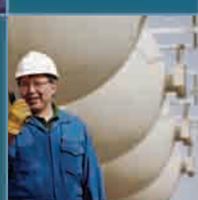
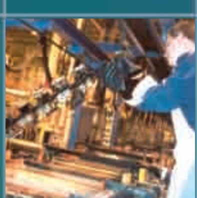
Energy Trends in Selected Manufacturing Sectors:

Opportunities and Challenges for Environmentally Preferable Energy Outcomes







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Appendix A: Energy Projections

To develop the “base case” and “best case” future energy consumption scenarios for each sector as described in Chapter 3, we relied primarily upon projections produced by three analyses:

- ***Scenarios for a Clean Energy Future* (CEF).** Commissioned by the U.S. Department of Energy (DOE) in 2000, this report was produced by the Interlaboratory Working Group for Energy-Efficient and Clean Energy Technologies. For 8 of the 12 industrial manufacturing sectors considered in this analysis, the CEF report projects future industrial energy consumption trends based on three alternative technology and policy-based scenarios.[324] In Chapter 3, the CEF analysis forms the basis for our “base case” and “best case” future energy scenarios for many of the sectors addressed in this report.[325]
- ***Annual Energy Outlook 2006* (AEO 2006).** AEO 2006 is the most recent annual forecast of energy demand, supply, and prices for the United States produced by DOE’s Energy Information Administration (EIA). AEO 2006 includes energy consumption and carbon emissions projections for U.S. industrial manufacturing as well as for eight of the twelve sectors considered in this analysis.[326] As the CEF report was produced in 2000, we used AEO 2006 to assess the impact of recent energy trends, and how those trends might be expected to produce different outcomes than projected by CEF in 2000. AEO 2006 also provided estimated annual carbon dioxide emissions for many of the sectors addressed in this analysis.
- ***Natural Gas Outlook to 2020.*** This analysis was produced by the American Gas Foundation (AGF) and develops natural gas consumption projections under three alternative public policy scenarios regarding natural gas exploration and production. Projections include consumption trends for certain industrial sectors that are heavily dependent on natural gas.[327]

In the following sections we provide a brief overview of the approaches taken by these studies, and discuss how they were used in our analysis. For CEF and AEO 2006, we highlight key similarities and differences between the projections and discuss general implications for future industrial energy consumption trends.

A.1. Clean Energy Future Scenarios

Overview

To develop CEF projections, the Interlaboratory Working Group used a modified version of the National Energy Modeling System (NEMS) developed and maintained by EIA to produce its *Annual Energy Outlook* projections. (The NEMS version used in connection with the CEF analysis was the version used to produce the 1999 *Annual Energy Outlook* (AEO 1999)).

For the reference case scenario, modifications to the NEMS industrial demand module were made in the following areas: (1) for all industrial sectors, equipment retirement rates were changed to reflect actual lifetimes of installed equipment and (2) for the paper, cement, steel, and aluminum industries, more detailed modifications were made to baseline energy intensities and rates of energy intensity improvement to reflect best available research from those sectors. As a result, the CEF reference scenario projects industrial energy consumption to be 3 percent lower by 2020 than the projection made by AEO 1999.

CEF developed moderate and advanced energy scenarios that are primarily based on voluntary commitments by industry to energy efficiency improvement. Our analysis focused on the advanced scenario, which promotes more aggressive energy efficiency improvement through a combination of (1) expanded voluntary federal programs such as the Combined Heat and Power (CHP) Challenge and ENERGY STAR; (2) expanded federal informational programs such as energy assessments and equipment labeling; (3) expanded investment enabling programs such as state grant programs, utility incentive programs, and tax rebates and credits; (4) mandatory efficiency standards for motors; (5) expanded federal demonstration and research and development (R&D) programs; and (6) a domestic carbon emissions trading program.

Table 58 compares the CEF reference case and advanced case projections for industrial energy consumption.

Table 58: Comparison of CEF industrial energy consumption projections through 2020: reference case and advanced case[328]

	Reference Case	Advanced Case
Base year energy consumption[qqqq] (1997)	27.0 quadrillion Btu	27.0 quadrillion Btu
Energy consumption in 2020[rrrr]	32.7 quadrillion Btu	27.8 quadrillion Btu
Annual energy consumption growth[ssss]	0.8% per year	0.1% per year
Annual energy intensity growth	-1.1% per year	-1.9% per year
Annual CHP capacity growth	No data available	No data available

qqqq Given the age of the CEF study and that current industrial energy consumption as reported in AEO 2006 is lower than the CEF base year, we put relatively little emphasis on CEF consumption data and greater emphasis on projected rates of consumption growth/decline, as well as relative changes in the fraction of various fuel inputs.

rrrr Energy consumption projections are in terms of site or delivered energy, though CEF also provides primary energy projections.

ssss All rate calculations are the calculated average growth rate.

	Reference Case	Advanced Case
Annual fuel consumption growth		
Petroleum	0.9%	0.0%
Natural gas	0.8%	0.3%
Coal	0.0%	-1.5%
Purchased electricity	1.1%	0.0%
Renewable	1.4%	1.7%
Total value of shipments in 2020 (billion 2000 dollars)	8,378	8,378

Advanced Energy Scenario

As discussed at the beginning of this section, the parameters that drive CEF's advanced energy projections include a broad range of policy pathways for improving environmental outcomes with respect to energy use, including a cap-and-trade system for greenhouse gas (GHG) emissions. Table 59 presents an abbreviated version of a table that appears in the CEF study showing how various advanced energy policies affected different NEMS model parameters for the industrial manufacturing sectors included in the CEF analysis. The policies appear in the header rows, and the affected parameters are listed by number, with a key below.

Table 59: Qualitative representation of advanced energy policy impacts on CEF-NEMS model[329]

	Technology Demonstration Programs	Energy Assessment Programs	Challenge Programs - Motor and Air	Challenge Programs - Steam	Challenge Programs - CHP	ENERGY STAR Buildings and Green Lights	Product Labels	State Programs	Clean Air Act Incentive Programs
Alumina and Aluminum	1,2,8	1	1,2,8	3,6,9	6,9	5	n/a	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
Chemical Manufacturing	1,2,8	1	1,2,8	3,6,9	6,9	5	n/a	1,2,3,5	1,2,3,6,7,9
Food Manufacturing	1,2,8	1	1,2,8	3,6,9	6,9	5	n/a	1,2,3,5	1,2,3,6,9
Iron and Steel	1,2,7,8	1,7	1,2,7,8	3,6,9	6,9	5	n/a	1,2,3,5	1,2,3,6,7,9
Metals-Based Durables[tttt]	1,2,8	1	1,2,8	3,6,9	6,9	5	n/a	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
Pulp and 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

tttt Section 3.8 includes a more detailed description of how CEF's definition of the "metals-based durables" sector matches with the metal finishing sector as defined in this analysis.

	R&D - Industries of the Future	Other R&D	ESCO / Utility Programs	Climate Wise Program	Pollution Prevention	Tax Incentives for Energy Managers	Tax Rebates for Specific Industrial Techs	Investment Tax Credit for CHP Systems	Carbon Trading System
Alumina and Aluminum	2	2,3,6	n/a	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	n/a	1,5,7	2	6,9	1-9
Chemical Manufacturing	2	2,3,6	1,5,6,9	1,2,8	n/a	1,5	2	6,9	1-6,8,9
Food Manufacturing	n/a	2,3,6	1,5,6,9	1,2,8	n/a	1,5	2	6,9	1-6,8,9
Iron and Steel	2	2,3,6	1,5,6,7,9	1,2,7,8	4	1,5,7	2	6,9	1-9
Metals-Based Durables	2	2,3,6	1,5,6,9	1,2,8	n/a	1,5	2	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
Pulp and Paper	2	2,3,6	1,5,6,7,9	1,2,7,8	4	1,5,7	2	6,9	1-9

Modeled within NEMS	Modeled outside NEMS, then used to adjust NEMS parameters
1: Increased annual rate of efficiency improvement in existing equipment	7: Increased annual rate of efficiency improvement in existing equipment (iron & steel, cement, and pulp & paper)
2: Increased annual rate of efficiency improvement in new equipment	8: Increased annual rate of efficiency improvement in existing equipment (motor electricity use)
3: Increased boiler efficiency	9: Increased use of cogeneration (DISPERSE modeling of CHP-policies)
4: Increased use of recycled materials (throughput changes)	
5: Improved building energy efficiency	
6: Increased use of cogeneration (within NEMS)	

Given that the CEF study (produced in 2000) predates recent price increases for natural gas, we vetted CEF base case projections against projections developed by AGF in its report, *Natural Gas Outlook to 2020*.[330] This study develops natural gas consumption projections under three alternative public policy scenarios regarding natural gas exploration and production, including consumption projections for certain industrial sectors that are heavily dependent on natural gas such as chemicals, petroleum refining, pulp and paper, and food manufacturing. These projections were developed by Energy & Environmental Analytics using a proprietary gas market data and forecasting model. We focused on the "expected" policy scenario for industrial demand as the closest approximation of a business-as-usual scenario (the "existing" and "expanded" scenarios, which respectively involve lesser and greater degrees of natural gas exploration and infrastructure development than is currently planned, were less useful for our analysis). Where appropriate, references to differences and similarities between the CEF and AGF projections for natural gas consumption are made in the sector summaries contained in Chapter 3.

A.2. Annual Energy Outlook Scenarios

Overview

Each year EIA uses NEMS to develop its long-term forecasts of energy supply, demand, and prices called the *Annual Energy Outlook*. Energy consumption projections for specific industrial manufacturing sectors are included as a supplement to the main report. The sector-specific projections that are applicable to this analysis include the following: aluminum, bulk chemicals (the commodity chemicals subset of chemical manufacturing), cement, fabricated metal products (which includes metal finishing), food manufacturing, iron and steel, petroleum refining, and pulp and paper (part of forest products). AEO 2006 also includes projected carbon dioxide (CO_2) emissions for these sectors, which EIA calculated based on fuel consumption projections using CO_2 coefficients from the EIA report, *Emissions of Greenhouse Gases in the United States 2004*.[331]

Our review of AEO 2006 began with comparing reference case projections for industrial manufacturing as a whole with projections under the high industrial technology case, which were examined as the EIA's closest approximation of a "best case" scenario for industrial energy consumption. Reference case projections are based on growth in gross domestic product (GDP) of 3 percent per year (based on 2000 chain-weighted dollars), population growth of about 0.8 percent per year, and oil prices of $55.93 in 2005 rising to $56.97/barrel by 2030 (all oil prices are in 2004 dollars). The industrial high technology case "assumes earlier introduction, lower costs, and higher efficiencies for energy technologies."[332]

Table 60 compares AEO 2006 reference case and high industrial technology case projections. Though AEO 2006 projections are made through 2030, we only include projection data through 2020 to facilitate comparison with the CEF analysis.

Table 60: Comparison of AEO 2006 industrial energy consumption projections through 2020: reference case and high technology case[333]

	Reference Case	High Technology Case
Base year energy consumption (2004)	25.68 quadrillion Btu	25.68 quadrillion Btu
Energy consumption in 2020[uuuu]	28.91 quadrillion Btu	27.48 quadrillion Btu
Annual energy consumption growth[vvvv]	0.7% per year	0.4%
Annual energy intensity growth[wwww]	-1.3%	-1.7%
Annual CHP capacity growth[xxxx]	2.6%	3.0%
Annual fuel consumption growth		
Petroleum	0.7%	0.2%
Natural gas	0.7%	0.4%
Coal	1.0%	0.6%
Purchased electricity	0.7%	0.2%
Renewable	1.1%	1.6%
Total value of shipments in 2020 (billion 2000 dollars)	7,778	7,778

uuuu Energy consumption projections are site or delivered energy, though AEO 2006 also provides primary energy projections.

vvvv All rate calculations are the calculated average growth rate.

wwww Energy intensity is measured as total energy consumption (TBtu) per dollar value of shipments (in 2000 dollars).

xxxx Industrial CHP capacity is measured in gigawatts.

Compared with the reference case, the AEO 2006 high technology case projects that faster adoption of new technologies will produce greater energy efficiency gains, particularly in manufacturing industries. To some degree, the high technology case envisions expanded energy production capacity through additional CHP and biomass recovery capacity, but overall efficiency improvements in energy production and process energy use means that the high technology case projects lower energy consumption by 2020 compared with the reference case.

Under the reference case, EIA predicts that energy intensity will decrease at a higher rate in the manufacturing sector (1.2 percent a year) than in the non-manufacturing sector (1.0 percent a year). EIA attributes this difference to a continuing shift within U.S. manufacturing where the value of shipments by non-energy-intensive sectors increases from 54 percent in 2004 to 61 percent in 2030, and the value of shipments by energy-intensive sectors declines from 21 percent in 2004 to 17 percent in 2030. The rate of energy intensity decrease is even greater under the high technology case due to efficiency gains, but the high technology case does not involve a faster macroeconomic shift from energy-intensive to non-energy-intensive manufacturing.

Under the reference case, industrial fuel consumption increases across all fuel types. The relatively higher rate of increase in coal consumption (compared with other fuels) is not strictly driven by energy-related end uses, as industrial coal consumption for traditional energy-related applications is fairly static. However, EIA assumes that expansion of coal-to-liquids (CTL) production in the petroleum refining industry will be associated with considerable cogeneration capacity additions through integrated gasification combined cycle (IGCC) technologies (see Section 3.11). IGCC technologies combust gasified coal in a modified gas turbine and recover exhaust heat to generate steam.

Aside from industrial energy consumption and intensity trends, another important factor affecting future environmental impacts of industrial energy use is the trend in fuel inputs for electric power generation. The AEO 2006 reference case projects that purchased electricity will meet 13.5 percent of industrial demand by 2020 (roughly the same fraction as in 2004). Through 2030, AEO 2006 projects that the majority of new electric generation capacity will be supplied by coal-fired plants, which are more expensive to build but much cheaper to operate than natural gas-fired plants that tend to be used primarily to meet peak demand. The Southeast and the West are expected to see the greatest additions of coal-fired electric generating capacity. The majority of power plants retired over the period are expected to be oil- and natural gas-fired steam capacity. By 2030, AEO 2006 projects that coal-fired plants will meet 57 percent of the nation's electricity demand, compared with 50 percent today. In part, increased coal consumption in the electric power sector is driven by increases in electricity generation from coal gasification in combination with IGCC technologies. Compared with traditional forms of coal-powered generation, IGCC technologies have lower CAP emissions but equivalent carbon dioxide emissions. Research is ongoing into carbon sequestration applications in combination with IGCC to improve environmental performance.

Comparison of CEF and AEO 2006 Projections

In comparing the CEF and AEO 2006 projections, it is important to note that the CEF base year (1997) value for industrial delivered energy consumption is higher than the AEO 2006 base year (2004) value. This difference is attributable to the roughly 5 percent decrease in industrial delivered energy consumption that occurred from 1997 to 2005.[334] Since base year industrial energy consumption in CEF is higher, it is misleading to compare 2020 consumption projections between the two studies. The calculated annual growth rates are therefore a more appropriate gauge for comparing the two analyses.

For the reference cases, CEF and AEO 2006 projections for annual increases in industrial energy consumption are fairly close—0.8 percent and 0.7 percent per year, respectively. The CEF reference case projects a slightly slower rate of energy intensity improvement than the AEO 2006 reference case projection of 1.3 percent per year. CEF projects that industrial energy intensity will decrease by 1.1 percent per year, with 75 percent of this improvement attributed to inter-sector structural change (i.e., shifts towards less energy-intensive manufacturing industries) and 25 percent to sector-specific efficiency improvement. Despite projections that aggregated industrial energy intensity will continue to decrease, in this analysis we are primarily interested in projected decreases or increases in energy intensity at the sector level, as discussed in Chapter 3.

In terms of projected annual changes in fuel consumption, the CEF reference case differs from the AEO 2006 reference case, projecting faster increases in consumption of all energy inputs (including renewables) except coal. It is unsurprising that CEF envisions no coal increase under the reference scenario, as the analysis was produced before recent price increases for natural gas that may create incentives for switching to coal, and as the analysis does not consider the energy-related impacts of CTL technology that are part of AEO 2006.

Where the CEF reference case projection is less optimistic than AEO 2006, the CEF advanced case projection is considerably more aggressive in terms of its energy consumption and intensity reduction outcomes. This too is unsurprising, given that AEO projections are policy neutral and limited to those policies that have already been enacted and funded, with implementation rules established.[335] Thus, the CEF reference case (which is based on AEO 1999) includes the effect of already adopted policies and regulations in place as of 1999.

Where appropriate, references to differences and similarities between the CEF and AEO 2006 projections for specific industrial manufacturing sectors are made in the sector summaries contained in Chapter 3.