ENERGY END-USE MODEL OF THE JORDANIAN SMES INDUSTRIES

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Abstract
In this paper, an energy end-use model of the Jordanian SMEs industries is presented. The industrial sector in Jordan consumes about 23% of the country's total energy. To establish the end-use model, a survey covering 150 facilities of different types of industries was conducted. The results show that the main electricity end-use consumers are electrical motors with a share of 55% of the total electricity consumption. On the other hand, fossil fuel is mainly used for hot water and steam generation with diesel fuel as a dominant fuel. The results of the study can be considered as an insight into the energy usage pattern of the Jordanian industrial sector for the policy maker. Furthermore, the results could provide important guidelines and insights for future research and development allocations and energy projects.

Keywords: Energy; End-Use Model; Efficiency.

1. Introduction

Jordan is considered among low-middle income countries, within the Middle East Region, with an average income per capita of about US$ 3,420, in 2008, and its population reached 5.850 million inhabitants [1]. It suffers from a chronic lack of adequate supplies of natural resources including fresh water, crude oil and other commercial minerals. Thus, Jordan depends heavily on imports of crude oil, refined products and natural gas from neighboring Arab countries as main sources of energy. Its current imports of around 100,000 barrels of crude oil per day are placing the country under extreme economic pressures, especially with increasing unit price of oil in the international market. The annual energy bill has been rapidly increasing over the past few years due to high rates of population and economic growth combined with the consecutive increase in oil price. Consequently, there has been a growing concern about energy consumption and its adverse impact on the economy and environment, with special focus on the industrial sector, because its contribution accounted for about one fourth of final energy and electricity consumption. The industrial sector was probably affected the most by the economic and technological changes that the country has witnessed during the past three decades. For example, in 1985, there were about 4,546 industrial facilities and workshops, and 43,313 employees [2]. Two decades later, the industrial sector has grown to include about 13,357 facilities and employed approximately 150 thousand workers, most of them are Jordanians [3]. Such enormous increase in the number of facilities and produced products has contributed to an increase on energy demand. In 2008, electricity consumption reached nearly 11,509 GWh with shares of 39, 27, 17, 15 and 2% for residential, industrial, commercial, water pumping, and street lighting respectively [4].

Energy issues are a subject of widespread current interest among Jordanian engineers and scientists concerned with problems of energy supply and demand in different sectors of the economy [5-11]. In spite of the existence of several studies attempting to analyze current and future energy requirements for different sectors and industries in Jordan [12-15], there is still a need for more detailed studies to analyze and explain the energy consumption in the industrial sector and other sectors of the economy. Therefore, this paper will use field gathered data to build a model in the form of an energy flow diagram that explains how total energy input is distributed and routed to different categories of end uses. This model can be used then as basis in energy research. The study is interesting not only because it is the first in Jordan but also because of the source of

the data used in the study where the data is gathered directly from the industry. This kind of research is useful for analysts and policymakers concerned with energy issues in Jordan, especially those interested in future directions of energy demand in Jordan due since the energy end-use model can help identify opportunities to improve energy efficiencies and enhance energy policies, it can also serve as key for other studies such as energy process-step models, energy cost and exergy analysis for manufacturing industries [16].

2. Energy situation in Jordan

The annual fuel consumption has been rapidly increasing over the past few years placing Jordan into critical situations. The imported energy costs approximately 3834 million $ in 2008 with an annual growth of 21% compared to 2007 [4]. This cost amounts to 50% of Jordan's exports and contributes to 23% of its imports and 20% of Jordan's GDP, which is a high percentage when compared with the 4% typical value for industrial countries [4]; this situation imposes a burden to the economy and the kingdom's development.

Table 1 and Figure 1 [4] show the Kingdom's sectoral energy consumption in 2008. They clearly show that the transportation sector represents the major consumer of final energy followed by industrial and residential sectors. The term "others" refers to services, agriculture and commercial sectors.

Table 1: Sector's consumption of final energy (000 TOE).

Sector	2004	2005	2006	2007	2008
Transportation	1693	1779	1822	1912	1767
Industrial	1.34	1159	1182	1192	1095
Residential	1007	1060	1064	1070	1010
Others	792	804	821	853	853
Total	4526	4802	4889	5027	4707

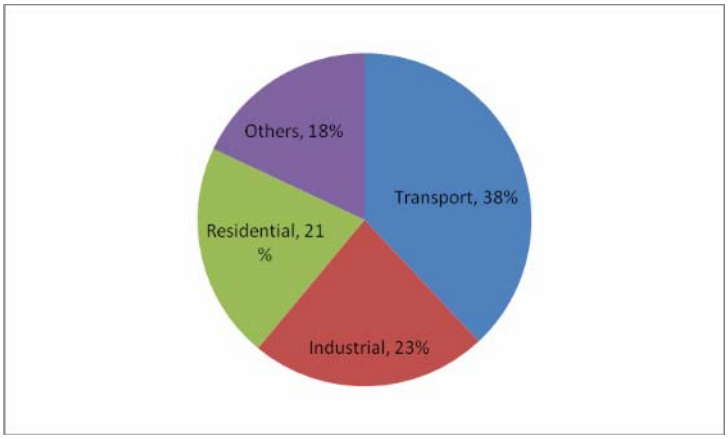

Figure 1: Energy consumption by sector (2008).

The electricity consumption among different sectors is presented in Table 2 and Figure 2 [4]. The residential sector is the highest electrical energy-consuming sector in Jordan, where it consumed about 39 % of the total electricity consumption followed by the industrial sector, which constitutes 27%.

3. Industrial firms in Jordan

Industry is a main contributor to Jordan's economy, accounting for 22.5% of Gross Domestic Product (GDP) in 2008, about 90% of national exports and employing 15% of the country's labor force [17].

Jordan's industrial sector is composed mainly of "mining and Quarrying" and "manufacturing". The mining and quarrying mainly includes potash and phosphate, and accounted 3.3% of GDP in 2008, while manufacturing contributed 19.2% of Jordanian GDP in 2008 [17].

The manufacturing sector has a wide range of activities. The national classification of industrial sectors has been determined by a decree issued by the Jordan cabinet on august 13, 2005 to cover all industrial enterprises operating in one activity or more of industry. Thus, the industrial activities are grouped according to the following ten sectors.

Table 2: Sector's consumption of electricity (GWh)

Sector	2005	2006	2007	2008
Residential	2989	3434	4017	4459
Industrial	2659	2758	2918	3128
Commercial	1317	1516	1757	1925
Water pumping	1298	1396	1592	1713
Street lighting	248	261	269	284
Others	201	228	-	-
Total	8712	9593	10553	11509

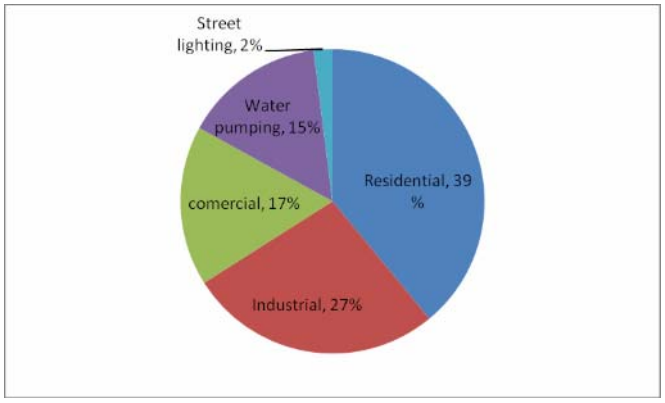

Figure 2: Electricity consumption by sector (2008).

- Leather and garments sector
- Therapeutics and medical sector
- Chemical and cosmetics sector
- Plastic and rubber sector
- Engineering, electrical industries and information technology sector
- Furniture and wooden sector
- Construction sector
- Food, supplies, agricultural and livestock sector
- Packing, packaging, paper, cartoon and stationeries sector
- Mining sector

Additionally, in order to obtain a comprehensive representation of the enterprises working in industry, the micro-enterprises are considered as the eleventh sector.

2008 data provided by the local chambers (Chambers of Industry in Amman, Zarqa and Irbid), show that approximately 14,923 enterprises are operating in industry, employing almost 198,876 employees, and having total registered capital if 2,900 million Jordan Dinar [17].

"Industrial Enterprises" (those with 10 or more Jordanian employees and registered capital of JD 30.000 or more) constitute 13.12% of the total number of enterprises operating in Jordan industrial sector, employing 79.29% of the total industry labor force, and accounting for 94.42% of the sum of industrial registered capital in 2008 [17].

Respectively, the "micro-enterprises" constitutes 86.88% of the total number of enterprises operating in Jordan industrial sector, employing 20.71% of the total industry labor force, and accounting for 5.58% of the sum of industrial registered capital in 2008. According to the certificates of origin issued by the local chambers, the industrial sectors exports has increased from JD 2,661 million in 2007 to reach around JD 3,053 million in 2008 [17].

4. Methodology

This section describes data collection and the approach used to estimate the Jordanian industrial end-use model. These are elaborated below:

4.1 Data sources

To determine the industrial energy end-use model, the energy end use quantities of a typical Jordanian industry should be known. Such detailed data and information are not available in Jordan not only for the industrial sector but also for most of Jordanian sectors. Since the collection and analysis of such data on a national scale is a costly process, a survey of a representative sample of 150 facilities was conducted. This survey was aimed at collecting relevant data that are necessary to complete this study, and to gain further insights into fuel and electrical energy consumption characteristics.

The Survey was distributed using the Jordan Chamber of Industry database and about 150 correctly completed questionnaires were gained. The questionnaire covered the following aspects:

- General Information about the industrial firm.
- The Electricity consumption kWh, power factor and peak demand measures.
- Type of fuel used and the fuel consumption quantity of each type.
- Type of lighting used, units quantity, power and working hours of each type.
- Type of boilers used, units quantity, power, heating degree, age and the working hours of each type.
- Type of compressors used, units quantity, power, working pressure, variable speed drive existence and the working hours of each type.
- Type of furnaces used, units quantity, power, heating degree, age and the working hours of each type.
- Type of cooling systems used, units quantity, power, heating degree, age and the working hours of each type.
- Type of pumps used, units quantity, power, working pressure, variable speed drive existence and the working hours of each type.
- Type of motors used, power, current type, age and the working hours of each type.

Within the scope of this study, questionnaires were sent to 800 manufacturers as a sample and 150 complete filled surveys are gathered. The gathered data had the following distribution based on sub-sectors:

Table 3: Number of completed surveys

Subsector	No. of Completed Surveys
Leather and garments sector	13
Therapeutics and medical sector	9
Chemical and cosmetics sector	18
Plastic and rubber sector	26
Engineering, electrical industries and information technology sector	11
Furniture and wooden sector	14
Construction sector	8
Food, supplies, agricultural and livestock sector	31
Packing, packaging, paper, cartoon and stationeries sector	16
Mining sector	4
Total	150

4.2 End-use model

Irrespective of the kind of industry or type of product considered, there are three primary end uses: process steam, direct combustion heating, and electricity for motors, heating, electrolysis processes, HVAC and lighting. For each industry considered in this research, a model in the form of an energy flow diagram that explains how total energy input is distributed and routed to different categories of end-uses will be developed. The model defines different energy input; electricity and fuel and the energy allocated to different end uses processes (compressors, pumps and fans, motors, furnaces, lighting and cooling system).

The main aim of this section is to describe the procedures that lead to the end use model of Figure 3 for the industry.

4.2.1 Industrial firms energy balance

For each industrial firm the energy balance is determined according to the end-uses processes mentioned above. For each end-uses process the consumed electricity assigned and simple percentages calculated by dividing the process electricity consumption kWh/Yr by the total firm electricity consumption kWh/Yr.

For example; The compressors electricity balance of firm "X" can be estimated as:

Compressors consumption % = (Compressors electricity consumption kWh/Yr) × 100 / (The firm electricity consumption kWh/Yr).

The same procedure can be used to estimate the other end-uses processes share.

Also, the consumed fuel assigned and the share of each fuel type determined by dividing the fuel consumption of each type L/Yr by the total firm fuel consumption L/Yr.

For example; The Diesel fuel balance of firm "X"can be estimated as:

Diesel consumption % = (Diesel consumption L/Yr) × 100 / (Total firm fuel consumption L/Yr)

The same procedure can be used to estimate the other fuel types share.

4.2.2 Sub-sectors end-uses processes

The sub-sectors electricity balance can be estimated as: End-uses process % = ∑i (End-uses process electricity consumption % of firm "Xi" × Total electricity consumption kWh/Yr of firm "Xi") / Total electricity consumption kWh/Yr of the subsector.

For example; Compressors consumption % of plastic and rubber subsector = ∑i (Compressors electricity consumption % of firm "Xi" × Total electricity consumption kWh/Yr of firm "Xi") / Total electricity consumption kWh/Yr of the plastic and rubber sub-sector.

The same procedure can be used to estimate the other end-uses processes share.

Likewise, the sub-sectors fuel balance can be estimated as:

Fuel "Z" % = ∑i (fuel "Z" consumption % of firm "Xi" × Total fuel consumption L/Yr of firm "Xi") / Total fuel consumption L/Yr of the sub-sector.

For example; Diesel consumption % of plastic and rubber subsector = ∑i (Diesel consumption % of firm "Xi" × Total fuel consumption L/Yr of firm "Xi") / Total fuel consumption L/Yr of the plastic and rubber subsector.

The same procedure can be used to estimate the other fuel types share.

4.2.3 Industrial sector end-uses processes

The industrial sector electricity balance can be estimated as: End-uses process % = ∑i (End-uses process electricity consumption % of subsector (i) × Total electricity consumption kWh/Yr of subsector (i)) / Total electricity consumption kWh/Yr of the industry.

For example; Compressors consumption % of the industrial sector = ∑i (Compressors electricity consumption % of subsector (i) × Total electricity consumption kWh/Yr of subsector (i)) / Total electricity consumption kWh/Yr of the industry.

The same procedure can be used to estimate the other end-uses processes share.

Likewise, the fuel balance of the industry can be estimated as:

Fuel "Z" % = ∑i (fuel "Z" consumption % of subsector (i) × Total fuel consumption L/Yr of subsector (i)) / Total fuel consumption L/Yr of the industry

For example; Diesel consumption % of the industry = ∑i (Diesel consumption % of sub-sector (i) × Total fuel consumption L/Yr of sub-sector (i)) / Total fuel consumption L/Yr of the industry.

The same procedure can be used to estimate the other fuel types share.

5. Results

The electricity, heavy fuel oil and diesel are the main sources of energy consumed in the industrial sector. Jordanian industrial sector consumed 1095*103 Toe in 2008 distributed as 33% electricity and 67% fuel [4].

As can be seen from our end- use model in figure 3, diesel fuel is the dominant fuel as 73% of the consumed fuel is diesel. Fuel is mainly used for hot water and steam generation with small contribution for transportation and other minor processes.

Among the electricity end-uses, it has been found that motors used the highest amount of energy (55%) followed by cooling systems (14.2%), compressors (10.4%),pumps and fans (7.9%), furnaces (5.6%), lighting(5.5%) and others (6.4%).

Also, we found that approximately 95% of motors are AC current type, only 2% of compressors and pumps have a variable frequency drive (VFD), average chillers coefficient of performance COP is 2 and 48% of the lighting units used in industry are Fluorescent

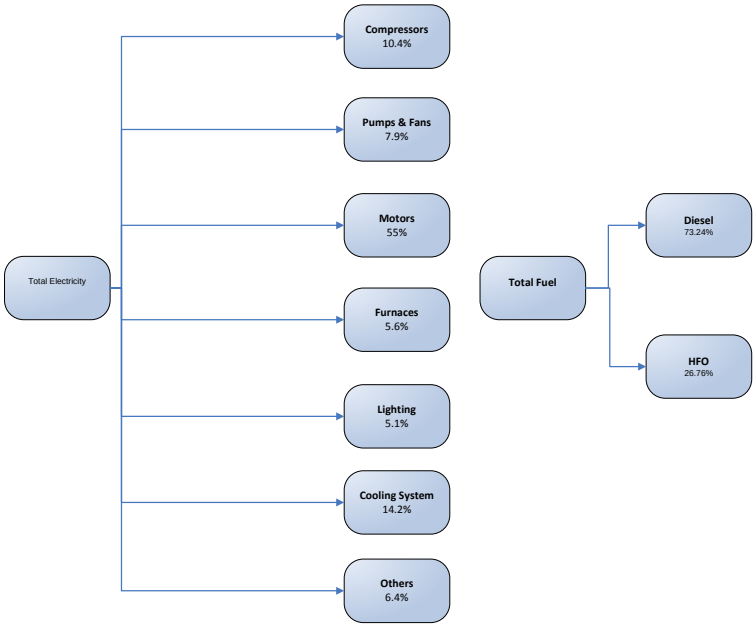

Figure 3: Energy End-Use Model of the Jordanian SMEs Industries.

6. Discussion

The proposed energy end-use model can help identify opportunities to improve energy efficiencies and enhance energy policies. From findings, obviously there are big opportunities to save energy in the Jordanian industrial sector.

More efforts to improve the energy efficiency in the Jordanian industrial sector should be done. Engineers and analysts should concentrate on the major energy consumers; where 80% of the electrical energy consumed by motors, compressors and cooling systems, energy conservation measures should apply on these processes to achieve highest efficiency in order to save energy.

As electric motors use a major fraction of industrial energy, several measures could be taken to reduce their energy use. The usage of energy- efficient motors can reduce the financial cost of the industrial sector such as the cost of motor maintenance. From the survey and data analysis, it has been found that most of the factories are still using the standard motors in their facilities and there is a common practice to rewind an existing motor when it burns out rather than purchase a high efficiency

replacement motor and the rewind motor are typically less efficient than a new model.

On the other hand, no more than 2% of the compressors and pumps have variable frequency drive VFD which means a great saving could gain from compressors and pumps since VFD help in reduce the power consumed by compressors and pumps.

Also, the average chiller's COP is found equal 2 which means low chillers efficiency, in this regard increase the chillers efficiency will save energy.

For more energy efficiency improvement, more energy conservation measures could apply on the minor energy consumers such as lighting. Most of lighting units used in the industry are inefficient, so an energy saving could achieve by introducing higher efficient lamps and using Occupancy Sensors.

It should be noticed that the use of renewable energy is too limited in the Jordanian industry and it mainly used for domestic hot water. Renewable energy should used in the industrial applications since its cheap and clean energy.

7. Conclusion

Jordanian industry sector is a very wide range sector based on products, most of the facilities in Jordan considers small and medium size facilities and the majority of them are not intensive energy facilities, but Jordan is an energy scarce country so studying and analyzing the energy consumption and the properties of the consumers in Jordan are too important toward saving energy and reduce the national energy bill.

We have presented an energy end-use model of the Jordanian SMEs industries as the data collected directly from the industry through filling questionnaires. From the analysis of data, it can be concluded that:

1) Among a wide variation of end-use electricity-consuming equipments, electric motors are the major consumers of electrical energy followed by cooling systems and air compressors. This study also found that majority of the factories is still using old equipments, which are not efficient and waste huge amount of energy.

2) Diesel fuel is the dominant fuel as 73% of the consumed fuel is diesel. Fuel is mainly used for hot water and steam generation with small contribution for transportation and other minor processes.

3) A big opportunity occurs for energy saving in the Jordanian industrial sector and wide range measures could apply to achieve the saving and improve the efficiency

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Appendix

- **Leather and garments sector**

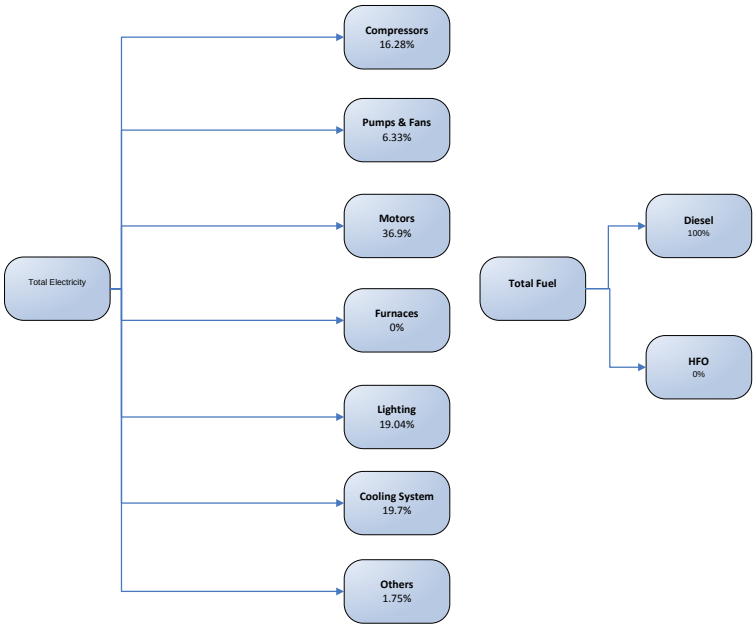

Figure 4: Energy End-Use Model of leather and garments sector.

- **Therapeutics and medical sector**

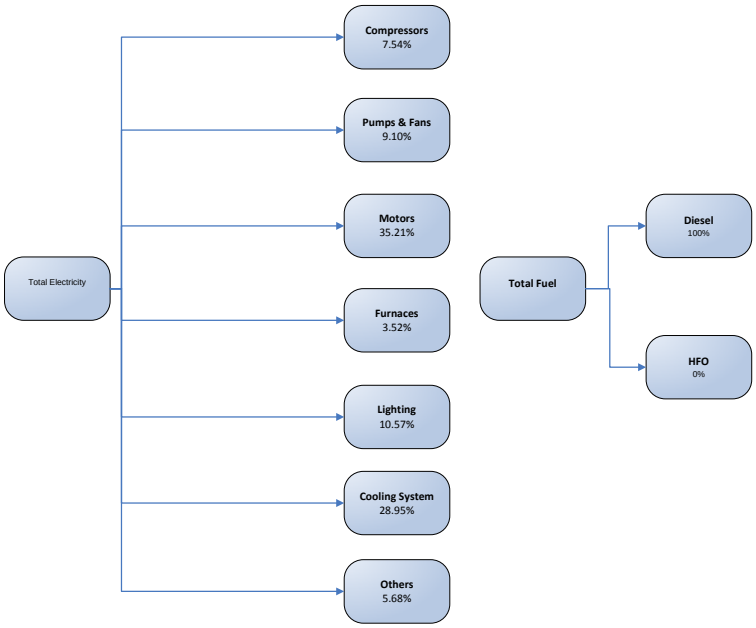

Figure 5: Energy End-Use Model of the therapeutics and medical sector.

- **Chemical and cosmetics sector**

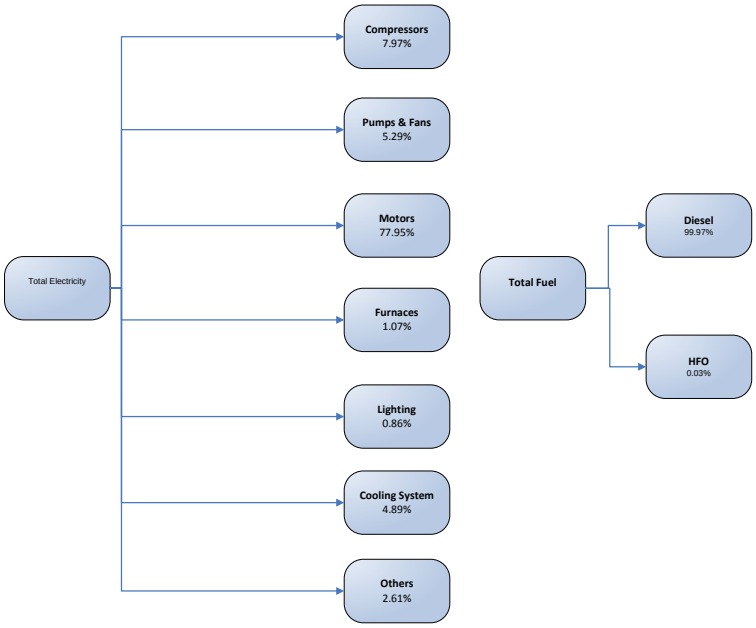

Figure 6: Energy End-Use Model of the chemical and cosmetics sector.

- **Plastic and rubber sector**

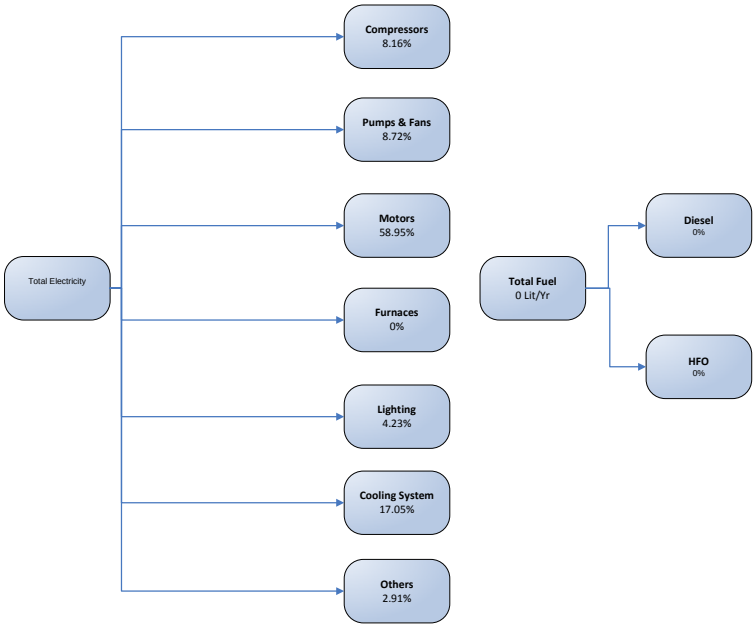

Figure 7: Energy End-Use Model of the plastic and rubber sector.

- **Engineering, electrical industries and information technology sector**

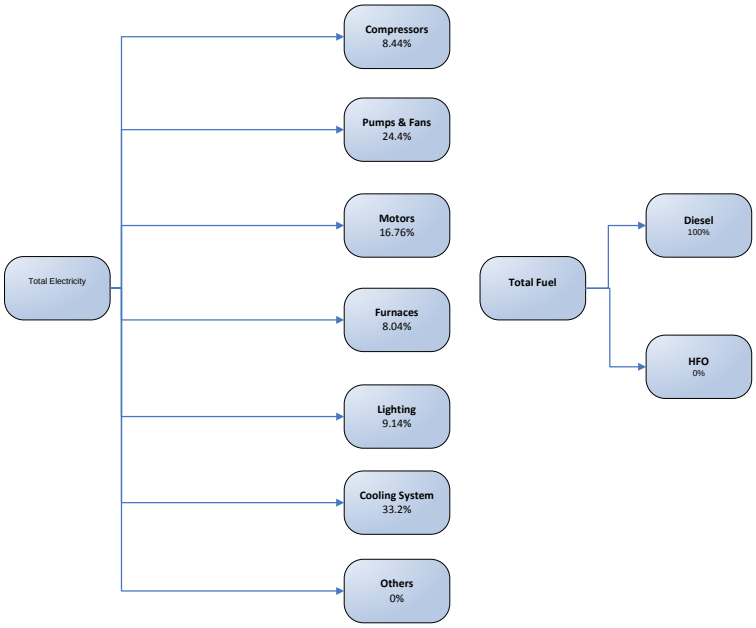

Figure 8: Energy End-Use Model of the engineering, electrical industries and information technology sector.

- **Furniture and wooden sector**

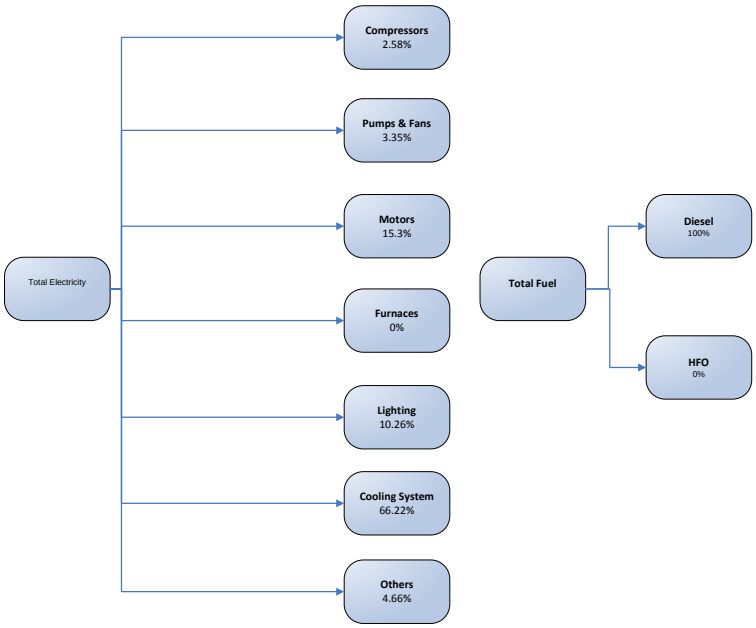

Figure 9: Energy End-Use Model of the furniture and wooden sector.

- **Construction sector**

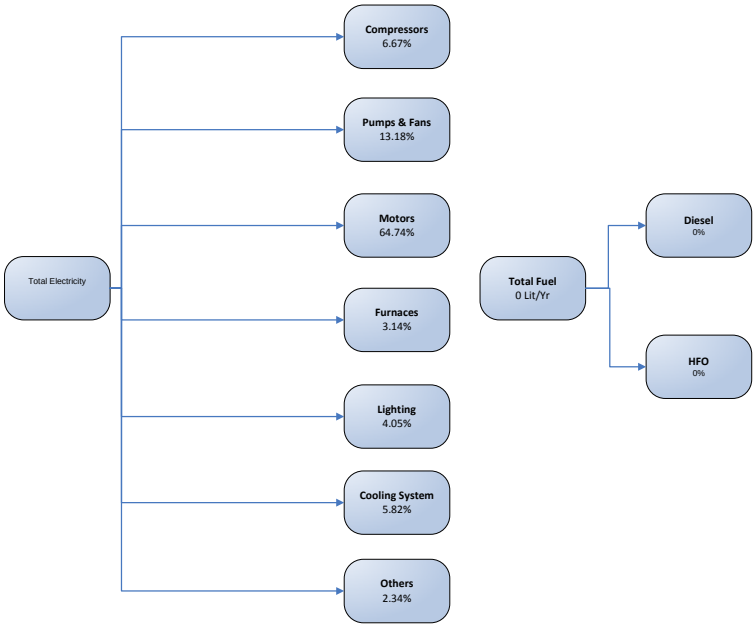

Figure 10: Energy End-Use Model of the construction sector.

- **Food, supplies, agricultural and livestock sector**

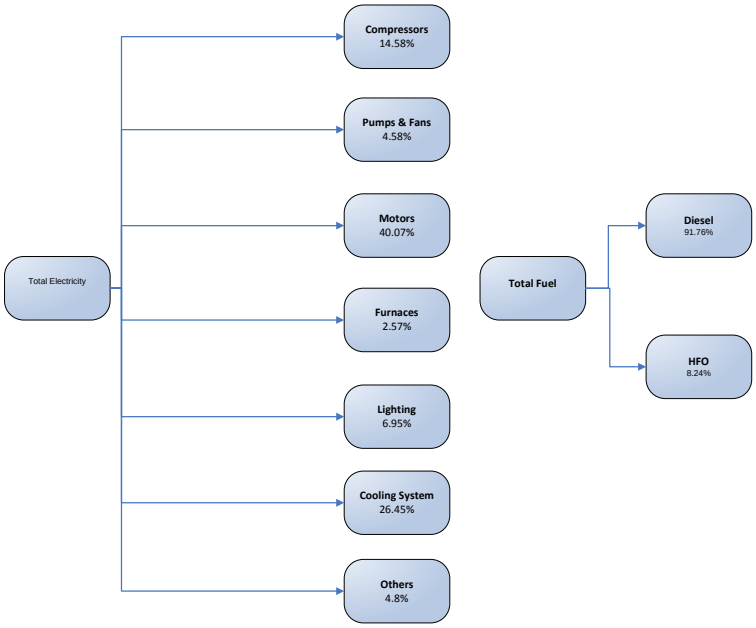

Figure 11: Energy End-Use Model of the food, supplies, agriculture and livestock sector.

- **Packing, packaging, paper, cartoon and stationeries sector**

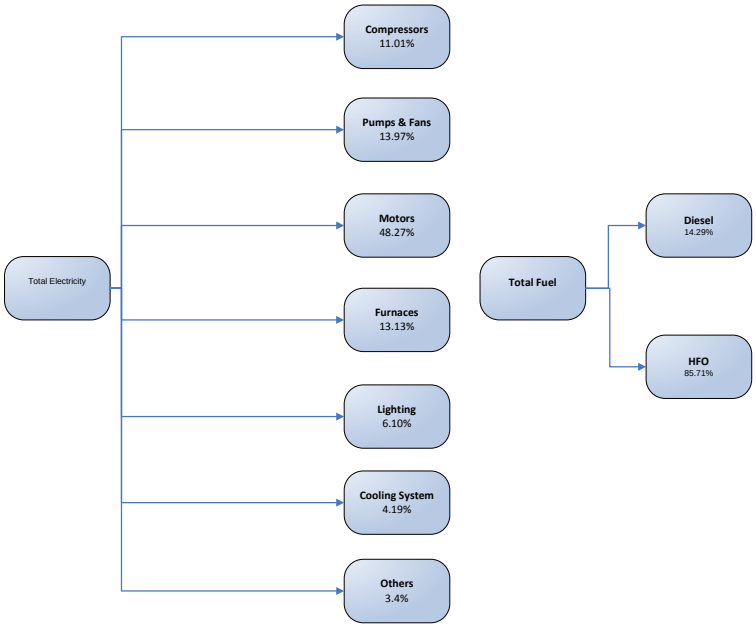

Figure 12: Energy End-Use Model of the packing, packaging, paper, cartoon and stationeries sector.

- **Mining sector**

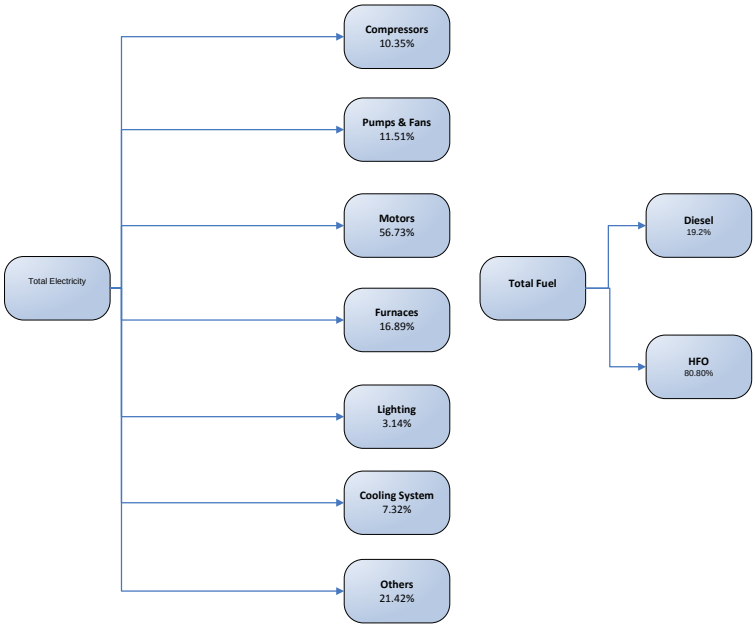

Figure 13: Energy End-Use Model of the mining sector.