**ENERGY SAVING OPPORTUNITIES IN JORDANIAN PHARMACEUTICAL INDUSTRIES**

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**Abstract:** An investigation of energy consumption saving opportunities in Jordanian pharmaceutical industry has been carried out in this paper, current status of energy consumption, possible saving techniques, and recommendations that could be implemented successfully through Energy Saving Program (ESP) is explored. All variables that influence energy consumption are considered accordingly using a suitable methodology. This methodology integrates a simulation programs into the analysis process; thereafter an accurate analysis and a reliable assessment for energy consumption is provided. HAP 4.41software has been used to simulate and to calculate energy consumption and costs. One biggest Jordanian pharmaceutical facility that produces Penicillin and Cephalosporin products is considered as an illustrative example, the facility consists of four main energy consumption centers and includes consuming systems namely; HVAC (Heating, Ventilating and Air Conditioning system), lighting, compressed air, steam boilers, and miscellaneous equipments like computers, refrigerators, fume hoods, etc. Historical energy consumption quantities are estimated, details of energy data are tabulated accordingly input data files for the computer simulation method using HAP 4.41 are created. Energy saving recommendations has been decided and incorporated into the ESP system. The paper concluded with a good quality room of energy saving opportunities that mirrored positively on the national energy bill with a reduction of 13% of the total annual energy consumption.

## Introduction

Energy management is one of the most important priorities for buildings and plants owners, especially in non-oil producing countries that depend on imported crude oil or natural gas. In Jordan, a fluctuating crude oil prices in the last years brought energy aspects and considerations into the top of hot topics that affect any investment. The industrial sector in Jordan represents about 24% of total energy consumption and almost 28% of total electrical energy consumption (Ministry of Energy and Mineral Resources, 2006). Energy cost contributes significantly in the total product cost for many industries.

Recently, Jordanian pharmaceutical industry has grown strongly, number of pharmaceutical companies now is 17, after merges and restructuring of many companies. The sector became an export driven industry distributing its products on more than 60 countries. Pharmaceutical industry in Jordan is a pioneer industry due to its high quality and excellent reputation. Therefore 81%

of production is exported to foreign markets. Jordan pharmaceuticals are now distributed worldwide in more than 60 countries, 90% of the exports are going to Arab countries. Jordan pharmaceutical companies have joint ventures and subsidiary companies in 8 Arab and foreign countries. The total value of domestic production rose to almost $230 million in 2009, up from $54 million and $130 million in 1990 and 1995, respectively (Jordanian Association of Manufacturers of Pharmaceuticals & Medical Appliances, 2007).

Energy is the ability to do work, physically expressed by Joules (J); this scalar physical quantity contributes to a wide variety of applications. Heat energy, mechanical energy, and chemical energy, are some forms which energy could be found in. Energy could be transformed from one form into another, but the total energy will remain the same, this result is a conclusion of the first law of thermodynamics (Yunus et al., 2008). Since the early days of the industrial revolution, when natural resources began to be intensively used in production processes, engineers have tried to increase the efficiency with which each of the factors of production is used. Energy is one of the basic input factors of production, along with labour, capital, and materials. Historically, energy is contributing about 5%–10% of the total cost for most of the products (Kreith, 2005).

Both the political and the scientific communities began to pay increased attention to the opportunities for improving the efficiency of energy use. The terms "enhanced energy use efficiency" and "energy conservation" could be used interchangeably, although there is a distinction between them.

To some extent, energy conservation denotes doing without, possibly giving up amenities to save energy. Examples of energy conservation are turning down the temperature in a home during the winter, or using mass transport instead of driving a car in order to save fuel. But, when a system can produce the same result with less expenditure of energy, the term improved energy use efficiency is more appropriate. Examples include, installing a more efficient cooling system that uses less fuel while maintaining a comfortable temperature in a home, or driving the same number of miles each year with less fuel by switching to a more fuel efficient car that provides the same level of comfort.

An investigation of energy consumption saving opportunities in Jordanian pharma-ceutical industry will be carried out here, current status of consumed energy, and the possible saving techniques and recommend-dations that could be implemented through implementing Energy Saving Programs (ESP's) will be explored.

Literature implies the role of the second law of thermodynamics in identifying the useful and usable energy, also implies the introduction of the second law efficiency as an effective diagnosis tool that helps in targeting all forms of energy inefficiencies in a microscopic point of view, through the introduction of "exergy" term that refers to available energy or usable energy (Kreith, 2005). In this work, we'll not go for a microscopic energy point of view rather than introducing a general techno-managerial methodology for implementing ESP's in Jordanian pharmaceutical industry, and estimating saving opportunities.

It is necessary to estimate energy saving value before applying any technical recommendations, specially, if the application of such recommendations will

cost a significant amount of financial fund. Therefore, an agreement should be done, between the managers and/or teams of the ESP and the decision maker, the method that should be followed to identify energy saves should also be clarified. Table 1, could be used to choose an appropriate energy saving estimation method.

## Literature review

Energy auditing and saving programs could have different meanings; energy audit is an analysis of a plant that describes energy usage patterns, opportunities of saving energy through implementation of operating and maintenance changes, energy conservation measures etc. Unfortunately, not enough studies were found in the field of energy in pharmaceutical industry, but as long as we are talking about buildings and systems, then analyzing method(s) used to enhance energy savings within any industrial or civilian building could serve as a useful tool for our approach.

The quest for improving energy performance of buildings and industrial facilities has provided the opportunity to develop tools and methodologies for performance optimization. There has been a very slow uptake of evaluation and optimization methodologies in the Middle East region. Hassan (2007) showed systematic methodology with respect to building design and operation, this methodology considers all the variables that influence the energy performance of industrial facilities. It integrates simulation programs into the analysis process; this has led to provide n accurate analysis and a reliable assessment for energy efficiency measures. Hassan's study (Hassan, 2007) showed that energy saving program should be comprehensive in application as well as in analysis, the method ended up with a 41.6% saving compared to 30% saving by algebraically adding savings from each action separately (Hassan, 2007). The importance of the integration and interoperability of the energy data and systems with business enterprise and energy modelling is presented in (Swords et al., 2008), which ends up with energy information system used for continuous development.

Once that basic data needed for implementing energy saving programs are collected, it is easy to perform technical calculations that may lead to decisions and recommendations for energy saving (Krarti, 2000).

Technically, calculating savings for each system separately and combining calculated results is not an efficient way to understand energy phenomena, so using simulation programs may help in developing more efficient actions to perform (Krarti, 2000).

Another study indicated that computer-based simulation is a valuable technique to assist facility managers in determining energy conservation solutions (Kreith, 2005). Simulation software developed by a will known software developing company (eQuest), used to create a virtual environment for the facility under study to develop technical recommendations for the Heating, Ventilating and Air Conditioning system (HVAC) and lighting systems (Kreith, 2005).

Introducing the concept of rational use of energy, outlines the microeconomics of end-use energy saving as a result of frugality or efficiency

measures. Frugality refers to the behaviour that is aimed at energy conservation, and with efficiency we refer to the technical ratio between energy input and output services that can be modified with technical improvements. An attempt to identify the effect of parameters that determine energy saving behaviour with the use of the microeconomic theory is presented in (Oikonomou et al., 2009); the role of these parameters is crucial and can determine the outcome of energy efficiency policies.

It was found that there is a large room of improving the efficiency of electricity consumption in Jordanian plastic industry with remarkable energy cost savings. The total electricity cost savings represent nearly 23% of the plastic industry's total annual electricity bill, the contribution of electricity cost to the total value added can be reduced significantly, and this can be considered as an effective option for increasing profit and competition within this sector (Al-Ghandoor and Al-Hinti, 2007), the used methodology concentrated on analyzing the electrical saving opportunities since electricity forms about 83% of the total energy cost input for Jordanian plastic industry. Another study investigated saving opportunities in Jordanian hotels sector through distributing a survey that measures the ability to improve energy consumption in that sector, then a classification for consumers where done and weighted by Yahya Ali et al., (2008) for both electrical and oil energies.

Implementing ESP's in industrial facilities depends strongly on decision makers and managers of these facilities; Figure 1 shows the most important obstacles that may prevent the implementation of such programs.

In addition to the previously published literature, this paper contributes the following; investigate energy consumption in a plant-wide approach by introducing all energy consuming systems found in Jordanian pharmaceutical industrial facilities and possible actions to enhance energy use efficiency, cures some of managerial obstacles that could prevent the application of an ESP due to lack of convincing reports to decision makers, and utilizes different energy saving estimators for the application of a proposed energy saving model the thing that gives some flexibility to apply any proposed ESP.

## Problem formulation and objectives

Energy consumption rates have become crucial in pharmaceutical industry. Pharmaceutical industry in Jordan was chosen to be investigated due to the following: (1) Importance of cutting the cost of pharmaceutical industry products and its positive effect on the health level of Jordanian society. (2) Supporting Jordanian pharmaceutical industry products through increasing added value to cost ratio. (3) Jordanian market is considered to be highly competitive market in pharmaceutical industry.

The main concern of this paper is to; develop an applicable energy saving model for Jordanian pharmaceutical industry, create an updateable energy saving recommendations, reduce the cost of industrial energy saving programs, through developing a generalized energy saving method that could be tailored to suit the requirements of any pharmaceutical facility in Jordan.

Upon the accomplishment of above mentioned concerns, it is expected that this paper will concluded with a good room of energy saving opportunities that could be mirrored positively on the national energy bill.

## Research methodology

The following work phases was carefully investigated and explored as a systematic approach for achieving and a accomplishing the objective of this paper:

1. Goals, objectives, and mission of this paper are clearly recognized.

2. Caring out frequent technical visits to most key players of pharmaceutical companies and collecting the required technical data that represents a comprehensive view of energy consumption, taken into consideration competition level of competition between these companies, confidentiality, and required meters and instrumentations. This implies; site surveys, technical interviews with related personnel, proper access to as built drawings and site inspection of the facilities, technical data catalogues of installed systems and equipments. The collected energy data are categorized as follows:

   a. Buildings related data; Air Conditioning (A/C) systems, exterior and interior wall sections, glazing types, heat transfer coefficient, etc.

   b. Systems related data; consumption rate of energy for each of the following:

      - Heating, Ventilation, and Air Conditioning (HVAC) systems; dampers, supply and exhaust fans, filters, humidifiers, dehumidifiers, heating and cooling coils, compressors, ducts, and various sensors.

      - Compressed air systems; vacuum cleaning systems, sprays systems, breathing air, and air in hazardous areas.

      - Pumps; pumps, drive motors, piping networks, and system controls.

      - Refrigeration; Condenser and evaporator.

      - Lighting systems; Lights in unoccupied areas, Electronic ballasts.

3. Suggesting a proposed design of the needed ESP

4. Selecting a proper energy saving estimation methods.

5. Reviewing the history of both the electric energy and the fuel energy saving, evaluating the current energy consumption, and realizing the benefit from applying technical recommendations.

6. Synthesizing a proposed alternative energy consumption model for enhancing the existing energy saving standards as well as the corresponding processes, procedures, and methods.

7. Comparing and implementing the new proposals.

## The developed energy saving model

The model depicted in figure 2 is proposed for the required Energy Saving Program ESP. History of energy saving is necessary for determining current energy status and realizing the benefits of any energy saving oriented

recommendation. Historical data is an effective input to validate the results of the proposed energy program. An input file that summarized all input data is to be created, this file will not be useful for using computer simulation method only, but it will be a reference for any future energy studies. The input file should include a comprehensive buildings and systems detailed data essential for evaluating energy consumption in pharmaceutical sector. Hourly Analysis Program software version 4.41 (HAP 4.41) will be used. Using HAP 4.41 tool to determine energy saving opportunities was due to the following;

- Possible run of 8640 energy simulated hours per year.

- User friendly software, and could be used by facility technical personnel.

- Ability to accurately edit built in libraries such as building envelopes, usage profiles and energy consuming systems to meet real requirements.

To estimate energy savings incurred by an energy saving program, it is important to identify the implementation period of the project which is divided by Krarti (2000) into; status identification period (Pre-Retrofit), construction period, and results identification period (Post-Retrofit).

Energy saving estimation method should be identified prior to starting an energy program. Following are the most important estimation methods, and the basis that should be taken into consideration when choosing among these methods:

Simplified Engineering Method, these methods are used usually for easy energy consumption calculated systems such as lighting and motors systems, and it involves stating the calculation method for energy consumption before applying the retrofit (technical recommendations). Using these methods is strongly recommended when inadequate data were collected provided that no comprehensive approach is required.

Regression Analysis Method, used to establish baseline models for buildings energy to estimate retrofit (after applying recommendations) savings (Krarti, 2000).

Dynamic Models, regression models cannot account for transient effects of energy consumption rates, such as thermal mass that can cause short-term temperature fluctuations during warm up or cool down periods of a building (Krarti, 2000). To capture such transient effects, dynamic models are typically recommended, but most of these models are complex in nature and require detailed calibration procedures (Rable, 2006).

Computer Simulation Model, detailed computer simulation programs could be used to estimate energy consumption rates provided that a detailed data is collected, a validation process to be done to ensure reliable results.

Evaluation of results to clarify financial and technical benefits is needed, this involves; illustrating the difference in energy consumption before and after, generating a payback period of applying technical recommendations accompanied with capital cost, and linking technical results within the facility.

Results declaration phase includes; location of the needed recommendation, building, office, or any other type of spaces, system to be modified, current status or value of the prospected input that was suggested to be modified, new

status or value of the prospected input that was suggested to be modified, and capital cost of modification, and the return on investment.

After convincing the top management with results, an action plan should be tailored to suite the situation of applying technical retrofits, the required action could need a financial fund or managerial decisions concerning some internal processes, so summarizing needed actions could be useful when applying needed actions. Table 2 summarizes the most important technical recommendations that could be taken into consideration when applying ESP.

## Computer simulation using HAP 4.41

HAP 4.41 software developed by CARRIER is used to design HVAC systems for buildings, to analyze simulate and to estimate energy use patterns. HAP 4.41 estimates thermal loads when designing systems. It is used to simulate and to calculate building energy and energy costs. HAP 4.41 uses the ASHRAE (American Society for Heating Refrigerating and Air Conditioning Engineers) methods for load calculations.

HAP 4.41 can generate about 12 reports illustrating and analyzing energy usage phenomena. HAP 4.41 has the following characteristics; (1) User friendly software with available sources of technical support for the program. (2) Used widely in the Jordanian engineering sector, hence making technical communication between local engineers and outsourced engineers is possible and easy. (3) Contains built in libraries taken from ASHRAE the thing that help in achieving good and accurate results. (4) Editable energy use patterns, hence, accurate energy use pattern could be achieved based on the accuracy of data taken from the facility under study. And (5) Good results were obtained in the validation phase.

## Implementations of the develop ESP

One of the biggest Jordanian pharmaceutical companies that produce Penicillin and Cephalosporin products is considered. The facility consists of four main energy consumption centres, these are; (1) Office and administration Building (OB), (2) Production Plant 1 (PP1), (3) Production Plant 2 (PP2), and (4) Restaurant (R). Major energy consuming systems in those buildings such as; HVAC systems, lighting systems, compressed air systems, steam boilers, and miscellaneous equipments like computers, refrigerators, fume hoods, etc. are recognized. Historical energy consumption rates during the period from April, 2009 up to April 2010 is estimated and tabulated as shown in Table 3.

Related energy data of OB, PP1, PP2, and R during the same period is tabulated in Table 4, Table 5, Table 6, and Table 7 respectively, then used to create an input data files for HAP 4.41 computer simulation to investigate energy saving opportunities.

To validate the use of HAP 4.41 software for energy simulation, a comparison between historical energy consumption quantities and simulation outputs before applying any energy saving recommendations has been carried out. As seen in Table 8 an average deviation of 5% is obtained, this is a strong evidence for the validity of using HAP 4.41 software for energy simulation. For instance the historical annual energy consumption of office building is $32,534

whereas it is calculated by HAP 4.41 to be $30,908 with deviation of 5%. As obtained from HAP 4.41, the monthly distribution of these $30,908 over the major energy consuming systems belong to OB is shown in figure 3. Similarly, monthly distribution of consumed energy cost over consuming systems belongs to PP1, PP2, and R can be simulated.

Making energy saving recommendation requires a good level of knowledge in energy management systems. Good energy simulation software could serve widely in that field, alongside help to know the constraints of the needed updates. To improve the above energy consumption rate some recommendations have been proposed among these;

- Using a double glazed section for all windows in buildings, this multiplies the overall heat transfer coefficient from 5.6 to 3.6 (Incropera et al., 2001).

- Adding insulation to the roof of OB with 3 centimetres of polystyrene, this multiplies the overall heat transfer coefficient from 1.432 to 0.513 (Incropera et al., 2001).

- As per local Jordanian codes for heating, setting A/C temperatures to 20 C° during winter time and to 24 C° during summer.

- As per ASHRAE ventilation standard, setting ventilation rates for offices to 0.36 Air Change number (ACH).

- Replacing magnetic ballast bulbs with electronic ballast ones in R.

When incorporating all energy saving recommendations into the system, accordingly replacing existing energy data by the recommended ones, new simulation results is obtained, thereafter a new monthly distribution of energy cost over the major energy consuming systems belong to OB is shown in figure 4. Similarly, the new monthly distribution of consumed energy cost over consuming systems belongs to the other three consumption centres can be simulated.

A comparison that highlighted saving obtained is summarized in Table 9. As shown 13% of the total consumed energy is saved.

## Conclusion and future research

There is a good potential of energy saving opportunities in the Jordanian pharmaceutical industry. Energy saving program is simulated successfully using computer simulation software HAP 4.41. A real life Jordanian pharmaceutical facility is examined; a total annual saving of 6608 KWh is achieved by simulating retrofitting actions and recommendations. Implementing this energy saving model is possible without the need of outsourcing expensive external ESP's.

Further research could be done regarding energy saving within Jordanian pharmaceutical industrial sector by investigating pharmaceutical industrial processes and accompanied energy saving opportunities.

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# Appendix

TABLE 1. ENERGY SAVING ESTIMATION METHODS

| Energy Estimator | Explanation |
|---|---|
| Simplified engineering method | Used to cure the energy consumption of a single system, usually lighting and motors systems |
| Regression analysis method | Used when historic data available about energy consumption and Independent variables capable of producing good regression model |
| Dynamic model | Used when transient data could be logged and interrelated to energy consumption |
| Computer simulation | Used when full comprehensive data could be gathered about the facility under study |

TABLE 2. SUMMARY OF SOME POSSIBLE ACTIONS
AND ENERGY SAVING RECOMMENDED

| Consuming System | Energy Saving Recommended Action(s) |
|---|---|
| HVAC | 1. Re-commissioning.<br>2. Non-production hours set back temperature.<br>3. Discharge air temperature management.<br>4. Adjustable speed drives.<br>5. Chiller efficiency improvement.<br>6. Building insulation.<br>7. Employees' energy awareness. |
| Compressed Air | 1. Maintenance.<br>2. Monitoring.<br>3. Leak reduction.<br>4. Turning off unnecessary compressed air systems.<br>5. Inlet air temperature reduction.<br>6. Natural gas driven air compressors where possible |
| Pumps | 1. Maintenance.<br>2. Monitoring.<br>3. Leak reduction.<br>4. Turning off unnecessary pumping systems.<br>5. Inlet water temperature reduction. |
| Refrigeration | 1. Monitoring of refrigerant charge.<br>2. Cleaning and maintenance of condenser and evaporator fins. |
| Lighting | 1. Employees' energy awareness.<br>2. Electronic ballasts. |

TABLE 3. HISTORICAL ENERGY CONSUMPTION

| Month | Consumed Electricity (MWh) | Consumed Diesel (Litre) |
|---|---|---|
| January | 654 | 3124 |
| February | 556 | 2736 |
| March | 532 | 2902 |
| April | 460 | 2995 |
| May | 479 | 3024 |
| June | 484 | 2875 |
| July | 535 | 3124 |
| August | 507 | 2902 |
| September | 491 | 2995 |
| October | 473 | 3124 |
| November | 427 | 2773 |
| December | 588 | 3124 |

TABLE 4. ENERGY DATA RELATED TO ADMINISTRATION BUILDING

| Item | Input | Pre status/ Value | Source/ Reference | Recommendation |
|---|---|---|---|---|
| 1 | Weather | N/A | ASHRAE Standard | Incontrollable Input |
| 2 | Building | | | |
| 2-A | Type | Offices | As Built Drawings | Incontrollable Input |
| 2-B | Subcategory Number of Stories | 2 Stories | As Built Drawings | Incontrollable Input |
| 2-C | Shape | Rectangular | As Built Drawings | Incontrollable Input |
| 2-D | Zoning | 18 Zones | A/C As Built Drawings | Incontrollable Input |
| 2-E | Dimensions | 51 m x 30 m | As Built Drawings | Incontrollable Input |
| 2-F | Ventilation Required | 1 ACH | Ventilation Fans Sizes / As Built Drawings | 0.34 ACH |
| 2-H | Lighting | Electronic Ballasts | Lighting As Built Drawings | Electronic Ballast |
| 2-I | Wall Construction | U = 1.2  W/M².K | Construction As Built Drawings | U = 1.2  W/ m².K |
| 2-J | Roof Construction | U = 0.513 W/M².K | Construction As Built Drawings | U = 0.513 W/ m².K |
| 2-K | Glazing Type | U = 3.6 W/M².K | Construction As Built Drawings | U = 3.6W/m².K |
| 3 | HVAC Equipments | | | |
| 3-A | Type | DX | Technical Catalogues | Incontrollable Input |
| 3-B | Heating Type | Heat Pump | Technical Catalogues | Incontrollable Input |
| 3-C | System Type | Constant Zone | HVAC As Built Drawings | Incontrollable Input |
| 3-D | | 23 C° Heating, 22 C° Cooling | Data Loggers | 20 C° (Heating), 24 C° (Cooling) |
| 3-E | Zoning | 18 Zones | HVAC As Built Drawings | Incontrollable Input |
| 3-F | EER | 4 (Max) | Technical Catalogues | Incontrollable Input |
| 3-G | COP | 4 (Max) | Technical Catalogues | Incontrollable Input |
| 3-H | Heat Reclaim | Doesn't exist | HVAC As Built Drawings | Install a heat reclaim unit |
| 4 | Miscellaneous Equipments | | | |
| 4-A | DHW Boiler | 8 hours per day | Mechanical As Built Drawings | Operate according to usage profile |
| 4-B | Personal Computers (400 Watt Each) | 8 hours per day | Furniture Layout | Operate according to usage profile |

TABLE 5. ENERGY DATA RELATED TO PRODUCTION PLANT 1

| Item | Input | Pre Status/ Value | Source/ Reference | Post status |
|---|---|---|---|---|
| 1 | Weather | N/A | ASHRAE Standard | Incontrollable Input |
| 2 | Building | | | |
| 2-A | Type | Offices | As Built Drawings | Incontrollable Input |
| 2-B | Subcategory Number of Stories | 1 Story | As Built Drawings | Incontrollable Input |
| 2-C | Shape | Rectangular | As Built Drawings | Incontrollable Input |
| 2-D | Zoning | 18 Zones | As Built Drawings | Incontrollable Input |
| 2-E | Dimensions | 100 m x 60 m | As Built Drawings | Incontrollable Input |
| 2-F | Ventilation Required | 4 ACH | As Built Drawings | 0.34 ACH |
| 2-G | Lighting | Electronic Ballast | Lighting As Built Drawings | Electronic Ballast |
| 2-H | Wall Construction | U = 1.2 W/M².K | Construction As Built Drawings | Incontrollable |
| 2-I | Roof Construction | U = 1.432 W/ M².K | Construction As Built Drawings | U = 0.513 W/ m².K |
| 2-J | Glazing Type | U = 5.6 W/M².K | Construction As Built Drawings | U = 3.6 W/ m².K |
| 3 | HVAC Equipments | | | |
| 3-A | Type | Chiller | Technical Catalogues | Chiller |
| 3-B | Heating Type | Boiler | Technical Catalogues | Boiler |
| 3-C | System Type | Constant Zone | HVAC As Built Drawings | Incontrollable Input |
| | | 23 C° Heating, 22 C° Cooling | Data Loggers | 20 C° (Heating), 24 C° (Cooling) |
| 3-D | Zoning | 2 zones | HVAC As Built Drawings | Incontrollable Input |
| 3-E | EER | 4 (Max) | Technical Catalogues | Incontrollable Input |
| 3-F | COP | 4 (Max) | Technical Catalogues | Incontrollable Input |
| 3-G | Heat Reclaim | Doesn't Exist | HVAC As Built Drawings | Install a heat reclaim unit |
| 4 | Miscellaneous Equipments | | | |
| 4-A | DHW Boiler | 12 hours | Mechanical As Built Drawings | Operate according to usage profile |
| 4-B | Personal Computers (400 Watt each) | 12 hours | Furniture Layout | Operate according to usage profile |

TABLE 6. ENERGY DATA RELATED TO PRODUCTION PLANT 2

| Item | Input | Pre- Status/ Value | Source/ Reference | Notes |
|---|---|---|---|---|
| 1 | Weather | N/A | ASHRAE Standard | Incontrollable Input |
| 2 | Building | | | |
| 2-A | Type | Offices | As Built Drawings | Incontrollable Input |
| 2-B | Subcategory Number of Stories | 1 Story | As Built Drawings | Incontrollable Input |
| 2-C | Shape | Rectangular | As Built Drawings | Incontrollable Input |
| 2-D | Zoning | 18 Zones | As Built Drawings | Incontrollable Input |
| 2-E | Dimensions | 100 m x 60 m | As Built Drawings | Incontrollable Input |
| 2-F | Ventilation Required | 4 ACH | Ventilation Fans Sizes / As Built Drawings | Incontrollable Input |
| 2-G | Lighting | Electronic Ballast | Lighting As Built Drawings | Electronic Ballast |
| 2-H | Wall Construction | U = 1.2 W/M².K | Construction As Built Drawings | Incontrollable Input |
| 2-I | Roof Construction | U = 1.432 W/M².K | Construction As Built Drawings | U = 0.531 W/ m².K |
| 2-J | Glazing Type | U = 5.6 W/M².K | Construction As Built Drawings | U = 3.6 W/ m².K |
| 3 | HVAC Equipments | | | |
| 3-A | Type | DX | Technical Catalogues | Incontrollable Input |
| 3-B | Heating Type | Heat Pump | Technical Catalogues | Incontrollable Input |
| 3-C | System Type | Constant Zone | HVAC As Built Drawings | Incontrollable Input |
| | | 23 Heating, 22 C° Cooling | Data Loggers | 20 C° (Heating), 24 C° (Cooling) |
| 3-D | Zoning | 2 zones | HVAC As Built Drawings | Incontrollable Input |
| 3-E | EER | 4 (Max) | Technical Catalogues | Incontrollable Input |
| 3-F | COP | 4 (Max) | Technical Catalogues | Incontrollable Input |
| 3-G | Heat Reclaim | Not Used | HVAC As Built Drawings | Install a heat reclaim unit |
| 4 | Miscellaneous Equipments | | | |
| 4-A | DHW Boiler | 12 hours | Mechanical As Built Drawings | Operate according to usage profile |
| 4-B | Personal Computers | N/A | Furniture Layout | Operate according to usage profile |

TABLE 7. ENERGY DATA RELATED TO RESTAURANT

| Item | Input | Pre- Status/ Value | Source/ Reference | Notes |
|---|---|---|---|---|
| 1 | Weather | N/A | ASHRAE Standard | Incontrollable Input |
| 2 | Building | | | |
| 2-A | Type | Offices | As Built Drawings | Incontrollable Input |
| 2-B | Subcategory number of Stories | 1 Story | As Built Drawings | Incontrollable Input |
| 2-C | Shape | Rectangular | As Built Drawings | Incontrollable Input |
| 2-D | Zoning | 18 Zones | As Built Drawings | Incontrollable Input |
| 2-E | Dimensions | 100 m x 60 m | As Built Drawings | Incontrollable Input |
| 2-F | Ventilation Required | 4 ACH | Ventilation Fans Sizes / As Built Drawings | Incontrollable Input |
| 2-G | Lighting | Electronic ballast | Lighting As Built Drawings | Incontrollable Input |
| 2-H | Wall Construction | U = 1.2 W/M².K | Construction As Built Drawings | Incontrollable Input |
| 2-I | Roof Construction | U = 1.432 W/M².K | Construction As Built Drawings | Incontrollable Input |
| 2-J | Glazing Type | U = 5.6 W/M².K | Construction As Built Drawings | U = 0.531 W/ m².K |
| 3 | HVAC Equipments | | | |
| 3-A | Type | DX | Technical Catalogues | Incontrollable Input |
| 3-B | Heating Type | Heat Pump | Technical Catalogues | Incontrollable Input |
| 3-C | System Type | Constant Zone | HVAC As Built Drawings | Incontrollable Input |
| 3-D | | 23 C° Heating, 22 C° Cooling | Data Loggers | 20C° (Heating), 24 C° (Cooling) |
| 3-E | Zoning | 1 Zone | HVAC As Built Drawings | Incontrollable Input |
| 3-F | EER | 4 (Max) | Technical Catalogues | Incontrollable Input |
| 3-G | COP | 4 (Max) | Technical Catalogues | Incontrollable Input |
| 3-H | Heat Reclaim | Not Used | HVAC As Built Drawings | Install a heat reclaim unit |
| 4 | Miscellaneous Equipments | | | |
| 4-A | DHW Boiler | 12 hours | Mechanical As Built Drawings | Operate according to usage profile |
| 4-B | Personal Computers | N/A | Furniture Layout | N/A |

TABLE 8. HISTORICAL ENERGY CONSUMPTION

| Energy Centre | Annual Energy Consumption | | | | Error (%) |
|---|---|---|---|---|---|
| | Historical | | HAP 4.41 Results | | |
| | KWh | Cost ($) | KWh | Cost ($) | |
| OB | 704,876 | 32,534 | 669,633 | 30,908 | 5% |
| PP1 | 2,912,504 | 134,788 | 2,708,629 | 125,353 | 7% |
| PP2 | 3,292,360 | 151,676 | 3,094,819 | 142,576 | 6% |
| R | 135,747 | 5,532 | 133,033 | 5,422 | 2% |
| | Average error | | | | 5% |

TABLE 9. ENERGY SAVING OPPORTUNITIES

| Energy Centre | Annual Energy Consumption (KWh) using AHP 4.41 | | Savings | |
|---|---|---|---|---|
| | Before saving recommendation | After saving recommendation | KWh | (%) |
| OB | 669,633 | 493,171 | 176,462 | 26 % |
| PP1 | 2,708,629 | 2,444,959 | 263,670 | 10 % |
| PP2 | 3,094,819 | 2,651,847 | 442,972 | 15 % |
| R | 133,033 | 126,425 | 6,608 | 5 % |
| Total | 6,606,114 | 5,716,402 | 6,608 | 13% |

FIGURE 1. OBSTACLES THAT MAY PREVENT THE IMPLEMENTATION OF ESP'S

FIGURE 2. THE MAIN STRUCTURE OF THE PROPOSED ENERGY SAVING MODEL



FIGURE 3. A SNAP SHOT HAP 4.41 DESCRIBES MONTHLY ENERGY COSTS OF OB BEFORE
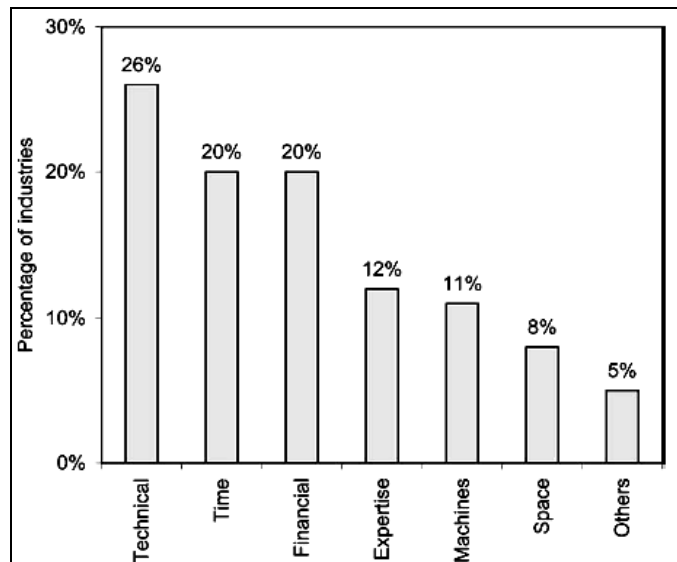IMPLEMENTING ANY OF THE ENERGY SAVING RECOMMENDATION

FIGURE 4. A SNAP SHOT HAP 4.41 DESCRIBES MONTHLY ENERGY COSTS OF OB AFTER
IMPLEMENTING THE ENERGY SAVING RECOMMENDATION