick's-neutral technological change parameter; a parameter which reflects the overall production efficiency of the vintage. The relative factor intensity parameters, therefore, do not differ between vintages within a sector or subsector and the scale parameters of each vintage production differ only by the rate of Hick's-neutral technological change.

As previously discussed, the following seven data items are required to estimate each sector's production function coefficients: (1) intermediate production data (based on the I-O accounts) by sector and subsector; (2) industry value-added data (also based on the I-O accounts) by sector and subsector; (3) final demand sector and subsector data; (4) capital stock data by sector and subsector and vintage; (5) assumptions on the lifetimes of each sector's capital stock; (6) assumptions on the rate of Hick's-neutral technological change; and (7) assumptions on the elasticities of substitution in production. Once these data are compiled, a method to compute CES production function coefficients is applied. This method was specially developed for the SGM in order to handle vintaged capital stock in production. The steps involved in the computation of these coefficients are as follows:

1. Except for land and labor, set all 1985 input prices[10] equal to 1. Compute the price of land and labor as follows[11]:

$$P_{land} = \frac{TE_{land}}{Total\ Land} \tag{4}$$

$$P_{labor} = \frac{TE_{labor}}{Total\ Labor} \tag{5}$$

where

| | | |
|---|---|---|
| $TE_{land}$ | = | Total land expenditures in 1985 (discussed in Section 3.2.2). |
| $TE_{labor}$ | = | Total labor expenditures in 1985 (based on I-O accounts). |
| Total Land | = | Total U.S. managed land in 1985 (in 1000 $km^2$). |
| Total Labor | = | Total U.S. employed population in 1985 (in 1000 persons). |

2. Compute the output price of a commodity as,

[10] Setting an input price to 1 is interpreting the unit good as the quantity of the input which can be purchased in 1985 with 1 million 1982 dollars (since the data of the SGM are in millions of 1982 dollars).
[11] Since the price of land is obtained by dividing 1985 total land expenditures (in millions of 1982 dollars) by total managed land (in 1000 km2), the price of land can be interpreted as the millions of 1982 dollars required to purchase 1000 km2 of land in 1985. Similar to the interpretation of the price of land, the price of labor can be interpreted as the millions of 1982 dollars required to hire 1000 workers annually.

$$P_0 = \frac{TO - IBT}{TO} \tag{6}$$

where

| | | |
|---|---|---|
| $P_0$ | = | Output price of the commodity[12] (in millions of 1982 dollars). |
| TO | = | Total output of the commodity (in millions of 1982 dollars). |
| IBT | = | Total indirect business taxes paid in 1985 associated with the production of the commodity (in millions of 1982 dollars). |

3. As discussed above, relative factor intensities within a sector or subsector do not differ. Therefore, factor intensity parameters for the variable inputs can be calculated based on the assumption that total output is produced from one vintage (i.e., total production can be described by one CES production function rather than a summation of multiple CES production function (as in equation (2)). The production function factor intensity parameters for the variable inputs are computed using the following equation which is a direct result of the SGM's profit-maximizing assumption:

$$\alpha_{i,j} = \left(\frac{X_{i,j}}{X_{i,other}}\right)^{\frac{\rho}{\mu}} \frac{P_{0,j}}{P_{0,other}} \qquad i = 1 \ldots N-1 \tag{7}$$

where,

| | | |
|---|---|---|
| $\alpha_{i,j}$ | = | factor intensity of the ith input in the production of commodity j, |
| $X_{i,j}$ | = | total demand for the ith input in the production of commodity j, |
| $X_{i,other}$ | = | total demand for the ith input in the production of the "other products" commodity, |
| $P_{0,j}$ | = | output price ("price received") of commodity j, |
| $P_{0,other}$ | = | output price ("price received") of the "other products" commodity, |
| $\rho$ | = | elasticity of substitution parameter, |
| $\mu$ | = | $\rho / (\rho-1)$, |
| N-1 | = | number of variable inputs. |

**Derivation of Equation (7)**

Hotelling's Lemma states that the partial derivative of the profit function with respect to the price of the ith input results in the negative profit-maximizing total factor demand for that input; i.e.,

$$\frac{\partial \pi_s}{\partial P_{i,s}} = - X_{i,s} \tag{8}$$

where

$\pi_s$ = total profit in the production of commodity s; i.e.,

[12] This price refers to the price *received* by this sector. The price *paid* is set to 1 (as mentioned in the input price discussion previously) and is the same as the input price for the commodity produced in this sector. As implied, the price received by producers of a commodity is less than the price paid by purchasers of the commodity as long as IBT is positive (i.e., taxes paid in a sector is less than subsidies received).

$$\pi_s = P_{0,s} q_s - \sum_{i=1}^{N-1} P_{i,s} X_{i,s} \tag{9}$$

where

| | | |
|---|---|---|
| $P_{0,s}$ | = | output price (price received) of commodity s, |
| $P_{i,s}$ | = | input price (price paid) of the ith commodity in the production of commodity s, |
| $X_{i,s}$ | = | total demand of the ith input in the production of commodity s, |
| $q_s$ | = | total output of commodity s, |
| N | = | number of inputs to production, |
| N-1 | = | number of variable inputs to production (since there is only one fixed factor (capital)). |

Evaluating equation (8) using equation (9) and the "single vintage" CES production function defined as,

$$q_s = \alpha_{0,s} \left( \sum_{j=1}^{N-1} \alpha_{i,s} X_{i,s}^{\rho} + \alpha_{N,s} X_{N,s}^{\rho} \right)^{1/\rho} \tag{10}$$

the demand for the ith factor input to the production process can be directly calculated as,

$$X_{i,s} = \left( \alpha_{0,s} P_{0,s} \frac{\alpha_{i,s}}{P_{i,s}} \right)^{\frac{\mu}{\rho}} \left( \frac{Y}{Z} \right)^{\frac{1}{\rho}} \qquad i = 1 \ldots N-1 \tag{11}$$

where, assuming capital is the only fixed factor,

$$Y = \alpha_{N,s} X_{N,s}^{\rho} \tag{12}$$

and

$$Z = 1 - (\alpha_{0,s} P_{0,s})^{\mu} \left( \sum_{i=1}^{N-1} \alpha_{i,s}^{(\mu/\rho)} P_{i,s}^{-\mu} \right) \tag{13}$$

Equation (7) is the result of normalizing Xi,s in equation (11) by dividing by the factor input demand equation for the "Other Products" sector. Note: the aother,s parameter is assumed to be equal to 1 in order to obtain the $\alpha_{i,s}$ parameters in relative terms.

4. As discussed in Step 3, the vintage capital structure of the SGM does not affect the calculation of factor intensity parameters for variable inputs. This vintage capital structure, as designed in Version 0.0 of the SGM, allows for overall efficiency gains in the production process. These overall efficiency gains are incorporated into the scale factor for each vintage, defined as,

$$\alpha_{o,s,v} = \beta_{o,s} * (1 + g_s)^{5*v} \qquad (14)$$

where

$\alpha_{o,s,v}$ = scale factor in vintage v's production of commodity s;
$\beta_{o,s}$ = overall scale factor in the production of commodity s (constant between vintages);
$g_s$ = Hick's-neutral techological change rate in the production of commodity s;
v = vintage (e.g., v = -3...0 for a sector or subsector whose capital lifetime equals 20 years).

In addition to the calculation of the scale parameter ($\alpha o,s,v$ ), "vintaging" also affects the calculation of the capital intensity parameter ($\alpha_{N,s}$ ). As previously discussed, total output in a sector or subsector is described as the summation of vintage production (equations (2) and (3) above). Capital is entered into the production process as separate vintage capital stock; not as a total annualized cost as with the variable inputs to production. Although the capital intensity parameter does not differ between vintages (similar to the variable inputs), due to the vintage capital structure of the SGM, the capital intensity parameter cannot be calculated similar to the variable inputs.

From equation (14), the vintage scale parameter ($\alpha_{0,s,v}$ ) can be determined given the Hick's-neutral technological change rate and the overall scale factor ($\beta_{o,s}$ ). Therefore, upon completion of Steps 1 through 3, two parameters still need to be estimated--the overall scale factor ($\beta_{o,s}$ ) and the capital intensity parameter ($\alpha_{N,s}$ ). Due to the vintage structure of the production process, these parameters cannot be directly determined; therefore, an iterative process must be applied to solve for $\beta_{o,s}$ and $\alpha_{N,s}$.

The steps involved in this iterative process are as follows:

(1) Choose an initial value for $\beta_{o,s}$.
(2) For each variable factor input, compute $X_{i,s}$ as the total expenditure for the ith input factor in the production of commodity s (value from the IO table) divided by the factor input price ("price paid")[13].
(3) For each variable factor input, calculate $\alpha_{i,s}$ using equation (7).
(4) Solve for $\alpha_{N,s}$ using equation (2) with equation (3); the variables determined in Steps (1) through (3); and assumptions on the elasticity of substitution parameter.
(5) Compute the difference between the actual and estimated input demand for the "other products" commodity in the production of commodity s. The estimated input demand for the "other products" commodity in the production of commodity s is defined as,

$$X_{other,s} = \sum_{v=-V_t}^{0} X_{other,s,v} \qquad (15)$$

where

$X_{other,s}$ = estimated input demand for the "other products" commodity in the production of commodity s;

[13] Except for land and labor, input price (price paid) should be equal to 1 in the benchmark year (as previously explained).

$-V_s$ = oldest vintage capital stock for industry s (equal to the negative of the average lifetime of capital for industry s divided by the length of a period (i.e., 5 years) plus 1); and

$X_{other,s,v}$ = estimated input demand for the "other products" commodity in vintage v's production of commodity s defined as,

$$X_{others,v} = (\alpha_{0,s,v} P_{0,s} \frac{\alpha_{others}}{P_{others}})^{\frac{\mu}{\rho}} (\frac{Y}{Z})^{\frac{1}{\rho}} \quad (16)$$

where

$$Y = \alpha_{N,s} X^{\rho}_{N,s,v} \quad (17)$$

and

$$Z = 1 - (\alpha_{0,s} P_{0,s})^{\mu} (\sum_{j=1}^{N-1} \alpha^{\mu/\rho}_{others} P^{-\mu}_{others}) \quad (18)$$

(6) If the difference computed in Step (5) is sufficiently close to zero (less than a specified convergence criterion), a solution is obtained; otherwise, a search procedure is applied to adjust $\beta_{0,s}$ and Steps (1) through (5) are repeated until a solution is reached.
(7) Once a solution has been found, the factor intensity parameters for each sector are normalized to sum to 100 in order to compare relative intensities between sectors. In addition, estimated production levels and profit rates are verified with actual data from the IO table.
(8) Steps (1) - (7) are repeated for each SGM sector and subsector.

## III.b. Computation of Reserves

Upon completion of the CES production function calibration, reserves of depletable resources by vintage for the base year (period 0) are calculated based on estimated levels of production in the depletable resource sectors. Actual total reserves produced in the base year (1985) is available from existing sources, but due to the vintage production structure of the SGM, reserves produced by each vintage need to be estimated. The ratio of actual energy extracted to actual levels of production was used to obtain estimated energy extracted (reserves) from estimated levels of production. The following equation was used to determine vintage reserves of depletable resources produced by each vintage in period 0:

$$Reserves_{j,v} = Q_{j,v}(L_j + 5 * v)\frac{PRDEN_j}{PRD_j} \qquad v = 0...-3 \quad (19)$$

where

$Reserves_{j,v}$[14] = reserves (in exajoules) of depletable resource j produced by vintage v;
$Q_{j,v}$ = output (in $) of depletable resource sector j produced from vintage v;

[14] Vintage 0 reserves pertain to the amount of resources which will be transferred to reserves in period 0.

$L_j$ = lifetime of capital stock in sector j;
$PRDEN_j$ = total depletable resource extracted of commodity j (exajoules) in period 0[15];
$PRD_j$ = actual total production of commodity j (in $ - from IO tables).

**IIIc. Calibration of the Investment Function**

Annual aggregate investment levels in each sector of the SGM is represented by the following functional relationship which is essentially an accelerator from the previous period's total investment levels:

$$I_{t,s} = \alpha_0 I_{t-1,s}(baserate_t)^{\alpha_1} f(\exp(\pi_{t,s}))^{\alpha_2} \tag{20}$$

where

$I_{t,s}$ = annual level of investment in sector s at time t;
$I_{t+1,s}$ = annual level of investment in sector s at time t+1;
$baserate_t$ = underlying growth in the economy affecting investment;
$f(\exp(\pi_{t,s}))$ = a function of the expected profit rate;
$a_0$ = scale coefficient; and
$a_1$, $a_2$ = sensitivity parameters.

In version 0.0 of the SGM, the baserate variable is represented by the growth in potential employment (labor supply) and growth in lagged productivity; specifically,

$$baserate_t = \left(\frac{PE_t}{PE_{t-1}}\right)\left(\frac{\left(\frac{GNP}{E}\right)_{t-1}}{\left(\frac{GNP}{E}\right)_{t-2}}\right) \tag{21}$$

where

PE = potential employment (population ages 15 to 64);
GNP = gross national product;
E = total employment; and
$(GNP/E)_{t-1}$ = gnp per worker (productivity) at time t-1.

In version 0.0 of the SGM, the function of expected profit is defined as the growth in expected profit ; specifically,

$$f(\exp(\pi_{t,s})) = \frac{\exp(\pi_{t,s})}{\exp(\pi_{t-1,s})} \tag{22a}$$

where

$\exp(\pi_{t,s})$ = the expected profit rate in sector s at time t.

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[15] These data were obtained from the Annual Energy Review 1985.

The expected rate of profit can be interpreted as the present value of an average profit rate occuring at the middle of each year for the lifetime of the capital investment; specifically,

$$f(\exp(\pi_{t,s})) = \frac{1}{(1+r+w_s)^{0.5}} \sum_{i=0}^{lifetime_s-1} \frac{\pi_{t,s}}{(1+r+w_s)^i} \tag{22b}$$

where

| | | |
|---|---|---|
| $r$ | = | the real interest rate (assumed to be 3% in the baseyear); |
| $w_s$ | = | the sector-specific interest rate wedge (representing the additional interest rate risk associated with sector s); |
| $lifetime_s$ | = | sector-specific lifetime of capital investment; and |
| $\pi_{t,s}$ | = | sector-specific profit rate at time t. |

Calibration to the base year

Calibrating sector level investment to the base year involves a two step process. First, in order to obtain the scale and sensitivity parameters ($\alpha_0$, $\alpha_1$, $\alpha_2$) an aggregate investment function (described by equation (20)) was econometrically estimated on the macroeconomy level. Next, these scale and sensitivity parameters were used in each sector-specific investment equation (equation (20) for each sector) to determine sector level investment in the base year. Estimated sector-specific investment levels in period 0 were reconciled with actual investment levels by adjusting the investment wedge parameter for each sector and subsector.

Investment levels at the subsector level are determined separately from sector-level investment. For each sector without subsectors, the investment equation given in equation (20) was calibrated by using the scale and sensitivity parameters which were estimated on an economy-wide scale and adjusting each sector's interest rate wedge until its base year investment level is achieved. Sector-specific variables in the investment equation include lagged investment and the expected profit rate. The base rate variable and the scale and sensitivity parameters are identical across sectors.

In the SGM, investment is determined at the sector level; therefore, investment equations only exist for sectors and not subsectors. Within a sector, investment for each subsector is determined by allocating sector level investment using the following logit share equation:

$$Share_{t,iss} = \frac{(E\,\pi_{t,iss})^{\rho}}{\sum_{iss=1}^{niss} (E\,\pi_{t,iss})^{\rho}} \tag{23}$$

where

| | | |
|---|---|---|
| $Share_{t,iss}$ | = | Share of total sector investment allocated to subsector iss; |
| $E\pi_{t,iss}$ | = | expected profit rate for subsector iss at time t; and |
| $\rho$ | = | sensitivity parameter. |

In order to calibrate the investment equation for a sector with subsectors, aggregate values for the sector-specific variables (i.e., lagged investment and the expected profit rate) within the investment equation are required. Lagged investment at the sector level is obtained by aggregating subsector lagged investment.

As previously stated, once all other variables and parameters in the sector-level investment equation are determined, the sector-specific interest rate wedge was adjusted to reconcile estimated investment with actual investment. To accomplish this task for a sector with subsectors, calibration of the logit share equation was required. From the investment equation, the sector-level expected profit rate was determined directly since all other variables and parameters are known. This sector-level expected profit rate is essentially the denominator of the logit share equation raised to the sensitivity parameter. Since the share of sector investment for each subsector and the sensitivity parameter were known for the baseyear, subsector-specific investment rate wedges are calculated directly from the logit share equation.

### III.d. Calibration of Final Demands

The SGM comprises three final demand sectors - government, households, and trade. These final demand sectors consume commodities produced in the nine producing sectors of the SGM and are not producers of any market commodity[16]. Input-output accounting ensures that the amount of commodities produced by the producing sectors is equal to the amount of commodities consumed by the producing and final demand sectors. Calibration of the final demand sectors is performed to ensure equilibrium by choosing final demand parameters which result in an exact replication of the final demand values provided in the baseyear input-output accounts. Details of each final demand sector's calibration process is provided below.

#### Government Final Demand

Commodities and primary factors of production (e.g., labor, land) are consumed by the government final demand in order to provide government services. Within the SGM, three government services comprise the government final demand sector - education, national defense, and general government which encompasses all other government services. Government expenditures must satisy the following identity:

$$TXtot \ - \ S_{gov} \ = \ TR_{gov} \ + \ \sum_{i-1}^{N} P_i \, X_{i,gov} \tag{24}$$

where

| | | |
|---|---|---|
| $TX_{tot}$ | = | total net tax revenues[17]; |
| $S_{gov}$ | = | net government savings or, for negative values, net government borrowing; |
| $TR_{gov}$ | = | transfer payment by the government; |

[16] The government final demand sector produces "government services" which are provided "free of charge" to all sectors of the economy. Therefore, although the government final demand sector produces services, it is not a producer of any market commodity as is the case with producing sectors.
[17] Subsidies are measured as negative taxes.

$P_i$ = price paid for input i; and
$X_{i,gov}$ = government demand for input i.

Equation (24) states that government expenditures (right side of the equation) should not exceed the government's budget constraint (left side of the equation).

Net tax revenue

Net tax revenue in the SGM comprises tax revenue from the following four sources: indirect business tax; corporate income tax; social security tax; and personal income tax. The SGM interprets indirect business tax as the difference between price paid (by consumers of a commodity) and price received (by the producer of a commodity)[18]. Indirect business tax expenditures for each producing sector is provided by the input-output accounts in industry value-added. The SGM calculates indirect business tax revenue by applying an indirect business tax rate to the value of production of each commodity. The following equation is used to calculate the indirect business tax rate for each commodity

$$IBTrate_i = \frac{IBTtot_i}{TO_i - IBTtot_i} \tag{25}$$

where

$IBTrate_i$ = indirect business tax rate for commodity i;
$IBTtot_i$ = total indirect business tax expenditures in the production of commodity i;
TO = total output of commodity i.

Combining Equations (6) and (25),

$$IBTrate_i = \frac{1}{P_0} - 1 \tag{26}$$

Corporate income tax is a tax on corporate profits. The SGM applies an average corporate income tax rate to all producing sectors. This average corporate income tax rate was determined by solving for CITR in the following equation:

$$Total\ Corporate\ Taxes = \sum_{i=1}^{N} IBT_i + \sum_{i=1}^{N} CITR * Profit_i \tag{27}$$

where

$IBT_i$ = total indirect business taxes paid by sector i;
CITR = average corporate income tax rate;
$Profit_i$ = total profits of sector i ("other value added" in the I/O accounts); and
N = number of producing sectors.

[18] For all practical purposes, indirect business tax can be interpreted as a sales tax.

Total corporate tax expenditures in 1985 was obtained from the "Economic Report of the President - 1990" and, as previously mentioned, total indirect business tax expenditures and profits for each producing sector was estimated from the 1985 input-output accounts. With knowledge of these data, an average corporate income tax rate can be determined directly from equation (27).

Social security tax is a tax on labor of which half is paid by employers as a tax on labor expenditures while the other half is paid by employees as a tax on earnings. For employers, the social security tax rate was determined using the following equation:

$$SSTR_{employer} = \frac{TLE}{(TLE - TSS / 2)} - 1 \qquad (28)$$

where

| | | |
|---|---|---|
| $SSTR_{employer}$ | = | social security tax rate for employers (applied to each employer's labor expenditure); |
| TLE | = | total labor expenditures across all sectors; and |
| TSS | = | total social security tax expenditures across all sectors. |

The social security tax rate for both employers and employees was assumed to be equal; therefore, the social security tax rate computed in equation (28) was assumed to be the social security tax rate charged to employees also.

Lastly, the personal income tax is a tax on income earned by consumers. This income includes: (1) labor income after taxes, (2) income from land rents (all land is assumed to be owned by consumers), and (3) corporate profits net of taxes and retained earnings (corporations are assumed to be owned by consumers (i.e., shareholders)). Both total personal income tax paid by consumers and total personal income for 1985 were obtained from the "Economic Report of the President - 1990" allowing an average personal income tax rate to be determined.

Government transfer payments

It was determined that a significant linear relationship exists between total government transfer payments and population. Therefore, a linear regression was conducted on the following equation using total population and total government transfers time series:

$$Total\ government\ transfers = G0 * Population + G1 \qquad (29)$$

where

GO, G1 = appropriate empirically determined coefficients.

Government demand for goods and services

The demand for goods and services by the government sector is modeled in the SGM as a constrained optimization problem. Instead of maximizing profit subject to a budget constraint (as is the case with the producing sectors), the objective of the government is to maximize utility subject to the government's budget constraint defined in equation (24). The following CES utility function defined over the three government services is used:

$$GU = \left(\sum_{ss=1}^{NGS} \delta_{ss} G_{ss}^{\mu}\right)^{(1/\mu)} \tag{30}$$

where

| | | |
|---|---|---|
| GU | = | government utility, an unobservable variable; |
| $G_{ss}$ | = | the production of government service ss; |
| $\delta_{ss}$ | = | distribution parameter for service ss; |
| $\mu$ | = | elasticity parameter (equal to -0.5); and |
| NGS | = | number of government services (equal to 3 in SGM Version 0.0). |

As discussed in Edmonds, et. al. [1991], the goal of the government sector is to maximize utility (Equation (30)) subject to its budget constraint (Equation (24)). The utility-maximizing production of government service ss is described as:

$$G_{ss} = (TXtot - S_{gov} - TR_{KGV})\,\beta_{ss}\,P_{g,ss}^{(\gamma-1)}\left(\sum_{iss=1}^{NGS} \beta_{iss} P_{g,iss}^{\gamma}\right)^{-1} \tag{31}$$

where

| | | |
|---|---|---|
| $\beta_{SS}$ | = | $\delta ss(-1/(m-1))$; |
| $\gamma$ | = | $\mu/(\mu-1)$; and |

$$P_{g,ss} = \sum_{i=1}^{N} a_{i,g,ss} P_i \tag{32}$$

where

| | | |
|---|---|---|
| $P_{g,ss}$ | = | the cost of the next unit of government service ss; |
| $P_i$ | = | the price of input i in the production process; and |
| $a_{i,g,ss}$ | = | the amount of input i required to produce government service ss. |

The government utility function was calibrated to the base year as follows. First, the $\alpha_{i,g,ss}$ parameters are defined as the ratio of the quantity of input i used in the production of service ss. Therefore, these parameters can be calculated using the input-output account values of each input in the production of government service ss, and the assumed base year prices of these inputs; i.e.,

$$a_{i,g,ss} = \frac{\left(\dfrac{IO_{i,g,ss}}{P_i}\right)}{\sum_{j=1}^{NIN} IO_{j,g,ss}} \tag{33}$$

where

| | | |
|---|---|---|
| $IO_{i,g,ss}$ | = | value of input i used in the production of government service ss (from the input-output accounts); |
| $P_i$ | = | price of input i ("price paid"); and |
| NIN | = | number of inputs. |

These $\alpha_{i,g,ss}$ are then used in equation (32) to obtain the value of $P_{g,ss}$ for each government service ss. Once the values of $P_{g,ss}$ are determined, the $\delta_{ss}$ parameters in equation (31) can be estimated using an interative process. This process involves minimizing the sum of squared differences between the actual and estimated production of each government service ($G_{XX}$) by choosing values for the parameters $\delta_{ss}$ (substituting $\delta_{ss}^{(-1/(\mu-1))}$ for $\beta_{ss}$ in equation (31)).

Note: As discussed in Section II.b. above, since the final demand sectors of the I/O table do not include "value added", labor expenditures of the government final demand sectors are found in the row component titled "Government Industry" of the I/O tables. This industry would be included in the SGM "Other Products" sector; therefore, the 1985 "Government Industry" values was separated from government's consumption of the "Other Products" commodity and considered labor expenditures for each of the government final demand sectors.

Similar to the process used to estimate land expenditures for each SGM industry (discussed in Section II.b.), government land expenditures were estimated by applying an average cost of agricultural land to the amount of land used for defense and education obtained from the "Statistical Abstract of the U.S., 1992" published by the Department of Commerce. These land expenditures were then subtracted from government's consumption of the "Other Products" commodity in order to guarantee data consistency.

Net government savings

If positive, net government savings is subtracted from total net tax revenues to obtain the government's budget constraint. In the year 1985, the government (federal, state and local together) ran a budget deficit (implying net government borrowing); therefore, this value would be added to total net tax revenues to obtain the government's budget constraint. Net government savings is calculated for the 1985 base year by subtracting 1985 total government expenditures from total net tax revenue (discussed above). To fund this government deficit, total savings (including personal savings and corporate retained earnings) less total investment was used. Since this amount is not adequate to cover the total government deficit in 1985, the excess was assumed to be funded through a foreign supply of capital. Since this version of the SGM is a closed economy (except for crude oil), the amount of foreign capital supplied was specified exogenously in the SGM's trade component as an import of capital in the base year and is constant through future periods. Since the SGM assumes market equilibrium, no government deficit will exist in future years; but in order to calibrate the SGM to the base year, this exogenous supply of foreign capital is necessary.

## Household Final Demand

The SGM assumes that a portion of the households' budget (personal income) is allocated to personal savings while the remainder is used to purchase produced commodities and primary factors of production. Disposable personal income consists of income from wages less taxes on labor; land rents (consumers are assumed to own all usable land) less taxes on land; corporate profits less profits tax and retained earnings; and government transfer payments.

Labor Supply

Household labor supply is estimated in the SGM using the following equation:

$$X_{labor} = WAP * \alpha_{labor} * (1 - e^{\beta_{labor} * P_{labor}}) \tag{34}$$

where

| | | |
|---|---|---|
| WAP | = | total working age population (ages 15 to 64); |
| $\alpha_{labor}$ | = | the maximum potential share of working age population employed in any given year; |
| $\beta_{labor}$ | = | a labor supply price responsiveness coefficient; and |
| $P_{labor}$ | = | an average annual wage rate ($M per 1000 persons). |

The following steps were taken to calibrate equation (34) to the base year: (1) the total working age population in 1985 was obtained from the "Statistical Abstract of the U.S."; (2) an average annual wage rate was calculated by dividing total labor expenditures (less amount paid in social security tax) in 1985 by total employment in 1985 (in thousands of persons); (3) the maximum potential share of working age population employed in any year was estimated to be 0.90 (or 90% of working age population) which assumes that in any given year 10 percent of the working age population cannot be employed; and (4) the labor supply price responsiveness coefficient was directly calculated from equation (34) given the information in (1) through (3).

Land Supply

Land supply is estimated in the SGM using the following equation:

$$X_{land} = TLA * \alpha_{land} * (1 - e^{\beta_{land} * P_{land}}) \tag{35}$$

where

| | | |
|---|---|---|
| TLA | = | total surface area potentially available for allocation; |
| $\alpha_{land}$ | = | the maximum potential share of land supplied to the market; |
| $\beta_{land}$ | = | a land supply price responsiveness coefficient; and |
| $P_{land}$ | = | an average annual rental rate on a unit of land ($M per 1000 $km^2$). |

The following steps were taken to calibrate equation (35) to the base year: (1) total usable surface area (which excludes unusable land such as deserts, marshes, rock, etc) was obtained from the "Statistical Abstract of the U.S." (equal to 8313 km2); (2) an average annual land rental rate was calculated by dividing total land expenditures in 1985 by total usable land area (in thousands of km2); (3) the maximum potential share of land supplied to the market was estimated to be 1 (or 100% of TLA) since TLA represents total usable land area; and (4) the land supply price responsiveness coefficient was directly calculated from equation (35) given the information in (1) through (3).

Household Savings Supply

The following equation is used in the SGM to estimate the supply of household savings:

$$S_{hh} = Y * \alpha_{hhsave} * (1 - \delta_{hhsave} e^{\beta_{hhsave} * r}) \tag{36}$$

where

| | | |
|---|---|---|
| Y | = | disposable personal income; |
| $\alpha_{hhsave}$ | = | the maximum potential savings rate; |
| $\delta_{hhsave}$ | = | a scale parameter; |
| $\beta_{hhsave}$ | = | the price sensitivity of households to the available interest rate; and |
| r | = | the real market interest rate. |

Equation (36) was calibrated by first assuming that the maximum potential savings rate for the U.S. is equal to 0.20 (i.e., 20% of total disposable personal income) and the real market interest rate is equal to 0.03 (i.e., 3%). With these assumptions and knowledge of the 1985 values for disposable personal income and total personal savings, equation (36) can be written in terms of $\delta_{hhsave}$ and $\beta_{hhsave}$:

$$\delta_{hhsave} = (1 - \frac{S_{hh}}{Y * \alpha_{hhsave}}) e^{-\beta_{hhsave} * r} \tag{37}$$

In addition, the interest elasticity of savings was assumed to be equal to 0.40. The equation for the interest elastiticity of savings is defined as:

$$\frac{\delta S_{hh}}{\delta r} * \frac{r}{S_{hh}} = (\frac{- \delta_{hhsave} \beta_{hhsave} e^{\beta_{hhsave} * r}}{(1 - \delta_{hhsave} e^{\beta_{hhsave} * r})}) * r = 0.40 \tag{38}$$

Combining equations (37) and (38), values for dhhsave and bhhsave can be determined.

Household Demand for Final Products

Household demand for the primary factors land and labor are computed separately from demands for other goods and services. Household demand for land is defined as:

$$X_{land,hh} = NHH \; \alpha_{land,hh} \; P_{land} \tag{39}$$

where

| | | |
|---|---|---|
| $\alpha_{land,hh}$ | = | the household land intensity factor; |

$P_{land}$ = the price of land; and
NHH = the number of households (in 1000s) which is defined as,

$$NHH = \frac{TOTPOP}{\beta_{hh}} \tag{40}$$

where

TOTPOP = total population (in 1000s); and
$\beta_{hh}$ = the average number of people per household.

Equation (40) was calibrated to the base year (1985) by solving for $\beta_{hh}$ using 1985 actual values for NHH and TOTPOP. Similarly, equation (39) was calibrated to the base year by solving for $\alpha_{land,hh}$ using estimated 1985 household demand for land (discussed in Section II.b.); 1985 price of land (discussed in Section III.a.); and the estimated 1985 value for NHH from equation (40).

Similar to the process used to estimate land expenditures for each SGM industry (discussed in Section II.b.), household land expenditures were estimated by applying an average cost of agricultural land to a portion (assumed to be 75%) of urban and transportation land obtained from the "Statistical Abstract of the U.S., 1992" published by the Department of Commerce. These land expenditures were then subtracted from household's consumption of the "Other Products" commodity in order to guarantee data consistency.

Household demand for labor is defined as:

$$X_{labor,hh} = X_{labor}\ \alpha_{labor,hh}\ P_{labor} \tag{41}$$

where

$\alpha_{labor,hh}$ = the household labor intensity factor;
$P_{labor}$ = the price of labor; and
$X_{labor}$ = total labor supply (in 1000s).

Equation (41) was calibrated to the base year by solving for $\alpha_{labor,hh}$ using estimated 1985 household demand for labor; 1985 price of labor (discussed in Section III.a.); and the estimated 1985 total labor supply from equation (34).

Since the final demand sectors of the I/O table do not include "value added", labor expenditures of the household final demand sector is found in the row component titled "Household Industry" of the I/O tables. This industry would be included in the SGM Everything Else sector; therefore, the 1985 "Household Industry" value was separated from household's consumption of the Everything Else commodity and considered labor expenditures for the household final demand sector.

Household demand for other goods and services are estimated as follows:

$$Xd_{i,hh} = \alpha_{i,hh} \; P_i^{\beta_{i,hh}} \; Y_c^{\gamma_{i,hh}} \left(\frac{1}{\lambda}\right) \tag{42}$$

$$Y_c = Y - S_{hh} - X_{land,hh} \; P_{land} - X_{labor,hh} \; P_{labor} \tag{43}$$

where

| | |
|---|---|
| $Xd_{i,hh}$ | = household demand for good i; |
| $\alpha_{i,hh}$ | = the household demand intensity factor for good i; |
| $\beta_{i,hh}$ | = the household price elasticity of demand for good i; |
| $Y_c$ | = total value of consumption which is defined as, |
| $\gamma_{i,hh}$ | = the household income elasticity of demand for good i; and |

$$\lambda = \sum_{i=1}^{NS} \alpha_{i,hh} \; P_i^{\beta_{i,hh}+1} \, Y_c^{\gamma_{i,hh}-1} \tag{44}$$

Table 3 contains the household price and income elasticities used in the SGM which were obtained from existing literature.

**Table 3**

| | Price Elasticity | Income Elasticity |
|---|---|---|
| Agriculture | -0.28 | 0.30 |
| Everything Else | -1.00 | 1.10 |
| Crude Oil | N/A | N/A |
| Natural Gas | N/A | N/A |
| Coal | -0.82 | 0.89 |
| Biomass | N/A | N/A |
| Uranium | N/A | N/A |
| Electricity | -0.82 | 0.89 |
| Refined Oil | -0.82 | 0.89 |
| Gas T&D | -0.82 | 0.89 |

N/A: commodity not consumed by the household sector.

Except for values of $\alpha_{i,hh}$, 1985 values of all the variables in equation (41) were determined as follows: (1) 1985 household demand for each good was obtained from the input-output accounts; (2) as previously discussed, all prices (except land and labor) were assumed to be 1 in the base year; (3) Since the 1985 values all of the components of equation (43) are either known or have been previously calculated, the total value of consumption ($Y_c$) can be determined. With these values determined, the values of $\alpha_{i,hh}$ can be calculated from equation (42).

**Trade**

As previously discussed, Version 0.0 of the SGM assumes a closed economy (i.e. zero trade) for all goods except crude oil. For calibration purposes, it is necessary to exogenously add 1985 net exports to demand and supply in order to replicate the 1985 base year values. Net exports for all tradeable commodities[19] (except Crude Oil and Other Products) are held constant at 1985 values for each period in the model. Net exports in the Crude Oil sector are set at 1985 values from the I/O tables for the base year, but are allowed to change in future periods; making up for the difference in domestic excess demand for crude oil. The SGM assumes balanced trade and implements this constraint by making up for any trade imbalances in the Other Products sector; therefore, a trade deficit would be set to zero by an equal amount in export demand for the Other Products commodity.

[19] In the SGM, "tradeable" commodities refer to those commodities which could be traded and in Version 0.0 include all commodities except electricity, land, and labor.

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