Appendix A-2

INDUSTRY: NEMS Input Data and Scenario Input

This appendix provides detailed information on 1) historical trends, 2) AEO99 reference case assumptions, 3) business-as-usual scenario assumptions, 4) policy drivers for model assumptions, 5) moderate scenario assumptions, and 6) advanced scenario assumptions for 12 industrial subsectors. The table below gives an overview of the sectors, as well as a comparison to the sector definitions used in the U.S. Department of Energy s Office of Industrial Technologies Industries of the Future program.

Table A-1 Sector Definition in CEF-NEMS and IOF

CEF-NEMS	IOF
Food and Kindred Products (SIC 20)	-
Paper and Allied Products (SIC 26)	Forest Products (SIC 24, 26)
Bulk Chemicals (SIC 281, 282, 286, 287)	Chemicals (SIC 28)
Glass and Glass Products (SIC 3211, 3221, 3229)	Glass (SIC 321, 322, 323)
Hydraulic Cement (SIC 324)	-
Blast Furnaces and Basic Steel (SIC 331)	Steel (SIC 331)
Aluminum (SIC 3334, 3353)	Aluminum (SIC 3334, 3341, 3353, 3354, 3355)
Metals Based Durables (SIC 34, 35, 36, 37, 38)	Metal Casting (332, 336, 34-38)
Other Manufacturing (all other manufacturing SIC)	-
Agriculture — Crops (SIC 01)	
Agriculture — Other incl. Livestock (SIC 02, 07, 08, 09)	Agriculture
Coal Mining (SIC 12)	
Oil and Gas Mining (SIC 13)	Mining
Metals and other Nonmetallic Mining (SIC 10, 14)	
Construction (SIC 15, 16, 17)	-
Petroleum Refining (not in industrial module)	Petroleum Refining

For each of the six sections, we discuss economic trends, production and technology trends, and energy consumption trends. In the discussion of economic trends, we focus on trends in value of output (also called gross output) which represents the market value of an industry s production including commodity taxes because this is the measure of economic production used in NEMS. For the discussion of production and technology trends, we describe trends related to total output in the sector as well as trends in process shares (e.g. the share of electric arc furnaces vs. basic oxygen furnaces), products produced, and capital stock retirement rates. The policy drivers for the changed CEF-NEMS inputs are discussed as well. Finally, in the section on energy consumption trends, we discuss overall energy consumption in the subsector, trends in unit energy consumption, energy use for boilers, and energy use in industrial sector buildings.

Each industrial sub-sector is evaluated to determine the potential energy savings and GHG emissions reductions. Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2.

In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios. Uncertainties in the assumptions affect the final results of the scenarios. However, as it is not always possible to quantitatively estimate the uncertainties (see sections 5.6 and 5.7 of the main report) and for reasons of presentation we only present point estimates.

AEO 99 projects energy intensity reductions of 1.0% per year in the baseline scenario, of which 80%, or 0.8% per year, are due to inter-sector structural change and the remaining 0.2% per year is due to efficiency improvements (U.S. DOE, EIA, 1998a). We have retained the AEO99 assumption of a 0.8% contribution inter-sectoral structural change in all CEF, and in the moderate and advanced scenarios modified the change due to efficiency improvements as discussed below.

Five industrial sub-sectors (paper, glass, cement, steel, and aluminum) are modeled in NEMS using physical production values to determine energy intensities. We evaluate three of these subsectors (paper, cement, and steel) in detail, relying on recent process-level assessments of energy use, carbon dioxide emissions, and efficiency potentials (Worrell et al., 1999; Martin et al., 1999; Khrushch et al., 1999). We assess the other two sectors based on historic trends and efficiency potentials identified in recent U.S. and international literature. The remaining industrial sub-sectors (agriculture, mining, construction, food, chemicals, metals-based durables, and other manufacturing) are modeled in NEMS using economic production values (value of output) to determine energy intensities. We evaluate these sub-sectors based on historic trends and efficiency potentials identified in recent U.S. and international literature.

All industrial sector policies were addressed to some degree within CEF-NEMS, including a carbon dioxide emissions cap and trade system with an assumed carbon price of $50/ton in the advanced scenario. We first assessed the level of future energy savings under many policies (see Appendix B-2). Next we determined where and how these energy savings might be achieved in terms of modeling parameters and modeled these changes in CEF-NEMS, on an aggregation level appropriate for the CEF-NEMS model. We adjusted the following parameters of the CEF-NEMS model to reflect the likely impact of the policies on the implementation rate and decision-making process: energy efficiency improvements in existing equipment, energy efficiency improvements in new equipment, material inputs, boiler efficiency, use of CHP, and building efficiency. Some policies may affect one parameter, e.g. research and development is most likely to affect the energy efficiency improvement and availability of new equipment. On the other hand, a cap and trade system will affect the price of energy and will likely influence all parameters of the CEF-NEMS model.

The section on historical trends is based on data we have collected at LBNL as well as numerous published reports that are referenced in each section. The NEMS reference case assumptions section describes the assumptions in the model related to economic trends, production and technology trends, and energy consumption trends. The business-as-usual scenario assumptions are included for those few sectors (steel, paper, cement, and aluminum) in which we did not adopt the NEMS reference case as the business-as-usual scenario. The moderate and advanced scenario sections describe the changes that we made to the NEMS reference case assumptions.

Tables A-3 and A-4 summarize the main changes in the CEF-NEMS inputs based on the estimated impact of the policies and measures. Available resources and the structure of the NEMS-model only allowed the detailed assessment of a limited number of sectors (i.e. aluminium, iron and steel, cement, pulp and paper). For the other sectors assumptions were made on the basis of other studies and policy experiences in other countries. The policy assumptions are briefly discussed in the discussion of each sub-sector and model inputs below.

Table A-2 Qualitative Representation of Policy and Program Impacts on CEF-NEMS Inputs by Industrial Subsector

	Demonstration Programs	Assessment Programs	Challenge Programs - Motors and Air	Challenge Programs - Steam	Challenge Programs -CHP	Energy Star Buildings and Green Lights	Product Labels	State Programs	SIPs/Clean Air Partnerships
Agriculture	1,2,8	1	1,2,8	3,6,9	6,9			1,2,3	
Mining	1,2,8	1	1,2,8	3,6,9	6,9			1,2,3	
Construction	1,2,8	1	1,2,8	3,6,9	6,9			1,2,3	
Food	1,2,8	1	1,2,8	3,6,9	6,9	5		1,2,3,5	1,2,3,6,9
Paper	1,2,7,8	1,7	1,2,7,8	3,6,9	6,9	5	4	1,2,3,5	1,2,3,6,7,9
Chemicals	1,2,8	1	1,2,8	3,6,9	6,9	5		1,2,3,5	1,2,3,6,7,9
Glass	1,2,8	1	1,2,8	3,6,9	6,9	5		1,2,3,5	1,2,3,6,9
Cement	1,2,7,8	1,7	1,2,7,8	3,6,9	6,9	5	4	1,2,3,5	1,2,3,6,9
Steel	1,2,7,8	1,7	1,2,7,8	3,6,9	6,9	5		1,2,3,5	1,2,3,6,7,9
Aluminum	1,2,8	1	1,2,8	3,6,9	6,9	5		1,2,3,5	1,2,3,6,9
Metals-Based Durables	1,2,8	1	1,2,8	3,6,9	6,9	5		1,2,3,5	1,2,3,6,9
Other Manufacturing	1,2,8	1	1,2,8	3,6,9	6,9	5		1,2,3,5	1,2,3,6,9
Petroleum Refining	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

	R&D - IOF	Other OIT R&D	ESCO Utility Program	Climate Wise Program	Pollution Prevention	Tax Incentives for Energy Managers	Tax Rebates for Specific Industrial Techs	Invest-ment Tax Credit for CHP Sytems	Cap and Trade
Agriculture	2	2,6	1,6,9	1,2,8		1		6,9	1-6,8,9
Mining	2	2,6	1,6,9	1,2,8		1		6,9	1-6,8,9
Construction				1,2,8				6,9	1-6,8,9
Food		2,3,6	1,5,6,9	1,2,8		1,5	2	6,9	1-6,8,9
Paper	2	2,3,6	1,5,6,7,9	1,2,7,8	4	1,5,7	2	6,9	1--9
Chemicals	2	2,3,6	1,5,6,9	1,2,8		1,5	2	6,9	1-6,8,9
Glass	2	2,3,6	1,5,6,9	1,2,8	4	1,5	2	6,9	1-6,8,9
Cement	2	2,3,6	1,5,6,7,9	1,2,7,8		1,5,7	2	6,9	1--9
Steel	2	2,3,6	1,5,6,7,9	1,2,7,8	4	1,5,7	2	6,9	1--9
Aluminum	2	2,3,6		1,2,8	4	1,5	2	6,9	1-6,8,9
Metals-Based Durables	2	2,3,6	1,5,6,9	1,2,8		1,5	2	6,9	1-6,8,9
Other Manufacturing			1,5,6,9	1,2,8		1,5		6,9	1-6,8,9
Petroleum Refining	n/a	n/a	n/a	n/a	n/a	n/a	n/a	9	1-6,8,9

Notes:

Modeled within NEMS:

1: increased TPCs in existing equipment
2: increased TPCs in new equipment
3: increased boiler efficiency
4: increased use of recycled materials (throughput changes)
5: improved building energy efficiency
6: increased use of cogeneration (within NEMS)

Modeled outside NEMS:

7: improved TPCs in existing equipment (LBNL-detailed analysis in steel, cement and pulp and paper industries)
8: improved TPCs in existing equipment (ORNL motor system assessment for motors electricity use)
9: increased use of cogeneration (DISPERSE modeling of CHP-policies)

Table A-3 CEF-NEMS Modifications for the Moderate Scenario

Sector	EE improvement in existing equip	EE improvement in new equip	Increased recycled material inputs	Improved boiler efficiency	Improved building efficiency	Increased use of cogeneration
Agriculture	Increased TPCs 1.5x base case	Increased TPCs 1.5x base case		0.2%/yr fossil fuels, 0.1%/yr biomass & waste	No bldgs	No
Mining	Increased TPCs 1.5x base case	Increased TPCs 1.5x base case		0.2%/yr fossil fuels, 0.1%/yr biomass & waste	No bldgs	No
Construction	Increased TPCs 1.5x base case	Increased TPCs 1.5x base case		No boilers	No bldgs	No
Food	Increased TPCs _ HiTech	Increased TPCs _ HiTech		0.2%/yr fossil fuels, 0.1%/yr biomass & waste	Same as commercial buildings	Yes
Paper	Increased TPCs based on analyses	Increased TPCs based on analyses	Increased waste paper share 0.2%/yr; reduced bleaching throughput 0.1%/yr	0.2%/yr fossil fuels, 0.1%/yr biomass & waste	Same as commercial buildings	Yes
Chemicals	Increased TPCs based on analyses	Increased TPCs based on analyses		0.2%/yr fossil fuels, 0.1%/yr biomass & waste	Same as commercial buildings	Yes
Glass	Increased TPCs*	Increased TPCs _ HiTech		No boilers	Same as commercial buildings	Yes
Cement	Increased TPCs based on analyses	Increased TPCs based on analyses	Reduced clinker production by 6.9 Mtons by 2020	No boilers	Same as commercial buildings	Yes
Steel	Increased TPCs based on analyses	Increased TPCs based on analyses		0.2%/yr fossil fuels, 0.1%/yr biomass & waste	Same as commercial buildings	Yes
Aluminum	Increased TPCs based on analyses	Increased TPCs based on analyses		0.2%/yr fossil fuels, 0.1%/yr biomass & waste	Same as commercial buildings	Yes
Metals-Based Durables	Increased TPCs 1.5x base	Increased TPCs 1.5x base		0.2%/yr fossil fuels, 0.1%/yr biomass & waste	Same as commercial buildings	Yes
Other Manufacturing	Increased TPCs 1.5x base	Increased TPCs 1.5x base		0.2%/yr fossil fuels, 0.1%/yr biomass & waste	Same as commercial buildings	Yes

*1/2 HiTech for melting/refining, same as base case for batch preparation, forming, and post forming.
**retirement rates for BOFs 1.0   1.5, EAFs 1.5   1.8, coke ovens 1.5   1.8; retirement rate for other steel is not accelerated.

Table A-4 CEF-NEMS Modifications for the Advanced Scenario

Sector	EE improvement in existing equip	EE improvement in new equip	Increased recycled material inputs	Improved boiler efficiency	Improved building efficiency	Increased use of cogeneration
Agriculture	Increased TPCs 2x base case	Increased TPCs 2x base case		0.2%/yr oil & renewables, 0.3%/yr gas & coal	No bldgs	No
Mining	Increased TPCs 2x base case	Increased TPCs 2x base case		0.2%/yr oil & renewables, 0.3%/yr gas & coal	No bldgs	No
Construction	Increased TPCs 2x base case	Increased TPCs 2x base case		No boilers	No bldgs	No
Food	Increased TPCs HiTech	Increased TPCs HiTech		0.2%/yr oil & renewables, 0.3%/yr gas & coal	Same as commercial buildings	Yes
Paper	Increased TPCs based on analyses	Increased TPCs based on analyses	Increased waste paper share 0.4%/yr; reduced bleaching throughput 0.2%/yr	0.2%/yr oil & renewables, 0.3%/yr gas & coal	Same as commercial buildings	Yes
Chemicals	Increased TPCs based on analyses	Increased TPCs based on analyses		0.2%/yr oil & renewables, 0.3%/yr gas & coal	Same as commercial buildings	Yes
Glass	Increased TPCs*	Increased TPCs HiTech		No boilers	Same as commercial buildings	Yes
Cement	Increased TPCs based on analyses	Increased TPCs based on analyses	Reduced clinker production by 16.4 Mtons by 2020	No boilers	Same as commercial buildings	Yes
Steel	Increased TPCs based on analyses	Increased TPCs based on analyses	Increased share of EAFs to 55%	0.2%/yr oil & renewables, 0.3%/yr gas & coal	Same as commercial buildings	Yes
Aluminum	Increased TPCs based on analyses	Increased TPCs based on analyses	Reduced production growth 0.05%/yr to account for increased recycling	0.2%/yr oil & renewables, 0.3%/yr gas & coal	Same as commercial buildings	Yes
Metals-Based Durables	Increased TPCs 2x base case	Increased TPCs 2x base case		0.2%/yr oil & renewables, 0.3%/yr gas & coal	Same as commercial buildings	Yes
Other Manufacturing	Increased TPCs 2x base case	Increased TPCs 2x base case		0.2%/yr oil & renewables, 0.3%/yr gas & coal	Same as commercial buildings	Yes

*HiTech for melting/refining, same as base case for batch preparation, forming, and post forming.
** retirement rates for BOFs 1.5 2.0, EAFs 1.8 2.5, coke ovens 1.8 2.5; retirement rate for other steel is not accelerated.

AGRICULTURE - Historical Trends

Economic Trends

Value of output in U.S. agriculture grew at an average of 2.1% per year between 1977 and 1997, increasing from $154B (1987$) in 1977 to $277B in 1997. Production hit a low of $150B in 1978 and its current high of $277B in 1997. Despite some dips and hikes, value of output was relatively static overall throughout the late 1970 s and early 1980 s, hitting $171B in 1982 and falling to $153B in 1983, resulting in no net gain between 1977 and 1983. From this point on, however, value of output has increased steadily with an annual average growth rate of 3.1% per year. While growth has leveled off at points, this growth has continued with no major recessions for the past 15 years (U.S.DOC, 1998).

Energy Consumption Trends

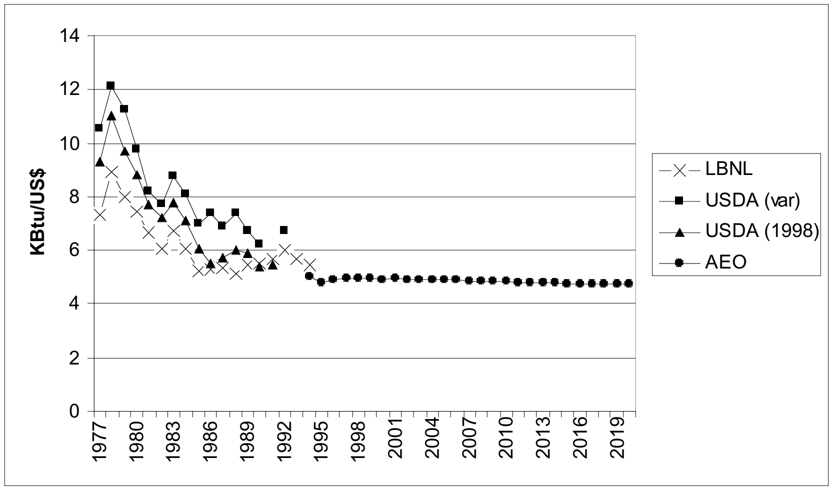
We have analyzed three historical data sets to understand past trends in energy consumption in the agriculture sector. The first and second sources are different estimates based on U.S. Department of Agriculture fuel expenditure data (U.S.D.A., 1998; U.S.D.A., various years). The third data set was developed at LBNL using U.S.DOC (1989) and U.S.EIA (1998) data.

Based on U.S.D.A. (various years) data, primary energy consumption in U.S. agriculture peaked in 1978 at 1.82 quads. Final energy consumption declined at roughly 3% per year (primary energy at 2% per year) between 1978 and 1992. Interpolated U.S.D.A. expenditure data show almost a 40% overall decline between 1978 and 1993 in fuel use (excluding electricity). Since 1978, energy consumption has maintained an overall decline. While total energy consumption appeared to jump in 1992 after a long decline, the U.S.D.A. stopped reporting electricity expenditures in 1992, and thus no total energy consumption analysis is possible. However, fuel use (excluding electricity) has increased since 1990 from 0.67 quads to 0.88 quads in 1995. Overall, energy use has declined since 1978, though fuel use has been increasing since 1990. U.S.D.A. (1998) follows the same trends as the data set discussed above, but the results range from 6% to 26% lower. Different methods were used to calculate the two data series from the same original fuel expenditure data.

LBNL data are similar to U.S.D.A. data in trends and growth, but are, on average, about 25% lower than calculated U.S.D.A. (various years) fuel consumption, though the two series results become much closer in the 1990s. Unlike the U.S.D.A. series, the LBNL series actually shows increasing energy consumption between 1970 and 1994, at 0.4% per year (0.6% for primary energy), and only decreases at 0.3% per year between 1978 and 1994 (-0.7% for primary energy). In addition, energy use between 1985 and 1994 grows at 2.5% per year. After a decline in fuel use from 1978-1988, energy consumption increases between 1989 and 1994.

The three data sets provide varying energy intensity results and growth rates. Historical economic primary energy intensity for the total agricultural sector (energy/value of output) declined on average —1.7% per year between 1977 and 1994 (U.S.DOC, 1989; AEO, 1998), -2.9% per year between 1977 and 1992 (U.S.D.A., various years), and —3.8% per year between 1977 and 1991 (U.S.D.A., 1998) (see Figure A-1).

Fig. A-1 Historical and Projected Economic Primary Energy Intensities
(KBtu/U.S.$) for U.S. Agriculture



AGRICULTURE - AEO99 Reference Case and Business-As-Usual Scenario

AOE99 divides agriculture into agricultural production — crops (SIC 01) and other agriculture including livestock (SIC 02, 07, 08, 09)[1]. We adopt the AEO99 reference case for the business-as-usual scenario.

Economic Trends
Unlike the historical trends discussed above, AEO99 projects a smooth, steady increase of only 1.2% annual average growth in value of output over the 26 year period 1994 to 2020. After a dip from 1994 to 1995, value of output is projected to increase steadily at an average of approximately $3.5B per year. The NEMS projection appears conservative when compared to the 3.1% historical average annual growth in value of output seen between 1983 and 1997.

Production and Technology Trends
The retirement rate of capital stock in all non-manufacturing subsectors is set at 2% per year in NEMS AOE99, for an average lifetime of 50 years. Equipment in this sector includes tractors, irrigation motors and pumps, drying equipment, greenhouses, and HVAC equipment and lighting in buildings that house livestock and other animals. We adjust the retirement rate to 2.5% per year, for an average lifetime of 40 years.

Energy Consumption Trends
The NEMS model projects a smooth increase in primary energy of 1.1% per year, increasing from 1194 TBtu in 1994 to 1537 TBtu in 2020. Energy use in agricultural buildings is not accounted separately in the NEMS model.

Economic energy intensity (MJ/value of output) for the agriculture sector is projected to decline at an average rate of —0.24% per year between 1994 and 2020 in the AEO99 reference case (see Figure A-1). Table A-5 provides NEMS baseline input UEC values for existing and new equipment for 1994 and 2020. The 1994 new UECs are exactly 10% lower than the 1994 existing UECs for all fuels in both subsectors.

[1] 02 = livestock and animal specialties; 07 = agricultural services; 08 = forestry; 09 = fishing, hunting, and trapping

The average annual decline in energy use/value of output between 1994 and 2020 is —0.1 and —0.2 for existing and new equipment, respectively.

Table A-5 NEMS Baseline Inputs for Existing and New Equipment for Agriculture

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Sub-sector	**Fuel**	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Agriculture — crops	Electricity	0.959	0.9316	-0.001	0.863	0.8143	-0.002
	Natural gas	0.318	0.3089	-0.001	0.286	0.2699	-0.002
	Dist. oil	4.004	3.8895	-0.001	3.603	3.3998	-0.002
	LPG	0.553	0.5372	-0.001	0.498	0.4699	-0.002
	Steam coal	0.002	0.0019	-0.001	0.001	0.0009	-0.002
	Motor gasoline	0.657	0.6382	-0.001	0.591	0.5577	-0.002
	Steam	0.139	0.135	-0.001	0.125	0.1179	-0.002
	Other petroleum	0.115	0.1117	-0.001	0.103	0.0972	-0.002
Agriculture — other	Electricity	0.254	0.2467	-0.001	0.228	0.2151	-0.002
	Natural gas	0.095	0.0923	-0.001	0.085	0.0802	-0.002
	Dist. oil	1.059	1.0287	-0.001	0.953	0.8992	-0.002
	LPG	0.146	0.1418	-0.001	0.132	0.1246	-0.002
	Motor gasoline	0.173	0.1681	-0.001	0.156	0.1472	-0.002
	Steam	0.033	0.0321	-0.001	0.03	0.0283	-0.002
	Other petroleum	0.032	0.0311	-0.001	0.029	0.0274	-0.002

AGRICULTURE — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2.

In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the agriculture sector include demonstration programs, assessment programs, Challenge programs, state programs, R&D programs, ESCO/utility programs, ENERGY STAR and Climate Wise programs, tax incentives for energy managers, investment tax credits for CHP systems, and a CO2 cap and trade system. For example, R&D programs will mainly affect the efficiency of new equipment, while demonstration programs can lead to improvements in existing equipment through demonstration of improved practices. Expanding assessment programs to large farm operations and cooperatives will lead to improved energy efficiency. Currently these programs aim at small and medium-sized enterprises. Long-term experience with the IAC program has demonstrated average annual energy savings of 2.5 to 4.4 billion Btus per assessment (U.S. DOE, 1996b), while 80% of the energy savings persist over a long period (over 7 years). Large amounts of energy are used for tractors and mobile equipment. The efficiencies of these are likely to be affected by improved efficiencies in engines (see transport sector).

AGRICULTURE - Moderate Scenario

Economic Trends
Economic trends remain the same as AOE99 under the moderate scenario.

Production and Technology Trends
The retirement rate of capital stock in all non-manufacturing subsectors is set at 2% per year in AOE99, for an average lifetime of 50 years. Equipment in this sector includes tractors, irrigation motors and pumps, drying equipment, greenhouses, and HVAC equipment and lighting in buildings that house livestock and other animals. We adjust the retirement rate to 2.5% per year, for an average lifetime of 40 years.

Energy Consumption Trends
We use the AEO99 UECs for 1994 existing and new equipment in the moderate scenario. We increase the TPCs to reflect both historical trends and the potential for energy efficiency in this sector. Historically, the ratio of primary energy to value of output declined on average—1.7% per year between 1977 and 1994 (U.S.DOC, 1989; AEO, 1998), -2.9% per year between 1977 and 1992 (U.S.D.A., various years), and —3.8% per year between 1977 and 1991 (U.S.D.A., 1998). Worrell et al. (1997) estimated 22% savings potential in energy use between 1990 and 2020 using state-of-the-art equipment in industrialized countries, representing an average decline over business-as-usual energy use of —0.8% per year. The same study found a 28% savings potential in energy use during the same period using advanced technology in industrialized countries, for an average annual decline of —1.1% per year. Another study estimated 73% technical potential savings in primary energy (57% electricity, 75% fuel) between 1990 and 2015 for agriculture in The Netherlands, representing an average annual decline of over —5.0% per year (de Beer et al., 1994). Individual studies have found energy efficiency potentials of 12 to 38% for improvements in diesel engines in tractors (Stout and McKiernan, 1992; de Beer et al., 1994), 27 to 33% savings for improved design and installation of irrigation pumps (Stout, 1989), 10 to 55% savings for drying system improvements (Baird and Talbot, 1992), 15 to 60% savings for a variety of efficiency improvement in livestock facilities (de Beer et al., 1994), and 77% savings for improvements in greenhouses (de Beer et al., 1994) over various time periods. Because these studies identify potential savings beyond business-as-usual, we accelerate the average decline in UECs in the moderate scenario to 1.5 times the rate in the base

case for existing equipment and new equipment for both the agriculture — crops and agriculture — other subsectors (see Table A-6). In addition, boiler energy efficiency improves at a rate of 0.2% per year for fossil fuels and 0.1% per year for biomass and waste in this scenario (CIBO, 1997; Einstein et al., 1999).

Table A-6 Moderate Scenario Inputs for Existing and New Equipment in Agriculture

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Sub-sector	**Fuel**	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Agriculture — crops	Electricity	0.959	0.9223	-0.0015	0.863	0.7982	-0.003
	Natural gas	0.318	0.3058	-0.0015	0.286	0.2645	-0.003
	Dist. Oil	4.004	3.8507	-0.0015	3.603	3.3323	-0.003
	LPG	0.553	0.5318	-0.0015	0.498	0.4606	-0.003
	Steam coal	0.002	0.0019	-0.0015	0.001	0.0009	-0.003
	Motor gasoline	0.657	0.6319	-0.0015	0.591	0.5466	-0.003
	Steam	0.139	0.1337	-0.0015	0.125	0.1156	-0.003
	Other petroleum	0.115	0.1106	-0.0015	0.103	0.0953	-0.003
Agriculture — other	Electricity	0.254	0.2443	-0.0015	0.228	0.2109	-0.003
	Natural gas	0.095	0.0914	-0.0015	0.085	0.0786	-0.003
	Dist. Oil	1.059	1.0185	-0.0015	0.953	0.8814	-0.003
	LPG	0.146	0.1404	-0.0015	0.132	0.1221	-0.003
	Motor gasoline	0.173	0.1664	-0.0015	0.156	0.1443	-0.003
	Steam	0.033	0.0317	-0.0015	0.03	0.0277	-0.003
	Other petroleum	0.032	0.0308	-0.0015	0.029	0.0268	-0.003

AGRICULTURE - Advanced Scenario

Economic Trends

Economic trends remain the same as AOE99 under the advanced scenario.

Production and Technology Trends

The retirement rate of capital stock in all non-manufacturing subsectors is set at 2% per year in NEMS AOE99, for an average lifetime of 50 years. Equipment in this sector includes tractors, irrigation motors and pumps, drying equipment, greenhouses, and HVAC equipment and lighting in buildings that house livestock and other animals. We adjust the retirement rate to 2.5% per year, for an average lifetime of 40 years.

Energy Consumption Trends

A recent study found a relationship between the price of energy and the use of conservation tillage (defined as any tillage and planting system that maintains at least 30% of the soil surface covered by residue after plant to reduce soil erosion by water). Energy use for tillage operations accounts for about 3% of total farm energy use and use of conservation tillage directly reduces energy use (Uri, 1998). Thus, if the cost of carbon is $50/tonne in the advanced scenario, this analysis indicates that energy-conserving tillage practices will be adopted in response to higher energy prices. Based on this analysis as well as the potentials described under the moderate scenario (above), we accelerate the average decline in UECs even further in the advanced scenario to 2 times the base case for existing and new equipment in both the agriculture - crops and agriculture — other subsectors (see Table A-7). In addition, boiler energy efficiency improves at a rate of 0.2% per year for oil and renewables and 0.3% per year for gas and coal (CIBO, 1997; Einstein et al., 1999).

Table A-7 Advanced Scenario Inputs for Existing and New Equipment in Agriculture

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Sub-sector	Fuel	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Agriculture - crops	Electricity	0.959	0.9104	-0.002	0.863	0.7776	-0.004
	Natural gas	0.318	0.3019	-0.002	0.286	0.2577	-0.004
	Dist. oil	4.004	3.8009	-0.002	3.603	3.2464	-0.004
	LPG	0.553	0.5250	-0.002	0.498	0.4487	-0.004
	Steam coal	0.002	0.0019	-0.002	0.001	0.0009	-0.004
	Motor gasoline	0.657	0.6237	-0.002	0.591	0.5325	-0.004
	Steam	0.139	0.1319	-0.002	0.125	0.1126	-0.004
	Other petroleum	0.115	0.1092	-0.002	0.103	0.0928	-0.004
Agriculture - other	Electricity	0.254	0.2411	-0.002	0.228	0.2054	-0.004
	Natural gas	0.095	0.0902	-0.002	0.085	0.0766	-0.004
	Dist. oil	1.059	1.0053	-0.002	0.953	0.8587	-0.004
	LPG	0.146	0.1386	-0.002	0.132	0.1189	-0.004
	Motor gasoline	0.173	0.1642	-0.002	0.156	0.1406	-0.004
	Steam	0.033	0.0313	-0.002	0.03	0.0270	-0.004
	Other petroleum	0.032	0.0304	-0.002	0.029	0.0261	-0.004

MINING - Historical Trends

Economic Trends

Value of output grew at an average of 0.6% per year between 1977 and 1997 in the U.S. mining sector. Growth was uneven over this period, with the value of output in 1986 ($146B) falling below the 1977 level ($149B), resulting in no net gain in value of output growth between 1977 and 1986. Growth has risen more consistently since 1986, at an average of 1.2% per year.

Energy Consumption Trends

We have analyzed data from two sources to form historical energy consumption patterns. We used data from Census of Mineral Industries, published every 5 years, as well as an LBNL-generated data set compiled using data from the National Energy Accounts and the Annual Energy Outlook (U.S.DOC, 1989; AEO, 1998).[2]

According to data from the Census of Mineral Industries, primary energy consumption grew at 1.5% per year between 1954 and 1992 (1.0% for final energy consumption), increasing from 1365 TBtu in 1954 to 2444 TBtu in 1992. Consumption grew steadily until the mid- to late 1970s, at which point it fell rather dramatically. Growth resumed in the mid-1980s, though the growth rate between 1982 and 1992 is actually slightly negative, at —0.2% per year.

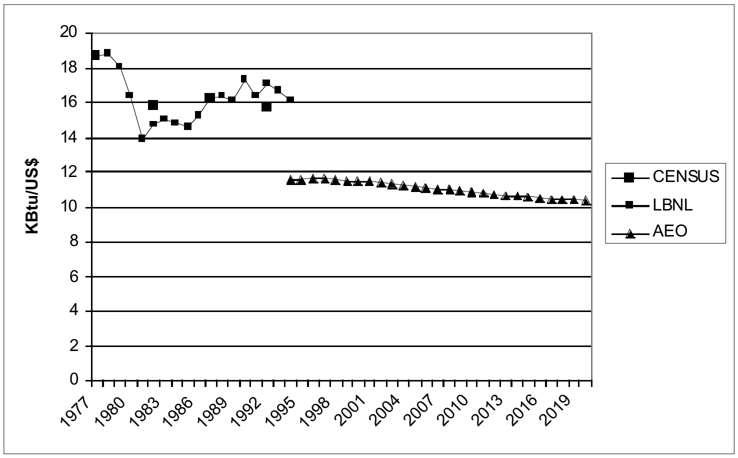
Data from the LBNL database correspond closely with the census data in both growth rate and absolute value. The LBNL database reports that primary energy consumption grew at 1.4% between 1958 and 1994. The drop in energy consumption during the late 1970s is more clearly illustrated in this data set. Primary energy consumption fell 20% between 1978 and 1981 (2870 TBtu to 2300 TBtu). After 1981, energy consumption started a slow increase. Between 1958 and 1978, energy consumption increased at 3.0% per year. The rate fell to 0.9% per year between 1981 and 1994, resulting in the total growth rate of 1.4% per year.

According to LBNL data, primary energy intensity fell 25% between 1978 and 1981. While energy intensity grew at 1.1% per year between 1981 and 1994, the huge decline from 1978 to 1981 resulted in

[2] The NEMS AOE99 mining energy consumption presented in Figure A-2 does not include lease and plant fuel national gas consumption which are modeled in the Natural Gas Transmission and Distribution Module of NEMS.

an overall declining energy intensity rate of —0.6% per year between 1977 and 1994. The Census of Mineral Industries data provide similar results, as they show primary energy intensity decreasing from 18.6 KBtu/U.S.$ in 1977 to 15.7 KBtu/U.S.$ in 1992, at a rate of —1.1% per year (See Figure A-2).

Fig. A-2 Historical and Projected Economic Primary Energy Intensities (KBtu/U.S.$) for U.S. Mining



MINING - AEO99 Reference Case and Business-As-Usual Scenario

AEO99 divides the mining sector into 3 subdivisions: coal mining (SIC 12), oil and gas mining (SIC 13), and metal and other nonmetallic mining (SIC 10, 14). We adopt the AEO99 reference case for the business-as-usual Scenario.

Economic Trends

In NEMS the mining industry production is modeled as gross output (using a monetary value), and not tons of material recovered from the mine. Gross output (in billion 1987 U.S.$) is projected to grow from 133 billion dollars in 1994 to 162 billion dollars in 2020, at an average annual growth rate of 0.8%. Between 1994 and 1997, the historical figures are, on average, 20% greater than the projected figures. In fact, the NEMS value of output projections through 2020 ($162B) never reach the 1997 levels ($166B) of historical production.

Production and Technology Trends

The retirement rate of capital stock in all non-manufacturing industry sub-sectors is set at 2% per year in the NEMS AEO99 model, for an average lifetime of 50 years. Jaccard and Willis (1996) estimate the average lifetime of mining equipment to be 25-30 years. Thus, we adjust the retirement rate to 2.5% per year, for an average lifetime of 40 years.

Energy Consumption Trends

Final energy consumption in the mining sector is projected to grow at 0.6% per year between 1994 and 2020. Primary energy consumption is predicted to grow slightly slower, at 0.4% per year, increasing from 1.53 quads to 1.68 quads. As with the value of output data, the absolute value estimates for predicted primary energy consumption are much lower than the historical values. In 1994, for example, the LBNL database states an energy consumption of 2580 TBtu, while the NEMS forecast offers a value of 1530 TBtu, 40% lower than the historical value. The majority of the difference lies in the oil and gas extraction energy consumption totals. The census estimates primary energy consumption in the subsector to be 1490 TBtu in 1992, while the 1994 NEMS estimate is 810 TBtu. The NEMS energy consumption growth rate forecast is similar to the historical growth rates experienced after the 1978-1981 energy consumption decline, though it varies significantly from long-term trends.

The fuel mix is dominated by three fuels: natural gas (39%), electricity (31%), and distillate fuel oil (18%). The remaining fuels (coal, gasoline, residual fuel oil, biomass) average between no contribution and 7%of fuel share. Fuel share is predicted to change little between 1994 and 2020.

Final energy intensity is projected to decrease from 6.9 KBtu/U.S.$ to 6.6 KBtu/U.S.$, at a rate of —0.2% per year. Primary energy intensity is projected to decrease from 11.5 KBtu/U.S.$ to 10.4 KBtu/U.S.$, at a rate of —0.4% per year. While the NEMS energy consumption trend appears to correspond with the historical energy consumption trend after the 1978-1981 decline, the opposite appears to be true here. The energy intensity trend appears to match the historical trend that includes the 1978-1981 decline. Primary energy intensity increased at 1.1% per year between 1981 and 1994, but the NEMS forecast projects a consistent decline. As expected, the energy intensity is much lower than the historical values, about 30% in 1994.

Table A-8 provides the NEMS baseline inputs for existing and new equipment for 1994 and 2020. The 1994 new UECs are exactly 10% lower than the 1994 existing UECs for all fuels in all three subsectors.

Energy use in buildings is not accounted separately for the mining sector in the NEMS model.

Table A-8 NEMS Baseline Inputs for Existing and New Equipment for Mining

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Sub-Sector	**Fuel**	MBtu/$	MBtu/$		Mbtu/$	MBtu/$	
Coal Mining	Electricity	1.566	1.5212	-0.001	1.409	1.3295	-0.002
	Natural gas	0.298	0.2895	-0.001	0.268	0.2529	-0.002
	Res. Oil	0.288	0.2798	-0.001	0.259	0.2444	-0.002
	Dist. Oil	2.013	1.9554	-0.001	1.812	1.7098	-0.002
	Motor	0.129	0.1253	-0.001	0.116	0.1095	-0.002
	Steam coal	0.296	0.2875	-0.001	0.266	0.251	-0.002
Gas/Oil	Electricity	1.565	1.5202	-0.001	1.409	1.3295	-0.002
	Natural gas	3.361	3.2649	-0.001	3.025	2.8544	-0.002
	Res. Oil	0.074	0.0698	-0.002	0.066	0.0641	-0.001
	Dist. Oil	0.526	0.4963	-0.002	0.473	0.4595	-0.001
	LPGs	0	0	-0.002	0	0	-0.001
	Motor	0.127	0.1198	-0.002	0.114	0.1107	-0.001
	Steam coal	0	0	-0.002	0	0	-0.001
	Steam	0.736	0.6945	-0.002	0.662	0.6431	-0.001
	Biomass	0.014	0.0132	-0.002	0.013	0.0126	-0.001
	Other Petr.	0.099	0.0934	-0.002	0.089	0.0865	-0.001
Metal Mining	Electricity	4.638	4.5054	-0.001	4.174	3.9386	-0.002
	Natural gas	0.0057	0.0055	-0.001	0.0051	0.0048	-0.002
	Res. Oil	0.393	0.3818	-0.001	0.354	0.334	-0.002
	Dist. Oil	2.629	2.5538	-0.001	2.366	2.2325	-0.002
	Motor	0.01	0.0097	-0.001	0.009	0.0085	-0.002
	Steam coal	2.219	2.1555	-0.001	1.997	1.8844	-0.002
	Steam	0.253	0.2458	-0.001	0.227	0.2142	-0.002

MINING — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2.

In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the mining sector include demonstration programs, assessment programs, Challenge programs, state programs, R&D programs, ESCO/utility programs, ENERGY STAR and Climate Wise programs, tax incentives for energy managers, investment tax credits for CHP systems, and a CO2 cap and trade system. Mines are large users of motors (for ventilation and transport), and some operations like iron ore agglomeration (pelletizing) are also done at the mine. Programs aimed at more efficient use of motors (e.g. Challenge programs), standards, as well as more directed state activities will have an impact on energy use of existing and new equipment. ENERGY STAR programs currently aimed at methane emission reduction will also affect compressor use in oil and gas mining. Other than the EPACT efficiency standards for motors, standards are less common for industrial equipment. EPACT standards result in savings of over 7 GWh per year. Newly proposed standards (CEE) are estimated to save another 4 GWh/year (Scheihing et al., 1998).

MINING - Moderate Scenario

Economic Trends
Economic trends remain the same as AEO99 under the moderate scenario.

Production and Technology Trends
Production trends remain the same as AEO99 under the moderate scenario. The retirement rate of capital stock in all non-manufacturing industry sub-sectors is set at 2% per year in the NEMS AEO99 model, for an average lifetime of 50 years. Jaccard and Willis (1996) estimate the average lifetime of mining equipment to be 25-30 years. Thus, we adjust the retirement rate to 2.5% per year, for an average lifetime of 40 years.

Energy Consumption Trends
For existing equipment in the moderate scenario, we used the UECs defined in AEO99. The TPC for existing equipment is estimated has been changed to reflect increased attention to energy efficiency improvement, resulting in replacement of motors by high efficiency motors, introduction of variable speed drives and efficient grinding equipment, as well as efficient pumps and ventilation systems. Jaccard and Willis (1986), in one of the few studies that explicitly models mining, found an economic savings potential of 1%/year for underground metal mining and 0.5%/year for metal open pit mining for the period 1990-2020 in Canada. The economic potential was determined using a real discount rate, and using stock turnover rates to model uptake of new equipment. This potential is given as an improvement over a business as usual scenario. Case studies (in the U.S., Canada, Australia and the U.K.) in the metal mining industry (Caddet, 1999) show large potential savings in many unit-operations. R&D may provide further improvements of new technologies (NMA, 1998). On the basis of these studies we assume a TPC for existing equipment of 1.5 times the base case for existing and new equipment in mining (see Table A-9). In addition, boiler energy efficiency improves at a rate of 0.2% per year for fossil fuels and 0.1% per year for biomass and waste in this scenario (CIBO, 1997; Einstein et al., 1999).

Table A-9 Moderate Scenario Inputs for Existing and New Equipment for Mining

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Sub-Sector	Fuel	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Coal Mining	Electricity	1.566	1.5061	-0.0015	1.409	1.3031	-0.003
	Natural gas	0.298	0.2866	-0.0015	0.268	0.2479	-0.003
	Res. Oil	0.288	0.2770	-0.0015	0.259	0.2395	-0.003
	Dist. Oil	2.013	1.9359	-0.0015	1.812	1.6758	-0.003
	Motor	0.129	0.1241	-0.0015	0.116	0.1073	-0.003
	Steam coal	0.296	0.2847	-0.0015	0.266	0.2460	-0.003
Gas/Oil	Electricity	1.565	1.5051	-0.0015	1.409	1.3031	-0.0030
	Natural gas	3.361	3.2323	-0.0015	3.025	2.7977	-0.0030
	Res. Oil	0.074	0.0684	-0.003	0.066	0.0635	-0.0015
	Dist. Oil	0.526	0.4865	-0.003	0.473	0.4549	-0.0015
	LPGs	0	0.0000	-0.003	0	0.0000	-0.0015
	Motor	0.127	0.1175	-0.003	0.114	0.1096	-0.0015
	Steam coal	0	0.0000	-0.003	0	0.0000	-0.0015
	Steam	0.736	0.6807	-0.003	0.662	0.6367	-0.0015
	Biomass	0.014	0.0129	-0.003	0.013	0.0125	-0.0015
	Other Petr.	0.099	0.0916	-0.003	0.089	0.0856	-0.0015
Metal Mining	Electricity	4.638	4.4605	-0.0015	4.174	3.8603	-0.003
	Natural gas	0.0057	0.0055	-0.0015	0.0051	0.0047	-0.003
	Res. Oil	0.393	0.3780	-0.0015	0.354	0.3274	-0.003
	Dist. Oil	2.629	2.5284	-0.0015	2.366	2.1882	-0.003
	Motor	0.01	0.0096	-0.0015	0.009	0.0083	-0.003
	Steam coal	2.219	2.1341	-0.0015	1.997	1.8469	-0.003
	Steam	0.253	0.2433	-0.0015	0.227	0.2099	-0.003

MINING - Advanced Scenario

Economic Trends
Economic trends remain the same as AEO99 under the advanced scenario.

Production Trends
Production trends remain the same as AEO99 under the advanced scenario. The retirement rate of capital stock in all non-manufacturing industry sub-sectors is set at 2% per year in the NEMS AEO99 model, for an average lifetime of 50 years. Jaccard and Willis (1996) estimate the average lifetime of mining equipment to be 25-30 years. Thus, we adjust the retirement rate to 2.5% per year, for an average lifetime of 40 years.

Energy Consumption Trends
In the advanced scenario, we used the UECs defined in AEO99. The TPC for existing equipment has been changed to reflect increased attention to energy efficiency improvement, resulting in replacement of motors by high efficiency motors, introduction of variable speed drives and efficient grinding equipment, as well as efficient pumps and ventilation systems. Jaccard and Willis (1986), in one of the few studies that explicitly models mining, found an economic savings potential of 1%/year for underground metal mining and 0.5%/year for metal open pit mining for the period 1990-2020 in Canada. The economic potential was determined using a real discount rate, and using stock turnover rates to model uptake of new equipment. This potential is given as an improvement over a business as usual scenario. Case studies (in the U.S., Canada, Australia and the U.K.) in the metal mining industry (Caddet, 1999) show large potential savings in many unit-operations. Accelerated R&D may provide further improvements of new technologies (NMA, 1998). On the basis of these studies we assume a TPC for existing equipment of 2 times the base case for existing and new equipment in mining (see Table A-10). In addition, boiler energy efficiency improves at a rate of 0.2% per year for oil and renewables and 0.3% per year for gas and coal (CIBO, 1997; Einstein et al., 1999).

Table A-10 Advanced Scenario Inputs for Existing and New Equipment for Mining

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Sub-Sector	Fuel	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Coal Mining	Electricity	1.566	1.4866	-0.002	1.409	1.2696	-0.004
	Natural gas	0.298	0.2829	-0.002	0.268	0.2415	-0.004
	Res. Oil	0.288	0.2734	-0.002	0.259	0.2334	-0.004
	Dist. Oil	2.013	1.9109	-0.002	1.812	1.6327	-0.004
	Motor	0.129	0.1225	-0.002	0.116	0.1045	-0.004
	Steam coal	0.296	0.2810	-0.002	0.266	0.2397	-0.004
Gas/Oil	Electricity	1.565	1.4856	-0.002	1.409	1.2696	-0.004
	Natural gas	3.361	3.1905	-0.002	3.025	2.7256	-0.004
	Res. Oil	0.074	0.0667	-0.004	0.066	0.0627	-0.002
	Dist. Oil	0.526	0.4739	-0.004	0.473	0.4490	-0.002
	LPGs	0	0.0000	-0.004	0	0.0000	-0.002
	Motor	0.127	0.1144	-0.004	0.114	0.1082	-0.002
	Steam coal	0	0.0000	-0.004	0	0.0000	-0.002
	Steam	0.736	0.6632	-0.004	0.662	0.6284	-0.002
	Biomass	0.014	0.0126	-0.004	0.013	0.0123	-0.002
	Other Petr.	0.099	0.0892	-0.004	0.089	0.0845	-0.002
Metal Mining	Electricity	4.638	4.4028	-0.002	4.174	3.7609	-0.004
	Natural gas	0.0057	0.0054	-0.002	0.0051	0.0046	-0.004
	Res. Oil	0.393	0.3731	-0.002	0.354	0.3190	-0.004
	Dist. Oil	2.629	2.4957	-0.002	2.366	2.1319	-0.004
	Motor	0.01	0.0095	-0.002	0.009	0.0081	-0.004
	Steam coal	2.219	2.1065	-0.002	1.997	1.7994	-0.004
	Steam	0.253	0.2402	-0.002	0.227	0.2045	-0.004

CONSTRUCTION - Historical Trends

Economic Trends
Gross output, or value of output, which represents the market value of an industry's production, including commodity taxes, in U.S. construction grew at an average of 0.9% per year between 1977 and 1997, increasing from $372B (1987$) in 1977 to $447B in 1997. Production hit a low of $320B in 1982 and its current high of $447B in 1997. Value of output in the construction industry has followed a series of dips and hikes, resulting in no net increase in value of output between 1977 and 1991. Value of output then increased 22% between 1991 and 1997, at 3.3% per year (U.S.DOC, 1998).

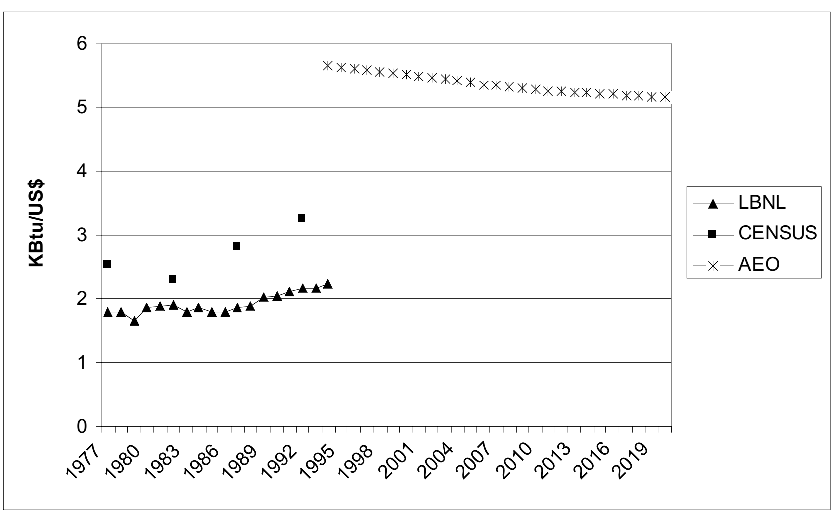
Energy Consumption Trends
We have analyzed data from two sources to form historical energy consumption patterns. We used data from the Census of Construction Industries, published every 5 years, as well as an LBNL-generated data set compiled using data from the National Energy Accounts and the Annual Energy Outlook (U.S.DOC, 1989; AEO, 1998). The AEO historical data do not include asphalt and road oil, which are the largest energy products consumed in the construction industry.

Based on LBNL-generated data, primary energy consumption in U.S. construction rose from 0.547 quads in 1960 to 0.910 quads in 1994, at a rate of 1.5% per year. Primary energy consumption changed little from 1960 to 1975, increasing only 4% total, from 0.547 quads to 0.570 quads. Energy consumption has increased more rapidly since them, at a rate of 2.5% per year.

Data from the Census of Construction Industries mirrors the trends in the LBNL data, but the data tends to be greater in value than the LBNL data, rising from 0.942 quads in 1977 to 1.25 quads in 1992, at a rate of 1.9% per year. The Census values range from 20% to 50% higher than the LBNL data.

According to LBNL data, primary energy intensity increased from 1.8 KBtu/U.S.$ in 1977 to 2.2 KBtu/U.S.$ in 1994, at 1.3% per year. According to census data, primary energy intensity increased from 2.5 KBtu/U.S.$ in 1977 to 3.3 KBtu/U.S.$ in 1992, at 1.7% per year. Both data sources show that the growth in construction energy consumption has outpaced the economic growth in the construction sector since 1977 (see Figure A-3).

Fig. A-3 Historical and Projected Economic Primary Energy Intensities (KBtu/U.S.$) for U.S. Construction



CONSTRUCTION - AEO99 Reference Case and Business-As-Usual Scenario

AOE99 aggregates construction into one group, encompassing SIC codes 15 through 17[3]. We adopt the AEO99 reference case for the business-as-usual scenario.

Economic Trends

Unlike the historical trends discussed above, the AEO99 projects a 2.0% annual average growth rate increase in value of output over the 26 year period 1994 to 2020, growing from $389B in 1994 to $657B in 2020. While the predicted values and growth rates match the historical trend from 1994-1997, the growth rate used by NEMS is double the historical growth rate (0.9%) in the long term. The projected growth rate experiences none of the dips and hikes of the actual historical value of output trends, and seems to follow only the most recent historical trend.

Production and Technology Trends

The retirement rate of capital stock in all non-manufacturing subsectors is set at 2% per year in NEMS AOE99, for an average lifetime of 50 years. We adjust the retirement rate to 2.5% per year, for an average lifetime of 40 years.

Energy Consumption Trends

AEO99 projects an increase in primary energy of 1.7% per year, increasing from 2.2 quads in 1994 to 3.4 quads in 2020. While this rate of increase matches the long-term historical trends, and is, in fact, the average of the two, the results are much higher than at any period in the historical data. In 1994, for example, the AEO projection of 2200 TBtu is roughly 240% the 1994 figure in the LBNL data (910 TBtu), and approximately 75% higher than the 1992 figure given in the Census data (1250 TBtu). It seems as though the definition of the construction sector must vary, though the AEO cites SIC codes 15-17 as their definition of construction. Energy use for buildings in the construction industry is not accounted separately in the NEMS model.

Economic energy intensity (KBtu/value of output) for the construction sector as a whole is projected to decline at an average rate of —0.4% per year between 1994 and 2020 in the AEO99 reference case (see Figure A-3). This is in contrast to the historical data, which offer increasing energy consumption growth rates of 1.3% from LBNL data and 1.7% from Census data. In the projected scenario, economic growth outpaces the growth in primary energy consumption in the construction sector. Due to energy consumption projections that vastly exceed historical figures, projected economic energy intensities for U.S. construction are up to 2.5 times greater than historical figures.

Table A-11 provides the NEMS baseline input values for existing and new equipment in 1994 and 2020.

Table A-11 NEMS Baseline Inputs for Existing and New Equipment for Construction

	Existing Equipment			New Equipment		
	1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Fuel	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Electricity	0.285	0.2768	-0.001	0.256	0.2416	-0.002
Natural Gas	0.438	0.4255	-0.001	0.394	0.3718	-0.002
Distillate Oil	0.439	0.4264	-0.001	0.395	0.3727	-0.002
Residual Oil	0.289	0.2807	-0.001	0.26	0.2453	-0.002
Asphalt and Road Oil	2.515	2.4504	-0.001	2.263	2.1482	-0.002
Motor Gasoline	0.27	0.2623	-0.001	0.243	0.2293	-0.002
LPG	0.077	0.0748	-0.001	0.069	0.0651	-0.002

[3] Building Construction (SIC 15), Heavy Construction other than Building Construction (SIC 16), Special Trade Contractors (SIC 17)

CONSTRUCTION — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2.

In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the construction sector include demonstration programs, assessment programs, Challenge programs, state programs, ENERGY STAR and Climate Wise programs, investment tax credits for CHP systems, and a CO2 cap and trade system. Currently, the construction industry is not specifically targeted by existing energy programs. However, expansion of other programs, such as motor standards, Motor Challenge activities, indirect price effects of cap and trade, and voluntary programs like Climate Wise will affect energy use in the construction industry. In addition, some larger companies (e.g. asphalt mixers) can use the services of expanded audit programs to develop improved energy use practices in plants and on construction sites.

CONSTRUCTION - Moderate Scenario

Economic Trends
Economic trends remain the same as AEO99 under the moderate scenario.

Production and Technology Trends
The retirement rate of capital stock in all non-manufacturing subsectors is set at 2% per year in NEMS AOE99, for an average lifetime of 50 years. We adjust the retirement rate to 2.5% per year, for an average lifetime of 40 years.

Energy Consumption Trends
We did not evaluate the energy efficiency improvement potential in this sector. Thus, under the moderate scenario, we assume a TPC for existing equipment of 1.5 times the base case for existing and new equipment in construction (see Table A-12).

Table A-12 Moderate Scenario Inpusts for Existing and New Equipment in Construction

	Existing Equipment			New Equipment		
	1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Fuel	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Electricity	0.285	0.2768	-0.0015	0.256	0.2368	-0.003
Natural Gas	0.438	0.4255	-0.0015	0.394	0.3644	-0.003
Distillate Oil	0.439	0.4264	-0.0015	0.395	0.3653	-0.003
Residual Oil	0.289	0.2807	-0.0015	0.26	0.2405	-0.003
Asphalt and Road Oil	2.515	2.4504	-0.0015	2.263	2.0929	-0.003
Motor Gasoline	0.27	0.2623	-0.0015	0.243	0.2247	-0.003
LPG	0.077	0.0748	-0.0015	0.069	0.0638	-0.003

CONSTRUCTION - Advanced Scenario

Economic Trends
Economic trends remain the same as AEO99 under the advanced scenario.

Production and Technology Trends
The retirement rate of capital stock in all non-manufacturing subsectors is set at 2% per year in NEMS AOE99, for an average lifetime of 50 years. We adjust the retirement rate to 2.5% per year, for an average lifetime of 40 years.

Energy Consumption Trends
We did not evaluate the energy efficiency improvement potential in this sector. Thus, under the moderate scenario, we assume a TPC for existing equipment of 2 times the base case for existing and new equipment in construction (see Table A-13).

Table A-13 Advanced Scenario Inputs for Existing and New Equipment in Construction

	Existing Equipment			New Equipment		
	1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Fuel	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Electricity	0.285	0.2768	-0.002	0.256	0.2307	-0.004
Natural Gas	0.438	0.4255	-0.002	0.394	0.3550	-0.004
Distillate Oil	0.439	0.4264	-0.002	0.395	0.3559	-0.004
Residual Oil	0.289	0.2807	-0.002	0.26	0.2343	-0.004
Asphalt and Road Oil	2.515	2.4504	-0.002	2.263	2.0390	-0.004
Motor Gasoline	0.27	0.2623	-0.002	0.243	0.2190	-0.004
LPG	0.077	0.0748	-0.002	0.069	0.0622	-0.004

FOOD - Historical Trends

Economic Trends

Value of output for the food and kindred products sector grew from $262B in 1977 to $371B in 1997, at an average annual growth rate of 1.7% per year (U.S.DOC, 1998).

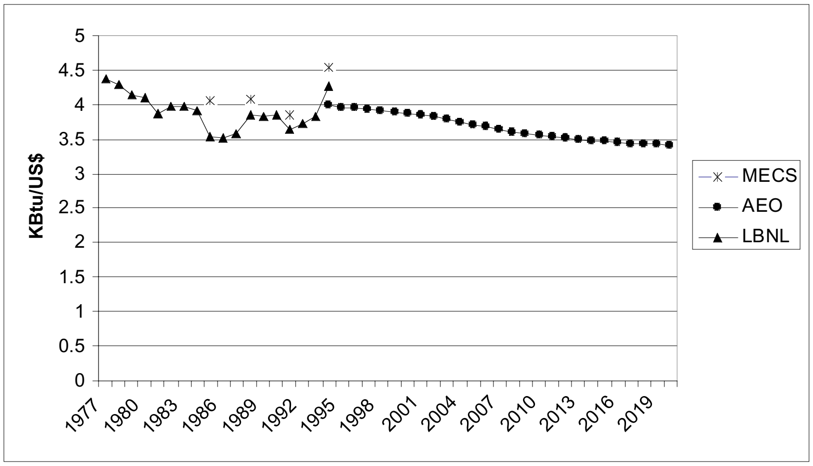
Energy Consumption Trends

Based on data from the Manufacturing Energy Consumption Survey, primary energy consumption in the food sector increased overall about 3% per year between 1985 and 1994 (U.S. DOE, EIA, 1988, 1991, 1994, 1997). However, the growth has not been steady. A 7% rise between 1985 and 1988 was followed by a 1% decline from 1988 to 1991, which was followed by a 23% increase in energy use from 1991 to 1994.

LBNL-developed data (U.S.DOC, 1989; U.S.DOE, various years) show that primary energy consumption increased 1.8% per year between 1960 and 1994, and 3.9% per year between 1985 and 1994.

While historical economic energy intensity for the food and kindred products sector (primary energy/value of output) changed little overall between 1977 and 1994, a series of dips and hikes produced this net lack of change. Economic energy intensity declined slightly over the long term, on average —0.16% per year (U.S.DOC, 1989; U.S.DOE, various years) between 1977 and 1994, though it increased from 4 KBtu/U.S.$ in 1985 to 4.5 KBtu/U.S.$ in 1994. Energy intensity increased on average 1.2% (U.S.DOE, selected years) per year between 1985 and 1994 (see Figure A-4).

Fig. A-4 Historical and Projected Economic Primary Energy Intensities (KBtu/U.S.$) for U.S. Food and Kindred Products



FOOD - AEO99 Reference Case and Business-As-Usual Scenario

We adopt the AEO99 reference case for the business-as-usual scenario.

Economic Trends
Projected economic growth in the food and kindred products sector, measured with value of output, is estimated at 1.2% per year between 1994 and 2020. This is almost 50% greater than the historical growth rate.

Production and Technology Trends
The retirement rate of capital stock in the food and kindred products sector is set at 1.7% per year in NEMS AOE99, for an average lifetime of 59 years. We adjust the retirement rate to 2.1% per year, for an average lifetime of 47 years.

Energy Consumption Trends
Primary energy consumption is projected to increase at 0.6% per year between 1994 and 2020, from 1511 Tbtu in 1994 to 1781 Tbtu in 2020 in the AEO99 reference, much more slowly than the historical energy consumption growth rates (see Figure A-4).

Economic energy intensity (MJ/value of output) for the food and kindred products sector as a whole is projected to decline at an average rate of —0.6% per year between 1994 and 2020 in the AEO99 reference case (see Figure A-4). Table A-14 provides the NEMS AEO99 input values for existing and new equipment for 1994 and 2020. NEMS provides values for four regions for this sector.

In NEMS, energy use in buildings in the food sector is set as energy use per employee, and only reacts to changes in number of employees in an industry, ignoring changes in building energy use, stock turnover of buildings, and also the potential impact of programs like Energy Star Buildings and Green Lights.

Table A-14 NEMS Baseline Inputs for Existing and New Equipment for Food

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Process	**Fuel**	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Heat	Natural Gas	0.3139	0.2896	-0.0031	0.2825	0.2586	-0.0034
Heat	Residual Oil	0.02	0.0184	-0.0031	0.018	0.0165	-0.0034
Heat	Distillate Oil	0.0196	0.0181	-0.0031	0.0176	0.0161	-0.0034
Heat	LPG	0.0086	0.0079	-0.0031	0.0077	0.0070	-0.0034
Heat	Steam Coal	0.0019	0.0017	-0.0044	0.0017	0.0015	-0.0049
Heat	Other Petroleum	0	0.0000	-0.0031	0	0.0000	-0.0034
Heat	Biomass - Wood	0.0038	0.0035	-0.0031	0.0034	0.0031	-0.0034
Water	Steam	0.7661	0.7067	-0.0031	0.6895	0.6311	-0.0034
Refrigeration	Electricity	0.1122	0.1071	-0.0018	0.101	0.0959	-0.002
Other electric	Electricity	0.2917	0.2784	-0.0018	0.2625	0.2492	-0.002
Heat	Natural Gas	0.5514	0.5086	-0.0031	0.4963	0.4542	-0.0034
Heat	Residual Oil	0.0051	0.0047	-0.0031	0.0045	0.0041	-0.0034
Heat	Distillate Oil	0.0028	0.0026	-0.0031	0.0026	0.0024	-0.0034
Heat	LPG	0.0058	0.0054	-0.0031	0.0052	0.0048	-0.0034
Heat	Steam Coal	0.0521	0.0465	-0.0044	0.0469	0.0413	-0.0049
Heat	Other Petroleum	0	0.0000	-0.0031	0	0.0000	-0.0034
Heat	Biomass - Wood	0.0013	0.0012	-0.0031	0.0012	0.0011	-0.0034
Water	Steam	1.5299	1.4113	-0.0031	1.3769	1.2602	-0.0034
Refrigeration	Electricity	0.1443	0.1377	-0.0018	0.1298	0.1232	-0.002
Other electric	Electricity	0.375	0.3578	-0.0018	0.3375	0.3204	-0.002
Heat	Natural Gas	0.424	0.3911	-0.0031	0.3816	0.3493	-0.0034
Heat	Residual Oil	0.0084	0.0077	-0.0031	0.0075	0.0069	-0.0034
Heat	Distillate Oil	0.0062	0.0057	-0.0031	0.0056	0.0051	-0.0034
Heat	LPG	0.0095	0.0088	-0.0031	0.0085	0.0078	-0.0034
Heat	Steam Coal	0.0095	0.0085	-0.0044	0.0086	0.0076	-0.0049
Heat	Other Petroleum	0	0.0000	-0.0031	0	0.0000	-0.0034
Heat	Biomass - Wood	0.007	0.0065	-0.0031	0.0063	0.0058	-0.0034
Water	Steam	1.4409	1.3292	-0.0031	1.2968	1.1869	-0.0034
Refrigeration	Electricity	0.1488	0.1420	-0.0018	0.1339	0.1271	-0.002
Other electric	Electricity	0.3869	0.3692	-0.0018	0.3482	0.3305	-0.002
Heat	Natural Gas	0.6405	0.5908	-0.0031	0.5764	0.5276	-0.0034
Heat	Residual Oil	0.006	0.0055	-0.0031	0.0054	0.0049	-0.0034
Heat	Distillate Oil	0.0157	0.0145	-0.0031	0.0141	0.0129	-0.0034
Heat	LPG	0.0148	0.0137	-0.0031	0.0133	0.0122	-0.0034
Heat	Steam Coal	0.0218	0.0194	-0.0044	0.0196	0.0173	-0.0049
Heat	Other Petroleum	0	0.0000	-0.0031	0	0.0000	-0.0034
Heat	Biomass - Wood	0	0.0000	-0.0031	0	0.0000	-0.0034
Water	Steam	1.5654	1.4440	-0.0031	1.4088	1.2894	-0.0034
Refrigeration	Electricity	0.1132	0.1080	-0.0018	0.1019	0.0967	-0.002
Other electric	Electricity	0.2942	0.2807	-0.0018	0.2648	0.2514	-0.002

FOOD — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2. In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the food sector include demonstration programs, assessment programs, Challenge programs, ENERGY STAR buildings and Green Lights, state programs, state implementation plans, R&D programs, ESCO/utility programs, ENERGY STAR and Climate Wise programs, tax incentives for energy managers, tax rebates for specific industrial technologies, investment tax credits for CHP systems, and a CO2 cap and trade system. The food industry encompasses a wide variety of operations, although large amounts of energy are used in power applications and hot water and steam systems. Programs aimed at motors (standards, Compressed Air Challenge), steam systems (Steam Challenge, CHP initiatives), buildings (ENERGY STAR, Green Lights), as well as state programs (RD&D, public benefit charges) will affect energy use of existing equipment (upgrade of steam distribution), new equipment (state R&D activities, using public benefit charges) and boilers and buildings. The Challenge programs aim to contribute to market transformation and use specific goals, e.g. a 10% reduction in electricity use by motors by 2002 and a reduction in energy use in steam systems with 20% by 2010. Deregulation has resulted in the use of public benefit charges on power consumption. The generated funds are used for several purposes including R&D and implementation programs. The effects are still difficult to estimate, but if implemented on the basis of ESCO practices in the past for utilities, the average savings are typically estimated at $0.06/kWh-saved annually (Goldman and Kito, 1994). Voluntary sector agreements in the food industries in The Netherlands achieved annual energy efficiency improvements ranging from 0.9% to 2.3% for various food industries (on average 1.8% per year).

FOOD - Moderate Scenario

Economic Trends
Economic trends remain the same as AEO99 under the moderate scenario.

Production and Technology Trends
The retirement rate of capital stock in the food and kindred products sector is set at 1.7% per year in NEMS AOE99, for an average lifetime of 59 years. We adjust the retirement rate to 2.1% per year, for an average lifetime of 47 years.

Energy Consumption Trends
Table A-15 provides the input values for the moderate scenario. We did not evaluate the energy efficiency improvement potential in the food sector. Thus, we derived moderate scenario values by taking the mid-point between the NEMS baseline and HiTech case values. However, we did increase boiler energy efficiency at a rate of 0.2% per year for fossil fuels and 0.1% per year for biomass and waste in this scenario (CIBO, 1997; Einstein et al., 1999). Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the moderate scenario.

Table A-15 Moderate Scenario Inputs for Existing and New Equipment in Food

		Existing Equipment			New Equipment		
		1994 UECs	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Process	**Fuel**	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Heat	Natural Gas	0.3139	0.2847	-0.00375	0.2825	0.2413	-0.0061
Heat	Residual Oil	0.02	0.0181	-0.00375	0.018	0.0154	-0.00605
Heat	Distillate Oil	0.0196	0.0178	-0.00375	0.0176	0.0150	-0.00605
Heat	LPG	0.0086	0.0078	-0.00375	0.0077	0.0066	-0.00605
Heat	Steam Coal	0.0019	0.0017	-0.0047	0.0017	0.0014	-0.0075
Heat	Other Petroleum	0	0.0000	-0.00375	0	0.0000	-0.00605
Heat	Biomass - Wood	0.0038	0.0034	-0.00375	0.0034	0.0029	-0.00605
Water	Steam	0.7661	0.6948	-0.00375	0.6895	0.5889	-0.00605
Refrigeration	Electricity	0.1122	0.1044	-0.00275	0.101	0.0894	-0.0047
Other electric	Electricity	0.2917	0.2715	-0.00275	0.2625	0.2322	-0.0047
Heat	Natural Gas	0.5514	0.5001	-0.00375	0.4963	0.4239	-0.00605
Heat	Residual Oil	0.0051	0.0046	-0.00375	0.0045	0.0038	-0.00605
Heat	Distillate Oil	0.0028	0.0025	-0.00375	0.0026	0.0022	-0.00605
Heat	LPG	0.0058	0.0053	-0.00375	0.0052	0.0044	-0.00605
Heat	Steam Coal	0.0521	0.0461	-0.0047	0.0469	0.0386	-0.0075
Heat	Other Petroleum	0	0.0000	-0.00375	0	0.0000	-0.00605
Heat	Biomass - Wood	0.0013	0.0012	-0.00375	0.0012	0.0010	-0.00605
Water	Steam	1.5299	1.3875	-0.00375	1.3769	1.1759	-0.00605
Refrigeration	Electricity	0.1443	0.1343	-0.00275	0.1298	0.1148	-0.0047
Other electric	Electricity	0.375	0.3491	-0.00275	0.3375	0.2986	-0.0047
Heat	Natural Gas	0.424	0.3845	-0.00375	0.3816	0.3259	-0.00605
Heat	Residual Oil	0.0084	0.0076	-0.00375	0.0075	0.0064	-0.00605
Heat	Distillate Oil	0.0062	0.0056	-0.00375	0.0056	0.0048	-0.00605
Heat	LPG	0.0095	0.0086	-0.00375	0.0085	0.0073	-0.00605
Heat	Steam Coal	0.0095	0.0084	-0.0047	0.0086	0.0071	-0.0075
Heat	Other Petroleum	0	0.0000	-0.00375	0	0.0000	-0.00605
Heat	Biomass - Wood	0.007	0.0063	-0.00375	0.0063	0.0054	-0.00605
Water	Steam	1.4409	1.3068	-0.00375	1.2968	1.1075	-0.00605
Refrigeration	Electricity	0.1488	0.1385	-0.00275	0.1339	0.1185	-0.0047
Other electric	Electricity	0.3869	0.3602	-0.00275	0.3482	0.3081	-0.0047
Heat	Natural Gas	0.6405	0.5809	-0.00375	0.5764	0.4923	-0.00605
Heat	Residual Oil	0.006	0.0054	-0.00375	0.0054	0.0046	-0.00605
Heat	Distillate Oil	0.0157	0.0142	-0.00375	0.0141	0.0120	-0.00605
Heat	LPG	0.0148	0.0134	-0.00375	0.0133	0.0114	-0.00605
Heat	Steam Coal	0.0218	0.0193	-0.0047	0.0196	0.0161	-0.0075
Heat	Other Petroleum	0	0.0000	-0.00375	0	0.0000	-0.00605
Heat	Biomass - Wood	0	0.0000	-0.00375	0	0.0000	-0.00605
Water	Steam	1.5654	1.4197	-0.00375	1.4088	1.2032	-0.00605
Refrigeration	Electricity	0.1132	0.1054	-0.00275	0.1019	0.0902	-0.0047
Other electric	Electricity	0.2942	0.2739	-0.00275	0.2648	0.2343	-0.0047

FOOD - Advanced Scenario

Economic Trends
Economic trends remain the same as AEO99 under the advanced scenario.

Production and Technology Trends
The retirement rate of capital stock in the food and kindred products sector is set at 1.7% per year in NEMS AOE99, for an average lifetime of 59 years. We adjust the retirement rate to 2.1% per year, for an average lifetime of 47 years.

Energy Consumption Trends
Table A-16 provides the input values for the advanced scenario. We did not evaluate the energy efficiency improvement potential in the food sector. Thus, we adopt the NEMS HiTech case values for the advanced scenario. In addition, boiler energy efficiency improves at a rate of 0.2% per year for oil and renewables and 0.3% per year for gas and coal (CIBO, 1997; Einstein et al., 1999). Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the advanced scenario.

Table A-16 Advanced Scenario Inputs for Existing and New Equipment in Food

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Process	**Fuel**	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Heat	Natural Gas	0.3139	0.2799	-0.0044	0.2825	0.2251	-0.0087
Heat	Residual Oil	0.02	0.0178	-0.0044	0.018	0.0143	-0.0087
Heat	Distillate Oil	0.0196	0.0175	-0.0044	0.0176	0.0140	-0.0087
Heat	LPG	0.0086	0.0077	-0.0044	0.0077	0.0061	-0.0087
Heat	Steam Coal	0.0019	0.0017	-0.005	0.0017	0.0013	-0.0101
Heat	Other Petroleum	0	0.0000	-0.0044	0	0.0000	-0.0087
Heat	Biomass - Wood	0.0038	0.0034	-0.0044	0.0034	0.0027	-0.0087
Water	Steam	0.7661	0.6831	-0.0044	0.6895	0.5494	-0.0087
Refrigeration	Electricity	0.1122	0.1019	-0.0037	0.101	0.0833	-0.0074
Other electric	Electricity	0.2917	0.2649	-0.0037	0.2625	0.2164	-0.0074
Heat	Natural Gas	0.5514	0.4917	-0.0044	0.4963	0.3954	-0.0087
Heat	Residual Oil	0.0051	0.0045	-0.0044	0.0045	0.0036	-0.0087
Heat	Distillate Oil	0.0028	0.0025	-0.0044	0.0026	0.0021	-0.0087
Heat	LPG	0.0058	0.0052	-0.0044	0.0052	0.0041	-0.0087
Heat	Steam Coal	0.0521	0.0457	-0.005	0.0469	0.0360	-0.0101
Heat	Other Petroleum	0	0.0000	-0.0044	0	0.0000	-0.0087
Heat	Biomass - Wood	0.0013	0.0012	-0.0044	0.0012	0.0010	-0.0087
Water	Steam	1.5299	1.3642	-0.0044	1.3769	1.0971	-0.0087
Refrigeration	Electricity	0.1443	0.1310	-0.0037	0.1298	0.1070	-0.0074
Other electric	Electricity	0.375	0.3405	-0.0037	0.3375	0.2782	-0.0074
Heat	Natural Gas	0.424	0.3781	-0.0044	0.3816	0.3040	-0.0087
Heat	Residual Oil	0.0084	0.0075	-0.0044	0.0075	0.0060	-0.0087
Heat	Distillate Oil	0.0062	0.0055	-0.0044	0.0056	0.0045	-0.0087
Heat	LPG	0.0095	0.0085	-0.0044	0.0085	0.0068	-0.0087
Heat	Steam Coal	0.0095	0.0083	-0.005	0.0086	0.0066	-0.0101
Heat	Other Petroleum	0	0.0000	-0.0044	0	0.0000	-0.0087
Heat	Biomass - Wood	0.007	0.0062	-0.0044	0.0063	0.0050	-0.0087
Water	Steam	1.4409	1.2848	-0.0044	1.2968	1.0333	-0.0087
Refrigeration	Electricity	0.1488	0.1351	-0.0037	0.1339	0.1104	-0.0074
Other electric	Electricity	0.3869	0.3514	-0.0037	0.3482	0.2871	-0.0074
Heat	Natural Gas	0.6405	0.5711	-0.0044	0.5764	0.4593	-0.0087
Heat	Residual Oil	0.006	0.0054	-0.0044	0.0054	0.0043	-0.0087
Heat	Distillate Oil	0.0157	0.0140	-0.0044	0.0141	0.0112	-0.0087
Heat	LPG	0.0148	0.0132	-0.0044	0.0133	0.0106	-0.0087
Heat	Steam Coal	0.0218	0.0191	-0.005	0.0196	0.0151	-0.0101
Heat	Other Petroleum	0	0.0000	-0.0044	0	0.0000	-0.0087
Heat	Biomass - Wood	0	0.0000	-0.0044	0	0.0000	-0.0087
Water	Steam	1.5654	1.3958	-0.0044	1.4088	1.1225	-0.0087
Refrigeration	Electricity	0.1132	0.1028	-0.0037	0.1019	0.0840	-0.0074
Other electric	Electricity	0.2942	0.2672	-0.0037	0.2648	0.2183	-0.0074

PAPER - Historical Trends

Economic Trends
Value of output for the paper industry grew at an average of 1.9% per year between 1977 and 1997, increasing from $88B to $128B during this period (U.S.DOC, 1998).

Production and Technology Trends
U.S. pulp production grew from 42 to 74 million tons between 1970 and 1995, with the bulk of the growth occurring in chemical pulp production (average annual growth of 2.6%). In 1995, chemical pulp accounted for 83% of all pulp, followed by mechanical pulp (9%) and other pulp (8%). U.S. paper production grew from 50 to 98 million tons during the same period. Wrapping and packaging paper clearly dominates, with 52% of production in 1995, followed by printing and writing (28%), newsprint (8%), sanitary and household (7%), and other paper (5%). While paper production grew at an average annual rate of 2.7%, growth in printing and writing paper and newsprint was faster, averaging 3.9% and 3.3%, respectively (U.N., 1998).

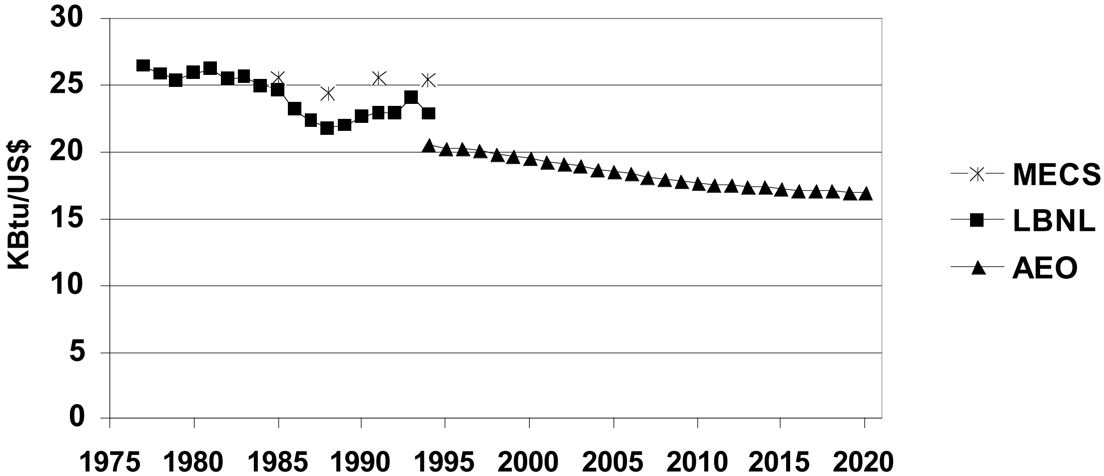
AEO99 distinguishes between four types of pulping: waste paper pulping, mechanical pulping, semi-chemical pulping, and kraft/sulfite pulping. Between 1970 and 1995, the share of mechanical pulping declined slightly from 9.8% to 9.2%. The share of semi-chemical pulping declined from 13.5% to 8.2%, while kraft/sulfite pulping grew from 76.7% to 82.6% during this period (U.N., 1998). In 1994, 28 Mt of wastepaper pulp was used in the pulp and paper industry (AFPA, 1998). This accounted for 32% of all pulp.

Energy Consumption Trends
LBNL-developed data show that primary energy used for papermaking in the U.S. grew from 1.3 Quads in 1960 to 2.8 Quads in 1994 (U.S.DOC, 1989; U.S.DOE, various years), an increase of 2.4% per year. Primary energy consumption increased at 1.5% per year between 1985 and 1994. Wood waste burned on-site provided most of the energy used, growing from 34% of final energy in 1960 to 48% in 1994. The shares of electricity and natural gas also grew during this time, while the use of coal & coke and oil declined. The shift away from oil after the oil embargoes of the 1970s was dramatic, with shares dropping from a high of 27% in 1973 to 8% in 1994. The Manufacturing Energy Consumption Survey data, which follow the same overall trends as the LBNL data, average between 4% and 14% higher than the LBNL data. The MECS data show primary energy consumption increasing at 2.3% per year between 1985 and 1994.[4]

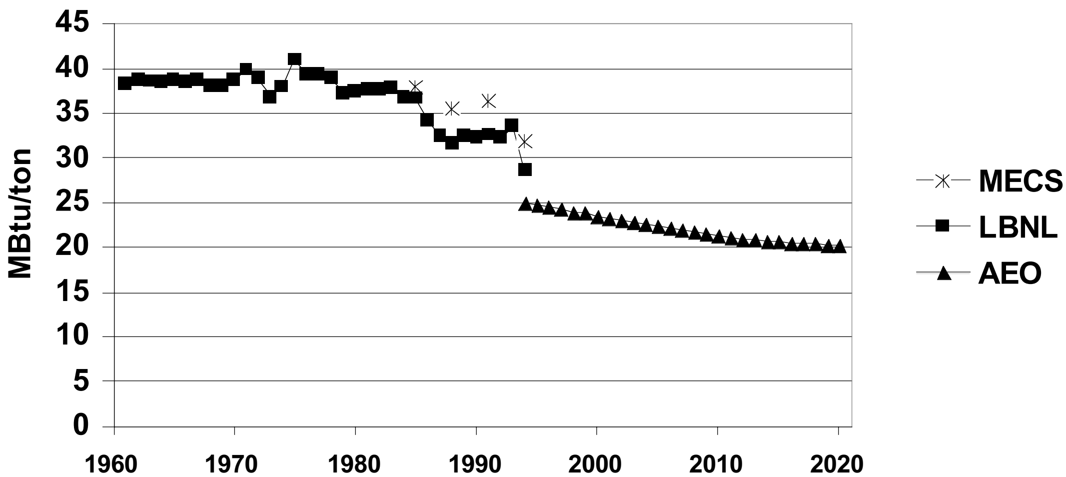
The economic primary energy intensity of paper production decreased from 26.4 KBtu/U.S.$ in 1977 to 22.9 KBtu/U.S.$ in 1994 (NEA, MECS), an annual average decline of —0.8% per year. The physical primary energy intensity of paper production declined at -1.2% per year between 1970 and 1994. The decrease would have been of lesser magnitude had not paper production jumped an astonishing 16% between 1993 and 1994, from 85 to 98 million tons.

[4] Primary energy use is calculated using the annual U.S. industrial conversion rate from final to primary electricity.

Fig. A-5 Historical and Projected Economic (KBtu/U.S.$) Primary Energy Intensities for U.S. Pulp and Paper



Historical and Projected Physical (MBtu/ton) Primary Energy Intensities for U.S. Pulp and Paper



PAPER - AEO99 Reference Case

Economic Trends
AEO99 projects that the value of output from the paper industry will increase at an average rate of 1.2% per year between 1994 and 2020, growing from $119B to $162B.

Production and Technology Trends
AEO99 projects that paper production will grow at an average of 1.2% per year between 1994 and 2020, increasing from 98.6 Mtons to 136 Mtons.

AEO99 projects that the share of kraft/sulfite pulping will increase from 83.7% in 1994 to 88.7% in 2020, while the share of mechanical pulping drops from 9.6% to 5.7% and the share of semi-chemical pulping drops from 6.7% to 5.6% during the same period. AEO99 also projects that the use of waste paper for pulping will grow at an average rate of 1.6% per year, increasing from 42.2 Mtons in 1994 to 63.2 Mtons in 2020.[5]

Retirement rates for pulp and paper mills in AOE99 are 2.3% per year, for an average lifetime of 45 years.

Energy Consumption Trends
AEO99 projects that final energy consumption from pulp and papermaking will grow at an average of 0.7% per year, from 1929 TBtu in 1994 to 2334 TBtu in 2020. Primary energy is projected to grow more slowly, at an average annual rate of 0.4%, increasing from 2461 TBtu in 1994 to 2754 TBtu in 2020.

Final economic energy intensity is projected to decline at an average of —0.4% per year, dropping from 16.1 KBtu/U.S.$ in 1994 to 14.4 KBtu/U.S.$ in 2020. Primary economic energy intensity is anticipated to drop from 20.6 KBtu/U.S.$ in 1994 to 17.0 KBtu/U.S.$ in 2020, at an average annual rate of —0.7%.

Final physical energy intensity is projected to decline at an average of —0.5% per year, dropping from 19.5 MBtu/ton in 1994 to 17.2 MBtu/ton in 2020. Primary physical energy intensity drops from 25.0 MBtu/ton in 1994 to 20.3 MBtu/ton in 2020, at an average annual rate of —0.8%. Table A-17 provides the NEMS AEO99 input values for existing and new equipment for 1994 and 2020.

In NEMS, energy use in buildings is a set as energy use per employee, and only reacts to changes in number of employees in an industry, ignoring changes in building energy use, stock turnover of buildings, and also the potential impact of programs like Energy Star Buildings and Green Lights.

[5] The NEMS industrial module includes market pulp with waste pulping.

Table A-17 NEMS Reference Case Inputs for Existing and New Equipment for Paper Production

		Existing Equipment			New Equipment		
Process	**Fuel**	**1994 UECs** MBtu/ton	**2020 UECs** MBtu/ton	**TPC**	**1994 UECs** MBtu/ton	**2020 UECs** MBtu/ton	**TPC**
Paper making	Electricity	1.5000	1.3466	-0.0041	1.125	0.991	-0.0049
	Steam	6.0000	4.9664	-0.0072	4.5	3.6027	-0.0085
	Natural Gas	0.1446	0.1197	-0.0072	0.1084	0.0868	-0.0085
	Residual Oil	0.2163	0.1791	-0.0072	0.1623	0.1299	-0.0085
	Distillate Oil	0.0082	0.0068	-0.0072	0.0062	0.0049	-0.0085
	LP Gas	0.021	0.0174	-0.0072	0.0158	0.0126	-0.0085
	Steam Coal	0.0098	0.0075	-0.0104	0.0074	0.0054	-0.122
	Biomass - Wood	0	0	-0.0072	0	0	-0.0085
	Other Petroleum	0	0	-0.0072	0	0	-0.0085
	Biomass — Pulping Liquor	0	0	-0.0072	0	0	-0.0085
Bleaching	Electricity	0.300	0.2849	-0.0020	0.2555	0.2453	-0.0016
	Steam	5.6	5.1158	-0.0035	4.7695	4.4421	-0.0027
Waste paper pulping	Electricity	1.30	1.2672	-0.0010	1.209	1.1835	-0.0008
	Steam	1.4	1.3387	-0.0017	1.302	1.2544	-0.0014
Mechanical pulping	Electricity	5.4	5.1863	-0.0016	4.536	4.4941	-0.0004
	Steam	0.5	0.4659	-0.0027	0.42	0.4132	-0.0006
Chemical pulping	Electricity	1.5000	1.4187	-0.0021	1.1916	1.1682	-0.0008
	Steam	5.3000	4.8071	-0.0037	4.2104	4.0666	-0.0013
Kraft pulping	Electricity	1.5	1.3615	-0.0037	1.095	1.0057	-0.0033
	Steam	11.3	9.5362	-0.0065	8.249	7.1071	-0.0057
	Natural Gas	0.6867	0.5795	-0.0065	0.5013	0.4319	-0.0057
	Residual Oil	1.0276	0.8672	-0.0065	0.7501	0.6463	-0.0057
	Distillate Oil	0.0391	0.033	-0.0065	0.0285	0.0246	-0.0057
	LP Gas	0.1	0.0843	-0.0065	0.073	0.0629	-0.0057
	Steam Coal	0.0467	0.0366	-0.0093	0.0341	0.0276	-0.0082
	Biomass - Wood	0	0	-0.0065	0	0	-0.0057
	Other Petroleum	0	0	-0.0065	0	0	-0.0057
Wood Preparation	Electricity	0.2700	0.2599	-0.0015	0.2268	0.2258	-0.0002

PAPER - Business-As-Usual Scenario

Economic Trends
Economic trends remain the same as AEO99 under the business-as-usual scenario.

Production and Technology Trends
We adopt the retirement rates for pulp and paper mills in AOE99 (2.3% per year, for an average lifetime of 43 years) for the business-as-usual scenario.

Energy Consumption Trends
Table A-18 provides the business-as-usual inputs for existing and new equipment for 1994 and 2020. For existing equipment in the moderate scenario, we adopted the NEMS 1994 UECs for paper making and adjusted the NEMS 1994 UECs for bleaching and pulping based on Khrushch et al. (1999). We adopted the NEMS TPCs for all processes except electricity use in papermaking and bleaching, where we adopted lower TPCs.

For new equipment in 1994, we adopted the NEMS 1994 UECs for paper making and adjusted the NEMS 1994 UECs for bleaching and pulping based on Khrushch et al. (1999). We adjust the TPCs based on the following information from Khrushch et al. (1999):

Raw Material Preparation
Wood preparation includes debarking, chipping and conveying to the pulp mill, and consists mainly of power use for motors. In cold climates some heat may be used, but we did not include this in this analysis.

Based on Nilsson et al. (1995) we estimated power use at 45 kWh/ADMT of pulp, equivalent to 0.14 MBtu/ton pulp. Energy efficiency improvements are minor, and hence annual improvement rates are estimated to be 0.05%/year in the business-as-usual scenario.

Kraft Pulp Mill

In the Kraft process, steam and electricity are used in the digesting, mixing and pumping of the material. Steam is also used to concentrate the black liquor and dry some of the pulp to be exported as market pulp. Fuels are mainly used in the lime kiln to re-calcinate the lime. Steam use is estimated on the basis of Nilsson et al. (1995) for a model 2000 mill, adapted for black liquor concentration of a model 1980 mill. This is equivalent to steam consumption of 7.47 MBtu/ton pulp. Energy use in the lime kiln is estimated on the basis of the model 1980 mill, using approximately 1.61 MBtu/ton. Electricity use is estimated on the basis of the Model 2000 mill, or 640 kWh/ADMT (equivalent to 1.89 MBtu/ton pulp). Table A-18 provides the TPCs by fuel that we adopt for the business-as-usual scenario for kraft pulping.

Semi-Chemical/Chemical Pulping

This process is not well defined in the NEMS model description. We have used the data for sulfite pulping given by Jaccard and Willis (1996) in the ISTUM model. The process includes pulping and black liquor evaporation (assuming the production of 0.6 ton of BL/ton pulp). We estimate 1994 steam use at 3.90 MBtu/ton pulp and power consumption at 1.97 MBtu/ton.

In 2020 we assume use of a computer controlled digester, a BL evaporator using vapor recompression and computer control (Jaccard and Willis, 1996). Steam use is reduced to 3.75 MBtu/ton in the advanced scenario and an estimated power use of 1.95 MBtu/ton pulp. Table A-18 provides the TPCs by fuel that we adopt for the business-as-usual scenario for semi-chemical and chemical pulping.

Mechanical Pulping

Mechanical pulping can use various processes and energy use depends on the quality of the fibers produced. We assume that the process is mainly groundwood pulping. For a new plant we assume the use of pressurized groundwood pulping, which enables heat recovery of low grade waste heat. Jaccard and Willis (1996) estimate power use at 4.21 MBtu/ton pulp. Modern PGW pulp mills can recover between 0.34 and 0.86 MBtu/ton pulp (Komppa, 1993). In 2000 we assume a heat recovery rate of 0.34 MBtu/ton, which will increase to 1.0 MBtu/ton in the advanced scenario by 2020. In the business-as-usual and moderate scenarios, the energy savings are a fraction of the rate in the advanced scenario. Electricity use decreases slowly, by 0.2% per year in the business-as-usual scenario, reflecting a slower penetration of efficient grinding technologies.

Waste Paper Pulping

We include pulping and de-inking in this process step. Pulping only consumes electricity, while de-inking uses heat. Future developments aim at enzymatic de-inking which may lead to reduction in heat demand (Eriksson and Adolphson, 1997). We assume power use of 1.09 MBtu/ton (Nilsson et al., 1995) in 1994. Komppa (1993) estimates heat use for waste paper pulping and de-inking at 0.344 MBtu/ton. In the business-as-usual scenario the improvement rates are —0.3% per year for electricity and —0.1% per year for steam.

Bleaching

Chlorine bleaching is the most common bleaching method in the paper industry. However, developments are under way to reduce the use of chlorine. The new processes may make use of oxygen, ozone or enzymes. Energy use in conventional bleachers depends on the number of bleaching stages, heat integration, and also the degree of bleaching needed. We estimate steam use for a new facility at 1.25 MBtu/ton bleached pulp (Jaccard and Willis, 1996) and power use at 0.18 MBtu/ton (Nilsson et al., 1995). Future developments in energy use are unclear due to the different paths that can be taken. We assume a small potential for efficiency improvement of —0.05% per year in steam use and -0.06% per year in power use in the business-as-usual scenario.

Papermaking

In the paper machine, energy is used for refining and screening the pulp, for forming and pressing, and for drying. Power is mainly used in the machine drives, pumps and fans in the drying sections. Modern paper machines have large capacities (a large web-width and speeds up to 2000 meter/minute) and are hence more efficient than older machines (Coleman and Haunreiter, 1998). Most energy is needed in the drying stage, where relatively small amounts of water are removed. Future developments aim to reduce the need for the drying stage by increasing the efficiency of pressing. Modern machines may have a long nip press. Future machines include the Condebelt-process and Impulse drying (de Beer et al., 1997). These technologies will reduce heat demand in the paper machine considerably.

Energy use will also depend on the paper type produced and the quality desired. For the calculation we use the 1994 product mix of the U.S. paper industry. We estimate heat use in a new paper machine at 6.013 MBtu/ton (printing paper) (Hekkert and Worrell, 1998), and power use at 1.45 MBtu/ton paper (Nilsson et al., 1995). Future paper machines will incorporate the new process developments. By 2020 we assume that the Condebelt process is commercially available, reducing heat demand by 20% in the business-as-usual scenario (de Beer et al., 1997).

Table A-18 Business-As-Usual UECs for Existing and New Equipment for Paper Production

		Existing Equipment			New Equipment		
Process	**Fuel**	**1994 UECs** MBtu/ton	**2020 UECs** MBtu/ton	**TPC**	**1994 UECs** MBtu/ton	**2020 UECs** MBtu/ton	**TPC**
Paper making	Electricity	1.7349	1.6642	-0.0016	1.4480	1.3047	-0.0040
	Steam	9.0967	8.4131	-0.0030	6.0130	4.8162	-0.0085
	Natural Gas	0.0000	0.0000	0	0.0000	0.0000	0
	Residual Oil	0.0000	0.0000	0	0.0000	0.0000	0
	Distillate Oil	0.0000	0.0000	0	0.0000	0.0000	0
	LP Gas	0.0000	0.0000	0	0.0000	0.0000	0
	Steam Coal	0.0000	0.0000	0	0.0000	0.0000	0
	Biomass - Wood	0.0000	0.0000	0	0.0000	0.0000	0
	Other Petroleum	0.0000	0.0000	0	0.0000	0.0000	0
	Biomass — Pulping Liquor	0.0000	0.0000	0	0.0000	0.0000	0
Bleaching	Electricity	0.3535	0.3330	-0.0023	0.1800	0.1772	-0.0006
	Steam	2.3989	2.3803	-0.0003	1.2476	1.2315	-0.0005
Waste paper pulping	Electricity	1.1094	1.1044	-0.00018	1.0900	1.0002	-0.0033
	Steam	0.6142	0.5785	-0.0023	0.3436	0.3348	-0.0010
Mechanical pulping	Electricity	5.8441	5.7536	-0.0006	4.7279	4.4881	-0.0020
	Steam	0.7780	0.7545	-0.00118	-0.3436	-0.4451	0.0100
Chemical pulping	Electricity	1.5635	1.4842	-0.0020	1.9726	1.9522	-0.0004
	Steam	5.0285	4.5309	-0.0040	3.9040	3.7546	-0.0015
Kraft pulping	Electricity	1.3739	1.3042	-0.0020	1.8910	1.8186	-0.0015
	Steam	11.9146	10.7355	-0.0040	7.4733	7.0943	-0.0020
	Natural Gas	0.6506	0.6257	-0.0015	0.4205	0.3889	-0.0030
	Residual Oil	0.9735	0.9363	-0.0015	0.6292	0.5744	-0.0035
	Distillate Oil	0.0370	0.0356	-0.0015	0.0239	0.0218	-0.0035
	LP Gas	0.0947	0.0911	-0.0015	0.0612	0.0559	-0.0035
	Steam Coal	0.0442	0.0399	-0.0040	0.0286	0.0258	-0.0040
	Biomass - Wood	0.0000	0.0000	0	0.0000	0.0000	0
	Other Petroleum	0.0000	0.0000	0	0.0000	0.0000	0
Wood Preparation	Electricity	0.1826	0.1795	-0.00068	0.1449	0.1430	-0.0005

PAPER — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2.

In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the paper sector include demonstration programs, assessment programs, Challenge programs, ENERGY STAR buildings and Green Lights, product labeling, state programs, state implementation plans, R&D programs, ESCO/utility programs, ENERGY STAR and Climate Wise programs, pollution prevention programs, tax incentives for energy managers, tax rebates for specific industrial technologies, investment tax credits for CHP systems, and a CO2 cap and trade system. The pulp and paper industry is specifically targeted by many programs, e.g. R&D under Industries of the Future, efficient motor use through Motor Challenge, as well as for efficient use of steam and increased use of cogeneration. Pollution prevention programs will help to reduce paper waste and improve recycling rates. The latter will increase the use of waste paper in the feedstock mix. Pollution prevention programs contribute to energy and cost savings through reduced material use. Carbon emissions reduction in 1997 were estimated at 5.2 million tonnes carbon, or roughly equivalent to annual energy savings of 0.2 Quads (EPA, 1998). OIT R&D programs will help to commercialize black liquor gasification, while project XL with EPA will allow easier demonstration of the technology. Audits and energy managers in larger facilities will find opportunities for efficient use of steam and electricity.

PAPER - Moderate Scenario

Economic Trends
Economic trends remain the same as AEO99 under the moderate scenario.

Production and Technology Trends
We adopt the retirement rates for pulp and paper mills in AEO99 (2.3% per year, for an average lifetime of 43 years) for the moderate scenario. We increase the share of waste paper by 0.2% per year and reduce bleaching thoughput by 0.1% per year.

Energy Consumption Trends
For existing equipment in the moderate scenario, we used the adjusted UECs defined by the 1994 baseline calculations in Khrushch et al. (1999). To derive the 2020 UECs, we used the savings associated with implementation of the following retrofit technologies and measures:

- Raw Material Preparation: modified debarkers
- Mechanical Pulping: heat recovery in TMP, refinery improvements
- Kraft and Chemical Pulping: improved screening, continuous digester modifications, batch digester modifications, falling film black liquor evaporation, lime kiln modifications
- Bleaching: oxygen bleaching, oxygen prelignification, ozone bleaching, washing presses
- Paper Making: gap forming, long nip press, reduced air requirements, infrared profiling
- General: efficient steam systems, efficient motors, preventative maintenance

For new equipment in the moderate scenario we generally adjust the annual rates of energy efficiency improvement to a mid-point between the business-as-usual and the advanced scenario values (see following discussion of advanced scenarios).

Boiler energy efficiency increases at a rate of 0.2% per year for fossil fuels and 0.1% per year for biomass and waste in this scenario (CIBO, 1997; Einstein et al., 1999). Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the moderate scenario.

Table A-19 Moderate Scenario Inputs for Existing and New Equipment for Paper Production

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Process	Fuel	MBtu/ton	MBtu/ton		MBtu/ton	MBtu/ton	
Paper making	Electricity	1.7349	1.5962	-0.0032	1.4480	1.3746	-0.0020
	Steam	9.0967	7.9852	-0.0050	6.0130	4.4513	-0.0115
	Natural Gas	0.0000	0	0	0.0000	0.0000	0
	Residual Oil	0.0000	0	0	0.0000	0.0000	0
	Distillate Oil	0.0000	0	0	0.0000	0.0000	0
	LP Gas	0.0000	0	0	0.0000	0.0000	0
	Steam Coal	0.0000	0	0	0.0000	0.0000	0
	Biomass - Wood	0.0000	0	0	0.0000	0.0000	0
	Other Petroleum	0.0000	0	0	0.0000	0.0000	0
	Biomass — Pulping Liquor	0.0000	0	0	0.0000	0.0000	0
Bleaching	Electricity	0.3535	0.3071	-0.0054	0.1800	0.1772	-0.0006
	Steam	2.3989	2.3618	-0.0006	1.2476	1.2315	-0.0005
Waste paper pulping	Electricity	1.1094	1.0994	-0.00035	1.0900	0.9821	-0.0040
	Steam	0.6142	0.5448	-0.0046	0.3436	0.3016	-0.0050
Mechanical pulping	Electricity	5.8441	5.6645	-0.0012	4.7279	4.1502	-0.0050
	Steam	0.7780	0.7318	-0.00235	-0.3436	-0.5898	0.0210
Chemical pulping	Electricity	1.5635	1.4536	-0.0028	1.9726	1.9522	-0.0004
	Steam	5.0285	4.2777	-0.0062	3.9040	3.5639	-0.0035
Kraft pulping	Electricity	1.3739	1.2773	-0.0028	1.8910	1.7719	-0.0025
	Steam	11.9146	10.1357	-0.0062	7.4733	6.8222	-0.0035
	Natural Gas	0.6506	0.6032	-0.0029	0.4205	0.3596	-0.0060
	Residual Oil	0.9735	0.9027	-0.0029	0.6292	0.5353	-0.0062
	Distillate Oil	0.0370	0.0343	-0.0029	0.0239	0.0203	-0.0062
	LP Gas	0.0947	0.0878	-0.0029	0.0612	0.0521	-0.0062
	Steam Coal	0.0442	0.0388	-0.0050	0.0286	0.0235	-0.0075
	Biomass - Wood	0.0000	0	0	0.0000	0.0000	0
	Other Petroleum	0.0000	0	0	0.0000	0.0000	0
Wood Preparation	Electricity	0.1826	0.1763	-0.00135	0.1449	0.1419	-0.0008

PAPER - Advanced Scenario

Economic Trends
Economic trends remain the same as AEO99 under the moderate scenario.

Production and Technology Trends
We adopt the retirement rates for pulp and paper mills in AOE99 (2.3% per year, for an average lifetime of 43 years) for the business-as-usual scenario. We increased the waste paper share by 0.4% per year and reduced bleaching throughput by 0.2% per year.

Energy Consumption Trends

For existing equipment in the advanced scenario, we used the adjusted UECs defined by the 1994 baseline calculations in Krushch et al. (1999). To derive the 2020 UECs, we used the savings associated with implementation of the following retrofit technologies and measures:

- Raw Material Preparation: modified debarkers
- Mechanical Pulping: heat recovery in TMP, refinery improvements, biopulping
- Kraft and Chemical Pulping: improved screening, continuous digester modifications, batch digester modifications, falling film black liquor evaporation, lime kiln modifications, tempella recovery system, black liquor gasification
- Bleaching: oxygen bleaching, oxygen prelignification, ozone bleaching, washing presses, biobleaching

- Paper Making: gap forming, long nip press, reduced air requirements, infrared profiling, hot pressing, high consistency forming
- General: efficient steam systems, efficient motors, preventative maintenance, power conditioners

For new equipment in the advanced scenario we make the following adjustments to the annual rates of energy efficiency improvements:

- Raw Material Preparation: increase TPCs to 0.1% per year.
- Kraft Pulping: The Kraft mill in the year 2020 is assumed to have modern multi-stage evaporators and/or mechanical vapor recompression. Lime use has been reduced slightly, while efficiency of the lime kiln has been improved to that of a Model 2000 plant (Nilsson et al., 1995), resulting in reduced fuel use in the lime kiln. Steam use in the advanced scenario will be reduced to 6.16 MBtu/ton pulp, while kiln fuel use will be around 1.16 MBtu/ton pulp. Power use will be reduced to 555 kWh/tonne ADMT pulp (or 1.72 MBtu/ton).
- Chemical Pulping: In 2020 we assume use of a computer controlled digester, a BL evaporator using vapor recompression and computer control (Jaccard and Willis, 1996). Steam use is reduced to 3.21 MBtu/ton in the advanced scenario and an estimated power use of 1.95 MBtu/ton pulp.
- Mechanical Pulping: In 2000 we assume a heat recovery rate of 0.34 MBtu/ton, which will increase to 1.0 MBtu/ton in the advanced scenario by 2020. Electricity use decreases slowly, by 0.11%/year, in the advanced scenario.
- Waste Paper Pulping: Future developments aim at enzymatic de-inking which may lead to reduction in heat demand (Eriksson and Adolphson, 1997). We assume power use of 1.09 MBtu/ton (Nilsson et al., 1995) which will decline to 0.95 MBtu/ton by 2020 in the advanced scenario. Komppa (1993) estimates heat use for waste paper pulping and de-inking at 0.344 MBtu/ton. We assume this figure for new plants, and a reduction of 1.0%/year to the year 2020 in the advanced scenario.
- Bleaching: We estimate steam use for a new facility at 1.23 MBtu/ton bleached pulp (Jaccard and Willis, 1996) and power use at 0.18 MBtu/ton (Nilsson et al., 1995). Future developments in energy use are unclear due to the different paths that can be taken. We assume a small potential for efficiency improvement limited to 0.1%/year in steam use and 0.06%/year in power use in the advanced scenario.
- Papermaking: Energy use will also depend on the paper type produced and the quality desired. For the calculation we use the 1994 product mix of the U.S. paper industry. We estimate heat use in a new paper machine at 6.013 MBtu/ton (printing paper) (Hekkert and Worrell, 1998), and power use at 1.45 MBtu/ton paper (Nilsson et al., 1995). Future paper machines will incorporate the new process developments. By 2020 we assume that the Condebelt process is commercially available, reducing heat demand by 20% in the business-as-usual scenario and by 26% in the moderate scenario (de Beer et al., 1997). For the advanced scenario we also expect the successful development of impulse drying and estimate the reduction in steam use at 30%. Power use will increase slightly when using impulse drying (de Beer et al., 1997), so savings in power use (e.g. more efficient drives) will be partially offset by increased power use, depending on the penetration of impulse drying.

In addition, boiler energy efficiency improves at a rate of 0.2% per year for oil and renewables and 0.3% per year for gas and coal (CIBO, 1997; Einstein et al., 1999). Table A-20 provides the moderate scenario inputs for existing and new equipment for 1994 and 2020. Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the advanced scenario.

Table A-20 Advanced Scenario Inputs for Existing and New Equipment for Paper Production

Process	Fuel	Existing Equipment 1994 UECs MBtu/ton	Existing Equipment 2020 UECs MBtu/ton	Existing Equipment TPC	New Equipment 1994 UECs MBtu/ton	New Equipment 2020 UECs MBtu/ton	New Equipment TPC
Paper making	Electricity	1.7349	1.5269	-0.0049	1.4480	1.5055	0.0015
	Steam	9.0967	7.0049	-0.010	6.0130	4.2118	-0.0136
	Natural Gas	0.0000	0	0	0.0000	0.0000	0
	Residual Oil	0.0000	0	0	0.0000	0.0000	0
	Distillate Oil	0.0000	0	0	0.0000	0.0000	0
	LP Gas	0.0000	0	0	0.0000	0.0000	0
	Steam Coal	0.0000	0	0	0.0000	0.0000	0
	Biomass - Wood	0.0000	0	0	0.0000	0.0000	0
	Other Petroleum	0.0000	0	0	0.0000	0.0000	0
	Biomass — Pulping Liquor	0.0000	0	0	0.0000	0.0000	0
Bleaching	Electricity	0.3535	0.2831	-0.0085	0.1800	0.1772	-0.0006
	Steam	2.3989	2.3252	-0.0012	1.2476	1.2156	-0.001
Waste paper pulping	Electricity	1.1094	1.0894	-0.0007	1.0900	0.9568	-0.005
	Steam	0.6142	0.4830	-0.0092	0.3436	0.2646	-0.01
Mechanical pulping	Electricity	5.8441	5.4901	-0.0024	4.7279	3.5463	-0.011
	Steam	0.7780	0.6883	-0.0047	-0.3436	-0.9989	0.0419
Chemical pulping	Electricity	1.5635	1.3761	-0.0049	1.9726	1.9522	-0.0004
	Steam	5.0285	3.9440	-0.0093	3.9040	3.2100	-0.0075
Kraft pulping	Electricity	1.3739	1.2091	-0.0049	1.8910	1.6643	-0.0049
	Steam	11.9146	9.3449	-0.0093	7.4733	6.1609	-0.0074
	Natural Gas	0.6506	0.5607	-0.0057	0.4205	0.3056	-0.0122
	Residual Oil	0.9735	0.8391	-0.0057	0.6292	0.4549	-0.0124
	Distillate Oil	0.0370	0.0319	-0.0057	0.0239	0.0173	-0.0124
	LP Gas	0.0947	0.0817	-0.0057	0.0612	0.0442	-0.0124
	Steam Coal	0.0442	0.0369	-0.007	0.0286	0.0193	-0.015
	Biomass - Wood	0.0000	0	0	0.0000	0.0000	0
	Other Petroleum	0.0000	0	0	0.0000	0.0000	0
Wood Preparation	Electricity	0.1826	0.1702	-0.0027	0.1449	0.1412	-0.001

BULK CHEMICALS - Historical Trends

Bulk chemicals includes SICs 281, 282, 286, and 287 (industrial inorganic chemicals, plastics, industrial organic chemicals, and agricultural chemicals), and omits SICs 283, 284, 285, and 289 (drugs, soap, detergents, cleaning preparations, paints, varnishes, and miscellaneous chemical products).

Economic Trends

Value of output in the bulk chemicals sector increased rapidly between 1970 and 1994, increasing at 8.6% per year, from $22.2B in 1970 to $162B in 1994. Bulk chemicals contributed 5% of total manufacturing value of output in 1994 (OECD, 1995).

Production and Technology Trends

Bulk chemicals comprise the main energy-intensive bulk chemicals such as ethylene, ammonia and chlorine. Ethylene and its derivatives are important petrochemicals in the U.S. economy and are feedstocks for many plastics and resins products as well as fibers and detergents. In 1994, ethylene was the fourth largest chemical produced while propylene was the seventh largest chemical produced (Chemical and Engineering News, 1995). The U.S. is currently the world s largest ethylene producer, accounting for 28% of world installed capacity (Oil and Gas Journal, 1997). Since 1974, ethylene production has grown by 3% annually while propylene has grown by over 4% annually. Propylene has grown more rapidly in the last decade 5% per year. Overall, however, industrial organic chemicals as a group have grown more slowly (2% per year) since 1985, due in part to a drop in output in 1996 (Chemical and Engineering News, 1997). Ammonia is one of the major chemicals produced in the U.S., with an estimated production of 18.0 M tons (CMA, 1996). Roughly 80% of ammonia production is used as fertilizer feedstock in the U.S. (PNL, 1994) and the remainder is used for a variety of products, mainly explosives and plastics. The most important fertilizers produced in the U.S. are ammonium nitrate (AN), nitric acid (NA), urea, compound fertilizers, and liquid ammonia. Ammonium sulfate (AS) is most commonly produced as a co-product of nylon manufacturing. Ammonia is produced through the high pressure synthesis of gases (carbon dioxide, hydrogen, and nitrogen). Urea is produced by a synthesis reaction of ammonia and carbon dioxide. The production of these products has grown on the order of 1% annually since 1974. The U.S. is the world s largest producer of chlorine, producing 12.19 M tons of chlorine in 1994. One of the main uses of chlorine (around 30%) is as an intermediate feedstock for polyvinyl chloride (PVC) which has been growing rapidly over the past decade (Lipinsky and Ingham, 1994). Chlorine is also used as a bleaching agent in pulping operations.

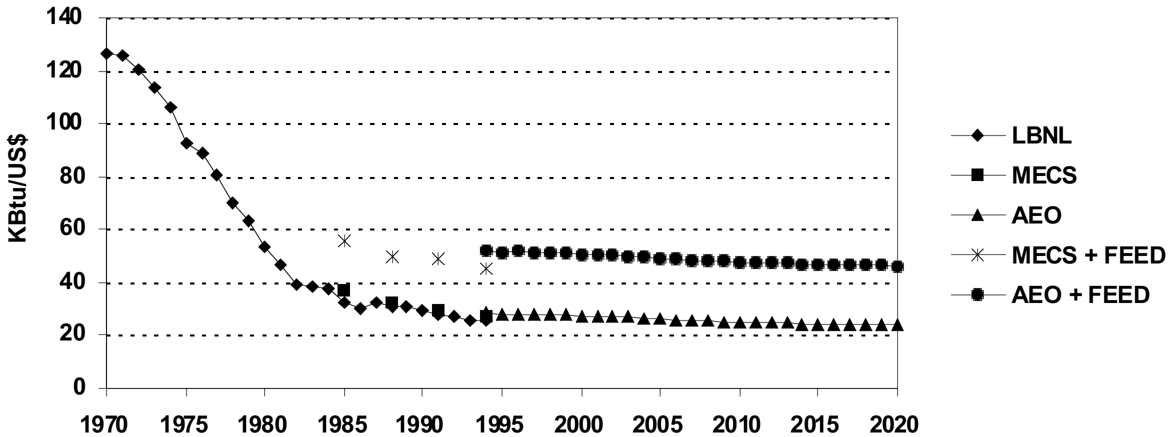
Energy Consumption Trends

Based on data from the *Manufacturing Energy Consumption Survey*, primary energy consumption in the chemicals sector increased overall about 3.7% per year between 1985 and 1994 (U.S. DOE, EIA, 1988, 1991, 1994, 1997). This number increases to 4.7% per year when feedstocks are included in the energy consumption total. Feedstock consumption increased at 7% per year between 1985 and 1994. Feedstocks averaged 34% of total energy consumption over this time period, hovering between 30% and 37%.

LBNL-developed data (U.S.DOC, 1989; U.S.DOE, various years) show that primary energy consumption (not including feedstocks) increased 2.1% per year between 1960 and 1994. Energy consumption increased consistently through the 1960s and on into the late 1970s, rising from 2100 TBtu in 1960 to 3600 TBtu in 1977. Fuel consumption then declined until the mid-1980s, falling to 2800 TBtu in 1986. Primary energy consumption increased 4.6% per year between 1985 and 1994, hitting a high of 4200 TBtu in 1994. Oil and electricity are the dominant fuels used in producing bulk chemicals, contributing 66% and 16% of total energy, respectively, in 1994. Oil and gas are the dominant feedstocks, contributing 64% and 27% of total nonfuel use, respectively, in 1994.

Historical analysis of energy intensity in the bulk chemicals sector shows two distinct trends (see Figure A-6). Between 1970 and the early 1980s, energy intensity fell dramatically, from 126 KBtu/U.S.$ in 1970 to 32.3 KBtu/U.S.$ in 1985, a decline of 75%, or -8.7% per year. According to both LBNL and MECS data, the decline in energy intensity slowed considerably between 1985 and 1994. LBNL data show a decrease in energy intensity of —2.4% per year between 1985 and 1994, while MECS data show a decrease of —3.3% per year over the same time period. Data on feedstock consumption is only available after 1984. Primary energy intensity of chemical production including feedstocks averages about 35% higher than intensity based on strict energy consumption. Primary energy intensity including feedstocks decreased from 55 KBtu/U.S.$ in 1985 to 45 KBtu/U.S.$ in 1994, at an average rate of -2.3% per year.

Fig. A-6 Historical and Projected Primary Economic Energy Intensities (KBtu/U.S.$) in U.S. Chemicals Production



BULK CHEMICALS - AEO99 Reference Case and Business-As-Usual Scenario

Economic Trends
The AEO99 model forecasts an increase of 1.1% per year in value of output between 1994 and 2020. This growth rate is much lower than the historical rate of 1970 to 1994 (8.6% per year).

Production and Technology Trends
Production is measured in monetary terms in the NEMS model, so it is not possible to separate out the different products, production trends and energy intensities. The retirement rate in NEMS is set at 2.3% per year, for an average lifetime of energy consuming equipment of 43 years. This seems long for total plants. Individual pieces of equipment (e.g. pumps, fans) may be replaced more often. Thus, we adjust the retirement rate to 2.5% per year, for an average lifetime of 40 years.

Energy Consumption Trends
The projected primary energy consumption in the AEO99 model increases at a steady 0.4% per year, or 0.6% per year when including feedstocks. In the AEO99 model, primary energy intensity decreases from 28.4 KBtu/U.S.$ in 1994 to 23.9 KBtu/U.S.$ in 2020, at a rate of —0.7% per year. When feedstocks are included in the energy consumption figures, energy intensity declines from 52.0 KBtu/U.S.$ in 1994 to 46.3 KBtu/U.S.$ in 2020, at —0.5% per year. The rate of decrease is much lower in magnitude than the historical figures. The AEO99 forecast matches the trends of the late 1980s and early 1990s much more than the long-term trends.

Table A-21 provides the NEMS baseline input values for existing and new equipment for 1994 and 2020. In the AEO 99 reference case the energy intensity varies by region. In this study we keep the regional distribution in tact, but vary the TPCs for the various scenarios, based on recent studies and our insights.

In NEMS, energy use in buildings in the chemical sector is set as energy use per employee, and only reacts to changes in number of employees in an industry, ignoring changes in building energy use, stock turnover of buildings, and also the potential impact of programs like Energy Star Buildings and Green Lights.

Table A-21 NEMS Baseline Inputs for Existing and New Equipment for the Bulk Chemicals Industry

		Existing Equipment			New Equipment		
		1994 UECs	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Process	**Fuel**	MBtu/k$	MBtu/k$		MBtu/k$	MBtu/k$	
Electrolysis	Electricity	0.7407	0.7076	-0.0018	0.6666	0.6334	-0.002
Other Electricity	Electricity	3.5489	3.3904	-0.0018	3.194	3.0349	-0.002
Direct	Natural gas	1.505	1.3892	-0.0031	1.3545	1.2386	-0.0034
	Resid. Oil	0.2214	0.2043	-0.0031	0.1992	0.1822	-0.0034
	Dist. Oil	0.0651	0.0601	-0.0031	0.0586	0.0536	-0.0034
	LPGs	0.0216	0.0199	-0.0031	0.0194	0.0178	-0.0034
	Steam Coal	0.0086	0.0077	-0.0044	0.0077	0.0068	-0.0049
	Other Petro	0	0	-0.0031	0	0	-0.0034
Steam	Steam	3.5917	3.3154	-0.0031	3.2325	2.9558	-0.0034
Feed	Natural gas	5.5251	5.1002	-0.0031	4.9726	4.547	-0.0034
	LPGs	12.5445	11.5798	-0.0031	11.2901	10.3238	-0.0034
	Petrochem	10.136	9.3565	-0.0031	9.1224	8.3417	-0.0034
Electrolysis	Electricity	1.3879	1.3259	-0.0018	1.2491	1.1869	-0.002
Other Electricity	Electricity	6.6495	6.3524	-0.0018	5.9845	5.6864	-0.002
Direct	Natural gas	3.1595	2.9165	-0.0031	2.8436	2.6002	-0.0034
	Resid. Oil	0.0106	0.0098	-0.0031	0.0095	0.0087	-0.0034
	Dist. Oil	0.0103	0.0095	-0.0031	0.0093	0.0085	-0.0034
	LPGs	0.0176	0.0163	-0.0031	0.0159	0.0145	-0.0034
	Steam Coal	0.0475	0.0424	-0.0044	0.0428	0.0376	-0.0049
	Other Petro	0	0	-0.0031	0	0	-0.0034
Steam	Steam	6.2611	5.7796	-0.0031	5.635	5.1527	-0.0034
Feed	Natural gas	4.2995	3.9688	-0.0031	3.8695	3.5384	-0.0034
	LPGs	9.7619	9.0111	-0.0031	8.7857	8.0337	-0.0034
	Petrochem	7.8876	7.281	-0.0031	7.0989	6.4913	-0.0034
Electrolysis	Electricity	0.6745	0.6444	-0.0018	0.607	0.5768	-0.002
Other Electricity	Electricity	3.2316	3.0873	-0.0018	2.9085	2.7636	-0.002
Direct	Natural gas	5.4499	5.0307	-0.0031	4.9049	4.4851	-0.0034
	Resid. Oil	0.0531	0.049	-0.0031	0.0478	0.0437	-0.0034
	Dist. Oil	0.0151	0.0139	-0.0031	0.0136	0.0124	-0.0034
	LPGs	0.0083	0.0077	-0.0031	0.0075	0.0069	-0.0034
	Steam Coal	0.0314	0.028	-0.0044	0.0283	0.0249	-0.0049
	Other Petro	0	0	-0.0031	0	0	-0.0034
Steam	Steam	9.9257	9.1624	-0.0031	8.9332	8.1686	-0.0034
Feed	Natural gas	4.7553	4.3896	-0.0031	4.2798	3.9135	-0.0034
	LPGs	10.7967	9.9664	-0.0031	9.717	8.8854	-0.0034
	Petrochem	8.7238	8.0529	-0.0031	7.8514	7.1794	-0.0034
Electrolysis	Electricity	1.4457	1.3812	-0.0018	1.3012	1.2364	-0.002
Other Electricity	Electricity	6.9268	6.6174	-0.0018	6.2341	5.9236	-0.002
Direct	Natural gas	4.4508	4.1085	-0.0031	4.0057	3.6629	-0.0034
	Resid. Oil	0.0059	0.0054	-0.0031	0.0053	0.0048	-0.0034
	Dist. Oil	0.0301	0.0278	-0.0031	0.0271	0.0248	-0.0034
	LPGs	0.0567	0.0524	-0.0031	0.051	0.0467	-0.0034
	Steam Coal	0.065	0.058	-0.0044	0.0585	0.0515	-0.0049
	Other Petro	0	0	-0.0031	0	0	-0.0034
Steam	Steam	8.0474	7.4285	-0.0031	7.2427	6.6228	-0.0034
Feed	Natural gas	2.1378	1.9734	-0.0031	1.924	1.7593	-0.0034
	LPGs	4.8538	4.4805	-0.0031	4.3684	3.9945	-0.0034
	Petrochem	3.9219	3.6203	-0.0031	3.5297	3.2276	-0.0034

BULK CHEMICALS — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2.

In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the chemical sector include demonstration programs, assessment programs, Challenge programs, ENERGY STAR buildings and Green Lights, state programs, state implementation plans, R&D programs, ESCO/utility programs, ENERGY STAR and Climate Wise programs, tax incentives for energy managers, tax rebates for specific industrial technologies, investment tax credits for CHP systems, and a CO2 cap and trade system. The chemical industry is a large user of oil and gas for energy and feedstocks. In this study we only assess ways to improve energy efficiency. Various large chemical companies have already announced plans to reduce energy consumption by significant quantities or to cut GHG emissions. These include mainly companies that operate internationally like Dow Chemical, DuPont, and Johnson & Johnson. These voluntary self-commitments are the basis for voluntary sector agreements to improve energy efficiency. In this agreement a group of industries (e.g. through an association) negotiates a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements of 0.6% and 1/5% per year are feasible.

While increased recycling has a very limited effect in the chemicals industry, programs aimed at R&D, improved use of steam and electricity in motors may have large impacts. Improved use of steam (through process integration and system upgrades, e.g. Steam Challenge) and increased cogeneration (e.g. through dedicated CHP-policies and deregulation) is a very important contributor to energy savings. Newly installed equipment will be more efficient due to R&D activities, both on the federal level (e.g. increased IOF-funding) and the state level. Audits of the many small chemical companies will help to identify energy efficiency opportunities. Tax incentives for energy managers will result in programs based on the successful experiences of Dow Chemical. Many large chemical companies have voluntarily announced energy efficiency and greenhouse gas emission targets that go well beyond the current baseline assumptions. Costs of air pollution reduction may vary depending on the way that states implement their Clean Air Act State Implementation Plans. Using energy-efficient technologies, air pollution levels would be reduced at a net benefit, compared to using end-of-pipe technologies. Assessments have shown that CO2 emissions could be reduced by 0.2% to 3% per percent-point reduction of NOx emissions (STAPPA/ALAPCO, 1999) due to energy savings.

BULK CHEMICALS - Moderate Scenario

Economic Trends

Economic trends remain the same as AEO99 under the moderate scenario.

Production and Technology Trends

Production trends remain the same as AEO99 under the moderate scenario. We retain the business-as-usual retirement rate of 2.5% per year for a lifetime of 40 years.

Energy Consumption Trends

Table A-22 provides the moderate scenario inputs for existing and new equipment in 1994 and 2020 for bulk chemicals. For existing equipment, we modify the TPCs for electrolysis based on developments in chlorine-alkaline electrolysis and assessment of developments in retrofitting existing cells with improved diaphragm and improved transformers. For other electricity, the TPC is based on successful programs for efficient drives, pumps, fans and compressors, and optimization of existing systems. The TPC for direct firing is based on the use of various technologies in ethylene and ammonia manufacture, e.g. selective radiant coils, controls, and reduced flaring in ethylene, and hydrogen recovery and process control in ammonia making. For steam use, the TPC is based on implementation of retrofit measures that have an estimated payback period of 1.5 years or less, including steam trap monitoring and maintenance, insulation, and condensate recovery. For feedstocks, we adopt the NEMS assumption that feedstock use changes at the same rate as direct firing.[6]

For new equipment, the electrolysis TPC is based on the use of modern membrane cells with successful development of zero gap membranes and improved membranes. For other electricity, the UECs and TPCs are based on the AEO 99 and NEMS Hi-Tech scenario inputs. For direct firing, the TPC is based on the retrofit measures, as well as efficient separation technologies in ethylene making, and gas turbine integration, new ammonia loop designs, and efficient CO2 recovery technologies in ammonia making. Other furnaces are expected to achieve similar savings. The new TPC for steam use is based on design and development of efficient steam use and distribution systems for new plants. For feedstocks, we adopt the NEMS assumption that feedstock use changes at the same rate as direct firing. (Einstein et al., 1999a; Einstein et al.,1999b; Phylipsen et al.,1999; WEC,1995; Worrell et al., 1994; Worrell and De Beer, 1995; Worrell et al., 1999b).

[6] Note that we do not understand the high feedstock use relative to direct firing in AEO99.

Boiler energy efficiency increases at a rate of 0.2% per year for fossil fuels and 0.1% per year for biomass and waste in this scenario (CIBO, 1997; Einstein et al., 1999b). Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the moderate scenario.

Table A-22 Moderate Scenario Inputs for Existing and New Equipment in Bulk Chemicals

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Process	Fuel	MBtu/k$	MBtu/k$		MBtu/k$	MBtu/k$	
Electrolysis	Electricity	0.7407	0.6940	-0.0025	0.6666	0.6165	-0.003
Other Electricity	Electricity	3.5489	3.3080	-0.0027	3.194	3.0320	-0.002
Direct	Natural gas	1.505	1.3211	-0.005	1.3545	1.1284	-0.007
	Resid. Oil	0.2214	0.1943	-0.005	0.1992	0.1659	-0.007
	Dist. Oil	0.0651	0.0571	-0.005	0.0586	0.0488	-0.007
	LPGs	0.0216	0.0190	-0.005	0.0194	0.0162	-0.007
	Steam Coal	0.0086	0.0075	-0.005	0.0077	0.0064	-0.007
	Other Petro	0	0.0000	-0.005	0	0.0000	-0.007
Steam	Steam	3.5917	3.0236	-0.0066	3.2325	2.6929	-0.007
Feed	Natural gas	5.5251	4.8500	-0.005	4.9726	4.1425	-0.007
	LPGs	12.5445	11.0117	-0.005	11.2901	9.4054	-0.007
	Petrochem	10.136	8.8975	-0.005	9.1224	7.5996	-0.007
Electrolysis	Electricity	1.3879	1.3005	-0.0025	1.2491	1.1552	-0.003
Other Electricity	Electricity	6.6495	6.1981	-0.0027	5.9845	5.6810	-0.002
Direct	Natural gas	3.1595	2.7734	-0.005	2.8436	2.3689	-0.007
	Resid. Oil	0.0106	0.0093	-0.005	0.0095	0.0079	-0.007
	Dist. Oil	0.0103	0.0090	-0.005	0.0093	0.0077	-0.007
	LPGs	0.0176	0.0154	-0.005	0.0159	0.0132	-0.007
	Steam Coal	0.0475	0.0417	-0.005	0.0428	0.0357	-0.007
	Other Petro	0	0.0000	-0.005	0	0.0000	-0.007
Steam	Steam	6.2611	5.2708	-0.0066	5.635	4.6943	-0.007
Feed	Natural gas	4.2995	3.7741	-0.005	3.8695	3.2236	-0.007
	LPGs	9.7619	8.5691	-0.005	8.7857	7.3191	-0.007
	Petrochem	7.8876	6.9238	-0.005	7.0989	5.9139	-0.007
Electrolysis	Electricity	0.6745	0.6320	-0.0025	0.607	0.5614	-0.003
Other Electricity	Electricity	3.2316	3.0122	-0.0027	2.9085	2.7610	-0.002
Direct	Natural gas	5.4499	4.7840	-0.005	4.9049	4.0861	-0.007
	Resid. Oil	0.0531	0.0466	-0.005	0.0478	0.0398	-0.007
	Dist. Oil	0.0151	0.0133	-0.005	0.0136	0.0113	-0.007
	LPGs	0.0083	0.0073	-0.005	0.0075	0.0062	-0.007
	Steam Coal	0.0314	0.0276	-0.005	0.0283	0.0236	-0.007
	Other Petro	0	0.0000	-0.005	0	0.0000	-0.007
Steam	Steam	9.9257	8.3558	-0.0066	8.9332	7.4420	-0.007
Feed	Natural gas	4.7553	4.1742	-0.005	4.2798	3.5654	-0.007
	LPGs	10.7967	9.4774	-0.005	9.717	8.0949	-0.007
	Petrochem	8.7238	7.6578	-0.005	7.8514	6.5408	-0.007
Electrolysis	Electricity	1.4457	1.3546	-0.0025	1.3012	1.2034	-0.003
Other Electricity	Electricity	6.9268	6.4566	-0.0027	6.2341	5.9179	-0.002
Direct	Natural gas	4.4508	3.9070	-0.005	4.0057	3.3370	-0.007
	Resid. Oil	0.0059	0.0052	-0.005	0.0053	0.0044	-0.007
	Dist. Oil	0.0301	0.0264	-0.005	0.0271	0.0226	-0.007
	LPGs	0.0567	0.0498	-0.005	0.051	0.0425	-0.007
	Steam Coal	0.065	0.0571	-0.005	0.0585	0.0487	-0.007
	Other Petro	0	0.0000	-0.005	0	0.0000	-0.007
Steam	Steam	8.0474	6.7746	-0.0066	7.2427	6.0337	-0.007
Feed	Natural gas	2.1378	1.8766	-0.005	1.924	1.6028	-0.007
	LPGs	4.8538	4.2607	-0.005	4.3684	3.6392	-0.007
	Petrochem	3.9219	3.4427	-0.005	3.5297	2.9405	-0.007

BULK CHEMICALS - Advanced Scenario

Economic Trends
Economic trends remain the same as AEO99 under the advanced scenario.

Production and Technology Trends
Production trends remain the same as AEO99 under the advanced scenario. We retain the same retirement rate as in the moderate scenario for the advanced scenario (2.5% per year for a lifetime of 40 years).

Energy Consumption Trends
Table A-23 provides the advanced scenario inputs for existing and new equipment in 1994 and 2020. For existing equipment, we modify the TPC for electrolysis based on developments in chlorine-alkaline electrolysis and assessment of developments in retrofitting existing cells with improved diaphragm and improved transformers. For other electricity, the TPC is based on successful programs for efficient drives, pumps, fans and compressors, and optimization of existing systems. The TPC for direct firing is based on the use of various technologies in ethylene and ammonia manufacture, e.g. selective radiant coils, controls, reduced flaring, and air preheating in ethylene, and adiabatic reforming, hydrogen recovery and process control in ammonia making. For steam use, the TPC is based on implementation of retrofit measures that have an estimated payback period of 3 years or less, including steam trap monitoring and maintenance, process integration, insulation, condensate recovery and flash steam recovery. For feedstocks, we adopt the NEMS assumption that feedstock use changes at the same rate as direct firing.

For new equipment, the electrolysis TPC is based on the use of modern membrane cells with successful development of zero gap membranes, improved membranes and air depolarized anode (the latter by 2020). For other electricity, the UECs and TPCs are based on the NEMS Hi-Tech scenario inputs. For direct firing, the TPC is based on the retrofit measures, as well as integration of gasturbines and advanced separation technologies in ethylene making, and authothermal reforming and gas turbine integration in ammonia making. Other furnaces are expected to achieve similar savings. The new TPC for steam use is based on design and development of efficient steam use and distribution systems for new plants. For feedstocks, we adopt the NEMS assumption that feedstock use changes at the same rate as direct firing. (Einstein et al., 1999a; Einstein et al.,1999b; Phylipsen et al.,1999; WEC,1995; Worrell et al., 1994; Worrell and De Beer, 1995; Worrell et al., 1999b).

In addition, boiler energy efficiency improves at a rate of 0.2% per year for oil and renewables and 0.3% per year for gas and coal (CIBO, 1997; Einstein et al., 1999b). Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the advanced scenario.

Table A-23 Advanced Scenario Inputs for Existing and New Equipment

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Process	**Fuel**	MBtu/k$	MBtu/k$		MBtu/k$	MBtu/k$	
Electrolysis	Electricity	0.7407	0.6815	-0.0032	0.6666	0.4383	-0.016
Other Electricity	Electricity	3.5489	3.2312	-0.0036	3.194	2.7529	-0.0057
Direct	Natural gas	1.505	1.2213	-0.008	1.3545	1.0708	-0.009
	Resid. Oil	0.2214	0.1797	-0.008	0.1992	0.1575	-0.009
	Dist. Oil	0.0651	0.0528	-0.008	0.0586	0.0463	-0.009
	LPGs	0.0216	0.0175	-0.008	0.0194	0.0153	-0.009
	Steam Coal	0.0086	0.0070	-0.008	0.0077	0.0061	-0.009
	Other Petro	0	0.0000	-0.008	0	0.0000	-0.009
Steam	Steam	3.5917	2.8393	-0.009	3.2325	2.4246	-0.011
Feed	Natural gas	5.5251	4.4838	-0.008	4.9726	3.9310	-0.009
	LPGs	12.5445	10.1802	-0.008	11.2901	8.9251	-0.009
	Petrochem	10.136	8.2256	-0.008	9.1224	7.2115	-0.009
Electrolysis	Electricity	1.3879	1.2769	-0.0032	1.2491	0.8212	-0.016
Other Electricity	Electricity	6.6495	6.0543	-0.0036	5.9845	5.1580	-0.0057
Direct	Natural gas	3.1595	2.5640	-0.008	2.8436	2.2479	-0.009
	Resid. Oil	0.0106	0.0086	-0.008	0.0095	0.0075	-0.009
	Dist. Oil	0.0103	0.0084	-0.008	0.0093	0.0074	-0.009
	LPGs	0.0176	0.0143	-0.008	0.0159	0.0126	-0.009
	Steam Coal	0.0475	0.0385	-0.008	0.0428	0.0338	-0.009
	Other Petro	0	0.0000	-0.008	0	0.0000	-0.009
Steam	Steam	6.2611	4.9495	-0.009	5.635	4.2267	-0.011
Feed	Natural gas	4.2995	3.4892	-0.008	3.8695	3.0589	-0.009
	LPGs	9.7619	7.9221	-0.008	8.7857	6.9453	-0.009
	Petrochem	7.8876	6.4010	-0.008	7.0989	5.6119	-0.009
Electrolysis	Electricity	0.6745	0.6206	-0.0032	0.607	0.3991	-0.016
Other Electricity	Electricity	3.2316	2.9423	-0.0036	2.9085	2.5068	-0.0057
Direct	Natural gas	5.4499	4.4227	-0.008	4.9049	3.8774	-0.009
	Resid. Oil	0.0531	0.0431	-0.008	0.0478	0.0378	-0.009
	Dist. Oil	0.0151	0.0123	-0.008	0.0136	0.0108	-0.009
	LPGs	0.0083	0.0067	-0.008	0.0075	0.0059	-0.009
	Steam Coal	0.0314	0.0255	-0.008	0.0283	0.0224	-0.009
	Other Petro	0	0.0000	-0.008	0	0.0000	-0.009
Steam	Steam	9.9257	7.8465	-0.009	8.9332	6.7006	-0.011
Feed	Natural gas	4.7553	3.8591	-0.008	4.2798	3.3833	-0.009
	LPGs	10.7967	8.7618	-0.008	9.717	7.6815	-0.009
	Petrochem	8.7238	7.0796	-0.008	7.8514	6.2067	-0.009
Electrolysis	Electricity	1.4457	1.3301	-0.0032	1.3012	0.8555	-0.016
Other Electricity	Electricity	6.9268	6.3068	-0.0036	6.2341	5.3731	-0.0057
Direct	Natural gas	4.4508	3.6119	-0.008	4.0057	3.1666	-0.009
	Resid. Oil	0.0059	0.0048	-0.008	0.0053	0.0042	-0.009
	Dist. Oil	0.0301	0.0244	-0.008	0.0271	0.0214	-0.009
	LPGs	0.0567	0.0460	-0.008	0.051	0.0403	-0.009
	Steam Coal	0.065	0.0527	-0.008	0.0585	0.0462	-0.009
	Other Petro	0	0.0000	-0.008	0	0.0000	-0.009
Steam	Steam	8.0474	6.3617	-0.009	7.2427	5.4326	-0.011
Feed	Natural gas	2.1378	1.7349	-0.008	1.924	1.5210	-0.009
	LPGs	4.8538	3.9390	-0.008	4.3684	3.4533	-0.009
	Petrochem	3.9219	3.1827	-0.008	3.5297	2.7903	-0.009

GLASS - Historical Trends

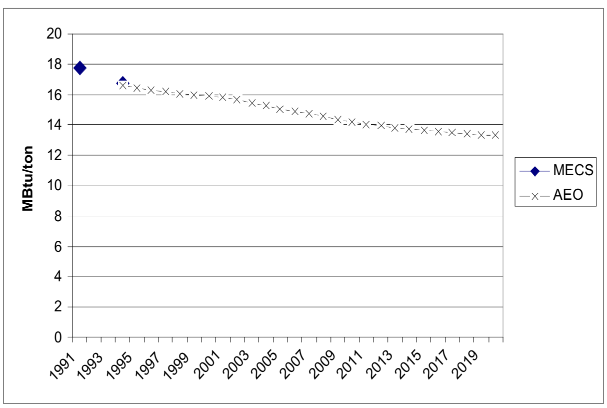
Economic Trends
Value of output in U.S. glass production declined —0.2% per year between 1977 and 1995 (U.S.DOC, 1998). In contrast, value added increased on average 1.1% per year between 1970 and 1995 (OECD, 1995).

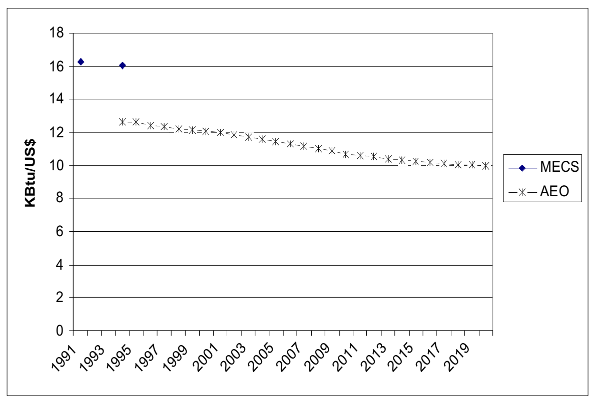
Production and Technology Trends
Glass production (excluding SIC 3620-05 due to inconsistencies in data reporting) grew at an average rate of 0.9% per year between 1985 and 1994 (UN, various years).

Energy Consumption Trends
Primary energy consumption for U.S. glass manufacture grew an average of 1.1% per year between 1991 and 1994 (U.S. DOE, EIA, 1994; U.S. DOE, EIA, 1997).

Historical economic energy intensity for the glass and glass products sector (primary energy/value of output) declined on average —0.5% per year between 1991 and 1994 (see Figure A-7). Historical physical energy intensity for the sector (primary energy/ton glass) declined on average —1.9% per year between 1991 and 1994 (see figure 1).

Fig. A-7 Historical And Projected Primary Economic (KBtu/ U.S.$) and Physical (MBtu/ton) Energy Intensities for U.S. Glass Production





GLASS - AEO99 Reference Case and Business-As-Usual Scenario

NEMS defines glass as SICs 3211, 3221, and 3229. We adopt the AEO99 reference case as the business-as-usual scenario.

Economic Trends
AEO99 projects value of output growth to average 0.8% per year between 1994 and 2020.

Production and Technology Trends
AEO99 projects physical production of glass to grow on average 0.8% per year between 1994 and 2020. The retirement rate of capital stock in the glass subsector is set at 1.3% per year in NEMS AOE99, for an average lifetime of 77 years. We adjust this rate to 1.4% per year, for an average lifetime of 70 years for the business-as-usual scenario.

Energy Consumption Trends

AEO 99 projects that primary economic energy consumption for glass production will decrease by —0.05% per year on average between 1994 and 2020. Economic energy intensity for the glass and glass products sector (primary energy/value of output) is projected to decline on average —0.9% per year between 1994 and 2020. Projected physical energy intensity for the sector (primary energy/ton glass) declines on average —0.8% per year between 1994 and 2020. Table A-24 provides the NEMS baseline input values for existing and new equipment for 1994 and 2020. In NEMS, energy use in buildings in the chemical sector is set as energy use per employee, and only reacts to changes in number of employees in an industry, ignoring changes in building energy use, stock turnover of buildings, and also the potential impact of programs like Energy Star Buildings and Green Lights.

Table A-24 NEMS Baseline Inputs for Existing and New Equipment for Glass Production

		Existing Equipment			New Equipment		
Process	**Fuel**	**1994 UECs**	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Batch Preparation — Recycled Glass	Electricity	0.17	0.1656	-0.001	0.1499	0.1499	0
Batch Preparation — Virgin Glass	Electricity	0.19	0.1851	-0.001	0.1676	0.1676	0
Melting/Refining — Recycled Glass	Electricity	0.37	0.3356	-0.0037	0.3244	0.2745	-0.0064
	Natural Gas	4.1418	3.4903	-0.0066	3.631	2.7093	-0.0112
	Residual Oil	0.1097	0.0925	-0.0066	0.0962	0.0718	-0.0112
	Distillate Oil	0.0144	0.0121	-0.0066	0.0126	0.0094	-0.0112
	LPG	0.0141	0.0119	-0.0066	0.0124	0.0092	-0.0112
	Other Petroleum	0	0	-0.0066	0	0	-0.0112
Melting/Refining — Virgin Glass	Electricity	0.46	0.4172	-0.0037	0.4034	0.3414	-0.0064
	Natural Gas	5.1773	4.3634	-0.0066	4.5407	3.388	-0.0112
	Residual Oil	0.1371	0.1156	-0.0066	0.1203	0.0897	-0.0112
	Distillate Oil	0.018	0.0151	-0.0066	0.0158	0.0118	-0.0112
	LPG	0.0176	0.0148	-0.0066	0.0155	0.0115	-0.0112
	Other Petroleum	0	0	-0.0066	0	0	-0.0112
Forming	Electricity	0.61	0.588	-0.0014	0.562	0.5393	-0.0016
	Natural Gas	1.5967	1.4975	-0.0025	1.471	1.3688	-0.0028
	Residual Oil	0.0423	0.0397	-0.0025	0.039	0.0363	-0.0028
	Distillate Oil	0.0055	0.0052	-0.0025	0.0051	0.0047	-0.0028
	LPG	0.0054	0.0051	-0.0025	0.005	0.0047	-0.0028
	Other Petroleum	0	0	-0.0025	0	0	-0.0028
Post Forming	Electricity	0.23	0.2176	-0.0021	0.1794	0.1774	-0.0004
	Natural Gas	1.8774	1.7039	-0.0037	1.4643	1.4364	-0.0007
	Residual Oil	0.0497	0.0451	-0.0037	0.0388	0.038	-0.0007
	Distillate Oil	0.0065	0.0059	-0.0037	0.0051	0.005	-0.0007
	LPG	0.0064	0.0058	-0.0037	0.005	0.0049	-0.0007
	Other Petroleum	0	0	-0.0037	0	0	-0.0007

GLASS — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2. In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the glass sector include demonstration programs, assessment programs, Challenge programs, ENERGY STAR buildings and Green Lights, state programs, state implementation plans, R&D programs, ESCO/utility programs, ENERGY STAR and Climate Wise programs, pollution prevention programs, tax incentives for energy managers, tax rebates for specific industrial technologies, investment tax credits for CHP systems, and a CO2 cap and trade system. The glass industry mainly uses fuel in firing the glass tanks. Energy can be saved through installing new equipment (developed as a result of R&D activities), improved heat recovery from existing glass tanks (identified through audits and energy management activities), and increased recycling of glass (especially in container manufacture through increased recycling and pollution prevention programs). OIT is the prime agent for government supported R&D in energy efficiency. The character of such programs makes it difficult to estimate the actual energy savings due to the program itself. However, estimates can and have been made for the technologies supported by OIT programs (U.S. DOE-OIT, 1998). Based on these assessments the current portfolio is expected to contribute to annual energy savings of 3.1 Quads by 2020 (U.S. DOE-OIT, 1999) through development and implementation of new energy-efficient industrial technologies in all industries, including the glass industry. Expanded R&D programs will increase these savings. Pollution prevention programs contribute to energy and cost savings through reduced material use. Carbon emission reduction in 1997 was estimated at 5.2 milllion tonnes carbon, or roughly equivalent to annual energy savings of 0.2 Quads throughout industry.

GLASS - Moderate Scenario

Economic Trends
Economic trends remain the same as AEO99 under the moderate scenario.

Production and Technology Trends
We retain the business-as-usual retirement rates in the moderate scenario.

Energy Consumption Trends
Unit energy consumption values and TPCs for the moderate scenario were calculated by taking the mid-point between the NEMS baseline and the HiTech scenarios for the melting/refining process stage of existing equipment and for all process stages for new equipment. For the other process stages in existing

equipment (batch preparation, forming, and post-forming), we adopted the NEMS baseline values because the NEMS HiTech values showed an increase in 2020 UECS for these processes in existing equipment. Boiler energy efficiency increases at a rate of 0.2% per year for fossil fuels and 0.1% per year for biomass and waste in this scenario (CIBO, 1997; Einstein et al., 1999b). Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the moderate scenario.

Table A-25 Moderate Scenario Inputs for Existing and New Equipment for Glass Production

		Existing Equipment			New Equipment		
Process	**Fuel**	**1994 UECs**	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Batch Preparation — Recycled Glass	Electricity	0.17	0.1656	-0.001	0.1499	0.1499	0
Batch Preparation — Virgin Glass	Electricity	0.19	0.1851	-0.001	0.1676	0.1676	0
Melting/Refining — Recycled Glass	Electricity	0.37	0.3185	-0.00575	0.3244	0.2401	-0.0115
	Natural Gas	4.1418	3.4685	-0.0068	3.631	2.5433	-0.0136
	Residual Oil	0.1097	0.0919	-0.0068	0.0962	0.0674	-0.0136
	Distillate Oil	0.0144	0.0121	-0.0068	0.0126	0.0088	-0.0136
	LPG	0.0141	0.0118	-0.0068	0.0124	0.0087	-0.0136
	Other Petroleum	0	0.0000	0	0	0.0000	0
Melting/Refining — Virgin Glass	Electricity	0.46	0.3960	-0.00575	0.4034	0.2986	-0.0115
	Natural Gas	5.1773	4.3357	-0.0068	4.5407	3.1806	-0.0136
	Residual Oil	0.1371	0.1148	-0.0068	0.1203	0.0843	-0.0136
	Distillate Oil	0.018	0.0152	-0.00655	0.0158	0.0112	-0.0131
	LPG	0.0176	0.0148	-0.00655	0.0155	0.0110	-0.0131
	Other Petroleum	0	0.0000	0	0	0.0000	0
Forming	Electricity	0.61	0.5882	-0.0014	0.562	0.5405	-0.0015
	Natural Gas	1.5967	1.4961	-0.0025	1.471	1.3946	-0.00205
	Residual Oil	0.0423	0.0396	-0.0025	0.039	0.0370	-0.00205
	Distillate Oil	0.0055	0.0052	-0.0025	0.0051	0.0048	-0.00205
	LPG	0.0054	0.0051	-0.0025	0.005	0.0047	-0.00205
	Other Petroleum	0	0.0000	-0.0025	0	0.0000	0
Post Forming	Electricity	0.23	0.2178	-0.0021	0.1794	0.1759	-0.00075
	Natural Gas	1.8774	1.7049	-0.0037	1.4643	1.4304	-0.0009
	Residual Oil	0.0497	0.0451	-0.0037	0.0388	0.0379	-0.0009
	Distillate Oil	0.0065	0.0059	-0.0037	0.0051	0.0050	-0.0009
	LPG	0.0064	0.0058	-0.0037	0.005	0.0049	-0.0009
	Other Petroleum	0	0.0000	-0.0037	0	0.0000	0

GLASS - Advanced Scenario

Economic Trends
Economic trends remain the same as AEO99 under the advanced scenario.

Production and Technology Trends
We retain the business-as-usual retirement rates in the advanced scenario.

Energy Consumption Trends
We adopted the NEMS HiTech UECs for melting/refining of existing equipment and for all process steps for new equipment. For the other process stages in existing equipment (batch preparation, forming, and

post-forming), we adopted the NEMS baseline values because the NEMS HiTech values showed an increase in 2020 UECS for these processes in existing equipment. Energy efficiency of industrial buildings in this sector improves at the same rate as that of commercial buildings under the advanced scenario. In addition, boiler energy efficiency improves at a rate of 0.2% per year for oil and renewables and 0.3% per year for gas and coal (CIBO, 1997; Einstein et al., 1999b). Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the advanced scenario.

Table A-26 Advanced Scenario Inputs for Existing and New Equipment for Glass Production

Process	Fuel	Existing Equipment 1994 UECs	Existing Equipment 2020 UECs	Existing Equipment TPC	New Equipment 1994 UECs	New Equipment 2020 UECs	New Equipment TPC
Batch Preparation — Recycled Glass	Electricity	0.17	0.1656	-0.001	0.1499	0.1499	0
Batch Preparation — Virgin Glass	Electricity	0.19	0.1851	-0.001	0.1676	0.1676	0
Melting/Refining — Recycled Glass	Electricity	0.37	0.2646	-0.0115	0.3244	0.1653	-0.023
	Natural Gas	4.1418	2.7836	-0.0136	3.631	1.631	-0.0272
	Residual Oil	0.1097	0.0737	-0.0136	0.0962	0.0432	-0.0272
	Distillate Oil	0.0144	0.0097	-0.0136	0.0126	0.0057	-0.0272
	LPG	0.0141	0.0095	-0.0136	0.0124	0.0056	-0.0272
	Other Petroleum	0	0	0	0	0	0
Melting/Refining — Virgin Glass	Electricity	0.46	0.329	-0.0115	0.4034	0.2055	-0.023
	Natural Gas	5.1773	3.4795	-0.0136	4.5407	2.0397	-0.0272
	Residual Oil	0.1371	0.0922	-0.0136	0.1203	0.054	-0.0272
	Distillate Oil	0.018	0.0123	-0.0131	0.0158	0.0073	-0.0262
	LPG	0.0176	0.012	-0.0131	0.0155	0.0072	-0.0262
	Other Petroleum	0	0	0	0	0	0
Forming	Electricity	0.61	0.5882	-0.0014	0.562	0.5147	-0.0030
	Natural Gas	1.5967	1.4961	-0.0025	1.471	1.3063	-0.0041
	Residual Oil	0.0423	0.0396	-0.0025	0.039	0.0346	-0.0041
	Distillate Oil	0.0055	0.0052	-0.0025	0.0051	0.0045	-0.0041
	LPG	0.0054	0.0051	-0.0025	0.005	0.0044	-0.0041
	Other Petroleum	0	0.0000	-0.0025	0	0	0
Post Forming	Electricity	0.23	0.2178	-0.0021	0.1794	0.1716	-0.0015
	Natural Gas	1.8774	1.7049	-0.0037	1.4643	1.3892	-0.0018
	Residual Oil	0.0497	0.0451	-0.0037	0.0388	0.0368	-0.0018
	Distillate Oil	0.0065	0.0059	-0.0037	0.0051	0.0048	-0.0018
	LPG	0.0064	0.0058	-0.0037	0.005	0.0047	-0.0018
	Other Petroleum	0	0.0000	-0.0037	0	0	0

CEMENT - Historical Trends

Economic Trends

Value of output increased slightly between 1981 and 1994, from $4.6B in 1981 to $5.0B in 1994, an increase of 0.6% per year. Value of output was erratic between over this period, hitting a low of $4.2B in 1982 and a high of $5.1B in 1987 (UNIDO, 1998).[7]

[7] The value of output data was deflated using the value of shipments deflator series for SIC 3241 (cement, hydraulic). The original value of output data is for ISIC 3692 (manufacture of cement, lime and plaster).

Production and Technology Trends

Cement is created when clinker is ground and mixed with other materials. The two dominant cement types in the U.S. are Portland and Masonry cement. U.S. production of cement, while not steady, increased from 74.3 Mton in 1970 to 91.0 Mton in 1997, at 0.8% per year. Cement production in the U.S. hit a low of 63.3 Mton in 1982, and its highest total to date in 1997. Portland cement remained the dominant cement type during that period, maintaining a share between 94% and 96%. Clinker, which is produced with either the wet or dry process, mirrored cement production. Clinker production increased from 72.2 Mton in 1970 to 80.1 Mton in 1997, at a rate of 0.4% per year, hitting a low of 59.3 Mton in 1982, and its current high in 1997.

Clinker is predominantly produced in two processes: the wet process and the more modern, more energy-efficient dry process. The U.S. has a high share of the wet process, higher than most industrialized countries. However, the share has been declining and between 1970 and 1997, clinker produced with the wet process decreased by —2.7% per year on average, falling from 60% to 26% of total clinker production. Clinker produced with the dry process increased at 2.6% per year, increasing from a 40% share of total clinker production in 1970 to a 72% share in 1997. The U.S. still has a much higher share of wet production than most industrialized and many developing countries

Clinker is ground and mixed with additives to produce cement. Although cement is the final product of the cement industry, cement is an intermediate material used to produce concrete. In the U.S., Portland cement (containing 95% clinker) is the dominant product. Small amounts of fly ash and blast furnace slags are used to produce different types of cement. This is likely to change in the future (PCA, 1997). The clinker and additive content of the product mix can be defined on the basis of the clinker/cement-ratio, dividing the clinker production by the cement production. The 1994 C/C-ratio of the U.S. cement industry is estimated at 88%, high compared to other industrialized countries. The use of additives will reduce the energy-intensive step of clinker production, and reduce the future C/C-ratio.

The number of clinker plants dropped from 168 in 1975 to 108 in 1995, mainly due to closure of older small capacity (wet process) plants. The number of cement plants has reduced from 172 in 1975 to 118 in 1995. The average kiln age is approximately 27 years, which is higher than that in Western Europe. The weighted average age of dry process kilns is 19 years and 29 years for wet kilns. In the U.S. less than 1% of kiln capacity is older than 50 years, while the vast majority of the kilns are between 10 and 40 years old. Cement markets have a regional character, where the development of production capacity depends on the local economic development. Hence, new plants are mainly constructed in regions with a fast growing construction industry, e.g. Florida, as well as for replacement of depreciated wet process capacity.

Energy Consumption Trends

Historical energy consumption data are available for SIC 3241 (cement, hydraulic) from two sources: the Manufacturing Energy Consumption Survey (1988, 1991, 1994, 1997), and the U.S. Geological Survey s *Minerals Yearbook* (various years).

Based on the MECS data, final and primary energy consumption changed little in the cement industry between 1985 and 1994. Final energy consumption increased from 328 TBtu in 1985 to 329 TBtu in 1994, while primary energy consumption increased from 417 TBtu in 1985 to 436 TBtu in 1994.

Based on U.S.GS data, energy consumption in the U.S. cement industry declined between 1970 and 1997. Primary energy consumption decreased at —0.6% per year, from 518 PJ in 1970 to 444 PJ in 1997, even as production increased over that time span. The overall energy consumption trend in the U.S. cement industry between 1970 and 1997 was a gradual decline, though energy consumption started to increase in the early 1990s and increased between 1992 and 1997 at about 4% per year. The share of process energy consumption changed significantly between 1970 and 1997. While the wet process consumed 62% of total cement energy consumption in 1970, it used only 31% in 1997, while energy consumption of the dry process rose from 38% of total cement energy consumption in 1970 to 67% in 1997.

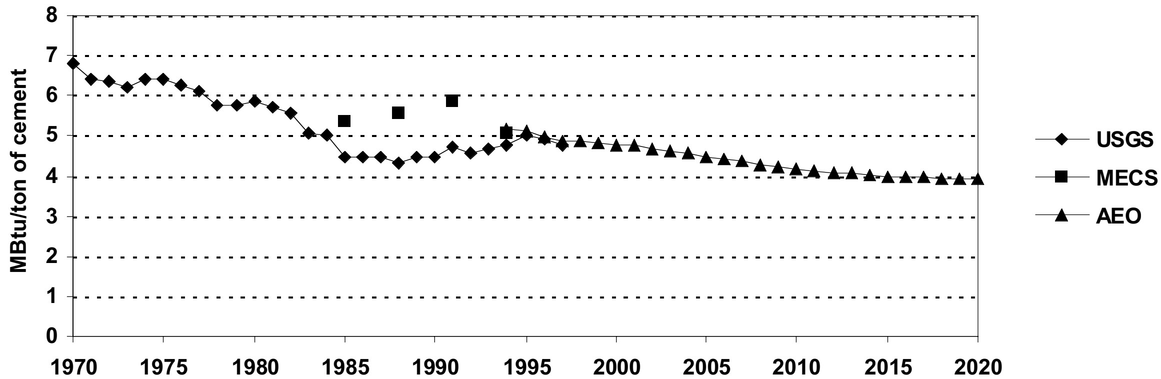
According to U.S.GS data, fuel use shifted considerably between 1970 and 1997. The largest change occurred in natural gas use, which decreased from a 44% fuel share in 1970 to a 6% fuel share in 1997. Much of the energy provided by natural gas was made up by coal and coke, which increased fuel share from 36% in 1970 to 71% in 1997. Oil s share of cement energy consumption fell from 13% in 1970 (17% in 1973) to 1% in 1997. Electricity s fuel share has increased from 7% in 1970 to 11% in 1997, while the remainder of the 1997 fuel share is composed of liquid waste fuel (8%) and tires and solid waste (a combined 2%). The share of waste fuels burned in kilns (e.g. tires, petroleum cokes, MSW) is increasing. MECS data for 1988 to 1994 shows an increase of waste fuels from 9% to 18% of total fuel consumption. Future use of waste fuels will depend on public acceptance of waste burning in cement kilns.

Since, according to MECS, energy consumption remained essentially unchanged between 1985 and 1994, changes in unit energy consumption are due almost entirely to changes in the denominator, in this case tons of cement. Final energy intensity fell from 4.2 MBtu/ton in 1985 to 3.8 MBtu/ton in 1994, decreasing at -1.1% per year. Primary energy intensity increased from 5.4 MBtu/ton in 1985 to 5.8 MBtu/ton in 1991, but then dropped to 5.1 MBtu/ton in 1994, decreasing at an average of —0.6% per year over the time period (see Figure A-7). Production increased from 77.9 M tons in 1985 to 85.9 Mt in 1994, 10% overall, producing the declining energy intensity. Between 1985 and 1994, the slowly increasing energy consumption was offset by increasing production, resulting in decreasing energy intensity.

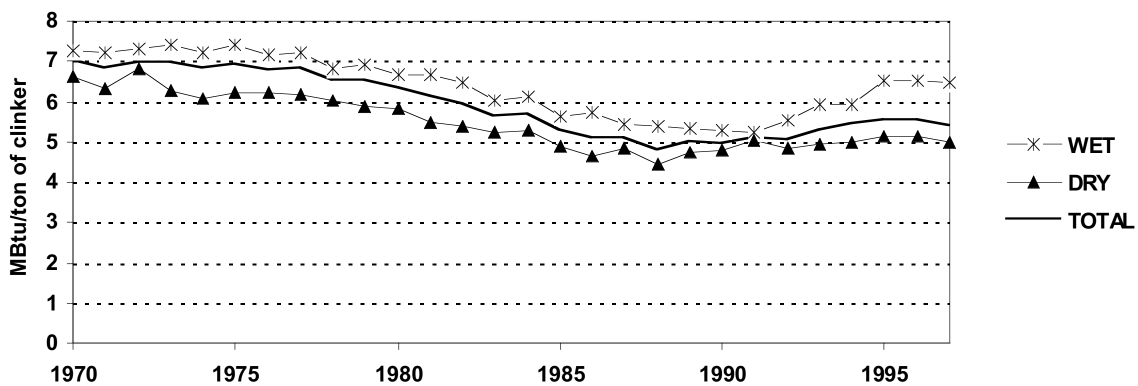
Energy intensity in the U.S. cement industry decreased between 1970 and 1997 according to U.S.GS data. Primary energy intensity of cement production decreased at —1.3% per year, from 6.8 MBtu/ton in 1970 to 4.8 MBtu/ton in 1997 (see Figure A-7). While intensity slowly decreased overall between 1970 and 1997, intensity started to climb in the early 1990s, rising 0.9% per year between 1992 and 1997. Both the wet and dry processes decreased in energy intensity, the wet process decreasing at -0.4% per year between 1970 and 1997 while the dry process more than doubled the wet process decrease, at —1.0% per year. Cement production increased while energy consumption decreased, producing the intensity decline. The composition of the cement production (wet vs. dry) also affected the intensity decline, as the more energy-efficient dry process gained production share over time.

Waste gas discharged from the kiln exit gases, the clinker cooler system, and the kiln pre-heater system all contain useful energy that can be converted into power. Cogeneration systems can either be direct gas turbines that utilize the waste heat (top cycle), or the installation of a waste heat boiler system that runs a steam turbine system (bottom cycle). Steam turbine systems have been installed in many plants worldwide and have proven to be economic under certain conditions (Steinbliss, 1990; Jaccard and Willis, 1996, Neto, 1990). While electrical efficiencies are still relatively low (18%), based on several case studies power generation may vary between 11-25 kWh/t clinker (Scheur and Sprung, 1990, Steinbliss, 1990; Neto, 1990). In 1994, 5 dry kiln plants generated a total of 593 Million kWh of electricity (Van Oss, 1995). Cogeneration, using a gas turbine, can also be used to dry blast furnace slag when producing blended cement with slags.

Fig. A-7 Historical and Projected Physical Energy Intensities (MBtu/ton) of U.S. Cement Production



Historical Physical Energy Intensity (MBtu/ton) of U.S. Clinker Production by Process



CEMENT - AEO99 Reference Case

Economic Trends
Value of output grew at 1.1% per year between 1994 and 2020.

Production and Technology Trends
AEO99 shows a steady production growth of 1% per year, while the clinker/cement ratio does not change, i.e. maintaining a similar growth in clinker output and in product mix. By 2020 the share of wet process is reduced to 13% of the total clinker production, or a decline of 2.2% per year, which is slower than the historical trend of 3.6% per year between 1976 and 1996.[8] The clinker/cement ratio does not change in AEO99 between 1994 and 2020.[9] Hence there is no change in the product mix of the cement industry, and the introduction of blended cements is not accelerated, compared to the historical trends. Retirement rates

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[8] The NEMS industrial module assumes no new wet process clinker plants are built.
[9] The clinker/cement ratio is not changed in the AEO projection because the use of blended cements will require changes to be made to the ASTM codes, which has not yet occurred.

for cement-making equipment (kilns and grinding) are 1.2% per year in the AEO99 reference case. We have adjusted the retirement rate to 2.0%/year, reflecting an average lifetime of 50 years.

Energy Consumption Trends

Energy consumption decreased slowly between 1994 and 2020. Final energy consumption decreased at -0.02% per year, while primary energy consumption decreased at —0.03% per year. The increasing physical (1.0%) and economic (1.1%) production resulted in decreasing energy intensity. Primary physical energy intensity declined from 5.2 MBtu/ton in 1994 to 3.9 MBtu/ton in 2020, at —1.1% per year, comparable to the U.S.GS historical energy intensity growth rate (-1.3% per year). Table A-27 provides the NEMS AEO99 UEC values for existing and new equipment for 1994 and 2020 as well as the resulting average annual growth rate, referred to as technology possibility curves (TPCs). Energy use in buildings is very small compared to the energy use in the production process. NEMS estimates final energy consumption for the building component at 2.78 TBtu, or less than 1% of total energy consumption in the cement industry. In NEMS, energy use in buildings is a set as energy use per employee, and only reacts to changes in number of employees in an industry, ignoring changes in building energy use, stock turnover of buildings, and also the potential impact of programs like Energy Star Buildings and Green Lights.

Table A-27 NEMS Baseline Inputs for Existing and New Equipment for Cement Production

		Existing Equipment			**New Equipment**		
		1994 UECs	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Process	**Fuel**	MBtu/ton	MBtu/ton		MBtu/ton	MBtu/ton	
Grinding (cement)	Electricity	0.22	0.2108	-0.0016	0.1789	0.1789	0
Dry Process	Electricity	0.23	0.212	-0.0031	0.1817	0.1677	-0.0031
	Natural Gas	0.3101	0.2688	-0.0055	0.245	0.2129	-0.0054
	Residual Oil	0.0139	0.0121	-0.0055	0.011	0.0096	-0.0054
	Distillate Oil	0.0315	0.0273	-0.0055	0.0249	0.0217	-0.0054
	Coke	0	0	-0.0055	0	0	-0.0054
	Steam Coal	2.7549	2.2451	-0.0078	2.1764	1.7809	-0.0077
	Coke Oven Gas	0	0	-0.0055	0	0	-0.0054
	Other Petroleum	0.7741	0.6709	-0.0055	0.6116	0.5316	-0.0054
Wet Process	Electricity	0.21	0.2046	-0.001	0.24	0.2338	-0.001
	Natural gas	0.4209	0.4022	-0.0018	0.444	0.444	0
	Residual Oil	0.0189	0.0181	-0.0018	0.0548	0.0548	0
	Distillate Oil	0.0428	0.0409	-0.0018	0.0414	0.0396	-0.0018
	Coke	0	0	-0.0018	1.47	1.4046	-0.0018
	Steam Coal	3.7393	3.5037	-0.0025	4.11	3.851	-0.0025
	Coke Oven Gas	0	0	-0.0018	0.1532	0.1464	-0.0018
	Other Petroleum	1.0508	1.004	-0.0018	0.154	0.1471	-0.0018

Note: in the NEMS baseline, a new plant UEC is given for the wet process. However, the documentation does not describe a new plant (ADL, 1998) and we believe that no new wet process clinker plants will be built in the U.S.

CEMENT - Business-As-Usual Scenario

Economic Trends

Economic trends remain the same as AEO99 under the business-as-usual scenario.

Production and Technology Trends

Production, process share, and product trends in the business-as-usual scenario remain the same as AEO99. Retirement rates for cement-making equipment (kilns and grinding) have been changed to 2.0% per year, based on the ages of existing kilns in the U.S. and the recent actual replacement of several kilns in the U.S.

Energy Consumption Trends

Unit energy consumption (UEC) values for existing equipment in 1994 were derived from a recent study energy use in the U.S. cement sector (Martin et al., 1999). UECs for new equipment in 1994 were calculated for an U.S. energy price-based new plant based on UECs reported in recent literature and by Niefer (1995). Niefer (1995) used census data of the 1991 MECS to determine the most efficient individual clinker plant in the U.S. We use this figure as an estimate of an average new U.S. clinker plant, although more efficient clinker plants are being built elsewhere.

Table A-28 provides the modified UECs based on Martin et al. (1999) and Niefer (1995). The TPCs in the business-as-usual scenario for existing plants are smaller than those in AEO 99, as under a scenario with low fuel prices there will be no incentive to upgrade exiting facilities, and the main energy efficiency improvement gains will be achieved by retiring of old plants and the subsequent construction of new dry cement plants. There is no increase in the production of power from waste heat recovery, as this is not an economically viable option in most parts of the U.S. under a low energy price scenario

Carbon Dioxide Emissions
Carbon dioxide emissions in the cement industry are produced both through the combustion of fossil fuels and the calcination of limestone. In the calcination process we assume that 0.138 tonnes of carbon are emitted for every tonne of clinker produced (UNEP et al., 1996). This amounts to 9.5 MtC given a production of 68.5 million tonnes of clinker (75.5 million short tons) in 1994 (van Oss, 1995). We rely on the U.S. EIA (U.S. DOE, EIA, 1996, Appendix B) for 1994 carbon coefficients for the various commercial fuels, except we use the Intergovernmental Panel on Climate Change (UNEP et al., 1996) for coke and breeze. For electricity we use the 1994 average fuel mix for electricity generation in the U.S.

Table A-28 Business-As-Usual Scenario Inputs for Existing and New Equipment for Cement Production

		Existing Equipment			New Equipment		
		1994 UECs	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Process	**Fuel**	MBtu/ton	MBtu/ton		MBtu/ton	MBtu/ton	
Grinding (cement)	Electricity	0.11	0.11	-0.0010	0.11	0.11	-0.0010
Dry Process	Electricity	0.18	0.18	0.0000	0.15	0.15	0.0000
	Natural Gas	0.22	0.21	-0.0011	0.18	0.17	-0.0011
	Residual Oil	0.00	0.00	0.0000	0.00	0.00	0.0000
	Distillate Oil	0.06	0.06	-0.0012	0.05	0.05	-0.0012
	Coke	0.00	0.00	0.0000	0.00	0.00	0.0000
	Steam Coal	3.25	3.16	-0.0010	2.63	2.56	-0.0010
	Coke Oven Gas	0.00	0.00	0.0000	0.00	0.00	0.0000
	Other Petroleum	0.17	0.17	-0.0011	0.14	0.13	-0.0011
Wet Process	Electricity	0.17	0.17	0.0000	0.00	0.00	0.0000
	Natural gas	0.27	0.27	-0.0010	0.00	0.00	0.0000
	Residual Oil	0.00	0.00	0.0000	0.00	0.00	0.0000
	Distillate Oil	0.02	0.02	0.0000	0.00	0.00	0.0000
	Coke	0.00	0.00	0.0000	0.00	0.00	0.0000
	Steam Coal	4.38	4.27	-0.0010	0.00	0.00	0.0000
	Coke Oven Gas	0.00	0.00	0.0000	0.00	0.00	0.0000
	Other Petroleum	0.50	0.49	-0.0010	0.00	0.00	0.0000

CEMENT — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2. In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the cement sector include demonstration programs, assessment programs, Challenge programs, ENERGY STAR buildings and Green Lights, product labeling, state programs, state implementation plans, R&D programs, ESCO/utility programs, ENERGY STAR and Climate Wise programs, tax incentives for energy managers, tax rebates for specific industrial technologies, investment tax credits for CHP systems, and a CO2 cap and trade system. The cement industry is currently not the focus of specific R&D activities of the Industries of the Future program. However, new cement plants are already much more efficient than older plants still in operation. New plants are being or have been constructed in regions with increased demand (e.g. Pacific Northwest, Florida). Due to the high share of energy in the production costs (30-40%) the cement industry will be particularly affected by a cap and trade system. This is likely to accelerate retrofitting of older plants. Changing standards for cement, pollution prevention practices, labeling and procurement policies will open markets for blended cements in the U.S. under the policy scenarios, affecting the clinker requirements for cement making. A detailed analysis of energy efficiency opportunities (Martin et al., 1999) found a considerable cost-effective potential for energy efficiency improvement and CO_2 emission reduction through retrofitting existing plants and use of blended cements. Demonstration activities have been effective in the cement industry (e.g. new burners) and may lead to installation of new technologies. Standards for large motors and Motor Challenge activities will affect the large power consumption for grinding in the cement industry.

CEMENT — Moderate Scenario

Economic Trends
Economic trends remain the same as AEO99 under the moderate scenario.

Production and Technology Trends
Production and process share trends remain the same as AEO99 in the moderate scenario. We assume that blended cements will start to penetrate the U.S. cement market at a slow rate. Based on a study of the Portland Cement Association (PCA, 1997), we assume the potential application of 30.7 Mtons of blended cements in 2001 (or 35% of 2001 cement demand) will be met in 2010. The cement types still have a relatively low application of blending of fly ash and blast furnace slag, resulting in the replacement of 6.9 Mtons of clinker by 2020. Blast furnace slags need to be dried before being used in cement, increasing fuel use by 0.018 MBtu/ton clinker.

Retirement rates for cement-making equipment (kilns and grinding) are the same as in the business-as-usual scenario (2.0%/year), based on the ages of existing kilns in the U.S. and the recent actual replacement of several kilns in the U.S.

Energy Consumption Trends
For existing equipment in the moderate scenario, we used the adjusted UECs defined by the 1994 baseline calculations in Martin et al. (1999). To derive the 2020 savings, we calculated the TPCs that result from comparing this adjusted 1994 baseline to the cost-effective savings identified in Martin et al. (1999) using a 30% discount rate. Table A-29 provides information on the 1994 UECs, the cost-effective UECs using a 30% discount rate, and the resulting TPCs assuming all cost-effective technologies are implemented by 2020. The cost-effective UECs using a 30% discount rate are derived from the savings associated with implementation of the following retrofit technologies and measures:

- Overall: preventative maintenance
- Dry Process: optimized heat recovery in the clinker grate cooler, conversion to grate clinker cooler, combustion system improvements
- Wet Process: conversion to semi-wet process, kiln combustion system improvements

For 1994 new equipment UECs in the moderate scenario, we used new dry process plant with multi-state preheating (4-stage) and pre-calcining. For 2020 we used the efficiency of a 5-6 stage preheater with a pre-calciner plant as built by Ash Grove in Seattle (WA) (Steuch and Riley, 1993) and in other countries (Conroy, 1997; Somani et al., 1997). Table A-29 provides information on the 1994 new plant UECs, the 2020 new plant UECs, and the resulting TPCs.

In the moderate scenario, natural gas use decreases more slowly due to the need for drying blast furnace slag. Energy efficiency of industrial buildings in this sector improves at the same rate as that of commercial buildings under the moderate scenario.

Table A-29 Moderate Scenario Inputs for Existing and New Equipment for Cement Production

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Process	**Fuel**	MBtu/ton	MBtu/ton		MBtu/ton	MBtu/ton	
Grinding (cement)	Electricity	0.11	0.10	-0.0032	0.09	0.084	-0.0027
Dry Process	Electricity	0.18	0.18	0.0000	0.15	0.15	0.0000
	Natural Gas	0.22	0.22	0.0002	0.1767	0.1955	0.0039
	Residual Oil	0.00	0.00	-0.0035	0.00	0.00	-0.0035
	Distillate Oil	0.06	0.06	-0.0032	0.05	0.05	-0.0032
	Coke	0.00	0.00	0.0000	0.00	0.00	0.0000
	Steam Coal	3.25	2.99	-0.0032	2.63	2.42	-0.0032
	Coke Oven Gas	0.00	0.00	0.0000	0.00	0.00	0.0000
	Other Petroleum	0.17	0.16	-0.0033	0.14	0.13	-0.0033
Wet Process	Electricity	0.17	0.17	0.0000	0.00	0.00	0.0000
	Natural gas	0.27	0.26	-0.0023	0.00	0.00	0.0000
	Residual Oil	0.00	0.00	0.0000	0.00	0.00	0.0000
	Distillate Oil	0.02	0.02	-0.0045	0.00	0.00	0.0000
	Coke	0.00	0.00	0.0000	0.00	0.00	0.0000
	Steam Coal	4.38	3.84	-0.0051	0.00	0.00	0.0000
	Coke Oven Gas	0.00	0.00	0.0000	0.00	0.00	0.0000
	Other Petroleum	0.50	0.44	-0.0051	0.00	0.00	0.0000

Note: 1994 existing equipment UECs based on Martin et al. (1999); 1994 new equipment UECs based on an assumed 4-stage preheater, pre-calciner kiln. 2020 existing equipment UECs based on TPCs that result from comparing the 1994 baseline to the cost-effective savings identified in Martin et al. (1999) using a 30% discount rate. 2020 new equipment UECs based on TPCs that result from comparing the 1994 baseline to that of a modern (currently available) 6-stage preheater, pre-calciner kiln (Somani et al., 1997).

CEMENT — Advanced Scenario

Economic Trends

Economic trends remain the same as AEO99 under the advanced scenario.

Production and Technology Trends

Production trends remain the same as AEO99 under the advanced scenario. We assume that blended cements will start to penetrate the U.S. cement market at a faster rate under the advanced scenario. Based on a study of the Portland Cement Association (PCA, 1997), we assume the potential application of 30.7 Mtonnes of blended cements in 2001 (or 35% of 2001 cement demand) will be met in 2010. The cement types have a higher share of blended material such as fly ash and blast furnace slag, resulting in the replacement of 16.4 Mtons of clinker by 2020. Blast furnace slags need to be dried before being used in cement, increasing fuel use by 0.042 MBtu/ton clinker. This is higher than in the moderate scenario because the use of blast furnace slags increases (using Type A, C, and E blended cements) (PCA, 1997).

Retirement rates for cement-making equipment (kilns and grinding) are the same as in the business-as-usual scenario (2.0%/year), based on the ages of existing kilns in the U.S. and the recent actual replacement of several kilns in the U.S.

Energy Consumption Trends

For existing equipment in the advanced scenario, we used the adjusted UECs defined by the 1994 baseline calculations in Martin et al. (1999). To derive the 2020 savings, we calculated the TPCs that result from comparing this adjusted 1994 baseline to the cost-effective savings identified in Martin et al. (1999) using a 15% discount rate. Table A-30 provides information on the 1994 UECs, the cost-effective UECs using a 15% discount rate, and the resulting TPCs assuming all cost-effective technologies are implemented by 2020. The cost-effective UECs using a 15% discount rate are derived from the savings associated with implementation of the following retrofit technologies and measures:

- Overall: preventative maintenance, energy management systems, and improved process control
- Dry Process: optimized heat recovery in the clinker grate cooler, conversion to grate clinker cooler, combustion system improvements, conversion to pre-calciner kiln (reducing Nox emissions simultaneously)
- Wet Process: conversion to semi-wet process, kiln combustion system improvements

For new equipment UECs in the advanced scenario, we used a modern large-scale dry process plant with multi-stage preheating and pre-calcining (Conroy, 1994; Steuch and Riley, 1993). For 2020, we used the efficiency of a 5-6 stage preheater with pre-calciner plant, using best available technologies as described by Cembureau (1997). Table A-30 provides information on the 1994 new plant UECs, the 2020 new plant UECs, and the resulting TPCs.

In the advanced scenario, natural gas use decreases more slowly than other fuels due to the need for drying blast furnace slag. Energy efficiency of industrial buildings in this sector improves at the same rate as that of commercial buildings under the advanced scenario.

Table A-30 Advanced Scenario Inputs for Existing and New Equipment for Cement Production

		Existing Equipment			**New Equipment**		
		1994 UECs	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Process	**Fuel**	MBtu/ton	MBtu/ton		MBtu/ton	MBtu/ton	
Grinding (cement)	Electricity	0.11	0.10	-0.0032	0.08	0.07	-0.0049
Dry Process	Electricity	0.18	0.18	0.0000	0.16	0.14	-0.0049
	Natural Gas	0.22	0.20	-0.0035	0.22	0.21	-0.0027
	Residual Oil	0.00	0.00	-0.0074	0.00	0.00	-0.0074
	Distillate Oil	0.06	0.06	-0.0045	0.05	0.04	-0.0045
	Coke	0.00	0.00	0.0000	0.00	0.00	0.0000
	Steam Coal	3.25	2.91	-0.0042	2.27	2.03	-0.0042
	Coke Oven Gas	0.00	0.00	0.0000	0.00	0.00	0.0000
	Other Petroleum	0.17	0.15	-0.0043	0.21	0.18	-0.0043
Wet Process	Electricity	0.17	0.17	0.0000	0.00	0.00	0.0000
	Natural gas	0.27	0.28	0.0006	0.00	0.00	0.0000
	Residual Oil	0.00	0.00	0.0000	0.00	0.00	0.0000
	Distillate Oil	0.02	0.02	-0.0045	0.00	0.00	0.0000
	Coke	0.00	0.00	0.0000	0.00	0.00	0.0000
	Steam Coal	4.38	3.78	-0.0057	0.00	0.00	0.0000
	Coke Oven Gas	0.00	0.00	0.0000	0.00	0.00	0.0000
	Other Petroleum	0.50	0.43	-0.0057	0.00	0.00	0.0000

Note: 1994 existing equipment UECs based on Martin et al. (1999); 1994 new equipment UECs based on an assumed 6-stage preheater, pre-calciner kiln. 2020 existing equipment UECs based on TPCs that result from comparing the 1994 baseline to the cost-effective savings identified in Martin et al. (1999) using a 15% discount rate. 2020 new equipment UECs based on TPCs that result from comparing the 1994 baseline to that of a modern preheater, pre-calciner kiln using best available technologies (Cembureau, 1997).

STEEL - Historical Trends

Economic Trends

Value of output in the U.S. steel industry declined at —0.6% per year between 1970 and 1994, falling from $100B in 1970 to $85B in 1994. Economic output in the steel industry hit a peak of $128B in 1974 before dropping off dramatically over the next decade, hitting a low of $62B in 1983. Production recovered during the next decade, increasing at 3.0% per year between 1983 and 1994[10].

Production and Technology Trends

Steel production in the U.S. has fluctuated dramatically since 1970, when production was 131.5 million tons. Production peaked at 150 million tons in 1973 and fluctuated between 110 and 145 million tons until it crashed to 75 million tons in 1982 as a result of a dramatic number of integrated mill closures. Since 1982, production has grown slowly, with two major declines in 1985-86 and 1991. In 1996, production reached 105 million tons (AISI, various years). Between 1970 and 1997, steel production grew at an average annual rate of —0.7%. However, there has been steady growth since 1982, averaging 2.5% per year through 1997, but slowing to 1.3% per year between 1990 and 1997.

Primary steel production using open hearth furnaces dropped from 48 million tons in 1970 to 6 million tons in 1982 and was completely phased out by 1992. Primary steel production using a basic oxygen furnace fluctuated between 45 and 83 million tons over the period, with a 1997 production level of 61.1 million tons or 56% of total steel production. Electric arc furnace steel production has more than doubled, growing from 20 million tons in 1970 to 47.5 million tons in 1997 (44% of total steel production). The share of EAF production grew an average of about 4% per year between 1970 and 1997 (AISI, various years).

Continuous casting grew significantly between 1970 and 1997, jumping from 5 million tons (3.8% of total production) in 1970 to 103 million tons (95%) in 1997. During the same period, ingot casting dropped from 127 to 5.7 million tons (OECD, World Steel Trade; AISI, 1997).

The steel industry produces a wide variety of products including blooms, slabs, billets, sheets, wire rods, rails, bars, pipe, tubing, plates, and strip. These products are rolled after the crude steel has been cast and can be grouped into those that require only hot rolling and those that also require cold rolling. Rolling of the cast steel begins in the hot rolling mill where the steel is heated and passed through heavy roller sections reducing the thickness of the steel. Hot rolling typically consumes 4.6 MBtu/ton of steel (Worrell et al., 1999a). The sheets may be further reduced in thickness by cold rolling. Finishing is the final production step, and may include different processes such as annealing, pickling, and surface treatment. Cold rolling and finishing add 1.5 MBtu/ton to the rolling energy use (Worrell et al., 1999a).

In 1980, 67.6 million tons of crude steel were hot rolled in the U.S. By 1997, this value had jumped to 105.9 million tons. Cold rolling followed a similar trend, starting at 29.2 million tons in 1980 and increasing to 41.7 million tons in 1997. The share of cold rolled steel fluctuated between 27% and 30% during this period and in 1997 was 28% (AISI, various years).

There were 142 operating steel plants in the U.S. in 1997. At that time, there were 14 integrated steel companies operating 20 integrated steel mills with a total of 40 blast furnaces (I&SM, 1997a). These mills are concentrated in the Great Lakes region, near supplies of coal and iron ore and near key customers such as the automobile manufacturers. The blast furnaces in these mills range in age accounting for

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[10] Value of output is for ISIC 371 (iron and steel) adjusted with value of shipments deflators for SIC 3312 (steel works, blast furnaces (including coke ovens), and rolling mills). The AEO99 model uses value of output for SIC 331 (steel works, blast furnaces, and rolling and finishing mills), and 332 (iron and steel foundries).

furnace rebuilds from 2 to 67 years, with an average age of 29 years. Production rates per plant vary between 0.5 and 3.1 million metric tons (Mt) per year. Total production of U.S. blast furnaces in 1997 was slightly over 54 Mt (I&SM, 1997a).

Secondary steel mills are located throughout the U.S, with some concentration in the South, near waterways for shipping and in areas with lower-cost electricity and labor (U.S. DOE, EIA, 1996; Hogan, 1987). In 1997 there were 85 secondary steel companies operating 122 minimills with 226 EAFs. These facilities are spread throughout 35 states, with the largest number of plants in Pennsylvania, Ohio, and Texas. The electric arc furnaces at these mills range in age from 0 (just starting production in 1997) to 74 years, with an average age of 24 years. Total annual nominal capacity listed in 1994 was 50.4 Mt and the average power consumption is 480 kWh/t (436 kWh/short ton) (I&SM, 1997b). Between 1995 and 1997 an additional 12 Mt of electric arc furnace capacity was built.

Energy Consumption Trends

Final energy use for the iron and steel industry (SIC 331,332) steel fluctuated significantly between 1958 and 1994, starting at 2.4 quads (2.6 quads primary energy) in 1958, climbing to 3.7 quads (4.2 quads primary energy) in 1973, dropping to 1.8 quads (2.1 quads primary energy) in 1982, and remaining level at 1.8 quads of final energy (2.3 quads primary energy) in 1994. Overall, energy consumption declined at —0.8% (-0.4% for primary energy) per year between 1958 and 1994, though after a decline between 1973 and 1982, final energy consumption increased at 0.3% per year between 1982 and 1994 (0.6% for primary energy). Between 1958 and 1994 the share of coal and coke used as energy sources dropped from about 75% to 57% of total fuels, followed by a drop in the share of oil from 10% to 3%. The share of natural gas used in the industry increased from 10% to 28%. The share of electricity increased from 4% to 11% during the same period, in large part due to increased secondary steel production.

Physical energy intensity of U.S. steel production, defined as primary energy use for SIC 331 and 332 per metric ton of steel produced, dropped 27%, from 30.6 MBtu/ton to 22.2 MBtu/ton, between 1958 and 1994.[11] Decomposition analyses indicate that about two-thirds of the decrease between 1980 and 1991 was due to efficiency improvements, while the remainder was due to structural changes (Worrell et al., 1997a).

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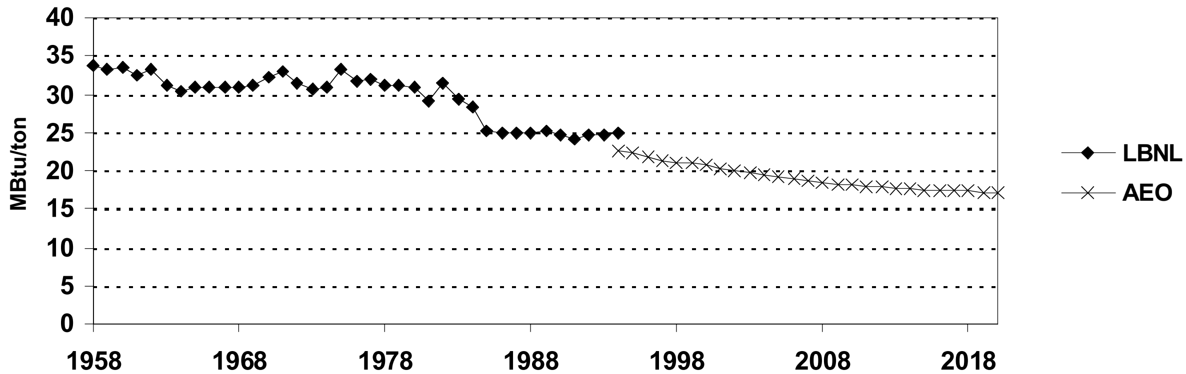
[11] Energy consumption values from 1991 through 1994 include SIC 3312 (blast furnaces and steel mills) 3313 (electrometallurgical products) and 3321 (gray and ductile iron foundries) in order to better match historical aggregate data. Due to limited coverage in the U.S. DOE, EIA *Manufacturing Energy Consumption Survey* data for 1985 through 1990 reflect energy use for SIC 3312 only, and therefore may be roughly 5-8% lower than energy use for the more aggregate SIC 331-332.

Fig. A-8 Historical and Projected Primary Energy Intensities (MBtu/ton) of U.S. Steel Production



STEEL - AEO99 Reference Case

Economic Trends

Value of output in the AEO99 model is much lower in magnitude than the historical figures, though the difference in this case could be definitional. Value of output rises from $64B in 1994 to $81B in 2020, at 0.9% per year. This trend seems to match the short-term (post-1982) growth in the steel industry, as opposed to the long-term decline in value of output growth.

Production and Technology Trends

AEO99 provides production data for 1994 to 2020. Historical values in AEO99 are about 5% lower than AISI values for 1994 through 1997. AOE99 forecasts average annual growth in steel production of 0.9% between 1996 and 2020. BOF steel production is forecast to drop from 61% of total steel production in 1994 to 54% in 2020 while EAF steel production grows from 39% to 46% over the same period in AEO99. AEO99 and AISI data agree on the share of continuous casting in 1994 (89.5%), but diverge from there, with AOE99 and AISI showing the share of continuous casting in 1997 to be 91.1% and 94.8%, respectively. AOE99 projects that the share of continuous casting continues to increase to 96.4% in 2020. AEO99 projects that the share of cold rolled products will remain a constant 27% from 1994 to 2020. AEO 99 retirement rates (percent) for iron and steel are 1.0 (100 years) for blast furnace and basic steel products (blast furnace/basic oxygen furnace), 1.5 (67 years) for basic steel products (electric arc furnace) and coke ovens, and 2.9 (35 years) for other steel.

Energy Consumption Trends

Both final and primary energy consumption remain essentially static between 1994 and 2020, final energy decreasing at —0.07% per year, while primary energy decreases at —0.03% per year. Due to a production increase of 1.0% per year, final energy intensity declines at —1.1% per year, while primary energy intensity declines at -—1.0% per year. Table A-31 provides the NEMS AEO99 input values for existing and new equipment for 1994 and 2020. In NEMS, energy use in buildings is set as energy use per employee, and only reacts to changes in number of employees in an industry, ignoring changes in building energy use, stock turnover of buildings, and also the potential impact of programs like Energy Star Buildings and Green Lights.

Table A-31 NEMS Baseline Inputs for Existing and New Equipment for Steel Production

		Existing Equipment			New Equipment		
		1994 UECs	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Process	**Fuel**	MBtu/ton	MBtu/ton		MBtu/ton	MBtu/ton	
Cold Rolled	Electricity	0.79	0.71	-0.0040	0.66	0.56	-0.0065
	Fuels	3.11	2.59	-0.0071	2.61	1.94	-0.0113
Hot Rolled	Electricity	0.35	0.30	-0.0061	0.18	0.16	-0.0041
	Fuels	2.02	1.53	-0.0106	1.01	0.84	-0.0072
Ingot	Electricity	0.30	0.30	0.0000	0.30	0.30	0.0000
	Fuels	1.78	1.75	-0.0132	1.69	1.69	0.0000
CC	Electricity	0.09	0.09	0.0000	0.09	0.09	0.0000
	Fuels	0.31	0.31	0.0000	0.31	0.31	0.0000
BF/OH	Electricity	0.11	0.11	0.0000	0.11	0.11	0.0000
	Fuels	7.12	7.12	0.0000	7.12	7.12	0.0000
BF/BOF	Electricity	0.20	0.19	-0.0016	0.20	0.18	-0.0034
	Nat.Gas	1.41	1.61	0.0050	1.41	2.36	0.0200
	Other Fuels	12.96	12.15	-0.0025	12.96	11.45	-0.0047
EAF	Electricity	1.59	1.54	-0.0013	1.53	1.45	-0.0020
	Fuels	0.58	0.54	-0.0023	0.55	0.50	-0.0035
Coke	Electricity	0.10	0.10	-0.0016	0.08	0.08	-0.0005
	Fuels	42.87	39.93	-0.0027	38.08	37.45	-0.0006

STEEL - Business-As-Usual Scenario

Economic Trends

Economic trends remain the same as AEO99 under the business-as-usual scenario.

Production and Technology Trends

Production, process share, casting, and product trends remain the same as AEO99 under the business-as-usual scenario. BF/BOF retirement rates are adjusted to 1.5% per year (for a lifetime of 67 years), EAF and coke oven turnover rates are adjusted to 1.8% per year (for a lifetime of 56 years), and other steel retirement rate is adjusted to 2.9% per year (for a lifetime of 34 years).

Energy Consumption Trends

Unit energy consumption (UEC) values for existing equipment in 1994 were derived from a recent study energy use in the U.S. steel sector (Worrell et al., 1999a). UECs for new equipment in 1994 were calculated for a U.S. energy price-based new plant based on UECs reported for the ECOTECH case in a recent report of the International Iron and Steel Institute (IISI, 1998). We call this plant U.S. ECOTECH . Table A-32 provides the modified UECs based on Worrell et al. (1999a) and IISI (1998) (discussed above). We projected 2020 UECs using the Technology Possibility Curves (TPCs) in NEMS AEO99 for both existing and new equipment. Buildings energy use remains the same as AEO99 under the business-as-usual scenario.

Table A-32 Business-As-Usual Inputs for Existing and New Equipment for Steel Production

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Process	**Fuel**	MBtu/ton	MBtu/ton		MBtu/ton	MBtu/ton	%
Cold Rolled	Electricity	0.40	0.36	-0.0040	0.29	0.24	-0.0065
Cold Rolled	Fuels	1.18	0.98	-0.0071	1.08	0.80	-1.0013
Hot Rolled	Electricity	0.61	0.52	-0.0061	0.31	0.28	-0.0041
Hot Rolled	Fuels	2.80	2.12	-0.0106	1.27	1.05	-0.0072
Ingot	Electricity	0.51	0.51	0.0000	0.00	0.00	0.000
Ingot	Fuels	1.21	0.86	-0.0132	0.00	0.00	0.0000
CC	Electricity	0.09	0.09	0.0000	0.04	0.04	0.0000
CC	Fuels	0.03	0.03	0.0000	0.04	0.04	0.0000
BF/OH	Electricity	0.00	0.00	0.0000	0.00	0.00	0.0000
BF/OH	Fuels	0.00	0.00	0.0000	0.00	0.00	0.0000
BF/BOF	Electricity	0.16	0.15	-0.0016	0.20	0.18	-0.0034
BF/BOF	Nat.Gas	1.92	2.19	0.0050	0.00	0.00	0.0200
BF/BOF	Other Fuels	10.15	9.51	-0.0025	9.17	8.10	-0.0047
EAF	Electricity	1.48	1.44	-0.0013	1.27	1.21	-0.0020
EAF	Fuels	0.15	0.14	-0.0023	0.46	0.42	-0.0035
Coke	Electricity	0.11	0.11	-0.0016	0.29	0.29	-0.0005
Coke	Fuels	40.63	37.85	-0.0027	39.99	39.33	-0.0006

Note: 1994 existing equipment UECs based on Worrell et al. (1999); 1994 new equipment UECs based on U.S. ECOTECH plant, a modified version of the ECOTECH plant (IISI, 1998). 2020 existing and new equipment UECs derived using NEMS AEO99 TPCs.

STEEL — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2.

In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the steel sector include demonstration programs, assessment programs, Challenge programs, ENERGY STAR buildings and Green Lights, state programs, state implementation plans, R&D programs, ESCO/utility programs, ENERGY STAR and Climate Wise programs, pollution prevention programs, tax incentives for energy managers, tax rebates for specific industrial technologies, investment tax credits for CHP systems, and a CO2 cap and trade system. Steel is one of OIT s Industries of the Future, and has also gone through some radical changes that will affect the future energy consumption and efficiency of this sector. New energy-efficient mini-mills have changed the structure of the steel industry, and this trend is likely to continue. In the advanced scenario we assume that increased recycling programs and efforts would further increase this trend compared to the baseline and moderate scenario. R&D efforts under IOF and by industry will help to develop new processes like smelt reduction and near net shape casting, which will profoundly change the energy intensity of new plants. This has been modeled by changing the annual energy improvement rates of new plants. Many of the other programs will influence the energy efficiency improvement rate in the steel industry, including programs like extended Motor and Steam Challenge, cogeneration initiatives, tax rebates for specific industrial equipment (e.g. smelt reduction, near net shape casting, scrap preheating), state activities including public benefit programs (especially for EAFs), and the industry may also benefit from environmental programs like the Clean Air Partnership to find integrated energy efficient opportunities. For example, the Challenge programs aim to contribute to market transformation and use specific goals, e.g. a 10% reduction in electricity use by motors by 2002 and a reduction in energy use in steam systems with 20% by 2010. The steel industry is also a large source of CO and PM emissions. Costs of air pollution reduction may vary depending on the way that states implement the Clean Air Act State Implementation Plans. Using energy-efficient technologies, air pollution levels would be reduced at a net benefit compared to using end-of-pipe technologies. Assessments have shown that CO2 emissions could be reduced by 0.2% to 3% per percent-point reduction of NOx emissions (STAPPA/ALAPCO, 1999) due to energy savings.

STEEL - Moderate Scenario

Economic Trends
Economic trends remain the same as AEO99 under the moderate scenario.

Production and Technology Trends
Production, process share, casting, and product trends remain the same as AEO99 under the moderate scenario. BF/BOF retirement rates are adjusted to 1.5% per year (for a lifetime of 67 years), EAF and coke oven turnover rates are adjusted to 1.8% per year (for a lifetime of 56 years), and other steel retirement rate is adjusted to 2.9% per year (for a lifetime of 34 years).

Energy Consumption Trends
For existing equipment in the moderate scenario, we used the adjusted UECs defined by the 1994 baseline calculations in Worrell et al. (1999). To derive the 2020 savings, we calculated the TPCs that result from comparing this adjusted 1994 baseline to the cost-effective savings identified in Worrell et al. (1999) using a 30% discount rate. Table A-33 provides information on the 1994 UECs, the cost-effective UECs

using a 30% discount rate, and the resulting average annual growth rate (TPCs) assuming all cost-effective technologies are implemented by 2020. The cost-effective UECs using 30% discount rate are derived from the savings associated with implementation of the following retrofit technologies and measures:

- Cold rolling: automated monitoring and targeting system
- Hot rolling: process control in hot strip mill; recuperative burners; controlling oxygen levels and VSDs on combustion air fans; energy-efficient drives in the rolling mill; 20% thin slab casting
- Casting: efficient ladle preheating
- Blast furnace/basic oxygen furnace: injection of natural gas to 14 kg/thm; pulverized coal injection to 130 kg/thm; hot blast stove automation; improved blast furnace control systems; pulverized coal injection to 225 kg/thm; recovery of blast furnace gas; preventative maintenance; energy monitoring and management system
- EAF: oxyfuel burners; scrap preheating, post combustion — shaft furnace (FUCHS); bottom stirring/stirring gas injection; improved process control (neural networks); DC-Arc furnace; scrap preheating — Tunnel furnace (CONSTEEL); preventative maintenance; energy monitoring and management system
- Coke: programmed heating

For 1994 new equipment UECs in the moderate scenario, we used the U.S. ECOTECH case described above (IISI, 1998). To derive the 2020 savings, we calculated the TPCs that result from comparing the 1994 U.S. ECOTECH new plant to the energy used by a hypothetical plant that uses (describe ALLTECH), called the ALLTECH plant in IISI (1998). Table A-33 provides information on the 1994 new plant UECs, the 2020 new plant UECs, and the resulting average annual growth rates.

Boiler energy efficiency increases at a rate of 0.2% per year for fossil fuels and 0.1% per year for biomass and waste in this scenario (CIBO, 1997; Einstein et al., 1999). Energy efficiency of industrial buildings in this sector improves at the same rate as that of commercial buildings under the moderate scenario.

Table A-33 Moderate Scenario Inputs for Existing and New Equipment for Steel Production

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Process	**Fuel**	MBtu/ton	MBtu/ton		MBtu/ton	MBtu/ton	
Cold Rolled	Electricity	0.40	0.35	-0.0055	0.29	0.28	-0.0013
Cold Rolled	Fuels	1.18	1.18	0.0000	1.08	0.73	-0.0150
Hot Rolled	Electricity	0.61	0.60	-0.0002	0.31	0.24	-0.oo98
Hot Rolled	Fuels	2.80	1.87	-0.0153	1.27	0.71	-0.0221
Ingot	Electricity	0.51	0.51	0.0000	0.00	0.00	0.0000
Ingot	Fuels	1.21	1.21	0.0000	0.00	0.00	0.0000
CC	Electricity	0.09	0.09	0.0000	0.04	0.02	-0.0263
CC	Fuels	0.03	0.03	-0.0111	0.04	0.03	-0.0110
BF/OH	Electricity	0.00	0.00	0.0000	0.00	0.00	0.0000
BF/OH	Fuels	0.00	0.00	0.0000	0.00	0.00	0.0000
BF/BOF	Electricity	0.16	0.14	-0.0053	0.20	0.11	-0.0227
BF/BOF	Nat.Gas	1.92	1.92	0.0000	0.00	0.00	0.0000
BF/BOF	Other Fuels	10.15	8.53	-0.0067	9.17	8.25	-0.0041
EAF	Electricity	1.48	1.19	-0.0086	1.27	0.96	-0.0107
EAF	Fuels	0.15	0.17	0.0056	0.46	0.40	-0.0054
Coke	Electricity	0.11	0.11	0.0000	0.29	0.10	-0.0401
Coke	Fuels	40.63	40.17	-0.0004	39.90	37.26	-0.0026

Note: 1994 existing equipment UECs based on Worrell et al. (1999); 1994 new equipment UECs based on U.S. ECOTECH plant, a modified version of the ECOTECH plant (IISI, 1998). 2020 existing equipment UECs based on TPCs that result from comparing the 1994 baseline to the cost-effective savings identified in Worrell et al. (1999) using a 30% discount rate. 2020 new equipment UECs based on TPCs that result from comparing the U.S. ECOTECH plant to the ALLTECH plant (IISI, 1998).

STEEL - Advanced Scenario

Economic Trends
Economic trends remain the same as AEO99 under the moderate scenario.

Production and Technology Trends
Production and product trends remain the same as AEO99 under the advanced scenario. The share of EAFs increased to 55% by 2020 (vs. 46% in AEO99). Continuous casting will increase to 99% in 2010 under the advanced scenario. BF/BOF retirement rates are adjusted to 1.5% per year (for a lifetime of 67 years), EAF and coke oven turnover rates are adjusted to 1.8% per year (for a lifetime of 56 years), and other steel retirement rate is adjusted to 2.9% per year (for a lifetime of 34 years).

Energy Consumption Trends
For existing equipment in the advanced scenario, we used the adjusted UECs defined by the 1994 baseline calculations in Worrell et al. (1999). To derive the 2020 savings, we calculated the TPCs that result from comparing this adjusted 1994 baseline to the cost-effective savings identified in Worrell et al. (1999) using a 15% discount rate. Table A-34 provides information on the 1994 UECs, the cost-effective UECs using a 15% discount rate, and the resulting average annual growth rate (TPCs) assuming all cost-effective technologies are implemented by 2020. The cost-effective UECs using 15% discount rate are derived from the savings associated with implementation of the following retrofit technologies and measures:

- Cold rolling: automated monitoring and targeting system; heat recovery on the annealing line

- Hot rolling: process control in hot strip mill; recuperative burners; controlling oxygen levels and VSDs on combustion air fans; energy-efficient drives in the rolling mill; hot charging; 20% thin slab casting
- Casting: efficient ladle preheating
- Blast furnace/basic oxygen furnace: injection of natural gas to 14 kg/thm; pulverized coal injection to 130 kg/thm; hot blast stove automation; improved blast furnace control systems; pulverized coal injection to 225 kg/thm; recovery of blast furnace gas; preventative maintenance; energy monitoring and management system
- EAF: oxyfuel burners; scrap preheating, post combustion — shaft furnace (FUCHS); bottom stirring/stirring gas injection; improved process control (neural networks); DC-Arc furnace; scrap preheating — Tunnel furnace (CONSTEEL); preventative maintenance; energy monitoring and management system; twin shell DC with scrap preheating; fluegas monitoring and control; transformer efficiency — UHP transformers
- Coke: programmed heating

For 1994 new equipment UECs in the advanced scenario, we used the U.S. ECOTECH case described above (IISI, 1998). To derive the 2020 savings, we calculated the TPCs that result from comparing the 1994 U.S. ECOTECH new plant to the energy used by a hypothetical plant that uses (describe ALLTECH), as well as smelting reduction and near net shape casting, that we call the ALLTECH-SM/NNSC plant (IISI, 1998). Table A-34 provides information on the 1994 new plant UECs, the 2020 new plant UECs, and the resulting average annual growth rates.

In addition, boiler energy efficiency improves at a rate of 0.2% per year for oil and renewables and 0.3% per year for gas and coal (CIBO, 1997; Einstein et al., 1999). Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the advanced scenario.

Table A-34 Advanced Scenario Inputs for Existing and New Equipment for Steel Production

		Existing Equipment			New Equipment		
		1994 UECs	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Process	**Fuel**	MBtu/ton	MBtu/ton		MBtu/ton	MBtu/ton	%
Cold Rolled	Electricity	0.40	0.34	-0.0058	0.29	0.28	-0.0013
Cold Rolled	Fuels	1.18	1.10	-0.0025	1.08	0.73	-0.0150
Hot Rolled	Electricity	0.61	0.60	-0.0002	0.31	0.10	-0.0426
Hot Rolled	Fuels	2.80	1.78	-0.0173	1.27	0.05	-0.1170
Ingot	Electricity	0.51	0.51	0.0000	0.00	0.00	0.0000
Ingot	Fuels	1.21	1.21	0.0000	0.00	0.00	0.0000
CC	Electricity	0.09	0.09	0.0000	0.04	0.02	-0.0263
CC	Fuels	0.03	0.03	-0.0111	0.04	0.03	-0.0110
BF/OH	Electricity	0.00	0.00	0.0000	0.00	0.00	0.0000
BF/OH	Fuels	0.00	0.00	0.0000	0.00	0.00	0.0000
BF/BOF	Electricity	0.16	0.14	-0.0053	0.20	0.25	0.0086
BF/BOF	Nat.Gas	1.92	1.92	0.0000	0.00	0.00	0.0000
BF/BOF	Other Fuels	10.15	8.53	-0.0067	9.17	9.32	0.0006
EAF	Electricity	1.48	1.14	-0.0102	1.27	0.96	-0.0107
EAF	Fuels	0.15	0.17	0.0056	0.46	0.40	-0.0054
Coke	Electricity	0.11	0.11	0.0000	0.29	0.01	-0.1215
Coke	Fuels	40.63	40.17	-0.0004	39.90	0.01	-0.2731

Note: 1994 existing equipment UECs based on Worrell et al. (1999); 1994 new equipment UECs based on U.S. ECOTECH plant, a modified version of the ECOTECH plant (IISI, 1998). 2020 existing equipment UECs based on TPCs that result from comparing the 1994 baseline to the cost-effective savings identified in Worrell et al. (1999) using a 15% discount rate. 2020 new equipment UECs based on TPCs that result from comparing the U.S. ECOTECH plant to the ALLTECH-SM/NNSC plant (IISI, 1998).

ALUMINUM - Historical Trends

Economic Trends

Economic growth, measured here with value of shipments, increased at 2.8% between 1958 and 1994[12]. Growth was uneven over this period, rising 56% between 1971 and 1973, and then falling 28% between 1979 and 1982. There was little net growth between 1973 and 1994, with value of shipments increasing at 0.08% per year.

Production and Technology Trends

Total U.S. production has grown from 4.8 Mtons in 1970 to 7.2 Mtons in 1995, or equivalent to an annual growth of 1.7% per year. U.S. aluminum demand has grown at a faster rate of 2.5%/year. The demand growth has been met by increased recycling of aluminum (see below) and increased imports (OIT, 1997). Primary aluminum production decreased slightly from 4.0 Mtons in 1970 to 3.9 Mtons in 1996, resulting in an annual average growth rate decrease of —0.03%. While primary, secondary, and total aluminum production varied considerably, both secondary and total aluminum increased production between 1970 and 1995, while primary aluminum ended the period with no net change in production.

Aluminum is produced by two processes: primary smelting and secondary production. Primary smelting is very electricity intensive consuming around 15 MWh/tonne aluminum, while secondary production only consumes fuel to re-melt the aluminum scrap, consuming about 5% of the primary energy consumption of primary aluminum. Secondary production has increased from 21% in 1970 to 49% in

[12] Value of output data is not available for SIC 3334 and 3353. Value of shipments data, which is value of output plus or minus the change in stocks, is available for both these aluminum subsectors.

1995 of total U.S. production (OIT, 1997). Primary aluminum production has decreased since 1991, while imports of primary aluminum have increased. This trend is expected to continue (EPA, 1998).

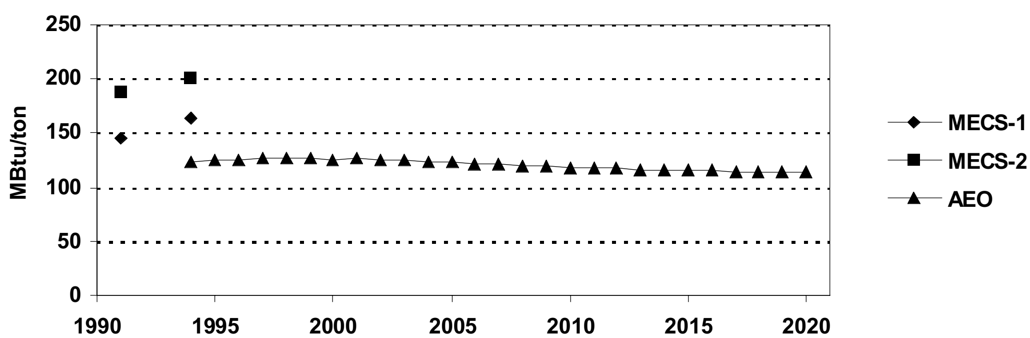
Secondary production is not modeled in NEMS, so we concentrate on primary aluminum smelting (ADL, 1998). NEMS does include aluminum semi-fabrication, and excludes alumina refining.[13] In NEMS capital stock turnover is estimated at 2.1%/year. We will maintain this stock turnover rate in the baseline and moderate scenario (EIA, 1998). In the advanced scenario a small increase of stock turnover may be expected, due to increasing electricity prices. We assume a small acceleration to 2.3%/year.

Energy Consumption Trends

Two analyses of time series data from the Manufacturing Energy Consumption Survey were used to develop final and primary energy estimates. In the first series, final energy consumption stays the same, 314 TBtu in both 1991 and 1994, while the second analysis shows final energy consumption dropping from 312 TBtu in 1991 to 274 TBtu in 1994. The two series estimates vary in primary energy consumption as well. The first (ERNST) series shows primary energy consumption falling 10% between 1991 and 1994, at a rate of —3.2% per year, while the second shows primary energy consumption decreasing 15% between 1991 and 1994, at —5.2% per year. Series 1 shows primary energy consumption falling from 660 TBtu in 1991 to 600 TBtu in 1994, while Series 2 offers a decline from 850 TBtu in 1985 to 730 TBtu in 1994. On average, the sector defined as SIC 3334 contributed about 80% of final and primary energy, while the sector classified as SIC 3353 contributed roughly 20%. Electricity is the dominant fuel in electricity production, averaging about 90% of total energy consumption.

Primary energy intensity increased between 1991 and 1994. Series 1 showed an increase of 4.2% per year (13% overall) between 1991 and 1994, while Series 2 showed an increase of 2.1% per year (6% overall) during the same time span.. The primary energy intensity of Series 1 rose from at 145 MBtu/ton in 1991 to 164 MBtu/ton in 1994, while Series 2 listed primary energy intensity at 187 MBtu/ton in 1991 and 200 MBtu/ton in 1994. Production decreased more quickly (-7.1% per year between 1991 and 1994) than did energy consumption during this time span, resulting in an increasing energy intensity.

Figure A-9. Historical and Projected Physical Primary Energy Intensities (MBtu/ton) in U.S. Primary Aluminum



[13] Future decline in U.S. primary production may result in reduced energy demand for alumina manufacturing, which is not accounted for in NEMS.

ALUMINUM - AEO99 Reference Case and Business-As-Usual

Economic Trends
Value of output is projected to rise at 0.2% per year between 1994 and 2020, a trend comparable to the growth in value of shipments between 1972 and 1994.

Production and Technology Trends
AEO99 shows a low production growth of approximately 0.2% per year. NEMS only models primary aluminum smelting and semi-fabrication (SIC 3353). In the business-as-usual scenario we do not assume increased recycling, so we follow the AEO 99 baseline.

Retirement rates for aluminum industry in NEMS are set at 2.1% per year. We adjust these rates to 2.3% per year for a lifetime of 43 years.

Energy Consumption Trends
The NEMS AEO99 model shows both final and primary energy intensity decreasing slightly between 1994 and 2020. Final energy decreases from 49.1 MBtu/ton in 1994 to 47.0 MBtu/ton in 2020, at —0.2% per year, while primary energy intensity decreases from 123 MBtu/ton in 1994 to 114 MBtu in 2020, at —0.3% per year. While both the final and primary energy intensity estimates are lower than historical values, the trends are similar in scale.

Table A-35 provides the NEMS AEO99 input values for existing and new equipment for 1994 and 2020. The new plant UECs and TPCs for existing and new plants are based on AEO99 as well.

We have followed the AEO99 baseline assumptions for the building component of the baseline. Unit energy consumption (UEC) values for existing equipment in 1994 are taken from the existing NEMS AEO99 input files. UECs for new equipment in 1994 were estimated on the basis of existing smelters in various parts of the world. Energy use in buildings is very small compared to the energy use in the production process. NEMS estimates final energy consumption for the building component at 7.1 Trillion Btu, or approximately 3% of total (modeled) final energy consumption in the aluminum industry.

Table A-35. NEMS Baseline Inputs for Existing and New Equipment for Aluminum Production

		Existing Equipment			New Equipment		
		1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Process	Fuel	MBtu/ton	MBtu/ton		MBtu/ton	MBtu/ton	
Smelting	Electricity	37.488	35.587	-0.20	28.491	27.046	-0.20
	Natural gas	13.067	11.928	-0.35	5.433	4.959	-0.35
	Steam coal	0.000	0.000	-0.35	0.000	0.000	-0.35
	Dist. Oil	0.025	0.023	-0.35	0.000	0.000	-0.35
	LPG	0.000	0.000	-0.35	0.000	0.000	-0.35
	Other petroleum	0.000	0.000	-0.35	0.000	0.000	-0.35

ALUMINUM — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2.

In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the aluminum sector include demonstration programs, assessment programs, Challenge programs, ENERGY STAR buildings and Green Lights, state programs, state implementation plans, R&D programs, ENERGY STAR and Climate Wise programs, pollution prevention programs, tax incentives for energy managers, tax rebates for specific industrial technologies, investment tax credits for CHP systems, and a CO2 cap and trade system. In the CEF-NEMS, the aluminum industry includes primary production and shaping of aluminum production, but excludes secondary production. Primary aluminum production is highly concentrated in a small group of companies and is responsible for the vast majority of the energy use in this sector. The primary aluminum industry already has a voluntary agreement with EPA to reduce PFC emissions (see above). It is not expected that new aluminum smelters will be built in the U.S. However, the energy consumption of a new plant is modeled in the CEF-NEMS model, based on modern processes in commercial operation. Energy efficiency improvement will mainly be achieved through retrofit of existing plants. Programs like Motor Challenge, assessments (for smaller aluminum-shaping industries), R&D, Climate Wise, credits for energy managers, as well as increased recycling efforts, will improve energy efficiency in this sector. Pollution prevention programs contribute to energy and cost savings through reduced material use. Carbon emission reductions in 1997 was estimated at 5.2 milllion tonnes carbon, or roughly equivalent to annual energy savings of 0.2 Quads throughout industry. Although cans are already recycled for a large share, increased recycling is feasible for cans and other aluminum products. This has been modeled as a reduction in primary production. R&D activities under the Industries of the Future program are assisting in the development of inert anodes which may lead to energy savings in the aluminum (and anode-producing) industry. OIT is the prime agent for government support R&D in energy efficiency. The character of such programs makes it difficult to estimate the actual energy savings due to the program itself. However, estimates can and have been made for the technologies supported by OIT programs (U.S. DOE-OIT, 1998). Based on these assessments the current portfolio is expected to contribute to annual energy savings of 3.1 Quads by 2020 (U.S. DOE-OIT, 1999) through development and implementation of new energy-efficient industrial technologies. Expanded R&D programs will increase these savings.

ALUMINUM - Moderate Scenario

Economic Trends

Economic trends remain the same as AEO99 under the moderate scenario.

Production and Technology Trends

Production and process share trends remain the same as AEO99 under the moderate scenario. Capital stock retirement rates are the same as those applied in the business-as-usual scenario.

Energy Consumption Trends

For existing equipment in the moderate scenario, we used the UECs defined in AEO99. The TPC for existing equipment is estimated on the basis of retrofitting existing cells and potentials for efficiency improvement (EPA, 1998) reducing power consumption to 13.6 MWh/tonne. The TPC for fuel use has been slightly accelerated, using modern furnace technology and (recuperative, submerged) burners.

New plant UECs are based on current Hall-Heroult cells using 13.2 MWh (Ravier, 1986). The TPC has been adapted to reflect technologies currently under demonstration in Norway, which can reduce specific electricity consumption to approximately 12 MWh/tonne.

Boiler energy efficiency increases at a rate of 0.2% per year for fossil fuels and 0.1% per year for biomass and waste in this scenario (CIBO, 1997; Einstein et al., 1999). Energy efficiency of industrial buildings in this sector improves at the same rate as that of commercial buildings under the moderate scenario.

Table A-36. Moderate Scenario Inputs for Existing and New Equipment for Aluminum Production

		Existing Equipment			**New Equipment**		
		1994 UECs	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Process Name	**Fuel Name**	MBtu/ton	MBtu/ton	%	MBtu/ton	MBtu/ton	%
Smelting	Electricity	37.488	30.90	-0.74	28.491	28.07	-0.25
	Natural gas	13.067	11.77	-0.40	5.433	4.959	-0.35
	Steam coal	0.000	0.00	-0.40	0.000	0.000	-0.35
	Dist. Oil	0.025	0.02	-0.40	0.000	0.000	-0.35
	LPG	0.000	0.00	-0.40	0.000	0.000	-0.35
	Other petroleum	0.000	0.00	-0.40	0.000	0.000	-0.35

ALUMINUM - Advanced Scenario

Economic Trends
Economic trends remain the same as AEO99 under the advanced scenario.

Production and Technology Trends
Production trends have been slightly reduced (by 0.05% per year) to reflect increased recycling (based on EPA, 1998). However, this can not be modeled in the NEMS model. Therefore, the UEC inputs (see below) have been changed to reflect the increased recycling. Capital stock retirement rates are the same as those applied in the business-as-usual scenario.

Energy Consumption Trends
The UECs of existing and new equipment are adapted to reflect increased recycling. The 2020 UEC is reduced by 2% to reflect increased recycling trend that will reduce primary aluminum production growth from 0.20%/year to 0.15%/year.

For existing equipment in the moderate scenario, we used the UECs defined in AEO99. The TPC for existing equipment is estimated on the basis of retrofitting existing cells and potentials for efficiency improvement (EPA, 1998) reducing power consumption to 13.6 MWh/tonne. The TPC for fuel use has been slightly accelerated, using modern furnace technology and (recuperative, submerged) burners.

New plant UECs are based on current Hall-Heroult cells using heat recovery equipment reducing power consumption to 12 MWh). The TPC has been adapted to reflect successful development of technologies currently under development, such as inert anodes, and bi-polar cell designs (Jarret, 1987; EPA, 1998; IOF,1998).

In addition, boiler energy efficiency improves at a rate of 0.2% per year for oil and renewables and 0.3% per year for gas and coal (CIBO, 1997; Einstein et al., 1999). Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the advanced scenario.

Table A-37. Advanced Scenario Inputs for Existing and New Equipment for Aluminum Production

		Existing Equipment			**New Equipment**		
		1994 UECs	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Process	**Fuel**	MBtu/ton	MBtu/ton		MBtu/ton	MBtu/ton	
Smelting	Electricity	37.488	28.57	-1.12	28.491	26.35	-0.38
	Natural gas	13.067	11.47	-0.58	5.433	4.90	-0.48
	Steam coal	0.000	0.00	-0.58	0.000	0.000	-0.48
	Dist. Oil	0.025	0.02	-0.58	0.000	0.000	-0.48
	LPG	0.000	0.00	-0.58	0.000	0.000	-0.48
	Other petroleum	0.000	0.00	-0.58	0.000	0.000	-0.48

METALS-BASED DURABLES — Historical Trends

The metals-based durables (also called fabricated metal products) sector is made up of products from 5 sectors (ISIC 34 through 38). These are: fabricated metal products (ISIC 34), machinery, except electrical (ISIC 35), electric and electronic equipment (ISIC 36), transportation equipment (ISIC 37), and instruments and related products (ISIC 38).

Economic Trends

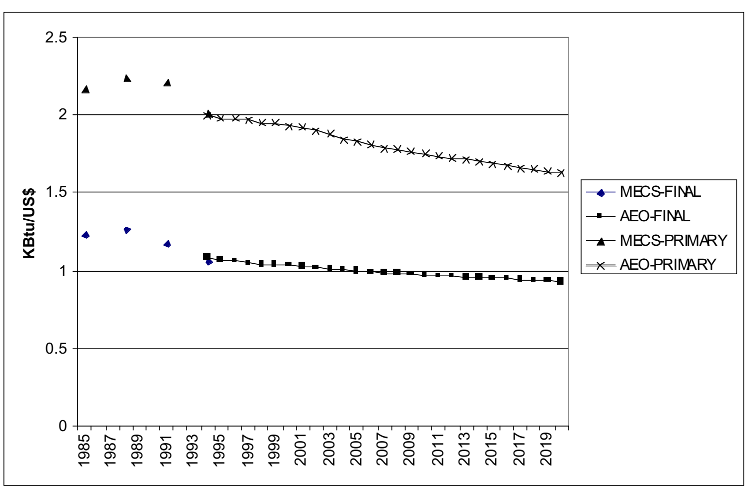
Value of output in the metals-based durables sector grew from $735B (1987$) in 1977 to $1645B in 1997. Value of output increased in the metals-based durables sector at 4.1% per year between 1977 and 1997. The rate has been increasing in recent years, as the AAGR grew at 5.6% per year in the 15-year period 1982-1997, and 5.5% per year between 1987 and 1997. The transport equipment subsector dominated the metals-based durables sector s economic production in the 1970s, contributing a 40% share of total value of output while the other sub-sectors contributed between 6% and 19% of value of output. The production distribution has changed over time. Electrical machinery and non-electrical machinery contributed the highest proportion of value of output in 1997, 28% each, while transport equipment has fallen to 24% and the other subsectors contribute between 8% and 11%. Electrical machinery (SIC 36), by itself, contributed 9.5% of total industrial value-of output in 1994 (14% in 1997), while consuming only 2% of its energy.

Energy Consumption Trends

Primary energy consumption increased at an average of 2.4% per year between 1985 and 1994. Primary energy use is much higher than final energy consumption in the metals-based durables sector due to the high fuel share of electricity (39% in 1994).

Historical economic energy intensity for the metals-based durables sector (primary energy/value of output) declined on average —0.86% per year between 1985 and 1994. As noted above, energy consumption has increased consistently, but the sector s economic growth has outpaced the energy consumption, resulting in a decreasing UEC.

Figure A-10. Historical and Projected Economic Energy Intensities (KBtu/U.S.$) for U.S. Metals-Based Durables



METALS-BASED DURABLES - AEO99 Reference Case and Business-As-Usual Scenario

Economic Trends
Value of output is projected to grow at an average of 3.2% per year between 1994 and 2020. While this is comparable to historical trends (4.1%), growth actually slows in the future, with an AAGR of 2.3% between 2010 and 2020.

Production and Technology Trends
Stock turnover rate for production equipment in the metals-based durables industry is 1.5% per year, equivalent to a lifetime of 67 years. We adjust this rate to 1.9% per year for a lifetime of 53 years.

Energy Consumption Trends
Primary energy consumption is projected to increase at 2.4% per year over the 26-year period 1994 to 2020, with growth slowing over time (2.0% per year from 2005-2020, 1.6% per year from 2010-2020). Primary energy use is much higher than final energy consumption in the metals-based durables sector due to the high fuel share of electricity (41% in 2020).

Economic energy intensity (KBtu/value of output) is projected to decline at an average rate of —0.78% per year between 1994 and 2020 in the AEO99 reference case, declining from 2.0 KBtu/U.S.$ in 1994 to 1.6 KBtu/U.S.$ in 2020.

Table A-38 provides the NEMS baseline inputs for existing and new equipment in 1994 and 2020. In NEMS, energy use in buildings is given as energy use per employee, and only reacts to a change in the number of employees in an industry, ignoring changes in building energy use, stock turnover of buildings, and the potential impact of programs aimed towards buildings. In the baseline scenario we use the AEO-99 assumptions.

Table A-38. NEMS Baseline Inputs for Existing and New Equipment for Metals-Based Durables

	Existing Equipment			New Equipment		
	1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Fuel	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Electricity	0.2626	0.2599	-0.0004	0.2495	0.2443	-0.0008
Natural gas	0.2528	0.2393	-0.0021	0.2401	0.2153	-0.0042
Steam coal	0.0047	0.0042	-0.0040	0.0044	0.0036	-0.0080
Residual oil	0.0029	0.0028	-0.0014	0.0027	0.0026	-0.0028
Distillate oil	0.0109	0.0105	-0.0014	0.0103	0.0096	-0.0028
LPGs	0.0056	0.0054	-0.0014	0.0053	0.0049	-0.0028
Steam	0.3983	0.3841	-0.0014	0.3784	0.3518	-0.0028
Biomass-wood	0.0009	0.0009	-0.0014	0.0009	0.0009	-0.0028

Note: We only depict the UECs for region 1 in the NEMS model. The UECs vary between the regions, but the TPCs are exactly similar for each region.

METALS-BASED DURABLES — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2.

In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S. DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the metals-based durables sector include demonstration programs, assessment programs, Challenge programs, ENERGY STAR buildings and Green Lights, state programs, state implementation plans, R&D programs, ESCO/utility programs, ENERGY STAR and Climate Wise programs, tax incentives for energy managers, tax rebates for specific industrial technologies, investment tax credits for CHP systems, and a CO2 cap and trade system. The metals-based durables industry is an extremely varied industry, not only with respect to products but also the different company sizes (from small casters with a few personnel to the world s largest companies) and varying organizational structures. This requires the use of a multitude of policy instruments to improve energy efficiency, such as assessment programs, Challenge programs, Energy Star programs, labeling and standard programs, state efforts and public benefit programs, RD&D, cogeneration policies, as well as pollution prevention and other environmental programs.

ENERGY STAR buildings are likely to have a large impact in this sector because a relatively large share of energy in these industries is used for building applications. Many industries in this sector already participate in this program and could further improve their performance, while many smaller companies do not yet participate. ENERGY STAR labeling for office equipment and Green Lights are important programs for this sector. With 1,400 companies currently participating in the Green Lights program, the annual energy savings are estimated at 4.8 GWh (Lupinacci-Rausch, 1999). Other than the EPACT efficiency standards for motors, standards are less common for industrial equipment. EPACT standards result in savings of over 7 GWh per year. Newly proposed standards (CEE) are estimated to save another 4 GWh/year (Scheihing et al., 1998). State programs can have several forms and may include elements such as development, demonstration or dissemination. Using the estimated the average cost-effectiveness, as given by Quinn and Reed (1997), we estimate annual energy savings at 0.6 quads at current funding levels. Expanding state programs will achieve higher levels of energy savings in many different industries.

METALS-BASED DURABLES - Moderate Scenario

Economic Trends
Economic trends remain the same as AOE99 under the moderate scenario.

Production and Technology Trends
Production and process share trends remain the same as AEO99 under the moderate scenario. Capital stock retirement rates are the same as those applied in the business-as-usual scenario.

Energy Consumption Trends
Table A-39 provides the moderate scenario inputs for existing and new equipment in 1994 and 2020. The energy efficiency improvement rates, both for existing and new equipment, have been increased by 50% in the moderate scenario, compared to the BAU scenario. This reflects the expansion of policy programs like the IACs. The metals-based durables industries were the largest participant in the IAC program, and the expansion is expected to improve the implementation rate of suggested measures.

Boiler energy efficiency increases at a rate of 0.2% per year for fossil fuels and 0.1% per year for biomass and waste in this scenario (CIBO, 1997; Einstein et al., 1999). Energy efficiency of industrial buildings in this sector improves at the same rate as that of commercial buildings under the moderate scenario.

Table A-39 Moderate Scenario Inputs for Existing and New Equipment for Metals-Based Durables

	Existing Equipment			New Equipment		
	1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Fuel	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Electricity	0.2626	0.2585	-0.0006	0.2495	0.2418	-0.0012
Natural gas	0.2528	0.2329	-0.0032	0.2401	0.2037	-0.0063
Steam coal	0.0047	0.0040	-0.0060	0.0044	0.0032	-0.0120
Residual oil	0.0029	0.0027	-0.0021	0.0027	0.0024	-0.0042
Distillate oil	0.0109	0.0103	-0.0021	0.0103	0.0092	-0.0042
LPGs	0.0056	0.0053	-0.0021	0.0053	0.0048	-0.0042
Steam	0.3983	0.3771	-0.0021	0.3784	0.3392	-0.0042
Biomass-wood	0.0009	0.0009	-0.0021	0.0009	0.0009	-0.0042

Note: We only depicted the UECs for region 1 in the NEMS model. The UECs vary between the regions, but the TPCs are exactly similar for each region.

METALS-BASED DURABLES - Advanced Scenario

Economic Trends
Economic trends remain the same as AOE99 under the advanced scenario.

Production and Technology Trends
Production and process share trends remain the same as AEO99 under the advanced scenario. Capital stock retirement rates are the same as those applied in the business-as-usual scenario.

Energy Consumption Trends

Table A-40 provides the advanced scenario inputs for existing and new equipment in 1994 and 2020. The energy efficiency improvement rates, both for existing and new equipment, have been doubled in the advanced scenario, compared to the BAU scenario. This reflects the expansion of policy programs like the IACs, and the effects of voluntary agreements with the larger companies in this sector. The metals-based durables industries were the largest participant in the IAC program, and the expansion is expected to improve the implementation rate of suggested measures.

In addition, boiler energy efficiency improves at a rate of 0.2% per year for oil and renewables and 0.3% per year for gas and coal (CIBO, 1997; Einstein et al., 1999). Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the advanced scenario.

Table A-40. Advanced Scenario Inputs for Existing and New Equipment for Metals-Based Durables

	Existing Equipment			New Equipment		
	1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Fuel	MBtu/$	MBtu/$		MBtu/$	MBtu/$	
Electricity	0.2626	0.2572	-0.0008	0.2495	0.2393	-0.0016
Natural gas	0.2528	0.2266	-0.0042	0.2401	0.1928	-0.0084
Steam coal	0.0047	0.0038	-0.0080	0.0044	0.0029	-0.0160
Residual oil	0.0029	0.0027	-0.0028	0.0027	0.0023	-0.0056
Distillate oil	0.0109	0.0101	-0.0028	0.0103	0.0089	-0.0056
LPGs	0.0056	0.0052	-0.0028	0.0053	0.0046	-0.0056
Steam	0.3983	0.3703	-0.0028	0.3784	0.3270	-0.0056
Biomass-wood	0.0009	0.0009	-0.0028	0.0009	0.0009	-0.0056

Note: We only depicted the UECs for region 1 in the NEMS model. The UECs vary between the regions, but the TPCs are exactly similar for each region.

OTHER MANUFACTURING - Historical Trends

Economic Trends

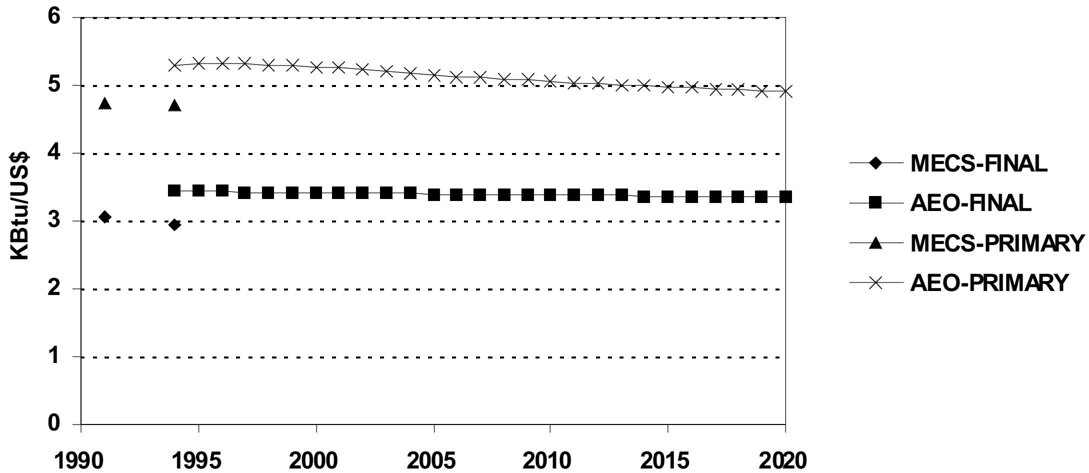
The Other Manufacturing category discussed herein encompasses an array of industries. We define the sector as SICs 21 through 25, 27, 30, 31, 39 and those portions of SICs 28, 29, 32, and 33 not examined in the AEO forecast. Value of output in the Other Manufacturing sector increased from $610B in 1977 to $830B in 1994, at an annual average rate of 1.8% per year. While there have been slight dips, the increase has been reasonably steady.

Energy Consumption Trends

The level of decomposition required to accurately report on Other Manufacturing is only available in the 1994 and 1997 national Manufacturing Energy Consumption Surveys. Final energy consumption increased from 2240 TBtu in 1991 to 2430 TBtu in 1994, at 2.8% per year, for an overall increase of 9%. Primary energy consumption grew from 3490 TBtu in 1991 to 3910 TBtu in 1994, at 3.9% per year, for an overall increase of 12%. The dominant fuels in the Other Manufacturing sector are natural gas, which held a 42% share in 1994, and electricity, which held a 27% share in 1994, up from 25% in 1991.

Unit energy consumption decreased slightly between 1991 and 1994. While both final (2.8% per year) and primary (3.9% per year) energy consumption increased over that span, value of output grew more rapidly (4.1% per year between 1991 and 1994), resulting in a decreasing final (-1.3% per year) and primary (-0.2% per year) energy intensity.

Fig. A-11 Historical and Projected Economic Energy Intensities (KBtu/U.S.$) in U.S. Other Manufacturing



OTHER MANUFACTURING - AEO99 Reference Case and Business-As-Usual Scenario

Economic Trends

Value of output for the Other Manufacturing sector in the AEO99 model increases at 1.6% per year between 1994 and 2020, from $800B in 1994 to $1190B in 2020. The long-term growth rate and crossover year (1994) are similar in magnitude to STAN/BEA and MECS data.

Production and Technology Trends

The retirement rate of capital stock in all non-manufacturing subsectors is set at 2.3% per year in NEMS AOE99, for an average lifetime of 43 years. We adjust this to a rate of 2.5% per year for an average lifetime of 40 years.

Energy Consumption Trends

Final energy consumption increases at 1.5% per year between 1994 and 2020, from 2740 TBtu in 1994 to 4000 TBtu in 2020. Primary energy consumption increases at 1.3% per year over this time span, from 4220 TBtu in 1994 to 5860 TBtu in 2020. Fuel share is dominated by natural gas (47% in 1994) and electricity (25% in 1994). Value of output increases at a greater rate than energy consumption between 1994 and 2020, thus both final (-0.1% per year) and primary (-0.3% per year) energy intensity decrease during this period. Table A-41 provides the NEMS baseline inputs for existing and new equipment in 1994 and 2020.

In NEMS, energy use in buildings is given as energy use per employee, and only reacts to a change in the number of employees in an industry, ignoring changes in building energy use, stock turnover of buildings, and the potential impact of programs aimed towards buildings. In the baseline scenario we use the AEO99 assumptions.

Table A-41 NEMS Baseline Inputs for Existing and New Equipment for Other Manufacturing

	Existing Equipment			New Equipment		
	1994 UECs	2020 UECs	TPC	1994 UECs	2020 UECs	TPC
Fuel	MBtu/$	MBtu/$	%	MBtu/$	MBtu/$	%
Electricity	0.4251	0.4207	-0.0004	0.4038	0.3955	-0.0008
Natural Gas	0.4952	0.4688	-0.0021	0.4704	0.4217	-0.0042
Residual Oil	0.0323	0.0311	-0.0014	0.0307	0.0285	-0.0028
Distillate Oil	0.0097	0.0094	-0.0014	0.0092	0.0086	-0.0028
LPG	0.0152	0.0147	-0.0014	0.0145	0.0134	-0.0028
Steam Coal	0.0336	0.0303	-0.004	0.0319	0.0259	-0.008
Other Petroleum	0	0	-0.0014	0	0	-0.0028
Steam	0.44	0.4243	-0.0014	0.418	0.3886	-0.0028
Biomass-Wood	0.0452	0.0452	0	0.0407	0.0407	0
Electricity	0.6073	0.601	-0.0004	0.5769	0.565	-0.0008
Natural Gas	0.8361	0.7916	-0.0021	0.7943	0.7119	-0.0042
Residual Oil	0.0105	0.0101	-0.0014	0.01	0.0093	-0.0028
Distillate Oil	0.014	0.0135	-0.0014	0.0133	0.0124	-0.0028
LPG	0.0324	0.0312	-0.0014	0.0307	0.0286	-0.0028
Steam Coal	0.0068	0.0062	-0.004	0.0065	0.0053	-0.008
Other Petroleum	0	0	-0.0014	0	0	-0.0028
Steam	0.4717	0.4548	-0.0014	0.4481	0.4166	-0.0028
Biomass-Wood	0.1787	0.1787	0	0.1787	0.1787	0
Electricity	1.0307	1.02	-0.0004	0.9792	0.959	-0.0008
Natural Gas	1.0069	0.9533	-0.0021	0.9565	0.8574	-0.0042
Residual Oil	0.0503	0.0485	-0.0014	0.0477	0.0444	-0.0028
Distillate Oil	0.0174	0.0168	-0.0014	0.0166	0.0154	-0.0028
LPG	0.2426	0.2339	-0.0014	0.2305	0.2142	-0.0028
Steam Coal	0.0263	0.0237	-0.004	0.025	0.0203	-0.008
Other Petroleum	0	0	-0.0014	0	0	-0.0028
Steam	1.3555	1.307	-0.0014	1.2877	1.1972	-0.0028
Biomass-Wood	0.4894	0.4894	0	0.4894	0.4894	0
Electricity	0.5362	0.5307	-0.0004	0.5094	0.4989	-0.0008
Natural Gas	0.4911	0.465	-0.0021	0.4665	0.4182	-0.0042
Residual Oil	0.0634	0.0611	-0.0014	0.0602	0.056	-0.0028
Distillate Oil	0.0057	0.0055	-0.0014	0.0054	0.005	-0.0028
LPG	0.0003	0.0003	-0.0014	0.0003	0.0003	-0.0028
Steam Coal	0.0025	0.0023	-0.0040	0.0024	0.002	-0.0080
Other Petroleum	0	0	-0.0014	0	0	-0.0028
Steam	1.3353	1.2875	-0.0014	1.2685	1.1793	-0.0028
Biomass-Wood	0.7177	0.7177	0	0.7177	0.7177	0

OTHER MANUFACTURING — Policies and Programs

Energy policies and programs are important drivers for energy efficiency improvements in the industrial sector. However, the NEMS framework does not allow direct modeling of most energy efficiency policies. Although evaluations of industrial energy efficiency policies are not always available, we have estimated the impacts of such policies on the basis of evaluated programs in the U.S. and abroad (e.g. Martin et al., 1998) as well as the information presented in Appendix B-2. In most sectors we assume that voluntary sector agreements are used as a way to set energy efficiency improvement targets. Due to the wide variety companies within the other manufacturing sector, various voluntary agreements will have to be developed for specific sub-sectors (e.g. textiles). These voluntary agreements are augmented by a number of policies and programs designed to provide support to each sector in achieving the targets because many instruments are complimentary in formulating an industrial energy efficiency policy (U.S.

DOE, 1996a). Under the voluntary agreement framework, we envision that a group of industries (e.g. through an association) will negotiate a specified target with the government. Experience with sector agreements in Europe and Japan has shown that annual industry-wide energy efficiency improvements between 0.6% and 1.5% per year are feasible (IEA, 1997a; Stein and Strobel, 1997). In the U.S., the primary aluminum industry and EPA have negotiated an agreement to reduce PFC emissions by 40% by 2000, while other sector agreements exist with the natural gas industry.

As described in Appendix B-2, we evaluated approximately 20 policies and programs that focus on improving energy efficiency in the industrial sector and that we assume will be used in conjunction with voluntary industrial sector agreements to provide further support to the industries which have set energy efficiency improvement targets. These various policies and programs can be directed at specific industrial subsectors or at cross-cutting technologies and measures. These various policies and programs influence energy use in many different ways. Some provide information or incentives for improving existing equipment while others focus on new equipment. Some focus on improving material efficiency and recycling, others promote increase boiler efficiency and use of cogeneration. Table A-2 shows how we changed various CEF-NEMS modeling parameters to reflect the expected impact of a policy or program in a specific industrial subsector, i.e. efficiency improvement rate of existing and new equipment, improved efficiency of boilers, improved efficiency in industrial buildings, and increased penetration of cogeneration. Some of the impacts have first been evaluated with different models before implementation in CEF-NEMS. Appendix B-2 provides further details regarding how we envision these policies and programs will be expanded under the moderate and advanced scenarios.

The policies and programs that can provide support in achieving energy efficiency improvement targets under a voluntary agreement in the other manufacturing sector include demonstration programs, assessment programs, Challenge programs, ENERGY STAR buildings and Green Lights, state programs, state implementation plans, ESCO/utility programs, ENERGY STAR and Climate Wise programs, tax incentives for energy managers, investment tax credits for CHP systems, and a CO2 cap and trade system. This subsector includes a wide variety of many light industries. The variation makes it essential to use a wide variety of instruments. The ENERGY STAR buildings program is likely to have a large impact in this sector, as a relatively large part of energy in these industries is used for buildings. Many industries in this sector already participate and could further improve their performance, while many smaller companies do not yet participate. ENERGY STAR labeling for office equipment and Green Lights are also important programs. With 1,400 companies currently participating in the Green Lights program, the annual energy savings are estimated at 4.8 GWh (Lupinacci-Rausch, 1999). Other EPACT standards for motors result in savings of over 7 GWh per year. Proposed standards (CEE) are estimated to save another 4 GWh/year (Scheihing et al., 1998). State programs may include development, demonstration or dissemination. Using the average cost-effectiveness, we estimate annual energy savings at 0.6 Quads at current funding levels (Quinn and Reed, 1997). Expanding state programs will achieve higher levels of energy savings in many different industries.

OTHER MANUFACTURING - Moderate Scenario

Economic Trends

Economic trends remain the same as AOE99 under the moderate scenario.

Production and Technology Trends

Production and process share trends remain the same as AEO99 under the moderate scenario. Capital stock retirement rates are the same as those applied in the business-as-usual scenario.

Energy Consumption Trends
Table A-42 provides the moderate scenario inputs for existing and new equipment in 1994 and 2020. The energy efficiency improvement rates, both for existing and new equipment, have been increased by 50% in the moderate scenario, compared to the BAU scenario.

Boiler energy efficiency increases at a rate of 0.2% per year for fossil fuels and 0.1% per year for biomass and waste in this scenario (CIBO, 1997; Einstein et al., 1999). Energy efficiency of industrial buildings in this sector improves at the same rate as that of commercial buildings under the moderate scenario.

Table A-42 Moderate Scenario Inputs for Existing and New Equipment in Other Manufacturing

	Existing Equipment			**New Equipment**		
	1994 UECs	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Fuel	MBtu/$	MBtu/$	%	MBtu/$	MBtu/$	%
Electricity	0.4251	0.4185	-0.0006	0.4038	0.3914	-0.0012
Natural Gas	0.4952	0.4562	-0.00315	0.4704	0.3991	-0.0063
Residual Oil	0.0323	0.0306	-0.0021	0.0307	0.0275	-0.0042
Distillate Oil	0.0097	0.0092	-0.0021	0.0092	0.0082	-0.0042
LPG	0.0152	0.0144	-0.0021	0.0145	0.0130	-0.0042
Steam Coal	0.0336	0.0287	-0.006	0.0319	0.0233	-0.012
Other Petroleum	0	0.0000	-0.0021	0	0.0000	-0.0042
Steam	0.44	0.4166	-0.0021	0.418	0.3747	-0.0042
Biomass-Wood	0.0452	0.0452	0	0.0407	0.0407	0
Electricity	0.6073	0.5979	-0.0006	0.5769	0.5592	-0.0012
Natural Gas	0.8361	0.7703	-0.00315	0.7943	0.6739	-0.0063
Residual Oil	0.0105	0.0099	-0.0021	0.01	0.0090	-0.0042
Distillate Oil	0.014	0.0133	-0.0021	0.0133	0.0119	-0.0042
LPG	0.0324	0.0307	-0.0021	0.0307	0.0275	-0.0042
Steam Coal	0.0068	0.0058	-0.006	0.0065	0.0047	-0.012
Other Petroleum	0	0.0000	-0.0021	0	0.0000	-0.0042
Steam	0.4717	0.4466	-0.0021	0.4481	0.4017	-0.0042
Biomass-Wood	0.1787	0.1787	0	0.1787	0.1787	0
Electricity	1.0307	1.0147	-0.0006	0.9792	0.9491	-0.0012
Natural Gas	1.0069	0.9276	-0.00315	0.9565	0.8116	-0.0063
Residual Oil	0.0503	0.0476	-0.0021	0.0477	0.0428	-0.0042
Distillate Oil	0.0174	0.0165	-0.0021	0.0166	0.0149	-0.0042
LPG	0.2426	0.2297	-0.0021	0.2305	0.2066	-0.0042
Steam Coal	0.0263	0.0225	-0.006	0.025	0.0183	-0.012
Other Petroleum	0	0.0000	-0.0021	0	0.0000	-0.0042
Steam	1.3555	1.2834	-0.0021	1.2877	1.1542	-0.0042
Biomass-Wood	0.4894	0.4894	0	0.4894	0.4894	0
Electricity	0.5362	0.5279	-0.0006	0.5094	0.4937	-0.0012
Natural Gas	0.4911	0.4524	-0.00315	0.4665	0.3958	-0.0063
Residual Oil	0.0634	0.0600	-0.0021	0.0602	0.0540	-0.0042
Distillate Oil	0.0057	0.0054	-0.0021	0.0054	0.0048	-0.0042
LPG	0.0003	0.0003	-0.0021	0.0003	0.0003	-0.0042
Steam Coal	0.0025	0.0021	-0.0060	0.0024	0.0018	-0.0120
Other Petroleum	0	0.0000	-0.0021	0	0.0000	-0.0042
Steam	1.3353	1.2643	-0.0021	1.2685	1.1370	-0.0042
Biomass-Wood	0.7177	0.7177	0	0.7177	0.7177	0

OTHER MANUFACTURING - Advanced Scenario

Economic Trends
Economic trends remain the same as AOE99 under the advanced scenario.

Production and Technology Trends
Production and process share trends remain the same as AEO99 under the advanced scenario. Capital stock retirement rates are the same as those applied in the business-as-usual scenario.

Energy Consumption Trends
Table A-43 provides the advanced scenario inputs for existing and new equipment in 1994 and 2020. The energy efficiency improvement rates, both for existing and new equipment, have been doubled in the advanced scenario, compared to the BAU scenario.

In addition, boiler energy efficiency improves at a rate of 0.2% per year for oil and renewables and 0.3% per year for gas and coal (CIBO, 1997; Einstein et al., 1999). Energy efficiency in buildings in this sector is assumed to improve at the same rate as commercial buildings under the advanced scenario.

Table A-43 Advanced Scenario Inputs for Existing and New Equipment in Other Manufacturing

	Existing Equipment			New Equipment		
	1994 UECs	**2020 UECs**	**TPC**	**1994 UECs**	**2020 UECs**	**TPC**
Fuel	MBtu/$	MBtu/$	%	MBtu/$	MBtu/$	%
Electricity	0.4251	0.4163	-0.0008	0.4038	0.3873	-0.0016
Natural Gas	0.4952	0.4439	-0.0042	0.4704	0.3778	-0.0084
Residual Oil	0.0323	0.0300	-0.0028	0.0307	0.0265	-0.0056
Distillate Oil	0.0097	0.0090	-0.0028	0.0092	0.0080	-0.0056
LPG	0.0152	0.0141	-0.0028	0.0145	0.0125	-0.0056
Steam Coal	0.0336	0.0273	-0.008	0.0319	0.0210	-0.016
Other Petroleum	0	0.0000	-0.0028	0	0.0000	-0.0056
Steam	0.44	0.4091	-0.0028	0.418	0.3612	-0.0056
Biomass-Wood	0.0452	0.0452	0	0.0407	0.0407	0
Electricity	0.6073	0.5948	-0.0008	0.5769	0.5534	-0.0016
Natural Gas	0.8361	0.7494	-0.0042	0.7943	0.6379	-0.0084
Residual Oil	0.0105	0.0098	-0.0028	0.01	0.0086	-0.0056
Distillate Oil	0.014	0.0130	-0.0028	0.0133	0.0115	-0.0056
LPG	0.0324	0.0301	-0.0028	0.0307	0.0265	-0.0056
Steam Coal	0.0068	0.0055	-0.008	0.0065	0.0043	-0.016
Other Petroleum	0	0.0000	-0.0028	0	0.0000	-0.0056
Steam	0.4717	0.4385	-0.0028	0.4481	0.3872	-0.0056
Biomass-Wood	0.1787	0.1787	0	0.1787	0.1787	0
Electricity	1.0307	1.0095	-0.0008	0.9792	0.9393	-0.0016
Natural Gas	1.0069	0.9025	-0.0042	0.9565	0.7681	-0.0084
Residual Oil	0.0503	0.0468	-0.0028	0.0477	0.0412	-0.0056
Distillate Oil	0.0174	0.0162	-0.0028	0.0166	0.0143	-0.0056
LPG	0.2426	0.2255	-0.0028	0.2305	0.1992	-0.0056
Steam Coal	0.0263	0.0213	-0.008	0.025	0.0164	-0.016
Other Petroleum	0	0.0000	-0.0028	0	0.0000	-0.0056
Steam	1.3555	1.2602	-0.0028	1.2877	1.1128	-0.0056
Biomass-Wood	0.4894	0.4894	0	0.4894	0.4894	0
Electricity	0.5362	0.5252	-0.0008	0.5094	0.4886	-0.0016
Natural Gas	0.4911	0.4402	-0.0042	0.4665	0.3746	-0.0084
Residual Oil	0.0634	0.0589	-0.0028	0.0602	0.0520	-0.0056
Distillate Oil	0.0057	0.0053	-0.0028	0.0054	0.0047	-0.0056
LPG	0.0003	0.0003	-0.0028	0.0003	0.0003	-0.0056
Steam Coal	0.0025	0.0020	-0.0080	0.0024	0.0016	-0.0160
Other Petroleum	0	0.0000	-0.0028	0	0.0000	-0.0056
Steam	1.3353	1.2414	-0.0028	1.2685	1.0962	-0.0056
Biomass-Wood	0.7177	0.7177	0	0.7177	0.7177	0

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- Energy Efficiency in Gold Mining (U.S.-93-518)
- Energy-Saving Air Pump (AU-95-505)
- Use of Variable Speed Drives at Wabush Mines (CA-99-514)
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