Energy Trends in Selected Manufacturing Sectors:

Opportunities and Challenges for Environmentally Preferable Energy Outcomes








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Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes

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3.6 Iron and Steel

3.6.1 Base Case Scenario

Situation Assessment

The iron and steel industry participates in EPA's Sector Strategies Program. To produce steel, facilities in the iron and steel industry (NAICS 331111) employ one of two production processes, which utilize a variety of raw materials and technologies and have different energy use profiles:

> Recent Sector Trends Informing the Base Case
>
> Number of facilities: ↓
> Value of shipments: Mixed (see text for explanation)
> Energy consumption/ton of steel shipped: ↓
>
> Major fuel sources: Coal, natural gas, coke, electricity
>
> Current economic and energy consumption data are summarized in Table 39 on page 3-55.

- Integrated steel mills use a blast furnace to produce molten iron from iron ore, coal, coke, and fluxing agents. A basic oxygen furnace (BOF) is then used to convert the molten iron, along with up to 30 percent steel scrap and alloys, into refined steel. Integrated steelmaking has declined from 52.6 percent of U.S. steelmaking production in 2001 to 44.9 percent of production in 2005 (estimated value updated March 2006).[161]
- Electric arc furnace (EAF) steel mills utilize steel scrap and up to 30 percent of other iron-bearing materials to produce steel. EAF steel plants primarily produce carbon steels as well as alloy and specialty steels. EAF steelmaking has grown from 47.4 percent of U.S. steelmaking production in 2001 to 55.1 percent of production in 2005 (estimated value updated March 2006).[162]

As certain steel qualities require the use of virgin materials, and as there are constraints on the supply of economically available steel scrap, both integrated steelmaking and EAF steelmaking are required and are not direct substitutes for one another. A recent study notes that some integrated steel companies have adopted production technologies traditionally used in minimills (such as advanced EAFs and thin slab casting), and distinctions between the integrated and EAF segments of the industry may be blurring.[163] Though the share of steel produced by the EAF process has steadily increased (growing from 47 percent to 55 percent of total steel production from 2001 to 2005[164]), expansion of EAF steelmaking capacity is predicated on the availability of adequate and cost-effective supplies of scrap. According to AISI, the addition of alternative ironmaking technologies will be essential to facilitating EAF capacity expansion.[165]

Though both processes are energy intensive, integrated steelmaking requires greater amounts of energy per ton of shipped product. Different studies of energy use in the iron and steel industry often employ somewhat different assumptions and boundary conditions which may lead to slightly different energy intensity measurements (energy use per ton of production). Industry data from 2004 establish an average energy intensity of 18.99 million Btu per ton (MBtu/ton) for integrated steelmaking and 5.01 MBtu/ton for EAF steelmaking, with an industry-wide intensity of 11.8 MBtu/ton (based on EAF steelmaking at a 53 percent market share).[166] A 2005 DOE study estimates the average energy intensity of integrated steelmaking at 16.5 MBtu/ton, and EAF steelmaking at 5.7 MBtu/ton.[167]

Iron and steel production is fairly concentrated geographically, with more than 85 percent of the sector's energy use occurring in the Midwest (64 percent) and South (23 percent).[168] Steelmaking in Indiana, Illinois, Ohio, Pennsylvania, Michigan, and New York accounts for approximately 80 percent of U.S. production.[169]

Beginning with employment contraction in the 1980s and accelerating through bankruptcies in the 1990s and early 2000s, the U.S. steelmaking industry has recently undergone major restructuring.[170] Despite the overall growth in value of shipments and value added from 1997 to 2004 (see Table 39), those metrics declined steadily from 1997 to 2003 and then jumped precipitously in 2004 following increases in the price of steel.[171] (The price increase was driven by a surge in global demand for raw materials due to economic growth in China and other Asian countries, as noted Section 2.4.1.) Restructuring strengthened the financial viability of domestic steel production, and the industry's dramatic turnaround was supported by temporary tariffs on imported steel enacted by the Bush Administration in 2002.[172] As a result of the industry's improved economic condition, an industry survey conducted in 2005 indicated that steel producers anticipated increasing their capital spending by 30 percent over the next two years to promote technological changes.[173] The same study notes that for 2005-2006, companies were expecting to increase investments in new equipment by 43 percent over 2003-2004 levels. Despite the recent return to profitability, in the long term U.S. steelmakers remain vulnerable to fluctuations in global supply and demand. China recently became a net exporter of steel, and the United States is joined by other steel-producing countries in its concerns about the potential for Chinese production to contribute to a glut in global steel supply.[174]

Since 1990, the widespread automation of steel production (facilitated by an industry R&D partnership with DOE) and the introduction of thin slab casting and ladle refining furnaces have also decreased the energy intensity of steelmaking. Thin slab casting reduced reheating energy requirements and increased the variety of products that EAF steelmakers were able to produce (such as flat rolled steel).[175] Economic trends and associated industry restructuring have also contributed to declining energy intensity. In the last fifteen years, there has been substantial industry consolidation that involved the closure of older and less efficient steelmaking facilities. According to data compiled by AISI, the composite energy intensity of the U.S. steelmaking industry (integrated and EAF production) has declined from 16.4 MBtu/ton in 1990 to 11.8 MBtu/ton in 2004, a decrease of 28 percent.[176]

Incremental energy efficiency improvements at the plant level may not be able to produce energy intensity reductions of similar magnitude to those that the industry has historically achieved through the transformational processes discussed above. AISI has launched an R&D initiative called "Saving One Barrel of Oil Per Ton (SOBOT)" that seeks to achieve the next revolution in energy intensity reduction through the development of new transformational technologies and processes that are less energy intensive as well as R&D efforts aimed at decreasing the energy intensity of existing processes.[177] Using different boundary assumptions than the AISI estimate, the 2005 *Steel Industry Marginal Opportunity Study* conducted by Energetics on behalf of DOE estimates that an energy intensity reduction of 5.1 MBtu/ton is technically achievable for integrated steelmaking, with implementation of industry best practices and commercially available technologies comprising slightly more than half of that potential, and R&D opportunities comprising the remaining fraction. For EAF steelmaking, the analysis estimates a technically achievable energy intensity reduction of 2.7 MBtu/ton,[xxx] with implementation of industry best practices and commercially available technologies comprising two thirds of that potential, and R&D contributing the remaining third.[178] Discussion of specific opportunities is included in Section 3.6.2.

Energy costs account for about 20 percent of the total cost of manufacturing steel.[179] Coke and coal meet a combined 39 percent of the iron and steel industry's energy needs. (Though not

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xxx DOE produced this estimate of technically achievable potential by taking the difference between the current energy intensity of EAF steelmaking (5.7 MBtu/ton) and a practical minimum energy requirement that is estimated to be 3.0 MBtu/ton. AISI notes that energy-savings opportunities described by DOE as technically available may not be economically viable in all facilities.

considered as part of this study, steelmaking also uses coal and coke as raw materials. They are sources of carbon which, in combination with iron, produces steel.) As natural gas meets 27 percent of the sector's energy requirements, increases in the price of natural gas are a significant concern for the industry. Reducing natural gas requirements is one of the goals motivating the industry's investment in SOBOT.[180] Byproduct fuels produced onsite (listed as "Other" in MECS, such fuels are primarily coal-based coke oven gas and blast furnace gas) and purchased electricity are also important energy inputs. The mix between fuel-based and electricity-based energy inputs differs between integrated and EAF steelmaking. Integrated steelmaking accounts for roughly 75 percent of the industry's fuel consumption and 36 percent of the industry's electricity consumption, while EAF steelmaking accounts for 25 percent of the industry's fuel consumption and 64 percent of its electricity consumption (fractions based on 1998 MECS data).[181]

Table 39 summarizes current economic trend and energy consumption data originally presented in Chapter 2.

Table 39: Current economic and energy data for the iron and steel industry

Economic Production Trends[yyy]				
	Annual Change in Value Added 1997-2004	Annual Change in Value Added 2000-2004	Annual Change in Value of Shipments 1997-2004	Annual Change in Value of Shipments 2000-2004
	1.1%	8.3%	1.7%	6.1%
Energy Intensity in 2002[zzz]				
	Energy Consumption per Dollar of Value Added (thousand Btu)	Energy Consumption per Dollar Value of Shipments (thousand Btu)	Energy Cost per Dollar of Value Added (share)	Energy Cost per Dollar Value of Shipments (share)
	66.5	27.8	20.4%	8.0%
Primary Fuel Inputs as Fraction of Total Energy Supply in 2002 (fuel use only)				
Coke & Breeze	Natural Gas	Other[aaaa]	Net Electricity	Coal
36%	27%	21%	13%	3%

[yyy] Economic trend data are for the larger NAICS category, iron, steel, and ferroalloy manufacturing (NAICS 33111).

[zzz] Energy intensity data are for the larger NAICS category, iron, steel, and ferroalloy manufacturing (NAICS 33111).

[aaaa] For iron and steel, the "other" category is largely composed of byproduct fuels such as coke oven gas and blast furnace gas (coal-based in origin).

Fuel-Switching Potential in 2002: Natural Gas to Alternate Fuels				
			Switchable fraction of natural gas inputs	12%
		Fuel Oil	Coal	Other
Fraction of natural gas inputs that could be met by alternate fuels		73%	13%	9%
Fuel-Switching Potential in 2002: Coal to Alternate Fuels				
			Switchable fraction of coal inputs	3%
		Other	Natural Gas	
Fraction of coal inputs that could be met by alternate fuels		60%	40%	

Expected Future Trends

Controlling energy costs is critical to maintaining the competitive viability of the U.S. iron and steel industry in the global marketplace. Recent restructuring has strengthened the industry's position and is expected to spur investment in new technologies.[182] In the long term, global supply and demand fluctuations will continue to play a role in the industry's financial condition and capacity for investment in energy efficiency improvement.

> **Voluntary Commitments**
>
> The American Iron and Steel Institute (AISI) collects data for five indicators of sustainability: energy intensity, GHG emissions, material efficiency, steel recycling, and implementation of environmental management systems. AISI has also shown its commitment to improvements with regard to energy and the environment by joining Climate VISION. With its participation in this program, AISI has committed to improving member energy efficiency by 10 percent by 2012 (from 2002 levels). See http://www.climatevision.gov/sectors/steel/index.html.
>
> The steel sector also participates in DOE's Industrial Technologies Program (ITP) as an "Energy Intensive Industry." ITP's goals for all energy intensive sectors include the following:
>
> - Between 2002 and 2020, contribute to a 30 percent decrease in energy intensity.
> - Between 2002 and 2010, commercialize more than 10 industrial energy efficiency technologies through research, development & demonstration (RD&D) partnerships.
>
> See http://www.eere.energy.gov/industry/steel/.

The expansion of EAF steel production and contraction of integrated steel production has historically decreased the overall energy intensity of the steelmaking industry. According to 2005 data, more than 75 percent of end-of-life steel products in the United States are recycled, including 100 percent of end-of-life automobiles, 90 percent of end-of-life appliances, and 63 percent of used steel cans.[183] Use of suboptimal scrap produces more waste and requires more energy to process. One industry assessment states that some EAF mills have sought to mitigate the risk of scrap market volatility through investment in onsite alternative ironmaking (AI) production units to supplement scrap inputs. According to that analysis, due to the energy intensity of AI production, increased domestic AI production could slow the rate of energy intensity reduction at EAF mills.[184]

As noted at the beginning of Chapter 3, the age of the CEF study (produced in 2000 and using energy data from 1998) means that its projections are outdated in some cases, and particularly for the iron and steel industry, which has undergone substantial restructuring since the CEF report was produced. However, as the CEF report provides the best-available cross-sector assessment of business-as-usual and environmentally preferable energy trends, we include its projections for the iron and steel sector as we do for other sectors addressed in this report.

The iron and steel industry is one of the three sectors (along with cement and paper) for which CEF made detailed parameter modifications to the NEMS model used to produce AEO 1999. Modifications included adjustments to baseline energy intensities and rates of annual improvement in energy intensity, which were adjusted to reflect best-available sector-specific research at the time (primarily a 1999 study by Worrell et. al. at Lawrence Berkeley National Laboratory, *Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the U.S. Iron and Steel Sector*).

Under the reference case scenario, CEF projects that energy consumption by the iron and steel industry will decrease 15 percent from the 1997 baseline by 2020 and that energy intensity will decline at 1.4 percent per year over the period.

CEF projects no major fuel mix shifts for the iron and steel industry under the reference case. Consumption of all fuels is expected to decline, with the exception of purchased electricity, which CEF expects will increase slightly (2 percent). Natural gas use falls by the greatest amount (28 percent), contributing to the increase in the relative importance of coal, despite the fact that coal consumption is projected to fall by 10 percent.

CEF's projections are based on the economic assumptions that steel production will increase at 0.9 percent per year. The projected reduction in energy consumption for the industry is in part attributable to CEF's assumptions about structural changes within the sector: CEF uses the AEO 1999 assumption that integrated steelmaking will drop from a 61 percent share of total production in 1994 to 54 percent in 2020, with an increase in EAF steelmaking from 39 percent to 46 percent over the same period. (These assumptions are outdated now that EAF steelmaking currently comprises more than 50 percent of steel production.) CEF's assumptions about adoption of energy-efficient technologies also contribute to the projected decline in energy consumption. For example, CEF made adjustments to the AEO 1999 NEMS parameters for the unit energy consumption values and retirement rates for existing equipment, as well as new equipment expected to be installed over the period. At the same time, CEF's technology assessments are based on a Lawrence Berkeley National Laboratory (LBNL) study that relied on industry data from 1994. A more recent industry assessment by DOE assumes that 50 percent of the energy-savings opportunities estimated in that LBNL study have already been achieved as of 2005.[185] (More detailed information about the assumptions underlying CEF's projections and how those assumptions were reflected in CEF-NEMS modeling can be found in Appendix A2 of the CEF report. However, it is not possible to determine from report documentation how much of the projected decline in energy consumption is attributable to structural change within the sector, and how much is attributable to energy efficiency improvement.)

CEF base case projections are summarized in Table 40.

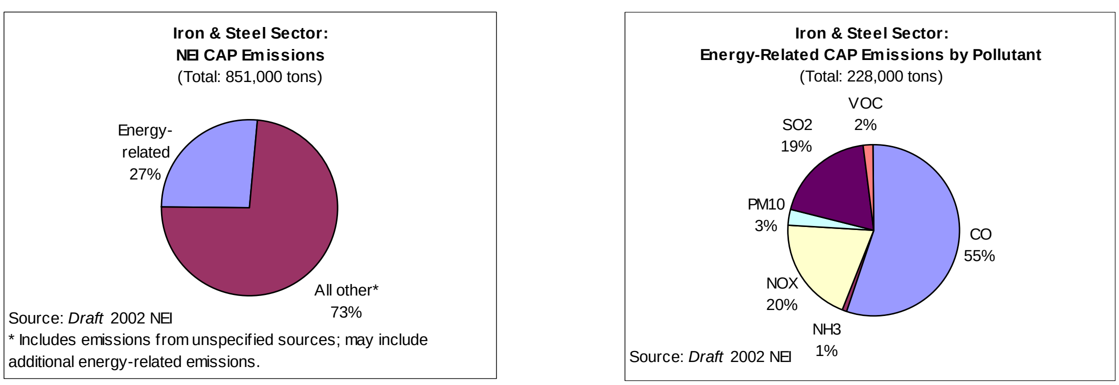
Table 40: CEF reference case projections for the iron and steel industry

	1997 Reference Case		2020 Reference Case	
	Consumption (quadrillion Btu)	Percentage	Consumption (quadrillion Btu)	Percentage
Petroleum	0.118	7%	0.103	7%
Natural gas	0.541	32%	0.390	27%
Coal	0.873	51%	0.783	54%
Delivered electricity	0.173	10%	0.176	12%
Total	1.705	100%	1.452	100%
Annual % change in energy intensity (energy consumption per dollar value of output)				-1.4%
Overall % change in energy use (1997-2020)				-15.0%

As previously noted, EAF steelmaking has surpassed the market share that CEF projected would be achieved by 2020. In an effort to assess the impact of recent trends that may have affected industry energy consumption since the CEF report was produced, we also examined reference case energy consumption projections for the iron and steel industry produced in connection with EIA's *Annual Energy Outlook 2006* (AEO 2006), which also uses the NEMS model but incorporates more recent energy and economic data. In line with CEF projections, AEO 2006 projects annual growth in the industry's value of shipments to be 0.9 percent per year, and industry-wide energy intensity to decline at 1.4 percent per year primarily due to the assumption that most new steelmaking capacity in the United States will be EAF production. (As previously noted, constraints on viable scrap supply impose limits on EAF production capacity, and the addition of alternative ironmaking technologies will be essential to facilitating EAF capacity expansion.) AEO 2006 projects that sector energy consumption will decline by 3.5 percent from 2004 to 2020 (substantially less than the 15 percent projected by CEF), with coal consumption decreasing by 11 percent, and electricity consumption increasing by 14 percent.

Environmental Implications

Figure 16: Iron and steel sector: energy-related CAP emissions



> **Effects of Energy-Related CAP Emissions**
>
> SO_2 and NO_x emissions contribute to respiratory illness and may cause lung damage. Emissions also contribute to acid rain, ground-level ozone, and reduced visibility.

Figure 16 presents NEI data on energy-related CAP emissions by pollutant type for the iron and steel industry. Although NEI data attribute emissions from electric power generation to the generating source rather than the purchasing entity, purchased electricity meets around ten percent of the sector's energy needs, so the above figure provides a fairly complete picture of the sector's energy-related CAP emissions. (Though EAF steelmaking is electricity intensive, the magnitude of the fuel requirements for integrated steelmaking means that electricity remains a fairly small fraction of total energy consumption.) Sulfur dioxide and nitrogen oxide emissions are the largest fractions of energy-related CAP emissions. (As noted in Section 2.3.3, NEI data on carbon monoxide emissions appear higher than would be expected for stationary sources, so we do not address carbon monoxide data in our assessment of CAP emissions for each sector.)

Figure 17: Iron and steel sector: CAP emissions by source category and fuel usage

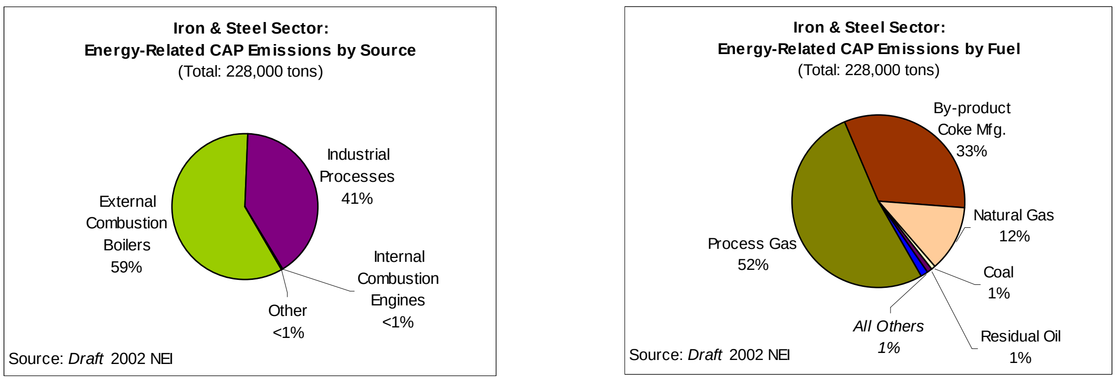


Figure 17 presents NEI data on energy-related CAP emissions by source category and fuel type. Though the largest fraction of energy-related CAP emissions is from external combustion boilers, emissions that are classified as related to industrial processes are also substantial. NEI data classifications are problematic due to reporting inconsistencies, as discussed previously, but equipment classified under "external combustion boilers" includes cogenerating units used to produce heat and electricity, and boilers used for process heating. Equipment classified under "industrial processes" in NEI likely includes fired systems such as blast furnaces, metal melters, and heaters. Highlighting possible issues with NEI data classifications, according to DOE, more than 80 percent of the industry's energy requirements are for fired systems such as furnaces, with boiler systems comprising approximately 7 percent of total energy use.[186]

In integrated steelmaking, the conversion of coal to coke is fueled by a mixture of natural gas and byproducts of the process such as coke oven gas. Energy-related emissions from this process are likely classified as "byproduct of coke manufacturing" in NEI data. The industry also uses other byproduct gases such as blast furnace gas, BOF gas, and EAF gas,[187] which may be classified in NEI as "process gas." Byproduct gases are also used as boiler fuel. As NEI data are dependent on emissions reporting from a number of different sources, it is difficult to precisely align reported energy-related emissions with sector energy consumption data from sources such as MECS.

As previously noted, the CEF energy consumption projections are dated for a number of reasons, and AEO 2006 projects that sector energy consumption will remain relatively static (decreasing at 0.2 percent per year). To the extent that declining coal consumption in the iron and steel industry is attributable to energy efficiency improvement (AISI states that as an industry-wide average, reasonable and obtainable energy efficiency improvements at the plant level can be expected to reduce energy consumption per ton of production by around 0.7 percent per year), such trends would decrease energy-related CAP emissions at the facility level.[188] Reducing natural gas consumption in favor of cheaper coal-based byproduct gases would reflect optimization of waste streams for their energy content. Increases in purchased electricity would affect CAP emissions at the utility level, and emissions impacts would depend upon local energy inputs for electric power generation. According to AISI, DOE's assumptions about increasing EAF production may not be accurate.

As NEI data do not include carbon dioxide emissions, we use carbon dioxide emissions estimates from AEO 2006, which totaled 127 million metric tons for the iron and steel industry in 2004. AEO 2006 projects that the industry's carbon dioxide emissions will decline by 3 percent from 2004 to 2020, in line with the expected decrease in sector energy consumption.

3.6.2 Best Case Scenario

Opportunities

Separate opportunity assessments have been conducted for integrated and EAF steelmaking processes using the DOE and AISI analyses. For integrated steelmaking, Table 41 ranks the viability of five primary opportunities for improving environmental performance with respect to energy use (Low, Medium, or High). A brief assessment of the ranking is also provided, including potential barriers. Table 42 provides a similar assessment for EAF steelmaking.

Table 41: Opportunity assessment for integrated steelmaking

Opportunity	Ranking	Assessment (including potential barriers)
Cleaner fuels	Low	Though the industry is likely to remain heavily dependent on coal, DOE estimates that there are opportunities for greater utilization of coke oven gas and other off-gas byproducts for energy content.[189] According to AISI, most coke oven gas produced by U.S. mills is already used, and other technologies for capture and reuse of steelmaking off-gases have not been adopted in the United States because they are not economically viable to deploy here given current energy prices.[190]
Increased CHP	Medium	Integrated steelmaking has less demand for electricity than EAF production, but the DOE marginal opportunity study notes the opportunity for increased cogeneration, including repowering current systems with off-gas turbine/steam turbine systems (0.48 MBtu/ton). According to DOE, heat recovery opportunities lie with the sintering (0.09 MBtu/ton), BOF (0.4 MBtu/ton), and annealing processes (0.29 MBtu/ton).[191] AISI describes cogeneration opportunities associated with non-recovery cokemaking, which combusts cokemaking off-gases to produce steam to drive a steam turbine generator and produce electricity, either for internal plant use or for sale to the grid. Currently, cokemaking off-gases are processed into materials with economic value (coke oven gas, tar, ammonia, and other chemicals).[192] Whether CHP is economically viable depends in large part upon the comparative value of electricity production versus the capital costs of the CHP equipment. New CHP installations also face barriers in terms of utility interconnection requirements if electricity production is expected to exceed onsite demand, and also from NSR/PSD permitting.[193]
Equipment retrofit/ replacement	Low	Equipment-related opportunities noted in the DOE marginal opportunity study include variable speed drives for pumps and fans (0.03 MBtu/ton), which AISI notes are already in wide use in the industry.[194] Additional equipment-related opportunities are included under "Process improvement."

Opportunity	Ranking	Assessment (including potential barriers)
Process improvement	Medium	AISI notes that with existing technologies and best practices, improvements in blast furnace efficiency are possible through optimized injection technologies and better sensors/process control. Other near-term opportunities noted by AISI include blast furnace coal injection modeling (to reduce energy losses in the cokemaking process) and optimizing processes through minimizing the generation of scrap and oxides.[195] Though some of the process-related energy-savings opportunities noted in the DOE study require equipment installation or retrofits, for the purposes of this analysis they have been classified as process-related so that DOE's estimated potential energy intensity reductions can be included. Options that are noted by DOE that are technically available but that may not be economically viable in all situations include the following: preventative maintenance (0.21 MBtu/ton); installation of energy monitoring and management systems for energy recovery and distribution between processes (0.06 MBtu/ton); coal moisture control and dry quenching in the cokemaking process (0.22 MBtu/ton); and in ironmaking (the most energy-intensive process), pulverized coal and natural gas injection, top pressure recovery turbines, hot blast stove automation, and systems for improved blast furnace control (combined 1.34 MBtu/ton). Casting/hot rolling energy efficiency opportunities include thin slab casting with tunnel furnace (0.93 MBtu/ton).[196]
R&D	High	According to AISI, the greatest potential for reducing the energy intensity of steelmaking lies with development of new transformational technologies and processes. Examples of such transformational R&D efforts (applicable both to integrated and EAF steelmaking) include the following: (1) Molten oxide electrolysis (under development at MIT); (2) ironmaking by flash smelting using hydrogen (under development at the University of Utah); and (3) the paired straight hearth furnace (under development at McMaster University in Ontario, Canada).[197] Other R&D opportunities for integrated steelmaking noted in the SOBOT analysis include reducing/optimizing energy usage in alternative ironmaking processes and increasing the scrap/hot metal ratio in the BOF charge.[198] An example of an alternative ironmaking process, the most significant R&D opportunity noted in the DOE study is replacement of traditional coke-based iron ore reduction (involving the energy-intensive blast furnace) with direct iron ore reduction using coal (2.58 MBtu/ton).[bbbb] [199] The direct reduced iron opportunity has a shorter timeline (2010) than the other R&D opportunities noted by DOE, which assume implementation occurs by 2020. Other R&D opportunities noted by DOE include increased direct carbon injection in the ironmaking process (0.7 MBtu/ton), blast furnace slag heat recovery (0.28 MBtu/ton), and increased scrap input into BOF (3.1 MBtu/ton).[200] Casting and rolling R&D opportunities (applicable both to integrated and EAF steelmaking) include reduction of heat losses from cast products prior to rolling/reheating (0.75 MBtu/ton) and near net shape casting. [201] Near net shape casting is a general term that refers to processes that eliminate a reheating step by casting in the final shape.[202] AISI also describes energy-savings opportunities potentially available from near net shape casting, with thin strip casting representing the largest opportunity in terms of tons of steel production. (DOE estimates potential energy intensity reductions from thin strip casting at 0.5–0.7 MBtu/ton.) Production of strip casting is presently limited to certain markets, and further research is needed to expand the market for this technology. AISI also notes beam blank casting as a growing opportunity for long products.[203] In general, major barriers to new technology and process development include not only the costs and risks associated with the research process itself, but also the implementation of new technology, once developed, is risky and in some cases may be considered a "bet the company" investment.[204] Federal funding (i.e., through DOE's Industrial Technologies Program) to mitigate the costs and risks associated with R&D efforts has also been reduced.

[bbbb] The DOE report notes that if direct iron reduction potential was fully exploited, then some of the other R&D opportunities (such as those affecting blast furnace ironmaking) would not be applicable as they would represent double-counting.

Table 42: Opportunity assessment for EAF steelmaking

Opportunity	Ranking	Assessment (including potential barriers)
Cleaner fuels	Low	Due to the substantial electricity requirements for EAF steelmaking, there is little opportunity for cleaner fuels. However, onsite renewable energy generation could have substantial environmental benefits. Barriers to onsite renewables include cost, resource intermittency, and utility interconnection requirements.
Increased CHP	Low	CHP does not represent a major energy efficiency opportunity for EAF steelmaking as the sector has relatively low demand for steam and waste heat is difficult to recover.
Equipment retrofit/ replacement	Low	Some equipment-related opportunities are included under "Process Improvement."
Process improvement	Medium	Process-related opportunities noted by AISI include improvements in process control (such as increased electrical energy transfer efficiency, reduced tap-to-tap times, and increased percentage of power-on time), and improved scrap preheating/charging practices and post-combustion practices.[205] Though some of the process-related energy-savings opportunities noted in the DOE study require equipment installation or retrofits, for the purposes of this analysis they have been classified as process-related so that DOE's estimated potential energy intensity reductions can be included. DOE estimates that for EAF steelmaking, the energy-savings opportunity bandwidth from implementation of best practices and commercially available technology is as twice as large as the R&D opportunity bandwidth. Options that are noted by DOE that are technically available but that may not be economically viable in all situations include: installation of energy monitoring and management systems for energy recovery and distribution between processes; preventative maintenance; and improvements in the EAF process such as improved process control, oxy-fuel burners, DC-arc furnaces, scrap preheating, and post-combustion processes. The combined best practice/commercially available technology opportunity quantified by DOE is 1.8 MBtu/ton. Casting/hot rolling energy efficiency opportunities include thin slab casting with tunnel furnace (0.93 MBtu/ton), which are applicable to both EAF and integrated steelmaking.[206]
R&D	High	According to AISI, the greatest potential for reducing the energy intensity of steelmaking lies with development of new transformational technologies and processes. Examples of such transformational R&D efforts (applicable both to integrated and EAF steelmaking) include: (1) Molten oxide electrolysis (under development at MIT); (2) ironmaking by flash smelting using hydrogen (under development at the University of Utah); and (3) the paired straight hearth furnace (under development at McMaster University in Ontario, Canada).[207] AISI lists the following additional areas as important R&D opportunities for EAF steelmaking: improved processes for low-grade scrap recovery, as well as sensible heat recovery from slags, fumes, and off-gases.[208] R&D opportunities noted in the DOE study include increasing the efficiency of melting processes (0.4 MBtu/ton), integration of refining functions/reductions of heat losses prior to casting (0.35 MBtu/ton), economical heat capture from EAF waste gas (0.26 MBtu/ton), purification/upgrading to scrap, and effective utilization of slag and dust. Casting and rolling opportunities (applicable both to integrated and EAF steelmaking) include reduction of heat losses from cast products prior to rolling/reheating (0.75 MBtu/ton) and thin strip casting (0.5 – 0.7 MBtu/ton). R&D barriers (high costs and risks associated with new technology development, exacerbated by reduced availability of federal funds) are the same as those discussed in association with the integrated steelmaking R&D opportunity assessment.

Optimal Future Trends

The CEF advanced case projection shows a greater reduction in sector energy use and a larger annual decrease in energy intensity than under the business-as-usual projection. The largest fuel decrease is seen in the petroleum category, which falls by 83 percent from 1997 to 2020. Natural gas consumption falls by 36 percent, and purchased electricity falls by 20 percent. Though the coal fraction grows relative to other fuel inputs, total coal consumption falls by 13 percent over the period. Table 43 summarizes the CEF advanced case projections for the iron and steel industry.

Table 43: CEF advanced case projections for the iron and steel industry

	1997 Advanced Case		2020 Advanced Case	
	Consumption (quadrillion Btu) [cccc]	Percentage	Consumption (quadrillion Btu)	Percentage
Petroleum	0.118	7%	0.020	2%
Natural gas	0.529	31%	0.336	27%
Coal	0.873	52%	0.758	60%
Delivered electricity	0.173	10%	0.140	11%
Total	1.693	100%	1.254	100%
Annual % change in energy intensity (energy consumption per dollar value of output)				-2.0%
Overall % change in energy use (1997-2020)				-26.0%

The economic assumptions underlying the CEF advanced case projections are unchanged from the business-as-usual assumptions (annual steel production increase of 0.9 percent per year and growth in the economic value of the industry's output at 0.9 percent per year). Under its advanced energy scenario, CEF projects that EAF steel production will increase to 55 percent of the market by 2020, compared to 46 percent under the reference scenario. Retrofit measures implemented under the advanced case reduce energy consumption in the following processes: blast furnace (injection of pulverized coal and natural gas, blast furnace gas recovery, improved control systems); EAF steelmaking (scrap preheating, improved process control with neural networks, DC-Arc furnace); cold rolling (automated monitoring and targeting systems, heat recovery on the annealing line); hot rolling (process controls, recuperative burners, energy-efficient drives in the rolling mill); casting (efficient ladle preheating); cokemaking (programmed heating).[dddd] Energy savings are also produced by increased adoption of new process technologies such as alternative ironmaking and near net shape casting. Advanced case assumptions common to all sectors include increased boiler efficiencies and commercial building efficiency.

The CEF advanced case projections likely overstate potential energy savings available under an optimal energy scenario, as EAF steelmaking already comprises 55 percent of production. In addition, many of the technologies noted above are already widely adopted in the industry, and industry restructuring since 2000 has resulted in further decreases in the energy intensity of U.S. steelmaking. At the same time, increased adoption of energy-efficient technologies and new technology development would be expected to accelerate the industry's current trend of decreased energy consumption.

[cccc] As is the case with several sectors addressed in the CEF analysis, there are slight differences between 1997 fuel consumption data in the reference and advanced cases. We could find no explanation for such differences in the CEF analysis, but it could be that CEF made modifications to the base year (1997) parameters under the advanced case as compared with the reference case.

[dddd] Retrofit measures are a partial list of those contained in Appendix A-2, Industry: NEMS Input Data and Scenario Input, of the *Clean Energy Future* report, pp. A-2.70-71.

Environmental Implications

The reductions in fossil fuel consumption that are achieved under the advanced energy scenario would lead to reductions in energy-related CAP emissions at the facility level, particularly sulfur dioxide and nitrogen oxides. CAP emissions reductions at the electric power generation level would also be expected from reductions in purchased electricity.

Under the advanced energy scenario, by 2020 CEF projects carbon emissions by the iron and steel industry to fall 27 percent from 1997 levels, which is roughly equivalent to the projected decline in sector energy usage.

3.6.3 Other Reference Materials Consulted

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