Journal of Energy and Power Engineering 5 (2011) 209-214

A Case Study of Energy Auditing—A Tool for Energy Conservation in Industry

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Received: January 19, 2010 / Accepted: February 22, 2010 / Published: March 31, 2011.

Abstract: In order to attain the best energy efficiency in an industrial plant, an energy audit is a prerequisite process for identifying the general energy consumption condition and to hence identify the measures that need to be taken to save the cost of excessive energy consumed and later to retrofit the faults that were observed. The case study presented in this paper is a medium industry plant located in Hebron. The audit methodology, observation, and audit results will be presented and discussed with the recommendation drawn.

Key words: Energy auditing, industrial buildings, energy mapping, Palestinian authority.

1. Introduction

From the perspective of its energy sector, the occupied Palestinian territories (OPT) are in an unusual position. The constraint imposed through Israeli policies on the ability of the Palestinian Authority (PA) to operate and develop its energy systems is an unusual challenge and as the Israeli army controls the West Bank area and impose tough sanctions on Gaza Strip, the PA cannot constructing the power network in OPT areas especially that areas assigned as “C”. Following the second Intifada in 2000 and until today’s, the Israeli army has intentionally destructed public utilities, including that in Gaza Strip, and restricted the proper importing of energy resources. Another important aspect that adversely impact the energy sector is the fact that the Palestinian energy market is considered small with no developed domestic resources of commercial energy, it is almost entirely dependent on imported energy supplies, specifically electricity and oil products. Because of political and logistical factors, nearly all of these supplies at present come from Israel. In addition, the fragmentation of the Palestinian areas into two distinct geographical zones with divergent economic characteristics is a huge burden.

The primary energy supplies to OPT are shown in Fig. 1. While Palestinian relay on Israel for securing their 85% of their energy, renewable energy source contribute to 15% of total supplies.

Sectors consumption of total energy supplies showed that the residential and commercial sectors both consume almost 70% of the total energy sources. The transpiration sector consumes 20% and then comes the industrial sector that consumes 6%, and the rest is consumed by other utilities [1].

Around 95% of electric energy consumed by the Palestinians in OPT are imported from Israeli Electric Company (IEC) [2]. In the West Bank area, eclectic power lines connect the West Bank from three main supply lines shown in Fig. 2. The rest of the 5% electric power is vested with the municipal departments or village councils in the different districts. The central West Bank and east Jerusalem areas are served by the Jerusalem District Electric Company (JDECO), which is a shareholder owned utility.

The electric power is consumed mainly by the residential sector in both the West Bank (WB) and Gaza Strip (GS), which consumes up to 60% of total electric

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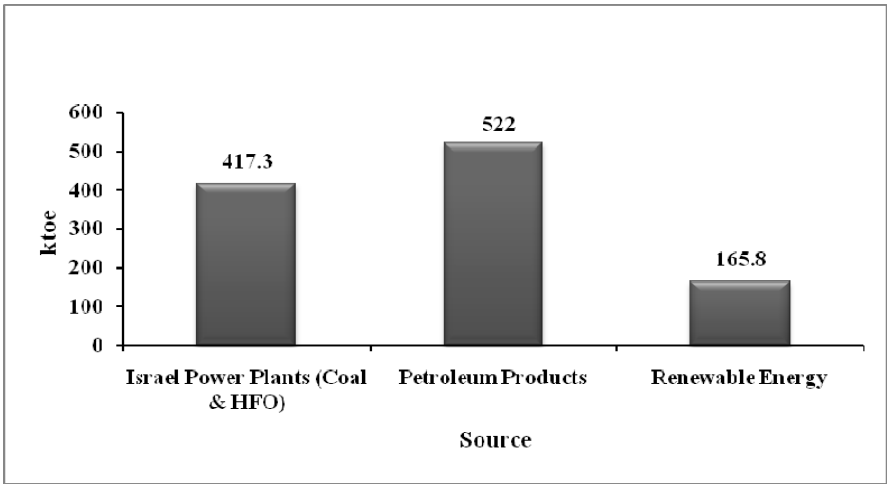

Fig. 1 Primary energy supplies to OPT [1].

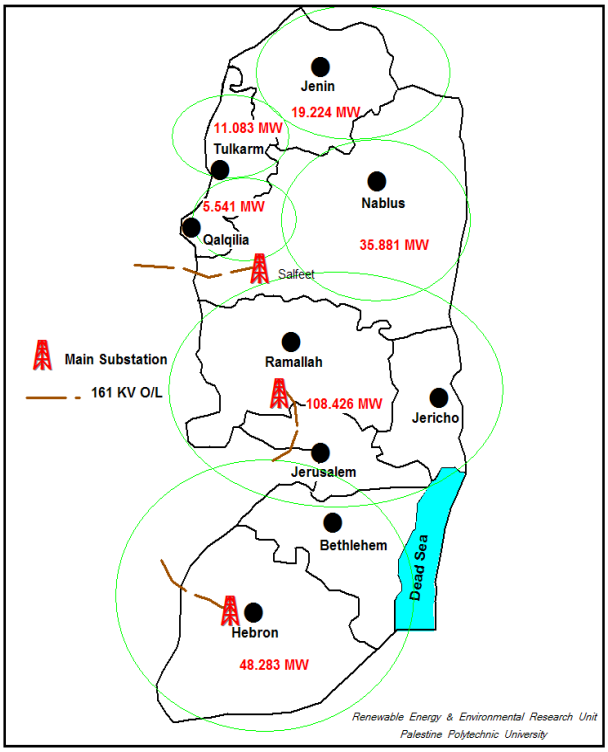

Fig. 2 Imported electric power main connection points.

energy. The commercial buildings and utilities consume almost 20% and then the industrial sector with a consumption of 10% (See Fig. 3).

The energy sector is a reflection of the socio-economic conditions that are harshly influenced by the political instability and the long-time Israeli occupation to Palestinian areas. The last ten years witnessed economical setback that comes to it peak after 2006. The United Nations Development Program [3] estimated in 2007 a poverty rate of 58% in Palestinian population which exceeds 3.7 million and an unemployment rate of 25%. The per capita GNI (Gross National Income) has fallen by 15% and so the GDP which declined by 6.6% since 2006 [4]. In addition the separation wall erected by Israeli occupation has severely impacted the socio-economical situation, including the industrial and commercial sectors.

The share of the industrial sector of the Palestinian GDP was estimated at 12% in 2005, which also share in total employment at 12.3%. After 2006 this sector, and specifically in Gaza Strip has seriously suffered. The vast industrial sector is characterized mainly by its small enterprises with an average size of four employees and only 20% of the industrial premises have a number of employees that may reach 100 employees or more [4].

In the West Bank area, most industrial sector is concentrated in the Hebron district. Industrial activities are quarrying and marble fabrication, metal forming, food and dairy processing, etc. that consume considerable amount of energy sources are scattered and not located in industrial areas with proper service utilities. This scattering has adverse implications that affect the surrounding residential communities especially when industrial premises consume the allocated electric power or if the overburdens of the industrial activities

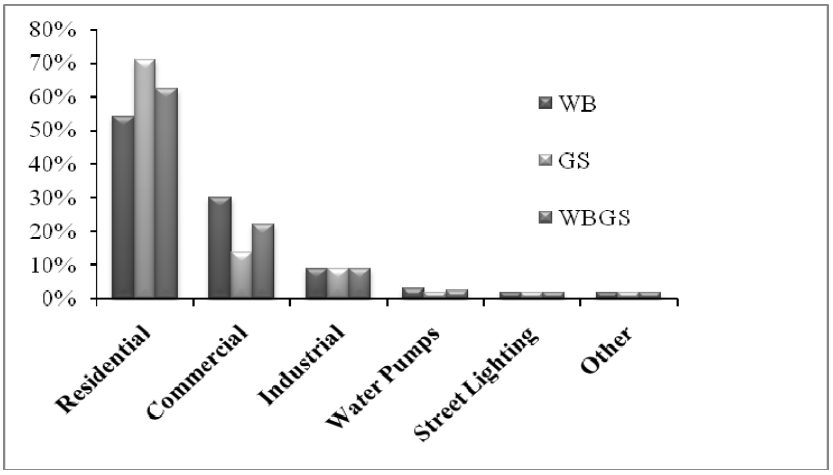

Fig. 3 Electric power consuption by sectors [2].

are either emitted (gases) to the surrounding air or dumped (solid or liquid) in surrounding places [5].

In this paper an energy management approach is used to assess energy consumption in Al-Zaghal factory for plastic products and shoes located in the Hebron district. The factory is located on a three-story construction of a total surface area of 7,866 m^2 in addition to a separate administrative and raw material store purpose one story building. An energy audit process is undertaken in the factory focusing on evaluating energy resources use, hardware performance with regard to energy conversion, and industrial expenditure for energy use.

2. Methodology

In industrial countries, big industries usually have utilities that perform detailed audits on regular basis. Small and medium industries have professional engineers on their staff to provide walk-through audits. In both cases the considered utilities are the lighting, HVAC systems, water heating, machine drive, etc.. Estimate of energy share in a standard industrial premise is shown in Table 1.

Values in Table 1 reflect a general classification, however this may vary from one factory to another depending on the specific functions involved. In Al-Zaghal factory all functions are performed through the different production processes. The factory has two main manufacturing sections shown in Table 2.

Table 1 Industrial energy function by consumption [6].

Function	% of total energy
Machine drive	12
Feedstock	35
Process Steam	23
Direct Heat	13
Indirect Heat	13
Electrolysis	3
Space Conditioning and Lighting	1
Total	100

Table 2 Main manufacturing sections.

Sections	Main functions
Plastic Glass manufacturing	Preparation of raw material (polymers), and by melting it plastic rolls are formed. Plastic rolls then used in molds of different shapes to produce the final glasses.
Shoes manufacturing	Molds fabrication, sewing leathers, melting raw material and casting them, and machinery of specific functions related to shoes finishing.

Machine drives required in manufacturing processes are listed in Table 3.

The factory depends mainly on electrical energy for producing and finishing the products. A total power of 220 kW drives the manufacturing process and secure most of the services. The utility for 2008 shows an electric power consumption of 895,315 kWh/year that costs 540,005 New Israeli Shekels (NIS). The distribution of consumption based on monthly increment is shown in Fig. 4. In that sense, auditing will concentrate on electrical energy.

Table 3 Production machines and service equipment and instruments.

Processes	Main contents
Extruder process with total power of 56 kW for motors and 42 kW for heaters (total 94 kW).	Main driving motor, shell roll motor, pull roll motor, winder motor, crane motor. In addition to 25 heating elements.
Thermoforming process with 7 kW of power for the different motors and another 58 kW for the heaters that makes a total of 63 kW.	Main motors are the un-wind motor, index motor, plug motor, scrap motor, isolator motor, and conveyer motor.
Cooling process with a total 4.5 kW power.	Three main motors of similar specifications.
Crushing process with a total of 3 kW power.	Main, staking and blower motors.
Air comprising process with a total of 32 kW power.	Main and cooling motors.
Chillers with a total power of 29.5 kW.	Chillers and a pump
Grinding process with a total power of 72 kW.	Three grinding motors, three suction motors and a roll pulling motor.
Lighting with 7 kW for first floor, 8 kW for second floor and 3 kW for third floor. This makes a total of 18 kW for internal lighting.	Tungsten bulbs (480), Osram CFL (54).

It should be noted that the electric power tariff has changed from 0.58 NIS/kWh to 0.61 NIS/kWh. This increase took place in the beginning of September 2008.

2.1 Energy and Noise Auditing

The audit services were planned for the whole factory. It started with a general inspection of the factory including all energy conversion utilities, lighting, and comfort. Auditing was carried out using relevant energy auditing in addition to noise auditing. In Table 4, the measuring instrumentations of energy auditing are tabulated.

2.1.1 Machine Drive and Service Equipments

Motors used are to transmit loads. They are of different types ranging from constant torque load, variable torque load to constant power loads. Inspection of the motors showed main faults that are listed in Table 5. It is worth mentioning that such faults allow for excess consumption of energy, lower the performance and efficiency, and speed malfunctions. It was noticed that proper regular maintenance lacks the

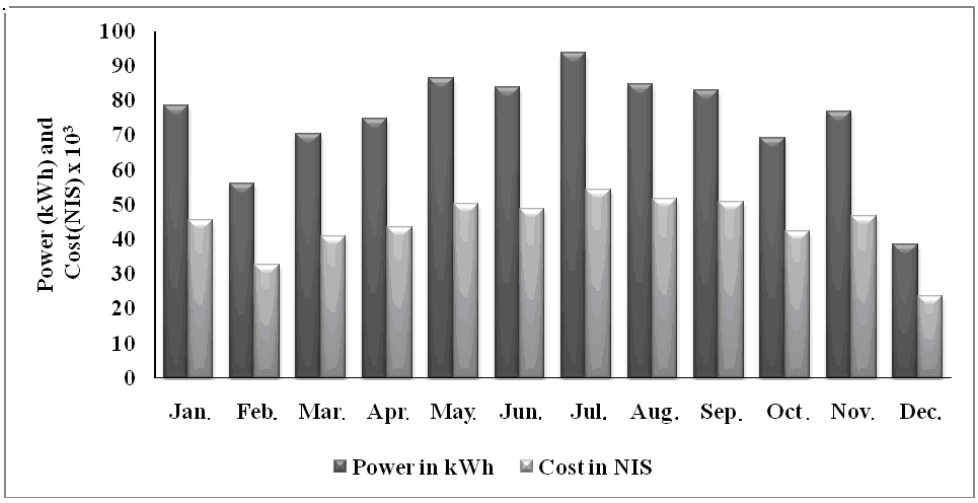

Fig. 4 Monthly electricity consumption and cost for 2008.

production lines. In addition design documents and manuals are not available.

Inspection of the electric power consumption was carried out for motors using measuring instrumentations, which revealed power losses amount to 54 kW representing an overall power conversion efficiency of 70% which is considered low in today's technology which suggests an efficiency that exceeds 85% [7]. It is obvious that in order to increase the conversion efficiency power losses should be reduced by replacing failed or outdated motors. It should be mentioned here that the level of training that the employees have is low and not aware much about energy efficiency issues and energy saving.

Heaters used in extruding and thermoforming processes consume huge energy especially for melting raw material. It is found that heaters need control system that maintains the required temperature in an effectively insulated closure. This can spare many wasted kilowatts. The ventilation system is not designed properly as it increases the heat losses by convection which takes place in the vicinity of the extruder. Instead, the technicians operate the heaters ON//OFF manually without any automatic control or sense of the heater delivered temperature. It is found that heaters loss considerable energy that could reach 6,000 kW/year. In addition to heaters, chillers are also found working with less efficiency as this equipment are old and need proper maintenance.

One should add here that due to the current economical situation, most factories' owners compromise upgrading machines and employing professional engineers and skilled technicians and thus live with the monthly excess energy loss instead of investing in expensively retrofitting their factories.

2.1.2 Lighting

The lighting system was checked in all factory areas with the help of light meter (Luxmeter). Data on number and types of light fixtures and lamps and light intensity were all recorded and assessed. The first inspection showed that lighting use mainly tungsten bulbs that consume considerable amount of electric energy. Only several CFI bulbs are used. It is also found that some areas use excessive number of light fixtures. Distribution of lighting system is not designed well.

2.1.3 Noise

Noise is considered because of its adverse effect in industry on employees. The level of noise may reach a point where it can easily hurt be harmful to hearing sense and human balance in general. A healthy person can withstand a noise in a plant that is less than 80 Decibel (dB) for not a long time. Measurements of noise levels in different places of the factory brought the figures shown in the Table 6 below.

It could be seen that the noise level in almost all places within the factory is high especially in the grinding and extruding areas. Precaution should be implemented by the employees to use hearing protection. In addition it appealed that machines are directly and rigidly installed on the factory floor. It is recommended to use noise absorbing means to avoid stress cycles and noise propagation.

Table 4 Auditing instrumentation.

Section	Main functions
Electric power—clamp-on	Measure single and three phases and reads KVA, kW, PF, Hz, Amps and Volts.
Thermometers	Temperature for fluids, gases and sold surfaces (contact thermometers).
Luxmeter	Measure illumination level.
Noise meter	Measure sound levels.
Flow meter	Measure liquids or gas flow.
Anemometer	Measure air flow in open spaces.

Table 5 Main motors' faults.

Fault	Action required
Motor mounting is loose	Motors are secured
Coupling is not precisely aligned	Correct alignment
Some bad electrical connections	Repair and tighten connections
Some bearings emit noise	They should be changed
Build up of heat	Motors need to be balanced and insure better voltage supply.

Table 6 Noise level in different places within the factory.

Place	Noise (dB)
Entrance area	89
Assembly area	78
Grinding area	106
Extruding	92
Thermoforming	86

The overall energy loss per year is assessed at 11,000 kW which costs 6,700 NIS (US $1,670). This amount of money could easily be spared doing the following:

(1) Replace all old motors and heaters;

(2) Organize a maintenance schedule for all sectors;

(3) Employee professional engineers and skilled technicians;

(4) Conduct awareness programs for employees about how to change the production style to reach better energy efficiency;

(5) Retrofit whenever possible;

(6) Construction need proper insulation and better air filtration;

(7) Invest money on new energy saving lights.

3. Conclusions

It is obvious that the socio-economical situation resulted from the long-time occupation and its harsh measures are adversely impacting the industrial sector in general. The main reason for the loss in energy is due to old technical means used, low maintenance, less professional employees, and due to some compromising solutions that do not take into account the current energy consumption trend. It is also clear that most owners of industrial sector do not have much knowledge about energy auditing, retrofitting solutions, and the payback notion. It is recommended therefore, to design awareness programs for targeting not only industrial sector, but other major sectors including the public and thus saving more energy in such bad situation.

Acknowledgments

The research carried out was in the framework of a graduation project implemented at the Faculty of Engineering and Technology, Department of Mechanical Engineering of the Palestine Polytechnic University.

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