

# Prospects of Energy Savings in the Jordanian Plastic Industry

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## Abstract

With the rapid and sharp rise in energy prices in Jordan, energy cost is becoming a value that cannot be ignored in the Jordan's industrial sector. However, there are still many practices adopted in industry that do not take energy efficiency as a prime consideration, but rather focus on immediate and direct savings in materials and machinery. This study examines potential opportunities of electrical energy savings in the Jordanian plastic industry. It demonstrates that electrical energy saving can be considered as a superior option to increase profit and competition within this sector. To achieve this purpose, detailed energy audits have been carried out for the most common plastic facilities in Jordan. An electrical energy conservation guideline is recommended and each recommendation is illustrated in terms of electrical energy savings, demand savings, cost savings, and payback period. A substantial annual electricity cost saving of 871,940 JD is reported in this study. This represents nearly 23% of the total plastic industry electricity bill with a payback period of less than 7 months. The contribution of electricity cost to the total value added can be reduced from 0.08 to 0.0616 (JD of electricity/JD of value added) if such recommendations are adopted.

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## 1. Introduction

In non-oil producing countries where energy resources are scarce and production of electricity is very costly, energy conservation studies are of great importance. Jordan, unlike most other countries in the Middle East region, does not produce its consumed oil and is totally dependent on imported oil from neighboring countries. The annual fuel consumption has been rapidly increasing over the past few years. Therefore, it is an extremely important duty to reduce the energy consumption and search for alternative resources of energy.

The industrial sector represents approximately 23% of the total Jordanian energy consumption [1]. The primary building units of the industrial sector are the facilities it is comprised from. Therefore, analyzing these building units will definitely improve the overall energy situation of this sector. In recent years, concerns about energy consumption in Jordan have been growing, especially in the industrial sector, since the energy cost represents a significant percentage of the total value added in most industries. The importance of energy conservation in Jordan has been outlined by Kablan [2] and Akash et al. [3] and has been identified and estimated for different industries in different

countries by Chan et al. [4], Markis et al. [5], Khan [6], Worrell et al. [7], and Fickett et al. [8]

Figure .1 shows the cost of electricity relative to the total value added of the most common products of the industrial sector in Jordan. As it is shown in the Fig. 1 plastic facilities use high rates of electrical energy consumption to maintain their productions. In fact, the plastic industry is ranked third among the most electrical energy intensive industries behind the non-metallic mineral, and mining and quarrying industries. In 2004, fuel and electricity bills of the Jordanian plastic industry were 4.589 million Jordanian Dinars (JD) [9]. In this industry, energy can be viewed as the most expensive and the most important form of inputs. At the same time, there are some primary energy end uses that are common among the plastic facilities: heaters, compressors, motors, lightings, HVAC, boilers, and chillers irrespective of the kind of products processed by the plastic facility .

The primary objective of this paper is to identify and evaluate opportunities for electrical energy conservation in the Jordanian plastic industry. This will be achieved through auditing the different types of Jordanian plastic facilities.

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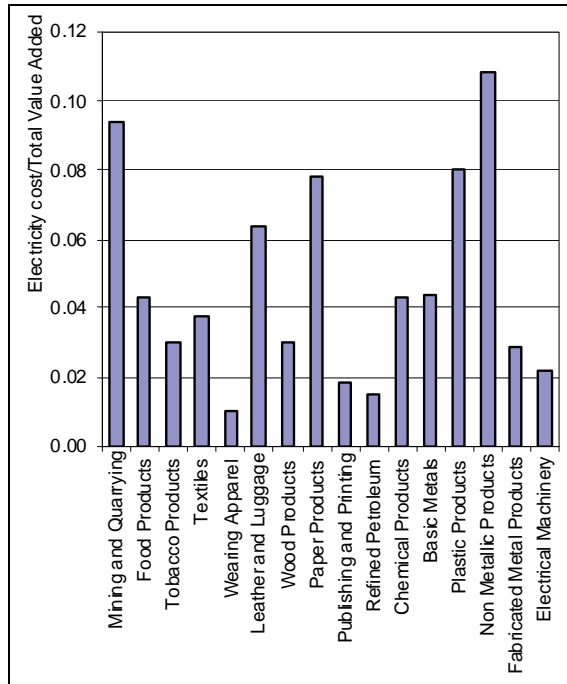


Figure 1: The cost of electricity relative to the total value added of the most common products of the industrial sector in Jordan.

The following four factors are considered when discussing energy conservation:

- Electrical energy savings (kWh)
- Electrical demand savings (kW)
- Electrical energy cost savings (JD)
- Payback period (month)

These factors will be quantified for the suggested recommendations throughout the paper.

## 2. Energy Consumption in Jordan

In 2005, Jordan's consumption of primary energy (crude oil and petroleum products, natural gas, renewable energy, imported electricity) amounted to  $7.028 \times 10^6$  Ton Oil Equivalent (TOE) while the final energy consumption was  $4.802 \times 10^6$  TOE. Final energy consumption in Jordan is mainly distributed between three major sectors: transportation, industrial, and residential. The distribution of final energy consumption among different sectors over the past five years is presented in Table 1, while a breakdown of electricity consumption among the different sectors is presented in Table 2 [1]. It can be seen from both tables that the industrial sector is the second largest consuming sector of final energy and electricity. The share of this sector has been nearly constant over the past few years at nearly 24% of final energy consumption and nearly 31% of the electricity consumption.

## 3. Plastic Industry in Jordan

Over the past two decades, the plastic industry in Jordan has witnessed a very fast growth as it can be seen in Figure .2, which shows the development of the number of facilities, employees and energy consumption relative to the base year of 1985. For example, in 1985, there were 58

facilities, and 1586 employees. Twenty years later, the industry has grown to more than 281 facilities and employed more than 5800 people [9]. Such enormous increase in the number of facilities and produced products has contributed to an increase in the indigenous energy and electricity demands. In 1985, the industry's energy consumption was 233 TJ compared to 506 TJ in 2004 [9].

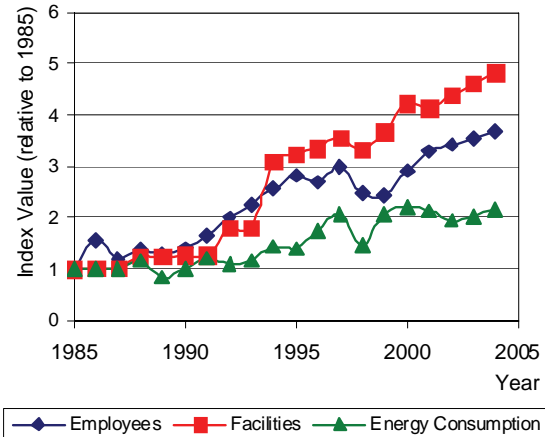


Figure 2: Development of the number of employees, facilities and energy consumption indices of the Jordanian plastic industry over the period 1985-2004.

Table 1: Sectoral distribution of the final energy consumption in Jordan during the period 2001-2005 (Thousand TOE) [1].

Year	Sector				Total
	Transport	Industrial	Household	Other	
2001	1411 (38.2%)	826 (22.4%)	849 (23.0%)	606 (16.4%)	3692 (100%)
2002	1435 (37.7%)	846 (22.2%)	868 (22.8%)	662 (17.4%)	3811 (100%)
2003	1495 (37.0%)	878 (21.7%)	945 (23.4%)	722 (17.9%)	4040 (100%)
2004	1693 (37.4%)	1034 (22.8%)	1007 (22.2%)	792 (17.5%)	4526 (100%)
2005	1779 (37.0%)	1159 (24.1%)	1060 (22.1%)	804 (16.7%)	4802 (100%)

Table 2: Sectoral distribution of electricity consumption in Jordan during the period 2001-2005 (GWh) [1].

Year	Sector						Total
	Household	Industrial	Commercial	Water Pumping	Street Lighting	Other	
2001	2110 (33.0%)	2024 (31.7%)	880 (13.8%)	982 (15.4%)	177 (2.8%)	219 (3.4%)	6392 (100%)
2002	2266 (32.8%)	2193 (31.8%)	971 (14.1%)	1044 (15.1%)	190 (2.8%)	236 (3.4%)	6900 (100%)
2003	2471 (33.7%)	2294 (31.3%)	1047 (14.3%)	1104 (15.1%)	201 (2.7%)	213 (2.9%)	7330 (100%)
2004	2745 (33.9%)	2479 (30.6%)	1190 (14.7%)	1261 (15.6%)	213 (2.6%)	201 (2.5%)	8089 (100%)
2005	2989 (34.3%)	2659 (30.5%)	1317 (15.1%)	1298 (14.9%)	248 (2.8%)	201 (2.3%)	8712 (100%)

The plastic industry in Jordan is mainly based on three manufacturing techniques: Extrusion, injection molding, and blow molding, in addition to some processes that

include combinations of some of these techniques. Hundreds of products are processed by the industry including: heating pipes, water pipes, strings, ropes, medicals cans, food and beverage cans, sheets, seals, grains, kitchen tools, molds, and bags. Table 3 shows the distribution of different plants that are associated with the most common plastic products [10].

Table 3: The distribution of plastic facilities according to processed products.

Type of product	Number of the facilities
Pipes	34
Ropes and strings	4
Medical containers	3
Sheets	5
Seals	15
Containers and Bottles	58
Granules	32
Kitchen tools	32
Food package	4
Plumping tools	8
Molds	5
Bags	61

#### 4. Methodology

This paper will concentrate on analyzing the electrical saving opportunities since electricity forms about 83% of the total energy cost input. In order to do so, the distribution of input electrical energy among different end uses should be known. Such data and information are unavailable in Jordan, not only for the plastic industry, but also for most other industries since the collection and analysis of such data on a national scale is a long, difficult and costly process. However, a survey on a narrow scale aiming at collecting relevant consumption data can be useful in bringing a good understanding of the characteristics of the electrical energy consumption in the plastic industry. For this reason, ten facilities of different products (such as: pipes, containers and bottles, granules, plumping tools, and kitchen tools) in Amman were visited and investigated. During the site visits, relevant measurements for various devices (motors, compressors, heaters, etc.) were taken as a part of energy survey. Also, several interviews with specialists in the plastic processing industries were conducted. This enabled the identification of potential opportunities of electricity savings, quantification of such savings, and the cost incurred for achieving them.

#### 5. Electrical Energy End Use Model

In order to determine the plastic industry's overall electrical energy conservation, the proportion of electrical energy consumed for each end use process within the industry should be known. Fortunately, irrespective of the kind of facility, the manufacturing techniques it uses, or the type of products it processes, there are six primary end uses of electricity: Space conditioning, lighting, motors, compressors, heating, and cooling. A model in the form of

an electrical energy flow diagram that explains how total electrical energy input is distributed and routed to different categories of end-uses has been developed as shown in Figure 3. This model is based on the data gathered during the site visits for the ten facilities. This paper will concentrate on motors, compressors, and heaters since they account for approximately 75% of the total electrical energy consumption.

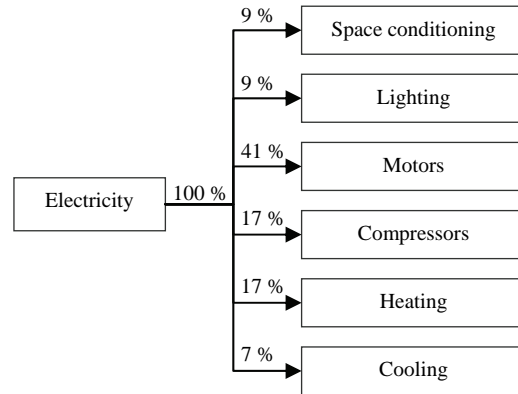


Figure 3: End use model for Jordanian Plastic Industry

To start the analysis, the total electrical energy input to the Jordanian plastic industry in terms of a physical unit (kWh for example) should be known. Although such data are not available, the total annual cost of the electricity input to plastic industry was reported as 3,803,700 JD in 2004 [9]. The total physical electricity input (kWh) to the plastic industry can be estimated as follows:

$$\text{Total physical electricity input (kWh)} = \frac{\text{Total cost of actual consumed electricity}}{\text{Electricity cost of kWh}} \quad (1)$$

The total reported cost of electricity (RCE) includes three types of costs: cost of actual electricity consumption (ACE), the power factor penalty (PP) applied to medium and large facilities and the peak load penalty (DP) applied to medium and large facilities. In order to estimate the total physical electricity input (kWh), the total cost of actual consumed electricity (ACE) should be known. Therefore, the penalties due to power factor and peak load should be taken out from the total reported electricity cost. The total cost of actual consumed electricity can thus be estimated as follows:

$$\text{ACE} = \text{RCE} - \text{PP} - \text{DP} \quad (2)$$

The power factor penalty is applied to medium and large facilities that have power factor less than 0.85. The average annual power factor penalty for each medium and large facility was reported as 2,250 JD [11]. There are about 43 medium and 13 large plastic industrial facilities in Jordan. Therefore, the annual power factor penalty can be estimated as 126,000 JD. The peak load penalty is applied also to medium and large facilities. This is charged for the maximum power consumption (kW) that occurs for continuous thirty minutes during the peak time (from 5:00 PM to 8:00 PM during winter and 7:00 PM-10:00 PM

during summer) within the month. It has been estimated that the electrical power of medium and large facilities during the peak time is 250 kW and 400 kW respectively [11]. Therefore, the total annual charges that are due to peak load penalty can be estimated as 543,210 JD. Applying these figures in Equation (2), the total annual cost of actual consumed electricity can then be found equal to 3,134,490 JD.

In order to estimate the total physical electricity consumption (kWh), the cost of each kWh should be known. However, this cost depends upon whether the facility is small, medium, or large. Also, it depends whether the consumption occurs during the day or night periods. In 2004, the weighted average cost of each kWh for small, medium, and large facilities are 0.0380, 0.0320, and 0.043 JD/kWh, respectively. The actual electricity consumption (kWh) distribution between small, medium, and large facilities is estimated as 40%, 48%, and 12%, respectively [11]. The weighted electricity cost of the small, medium, and large facilities can be estimated as 0.0357 JD/kWh. Using this value with the total annual cost of actual consumed electricity, the total annual physical electricity input can finally be calculated and found equal to 87,809 MWh.

## 6. Energy Conservation Opportunities

This section presents the most common recommendations of electrical energy conservations that have been found in the visited ten facilities and can be applied in a typical plastic facility. The analysis will be shown in detail for one recommendation (replacement of energy inefficient motors with efficient ones) while summaries for other recommendations will be given.

### 6.1. Improvement of the Electrical Power Factor of the Facility:

The average power factor in this sector has been estimated as 0.7, which is considered low in terms of industry standards. Power factor can be an important aspect to consider in an AC circuit; because any power factor less than unity means that the circuit's wiring has to carry more current than what would be necessary with zero reactance in the circuit to deliver the same amount of (true) power to the resistive load. Hence, the power factor of the generator can be improved by addition of capacitors parallel to the line. As discussed earlier, the total annual penalty that is due to power factor has been estimated as 126,000 JD. By adding the appropriate capacitor, the charged amount will be reduced to zero with an average total cost of 3500 JD/facility. The payback period will be approximately 7 months.

### 6.2. Replacement of Energy-Inefficient Motors:

For the visited facilities, currently in Jordan, the demand electricity costs are 2.4 and 3.05 JD/(kW.mo) for large and medium facilities respectively. It has been found that the average current operating efficiency of a typical motor is 78%. This low efficiency is due to the common practice by many facilities to simply rewind an existing

motor when it burns out rather than purchasing a high efficiency replacement motor. However, a rewind motor is typically less efficient than a new one. The loss of efficiency is due to the age of the failed motor and degradation of its stator core during failure, or as a result of the rewind process. The typical efficiency loss ranges from 1% to 5% for each rewinding process [12].

The energy savings,  $ES$ , and energy cost savings,  $ECS$ , for replacing an old motor with a new high efficiency motor, can be estimated as follows:

$$ES = ECM \left( \frac{1}{E_c} - \frac{1}{E_p} \right) \quad (3)$$

$$ECS = ES \times \text{cost of electricity} \quad (4)$$

Where  $ECM$  is the electrical energy consumed by motors (can be estimated from figure 3 as 36,001.7 MWh),  $E_p$  the efficiency of proposed high efficiency replacement motor (assume 90%), and  $E_c$  the efficiency of the current motor (assume 78%). As estimated earlier, the weighted average electricity charge is 0.0357 JD/kWh, the annual electrical energy savings,  $ES$ , and the resulting annual electrical energy cost savings,  $ECS$  will be 6,154.1 MWh and 219,703 JD, respectively.

Demand savings will result from using a smaller capacity load per unit time. The demand savings by replacement of inefficient motors with energy efficient motors can be derived as:

$$EDS = \frac{SF \times ES}{AOH} \quad (5)$$

Where  $EDS$  is the electricity demand savings,  $SF$  is the sharing factor of electrical energy consumption for medium and large facilities (0.6),  $AOH$  is the annual operating hours. The average annual operating hours are estimated to be 6,257 h. The annual demand cost savings ( $EDCS$ ), can be estimated from

$$EDCS = DC \times EDS \times 12 \quad (6)$$

Where  $DC$  is the demand cost (estimated on the basis of a weighted average of medium and large facilities equal to 2.92 JD/(kW.month)). The resulting demand savings and annual demand cost savings are then 590.13 kW and 20,678 JD, respectively. In average, the payback period will be approximately 9 months.

### 6.3. Installation of Variable Frequency Drives (VFD):

In many industrial environments, the application of variable speed control is cost effective. Energy savings result from reduced power consumption by the motors. As the system power requirements are reduced, the power consumed by the equipment can be reduced by an amount significantly greater than can be achieved with the existing controls. For example, in the case of pumps, flow is often controlled (throttled) by valves, which increase the pump head and reduce the flow rate. In the Plastic industry, VFDs can be applied to injection and blow molding

motors, pumps, and compressors. It is estimated that a saving of 15-20% of the motor electrical energy can be achieved if such controllers are adopted. Assuming an average saving of 17.5%, the annual electrical energy savings and electrical energy cost savings will be 6,300.3 MWh and 224,921 JD, respectively. The resulting demand savings and annual demand cost savings are 604.15 kW and 21,170 JD, respectively. In average, the payback period will be approximately 9 months.

#### 6.4. Repair of Compressed Air Leaks

The cost of compressed air leaks is the energy cost to compress the volume of lost air from atmospheric pressure to the compressor operating pressure. The amount of lost air depends on the line pressure, the compressed air temperature at the point of the leak, the air temperature at the compressor inlet, and the estimated area of the leak. The leak area is usually detected depending on the sound and feeling of air flow from the leak. The detailed equations to estimate the air leaks are given by Shapiro [13]. An alternative method to determine total losses due to air leaks is to measure the time between compressor cycles when all air operated equipment are shut off. It is estimated that a saving of 15-20% of the compressor electrical energy can be achieved if air leaks are eliminated. Assuming an average saving of 17.5%, the annual electrical energy savings and electrical energy cost savings will be 2,612.3 MWh and 93,260 JD, respectively. The resulting demand savings and annual demand cost savings are 250.50 kW and 8,778 JD, respectively. In general, implementation involves one or two of the following: replacement of couplings and/or hoses, replacement of seals around filters, shutting off air flow during lunch or break periods, and repairing breaks in lines, etc. The payback period will be approximately 10 days.

#### 6.5. Avoiding Poor Practices of Compressed Air Usages:

During the site visits, several poor practices of compressed air usage have been noticed. For examples: Several companies use the compressed air to cool the extruded pipes or some devices such as motors, while others use it for cleaning purposes. Since the use of compressed air is either for cooling or cleaning purposes, air at sufficient flow rates can be adequate for these purposes. This can be done by blowers which use much less energy. It was estimated that a saving of 10-20% of the compressor electrical energy can be achieved by avoiding such poor practices. Assuming an average saving of 15%, the annual electrical energy savings and electrical energy cost savings will be 2,239.16 MWh and 79,937 JD, respectively. The demand savings and annual demand cost savings are then found to be equal to 214.72 kW and 7,524 JD, respectively. Implementation costs include purchasing blowers to replace the compressed air. The payback period will be approximately 1 month.

#### 6.6. Insulation of the Extrusion, Injection, and Blow Molding Machine Heaters:

During the site visits, it was found that some areas of the extrusion, injection, and blow molding machines are not well insulated. This results in heat losses and associated energy costs. These areas of heat losses were studied and carefully calculated using the equations of heat transfer from bare surfaces [14]. The energy savings were estimated to be 10-14% of the total input electricity to heaters. Assuming an average saving of 12%, the annual electrical energy savings and electrical energy cost savings will be 1,791.3 MWh and 63,950 JD, respectively. The resulting demand savings and annual demand cost savings are then 171.77 kW and 6,019 JD, respectively. Implementation costs include purchasing of insulation material in addition to labor costs with a payback period of approximately 1 month.

#### 6.7. Overall Energy and Cost Savings:

After implementing the previous recommendations for all plastic processing facilities in Jordan, the total annual electrical energy savings, the electrical demand savings, and the total annual cost savings are estimated to be equal to 19,097.2 MWh, 1,831.27 kW, and 871,940 JD, respectively. The average payback period will not exceed 7 months.

## 7. Conclusions

An analysis and estimation of the potential electrical energy saving opportunities in the plastic industry in Jordan was carried out. The results revealed that there is a large room of improving the efficiency of electricity consumption in this industry with remarkable energy cost savings. The total electricity cost savings represent nearly 23% of the industry's total annual electricity bill. The contribution of electricity cost to the total value added can be reduced from 0.08 to 0.0616 (JD of electricity/ JD of value added). This can be considered as an effective option for increasing profit and competition within this sector.

Having listed all the different remedies that can lead to electrical energy conservation, the implementation of these recommendations is very crucial for the plastic industry in Jordan to reach the desired cost savings. Such study can be considered as the corner stone in achieving national energy savings among all Jordanian industries. Therefore, it is highly recommended to carry out such studies and analyses for other Jordanian industries.

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