Future Energy: Opportunities and Challenges

Part III. Energy Demand

Chapter 17. Industrial Energy Use

Future Energy:
Opportunities and Challenges

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17
Industrial Energy Use

The Main Points

- **Around one-third of the energy produced in the U.S. is used for industrial activities.**
- **Industrial energy use has varied over a narrow range (around 30 to 35 Quads per year) in recent decades.**
- **Around half of fuel use in the chemical industry is for chemical feedstock.**
- **Manufacturing and mining use around four-fifths of all industrial energy.**
- **Eight industries dominate industrial energy use.**
- **Energy for heating consumes around three-fourths of industrial energy and represents the greatest opportunity for energy savings.**
- **Labor cost, energy cost, raw material cost, and regulations influence decisions on locations for new industrial facilities.**

17.1 Introduction

The industrial sector accounts for a large portion (around one-third) of total U.S. energy consumption, and it uses that energy in many different ways. Energy for transportation, residential, and commercial applications is almost all used for heating or mechanical work, and most of the energy used in these sectors is often supplied by one or two dominant sources. On the other hand, the industrial sector uses all energy sources and uses hydrocarbons for feedstocks as well as for fuel. End uses in industry include energy for electrolytic processes as well as for heating and mechanical work. Consequently, energy accounting in industry is more complex than in other sectors.

17.2 Consumption by Energy Type

U.S. industrial energy consumption in the late twentieth and early twenty-first century has varied over a narrow range. Total energy consumption in industry in 2008 was essentially identical to 1970 consumption in spite of growth in population and in gross domestic product. Three factors explain this behavior: increases in energy efficiency by industry, changes in products used by consumers, and departure of the U.S. industry to foreign countries (see Figure 17-1 for the recent history [through 2009] of primary energy consumption for U.S. industry[1]. It should be noted that after the recession of 1980, industrial energy use remained nearly constant until 2009, when it dropped by around 10 percent as a result of another economic recession.)

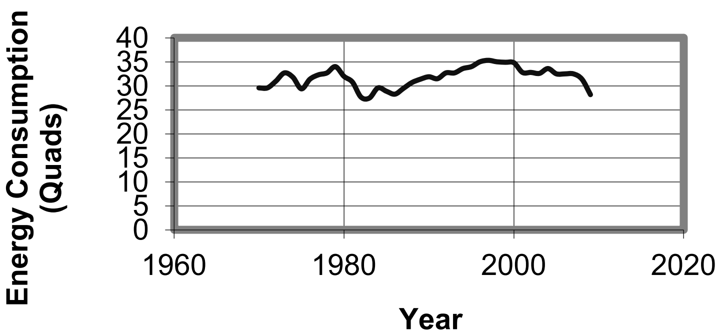

Figure 17-1. Industrial Primary Energy Consumption

The contributions of the industrial delivered and primary energy sources appear in Figures 17-2 and 17-3[1].

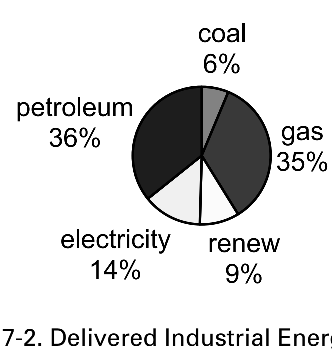

Figure 17-2. Delivered Industrial Energy (2009)

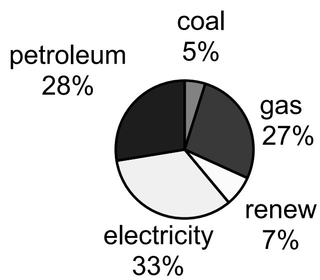

Figure 17-3. Primary Industrial Energy (2009)

The U.S. industry currently relies on fossil fuels. Natural gas and petroleum provide the greatest share of delivered industrial energy. Coal serves as the current main energy source for the production of electrical energy and as a source of coke used in iron making. If availability or environmental protection concerns cause curtailment of fossil fuel use, switching to alternative energy in processes where this change is possible will be difficult and expensive.

The trend to heavy reliance on natural gas by industry is because it is clean-burning, it is still plentiful, it is useful as a feedstock, and it is still cheap. Until a delivery network for natural gas was built, it was a nuisance that was burned (flared) to simply get rid of it. After pipelines from major natural gas sources to users were built in the second half of the twentieth century, use of this fuel grew rapidly in the industrial, residential, and commercial sectors. The government imposed regulations that encouraged this shift in its efforts to decrease emissions. Natural gas became the fuel of choice for many electric utilities.

17.3 Consumption by Use

Manufacturing and mining use the bulk of industrial delivered energy (around 80 percent). Figure 17-4 shows the ways in which this energy is used. (Fired systems shown in Figure 17-4 are heating systems, such as furnaces and dryers.)

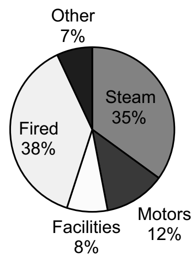

Figure 17-4. Energy Uses for Mining and Manufacturing

In the industrial sector, some resources suitable for energy production are used instead as feedstock. That is, their chemical constituents are used to make useful materials such as plastics, pharmaceuticals, and fertilizer. In accounting for primary energy consumption, feedstock materials are counted as energy consumption (equivalent to the energy that would have been released if they had been used as fuel). For example, feedstock energy equivalent use totals over 1/2 of energy consumption in the chemical industry[2]. Efforts are under way to reduce hydrocarbon use for feedstocks by implementing more efficient technology in using the feedstock and by switching to biomass based feedstock.

Energy losses in production and delivery to industrial users consume about 30 percent of primary energy destined for industrial delivered energy[3]. Another 30 percent of primary energy is lost within the industrial activities. This leaves around 40 percent of primary energy produced for industry being used to serve process needs for delivered heat and electricity.

The U.S. Department of Energy (DOE) compiles and reports information on industrial energy use. There are various ways to categorize and organize these data. For example, tabulations may report total primary energy use, total delivered energy use or delivered energy use for heat and power only. Those who consult DOE tabulations are cautioned to check the basis for the reported data.

17.4 Industry-Specific Consumption

Eight energy-intensive industries consumed around 64 percent of total delivered industrial energy in the U.S. in 1998[4]. The eight industries are bulk chemicals, petroleum refining, paper, food, steel, aluminum, cement, and glass. Manufacturing is the largest consumer of energy in the industrial sector by a wide margin.

Data on delivered energy consumption in industry appear in Table 17-1. These data illustrate the energy use distribution among various industries. These data are rather old, but they provide a unique snapshot that presents manufacturing and non-manufacturing energy use on a consistent basis. Appendix Q provides details on energy use in selected industries.

Table 17-1. Delivered Energy Consumption in Industry (1998)[4]

Manufacturing	**Consumption Quads**
Food	1.03
Paper	2.73
Bulk Chemicals	6.70
Petroleum Refining	3.13
Glass	0.20
Cement	0.36
Steel	1.59
Aluminum	0.45
Metal-Based Durables	1.47
Others	2.90
Total Manufacturing	**20.56**
Non-Manufacturing	
Agriculture-Crops	0.71
Agriculture-Other	0.41
Coal Mining	0.09
Oil and Gas Extraction	1.51
Other Mining	0.31
Construction	1.78
Total Non-Manufacturing	**4.81**
Total for All Industry	**25.37**

The primary energy consumed to produce the delivered energy was about 35 Quads in 1998, indicating production, transmission, and distribution losses amounted to almost 30 percent of primary energy consumption.

17.5 Industrial Energy Consumption and the U.S. Economy

The U.S. economy is shifting toward importing finished products rather than producing those products domestically from either domestic or imported raw materials. The media often inform readers and viewers that this is because low cost foreign labor is causing industries to leave the U.S. Less noticed, but also important, are stringent U.S. environmental regulations and the influence of lower foreign energy cost on decisions by industries to leave the U.S.[5]. For example, natural gas (which we have seen to be essential for many industrial processes) has been much less expensive in the Middle East than the U.S. in recent years. (Natural gas cost in the Middle East was less than one-fourth of the U.S. cost in 2005.)

The impact of natural gas cost is especially strong in the chemical industry. Almost all new chemical plant construction is outside of the U.S. However, the increase in natural gas availability in the U.S. due to hydrofracturing of shale gas deposits may influence future decisions on locating chemical plants.

Energy-intensive industries also face the decision of whether to bring the raw materials to places where energy is cheap or to produce the energy where raw materials are cheap. For example, in the past, it was decided to bring bauxite (aluminum oxide ore) to aluminum plants located where electrical energy was cheap. Such trade-offs will require re-evaluation as energy costs rise.

Of course, world industrial energy consumption is experiencing changes in demand as well as supply. Increasing populations in developing countries are creating greater demand for industrial products. These changes will be felt worldwide as new markets develop and energy requirements increase.

17.6 Supply Side Opportunities for Reducing or Modifying Energy Consumption

Energy is wasted in all industries. Eliminating all energy losses is impossible, but significant reductions are possible. American industry has already increased its energy efficiency in recent years. One index of manufacturing energy efficiency is the energy intensity, defined as the number of BTUs of energy consumed per dollar value of product shipments. For example, the manufacturing energy intensity decreased from 8,900 in 2002 to 6,900 in 2006.[6]

The dominant drivers for improved efficiency in industry are reducing production costs and complying with regulations. The capital cost of these changes is incurred when industries expect adequate subsequent operating cost reductions or when required by regulations. The changes may involve replacement of old equipment with new equipment of the same type, replacement with more efficient versions of the same type of equipment, modification of existing equipment or switching to a new, different type of equipment.

Manufacturing, which uses about 80 percent of delivered industrial energy, loses over 30 percent of the delivered energy to the environment rather than using it productively.[3] Most of the delivered energy used in manufacturing is used for steam generation or for direct-fired process heaters (see Figure 17-4). These applications account for about three-fourths of delivered energy use in industry. In many processes, a material is heated to accomplish a desired change in chemical or physical properties and then cooled for storage, delivery or subsequent processing. The energy used for heating is lost if the cooling involves heat transfer to the environment. Some of that energy can often be recovered and used to preheat new material entering the process. Energy losses can also be reduced by installing better insulation on pipes, vessels, steam traps, etc., that contain hot or cold materials. Heat recovery and improved insulation have the greatest potential for energy savings in industry, but the economic practicality depends on the relative cost of the energy used and the capital cost for the modifications.

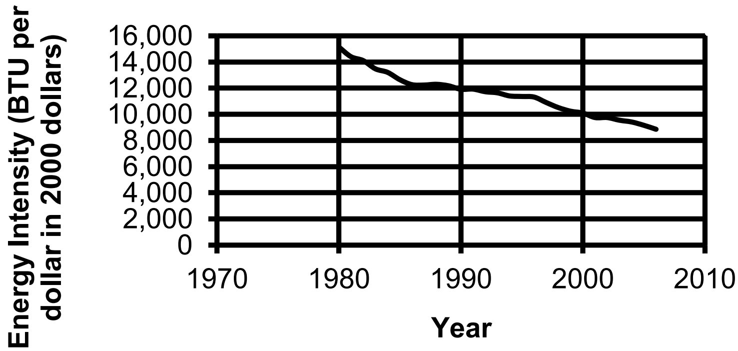

Figure 17-5. U.S. Energy Intensity

As availability, costs, and regulations related to energy from the various sources change, industry will adapt when possible by switching from one energy source to another. If petroleum and natural gas become too dear for use in some industrial process, then the most likely alternatives are coal and electricity. Coal use creates pollution and greenhouse gases, and its use will likely be restricted in the future. Transportation needs will probably account for all of the biofuel that can be produced. Electricity is the only energy supply that can grow without intolerable environmental effects or high costs due to supply shortages. The electricity for this transition could potentially be provided by wind, solar or nuclear power plants in order to reduce environmental effects that accompany use of coal fueled power plants. Also, producing electricity in plants that use natural gas is an option that causes smaller environmental effects than coal fueled plants, albeit while using a non-renewable resource.

Industrial plants with large electricity needs can often benefit by building and operating on-site cogeneration facilities. Cogeneration is the production of electricity and process heat in the same facility. Recall that thermal power plants necessarily waste about two-thirds of the thermal energy used to produce electricity. This wasted heat is usually dumped into a body of water or the atmosphere because there is no practical use for the heat at typical sites for power plants. Conversely, many industries need electricity and process heat. Cogeneration is often economical, especially when the process temperatures needed are moderate.

17.7 Reinventing Industrial Processes

Many of the industrial processes that provide the products that sustain modern societies were developed when resources, especially energy resources, were plentiful and cheap, and there was little concern about environmental impacts. Now energy availability and cost are growing concerns, and simply moving industries to places that tolerate environmental damage is unsatisfactory. These factors are motivating an effort by researchers to reinvent industrial processes so they can produce the same products in a different way or can produce completely new products that can substitute for the old ones. Much work is under way, but much remains to be done before significant new energy-saving processes move from laboratory scale to industrial scale.

Industrial reinvention has occurred before, but the motivation was reduced cost and/or increased convenience, rather than energy conservation and environmental protection. For example, plastic bottles and aluminum cans have essentially replaced glass bottles for soft drinks. Plastic bags have largely replaced paper grocery bags. A revolution in the electronics industry occurred when transistors, then integrated circuits replaced vacuum tubes. The aircraft industry changed radically when jet engines replaced piston engines. These and many other changes show, with adequate motivation, that industry can reinvent the processes needed to provide desired commodities or services. Now, the challenge is to respond to a new set of motivations.

Steel production is a good example of recent industrial reinvention efforts. Traditional steelmaking starts in a blast furnace where iron ore (iron oxide) is mixed with coke (mostly carbon) at high temperature. The oxygen moves from the iron oxide to the carbon, forming carbon dioxide and iron. The iron takes in traces of carbon and other chemicals derived from the coke, and the resulting product is steel. So, traditional steelmaking results in heat energy consumption and carbon dioxide release. One potential method for changing steelmaking is the electrolytic process. Laboratory results show electrolysis of iron ore dissolved in lithium carbonate at high temperature produces pure iron and oxygen[7]. Methods for the economical conversion of this pure iron into steel are yet to be developed, but this possible reinvention of steelmaking is the sort of thing that may revolutionize industrial processes.

There is no way to judge the future success of efforts to reinvent industrial processes. However, the potential payoff is so great that research in this area deserves major funding from government and industry.

17.8 What Can I Do?

The private citizen has no way to exercise direct control over energy use in industry. The most effective influence a private citizen can have is to develop an understanding of the energy used to make consumer products, and to choose products made by energy-efficient processes when possible. (See Section 20.2 for information on the energy needed to produce various products.)

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Exercises

17-1. In difficult economic times, one would expect industrial activity to change in proportion to commercial activity. Use the Internet to determine whether this proportionality occurred in the recession that happened in the first decade of the twenty-first century. Discuss and interpret your findings.

17-2. It has been said industry must turn to greater use of electrical energy relative to other energy forms in the future. What do you think is the basis for this statement? Do you agree? Why?