Energy Consumption Projections for Selected Industries, Annual Energy Outlook 2001

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ABSTRACT

The industrial sector demand module of the National Energy Modeling System (NEMS) is used to project energy consumption for several industries that comprise the industrial sector. This paper provides an analysis of the energy intensive industry-level projections underlying the *Annual Energy Outlook 2001* forecast of industrial energy consumption to 2020. The analysis includes projections for the food, pulp and paper, bulk chemicals, glass, cement, steel, and aluminum industries. The methodology used to project technology improvements that reduce energy intensity is discussed. Key variables discussed in the paper include projections of industry output, energy consumption, and changes in energy intensity.

Introduction

This analysis presents projections of output, delivered energy consumption, and energy intensity for selected manufacturing sectors included in the industrial sector demand module of the National Energy Modeling System (NEMS). The manufacturing sectors covered in this report, and their corresponding Standard Industrial Classifications (SIC) are as follows.[1]

Food and Kindred Products – SIC 20;
Paper and Allied Products – SIC 26;
Bulk Chemicals – SIC 281, 282, 286, 287;
Glass – SIC 3211, 3221, 3229;
Cement – SIC 324;
Steel – includes SIC 331 (which is the same as SIC 3312);
Aluminum – includes primary aluminum, SIC 3334, and sheet, plate, and foil, SIC 3353.

These seven industries are isolated within the industrial module of NEMS because they consume large quantities of energy, they have high energy intensities, or both.

[1] The recently completed Manufacturing Consumption of Energy 1998 (MECS98) survey collected data based on the North American Industry Classification System (NAICS). However, the Manufacturing Consumption of Energy 1994 (MECS94, EIA 1997) data used to derive the base year Unit Energy Consumption (UEC) values in the AEO2001 projections were based on SIC designations. Therefore, all industry classifications included in this paper are based on the SICs.

Methodology and Data

The reference case projections in this analysis are based on model runs of the National Energy Modeling System from the *Annual Energy Outlook 2001* (AEO 2001, EIA 2000c). The projection methodology for the NEMS industrial model is documented in (EIA 2000d). The NEMS modeling system is summarized in (EIA 2000a).

The aggregate industrial energy consumption forecast contained in the AEO 2001 is similar to the routine forecasts by DRI, GRI, and WEFA.. Projected growth of industrial energy demand ranges from1.0 percent to 1.4 percent across the four forecasts, with the *Annual Energy Outlook*'s in the middle at 1.2 percent per year (EIA 2000c).

Industrial Module Description

The NEMS industrial model uses "technology bundles" to characterize technical change in the energy-intensive industries. These bundles are defined for each production process step for five of the industries and for each end use in two of the industries. The process step industries are paper, glass, cement, steel, and aluminum. The end-use industries are food and bulk chemicals.

Specific technologies are not characterized by cost and performance, but the evaluation of the likely intensity change for a process step incorporates expectations about specific technologies. Overall energy intensities for discrete production process steps are used. The industrial model incorporates data from Arthur D. Little about projected trends in energy intensity for process steps or end uses in the energy-intensive industries.[2]

Energy intensity is measured as the unit energy consumption (UEC), defined as the energy use per ton of throughput at a process step or as energy use per dollar of output for the end-use industries. For each industry, three Relative Energy Intensity ratios (REI) were developed based on engineering analysis of likely trends in technology availability and adoption (Appendix Table 1). The REI 2020 for old facilities is the ratio of 2020 energy intensity to 1994 energy intensity for existing facilities. The REI 1994 for new facilities is the ratio of the energy intensity of new state-of-the-art facilities in 1994 to the average existing energy intensity in 1994. Similarly, the REI 2020 for new facilities is the energy intensity of new state-of-the-art facilities in 2020 relative to the average existing 1994 intensity. The REIs capture the technological trends that result in decreased energy intensity over time, independent of other economic factors, such as energy prices. If energy prices increase substantially, the energy intensity of added capacity can approach the REI 2020 for new industries several years prior to 2020. In the model, the REI for intervening years is extrapolated using the Technology Possibility Curve (TPC), which is a linear extrapolation from 1994 to 2020.

[2]These data are revised after the publication of each *Manufacturing Consumption of Energy* report. These data have been evaluated in two multi-laboratory studies: Interlaboratory Working Group 1997 and 2000.

Significance of Selected Industries

The seven industries covered in this report accounted for more than 64 percent of manufacturing energy consumption in 1994. The share ranges from 1 percent (197 trillion Btu) for the glass industry to 32 percent (6,244 trillion Btu) for the bulk chemicals industry (Appendix Table 2). At the same time, these industries accounted for only 26 percent ($852 billion) of total manufacturing output in 1994.[3] Typically, these industries' outputs are quite small compared with all of manufacturing. Cement is the smallest, $4.2 billion, with a 0.1 percent share, while food is the largest, $423.7 billion, with 13.1 percent of manufacturing output (Appendix Table 2).

Results

Energy and output projections for seven industries are presented in this section. Food, paper products, bulk chemicals, glass, cement, steel, and aluminum are discussed. Appendix Table 2 summarizes the economic output, industrial sector energy price, energy consumption, and energy intensity projections for these seven industries.

Economic Output and Energy Price Assumptions

The average intensity decline rate for each industry is determined by the REIs and by the rate and timing of new additions to capacity. The rate and timing of new additions are a function of baseline equipment retirement rates and industry growth rates. Retirement rates are estimated for the base year and held constant in the absence of energy price increases. If energy prices increase by more than 10 percent, retirement rates are increased from their baseline levels to as much as double the base year rates.

Manufacturing output growth has historically not kept pace with overall economic growth, as measured by the Gross Domestic Product (GDP). Between 1978 and 1999, manufacturing growth averaged 1.7 percent per year, while GDP growth averaged 3.0 percent per year. Furthermore, within the manufacturing sector, the industries discussed in this paper have generally grown more slowly than the manufacturing average (Figure 1). Food and paper were the only sectors to match or exceed growth for the manufacturing sector as a whole between 1978 and 1999.

The economic projections included in the AEO 2001 continue these trends. GDP growth is projected to be higher than the average for the manufacturing sector, and the individual growth rates for the industries discussed in this paper lag behind the manufacturing average (Figure 1 and Appendix Table 2). Over the 1999-2020 period, the projected growth for the fastest growing energy intensive industry (paper products) is about half the projected growth rate for manufacturing as a whole.

Industrial energy price projections from the AEO 2001 are also included in Appendix Table 2. Between 1999 and 2020, natural gas and petroleum prices are projected to increase, while electricity and steam coal prices are projected to decrease.

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[3]The value of output used in the NEMS industrial model is in constant 1992 dollars.

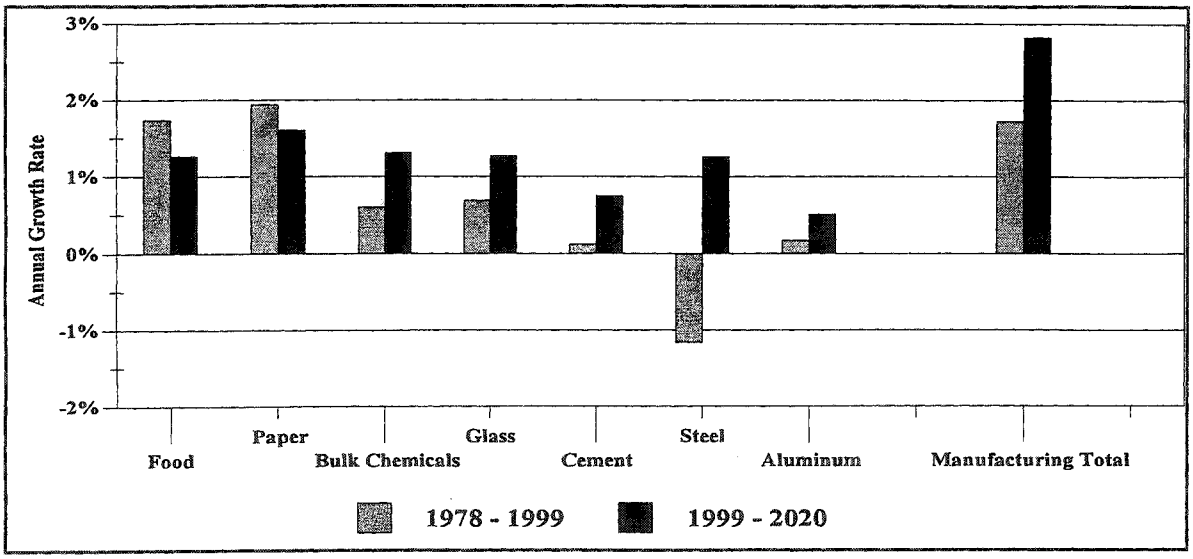

Figure 1. Output Growth for Selected Manufacturing Industries, History and Projections

Food Industry

The food industry consists of SIC code 20. In NEMS, the food industry is modeled as an end-use industry due to the wide array of physical products. The end uses are refrigeration, hot water/steam, direct heat requirements, and other electric requirements (primarily motors). The REIs for the end uses are presented in Appendix Table 1.

The food industry's gross value of output grew 1.7 percent annually over the 1978-1999 period to $465.2 billion in 1999. Over the 1999-2020 period, output is projected to grow 1.3 percent per year to $605.2 billion in 2020.

During 1991-1994, energy consumption increased 7.6 percent annually to 1.2 quadrillion Btu in 1994 (Appendix Table 2). Energy intensity increased by 4.9 percent annually during that period. However, energy intensity is projected to fall 0.4 percent annually in the forecast period. Together with the output forecast, this yields projected energy consumption of 1.4 quadrillion Btu in 2020.

Paper Industry

The paper industry consists of SIC 26. The pulp and paper industry produces pulp and a variety of paper products using fibers from timber or from recycled paper products. The pulp and paper industry is very energy intensive. However, it meets a large share of its energy demand by recovery and consumption of waste pulping fibers and wood waste. The production steps are wood preparation, waste pulping, mechanical pulping, semi-chemical pulping, kraft (sulfite) pulping, bleaching, and paper making (Appendix Table 1).

The paper industry's value of gross output grew 1.9 percent annually from 1978 to 1999. In the forecast period of 1999 to 2020, gross output is projected to grow 1.6 percent annually. The U.S. industry is relatively mature and will face increasing competition for foreign markets which reduces the projected industry growth rate.

The paper industry's energy intensity fell 0.8 percent per year between 1991 and 1994. Over the 1999-2020 period, energy consumption is projected to increase 1.0 percent per year, reaching 3.3 quadrillion Btu in 2020. Growth in energy consumption is dampened by increased waste pulping and a rapid fall in energy intensity for kraft pulping and papermaking as can be seen by their REIs in Appendix Table 1. Consequently, the paper industry's energy intensity is projected to decline by 0.6 percent per year between 1999 and 2020.

Typically, the largest improvement in energy intensity occurs when existing facilities are replaced rather than from future improvements in energy intensity. For example, a new state-of-the-art wood preparation facility in 1994 was 84 percent as energy intensive as the average existing wood preparation plant (Appendix Table 1). By 2020, a new state-of-the-art wood preparation facility would be 83 percent as energy intensive as the average existing wood preparation plant in 1994.

The pulp and paper industry uses large quantities of renewable energy which are byproducts of the wood preparation and the virgin pulping processes. Biomass is projected to increase 1.6 percent annually, reaching 2.0 quadrillion Btu in 2020. The current forecast does not include commercialization of pulping liquor gasification plants for electricity generation. If successful, these plants could increase electricity self-generation substantially.

Bulk Chemicals Industry

The bulk chemicals industry consists of SIC codes 281 (industrial inorganic chemicals), 282 (plastics and synthetics), 286 (industrial organic chemicals), and 287 (agricultural chemicals). This definition excludes pharmaceuticals, cosmetics and the like. In NEMS, the bulk chemicals industry is modeled as an end-use industry due to the wide array of physical products. The end uses are electrolytic, steam, direct heat requirements, and other electric requirements (primarily motors). The REIs for the end uses are presented in Appendix Table 1.

The bulk chemicals industry's gross value of output grew 0.6 percent annually over the 1978-1999 period to $177.4 billion in 1999. The industry's growth rate over that period was dampened by its relatively slow recovery from the economic recession of 1991. Over the 1999-2020 period, output is projected to grow 1.3 percent per year to $233.4 billion in 2020.

During 1991-1994,[4] energy consumption increased 1.8 percent annually to 6.2 quadrillion Btu in 1994 (Appendix Table 2). Energy intensity fell slightly during that period. Energy intensity is projected to fall more rapidly, 0.3 percent annually, in the forecast period. Together with the output forecast, this yields projected energy consumption of 8.1 quadrillion Btu in 2020.

Over half the energy used in the bulk chemicals industry is for feedstock purposes. The current projection does not include significant opportunities to reduce feedstock requirements because feedstock input demands are based on molecule requirements not the caloric value of the input. Future developments could lead to increased use of bioengineered feedstocks to replace hyrodcarbon feedstocks.

[4]The growth rate is based on consumption adjusted for inter-establishment shipments.

Glass Industry

The glass industry consists of SIC codes 3211, 3221, and 3229. This definition includes flat glass, containers, and pressed or blown glass. The industry uses energy primarily in melting furnaces. The production steps are batch preparation, melting/refining, forming, and post-forming (Appendix Table 1). (Use of recycled glass has a lower energy intensity but the relative energy intensities are assumed to be the same as for virgin glass.)

Glass industry output grew 0.7 percent annually over 1978-1999. Future growth of the industry is projected to be somewhat faster, 1.3 percent per year, over the 1999-2020 period.

Glass industry energy consumption grew from 183 trillion Btu in 1991 to 197 trillion Btu in 1994.[5] Over the forecast period 1999-2020, glass industry energy consumption is projected to increase by 0.4 percent annually, reaching 217 trillion Btu in 2020.

Glass industry energy intensity fell 2.1 percent annually over the 1991-1994 period. The rate of decline over the forecast is projected to be 0.9 percent. This result is due primarily to projected improvements in energy intensity for the melting/refining process.

Cement Industry

The NEMS cement industry consists of SIC code 324. The production steps for the cement industry are the dry process, wet process, and finish grinding.

Although tiny in terms of its share of manufacturing gross output (0.1 percent in 1994), the cement industry is important from an energy perspective because of its tremendous intensity. From 1978 to 1991, the cement industry's value of output increased 0.1 percent annually to reach $5.2 billion. Over the 1999-2020 period, cement industry value of output is projected to grow 0.8 percent per year.

Cement industry energy consumption decreased 0.2 percent per year from 1991 to 1994, yielding a 3.9 percent annual fall in energy intensity. The rapid output growth was due to the industry's rapid recovery from the 1991 recession.

Cement industry energy intensity is projected to fall 0.8 percent per year over the 1999-2020 period. It is assumed that all new capacity utilizes the dry process which has a much lower REI than existing capacity. Over the 1999-2020 period, energy consumption is projected to decrease by 0.1 percent per year.

Steel Industry

The NEMS steel industry consists of SIC code 331. This definition includes blast furnaces and steel mills, including coking facilities. The production steps for the steel industry are coke oven, blast furnace with basic oxygen furnace, electric arc furnace, ingot casting, continuous casting, hot rolling, and cold rolling (Appendix Table 1). No new ingot casting is projected.

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[5]Energy consumption for SIC 3229, Pressed and Blown Glass was not published in 1991. Consumption was estimated assuming that the energy intensity of SIC 3229 was the same in 1991 as it was in 1994. This procedure could underestimate the intensity decline rate from 1991 to 1994.

From 1978 to 1999, the steel industry's value of output decreased 1.2 percent annually to reach $67.8 billion. Over the 1999-2020 period, steel industry value of output is projected to grow 1.3 percent per year.

Steel industry energy consumption increased 4.9 percent per year from 1991 to 1994.[6] Over that period, industry output increased 7.1 percent annually, which yields a 2.1 percent annual fall in energy intensity. The rapid output growth was due to the industry's rapid recovery from the 1991 recession.

Steel industry energy intensity is projected to fall 1.3 percent per year over the 1999-2020 period. Increased use of electric arc furnaces and near-net-shape casting developments are primary drivers for the projected fall in energy intensity. However, electricity intensity increases because of the greater use of electric arc furnaces. Over the 1999-2020 period, total delivered energy consumption is projected to decrease by 0.1 percent per year, while electricity consumption is projected to increase by 1.1 percent annually.

The REIs for the steel industry process steps are given in Appendix Table 1. The hot and cold rolling steps have low REI 2020 due to a combination of lower intensity and reduced rolling requirements resulting from the growth of near-net-shape casting. For NEMS forecasting purposes, no coke ovens are assumed to be added to replace the retiring ovens. While increased electric arc furnace capacity reduces coke requirements, coke imports are projected to increase over the forecast period.

Aluminum Industry

The aluminum industry consists of SIC codes 3334 and 3353. This definition includes primary aluminum and establishments producing aluminum plate, sheet, and foil. The production steps are primary aluminum (smelting) and semi-fabrication.

The aluminum industry's output grew 0.2 percent annually from 1978 to 1999, reaching $36.0 billion in 1999. Over the 1999-2020 period, output is projected to grow 0.5 percent annually.

Energy consumption fell from 354 trillion Btu in 1991 to 314 trillion Btu in 1994. This was attributable to the sharp fall in U.S. production of primary aluminum, which is the most energy intensive part of the aluminum industry. Energy consumption is projected to increase slightly over the forecast period, reaching 391 trillion Btu in 2020. The retirement of existing facilities and some growth in recycling, which reduces primary smelting, result in a projected intensity decline of 0.7 percent per year. Energy and production cost savings in primary smelting could be achieved with further development of inert anodes and wettable cathodes.

Summary

The projected output growth rates over the 1999-2020 period for the selected industries discussed in this paper are less than the 2.8 percent growth rate for manufacturing as a whole (Appendix Table 3). In fact, only the paper industry grows at even half the aggregate growth rate for the economy. The cumulative energy intensity decline for the selected industries varies,

[6]The growth rate is based on consumption adjusted for inter-establishment shipments.

depending on the particulars of each industry (Figure 2). The bulk chemicals industry is projected to have the smallest improvement, with cumulative energy intensity declining by only 5.7 percent between 1999 and 2020, because there is little ability to reduce feedstock intensity. The steel industry is projected to have the largest improvement, with cumulative energy intensity falling by 24.2 percent between 1999 and 2020 in part because electric arc furnaces, which have a lower energy intensity, are favored over basic oxygen furnaces.

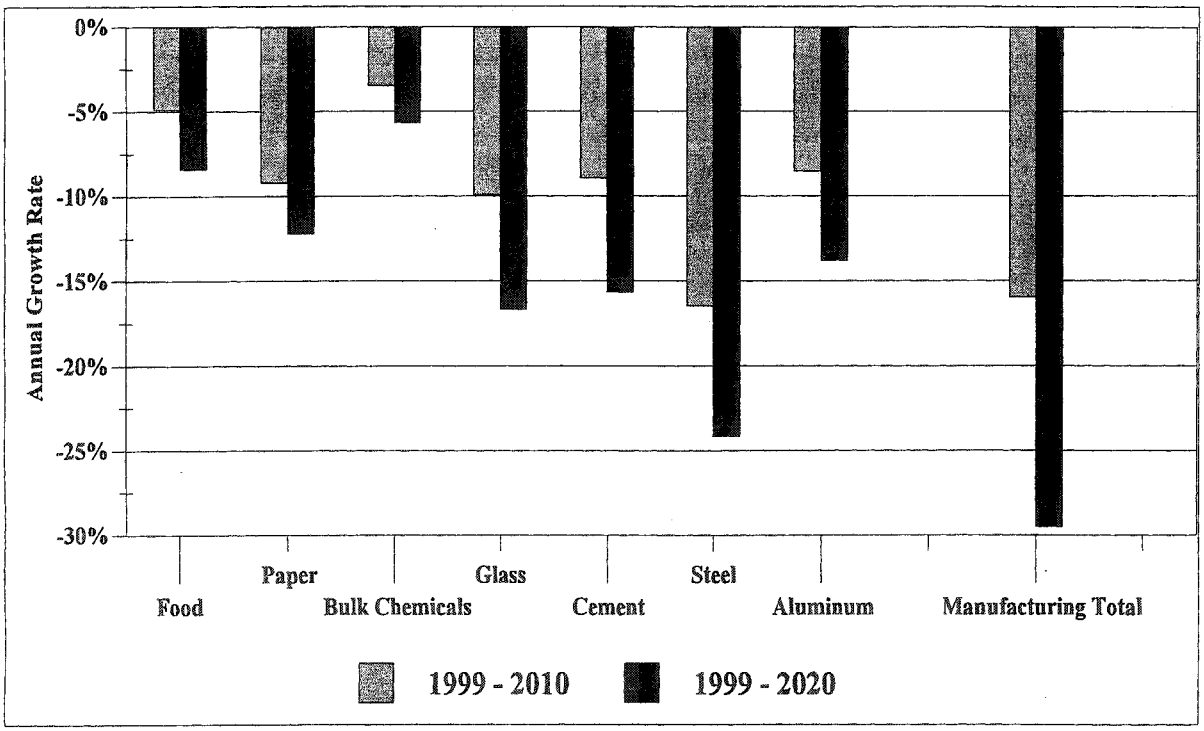

Figure 2. Projected Cumulative Change in Energy Intensity

Overall, the energy consumption forecasts of the NEMS industrial module may be optimistic in terms of energy intensity changes, given the low projected output growth rates of the energy-intensive industries and relatively small changes in projected energy prices. Total manufacturing energy intensity fell 1.6 percent per year from 1991 to 1994. In the AEO 2001, manufacturing energy intensity is projected to fall 1.7 percent per year.

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Appendix

Table 1. Coefficients for Technology Possibility Curves

Industry Process Unit	Old Facilities		New Facilities			Retirement Rate
	REI 2020	TPC[a]	REI 1994	REI 2020	TPC[a]	
Food						
Direct Fuel	0.897	-0.004	0.90	0.80	-0.004	1.7
Hot Water/Steam	0.922	-0.003	0.90	0.80	-0.004	1.7
Refrigeration	0.947	-0.002	0.90	0.80	-0.004	1.7
Other Electric	0.947	-0.002	0.90	0.80	-0.004	1.7
Pulp & Paper						
Wood Preparation	0.950	-0.003	0.840	0.831	-0.0004	2.3
Waste Pulping	0.974	-0.001	0.930	0.885	-0.002	2.3
Mechanical Pulping	0.944	-0.003	0.840	0.822	-0.0009	2.3
Semi-Chemical Pulping	0.894	-0.006	0.730	0.697	-0.002	2.3
Kraft (Sulfite) Pulping	0.903	-0.005	0.730	0.600	-0.008	2.3
Bleaching	0.910	-0.005	0.750	0.683	-0.004	2.3
Paper Making	0.910	-0.005	0.750	0.560	-0.012	2.3
Bulk Chemicals						
Direct Fuel	0.897	-0.004	0.90	0.80	-0.004	1.9
Hot Water/Steam	0.922	-0.003	0.90	0.80	-0.004	1.9
Electrolytic	0.980	-0.0008	0.90	0.80	-0.004	1.9
Other Electric	0.947	-0.002	0.90	0.80	-0.004	1.9
Glass[b]						
Batch Preparation	0.957	-0.002	0.882	0.882	0	1.3
Melting/Refining	0.892	-0.006	0.850	0.448	-0.027	1.3
Forming	0.952	-0.003	0.818	0.744	-0.004	1.3
Post Forming	0.921	-0.004	0.780	0.760	-0.001	1.3
Cement						
Dry Process	0.982	-0.0009	0.790	0.657	-0.008	1.2
Wet Process[c]	0.954	-0.002	NA	NA	NA	1.2
Finish Grinding	0.943	-0.003	0.813	0.641	-0.010	1.2
Steel						
Coke Oven[c]	1.00	0	0.840	0.817	-0.001	1.5
BF/Basic Oxygen	1.00	0	1.00	0.982	-0.0008	1.0
Electric Arc Furnace	1.00	0	0.960	0.960	0	1.5
Ingot Casting[c]	1.00	0	NA	NA	NA	2.9
Continuous Casting	1.00	0	1.00	1.00	0	2.9
Hot Rolling	0.698	-0.019	0.500	0.401	-0.009	2.9
Cold Rolling	0.877	-0.007	0.840	0.488	-0.023	2.9
Aluminum						
Primary Aluminum	0.936	-0.003	0.910	0.812	-0.005	2.1
Semi-Fabrication	0.855	-0.008	0.610	0.506	-0.008	2.1

[a]TPC is the annual rate of change between 1994 and 2020.
[b]REIs apply to both virgin and recycled materials.
[c]No new plants are likely to be built that use these technologies.
Source: EIA 2000d

Table 2. Economic Output, Energy Prices, Energy Consumption, and Energy Intensity , 1991 - 2020

	1991	1994	1999	2010	2020	Annual Growth 1999 - 2020
Real GDP (billion 96$)	6,676	7,348	8,876	12,667	16,515	3.0%
Industry Output (billion 92$)						
Food and Kindred Products	392.8	423.7	465.2	531.1	605.2	1.3%
Paper and Paper Products	126.7	137.3	150.5	186.1	210.3	1.6%
Bulk Chemicals	158.7	167.6	177.4	207.6	233.4	1.3%
Glass	16.6	19.1	20.9	24.2	27.2	1.3%
Cement	3.8	4.2	5.2	5.6	6.0	0.8%
Steel	55.2	67.9	67.8	81.4	88.3	1.3%
Aluminum	29.4	32.3	36.0	38.4	40.1	0.5%
Manufacturing Total	2,835	3,239	3,749	5,089	6,726	2.8%
Industrial Energy Prices (99$ / million Btu)						
Petroleum	5.65	4.95	5.55	6.05	6.27	0.6%
Natural Gas	2.67	2.79	2.79	3.31	3.76	1.4%
Steam Coal	1.42	1.43	1.43	1.29	1.21	-0.8%
Electricity	13.34	14.23	13.09	11.24	11.62	-0.6%
Energy Consumption (trillion Btu)						
Food and Kindred Products	959	1,193	1,180	1,281	1,405	0.8%
Paper and Paper Products	2,507	2,665	2,704	3,036	3,319	1.0%
Bulk Chemicals	5,918	6,244	6,568	7,416	8,149	1.0%
Glass	183	197	199	209	217	0.4%
Cement	329	327	402	394	396	-0.1%
Steel	1,408	1,623	1,589	1,594	1,568	-0.1%
Aluminum	354	314	408	398	391	-0.2%
Manufacturing Total	18,390	19,607	20,309	23,168	25,680	1.1%
Consumption per Unit of Output (thousand Btu/92$ output)						
Food and Kindred Products	2.44	2.82	2.54	2.41	2.32	-0.4%
Paper and Paper Products	19.79	19.42	17.97	16.32	15.78	-0.6%
Bulk Chemicals	37.29	37.25	37.01	35.73	34.91	-0.3%
Glass	10.99	10.30	9.56	8.61	7.96	-0.9%
Cement	86.87	77.14	77.91	70.94	65.71	-0.8%
Steel	25.53	23.90	23.44	19.58	17.77	-1.3%
Aluminum	12.05	9.73	11.33	10.36	9.77	-0.7%
Manufacturing Total	6.49	6.05	5.42	4.55	3.82	-1.7%

Table 3. Average Energy Intensity and Gross Output Change, 1999 - 2020

Manufacturing Sector	Energy Intensity	Fuel Intensity	Purchased Electricity Intensity	Gross Output
Energy Intensive Average	-0.5%	-0.5%	-0.9%	1.3%
Steel	-1.3%	-1.4%	-0.2%	1.3%
Glass	-0.9%	-0.9%	-0.6%	1.3%
Cement	-0.8%	-0.8%	-0.5%	0.8%
Aluminum	-0.7%	-0.7%	-0.7%	0.5%
Paper and Paper Products	-0.6%	-0.6%	-1.0%	1.6%
Food and Kindred Products	-0.4%	-0.3%	-0.9%	1.3%
Bulk Chemicals	-0.3%	-0.3%	-1.0%	1.3%
Manufacturing Total Average	-1.7%	-1.7%	-1.3%	2.8%