Understanding the 2010 Manufacturing Energy and Carbon Footprints

The Manufacturing Energy and Carbon Footprints map energy use and combustion greenhouse gas (GHG) emissions from energy supply to end use. Footprints are published for 15 manufacturing sectors (representing 95% of all manufacturing energy use and 94% of U.S. manufacturing combustion GHG emissions) and for U.S. manufacturing as a whole (NAICS 31 – 33). These sectors are described in more detail in the document *2010 Manufacturing Energy and Carbon Footprints: Scope*.

Manufacturing Energy and Carbon Footprint Sectors:

All Manufacturing	Foundries
Alumina and Aluminum	Glass and Glass Products
Cement	Iron and Steel
Chemicals	Machinery
Computers, Electronics, and Electrical Equipment	Petroleum Refining
Fabricated Metals	Plastics and Rubber Products
Food and Beverage	Textiles
Forest Products	Transportation Equipment

Each footprint visualizes the flow of energy (in the form of fuel, electricity, or steam) to major end uses in manufacturing, including boilers, power generators, process heaters, process coolers, machine-driven equipment, facility heating, ventilation, and air conditioning (HVAC), and lighting. The footprints present data at two levels of detail. The first page provides a high-level view of primary energy (offsite and onsite), while the second page shows details of how energy is distributed to onsite end uses. It is important to note that energy consumed as a feedstock (i.e., nonfuel energy supply that is converted to manufactured product and not used for heat, power, or electricity generation) is not included in the energy values presented in footprints[1].

Aggregate data provided in each of the sectors includes:

- Electricity and steam generated offsite and transferred to the facility, as well as electricity and steam generated onsite
- Fuel, electricity, and steam consumed by major end uses in a manufacturing facility
- Offsite and onsite energy losses due to the generation, transmission and distribution, and end use consumption of energy (some losses are unrecoverable)
- Greenhouse gas emissions released during the combustion of fuel

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[1] Energy used as a nonfuel feedstock is quantified separately for each manufacturing sector in EIA MECS Table 2.2; though caution should be exercised when combining nonfuel feedstock energy with onsite energy use values due to potential double-counting issues.

Stakeholders, analysts and decision-makers can utilize the Manufacturing Energy and Carbon Footprints to better understand the distribution of energy use in manufacturing sectors and to compare the use, loss, and combustion GHG emission characteristics within and across sectors. Within a footprint, areas of high energy consumption or significant energy losses can indicate opportunities to improve efficiency by implementing energy management best practices, upgrading energy systems, or developing new technologies. The footprints provide a macro-scale benchmark from which to calculate the benefits of improving energy efficiency and for prioritizing opportunity analysis in manufacturing

The Role of Energy Efficiency

The U.S. manufacturing sector depends heavily on energy resources to provide fuel, power and steam for the conversion of raw materials into usable products. The efficiency of energy use, as well as the cost and availability of energy, consequently have a substantial impact on the competitiveness and economic health of U.S. manufacturers. More efficient use of energy lowers production costs, conserves limited energy resources, and increases productivity. The more efficient use of energy also has positive impacts on the environment, including reduced emissions of greenhouse gases (GHGs) and air pollutants.

Energy efficiency varies across the various process and non-process end uses within each sector. The physical and chemical parameters of a process, as well as equipment design, age, and operating and maintenance practices, can lead to real-world performance below the ideal efficiency. Less-than-optimal energy efficiency means that some of the input energy is lost either mechanically or as waste heat. In the manufacturing sector, energy losses amount to billions of dollars of energy costs each year, and millions of metric tons of GHG emissions.

It is clear that increasing the efficiency of energy use could result in substantial benefits to both U.S. manufacturers and the nation. Unfortunately, the sheer complexity of the thousands of processes used in the manufacturing sector makes this a daunting task. There are, however, significant opportunities to address energy efficiency in the common energy systems that are used across manufacturing, such as onsite power systems, fired heaters, boilers, pumps, facility HVAC equipment, and others. A first step in realizing these opportunities is to identify how industry is using energy. Where does it come from? What form is it in? Where is it used? How much is lost? Answering these questions for U.S. manufacturing sectors is the focus of the footprint analysis.

Carbon Footprint Analysis

In addition to energy, the footprint analysis also shows combustion GHG emissions in units of million metric tons of carbon dioxide equivalent. The GHG footprint calculations conform to the EPA GHG mandatory reporting requirements, including emissions calculations and fuel-specific emission factors. Unique emission factors were used for each sector based on fuel type breakdown. Process emissions are excluded from the analysis as these are not directly related to the use of energy as fuel. Emissions are reported as CO_2-equivalent (CO_2e), as per the GHG reporting requirements. CO_2e consists of contributing CO_2, CH_4, and NO_2 emissions. More details on the carbon footprint analysis methodology are shown in the document *2010 Manufacturing Energy and Carbon Footprints: Definitions and Assumptions*.

A Walkthrough of the Footprints

These footprints are based on an analytic model that was developed using sector-specific energy statistics, combustion-related GHG emissions data and guidelines, and the guidance of industry experts.

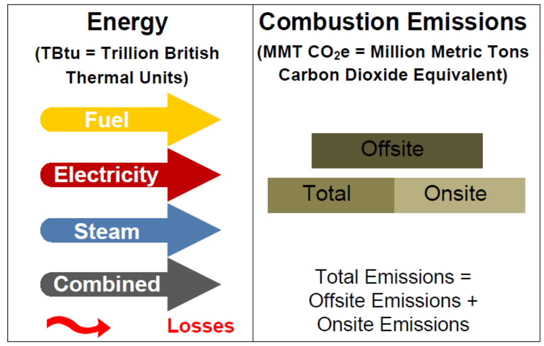

Figure 1. Footprint legend

The output from the footprint model is presented in the form of graphical “footprints” that map the flow of energy supply, demand, and loss for selected U.S. manufacturing industries. Figure 1 shows the color legend used in the footprints, as shown in the example footprint for the chemicals sector in Figure 2 and Figure 3. Each footprint consists of two figures; the first figure offers an overview of the sector’s total **primary energy** flow including offsite energy and losses, while the second figure presents a more detailed breakdown of the **onsite energy** flow. The term “Total” in the footprints refers to the total sum of offsite and onsite values. In energy terms, this is referred to as *total primary energy*.

Energy use is shown as input and output flow lines to the various pathway stages; energy values appear in white font within the flow arrows. Energy use is broken down by energy type and distinguished by color (as shown in Figure 1): dark gray = all energy, yellow = fuel, dark red = electricity, and blue = steam. Energy losses are represented as wavy red arrows. Combustion GHG emissions are shown in the boxes along the bottom of each pathway stage. Offsite, onsite, and total GHG emissions are distinguished by color as shown in the legend: dark brown = offsite GHG emissions, light brown = onsite GHG emissions, and medium brown = total GHG emissions (offsite + onsite).

The footprint pathway captures both energy supply and demand. On the supply side, the footprints provide details on energy purchases and transfers into a plant site (including fuels derived from onsite produced byproducts), and onsite generation of steam and electricity. On the demand side, the footprints illustrate the end use of energy within a given sector, from process energy uses such as heaters and motors to nonprocess uses such as HVAC and lighting. The footprints identify where energy is lost due to generation and distribution losses and system inefficiencies, both inside and outside the plant boundary. Losses are critical, as they represent potential opportunities to improve efficiency and reduce energy consumption through best energy management practices and technologies.

In the primary energy footprint shown in Figure 2, the energy supply chain begins with the fuel, electricity, and steam supplied to the plant boundary from offsite sources (power plants, fuel and gas distributors, etc.). Many industries generate byproduct fuels, and these are also part of the energy supply. Notable examples of byproduct fuels include black liquor and wood byproducts in pulp and paper mills and still gas in petroleum refineries. As noted earlier in this document, a substantial amount of energy is consumed in the form of non-fuel feedstocks in manufacturing (e.g., crude oil feedstock in the petroleum refining sector, liquefied petroleum gases in chemicals, or coal feedstock in the iron and steel sector). Over 6 quads of non-fuel feedstock energy is quantified for all of manufacturing in 2010 EIA MECS Table 2.2; caution should be exercised when combining nonfuel feedstock energy with onsite energy use values due to potential double-counting issues.

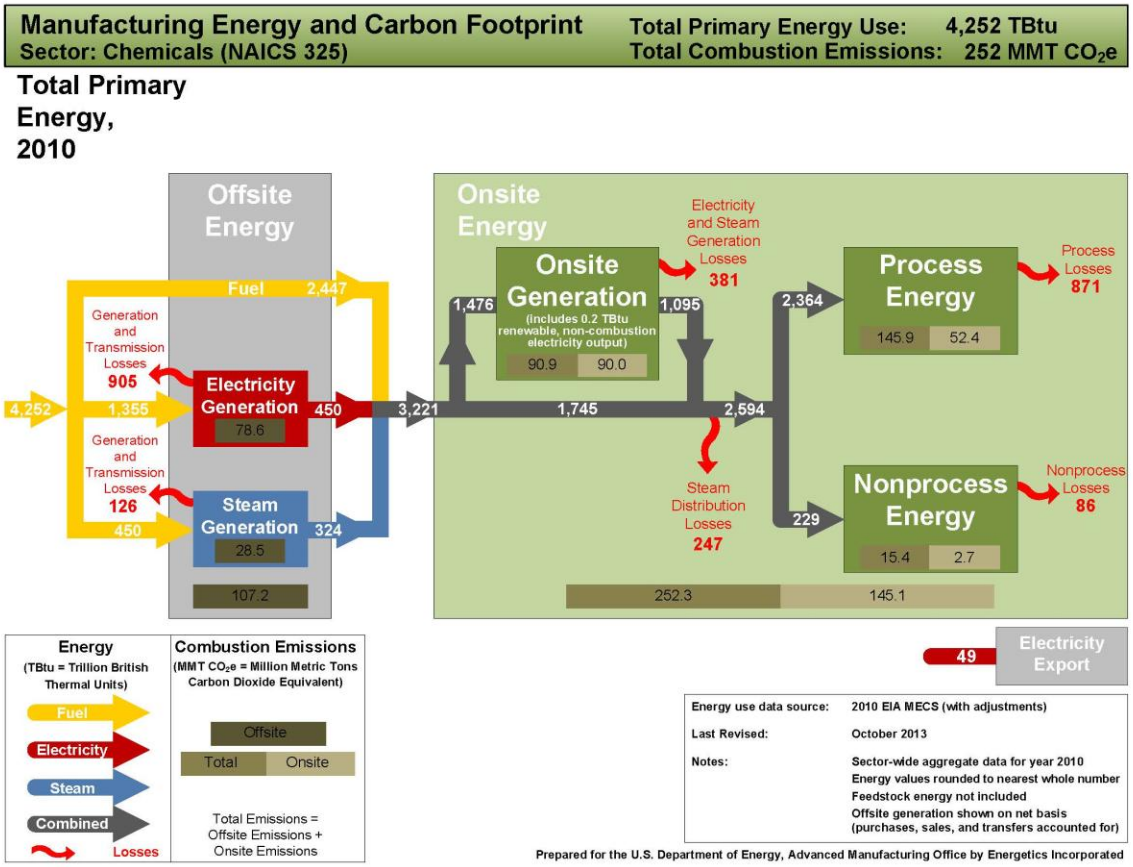

Figure 2. Total primary energy use and GHG combustion emissions for the chemicals sector

In the onsite energy footprint shown in Figure 3, energy demand is shown by energy type and end use. The onsite energy that reaches the plant boundary is used indirectly for onsite generation or directly for process and nonprocess end uses. Onsite energy generation, which consists of conventional boilers, combined heat and power (CHP)/cogeneration systems controlled by a manufacturing establishment, and other onsite electricity generation such as renewable energy sources, contributes to the electricity and steam demands of process and nonprocess end uses. A percentage breakdown of energy use by fuel type, including fuels derived from byproducts, is presented as a yellow call out box at the beginning of the onsite fuel pathway. Often, onsite generation of energy creates more energy than is needed at the plant site, allowing any excess energy to be exported offsite to the local grid or other nearby plants. Total primary and onsite energy use values are based on net electricity and do not include exported electricity. Exported steam is accounted for in MECS net steam data, and thus is not explicitly shown in the footprint.

Process energy systems consist of the equipment necessary for process heating (e.g., kilns, ovens, furnaces, strip heaters, and associated burners), process cooling and refrigeration, electro-chemical processes (e.g., reduction processes), machine drive (e.g., motors and pumps associated with process equipment), and other direct process uses. Another end use energy pathway is the energy that is distributed to nonprocess activities. This involves the use of energy for facility HVAC, facility lighting, other facility support (e.g., water heating and office equipment), onsite transportation, and other nonprocess use.

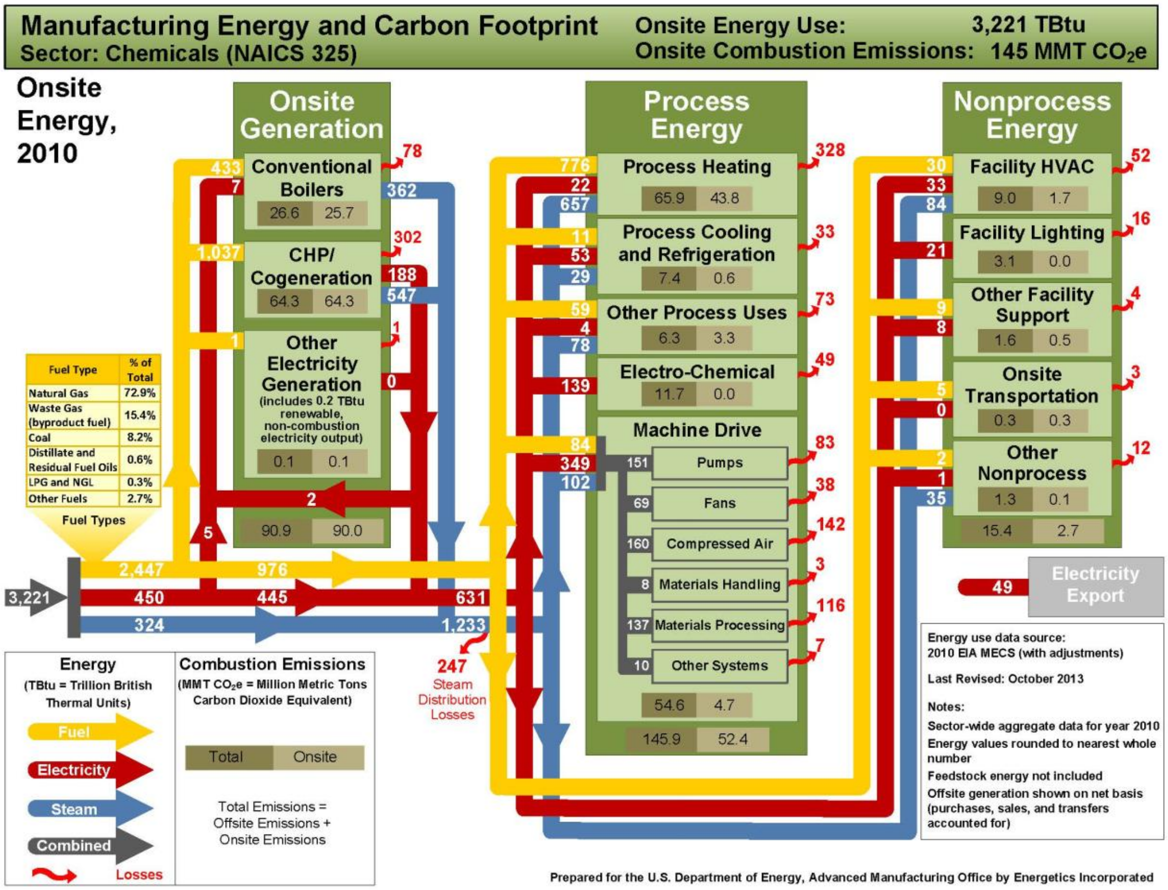

Figure 3. Onsite energy and carbon emissions for the chemicals sector

Energy losses occur along the entire energy pathway from generation and delivery to end use. Energy is lost in generating and transmitting power and steam and in process and nonprocess end use of power, steam, and fuel. In the footprint analysis these energy loss values are estimated based on literature search and peer review. Since energy losses vary greatly by industry and by facility, appropriate sector-wide and sector-specific energy loss estimate assumptions are made with the understanding that these estimates are highly dependent on the specific manufacturing plant site. A summary of footprint loss assumptions is outlined in the document *2010 Manufacturing Energy and Carbon Footprints: Definitions and Assumptions*. Energy losses do not equate to recoverable energy. While a portion of energy losses are recoverable, the footprints do not attempt to identify and distinguish between recoverable and non-recoverable losses.

The energy and carbon footprints are based on actual plant survey data and therefore represent a reasonable distribution of energy use and losses across the sector as a whole. Through them, we can begin to assess the magnitude of energy consumption and losses, both by end use and fuel type. They also provide a baseline from which to calculate the benefits of improving energy efficiency. The GHG values in the footprint can be used to support GHG management planning and analysis.