Energy consumption in MDF production: Overview of use renewable and non-fossil energy sources in a Brazilian mill

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Abstract

This paper aims to report the energy consumption for the production of reconstituted wood panel MDF (Medium Density Fibreboard) in terms of employing renewable and non-fossil energy sources. The MDF is a composite wood panel product comprised of wood fibres, urea-formaldehyde resin, wax, and other chemicals. Data were achieved through the development of Life Cycle Inventory of MDF in a Brazilian industry. The Methodology used was based in the ISO 14040:2009 standard, which determines the principles and structure for life cycles studies. The boundaries of the system studied involve the on-site system manufacturing, delimited to the operations within the industry. The energies consumptions are reported according to the functional unit of 1 m^3 of MDF, without decorative coatings, ready to be dispatched. In order to produce 1 m^3 of MDF were necessary 1.19 MWh. About 71% of this demand is thermal energy. MDF has favorable characteristics in terms of the use of energy, more than 80% of the energy needed to produce 1 m^3 of MDF are renewable and non-fossil.

Keywords: MDF; LCI; renewable energy; non-fossil energy.

1 Introduction

One of the greatest technological challenges that will rule this century must surely be the use and access to clean and sustainable energy supplies. In an environmentally responsible society, the use of renewable and non-fossil energy sources reflects positively on the image or brand of a company and its products.

Currently, companies are changing their production processes in order to reduce their dependence on fossil and non-renewable fuels. Nevertheless, some of them have the knowledge neither about the use of their energy matrix in their operations, nor about the overview of the sector where they operate.

With the increasingly global warming and energy concerning in world, further regulations have been added to the panel mills and the pressure is toward making all panel mills as environmentally-friendly as possible. (WBPI, 2009)

In this context, the objective of this study was to develop high quality data about the energy consumption to produce medium density fibreboard (MDF). The data provide an overview of the renewable and non-fossil energy sources used in this product. MDF is produced by consolidating wood fibres under heat and pressure that have been mixed with resin, urea, wax and other additives to form a uniform, dense panel product that is sawn to size and sanded on both sides to be used in furniture and interior fitments.

This study was made through the analysis of the Life Cycle Inventory (LCI) of the MDF. The Methodology used was based in the NBR ISO 14040: 2009 standard, which determines the principles and structure for life cycles studies. The boundaries of the system studied involve the on-site system manufacturing, delimited to the operations within a Brazilian mill.

Issues where these data can be applied include sustainability, global warming, climate change, carbon storage, carbon trading and caps, carbon taxes, biofuel use, green purchasing, and green building

(WILSON, 2010). These data can also be used to establish the performance of MDF in comparison with others wood based panels and with the energy performance in other MDF mill.

2 Goal, Scope and Procedures

2.1 Objectives

This work aims to develop high quality data about the energy consumption to produce reconstituted wood panel MDF (Medium Density Fibreboard) in a Brazilian mill and to report the use of energy in terms of employing renewable and non-fossil energy sources. Besides, providing analyses about the demand of energy required to produce 1 m^3 of MDF in terms of electrical and thermal energy.

In order to establish the energy use performance of MDF produced in this mill, a life-cycle inventory (LCI), which consists of an accounting of all inputs and outputs in a product manufacturing, was done. The system boundary in study comprised the on-site system production.

2.2 Functional Unit

For this study, material flows and energies used were expressed as a function of the functional unit: 1.0 m^3 of MDF, oven-dry, without decorative coatings, finished, ready to be ship. For those LCI practitioners who conduct studies based on mass, 1.0 m^3 of MDF weights 681 kg oven-dry. The MDF had 7.3% water content.

2.3 Description of the system under study

Medium Density Fibreboard (MDF) is an engineered wood product formed by breaking down softwood into wood fibres, often in a defibrator, combining it with wax and resin, and forming panels by applying high temperature and pressure. It is a building material similar in application to plywood but made up of separated fibres, not wood veneers. MDF has a typical density of 600-800 kg/m^3 and similar manufacturing processes are used in all MDF mills around the world (WORLD PANEL INDUSTRY, 2012).

The MDF began to be produced in Brazil in 1997 and quickly gained the market. According to the Brazilian overview of wood panels, published by BNDES (2010), the Brazilian market for wood panels is still in a process of consolidation and shows great dynamism, especially in the segment of MDF, which consumption has grown above the industry average in the last 12 years. When comparing this growth with the evolution of national GDP (Gross Domestic Product), the difference is even greater. For every 1% increase in GDP between 1997 and 2008, the MDF has grown on average 11.8% (BNDES, 2010).

The representative of the sector in the current national scene, according to data from the Brazilian Association of Wood Panels (ABIPA, 2011), accounts for about 500,000 hectares of pine and eucalyptus and employs approximately 5,500 employees directly and 25,000 indirectly.

An outlook of the sector of wooden panels shows that the demand for reconstituted wood panels grows on average 14.1% per year by 2013, whereas MDF grows 15.7% (BNDES, 2010).

Current MDF manufacturing industries, throughout the world, have basically the same sequence of activities and processes for the manufacture of the panel. The MDF manufacturing process is highly automated, process-controlled, and fairly linear. The Figure 1 illustrates the manufacturing process of the Brazilian mill studied.

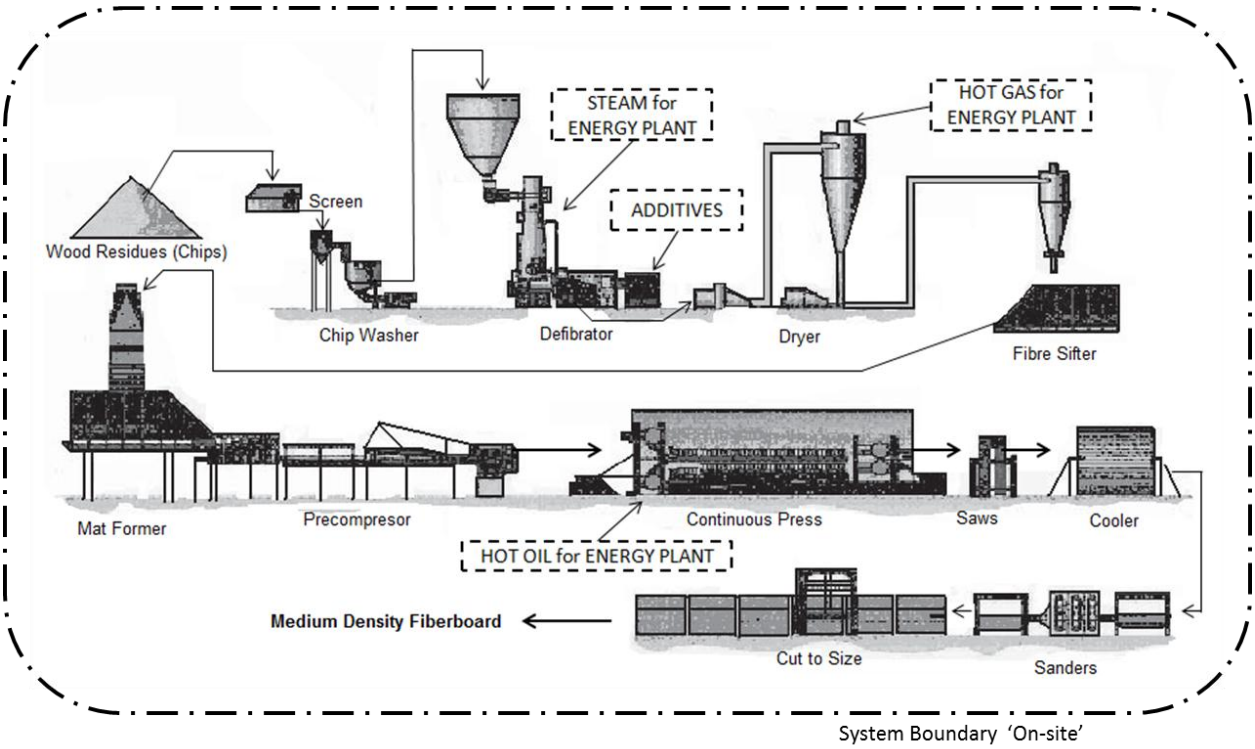

Figure 1: Flow Sheet of MDF Manufacturing System. Source: Adapted of Rivela, Moreira and Feijoo (2007)

The process consists of the following steps:

- Alimentation: The wood chips are delivered to the mill by truck, the chips. The chips are made of pine and eucalyptus and are stored in the wood yard, without coverage. The moisture content of the chips can range from 40 to 70% on an oven-dry weight basis.
- Screen: Small Particles (Fines) and Large Particles/Peel (Oversize) are removed from the chips during the screening. The Fines returns to the process and the oversizes are sold as biomass to another mill. Only the appropriate sized chips are fed to the process.
- Chip Washer: The chips are washed to remove dirt. The residues and extractives are treated as effluent through a centrifuge on the mill.
- Defibrator: Clean chips are softened in a steam-pressurized digester and then transported into a pressurized refiner chamber. The heated wood chips are then refined, a process of mechanically reducing it into fibres by shearing the wood between two rotating metal disks that separate the fibres; this process is accomplished by the use of a pressurized disk refiner.
- Blowline: In this process resin, wax and other additives are blended with the fibres. Friction and contact between fibres may help to distribute the resin. The resin used is based on Urea-Formaldehyde (UF).
- Dryer: The fibres drying occurs in tube dryer of hot air, where the hot air is responsible for drying the fibre. The hot air stream evaporates the moisture and conducts the fibre. The hot air dryer is generated by the power plant, usually by combustion of wood dust generated by the mill or eventually by natural gas.
- Fibre Sifter: After drying, the fibres (7-9% moisture content) pass through a wind filter (Sifter). The sifter is used to remove clumps of fibres or other heavy materials that may cause problems to the process and the final product. The dry fibre is selected and conducted to the mat former.

- Mat former: The dry and selected fibre goes to feeder bin with a uniform distribution through the action of pendulum fibre distribution. The fibres are uniformly distributed by forming and become a mat fibre.
- Pre-compressor: The mat fibre cross the deaerator (to remove air between the fibres) and, finally, the mat is pre-compressed by the compressor. The mat is moistened with its upper and lower surface during the formation process to enter the pressing.
- Continuous Press: The continuous press operate as a function of temperature and pressure. Press operates at about 170 - 230ºC in a sufficient time to cure the resin and at a pressure to consolidate the mat to a desired density, thereby controlling the physical properties of the panel. The continuous press is heated by hot oil generated in thermal plant.
- Saws: The diagonal saw cuts the panel in the transverse direction.
- Cooler: The MDF goes first to a cooler, where it stays for 40 minutes. After that, the produced panels remain resting for 48 hours so that their physical and mechanical properties are stabilized.
- Sanders: Panels are sanded on both major surfaces to targeted thickness and smoothness. Sander dust coming off this process is recycled back into the process as fuel for thermal plant.
- Cut-to-size: The large panels are sawn to dimensions of panel width and length. Panel trim is hammermilled into particles and sent back into the process. All the sawing dust is sent back to the process in the thermal plant.
- Energy Plant: It consists of two Thermal Plants. The first is responsible for heating the hot oil used in continuous press where its fuel is natural gas. The second provides steam and hot air to the process, where its main fuel is biomass (wood dust from the process and purchased from other plants) and occasionally it also burns natural gas as fuel.

2.4 Data Quality and Calculations Procedures

High quality data are fundamental to make a reliable analysis. All data were related to inputs and outputs of the MDF manufacturing in a Brazilian mill during an one year period (2010). The data were collected through questionnaires. The questionnaires were developed based on two models:

a) Questionnaire developed by the Athena Sustainable Materials Institute (2009) for the Life Cycle Assessment (LCA) of the Canadian MDF, which follows the methodology proposed by the ISO 14040 series;

b) Sheets of collection data suggested by the NBR ISO 14044 (ABNT, 2009).

Data were collected from managers responsible for each specific area and the treatment of these data was performed by analysis of the Life Cycle Inventory (LCI), following the guidelines of NBR ISO 14040 and NBR ISO 14044 (2009). For the LCI, was used the software Umberto 5.5.

The main source of data collection was the production management software. It communicates devices such as scales, sensors, controllers, flow meters and other equipment to quantify the process variables. Data collection was also followed up on and their quality was verified. The survey of all data in the mill took five months.

The procedures for calculating the LCI involved the mass and energy balances of the process defined at the boundary on-site. Inputs and outputs of materials and energy for each elementary process were quantified (Figure 1). Regarding the mass and energy balances, it was necessary to consider some specific parameters and coefficients of materials and energy used in manufacturing process. It was defined for the units "kg" and "MJ" for mass and energy balances, respectively. All data were computed in dry mass.

A mass balance considering all inputs materials and all outputs of product and emissions had a difference of 0.41% that is suitable within the maximum 5% balance required of the CORRIM protocol, apud Wilson

(2008). According Wilson (2008) the Energy balances are done mainly to determine the expected energy consumption to remove the desired amount of water from the wood fibres during processing. The average Moisture Content (MC) of wood material coming into the mill in this study was 54.12% on an oven-dry weight basis. The targeted MC for the dried material with resin applied was 6 – 10%, in mat formation. The MC of the MDF finished was approximately 7.3% on an oven-dry.

The Brazilian plant studied produced around 300,000 m^3 of MDF during the year 2010. The average thickness of the panels produced was 16 mm and the average density was 681 kg/m^3 on an oven-dry weight basis.

3 Energy Use in MDF Manufacturing

The energy for the production of MDF results from sources of electricity, wood, natural gas and hot oil while diesel fuel is responsible for powering transport in the plant. Electrical power is used all over the manufacturing process in order to operate equipment inside the plant, such as conveyors, grinders, fan motors, hydraulic motors, sanders, among others.

The thermal energy is generated by two plants. The first is responsible for the heating of the hot oil used in continuous press where its fuel is natural gas. The second provides steam and hot air to the process, where its main fuel is biomass (wood dust from the process and purchased from other plants) and occasionally it also burns natural gas as fuel.

The total energy demand required for the production of 1.0 m^3 MDF is 1.2 MWh. Table 1 presents the inventory of energy for the production of 1.0 m^3 of MDF in Brazilian mill.

Table 1: Energy Inventory to produce 1.0 m^3 in Brazilian mill

Inputs	**Unit**	**Unit/m^3**	**MWh/m^3**	**Percent**
Electric Energy	MJ	1,009.68	0.28	23.3%
Natural Gas	m^3	17.40	0.19	15.8%
Diesel Oil	L	0.41	0.003	0.3%
Wood Dust (Purchased)	Kg	87.39	0.38	31.7%
Wood Dust (Generated in mill)	Kg	80.22	0.35	29.2%
Sanding Dust	Kg	50.27	0.26	21.7%
Saw Dust	Kg	29.95	0.09	7.5%
TOTAL	-	-	1.2	100.0%
Outputs	**Unit**	**Unit/m^3**		
MDF	Kg	681.0		
Wood Waste and Boiler Ash	Kg	3.59		

Source: Authors (2012)

Calculations were performed using the methodology of Life Cycle Inventory. It was employed the software Umberto as a tool for calculations procedures. Since data is validated for elementary processes and functional unit, it is had an inventory of energy calculated. Figure 2 illustrates the total electric power demand compared to the consumption of thermal energy at specific elementary processes.

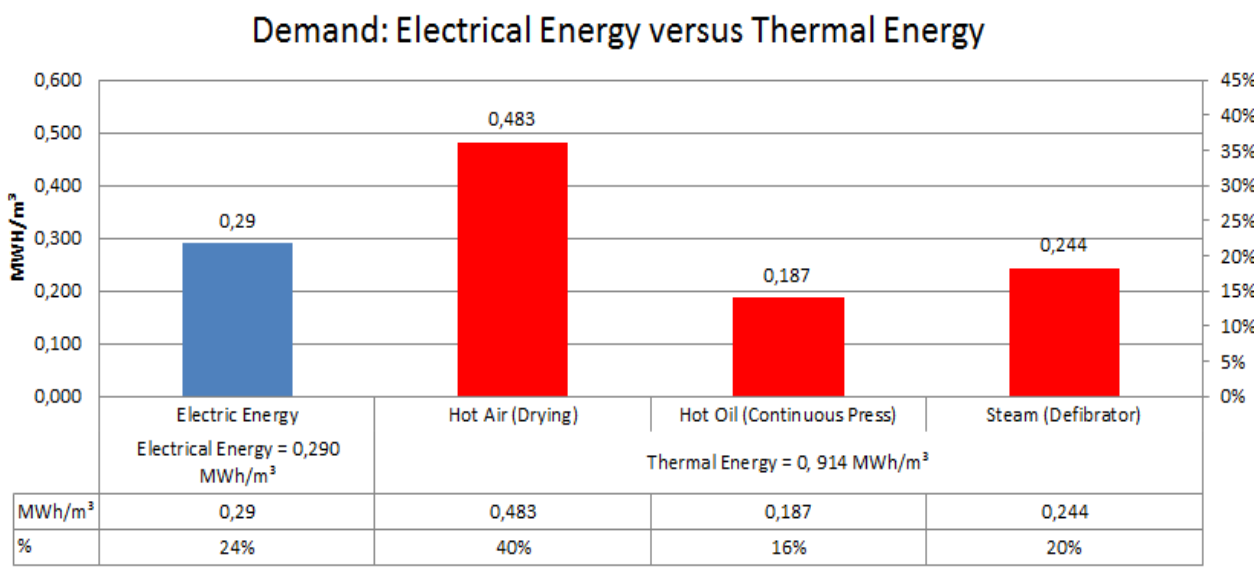

Figure 2: Energy Demand for MDF Manufacturing. Source: Authors (2012)

Approximately 76% of the demand for energy is thermal, where 40% comes from thermal energy required for drying fibres (hot air dryer). The demand for electricity represents 24% of total energy demand.

The thermal plant responsible for the generation of steam and hot air has its operation with the combustion of natural gas and wood fuel (wood dust). Figure 3 represents the contribution of each energy source used in this energy plant to generate a 1.0 m³ of MDF in the period studied.

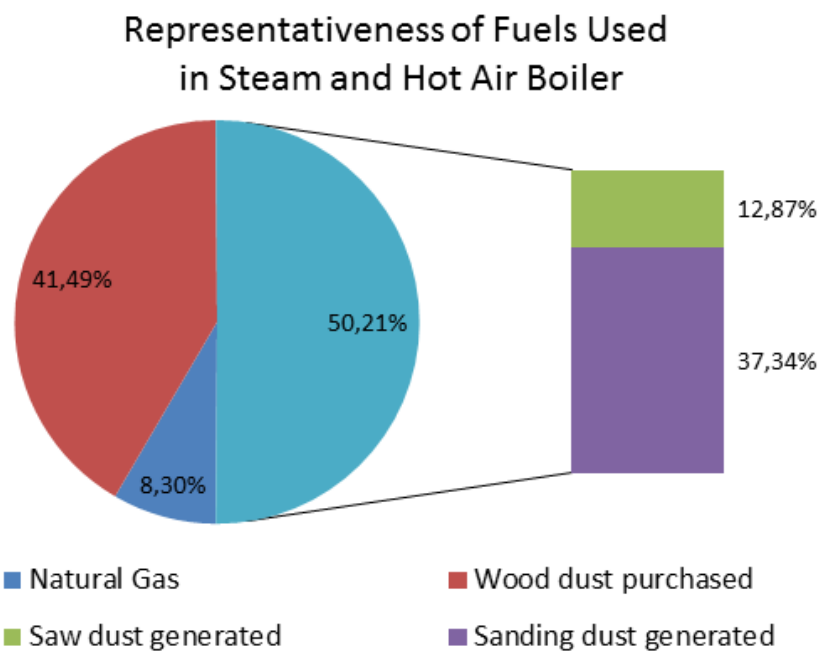

Figure 3: Representativeness of Fuels Used in Steam and Hot Air Boiler. Source: Authors (2012)

The wood fuel (saw dust generated, wood dust purchased and sanding dust generated) accounts for 91.7% of the total heat generated by the steam boiler. Where 50.21% are generated in manufacturing system and the remaining 41.49% are purchased from other mill.

The burning of natural gas represents only 8.30% of the total thermal energy generated in this energy plant. This means that less than 10% of the fuel sources used to generate steam and hot air are fossil fuels and non-renewable natural resources.

Nevertheless, the thermal plant that heats the hot oil is exclusively dependent on burning natural gas - a fossil and non-renewable fuel. The interest in reducing fossil fuels in order to reduce global warming, coupled with the increase in fuel prices and electricity, makes the energy issue call considerable attention in the coming years to mills that seek to maintain the competitiveness reducing their costs and their dependence on fuel fossils (WILSON, 2010).

In this context, the LCI analysis of the MDF allows verifying the contribution of non-renewable and fossil fuels in the manufacturing system. The Figure 4 provides an overview of all energy sources used to produce 1m^3 of MDF in this study.

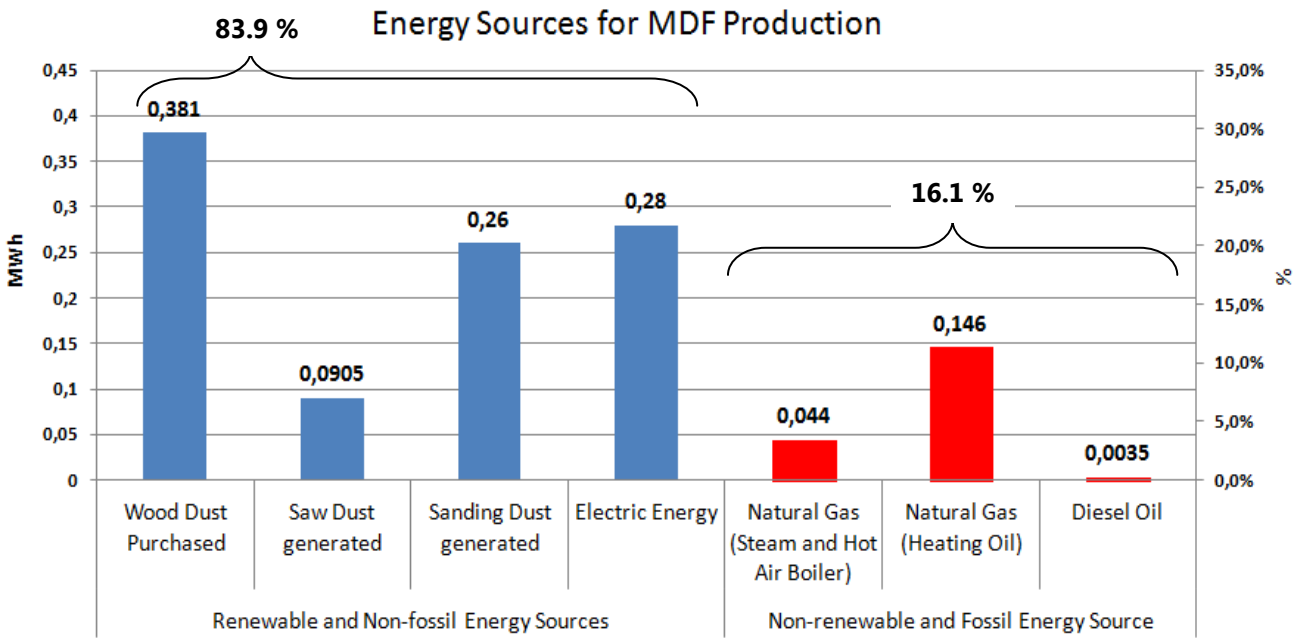

Figure 4: Energy Sources for MDF Production. Source: Authors (2012)

In total 16.1% of the energy consumption are non-renewable and fossil where the natural gas used to heat thermal fluid to the press represents approximately 12%. More than 80% of the energy required for the MDF production is from renewable sources.

In terms of fuel, the industry produces 41.4% of its total consumption. The generation comes from wood fuel generated in the process. From the total of wood fuel employed (wood dust), the company purchased approximately 45.3% of its demand, while the remaining 54.7% were generated in the boundaries of the system under study.

The use of wood fuel is important because it is a sustainable and renewable fuel that is taking the place of fossil fuel, a non-renewable fuel. Furthermore, wood fuel is considered global-warming and climate-change neutral (Wilson, 2010).

4 Conclusion

An energy inventory was developed for the production of 1.0 m^3 of MDF produced in Brazilian mill. The system boundary considered involves the on-site manufacture system of MDF. The quality of data collected by survey questionnaire of MDF manufacturer resulted from answers from managers responsible

for each specific area. The treatment of these data was performed by analysis of the MDF Life Cycle Inventory, following the guidelines of NBR ISO 14040 and NBR ISO 14044 (2009). It was used the software Umberto as a tool for calculations procedures. As a result of analyses of the Energy consumption in Brazilian MDF mill, the following conclusions are achieved:

- In order to produce 1.0 m^3 of MDF was required 1.2 MWh. Around 76% of this demand is thermal energy. From this percentage, 52.8% is represented by the energy required for the drying process of wood fiber. The electric power demand represents 24% of total energy required.
- Overall, 16.1% of energy consumption comes from non-renewable sources and fossil. More than 80% of the energy required to the production of 1.0 m^3 of MDF comes from renewable sources.
- Concerning all fuels used, the mill produces nearly 41.4% of its total demand. Regarding the generation of wood fuel (wood dust) for combustion in thermal plant, the industry supplies 54.7% of its demand. The majority of the wood dust generated is resulting from the action of sanding on the panel, its represents 74.26% of the total generated. The remainder of wood fuel necessary was purchased from outsiders.

This study provides an overview of the energy consumption to produce a MDF in Brazilian mill. The data may be used as an environmental performance to improve manufacturing process or to compare with other wood panels. As example, the analysis of the overview of the use of energy in MDF mill studied showed a significant influence of the natural gas used in the thermal plant that heats the hot oil.

As a suggestion, the replacement or adjustment of this thermal plant to use renewable fuels (for example, bark of logs) would reduce the dependence on fossil fuels and non-renewable sources by approximately 75% (from 16.1% to 4% of dependence).

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