2.3 FOREST PRODUCTS SECTOR (NAICS 321 AND 322)

2.3.1. Overview of the Forest Products Manufacturing Sector

The forest products sector produces thousands of products from renewable raw materials (wood) that are essential for communication, packaging, consumer goods, and construction.

The sector is divided into two major categories: Wood Product Manufacturing (NAICS 321) and Paper Manufacturing (NAICS 322). These industries are often grouped together because both rely on the nation's vast forest resources for raw material. In addition, many companies that produce pulp and paper also produce lumber and wood products in integrated operations. Table 2.3-1 presents the subsectors in forest products with data reported in the 2006 EIA Manufacturing Energy Consumption Survey (MECS).

Table 2.3-1. Forest products subsectors with data reported in MECS

NAICS code	Forest products subsector
321	Wood product manufacturing
321113	Sawmills
3212	Veneer, plywood, and engineered woods
3219	Other wood products
322	Paper manufacturing
322110	Pulp mills
322121	Paper mills, except newsprint
322122	Newsprint mills
322130	Paperboard mills

Based on total primary energy use, the forest products sector is the second largest consumer of fuels and power in U.S. manufacturing. The manufacture of wood and paper products is highly energy-intensive, requiring large quantities of thermal energy to convert raw materials to useful products. In addition to fossil fuels, the forest products sector uses wood residues and byproducts (black liquor) to self-generate almost half of its energy needs.

2.3.2. Energy Use Profile for the Forest Products Sector

Differentiating between inside or outside the plant boundary is important when evaluating technology options for improving energy efficiency. Within the plant boundary, companies have control over plant 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, companies can reduce energy losses associated with external energy supply by adopting technologies that allow facilities to generate more energy onsite, more efficiently than the utility (e.g., cogeneration).

A snapshot of where the forest products sector ranks in terms of energy use, losses, and emissions within U.S. manufacturing is shown in Table 2.3-2. 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 forest products sector ranks among the top three in U.S. manufacturing in nearly every energy end use category. The sector ranks first in onsite generation output, and second only to chemicals in primary energy use.

Table 2.3-2. Snapshot of the forest products sector: energy use and rank within U.S. manufacturing

Category	Rank	Energy (TBtu)
Total primary energy use	2	3,559
Offsite losses	2	760
Onsite energy use	3	2,799
Onsite losses	1	1,977
Steam generation and distribution	1	748
Electricity generation	2	57
Process energy	1	1,079
Nonprocess energy	1	94
Feedstock energy	6	8
Total primary and feedstock energy*	3	3,565
GHG combustion emissions		**MMT CO_2e**
Total	3	140
Onsite	3	68

* 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 outside the scope of the footprint analysis, it is worth noting that a small amount of energy is consumed as non-fuel feedstock in this sector. As shown in Fig. 2.3-1, the total feedstock energy consumed by the forest products sector is 8 TBtu. This amount is minimal in comparison with the greater feedstock energy use in the petroleum refining sector (NAICS 324110, feedstock energy consumption equal to 3.4 quads) and the chemicals sector (NAICS 325, feedstock energy consumption equal to 2.8 quads). When feedstock and primary energy are summed, total primary and feedstock energy is about 3.6 quads for the forest products sector.

The focus of the energy use and loss analysis that follows excludes all feedstock energy use.

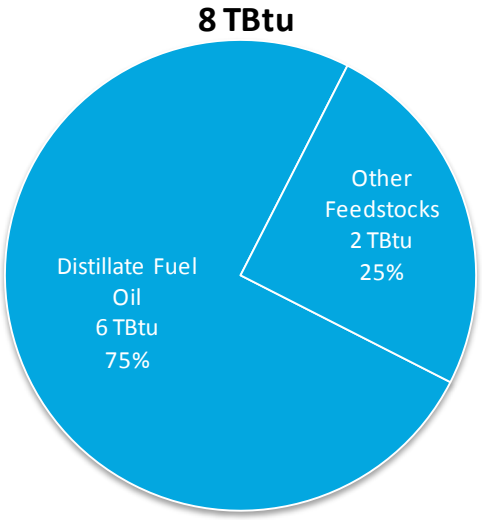


Fig. 2.3-1. Feedstock energy use in the forest products sector

2.3.2.1. Energy and carbon footprint

The *Manufacturing Energy and Carbon Footprint* for the forest products sector is shown in Fig. 2.3-2 and Fig. 2.3-3. The footprints serve 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.

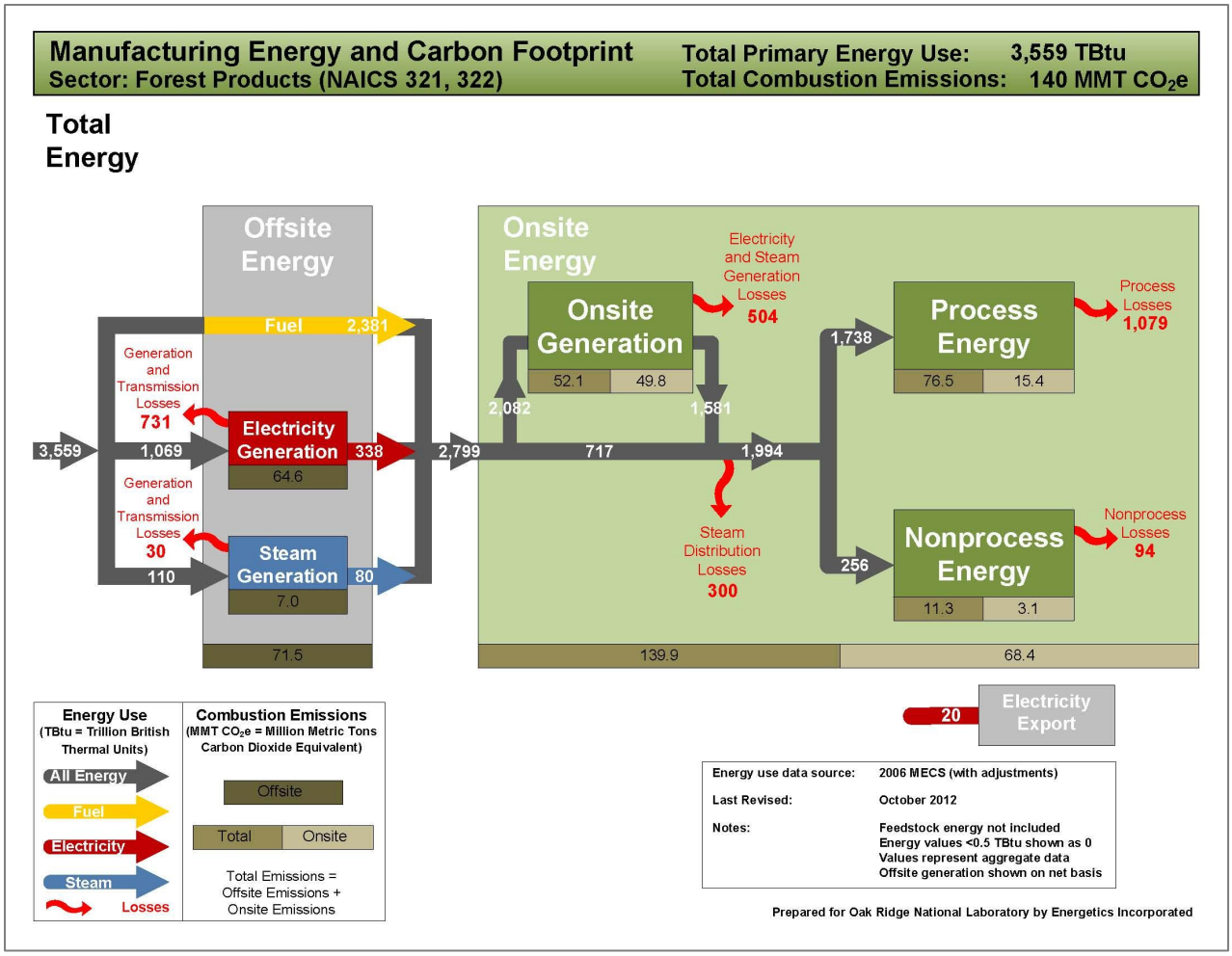


Fig. 2.3-2. Total energy and carbon footprint for the forest products sector

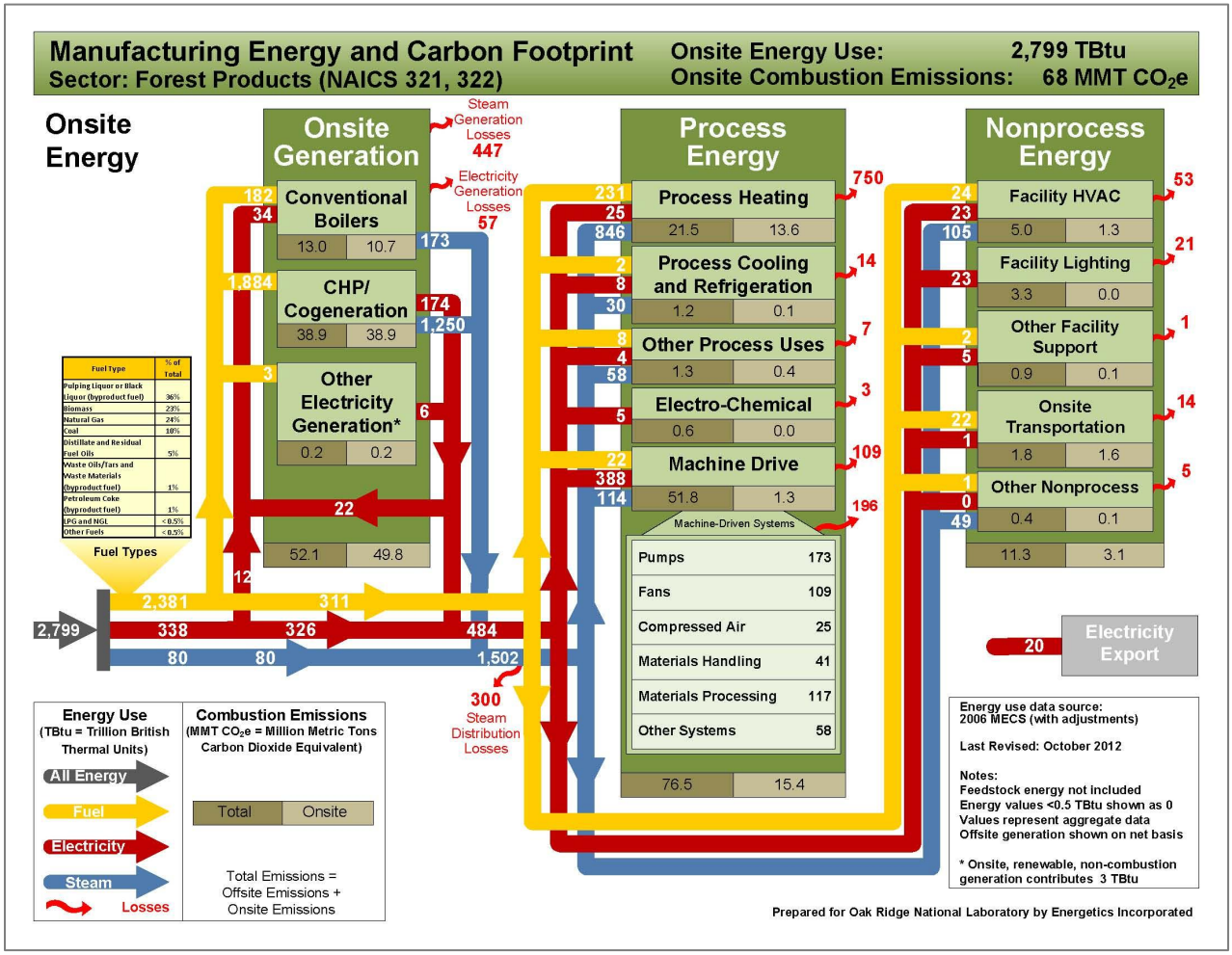


Fig. 2.3-3. Onsite energy and carbon footprint for the forest products sector

2.3.2.2. 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 forest products sector is depicted in Fig. 2.3-4. The forest products sector consumes 3,559 TBtu of primary energy, ranking second across U.S. manufacturing. Steam and electricity generation consume 55% and 36% of primary energy, respectively. Direct fuel use comprises the remaining 9% of primary energy consumption. Consistent with the footprints, blue represents steam energy, red represents electric energy, and yellow represents fuel energy.

Steam is the largest category of primary energy—consuming 1,979 TBtu (55%) of total primary energy. Onsite generation of steam accounts for 1,138 TBtu of this total, while losses from this onsite generation and steam distribution losses account for a further 748 TBtu of this total. Together, onsite steam and associated losses account for 95% of total steam generation, with the remaining steam due to offsite steam and associated generation and distribution losses.

Electricity is the second largest category of primary energy, using 1,269 TBtu (36%) of primary energy consumption. Offsite electricity (including losses) accounts for 84% of electricity generation, with the remaining 16% of electricity generation from onsite generation. Offsite electricity losses account for 58% of electricity generation energy consumption (731 TBtu). Offsite generated electricity provides 326 TBtu to direct end uses (excludes electricity used to generate steam onsite), while onsite electricity generation provides an additional 155 TBtu to direct end uses. Onsite electricity losses account for 57 TBtu of energy.

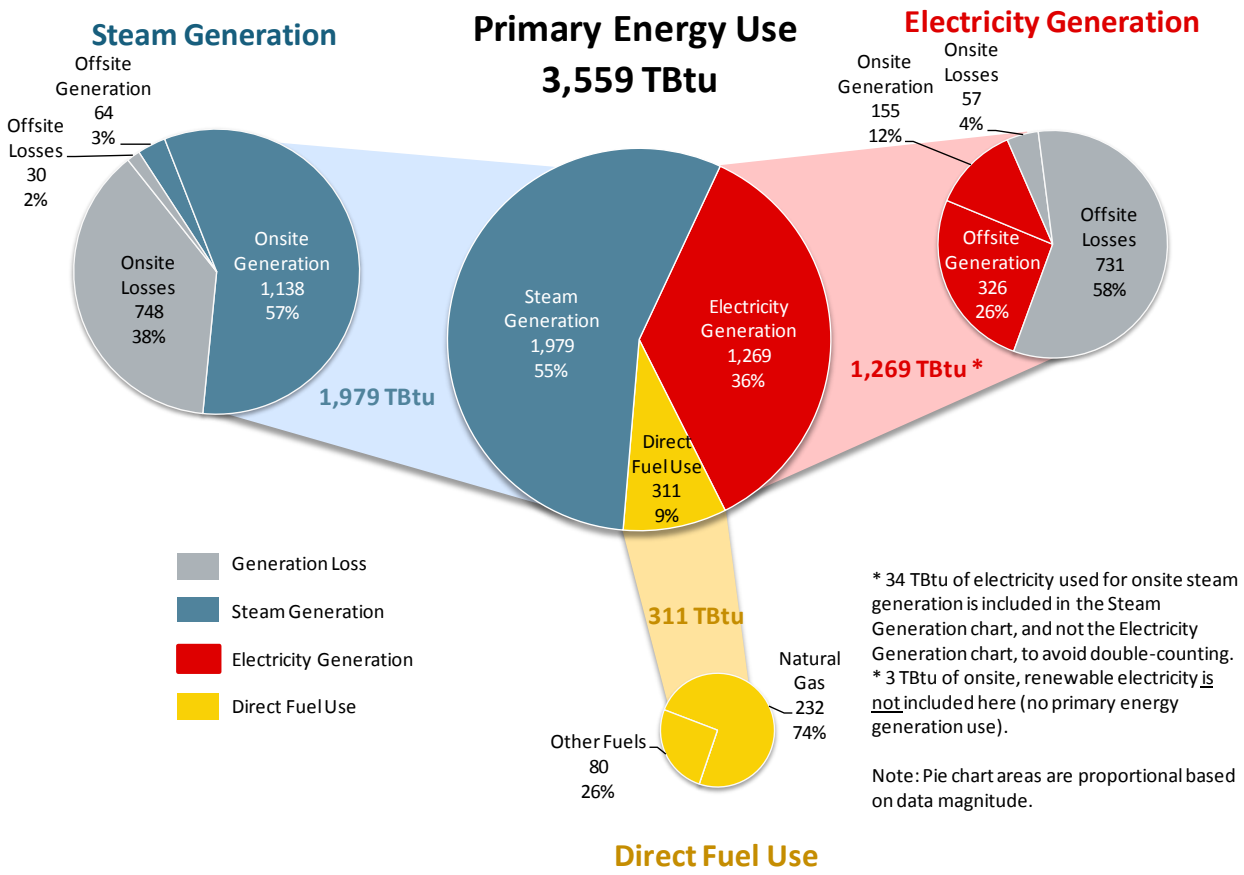


Fig. 2.3-4. Primary energy use by energy type for the forest products sector

2.3.2.3. Onsite energy

About 2.8 quads, or 79% of primary energy, were consumed onsite by the forest products sector in 2006. This onsite energy enters the plant boundary in the form of three offsite energy types: fuel, steam, and electricity. As shown in Fig. 2.3-5, this energy is composed of 85% fuel (or feedstock that becomes a byproduct fuel), 12% offsite electricity, and 3% offsite steam. Onsite fuel use is further broken down by fuel type in the yellow portion of the chart.

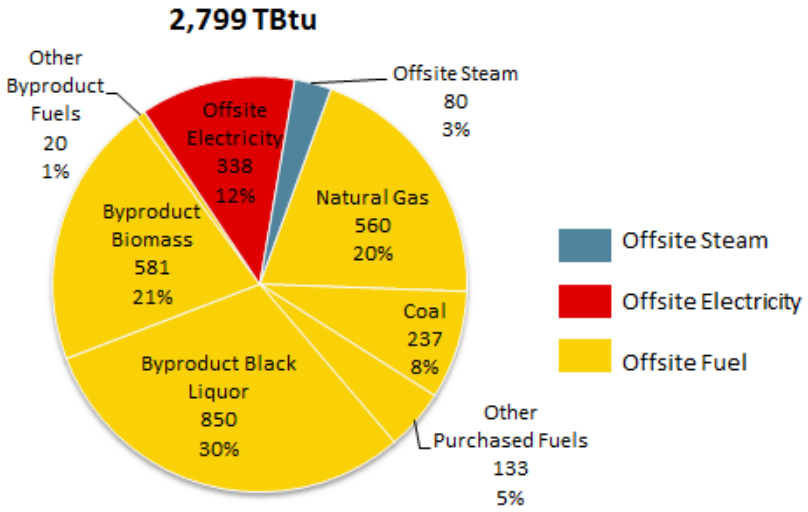


Fig. 2.3-5. Offsite energy supply in the forest products sector

Figure 2.3-6 illustrates the onsite energy consumption patterns across major subsectors of the forest products sector (the sum of onsite energy use across these subsectors is equal to 88% of sector-side onsite energy use). Overall, paper mills (except newsprint) and paperboard mills consume more energy than any other subsector in 2006 at 939 TBtu and 827 TBtu, respectively. The remaining other subsectors of veneer, plywood, and engineered woods; other wood products; sawmills, pulp mills, and newsprint mills each use about 200 TBtu or less of fuel energy.

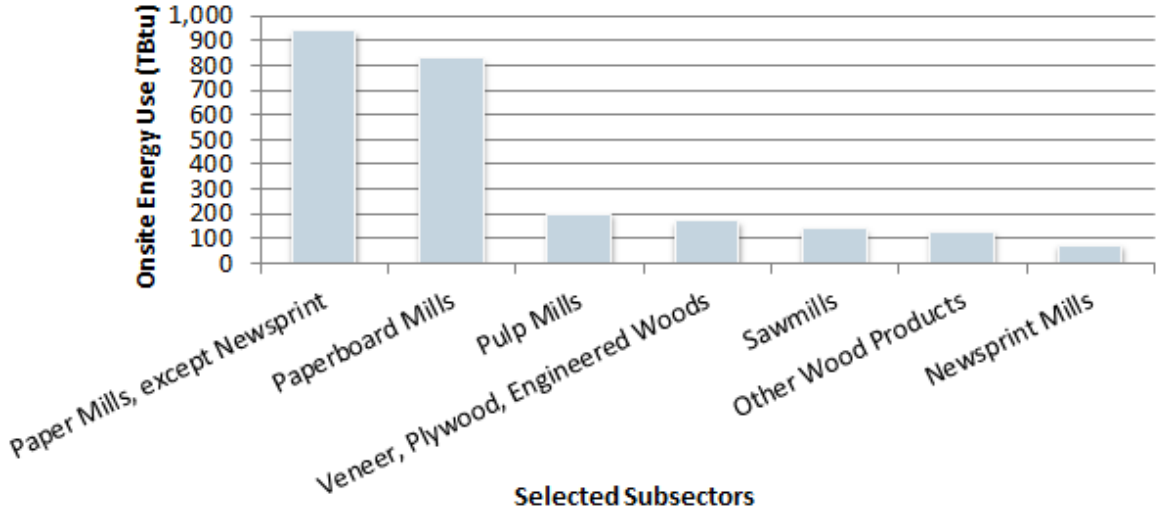


Fig. 2.3-6. Onsite energy use in selected forest products subsectors

However, it should be noted that the data reported may be somewhat misleading due to how sectors are categorized by NAICS. Paper and Paperboard Mills, for example, include operations where pulping is done at the same facility (integrated pulp/paper mills). Subsequently, in those cases, energy reported includes energy for pulping as well as papermaking. Energy shown for pulp mills only includes mills that do not make paper.

2.3.2.4. Fuel energy

Onsite fuel use in the forest products sector is 2,381 TBtu. The forest products sector is the second largest user of fuel behind the petroleum refining sector and almost 80% of this fuel is used for onsite CHP generation, making forest products the largest user of CHP, with almost two and half times as much CHP output as the second-ranked chemicals sector.

Forest products manufacturing constitutes the largest manufacturing use of biomass. Biomass resources utilized by the industry include black liquor produced by kraft pulping processes and wood residues collected from wood handling and manufacturing processes. These wood byproducts are burned by the forest products industry to generate steam and electricity. As shown in Fig. 2.3-5, pulping/black liquor itself provides 850 TBtu, or 30% of offsite energy supply. Combined with other forms of biomass such as wood residues, biomass comprises about 51% (1,431 TBtu) of offsite energy supply. Coal, fuel oils, and other petroleum-based fuels make up the remainder of fuel use.

Improvements in the efficiency of energy systems impact fuel use distribution directly in forest products. The forest products industry is steam intensive, so increasing boiler and process heat transfer efficiencies can have a significant impact. Much of boiler fuel, however, comes from process byproducts. There is subsequently a trade-off between increased yield and process efficiency (producing less byproducts), the biomass available for boiler fuel, and the use of more costly fossil fuels.

2.3.2.5. Electrical energy

The forest products sector ranks second among U.S. manufacturing sectors in electricity demand at 518 TBtu. Electricity demand, equal to the sum of net purchased electricity and electricity generated onsite, provides the most complete picture of facility electricity use. Electricity only accounts for less than 15% of energy consumption across the sector. The sector creates a diversity of products with many different production processes, so energy use patterns do vary across subsectors. Within the same product subsector, processes (and associated energy demand) can also differ depending on the technology used. For example, pulp can be made by chemical pulping, mechanical pulping, or a combination of the two pulping processes.

As shown in Fig. 2.3-7, the forest products sector used 484 TBtu of electricity for direct[11] process uses. A large portion of the primary energy consumed for electricity end 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 705 TBtu of energy losses in order to produce 326 TBtu of electricity that is used in the sector. The forest products sector also does meet a moderate portion of its electricity demand through onsite generation. Approximately 158 TBtu of energy use is associated with the production of onsite electricity. Most of the onsite produced electricity is generated using CHP units, with only a small percentage originating from other generation methods such as the use of generators running on combustible energy sources or electricity from renewable resources. Renewable electricity generation contributes about 3 TBtu to onsite electricity generation in forest products, more than any other sector.

Approximately 80% of the electricity is consumed by machine-driven systems such as pumps, conveyors, compressors, fans, mixers, grinders, and other materials handling or processing equipment. Facilities use, such as HVAC and lighting, is the next largest category of electricity consumption within the sector, consuming 11% of electricity use. The remaining 9% of sector electricity use is consumed by other process uses including process heating, process cooling and refrigeration, and electro-chemical processes.

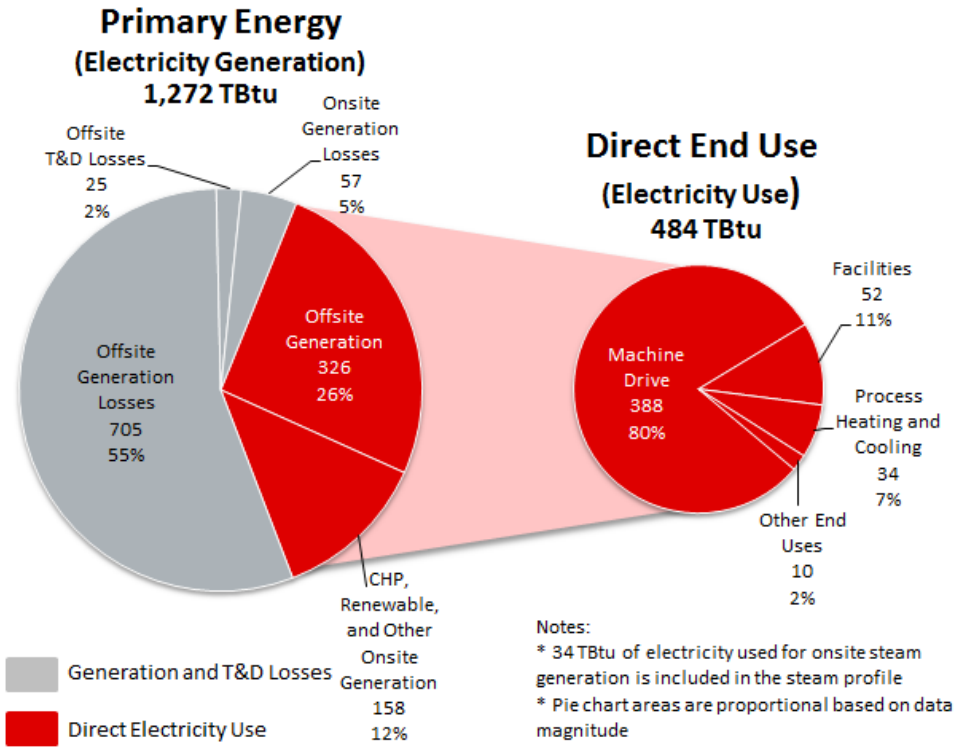


Fig. 2.3-7. Electricity generation and direct end use in the forest products sector

[11] Offsite electricity generation (326 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 (338 TBtu). This difference is due to the small portion of offsite electricity (12 TBtu) that is used by conventional boilers to generate steam.

2.3.2.6. Steam energy

The forest products sector ranks first across U.S. manufacturing in steam usage. A profile of the forest products sector steam use from primary energy and associated losses is shown in Fig. 2.3-8. About 39% of primary energy inputs are lost due to system inefficiencies in steam generation and transmission, both offsite and onsite. CHP generation comprises just over half (51%, 1,000 TBtu) of primary energy, serving as the principal source of energy to be applied towards end use. Conventional boiler steam provides for about 7% (138 TBtu) of the energy for end use, followed by steam generated offsite at 3% (64 TBtu). Of the 1,979 TBtu of primary energy made available for steam, 1,202 TBtu of energy is applied to end use. Process heating systems, particularly those used for drying or evaporation, receive the bulk of the energy at 70% (846 TBtu), followed by machine drive and facility HVAC uses each at 9% (114 and 109 TBtu respectively), 5% to other process uses (58 TBtu), 4% to other nonprocess uses (49 TBtu), and the remaining 3% going to process cooling and refrigeration (30 TBtu).

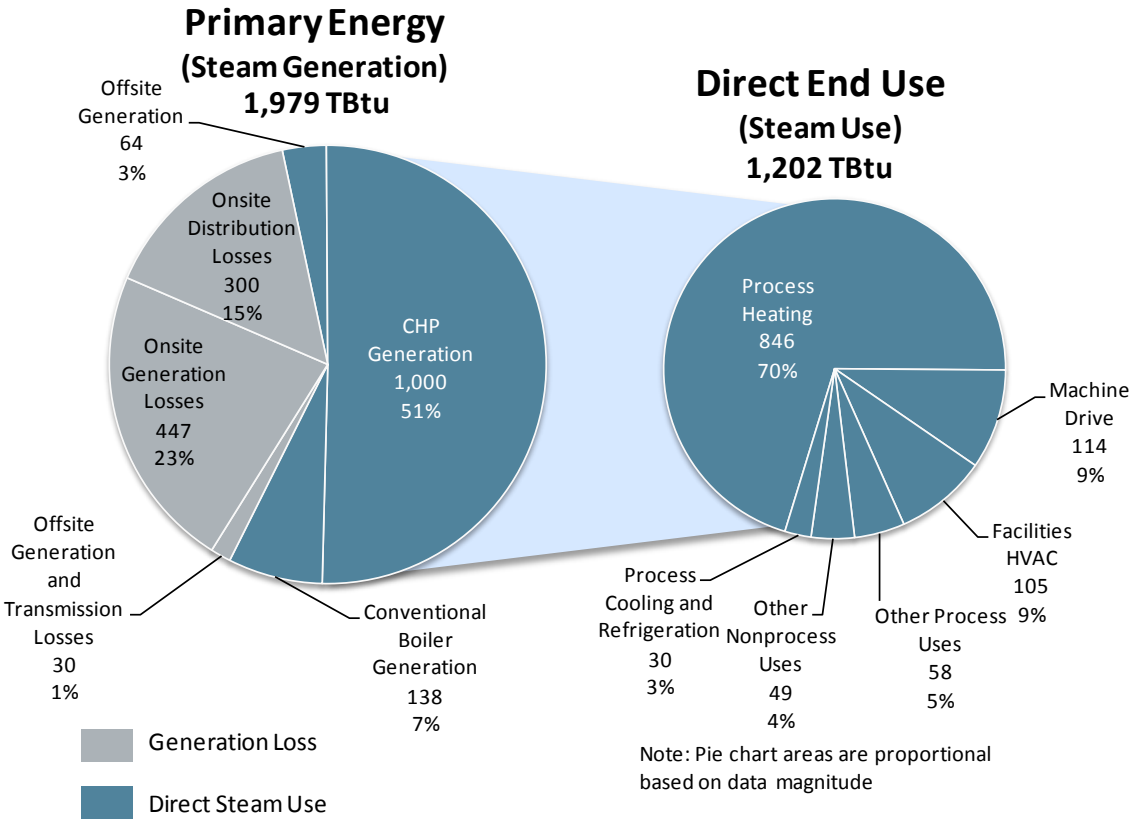


Fig. 2.3-8. Steam generation and *direct* end use in the forest products sector

2.3.2.7. Combined heat and power energy

The forest products sector meets a significant amount of energy demand through onsite generation, especially steam, ranking first in CHP output across U.S. manufacturing. As shown Fig. 2.3-9, fuel use for combined heat and power systems produces 1,884 TBtu of energy output, with about two-thirds in the form of steam (1,250 TBtu, 66%). Electricity encompasses about 9% of CHP output (174 TBtu), with the remaining 25% of energy composed of losses (461 TBtu). Three-fourths of fuels entering CHP units are biomass-related, consisting of pulping/black liquor (45%, 850 TBtu) and other biomass sources such as wood residues (31%, 581 TBtu). Coal comprises 11% of fuel used for CHP at 204 TBtu, followed by 9% (179 TBtu) from natural gas, with the remaining 4% (71 TBtu) composed of other fuels such as distillate and residual fuel oils.

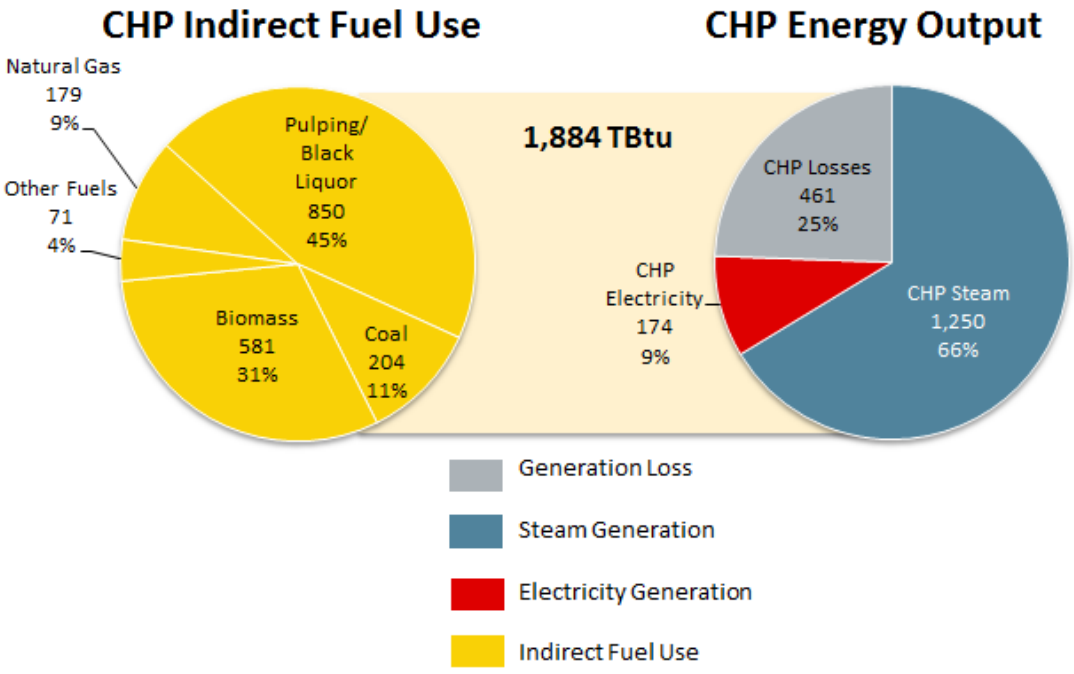


Fig. 2.3-9. CHP fuel consumption and energy output in the forest products sector

2.3.2.8. Direct end use energy

Energy is consumed in forest product 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 its direct end use is shown in Fig. 2.3-10.

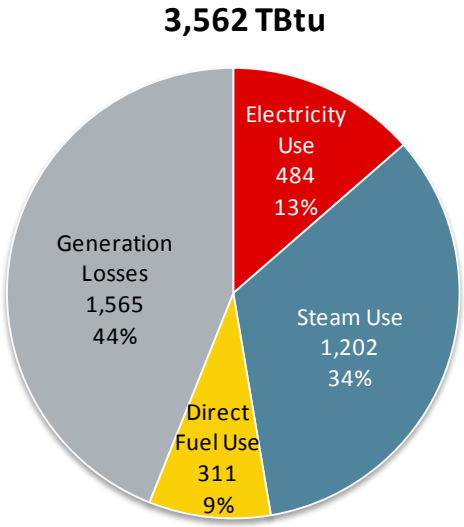


Fig. 2.3-10. Primary energy by type at *direct* end use in the forest products sector

A breakdown of primary energy by all direct end uses is shown in Fig. 2.3-11, which shows 49% of primary energy used for process used (49%, 1,741 TBtu). Losses incurred during the generation of electricity and steam at accounts for a further 44% (1,565 TBtu) of primary energy and nonprocess uses account for only about 7% (256 TBtu) of sector primary energy use.

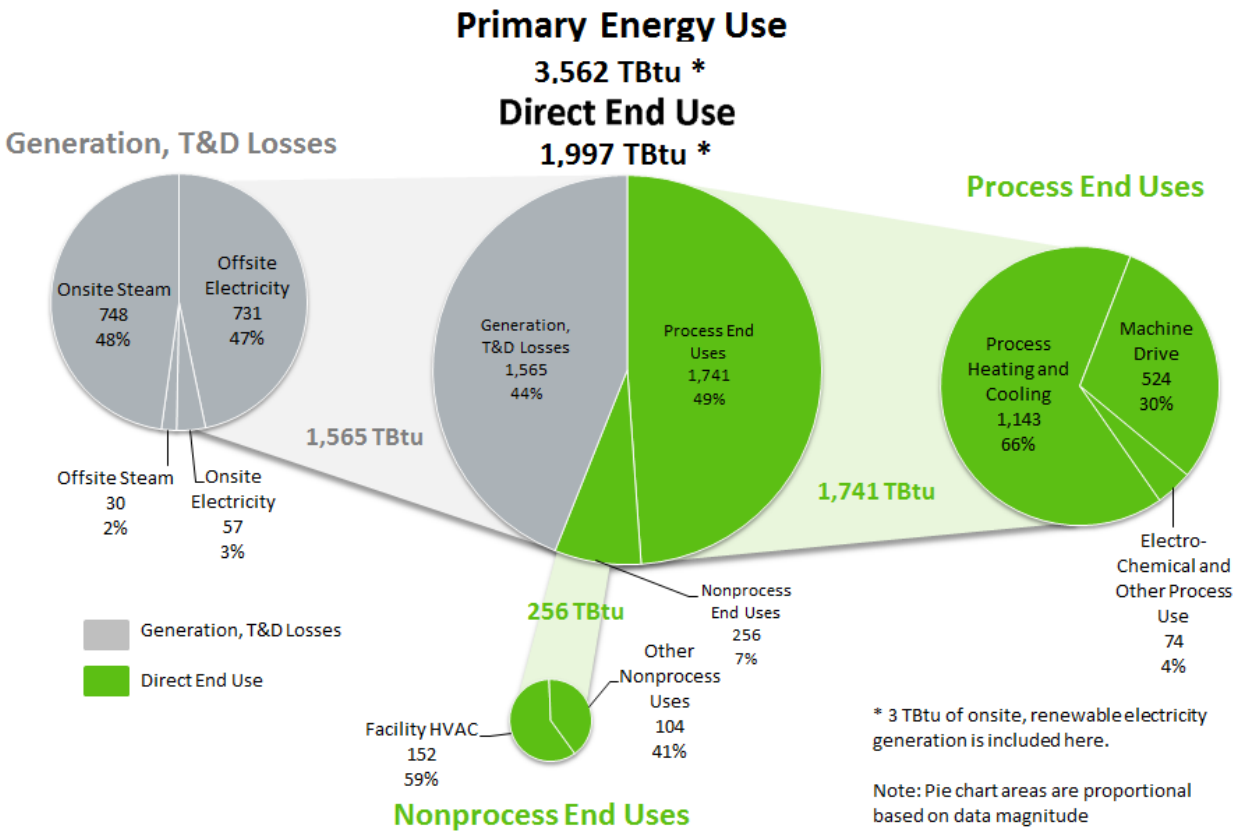


Fig. 2.3-11. Primary energy by *direct* end use in the forest products sector

The forest products sector ranks third across U.S. manufacturing in the use of process heating and cooling systems, and second in the use of machine-driven systems. Heating and cooling processes consume 1,143 TBtu out of the 1,741 TBtu (66%) total delivered to process end uses. These include steam systems and fired systems such as furnaces and reboilers. Machine-driven systems are the next largest use of process energy in the sector at 524 TBtu (30%). As shown in Fig. 2.3-8, 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. Further, the majority of other fuels are primarily comprised of biomass sources such as pulping/black liquor and wood residues, as described in the combined heat and power section.

The forest products sector also ranks first across U.S. manufacturing in nonprocess energy end uses. Facility HVAC is the largest user of nonprocess energy, followed by other nonprocess energy uses such as facility lighting, onsite transportation, and other facility support.

2.3.2.9. 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. 2.3-4, which shows primary energy by energy type for the forest products 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. 2.3-7), the majority of steam generation losses are onsite (as shown in Fig. 2.3-8), 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. 2.3-12.

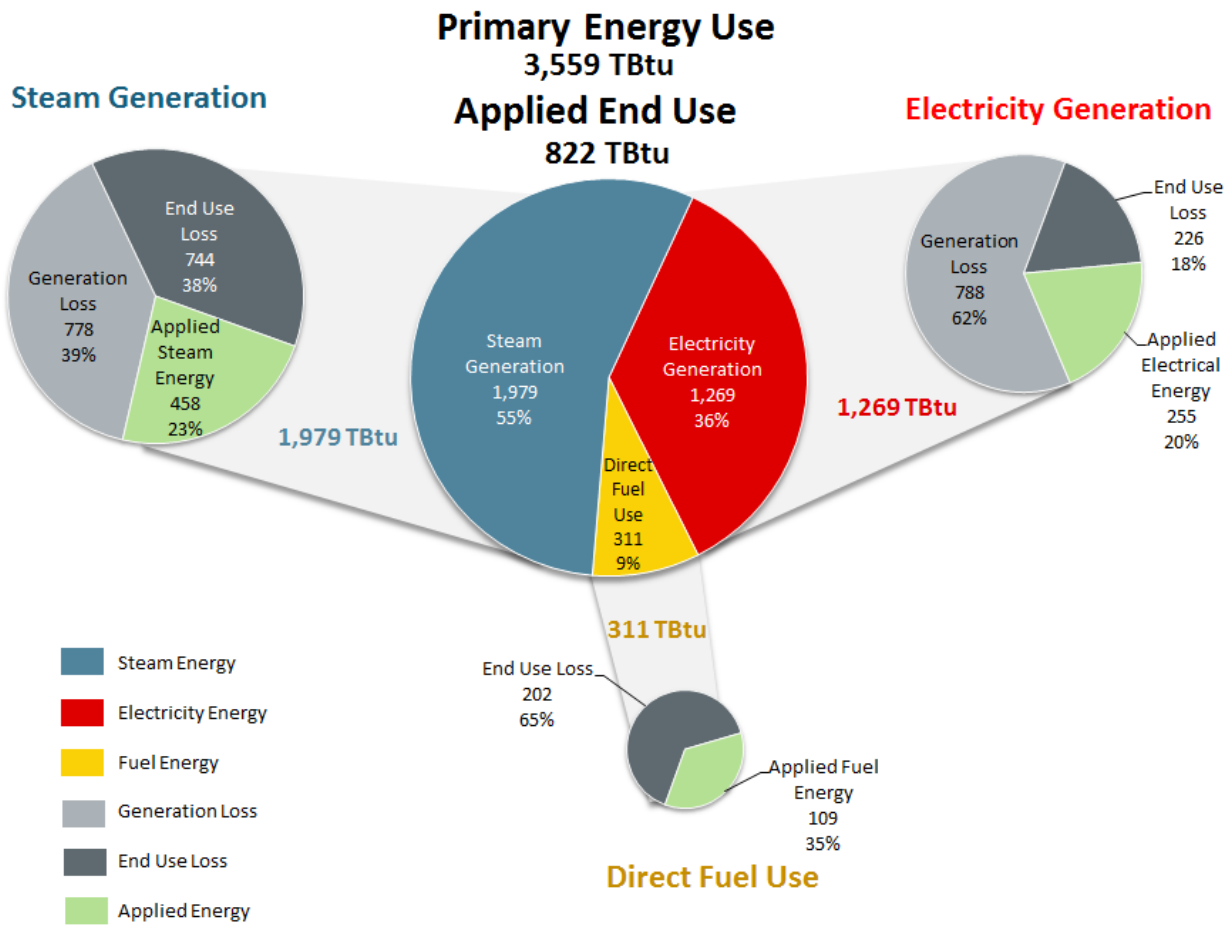


Fig. 2.3-12. Primary energy use and applied energy by energy type in the forest products sector

Fig. 2.3-13 shows the breakdown of primary energy by energy loss and applied energy. In this sector, only 23% of primary energy input is applied to process and nonprocess end uses, significantly less than the manufacturing average of 34%. Generation losses account for 44% of primary energy input and end use losses account for the remaining 33% of primary energy input.

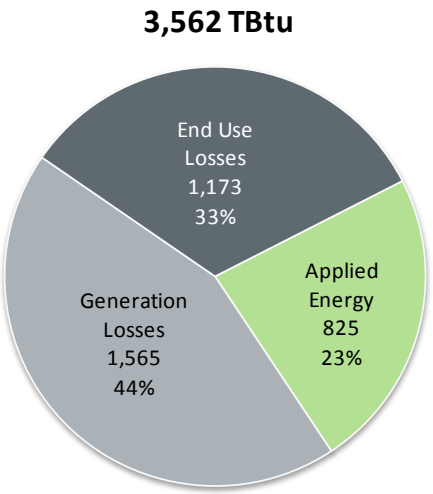
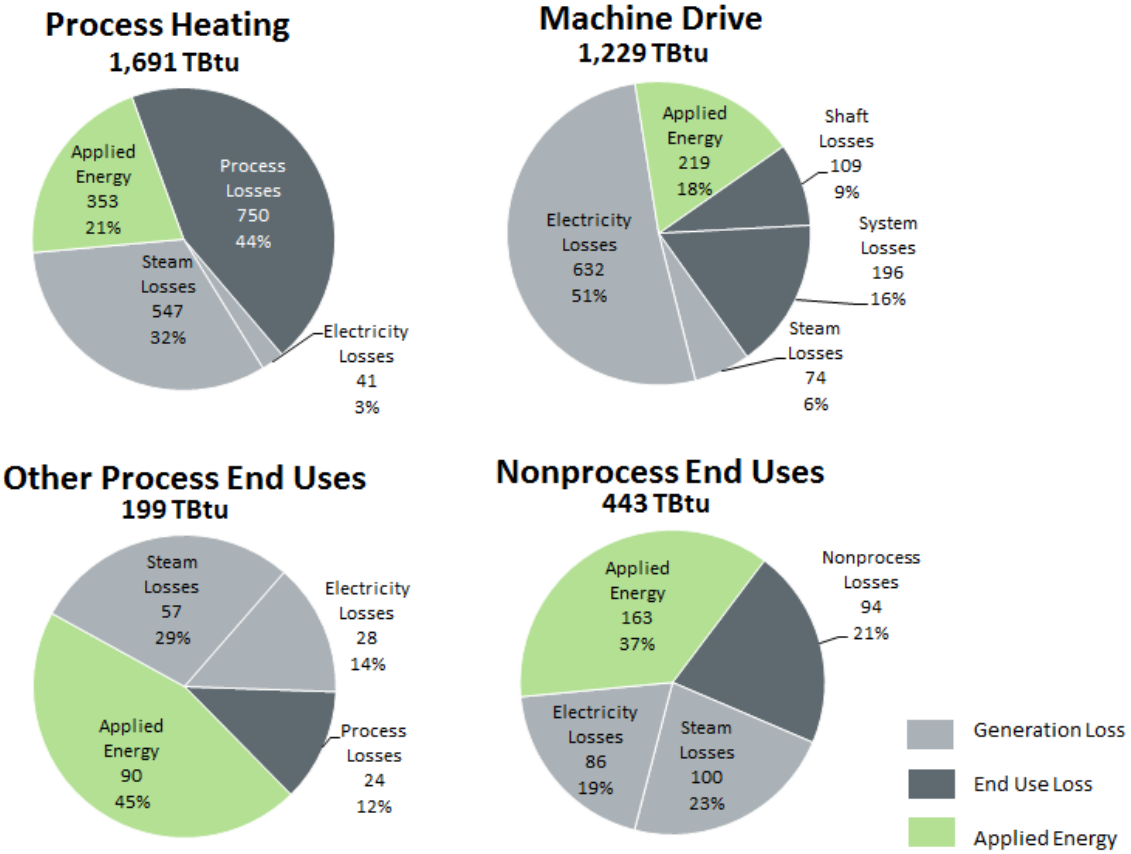


Fig. 2.3-13. Primary energy by loss and applied energy in the forest products sector

Applied energy can also be calculated for specific end uses, as shown in Fig. 2.3-14. This figure shows generation losses labeled as either steam or electricity losses. 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 systems, only 21% 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, 18% of primary energy is applied to direct end uses, primarily due to the inefficiency in electricity generation.



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

Fig. 2.3-14. Primary applied energy by *direct* end use in the forest products sector

2.3.3. Greenhouse Gas Combustion Emissions Profile for the Forest Products Sector

The forest products sector released a total of 140 MMT CO_2e in 2006, making it the third greatest emitter of GHG combustion emissions among U.S. manufacturing sectors. Emissions by offsite energy supply type are shown in Fig. 2.3-15. Emissions released during offsite production of electricity contribute 46% of sector emissions, while 5% of emissions are attributed to the production of offsite steam. The onsite consumption of fuels (shown in yellow), including natural gas, byproduct fuels, coal, and other fuels accounts for 49% 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. Fuels such as natural gas and coal contributed about 49% of total emissions, while offsite electricity alone contributed nearly half (46%) of emissions as well. Biomass and pulping/black liquor emissions reflect CH_4 and N_2O emissions from the combustion of these fuels, while CO_2 emissions from these two fuels are excluded because the uptake of CO_2 during biomass growth results in zero net emissions over time. Table D.5 shows fuel GHG combustion emission factors associated with fuel combustion, as well as electricity and steam generation.

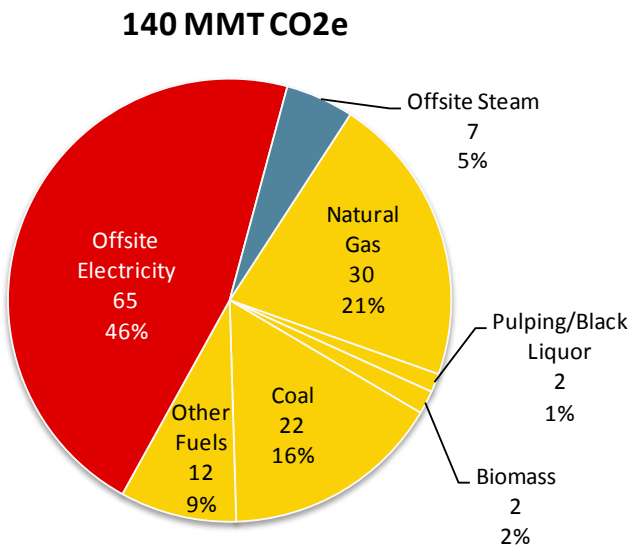


Fig. 2.3-15. Total GHG combustion emissions in the forest products sector (shown by energy supply type)

Figure 2.3-16 presents an alternate view, where total emissions are shown 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. The fuel emissions that are not associated with steam or electricity generation are assigned to either process or nonprocess emissions, shown in yellow. This figure shows that combined offsite and onsite electricity comprise approximately 50% of all emissions. Offsite and onsite steam make up about 37%, and process and nonprocess fuel makes up the remaining 13% of emissions.

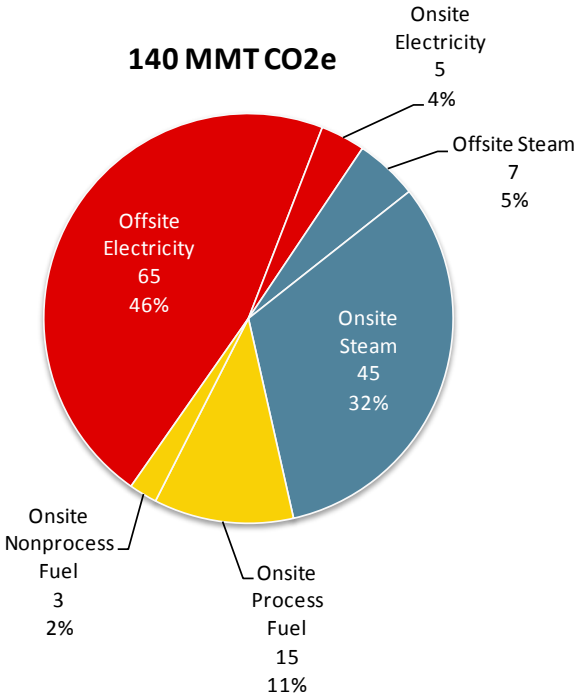


Fig. 2.3-16. Total GHG combustion emissions in the forest products sector (shown by energy end use type)

Emissions can also be associated with the direct end uses of energy, as is shown in Fig. 2.3-17. 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. Process heating and cooling and machine-driven uses, both with their heavy steam system and electricity usage, contribute almost equally towards emissions at over 40% each. Facilities and HVAC nonprocess uses contribute nearly 10% of emissions, while all other process and nonprocess uses contribute just fewer than 10% of emissions.

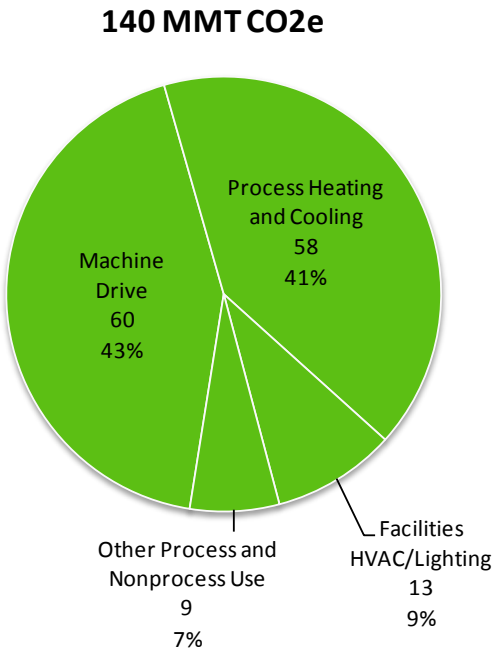


Fig. 2.3-17. Total GHG combustion emissions in the forest products sector (shown by direct energy end use)

2.3.4. Energy and Emissions Profile Summary Table

The energy and emissions profiles for the forest products sector are summarized in Table 2.3-3 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 2.3-3. Energy use, loss, and GHG combustion emissions in the forest products sector

Forest products			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 (2,381 TBtu)	-	-	N/A	-	Distributed to onsite	Distributed to onsite direct
		Electricity generation/transmission	1,069	731		64.6		
		Steam generation/transmission	110	30		6.9		
		Total offsite (including fuel supply)	**3,559**	**760**		**71.5**		
Onsite	Indirect	Conventional boilers	216	43	N/A	10.7	13.0	Distributed to onsite direct
		CHP/cogeneration	1,884	461		38.9	38.9	
		Other electricity generation[a]	3	1		0.2	0.2	
		Steam distribution	-	300		0.0	0.0	
		Total onsite generation	**2,103**	**805**		**49.8**	**52.1**	
	Direct	Process heating	1,102	750	353	13.6	21.5	55.0
		Process cooling and refrigeration	40	14	26	0.1	1.2	2.5
		Machine drive	524	305	219	1.3	51.8	60.3
		Electro-chemical	5	3	2	0.0	0.6	0.6
		Other process uses	69	7	62	0.4	1.3	3.6
		Nonprocess energy	256	94	163	3.1	11.3	17.9
		Total process and nonprocess	**1,997**	**1,173**	**825**	**18.5**	**87.8**	**139.9**

* 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)
[a] Onsite, renewable, non-combustion generation contributes 3 TBtu