2009

Promoting Energy-Efficient Buildings in the Industrial Sector

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ALLIANCE TO SAVE ENERGY

Creating an Energy-Efficient World

Acknowledgements

The Alliance to save energy would like to thank the U.S. Department of Energy and BCS, Inc. for their support in this research effort. All opinions expressed in this paper are those of the individual authors and the Alliance to Save Energy (ASE), and in no way reflect those of any supporting organizations.

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Alliance to Save Energy

Founded in 1977, the Alliance to Save Energy is a non-profit coalition of business, government, environmental and consumer leaders. The Alliance to Save Energy supports energy efficiency as a cost-effective energy resource under existing market conditions and advocates energy-efficiency policies that minimize costs to society and individual consumers, and that lessen greenhouse gas emissions and their impact on the global climate. To carry out its mission, the Alliance to Save Energy undertakes research, educational programs, and policy advocacy, designs and implements energy-efficiency projects, promotes technology development and deployment, and builds public-private partnerships, in the U.S. and other countries.

Executive Summary

The industrial sector accounts for approximately one-third of total energy use in the United States and emits 28.7 percent of the country's greenhouse gases. Industrial processes, such as steam, process heating systems, compressed air and other mechanical equipment are the principle energy consumers in the industrial sector and have demanded the most scrutiny in the search for energy savings. For this reason, energy saving opportunities in the operation of industrial buildings are often overshadowed. Lesser, yet significant, amounts of energy are used for basic functionality of industrial buildings including heating, ventilation, and air conditioning (HVAC), lighting and facility use ("plug loads," e.g., computers, appliances, other office equipment).

Due to economic growth, energy demand in the industrial sector will continue to increase gradually. However, by improving HVAC, lighting, and other aspects of building operation, growth in industrial building energy requirements can be minimized. Analyses show that most of the technologies and measures to save energy in industrial buildings would be cost-effective with attractive rates of return. However, analysis of the U.S. Department of Energy's Industrial Assessment Centers' database of completed assessments reveals limited implementation of buildings-related measures by industrial companies.

This report investigates varying energy performance in buildings within the major subsectors of the manufacturing sector, as classified in the North American Industry Classification System (NAICS). Industrial subsectors with particularly high building energy consumption are identified as "building-intensive," as compared to remaining subsectors termed "process-intensive." Energy-saving opportunities are then explored by U.S. region and overall savings potential from industrial buildings is modeled and evaluated, along with associated CO_2 emissions reductions under the modeled scenarios.

Summary of Energy Savings Potential

In quantifying energy savings potential[1] in U.S. manufacturing buildings, this study contrasts two separate scenarios over the years 2007 to 2016. The "business-as-usual" (BAU) scenario assumes standard adoption of low-cost HVAC and lighting replacement technologies at a standard rate of turnover, according to ordinary operations and maintenance. In contrast, the optimal scenario assumes the replacement of HVAC and lighting equipment with market-mature energy-efficient technologies at an accelerated rate of turnover.

In comparing the two scenarios, accelerated adoption of high efficiency HVAC equipment revealed an energy savings potential of 122 trillion Btu (TBtu) by 2012, an 11.2 percent energy reduction as compared to the BAU scenario. Extending the timeline out to 2016, the model projected energy savings of 174 TBtu by HVAC equipment, representing a 15.5 percent reduction from business-as-usual. Substantial savings for lighting are also demonstrated,

[1] Energy saving potential estimated in this study is onsite energy saving.

identifying a 25 TBtu savings potential by 2012 and 37 TBtu by 2016—11.5 percent and 16 percent energy reductions from the BAU scenario, respectively (see Table ES-1).

Table ES-1. Lighting and HVAC Energy Saving Potential in the Manufacturing Sector (TBtu)

	Baseline	Scenarios				Savings			
	2002	2012		2016		2012		2016	
		BAU	Optimal	BAU	Optimal	TBtu	%	TBtu	%
HVAC	979	1,081	960	1125	951	122	11.2%	174	15.5%
Lighting	196	216	191	225	189	25	11.5%	37	16.3%
TOTAL	1,175	1,297	1,151	1,350	1,140	147	11.3%	211	15.7%

Table ES-2. Energy Saving Potential and Gross Benefit from the Manufacturing Sector

	2012			2016		
	Energy Savings	CO_2 Reduction (MMT)	Gross Benefit (million $)	Energy Savings	CO_2 Reduction (MMT)	Gross Benefit (million $)
Electricity	18 TWh	18.0	$1,900	26 TWh	26.4	$2,800
Natural Gas	84 TBtu	4.5	$650	120 TBtu	6.4	$930
TOTAL		22.5	$2,550		32.8	$3,730

*: In 2007, average electricity price for industry - 6.4 ¢/kWh and average natural gas price for industry - 7.73 $/1000 ft^3 are used to estimate gross benefit of energy savings.

The implications of these potential energy savings are noteworthy. To express these figures in terms of conventional power generation using MECS 2002 data as baseline, this study identifies an aggregate electricity savings potential of 26 TWh in 2016, the equivalent of nearly 9 Rosenfelds[2] (the consideration of 7 percent transmission and distribution losses are included), as the direct result of accelerated adoption of high efficiency lighting and HVAC systems in manufacturing facilities between 2007 and 2016. To account for the prevalence of natural gas as a primary fuel for heating systems in the industrial setting, only about 31 percent of heating systems was assumed to be electric and 69 percent[3] of heating systems was assumed to be gas-driven for modeling purposes. When including natural gas HVAC units, an additional 120 TBtu of natural gas could be saved by 2016.

Key Recommendations

Energy consumption is more relevant than ever as fuel prices continue to rise and the U.S. industrial sector is faced with adapting to a low-carbon economy. This study makes targeted recommendations to limit energy consumption by industrial buildings, which represent easily-achievable efficiency gains in overall industrial energy use.

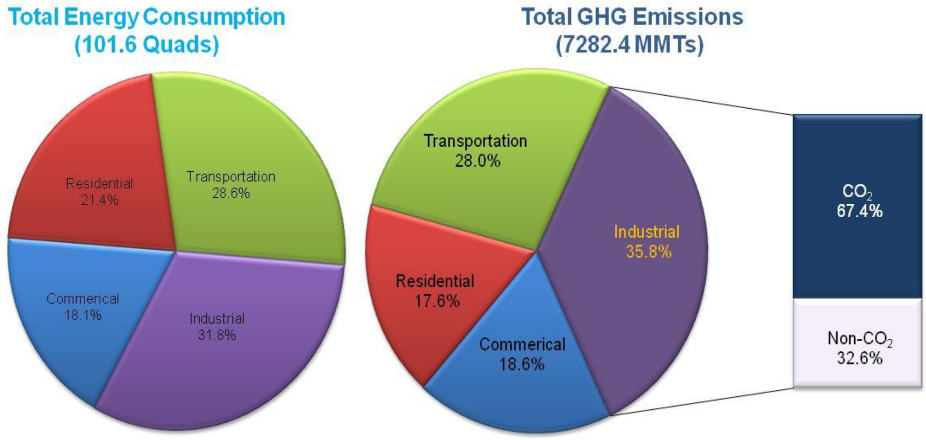
[2] A Rosenfeld, as defined by Koomey and Akbari et al. (2009), is a standardized unit of energy efficiency expressing the equivalent of one power plant avoided. For the purposes of this standardized metric, the follow power plant is profiled: 500mw coal plant operating at a 70% capacity factor with 7% T&D losses. Each rosenfeld unit implies 3 billion kWh/year in electricity savings and 3 million metric tons of CO_2 /year.
[3] These assumptions were drawn from modeling assumptions from the Energy Information Administration (EIA), "Integrating Module of the National Energy Modeling System (2008)."

Realizing these opportunities requires several actions at the program, policy, and facility levels. These actions include the collection of more comprehensive industrial energy data, implementing advanced energy management, setting and enforcing adequate energy standards for new industrial buildings, creating attractive financial incentives to retrofit existing facilities, and developing a well-trained workforce. These mechanisms, the cornerstones of enhanced efficiency in the industrial sector, are explored in greater detail in section 5 of this report as important stepping stones in the achievement of economic and environmental goals for U.S. industry. In general, these areas recommended in the following as opportunities to increase industrial buildings energy efficiency in United States:

- Voluntary programs fall into several areas survey participants
- Utility rebates and tax incentives
- Demand response technologies and programs
- Industrial buildings data
- Facility energy benchmarking
- ISO energy management standards
- New construction of buildings with stronger building energy code provisions
- Workforce development
- Equipment efficiency

1. Introduction

Producing the materials and goods that fuel the U.S. economy makes the industrial sector the largest single contributor to annual U.S. energy consumption. In 2007, U.S. energy consumption totaled 101.1 Quads, 32.2 percent of which was consumed by the industrial sector, 28.2 percent by the transportation sector, 21.4 percent by the residential sector and 18.2 percent by the commercial sector (see Figure 1.1) (EIA, 2009).



Note: Over 60% of non-CO_2 industrial GHG emissions come from agricultural sources such as methane and nitrous oxide.

Figure 1.1 Total Energy Consumption and GHG Emissions by Sector, 2007

Total U.S. energy consumption has experienced considerable growth, with aggregate energy use increasing by 34.6 percent between 1973 and 2007. However, much variability exists when comparing trends by sector within the U.S. economy. Between the years 1973 to 2007 residential sector energy consumption has increased by 45.7 percent, commercial sector consumption has increased 93.8 percent and transportation sector consumption has increased 55.1 percent (See Figure 1.2) (EIA, 2008a). Despite an upward trend of overall energy use, consumption within the industrial has remained relatively stable.

It is important to recognize a number of other factors account for this steady rate of consumption beyond increased energy efficiency. The most significant factor is continuous change to the structural makeup of the U.S. industrial sector over the past decade. These structural changes include outsourcing selected energy intensive manufacturing operations abroad (iron and steel, paper, rubber, cement, etc.) and the rapid growth of less energy intensive subsectors such as food processing and computers. Within this context, the industrial sector still provides abundant opportunities for energy efficiency improvements.

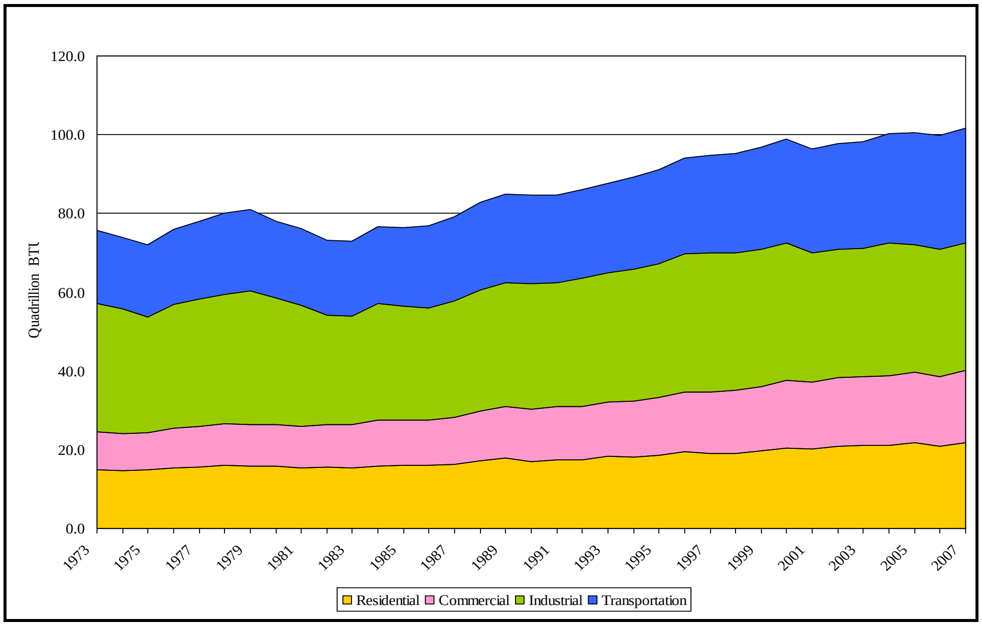


Figure 1.2. Energy Use Trends by Sector, 1973 to 2007

Source: EIA, 2008a

Figure 1.3 (BEA, 2009; DOE, 2008b), illustrates total U.S. industrial energy consumption, actual industrial energy intensity (Energy/Value Added to GDP), and economy-wide energy intensity from 1987 to 2007. Much has changed in the U.S. energy profile in the past two decades. Particularly noteworthy is the steady decline of industrial energy intensity, albeit partially due to structural change. Linking the efficiency gains of the industrial sector to the overall U.S. economy, it is apparent that the impacts of industrial efficiencies contribute considerably to economy-wide energy intensity.

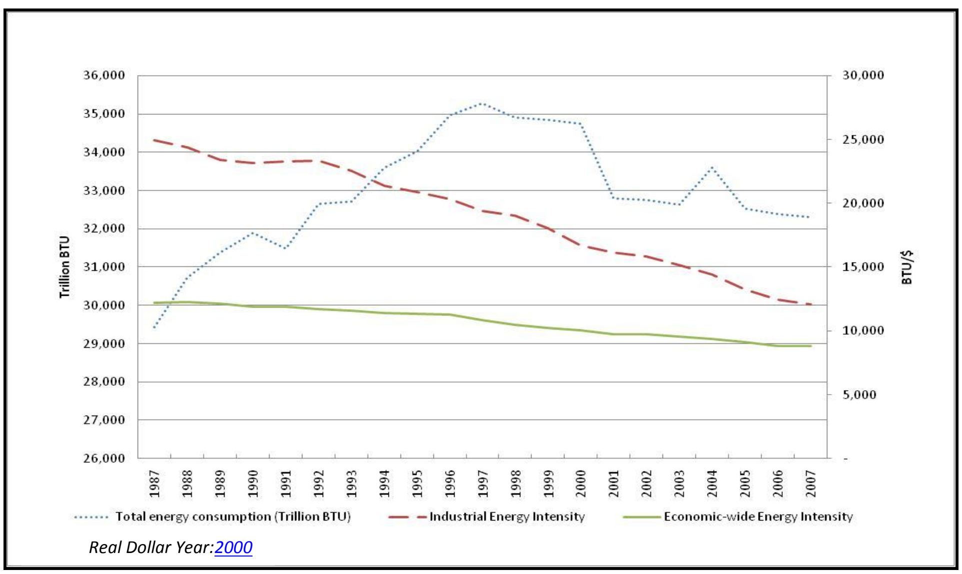


Figure 1.3. Industrial Energy Consumption and Intensity Trends, 1987 to 2007

Source: BEA, 2009; DOE, 2008

As indicated by the EIA data, buildings (commercial plus residential sector) are the largest energy user in the United States (EIA, 2009). Buildings consume about 72 percent of U.S. electricity and 55 percent of U.S. natural gas (EIA, 2009). When evaluating building energy consumption, it is important to note that energy use in commercial buildings includes energy required for all commercial activities within the building; likewise, residential buildings include all energy use associated with daily living activities. By way of this methodology, the buildings sector accounts for 39.6 percent of total U.S. energy consumption in 2007. Residential and commercial buildings accounted for 21 and 18 percent, respectively, of 2005 U.S. GHG emissions.

Industrial buildings are not included in these figures, but rather are grouped together with sector-wide industrial data; therefore industrial buildings have not received the same attention as commercial and residential building stock in the search for efficiency gains. Energy consumption by buildings in the commercial and residential sectors is well documented through federal reporting mechanisms such as the Commercial Building Energy Consumption Survey (CBECS) and the Residential Energy Consumption Survey (RECS). Energy use by the buildings that house the nation's manufacturing processes is not so thoroughly investigated. Industrial energy use is largely for various production processes requiring steam, heating and cooling, compressed air and electricity to power machinery. Due to the immense energy requirements of these industrial processes, energy consumption of their host buildings is often overlooked. The primary energy consumers for industrial buildings are similar to those in commercial buildings—mainly heating, ventilation and air conditioning (HVAC), lighting, and facilities ("plug loads," eg: computers, other office equipment and appliances)—although industrial buildings face a unique set of energy challenges including higher HVAC and lighting loads, and typically longer operating hours (See Figure 1.4) (DOE, 2008a). Nevertheless, recent studies have found that significant energy savings potential exists in industrial buildings without altering production processes in any way (EPA, 2007; Sentech, 2003).

This report investigates the energy use profile of industrial buildings within select manufacturing subsectors and evaluates energy saving opportunities that currently exist. Additionally, the report includes specific recommendations to capture available efficiency savings.

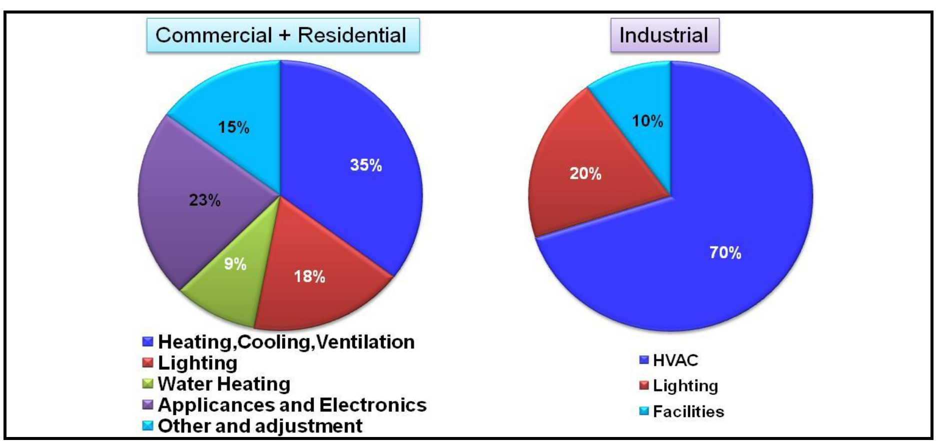


Figure 1.4. Energy Use Comparison; Commercial, Residential and Industrial Buildings

Source: DOE, 2008

2. Profile of Industrial Buildings Energy Use

Buildings in the industrial sector are used for offices, laboratories, warehousing, maintenance shops, and many other functions in addition to housing manufacturing processes and assembly lines. The industrial sector may be defined to include manufacturing, agriculture, forestry, mining (including oil and gas extraction), and construction. Within U.S. industry, the manufacturing sector is the largest energy consumer, representing about 85 percent of industrial energy consumption (see Figure 2.1) (DOE, 2004). Furthermore, the majority of industrial buildings are occupied by the manufacturing sector (EIA, 2007). For these reasons—in addition to data availability—this study will focus on buildings operated in manufacturing industries. Specifically addressed in this report are subsectors classified under North American Industry Classification System (NAICS) codes 31 through 33, including Food Processing, Textiles, Forest Products, Petroleum Refining, Chemicals, Plastics and Rubber Products, Glass and Glass Products, Cement, Iron and Steel, Fabricated Metal Products, Heavy Machinery, Computer/Electronics, and Transportation Equipment among others. A comprehensive listing of all subsectors included in this classification is found in table 2.1.

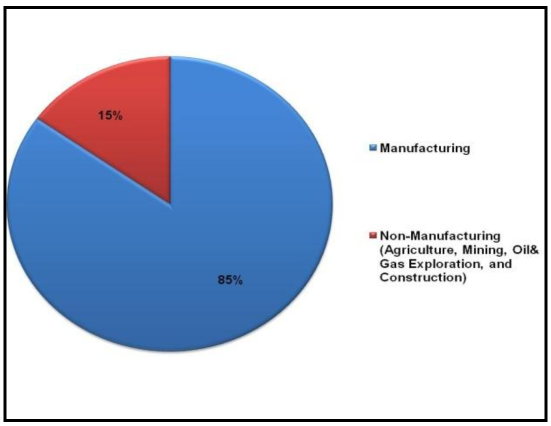


Figure 2.1. U.S. Industrial Sector Total Energy Use, Manufacturing vs. Non-Manufacturing

Source: DOE, 2004

The Manufacturing Energy Consumption Survey (MECS) conducted by EIA in 2002 reported energy use by industrial buildings as 10% of total energy consumption in the manufacturing sector and was negligible in nonmanufacturing industries; of this 10 percent, HVAC accounted for 7 percent, lighting for 2 percent and energy use by facilities, approximately 1 percent. According to MECS data, building-related energy use by the industrial sector is about 2.8 quads annually, though estimates cited in a recent NREL study are somewhat lower.

Table 2.1. Manufacturing Subsectors in Industry

NAICS Code	Manufacturing Subsector
311	Food Manufacturing
312	Beverage and Tobacco Product Manufacturing

313	Textile Mills
314	Textile Product Mills
315	Apparel Manufacturing
316	Leather and Allied Product Manufacturing
321	Wood Product Manufacturing
322	Paper Manufacturing
323	Printing and Related Support Activities
324	Petroleum and Coal Products Manufacturing
325	Chemical Manufacturing
326	Plastic and Rubber Products Manufacturing
327	Nonmetallic Mineral Product Manufacturing (including Glass, Glass Products and Cement)
331	Primary Metal Manufacturing (including foundries, iron and steel)
332	Fabricated Metal Product Manufacturing
333	Machinery Manufacturing
334	Computer and Electronic Product Manufacturing
335	Electrical Equipment, Appliance and Component Manufacturing
336	Transportation Equipment Manufacturing
337	Furniture and Related Product Manufacturing
339	Miscellaneous Manufacturing

Source: NAICS, 2009

The Manufacturing Energy Consumption Surveys[4] (MECS) conducted by the EIA in 1998 and 2002 indicated a net decrease in floorspace in the industrial sector due to sizable floorspace reductions in most energy-intensive subsectors—most notably chemicals, heavy machinery, petroleum, and primary metals—as a direct result of structural change. Similarly, labor-intensive industries, such as textiles and computer/electronics, relocated domestic facilities overseas to pursue lower labor costs and access to international markets, also resulting in a significant drop in subsector floorspace (See Figures 2.2) (MECS; 1998, 2002). The nonmetallic minerals (mainly glass and cement) industry was an exception; its floorspace increased over 15 percent. Traditional plant relocation strategies are typically ineffective for U.S. nonmetallic minerals companies due to the high cost of shipping associated with moving heavy product for U.S. sales.

[4] The DOE Energy Information Administration's Manufacturing Energy Consumption Survey is a national energy consumption survey for the manufacturing sector. The past MECS data are available for 1985, 1988, 1991, 1994, 1998 and 2002 at the EIA website. The 2006 MECS full report was not released as of June 2009.

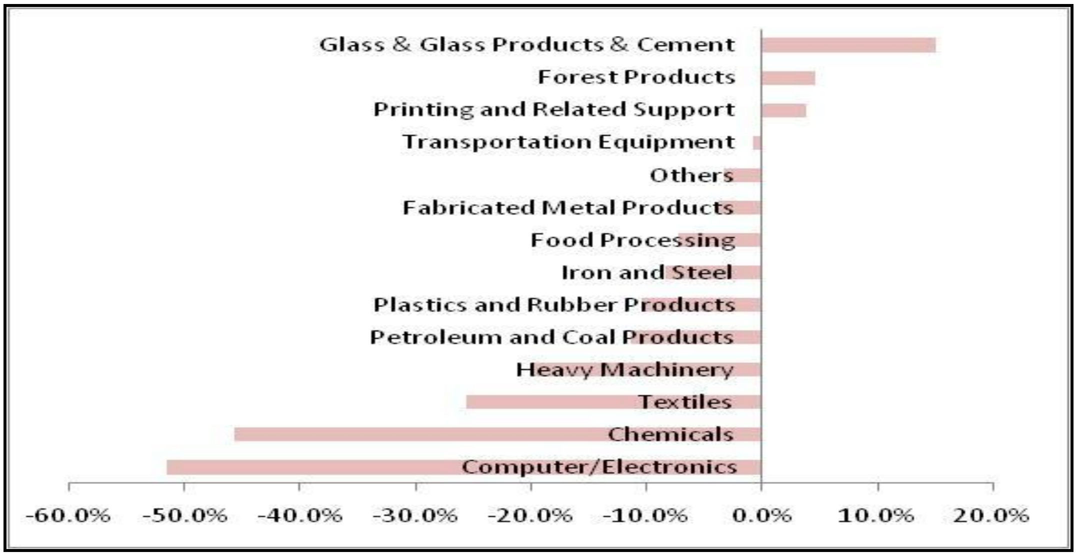


Figure 2.2. Percent Change in Enclosed Floorspace in Manufacturing Subsectors, 1998 to 2002

Source: MECS; 1998, 2002

As a result of these structural shifts, less energy intensive manufacturing subsectors are growing in size to fill the industrial void. These subsectors are particularly attractive prospects for building energy improvements, as buildings represent a higher portion of the overall subsector energy profile. A recent regression analysis by Price (2008) reveals a linear relationship between number of employees and enclosed floorspace within the manufacturing sector. Thus, this study chose number of employees as a proxy of enclosed floorspace, assuming floorspace is directly related to employment numbers. According to the U.S. Bureau of Economic Analysis (BEA, 2008) the manufacturing subsectors experienced a dramatic decline in employees between 1998 and 2002 and was relatively stable between 2002 and 2006. Figure 2.3 plots these numbers. Using information from MECS 2003, this study extends Price's analysis to estimate enclosed floorspace based on employment numbers in each sub-sector.

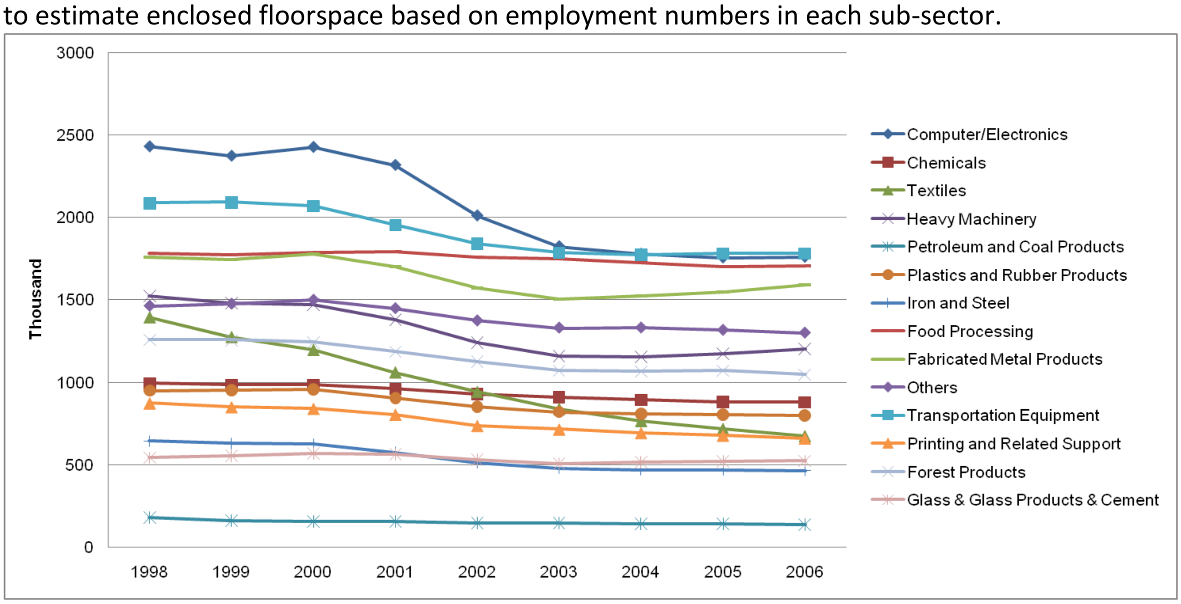


Figure 2.3. Employment Trend in Manufacturing Subsectors from 1998- 2006

Source: BEA, 2008

The 2002 MECS also indicated that the energy use for HVAC and lighting varies significantly across the manufacturing sector. The 2002 MECS was used to determine the total energy consumption in 14 manufacturing subsectors. A comparison of facility plug loads (e.g: office equipment, computers etc.), lighting and HVAC is illustrated by Figures 2.4 and 2.5.

Figure 2.4 (MECS, 2002) indicates that the primary energy use for industrial processes overshadows the non-process energy use, but it also illustrates the variance of building energy consumption by industrial subsector. In fact, industrial building energy use (sum total of HVAC, lighting and facilities) ranges from 7 TBtu to 292 TBtu in various subsectors, comprising anywhere from 4.3 percent to nearly 41 percent of total subsector energy consumption (See Figure 2.5). This information suggests that building-related energy efficiency measures will be of more importance in certain sectors. These sectors, denoted as “building-intensive” for the purpose of this report, include Computers/Electronics, Heavy Machinery, Transportation Equipment, Fabricated Metals, Foundries, Plastic/Rubber Products, and Textiles. The remainder of manufacturing subsectors examined in this paper will be considered “process-intensive”.

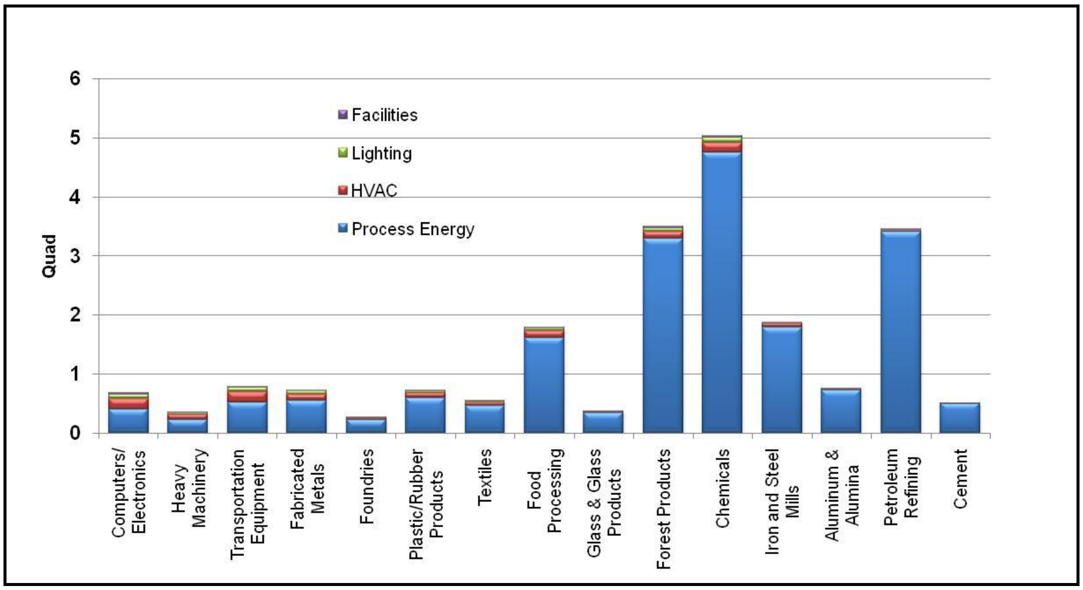


Figure 2.4. Primary Energy Use of Process/Facilities/Lighting/HVAC by Manufacturing Subsector

Source: MECS, 2002

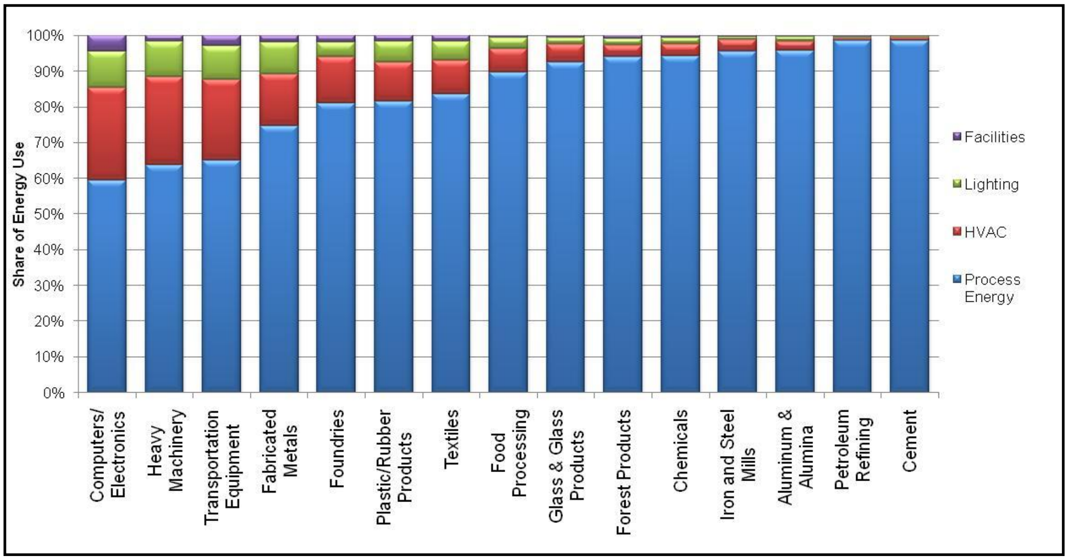


Figure 2.5. Proportional Energy Use for Process/Facilities/Lighting/HVAC by Manufacturing Subsector

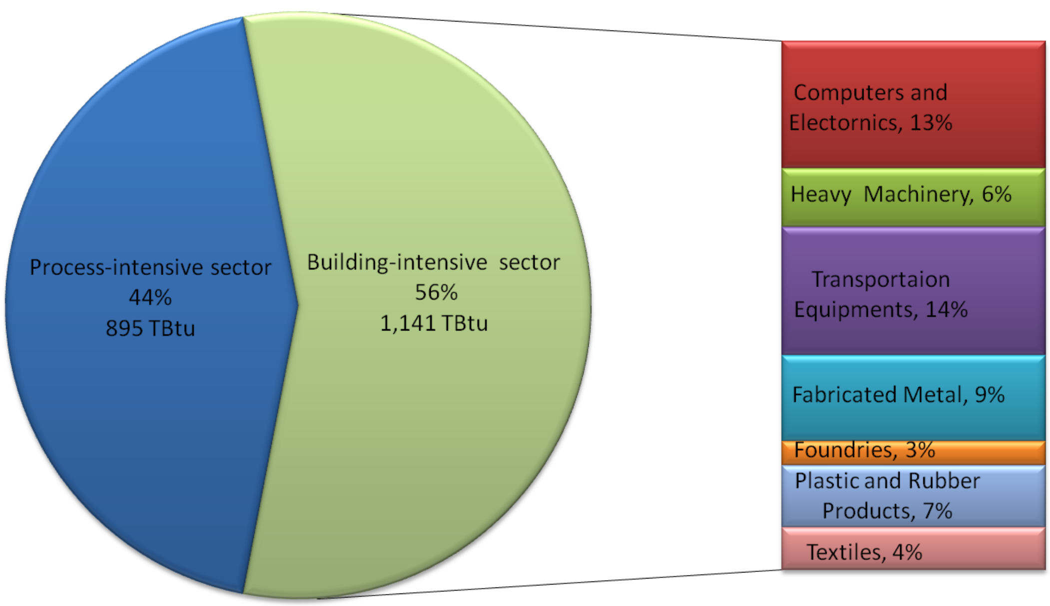


Figure 2.6. Enclosed Floorspace Area by Building-intensive and Process-intensive Sectors

Figure 2.6 indicates the distribution of enclosed floorspace in the manufacturing sector for 2002. Total enclosed floorspace area is 10,641 million ft^2 of which 5,770 million ft^2 (54%) is located in building-intensive sectors, 4,871 million ft^2 (46%) is located in process-intensive sectors. The building-intensive sector, as defined for this study, includes computer/electronics, heavy machinery, transportation equipment, fabricated metals, foundries, plastic/rubber products and textiles.

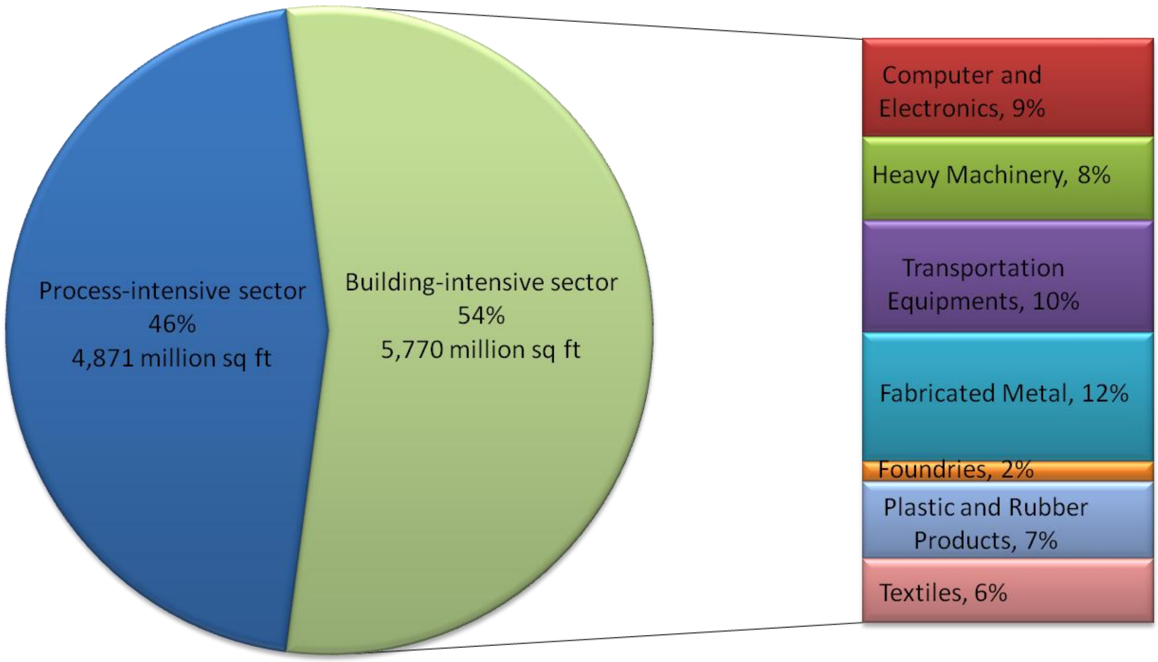


Figure 2.7. Energy Use in Enclosed Floorspace by Building-intensive and Process-intensive Sectors

The building-intensive sector consumed 1,141 TBtu for HVAC, lighting and facilities applications in buildings. In contrast, the process-intensive sector used 895 TBtu for the same applications in buildings.

Energy use per square footage in enclosed floorspace by manufacturing subsectors is estimated using MECS 2002 data(Table 2-2). The table shows that building-intensive facilities have higher energy use per square footage than process-intensive facilities, and the computers/electronics subsector has the highest energy use per square footage within the building-intensive group, followed by foundries and transportation.

Table 2-2 Energy Usage of Enclosed Floorspace per Square footage in Manufacturing Sector

	Energy Use for Buildings (TBtu)	Floorspace (million ft^2)	Energy Intensity (Therm/ft^2)
Process-intensive	894.87	4871.29	1.84

Building-intensive	1141.44	5769.71	1.98
Computers/Electronics	274.42	974.00	2.82
Heavy Machinery	127.90	825.00	1.55
Transportation	276.92	1111.00	2.49
Fabricated Metal Products	184.98	1277.00	1.45
Foundries	51.49	192.71	2.67
Plastics and Rubber Products	135.12	767.00	1.76
Textiles	90.61	623.00	1.45

According to Figure 2.7, Computers/Electronics and Transportation are also the two largest building energy consumers, followed by fabricated metals in building-intensive sector.

3. Energy Efficiency Improvements in the Manufacturing Sector

To further distinguish between building-related and process-related energy consumption in the manufacturing sector, data from the university-based Industrial Assessment Centers (IACs) were evaluated. The IAC database was developed to catalog information from assessments of small and medium-sized manufacturing facilities performed by the IACs, which are a part of the Industrial Technologies Program within the U.S. Department of Energy (DOE). To date more than 90,000 recommendations have been made by DOE ITP. Each recommendation is industry-specific in accordance with the North American Industry Classification System (NAICS) or the older Standard Industrial Classification (SIC) code and classified using an Assessment Recommendation Code (ARC), which represents the principal product manufactured by the plant and the energy efficiency recommendation type. According to information provided in the IAC database, the majority of building-related recommendations included adjustments or upgrades to cooling towers, chillers and refrigeration, space heating, ventilation, and lighting. Process-related recommendations were specific to industrial equipment and process improvements. Figures 3.1 and 3.2 provide a summary of implemented projects by type.

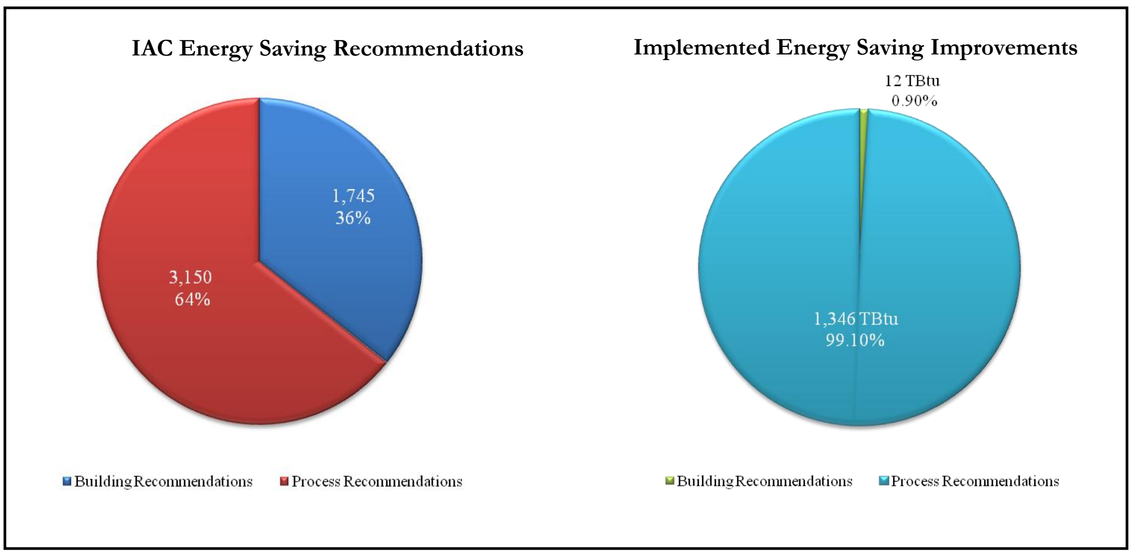


Figure 3.1. Energy Saving Recommendations vs. Implemented Improvements in Building-Intensive Plants

Source: IAC, 2008

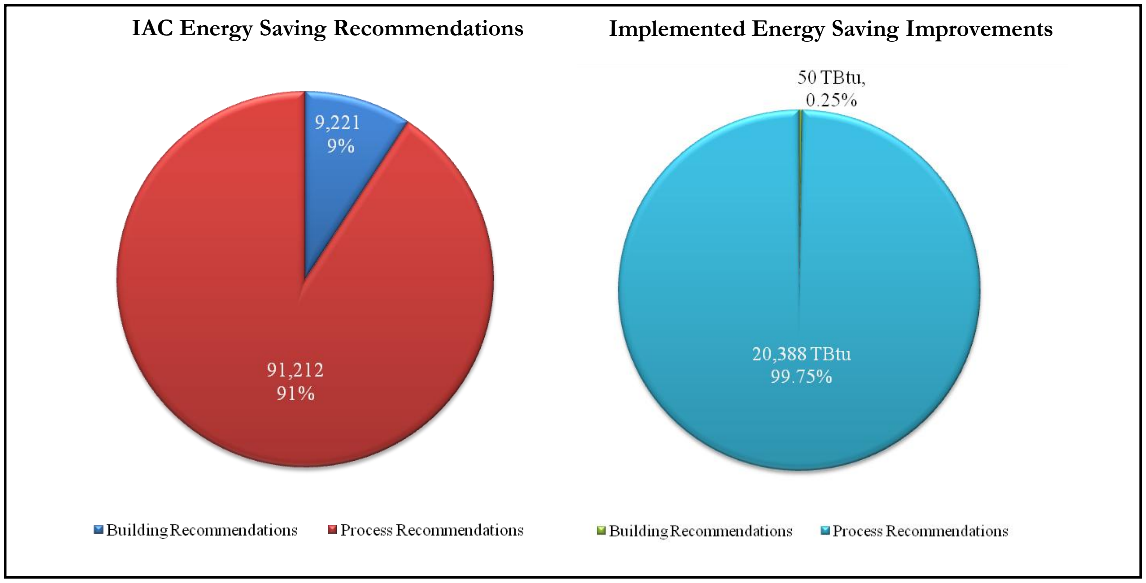


Figure 3.2. Energy Saving Recommendations vs. Implemented Improvements in Process-Intensive Plants

Source: IAC, 2008

Despite a focus on process energy in the industrial sector, the data show that opportunities to enhance building efficiency are recognized by IAC assessments, as building-related energy efficiency recommendations represent 36 percent and 9 percent of total efficiency recommendations for building-intensive and process-intensive facilities, respectively. However, when comparing these proportions to energy efficiency modifications that are actually implemented, process efficiency is clearly positioned "top-of-mind". Figures 3.1 and 3.2 also correspond to IAC energy efficiency recommendations applied in the industrial sector as a result of an energy assessment. In each category, building-intensive and process-intensive, implemented building enhancements makeup less than 1 percent of total industrial energy efficiency improvements. These findings imply that industrial facilities are reluctant to implement building efficiency upgrades despite recommended action.

IAC case studies (DOE, 2003;2006) state most energy saving measures recommended for industrial buildings have short, simple payback periods, which are typically less than 2 years and often less than 6 months. In contrast, many energy saving technologies recommended for industrial processes have payback periods longer than 2 years.

4. Methodology for Energy Savings Potential Analysis

To evaluate the potential for energy savings (as well as GHG emissions reduction), this report creates an energy efficiency benchmark for improving industrial building lighting and HVAC applications. Energy use for facilities' loads is negligible relative to lighting and HVAC energy use, and is therefore not considered in the subsequent discussion. Lighting use in the industrial sector is consistent by region; however, the energy use by HVAC varies greatly from one region to another. This report adopts the four major regions defined by the US Census Bureau to evaluate the energy consumption by HVAC in these four regions: Northeast, Midwest, South, and West. The states in each region are listed in Table 4.1 and illustrated as Figure 4.1.

Table 4.1. Four Census Regions for HVAC Energy Use Analysis

	States
Northeast	ME, NH, VT, MA, RI, CT, NY, NJ, PA
Midwest	OH, IN, IL, MI, WI, MN, IO, MO, ND, SD, NE, KS
South	DE, MD, DC, VA, WV, NC, SC, GA, FL, KY, TN, AL, MS, AR, LA, OK, TX
West	MT, ID, WY, CO, NM, AZ, UT, NV, WA, OR, CA, AK, HI

Source: Census Bureau, 2008

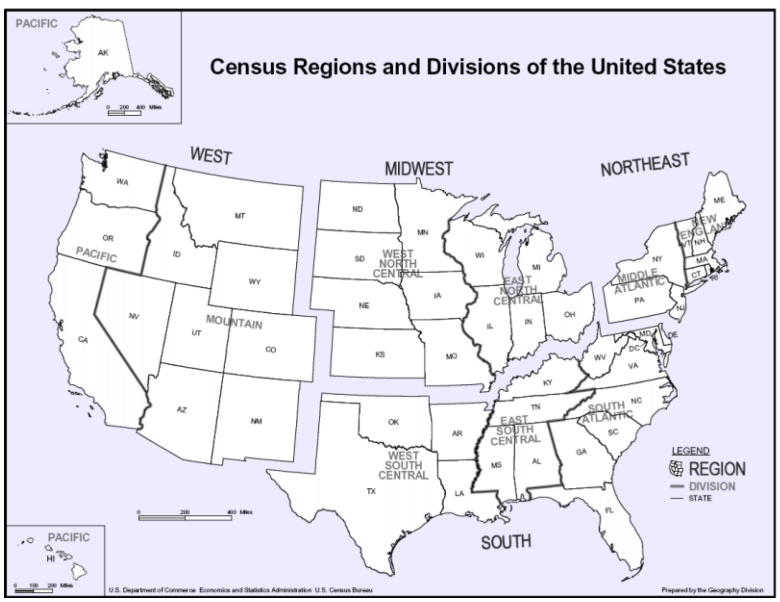


Figure 4.1. Census Region Classification Map

Source: Census Bureau, 2008

The following analysis evaluates energy use in industrial buildings by subsector. Our analysis is focused on lighting and HVAC energy consumption and provides energy use forecasts for each subsector under business-as-usual ("BAU") and an alternative high efficiency scenario ("Optimal scenario"). Since no single data source currently exists for energy use by industrial lighting and HVAC, the analysis involved pulling key information from various reports, then developing an integrated spreadsheet model to estimate the energy consumption of lighting and HVAC in industrial buildings in 2012 and 2016, using 2002 as the base year. This spreadsheet model evaluates the overall potential for energy efficiency improvements in industrial buildings. The time horizon of the analysis was selected to align with the voluntary agreements target of 2016 per EPACT-05[5].

Key documents and organizations supporting our analysis include: EIA MECS 2002, a 2008 DOE study examining energy consumption in select industrial subsectors, a 2006 Navigant study (Navigant, 2006) providing a comprehensive lighting inventory for select manufacturing subsectors, and office of Energy Efficiency and Renewable Energy's (EERE) Federal Energy Management Program (FEMP) resources for HVAC equipment efficiency metrics and product lifetimes.

"BAU Scenario"

Our analysis uses figures for total lighting fixtures per subsector classified by lamp type, average operating hours by subsector, and average wattage by fixture according to DOE-funded research (Navigant, 2003). This model assumes standard lighting devices will be gradually upgraded to high-efficiency lighting devices at an annual turnover rate of 10%. Additionally, all incandescent bulbs with energy requirements between 40 watts and 150 watts will be fully phased out according to the Clean Energy Act of 2007.

Table 4.2. Parameters for HVAC Equipment Applications

	Heating	**Cooling**
Energy Source	Gas: 69% Electricity: 31%	Gas: 7% Electricity: 93%
Equipment Type	Boiler, Heat Pump	Unitary AC, Chiller
Efficiency & Lifetime	Data are adopted based on FEMP Energy Efficient Products Purchasing Specifications	

Source: EIA, 2008b; FEMP, 2009.

Due to a shortage of comprehensive HVAC data, our analysis developed an HVAC inventory for the U.S. manufacturing sector based on total heating and cooling energy consumption within the sector from a recent Department of Energy study (DOE, 2004). Primary fuel distribution data (see Table 4.2) and FEMP equipment consumption metrics also were critical in the development of an HVAC inventory. For the purposes of this model, manufacturing HVAC systems are generally comprised of the following technologies: commercial unitary air conditioners, air-cooled chillers, water-cooled chillers, commercial heat pumps, ground-source heat pumps, and boilers. Under the BAU scenario, these systems are replaced in the analysis according to standard FEMP equipment lifetimes (see Table 4.3). To account for general manufacturing sector expansion, equipment inventories are assumed to grow at a rate of 1 percent.

[5] EPAct of 2005 calls for voluntary agreements with members of the industrial sector to reduce the energy intensity of their production activities by 2.5 percent per year from 2007-2016.

Table 4.3. Energy Use and Lifetime by Typical Size of Selected Heating and Cooling Equipment

	Annual Energy Use		Lifetime (year)
	BAU	Optimal	
Commercial Unitary AC	19,600 kWh	15,800 kWh	15
Air-Cooled Chillers	250,000 kWh	196,000 kWh	23
Water-Cooled Chillers	680,000 kWh	560,000 kWh	23
Commercial Heat Pumps	37,100 kWh	33,800 kWh	15
Ground-source Heat Pumps	37,700 kWh + 1,970 therms	30,700 kWh + 430 therms	15
Boilers	962,000 therms	937,000 therms	25

Source: FEMP, 2009

"Optimal Scenario"

Under the Optimal scenario, the replacement of conventional lighting fixtures with high efficiency fixtures is accelerated to a lighting turnover rate of 20% per year. This rate of turnover simulates an aggressive effort to improve building energy-efficiency, and is also aligned with the EPACT-05 energy intensity reduction target of 25% by 2016. The lighting replacement options assumed under our optimal scenario include:

1. T12 to T8 Fluorescent (25%-50% savings)
2. HID to Fluorescent (25%-60% savings)
3. Incandescent to Compact Fluorescent (75% savings)
4. Efficient Mercury Vapor Replacement (40% savings)

It is important to note that total fixture count by subsector and assumed operating hours by facility remain constant throughout the modeling of the both scenarios.

Table 4.4. Comparison of BAU and Optimal Scenarios

	BAU SCENARIO	**Optimal SCENARIO**
Lighting Model	• Base year 2002 • Standard Rate of Lamp/Fixture Turnover (10%) • No incandescent lamps after 2014 • Annual Growth Rate of 1%	• Base year 2002 • Standard Rate of Lamp/Fixture Turnover (20%) • No incandescent lamps after 2014 • Assumed compliance w/ EPACT-05; energy intensity reduction of 25% by 2016 • Annual Growth Rate of 1%
HVAC Model	• Base year 2002 • Equipment distribution according to NEMS data • Replacement with equivalent equipment due to regular O&M • Turnover rate according to FEMP equipment lifetime	• Base year 2002 • Equipment distribution according to NEMS data • Replacement with efficient equipment according to FEMP specifications • Accelerating turnover rate 4-7% higher than FEMP equipment lifetime

	• Annual Growth Rate of 1%	• Annual Growth Rate of 1%

The optimal scenario includes accelerated replacement with high efficiency HVAC units assumed to be 4 to 7 percent higher than typical equipment lifetimes depending on the type of HVAC equipment. HVAC equipment replacements employ comparable high efficiency alternatives that are commercially available today (see Table 4.3).

5. Estimation of Energy Savings Potential

Table 5.1 summarizes the results of the modeling for the savings potential in lighting and HVAC from buildings in the manufacturing sector. Under the BAU scenario, energy use by lighting steadily increases from 216 trillion Btu in 2012 to 225 trillion Btu in 2016. However, in the Optimal scenario, overall energy use by lighting decreases slightly from 191 trillion Btu in 2012 to 189 trillion Btu in 2016. The Optimal scenario represents an energy reduction of 11.5 percent by 2012 and 16.27 percent by 2016 as compared to business-as-usual.

The results are similar under the HVAC modeling. In the BAU scenario, energy use by HVAC increases from 1081 trillion Btu in 2012 to 1125 trillion Btu in 2016. Under the Optimal scenario, HVAC energy use is reduced slightly from 960 trillion Btu in 2012 to 951 trillion BTU in 2016. The HVAC energy savings potential under Optimal scenario conditions are 11.2 percent by 2012 and 15.5 percent by 2016 relative to business as usual.

The model indicates an attractive opportunity exists to reduce consumption for lighting and HVAC. According to this model, a 15.7 percent building energy savings is achievable under the Optimal Scenario (see Table 5.1). Table 5.2 summarizes the savings potential in terms of electricity and natural gas, as well as estimated cost savings. The total potential cost savings by 2010 is $1,815,000, and $2,620,000 by 2016.

Table 5.1. Lighting and HVAC Energy Saving Potential in the Manufacturing Sector (TBtu)

	Baseline	Scenarios				Savings			
	2002	2012		2016		2012		2016	
		BAU	Optimal	BAU	Optimal	TBtu	%	TBtu	%
HVAC	979	1,081	960	1125	951	122	11.2%	174	15.5%
Lighting	196	216	191	225	189	25	11.5%	37	16.3%
TOTAL	1,175	1,297	1,151	1,350	1,140	147	11.3%	211	15.7%

Table 5.2. Energy and Cost Savings Potential from Buildings in the Manufacturing Sector

	2012		2016	
	Energy Savings	Cost Savings (million $)	Energy Savings	Cost Savings (million $)
Electricity	18.2 TWh	1,165	26.4 TWh	1,690
From Lighting	7.2 TWh	461	10.7 TWh	685
From HVAC	11.0 TWh	704	15.7 TWh	1005
Natural Gas	84 TBtu	650	120 TBtu	930
TOTAL		1,815		2,620

*: In 2007, average electricity price for industry - 6.4 ¢/kWh and average natural gas price for industry - 7.73 $/1000 ft^3 are used to estimate gross benefit of energy savings.

In specific geographic regions, the analysis found little variation in lighting energy consumption for facilities of the same or similar type. However, some regional differences were found in the consumption of energy for heating and cooling. The South region consumes more energy for heating and cooling than any other region, followed by Midwest region, then the Northeast and West. Examining cooling demands explicitly, the greatest electricity consumer is the South region, followed by the Midwest. Roughly equivalent were the Northeast and the West regions, which consume the least energy for cooling.

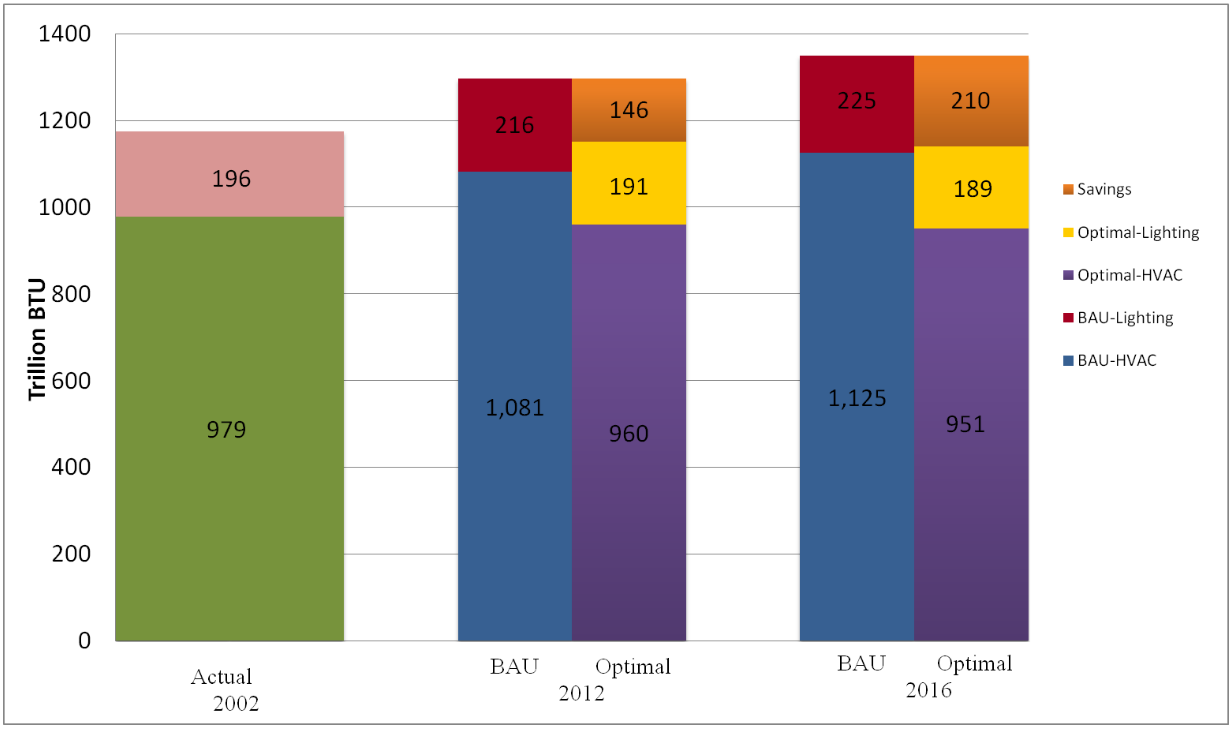


Figure 5.1. Energy Consumption Estimates for Lighting, HVAC in Manufacturing Sector

Analysis indicates an annual energy savings potential of 7.2 TWh by 2012 and 10.7 TWh by 2016 from lighting alone. HVAC energy savings potential totals 11.0 TWh of electricity and 84.2 trillion Btu of natural gas by 2012 and 15.7 TWh of electricity and 120.4 trillion Btu of natural gas by 2016. A standard metric for electricity savings – the Rosenfeld Unit – is defined by Koomey and Akbari et al. (2009). Given the average coal-fired power plant capacity of 500 MW with 70% capacity factor, plus 7 percent of system-wide transmission and distribution losses, a unit of Rosenfeld is equal to annual electricity delivered at the meter of about 3 TWh per year. The CO_2 emissions abatement from saving one Rosenfeld is estimated at 3 MMT per year using the average CO_2 emission factor and efficiency of existing coal power plants. Therefore, the electricity savings potential in manufacturing buildings from HVAC and lighting is equivalent to 6 Rosenfelds by 2012. Energy savings potential forecasted out to 2016 is the equivalent of 8.8 Rosenfelds. Annual energy savings from lighting and HVAC systems has the potential to reduce carbon emissions from fossil fuel combustion by an estimated 22.5 million metric tons by 2012. Carbon abatement potential by 2016 is estimated at 32.8 million metric tons (see Figure 5.2 and 5.3).

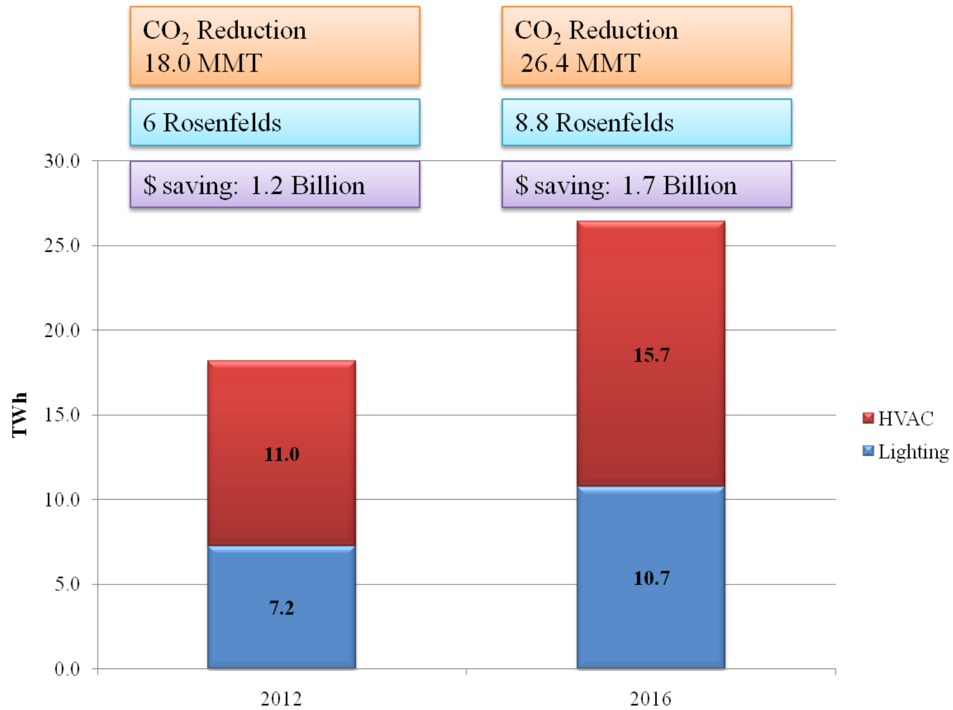


Figure 5.2. Potential Electricity Savings from Lighting and HVAC in 2012 and 2016

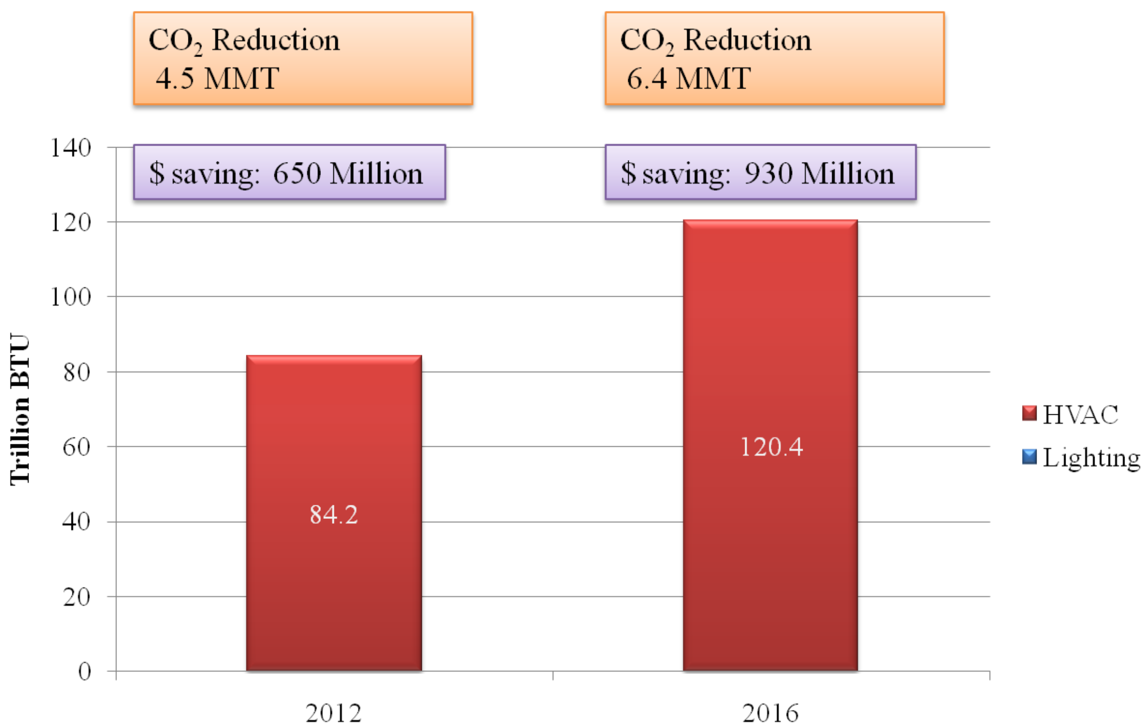


Figure 5.3. Potential Natural Gas Savings from HVAC in 2012 and 2016

6. Recommendations

A number of existing programs and activities can be tailored to the industrial sector to achieve energy savings and reduce greenhouse gas emissions, especially in the building-intensive subsectors. These programs and initiatives have proven effective when applied to commercial and institutional buildings. These opportunities fall into several areas:

- Voluntary programs - Support the inclusion of lighting and HVAC system improvement in voluntary initiatives and recognition programs for the manufacturing sector. This includes programs at the utility, state, and federal levels.
- Utility rebates and tax incentives - Encourage industry participation in utility demand-side management (DSM) programs, demand-response incentive rates, federal and state tax incentives, and other market transformation initiatives that provide incentives for manufacturers to invest in more efficient lighting and HVAC equipment and other energy-efficient building technologies.
- Demand response technologies and programs - Encourage deployment and facilitation of demand response technologies and programs.
- Industrial buildings data - Encourage the Energy Information Administration to work with industry representatives, utilities, and others to identify ways to improve MECS data collection and other estimates of non-process energy end-uses, energy-related facility characteristics, and key trends.
- Facility energy benchmarking - Include metrics for building energy performance as well as process efficiency in voluntary energy benchmarking systems developed for use by industry.
- ISO energy management standards - Similarly assure that international energy management standards for industry, being developed as part of an ISO process, incorporate facility as well as process efficiency.
- New construction - Work with ASHRAE and other code development bodies, as well as state and local code adoption and enforcement agencies, to strengthen the building energy code provisions for construction or renovation of industrial and mixed-use buildings.
- Workforce development - Expand activities of the Industrial Assessment Centers program at DOE, and encourage students and faculty to address both facility and process energy uses and savings opportunities.
- Equipment efficiency - In consultation with NEMA, Energy Star, and other organizations and initiatives, the Department of Energy should explore opportunities to expand voluntary energy testing, rating, and labeling of additional categories of high-efficiency building equipment used in industrial facilities (e.g., in addition to the NEMA Premium rating for motors and transformers, consider energy ratings and recognition for industrial boilers and chillers, industrial lighting systems, and other non-process equipment and systems).

7. Conclusions

Energy use by industrial buildings has received little attention to date, but the lighting and HVAC areas present substantial energy savings potential. Many strategies to reduce energy consumption in industrial buildings exist, such as fixture/equipment replacement, automated energy management, and behavioral change, (e.g.: turning off lights when rooms are unoccupied, lowering heating setting or raising cooling setting). Even more energy savings could be achieved through accelerated lamp and ballast replacement -- exchanging the use of incandescent bulbs with compact fluorescent lamps and replacing older T12 and T8 lamps and ballasts with T8 or T5 lamps and ballasts. Based on results achieved in commercial building efficiency improvement projects, most of the potential savings can be achieved cost-effectively, having short payback periods and high rates of return. A recently published paper from DOE concludes that most building efficiency installations can occur during normal facility operation, alleviating concerns of equipment downtime or reduction in productivity (Butters, 2009).

This study illustrates that energy efficient HVAC and lighting technologies and improved energy management practices for industrial buildings are not widely adopted in the industrial sector. For HVAC system improvements, there are concerns about first-cost and performance risk. Both lighting and HVAC energy costs make up a small percentage of total energy expenditures for the manufacturing sector as a whole, therefore many facility managers have focused less on these systems than efficiency investments in process equipment and systems. However, as demonstrated, for selected subsectors that do not involve heavy process energy loads, building-related energy uses represent a significantly higher share of total energy use and cost, and thus merit more attention from both facility and corporate managers.

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