2.5 FOOD AND BEVERAGE SECTOR (NAICS 311 AND 312)

2.5.1. Overview of the Food and Beverage Manufacturing Sector

The food and beverage sector is an integral component of the U.S. economy, transforming livestock and agricultural products into intermediate and final food and beverage products. Food and beverage is one of the largest manufacturing sectors, resulting in considerable consumer expenditures for food and beverage products. In addition, increasing globalization of agriculture markets and companies has led to increased trade for food and beverage products.

The food and beverage sector is highly diversified and produces thousands of different products. Processing facilities range from small plants to large industrial units, and most plants produce more than one product. Major NAICS code subsectors for the food and beverage sector are shown in Table 2.5-1.

Table 2.5-1. Food and beverage subsectors with data reported in MECS

NAICS code	Food and beverage subsector
311	Food manufacturing
3112	Grain and oilseed milling
311221	Wet corn milling
31131	Sugar manufacturing
3114	Fruit and vegetable preserving and specialty foods
3115	Dairy products
3116	Animal slaughtering and processing
312	Beverage and tobacco products
3121	Beverages
3122	Tobacco

The food and beverage sector is one of the top five consumers of fuels and power in U.S. manufacturing. The manufacture of foods and beverages often requires significant quantities of thermal energy to convert raw materials to useful products. The efficiency of the processes and equipment used to produce foods and beverages is often constrained by thermodynamic, kinetic, or transport limitations, and high temperature or pressure operating conditions.

2.5.2. Energy Use Profile for the Food and Beverage Sector

Differentiating between inside or outside the plant boundary is important when evaluating technology options for improving energy efficiency. Within the plant boundary, food and beverage companies have control over facility energy consumption. Outside the plant boundary, where energy is generated by or provided by utilities, companies have little or no control over technology efficiency. However, a company can reduce energy losses associated with external energy supply by adopting technologies that allow its facilities to generate more energy onsite, more efficiently than the utility (e.g., cogeneration).

A snapshot of where the food and beverage sector ranks in terms of energy use, losses, and emissions within U.S. manufacturing is shown in Table 2.5-2. Energy losses are shown in red font. All values are based on the most currently available complete set of manufacturing energy use statistics, representing annual energy use and loss values for calendar year 2006. The food and beverage sector ranks among the top five in nearly every energy and loss category.

Table 2.5-2. Snapshot of the food and beverage sector: Energy use and rank within U.S. manufacturing

Category	Rank	Energy (TBtu)
Total primary energy	4	1,934
Offsite losses	3	639
Onsite energy	4	1,295
Onsite losses	4	831
Steam generation and distribution	4	238
Electricity generation	5	7
Process energy	4	524
Nonprocess energy	4	63
Feedstock energy	9	3
Total primary and feedstock energy*	4	1,932
GHG combustion emissions		**MMT CO_2e**
Total	4	117
Onsite	4	56

*When total primary energy and feedstock energy are summed, the energy value of byproduct fuels derived from feedstock energy sources is excluded to avoid double counting of feedstock energy

Although it is outside the scope of the footprint analysis, a small amount of energy in the food and beverage sector is consumed as non-fuel feedstock. Of the 3 TBtu of feedstock energy use shown in Fig. 2.5-1, 2 TBtu is natural gas used for non-fuel purposes in grain and oilseed milling.

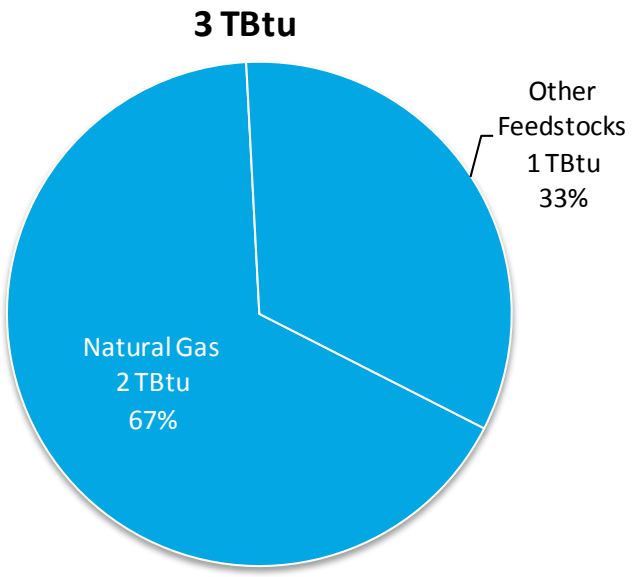


Fig. 2.5-1. Feedstock energy use in the food and beverage sector

2.5.2.1. Energy and carbon footprint

The *Manufacturing Energy and Carbon Footprint* for the food and beverage sector is shown in Fig. 2.5-2 and Fig. 2.5-3. The footprint serves as the basis for characterizing the offsite and onsite flow of energy, as well as carbon emissions, from generation through end use in the sector.

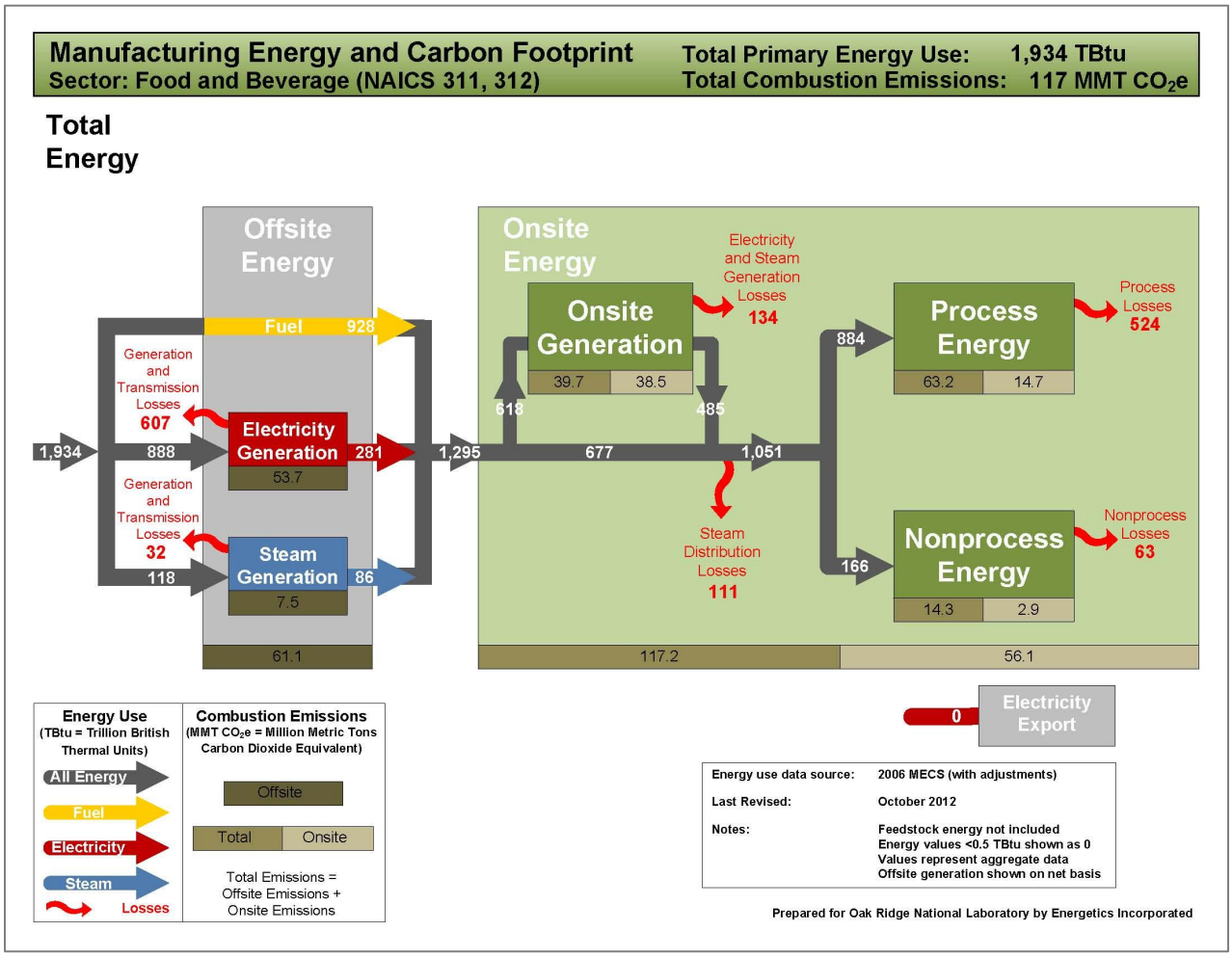


Fig. 2.5-2. Total energy and carbon footprint for the food and beverage sector

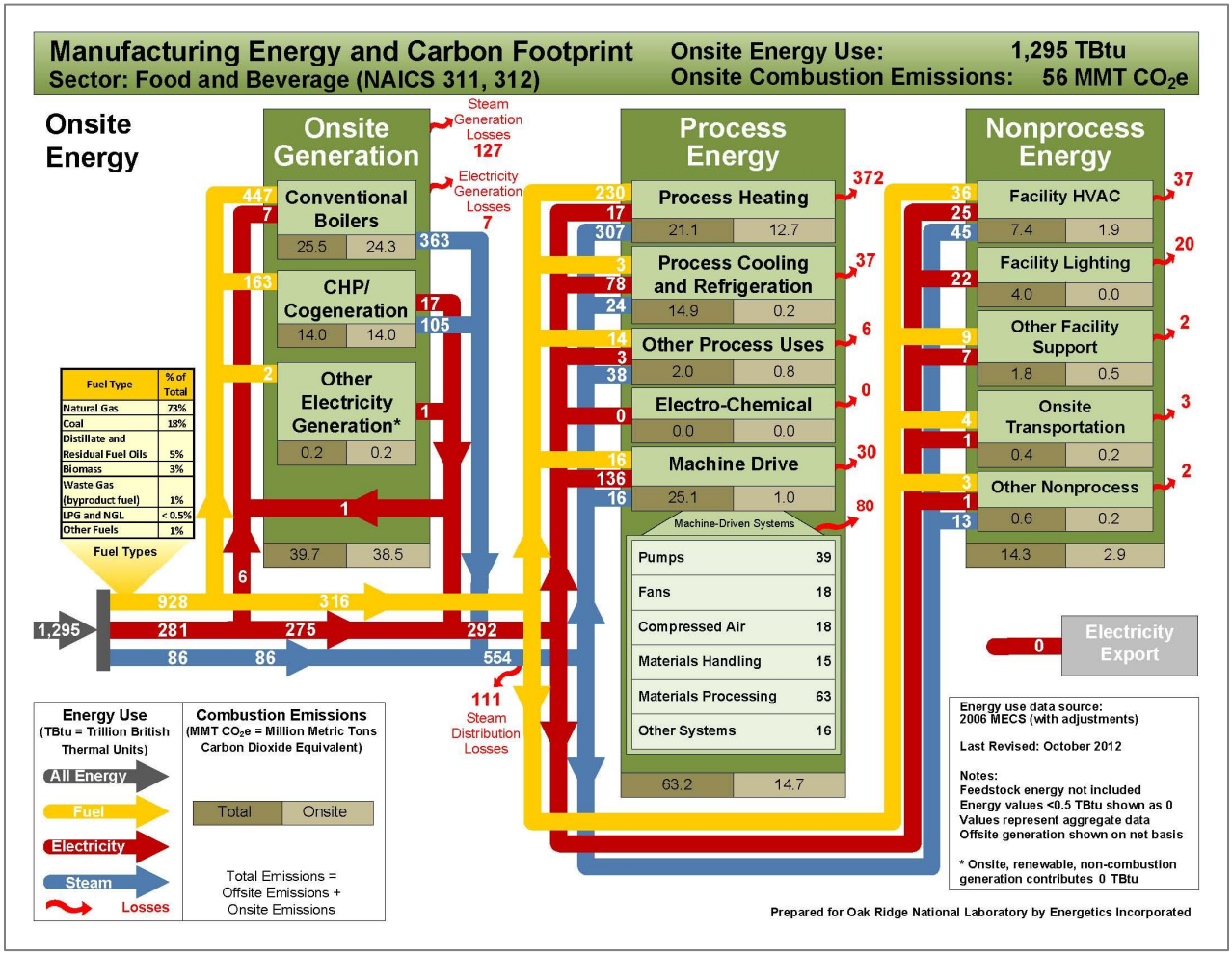


Fig. 2.5-3. Onsite energy and carbon footprint for the food and beverage sector

2.5.2.2. Primary energy

Primary energy use includes fuels, electricity, and steam consumed in manufacturing, including the generation and distribution/transmission losses associated with offsite and onsite electricity and steam generation. The primary energy use by energy type for the food and beverage sector is depicted in Fig. 2.5-4. Consistent with the footprints, blue represents steam energy, red represents electric energy, and yellow represents fuel energy.

The food and beverage sector utilizes 1,934 TBtu of primary energy, ranking fourth across U.S. manufacturing. Electricity generation accounts for 906 TBtu (47%) of this total primary energy consumption, accounting for the largest piece of this total. Offsite electricity *losses*, which consume 607 TBtu, are the single greatest portion of electricity consumption. Offsite generated electricity provides 275 TBtu to direct end uses (excludes electricity used to generate steam onsite), while onsite electricity generation provides an additional 17 TBtu to direct end uses. Onsite electricity losses account for 7 TBtu of energy.

Steam generation is the next largest use of primary energy, consuming 713 TBtu (37%) of total primary energy. Onsite generation of steam accounts for 375 TBtu of this total, while associated onsite generation and distribution losses accounts for a further 238 TBtu. The remaining steam is due to offsite steam and associated generation and distribution losses, accounting for 69 TBtu and 32 TBtu, respectively.

Direct fuel uses comprise the smallest application of primary energy at 316 TBtu (16%). Natural gas accounts for 287 TBtu—about 91% of direct fuel consumption. Other fuels including coal, distillate fuel oil, residual fuel oil, LPG and NGL, and coke and breeze consume the remaining 29 TBtu of energy.

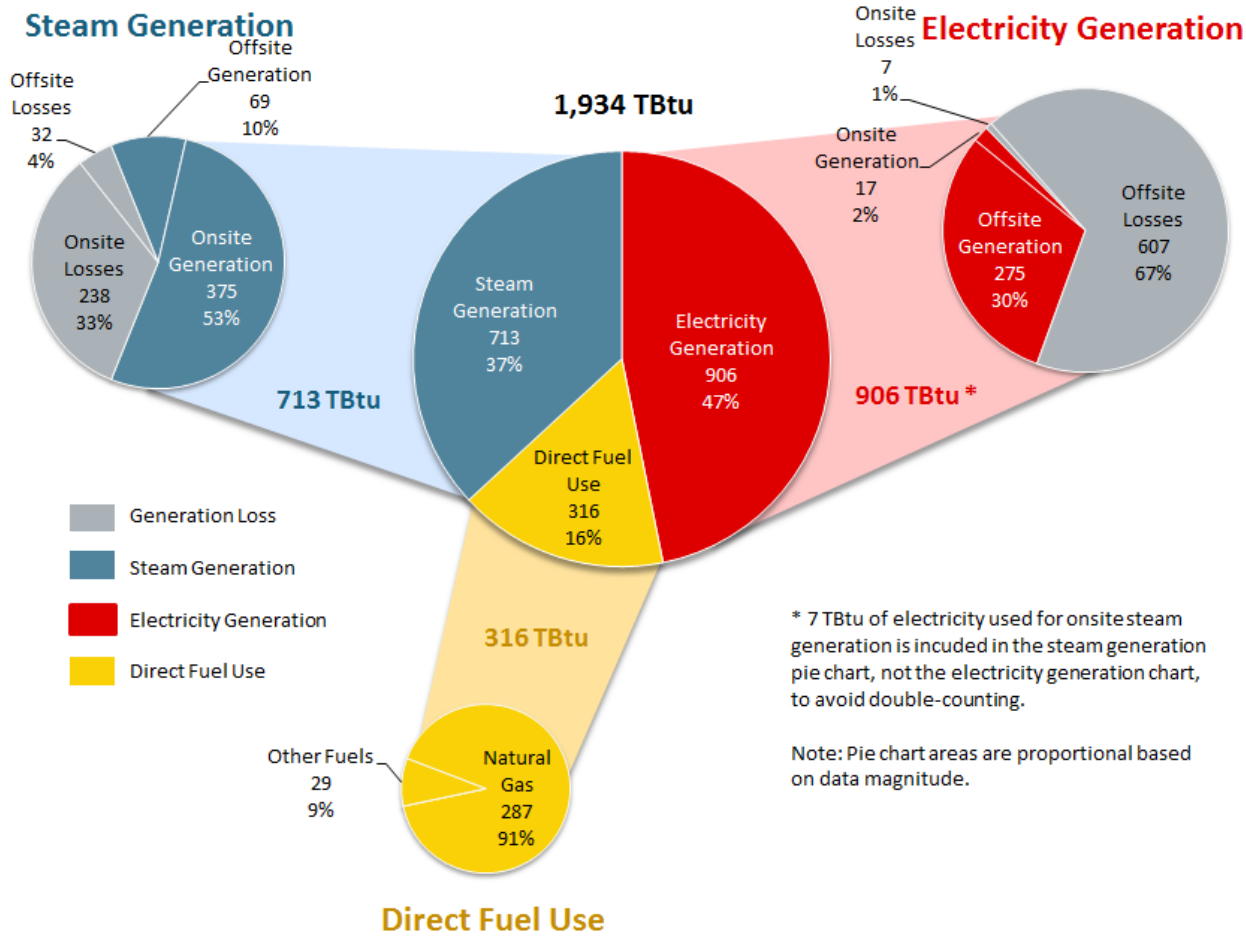


Fig. 2.5-4. Primary energy by energy type in the food and beverage sector

2.5.2.3. Onsite energy

Onsite energy is a measure of the energy entering the plant boundary in the form of three offsite energy types: fuel, steam, and electricity. Sector energy consumption from offsite energy supply totaled 1,295 TBtu in 2006. The sector makes an array of different products and uses many different processes in their manufacture. As a result, energy use patterns can vary significantly across subsectors.

Overall, as shown in Fig. 2.5-5, natural gas provides for over half (52%) of the onsite energy in the sector at 676 TBtu. Offsite electricity is the next largest with 22% of the total (281 TBtu), followed by coal at 13% (167 TBtu). Offsite steam comprises 86 TBtu, or 7% of total offsite energy supply. Lesser amounts of biomass and other fuels serve as sources energy for use in the sector.

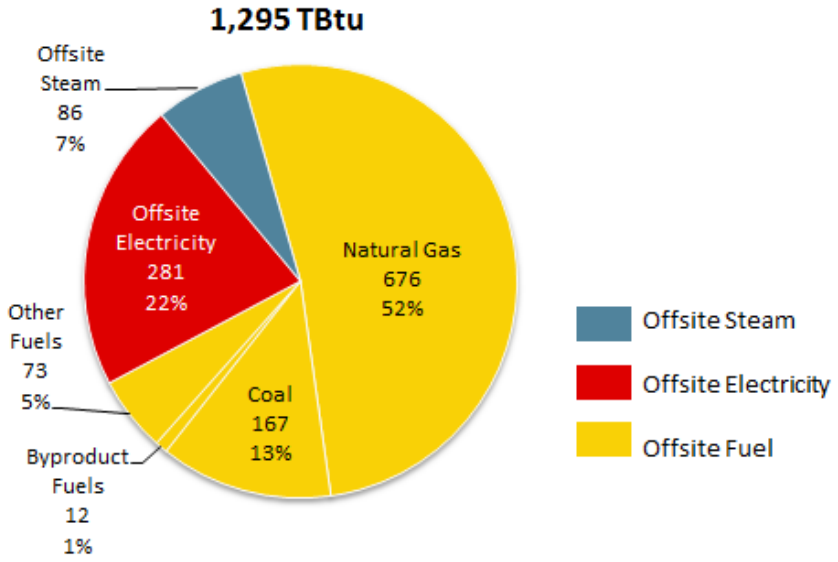


Fig. 2.5-5. Offsite energy supply in the food and beverage sector

Fig. 2.5-6 illustrates the energy consumption patterns across major subsectors in the food and beverage sector (the sum of onsite energy use across these subsectors is equal to 93% of sector-wide onsite energy use). The largest onsite energy using subsector is grain and oilseed milling (NAICS 3112), which consumes over 300 TBtu. The remaining other subsectors such as animal slaughter and processing (NAICS 3116), dairy products (NAICS 3115), and beverages (NAICS 3121) each use less than 250 TBtu of onsite energy.

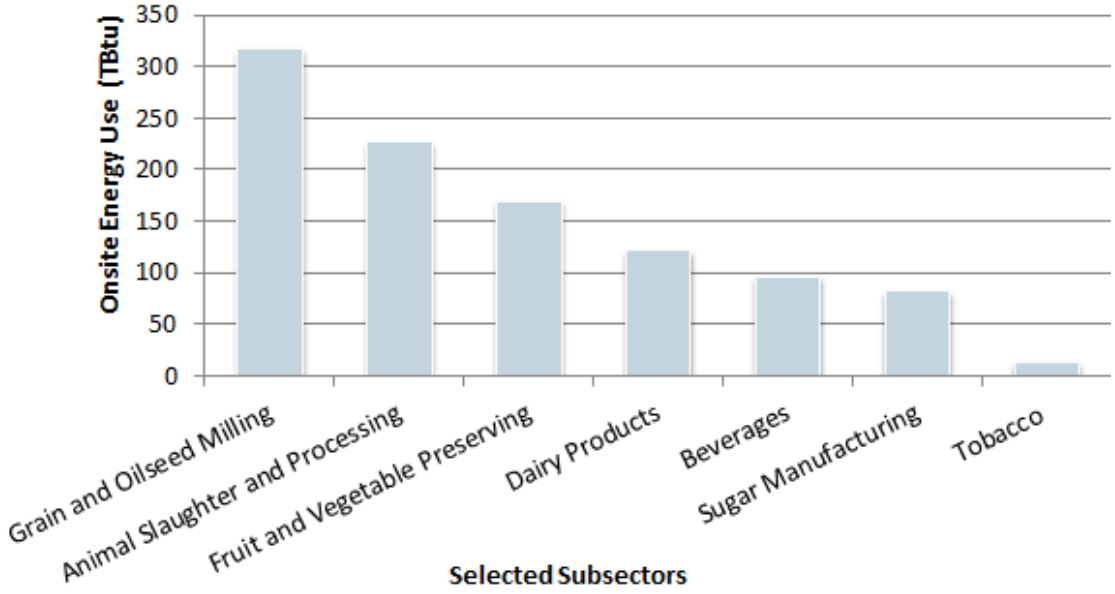


Fig. 2.5-6. Onsite energy use in selected food and beverage subsectors

2.5.2.4. Fuel energy

Onsite fuel use in the food and beverage sector is 928 TBtu. Natural gas makes up over half of onsite fuel use, with coal providing the next largest contribution at 13%. Natural gas is used primarily in process heating applications such as food dehydration. Coal is the most commonly used fuel for CHP and/or cogeneration processes, which is a unique characteristic of CHP operations for this sector.

2.5.2.5. Electrical energy

The food and beverage sector is ranked third among U.S. manufacturing sectors in onsite direct demand for electricity at 292 TBtu per year. Onsite direct electricity demand is equal to purchases of electricity summed with electricity generated onsite, and provides the most complete picture of actual electricity use. On average, electricity use only accounts for a little more than 20% of onsite and 15% of primary energy consumption. However, some subsectors may be more electricity intensive than others.

As shown in Fig. 2.5-7, a large portion of the primary energy consumed for electricity use is associated with generation, transmission and distribution (T&D) losses, taking place mostly offsite. On average, the efficiency of utility power generation and transmission is assumed to be 31.6%, generating over 614 TBtu of energy losses in order to produce 292 TBtu of electricity that is used for direct[16] end uses in the sector.

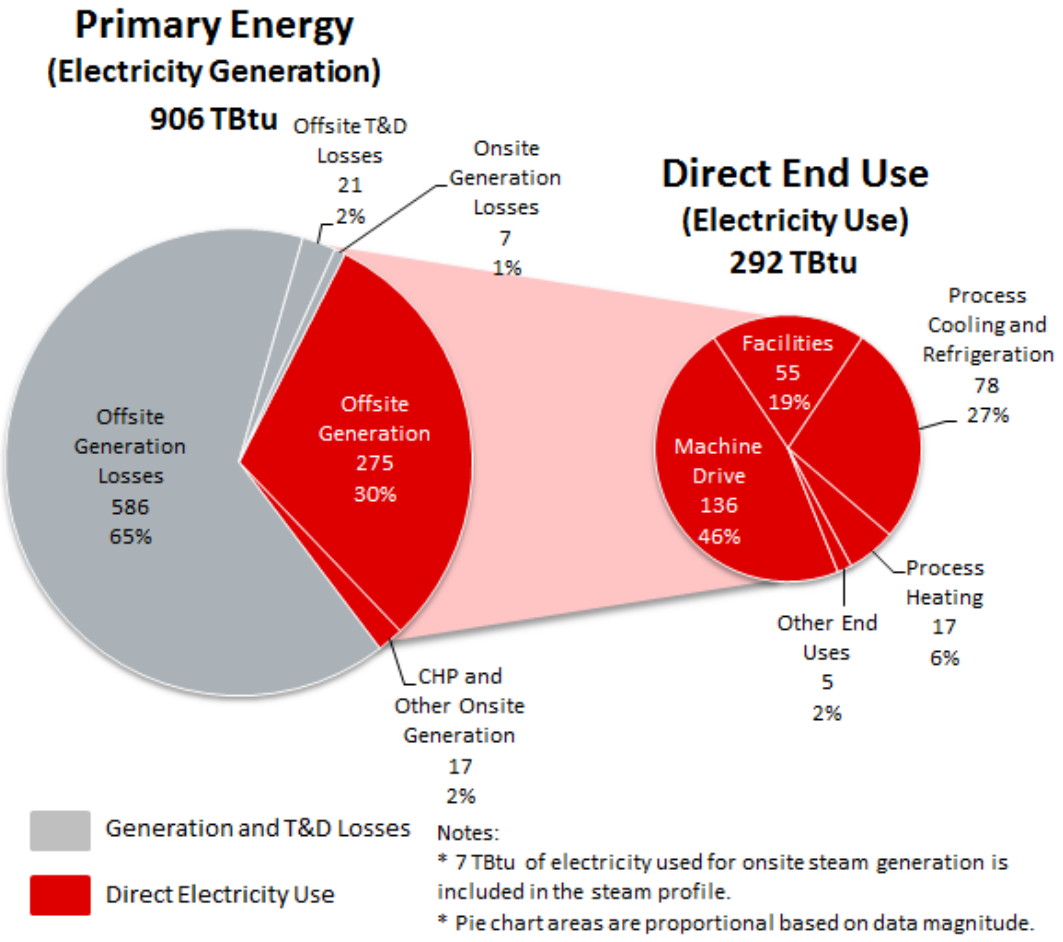


Fig. 2.5-7. Electricity generation and *direct* end use in the food and beverage sector

The food and beverage sector does meet a small portion (6%) of direct end use energy through onsite generation. About 17 TBtu of energy use is associated with the generation of onsite electricity. Most of the electricity produced onsite in the sector comes from CHP units, with only a small percentage of onsite generation originating from other generation methods such as the use of generators running on combustible energy sources or renewable energy such as wind or solar.

[16] Offsite electricity generation (275 TBtu) shown in this chart is lower than the value of offsite energy entering the plant boundary shown in the energy and carbon footprint for this sector (281 TBtu). This difference is due to the small portion of offsite electricity (7 TBtu) that is used by conventional boilers to generate steam.

About 46% of the electricity use in the food and beverage sector is consumed by machine-driven systems such as pumps, conveyors, compressors, fans, mixers, grinders, and other materials handling or processing equipment. Process cooling and refrigeration is the next largest category of electricity consumption within the sector, comprising 27% of electricity usage. Facilities use, such as HVAC and lighting, follows at 19%. The remaining 8% of sector electricity use is consumed by other process uses such as process heating, boilers, and other end uses.

2.5.2.6. Steam energy

The food and beverage sector ranks fourth across U.S. manufacturing in steam usage. A profile of food and beverage sector steam use from primary energy and associated losses is shown in Fig. 2.5-8. About 38% of primary energy inputs are lost due to system inefficiencies in steam generation and transmission, both offsite and onsite. The bulk of these occur in the boiler, where thermal efficiencies range between 55%—85%, depending upon the age of the boiler and type of fuel burned. Conventional boiler steam comprises 41% (291 TBtu) of primary energy, serving as the principal source of energy to be applied towards end use. CHP steam generation provides for about 12% (84 TBtu) of the energy for end use, followed by steam generated offsite at 10% (69 TBtu).

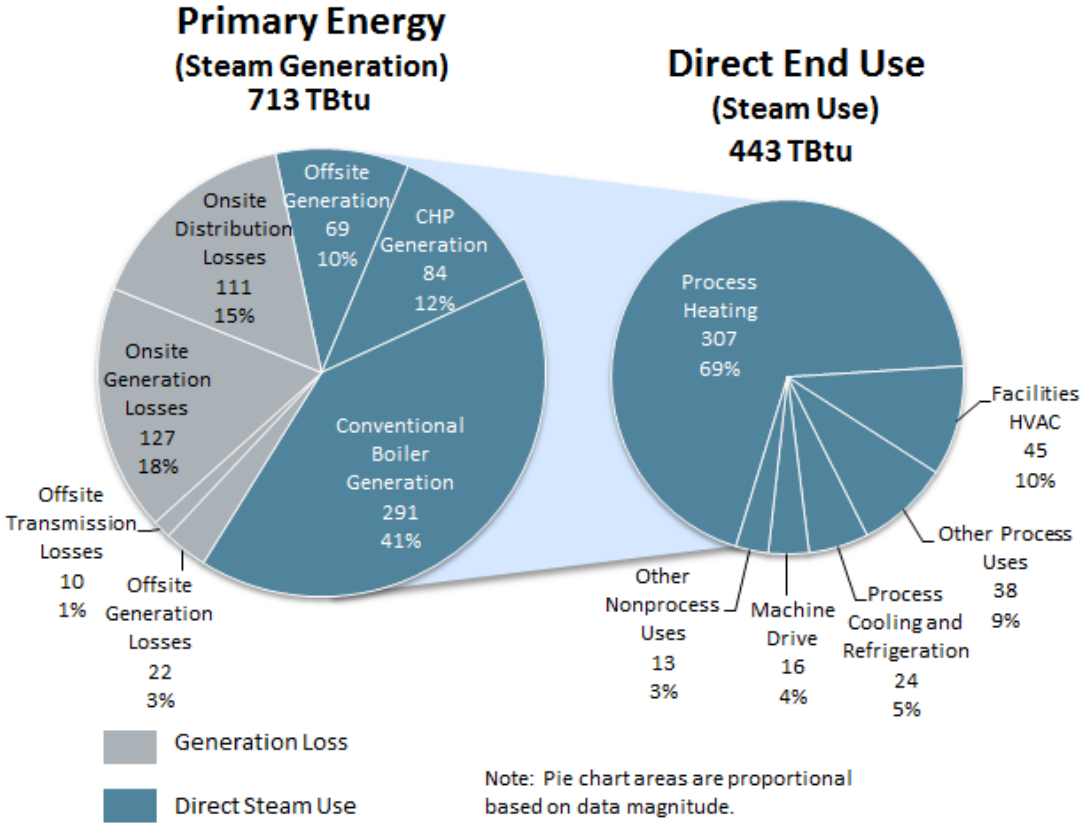


Fig. 2.5-8. Steam generation and *direct* end use in the food and beverage sector

Of the 713 TBtu of primary energy made available for steam, 443 TBtu of energy is used onsite. Process heating receives the bulk of the energy at 69% (307 TBtu), followed by facility HVAC uses at 10% (45 TBtu), other process uses at 9% (38 TBtu), process cooling and refrigeration at 5% (24 TBtu), machine drive uses at 4% (16 TBtu), and the remaining 3% going to other nonprocess uses (13 TBtu).

2.5.2.7. Combined heat and power energy

The food and beverage sector meets a moderate amount of energy demand through onsite generation, ranking fourth in CHP output across sectors. As shown in Fig. 2.5-9, CHP units produce 163 TBtu of energy output, with 64% of this output in the form of steam. Electricity encompasses about 10% of CHP output, with the remaining 26% of energy composed of losses. More than three-fourths (76%) of fuel energy to CHP units is in the form of coal, which is significantly higher than other energy-intensive sectors where waste fuels, waste gas, and natural gas are more typical CHP fuels. Natural gas supplied 18% of fuel used for CHP with the remaining 6% consisting of other fuels such as distillate and residual fuel oils.

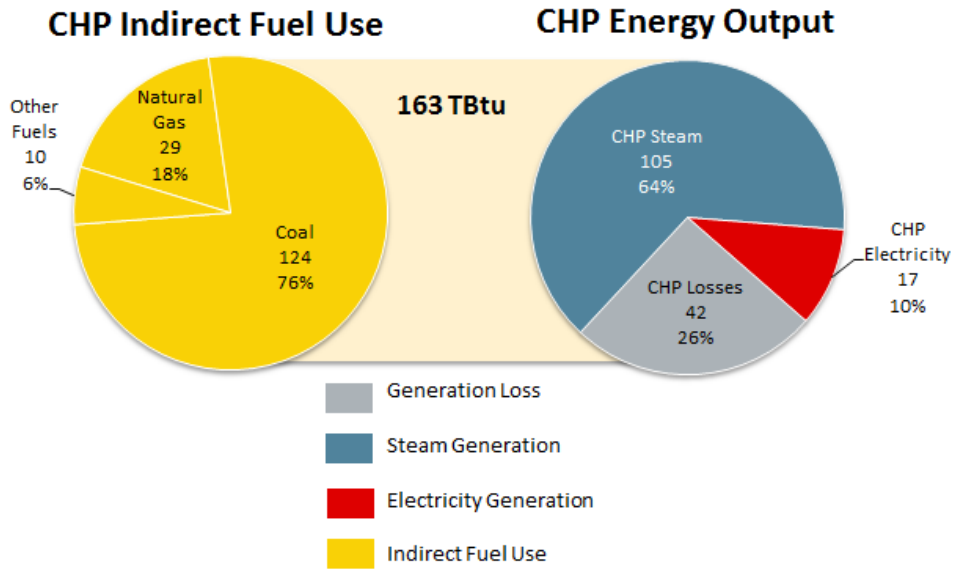


Fig. 2.5-9. CHP fuel consumption and energy output in the food and beverage sector

2.5.2.8. Direct end use energy

Energy is consumed in food and beverage manufacturing to provide process heating and cooling, to power motor-driven systems, and for various other purposes. A simple breakdown of primary energy by type at direct end use is shown in Fig. 2.5-10. It should be noted that the energy trends shown here are an average for the sector and may not reflect subsector differences. Steam comprises over half the energy used in process heating, followed by natural gas, while electricity serves as the major input for machine-driven systems. As mentioned in the CHP section above, coal serves as the primary fuel in cogeneration.

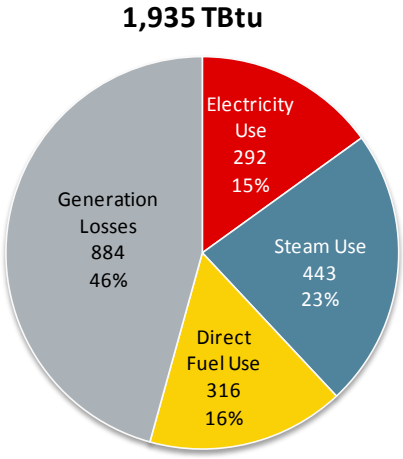


Fig. 2.5-10. Primary energy by type at *direct* end use in the food and beverage sector

A breakdown of primary energy by all direct end uses is shown in Fig. 2.5-11. Process uses and losses incurred during the generation of electricity and steam both consume 884 TBtu (46%). Nonprocess uses account for only 8% (166 TBtu) of energy use in the sector.

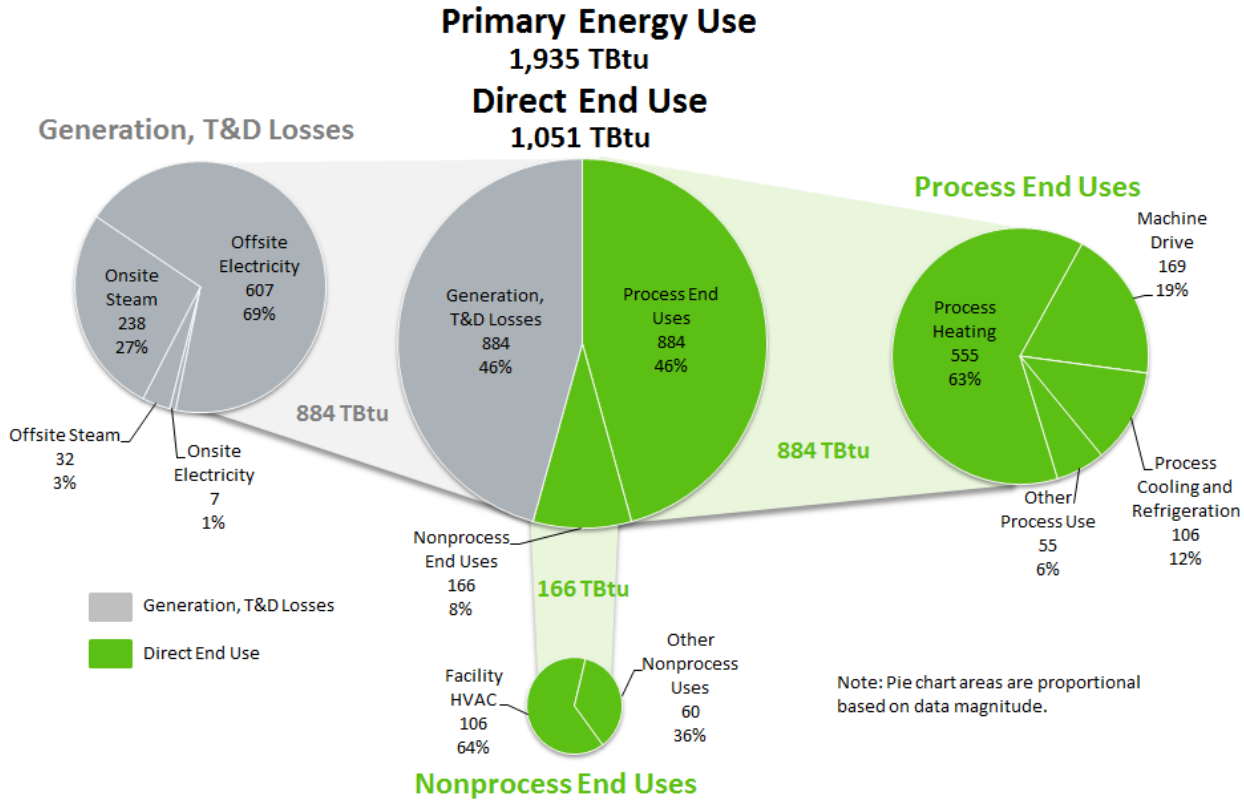


Fig. 2.5-11. Primary energy by *direct* end use in the food and beverage sector

The food and beverage sector ranks fifth across U.S. manufacturing in the use of process heating and cooling systems, and fourth in the use of machine driven systems. Process heating systems consume 63% (555 TBtu) of the 884 TBtu consumed by process end uses. These systems include steam systems and fired systems such as ovens and furnaces. Machine-driven systems are the next largest use of process energy in the sector at 169 TBtu (19%), followed by process cooling and refrigeration systems at 106 TBtu (12%). As shown in Fig. 2.5-8, steam serves as the primary energy source for process heating systems, while electricity is the main source of energy for the largely electric-based, machine-driven systems. The food and beverage sector also ranks fourth across U.S. manufacturing in nonprocess energy end uses, with facility HVAC the largest user of nonprocess energy.

2.5.2.9. Applied end use energy

In addition to the energy generation losses identified above, direct end use losses have also been calculated in the energy footprint model. When both generation and end use losses are accounted for, the energy that remains is the *applied energy*. Applied energy can be illustrated by re-examining Fig. 2.5-4, which shows primary energy by energy type for the food and beverage sector. Each of the energy types (i.e., fuel, electricity, or steam) shown in this figure have associated onsite and offsite generation losses (shown with onsite and offsite losses combined in light gray) that are incurred during energy generation (and transmission and distribution). While the majority of electricity generation losses take place offsite (as shown in Fig. 2.5-7), the majority of steam generation losses are onsite (as shown in Fig. 2.5-8), and direct fuel use is assumed to have no associated generation losses. After taking into account these generation losses, a further portion of the remaining energy is lost at direct end uses, due to process and nonprocess system and equipment inefficiencies, shown in dark gray. The remaining energy is applied to end uses, shown in light green as "Applied Energy" in Fig. 2.5-12.

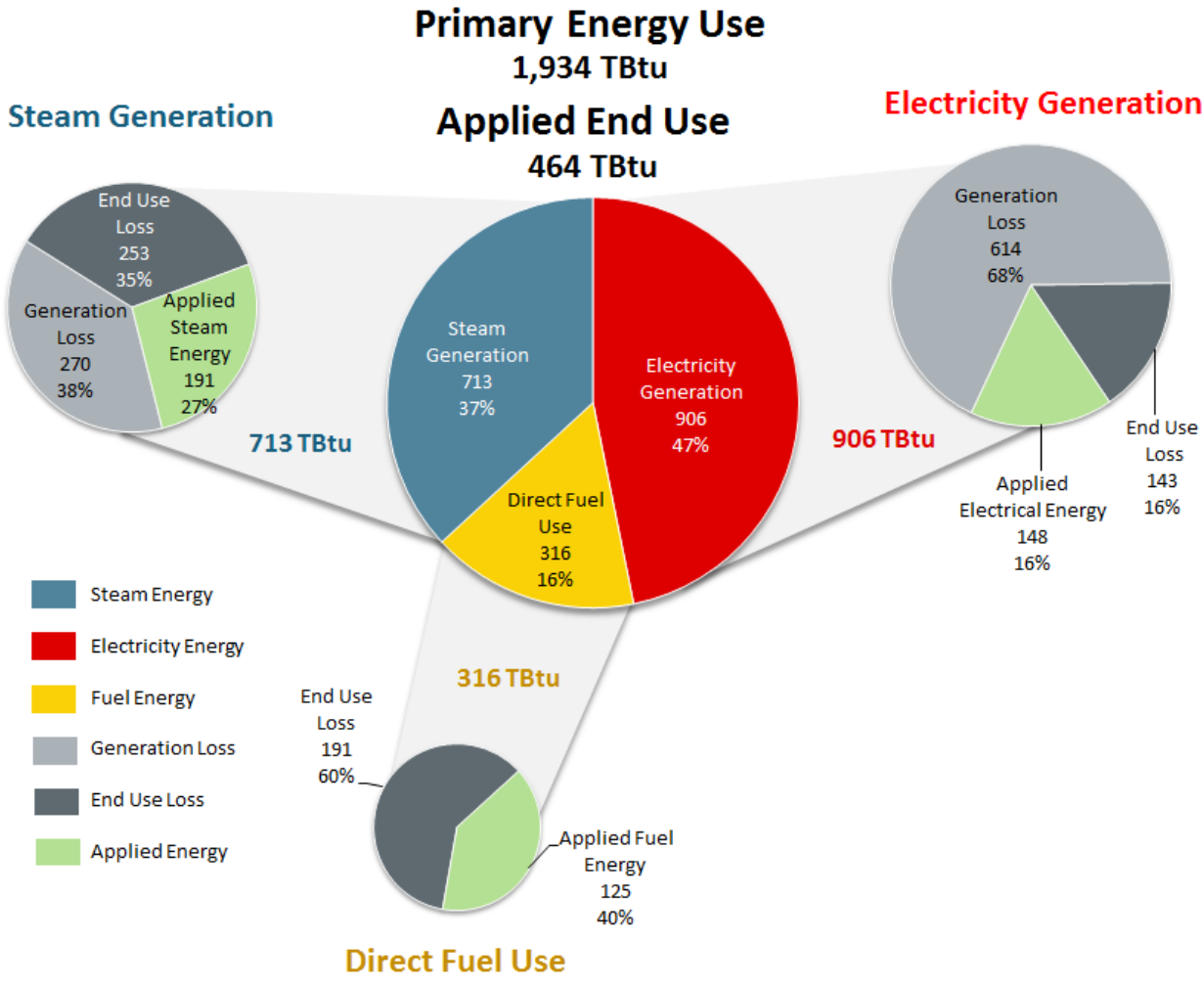


Fig. 2.5-12. Primary energy and applied energy by energy type in the food and beverage sector

Figure 2.5-13 shows the breakdown of primary energy by energy loss and applied energy. In this sector, only 24% of primary energy input is applied to process and nonprocess end uses, significantly less than the manufacturing average of 34%. Generation losses account for 46% of primary energy input and end use losses account for the remaining 30% of primary energy input.

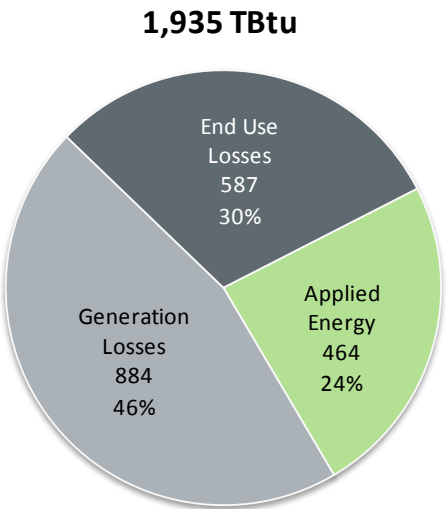
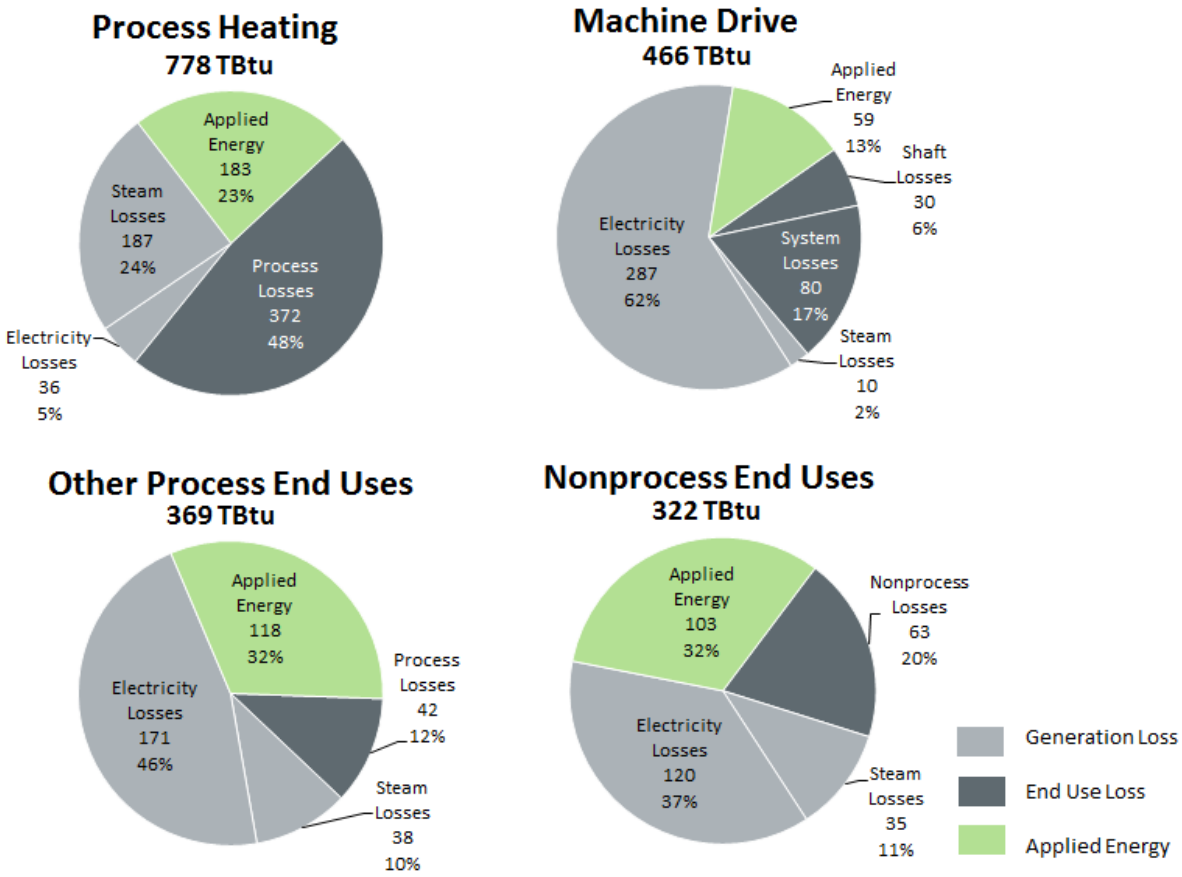


Fig. 2.5-13. Primary energy by loss and applied energy in the food and beverage sector

Applied energy can also be calculated for specific end uses, as shown in Fig. 2.5-14. End use losses are labeled as process or nonprocess losses; in the case of machine drive end use, process losses are further defined as machine drive, or machine driven system losses. For process heating, 23% of primary energy is applied to the process (detail of the methodology to estimate process heating losses are shown in Appendix F). In machine-driven systems, only 13% of primary energy is applied, primarily because of the inefficiency in electricity generation.



Note: Pie chart areas are not proportional to magnitude of energy consumption

Fig. 2.5-14. Primary applied energy by *direct* end use in the food and beverage sector

2.5.3. Greenhouse Gas Combustion Emissions Profile for the Food and Beverage Sector

Emissions from the food and beverage sector totaled 117 MMT CO_2e in 2006, fourth highest among U.S. manufacturing sectors. Greenhouse gas emissions by offsite energy supply type are shown in Fig. 2.5-15. Emissions released during offsite production of electricity contribute 46% of sector emissions, while 6% of emissions are attributed to the production of offsite steam. The onsite consumption of fuels (shown in yellow), including natural gas, coal, and other fuels, accounts for nearly half of total emissions. These fuels are used for both direct (e.g., process or nonprocess) and indirect (e.g., fuel for CHP units or boilers) end uses. Table D.5 shows fuel GHG combustion emission factors associated with fuel combustion, as well as electricity and steam generation.

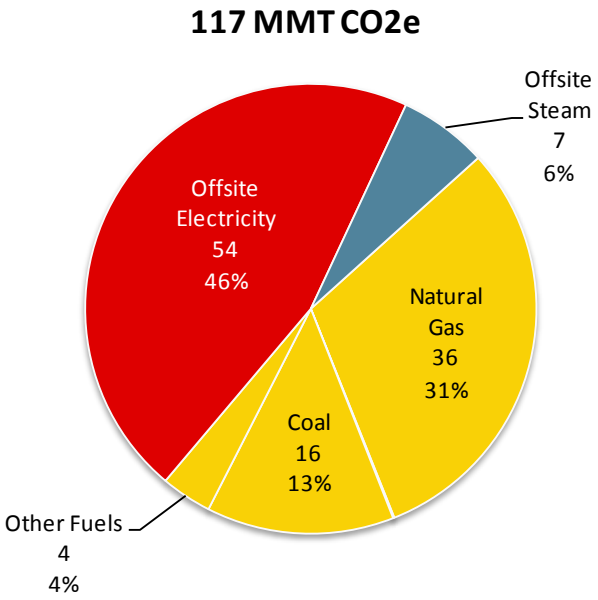


Fig. 2.5-15. Total GHG combustion emissions in the food and beverage sector (shown by energy supply type)

An alternative view of emissions is shown in Fig. 2.5-16, which also shows total emissions by energy type, but this figure assigns emissions to onsite electricity and steam production (as opposed to assigning emissions strictly to offsite supplied fuels). All emissions associated with electricity production are shown in red, including emissions released during offsite electricity generation and emissions released during onsite generation of electricity. All emissions associated with steam production are shown in blue, including emissions released during offsite steam generation and emissions released to generate steam onsite in boilers and CHP systems. Lastly, all emissions associated with fuel combustion at process and nonprocess end uses are shown in yellow. Electricity generation (offsite and onsite) contributes about 48% of all emissions. Steam generation (offsite or onsite) contributes a further 37% of emissions, while the remaining 15% of emissions are released during fuel combustion for process and nonprocess end uses.

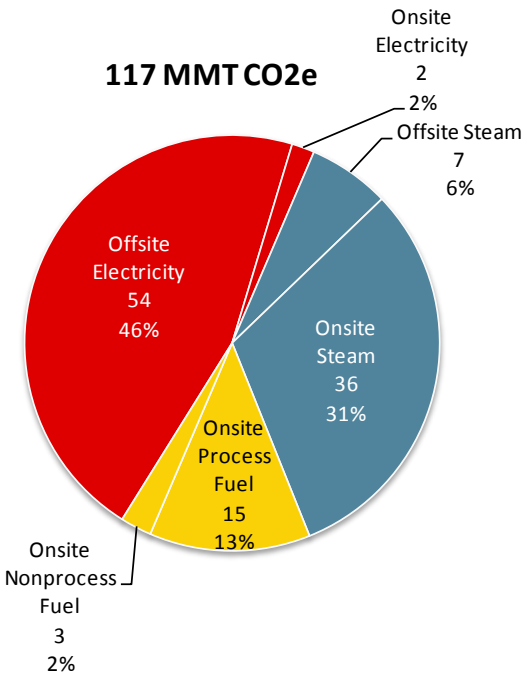


Fig. 2.5-16. Total GHG combustion emissions in the food and beverage sector (shown by energy end use type)

Emissions can also be associated with the direct end uses of energy, as is shown in Fig. 2.5-17. In this figure, the emissions released from offsite both offsite and onsite electricity and steam generation are distributed to direct end uses, along with emissions resulting from fuel consumed at the direct end uses. This pie chart allows for a direct comparison of the emissions resulting from individual direct process and nonprocess end uses. Similar to the forest products sector, CO_2 emissions from biomass use (within the other fuels category) are excluded. Process heating accounts for 40% of emissions, while machine driven end uses account for 24% of emissions. Process cooling and refrigeration end uses account for 15% of sector emissions, equal to one-third of all manufacturing process cooling and refrigeration emissions. Emissions resulting from facilities, HVAC and lighting nonprocess end uses account for an additional 13% of emissions, while other process and nonprocess end uses account for just 8% of emissions.

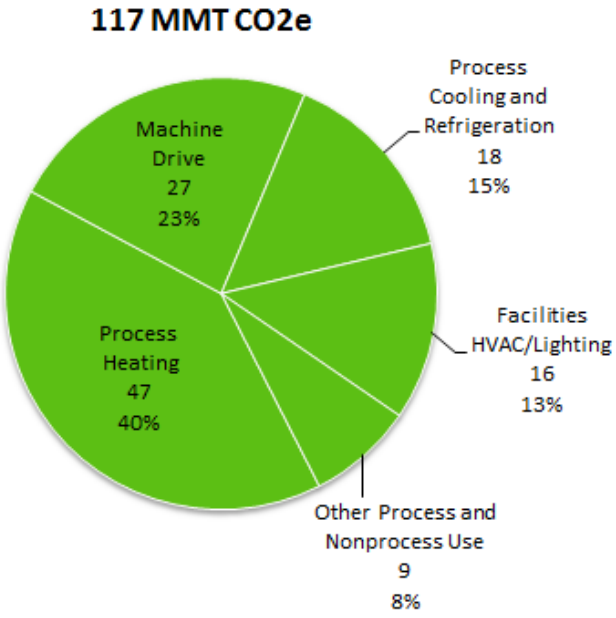


Fig. 2.5-17. Total GHG combustion emissions in the food and beverage sector (shown by direct energy end use)

2.5.4. Energy and Emissions Profile Summary Table

The energy and emissions profiles for the food and beverage sector are summarized in Table 2.5-3 below. Offsite and onsite contributions to energy supply, use and loss are shown separately in this table, along with GHG combustion emissions. "Applied energy" is calculated for each direct energy use area by subtracting associated offsite and onsite energy losses. For GHG combustion emissions, emissions from the point of use, whether offsite or onsite, are depicted in the first emissions column; offsite emissions are combined with onsite emissions in the total emissions columns. The values in this table correspond to the energy and carbon footprints, which show two carbon values associated with each onsite end use: at point of use and the total based on onsite use.

Table 2.5-3. Energy use, loss, and GHG combustion emissions in the food and beverage sector

Food and beverage			Energy (TBtu)			GHG combustion emissions (MMT CO_2e)		
			Energy use	Energy loss	Applied energy	At point of use	Total based on onsite use*	Total based on direct end use**
Offsite		Fuel supply (928 TBtu)	-	-	N/A	-	Distributed to onsite	Distributed to onsite direct
		Electricity generation/transmission	888	607		53.7		
		Steam generation/transmission	118	32		7.5		
		Total offsite (including fuel supply)	**1,934**	**639**		**61.1**		
Onsite	Indirect	Conventional boilers	454	91	N/A	24.3	25.5	Distributed to onsite direct
		CHP/cogeneration	163	42		14.0	14.0	
		Other electricity generation	2	1		0.2	0.2	
		Steam distribution	-	111		0.0	0.0	
		Total onsite generation	**619**	**244**		**38.5**	**39.7**	
	Direct	Process heating	555	372	183	12.7	21.1	47.3
		Process cooling and refrigeration	106	37	69	0.2	14.9	17.5
		Machine drive	169	110	59	1.0	25.1	27.5
		Electro-chemical	0	0	0	0.0	0.0	0.0
		Other process uses	55	5	49	0.8	2.0	5.2
		Nonprocess energy	166	63	103	2.9	14.3	19.7
		Total process and nonprocess	**1,051**	**587**	**464**	**17.5**	**77.5**	**117.2**

* These values are referenced as "Total" emissions in the footprints, Total emissions = onsite emissions + offsite emissions (i.e., emissions associated with offsite generation are distributed to indirect and direct onsite end uses)
** These values represent direct end use carbon emissions only (i.e., emissions associated with offsite and onsite generation are distributed to direct (and final) end use)