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Assessing Energy-Saving in JUST Facilities: A Case Study

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Abstract

By increasing the consumption of energy in all over the world, a sharp shortage in sources and an increasing in costs of energy face the consumers in all different sectors, so the energy conservation becomes more important to apply. This research presents an energy auditing case study in Jordan University of Science and Technology (JUST) facilities in addition to economical evaluations using payback method. The energy audit team worked in the facilities at many systems such as electrical system, and mechanical system (Boilers and chillers). In electrical system the team chooses the new electrical tariff, improves the power factor and installs electronic ballast. Also an efficiency test was performed for two steam boilers; these tests were based on flue gas measurement, calculating radiation and convection losses and direct measurement of the amount of diesel consumed during the test. In addition to that there were monitoring for the power consumption of chillers for a period of 8 days to observe the running time for each one, and the refrigeration capacity was determined by measuring the condenser water flow rate, water temperature difference and chiller power consumption. During this study it was found that the total annual saving is equal to117,053 JD which represents 10.4 % from the total energy bill.

Keywords: *Energy saving, Auditing, Building energy Management systems, Energy efficiency*

1. Introduction

Over the period 2000 - 2030, nearly 5,000 GW of generating capacity is expected to be built worldwide. The total installed capacity will rise from 3,397 GW in 1999 to reach 7,157 GW by 2030 as shown in Figure1. Almost two-thirds of installed capacity is being built after 2000. About a third of new capacity will be developed in area of Asia. Organization for Economic Co-operation and Development countries (OECD) will require more than 2,000 GW to replace old plants and to meet rising demand. Big increases are expected in the transition economies and developing countries [1].

The 30 nations of the OECD which are comprised mainly of the wealthy industrialized countries of the global consume the majority of energy resources in almost every category of energy. This includes two of the three dominant energy sources (petroleum and natural gas) along with the lesser energy sources of hydroelectric power, nuclear electric power, and renewable sources (biomass, geothermal, solar, and wind electric power). In 1999 the relatively small number of OECD countries consumed 63.5% of the world's petroleum, 54.5% of the natural gas, and 49.5% of the coal in the global economy.

2. Energy Situation in Jordan

Jordan has a total area of 92,300 km^2, with mostly desert climate and a rainy season in the west, from November to April of the year. The population of the kingdom is 5,906,760 (July 2006 estimated) [2]. Electricity production in Jordan is still predominantly based on thermal power plants, primarily using fuel and gas oil.

The Primary energy demand level is reached about 5.29 million TOE in 2002, representing a growth rate of 2.7% compared to 5.6% in 2001. The total primary energy consumption per capita was about 993 kg oil-equivalent (KOE) in 2002, compared to 994 kg in 2001. Electric power consumption in Jordan was 6900 million kWh in 2002, compared to 6392 million kWh during 2001, i.e. an annual increase of 7.9% compared to an increase of (4.2%) during 2001. Correspondingly, the average per capita electricity consumption reached 1585 kWh in 2002, compared to 1507 kWh in 2001 [3].

Figure 2 shows the 2004 electric energy consumption in Jordan by sectors. In 2001, residential or households electricity consumption in Jordan was 2717 GWh which is 35% of the total electricity consumption in the kingdom [4].

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A continuous increase in energy demand in Jordan as shown in Figures 3 brings up the challenge to find ways to manage this increase [5] and to explain how much the increasing will be in future.

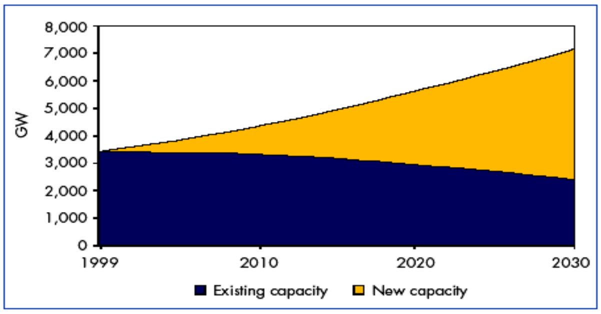

Fig.1. World Installed Electricity Generation Capacity

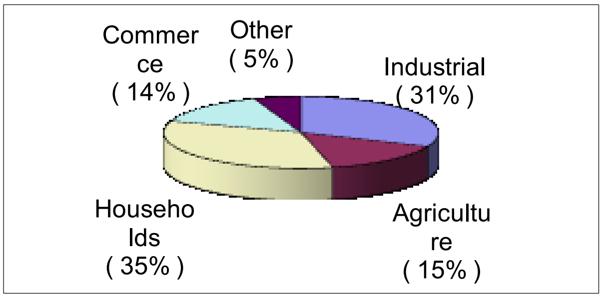

Fig.2. Electricity consumption in Jordan @ 2004 by different sectors

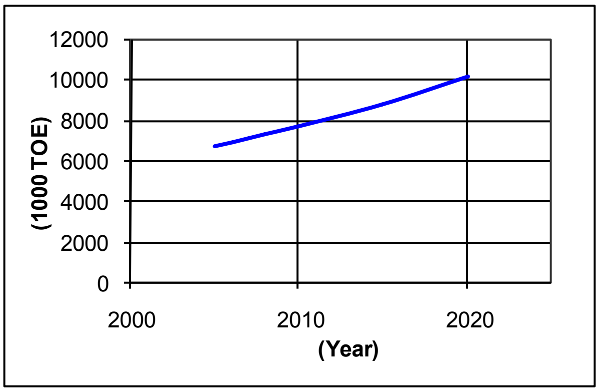

Fig.3. Primary energy demand at future in Jordan

Figure 3 shows a sharp increasing estimation in the Primary energy demand between 2005 to 2020, and this increasing reaches nearly 153 %. Also the estimated increasing in the electrical energy demand between 2005 to 2020, and this increasing reaches nearly 166 %. In addition to that, there is an increase in prices of energy go along the increase in demand, for example the diesel price in Jordan in 1999 was 106 (Fils/Liter) and it is now 435 (Fils/Liter), which means more than 400% increasing in the price.

3. Economic Analysis

The purpose of any energy conservation project is to save money by using less energy or using energy more efficiently. An economy study may be defined as a comparison between alternatives in which differences between the alternatives are expressed so far as practicable in monetary terms. Engineering economy studies stress the importance of clearly identifying the alternatives to numerical data that can be compared on monetary basics. Also economic analysis is a process in which financial costs, revenues, and savings are evaluated for a particular project. This analysis is necessary to evaluate the economic advantages of competing projects and is used to determine how to allocate scarce resources.
Financial performance indicators are needed to allow comparisons to be made between competing project alternatives. Three methods of comparison are currently in widespread use: Payback Period, Life-Cycle Cost, and Accounting Rate of Return. Several data are needed to perform an appropriate and meaningful economic analysis.

4. General Description of JUST Facilities

The University Campus sits at 70 km north of Amman, the capital of Jordan, and 20 km east of Irbid City. The campus which covers 11 km^2 features main buildings with total area of 355,000 m^2 that were constructed according to the latest architectural designs confirming to the natures of its scientific faculties. The campus also includes: the University farm, outstanding teaching and research facilities in the fields of computers, engineering, electronics, industry, environment and medicine that are complemented by cultural and recreational facilities: 12 auditoriums, a music hall, fine arts galleries, museums, 8 restaurants, housing complex, workshops, modern libraries, clinic, sports gyms, tennis courts, and football playground which include more than 7000 seats. Those facilities are linked with 160 km of illuminated modern roads. The students number was (2300) students in the year 86/87 and increases to more than (20500) undergraduate and graduate students in the academic year 2007/2008 instructed by about (730) faculty members compared with (110) in the year when the University was founded. JUST is using three types of energy sources, gas, diesel and electricity as shown in Figure 4.

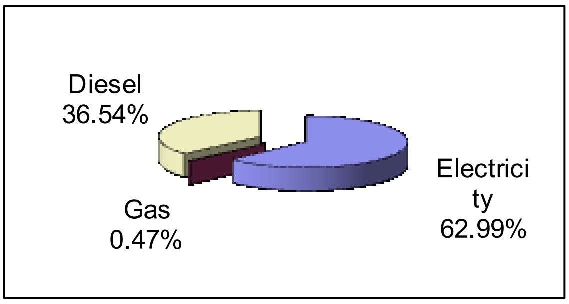

Fig.4. Energy distribution by cost in JUST in 2005

4.1 Description of Electrical System

Electrical distribution system of JUST consists of 10 MVA main transformer connected to Irbid electrical distribution network. The main transformer is a step down transformer from 33KV to 11 KV and then other 53 transformers to step down the voltage from 11 KV to 0.4 KV with different capacities nearly in the range 1250 KVA to 250 KVA. The electrical wires in this high voltage network are copper cables (3x185 mm^2).
The objective is to save energy by switching off the primary side of transformers on useless time periods. This will effect on wire losses. In this study we will take a sample from the JUST facilities, which consists the Presidentship transformer (A3), Stadium transformer (which locates on the right of CH2), Lake transformer and two transformer inside the Engineering Faculty called M7 and C6. Samples of five transformers in addition to the main transformer which is between nodes (1 and 4) were shown in Figures 5.

By using Power World Simulator 11.0 program with two cases, one in summer loads and the second in winter loads , it was found that the higher losses were between nodes (1,4) on the main transformer, and lowest were in winter between nodes (2,3) on Lake transformer, which means there are no loads operating on this transformer. Lake transformer approximately works 8 hours daily except in winter (Suppose 3 months), so the useless time in winter will be 3 months or 2160 hrs. Also if we separate the Lake transformer from the side of primary in winter, the no load losses will be saved.

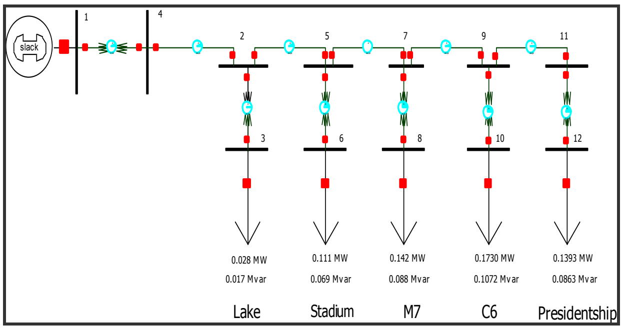

Fig.5. A sample of distribution system in JUST during summer

The annual energy saving = No load losses x time = 900 Watt x 2160 hour = 1944 kWh

The annual saving in cost = 1944 (KWh) x 0.085 (JD / KWh) = 165.24 JD

4.2 Load management

Load management basically aims to improve system Load Factor. Load Factor is defined as the ratio of the average load over a designated period to the peak demand load occurring in that period, say a day, a month, or a year.

Jordan Electricity Authority defined the maximum demand tariff as follows: " The maximum demand tariff is charged as monthly lump sum per kW of the monthly maximum load which occurs for a period of 30 minutes during the peak period". This tariff is 3.05 JD per kW per month for all bulk consumers. Peak demand is measured every half hour in a month of 72 hours; the highest measurements will be taken as the peak demand. Average kW demand can be calculated by dividing KWh consumption by the number of hours.

Load Factor = Average demand / Peak demand (3)

To improve Load Factor it is necessary to reduce peak demand which may be occurring only for short periods. Take a daily demand curves as shown in Figures 6 and 7. The average values of demand in MW during peak period in Mon. is 3.259842 MW.

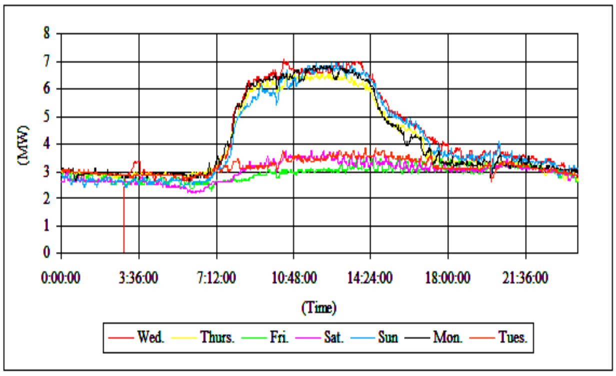

Fig.6. Daily demand curve for a weak in summer

Whereas the peak demand in Monday during peak period, is 3.619 MW.

As a result the Load Factor = 3.259842 / 3.619 = 0.9

Also take a daily demand curves as shown in Figure 11 from the average demand in Monday was 2603.053 KW and the average of 2880 readings taken in this time period. The peak demand in Monday during peak period, is 5164.8 KW.

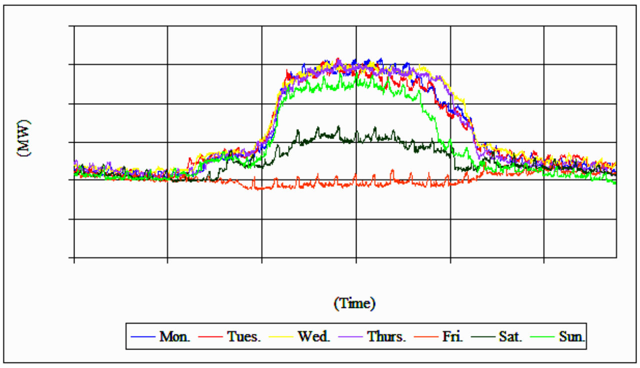

Fig.7. Daily demand curve for a weak in winter

As a result the Load Factor = 2603.053 / 2955.1 = 0.88. The peak period is from 17:00 to 21:00 during the winter and from 19:00 to 22:00 during the summer months.

The university tariff is normal participant which means 0.082 JD per KW when the consumption is over 500 KW, also there is pumping water participation which is 0.04 JD per KW. In both participations there is no maximum demand tariff, and the peak demand is out of peak period as shown in figures 10-11.

4.3 The Power Factor (PF)

In general, using Inductive devices such that lighting fixture ballast, induction motors, transformers, arc welders and solenoids, make the PF low. So, the Electrical Company encourage people to increase PF. The advantages of power factor improvement are: Reduction in circuit current, improvement in voltage regulation, reduction in copper losses in the system due to reduction in current, and reduced power factor penalty charges for electric utility.

Power factor can be improved by using shunt capacitor banks or using synchronous condenser [7]. Jordan Electricity Authority determine the lowest PF by 0.85, otherwise penalty will be imposed according to decreasing in PF as shown in Table 1 [8].

Table1: The penalty of PF in Jordan

PF	Penalty
Over 0.85	No thing
Less 0.85 to 0.7	0.77% from the value of bill to each 0.01 of PF less than 0.85
Less 0.7 to 0.6	0.95% from the value of bill to each 0.01 of PF less than 0.85
Less 0.6 to 0.5	1.2% from the value of bill to each 0.01 of PF less than 0.85
Less 0.5	1.5% from the value of bill to each 0.01 of PF less than 0.85

The PF measured in JUST in summer was in the range of 0.850031, the maximum value was 1 and the minimum -0.994. These maximum and minimum values are irregular values, since the PF cannot be one where an inductive load are exists. This irregular because there was a problem occurred and caused a separation of source. On the other hand the PF measured in JUST in wintertime was in the range of 0.907605, the maximum value was 0.946 and the minimum 0.854. The PF value indicates how much the system has more inductive loads. This may be useful in future if the PF increasing to the unallowable range to determine the reasons of increasing, and then it is easy to solve the problem. In general, we can conclude based on these measurements that the PF is in good range.

4.4 Power Quality and Total Harmonic Distortion (THD)

The quality of electric power is becoming a matter of increasing concern to both power utilities and their customers. There major reasons for this:

1. Customer equipments today are more sensitive to power quality variations than equipment used in the past. Modern microprocessor-based controllers and power electronic devices are very sensitive to various disturbances in the power supply.
2. Increasing levels of harmonics in power systems give rise to concerns about the future impact on the system performance.
3. Customers are becoming better informed about power quality problems and are challenging the utilities to improve power quality.

Power quality may deteriorate due to a variety of reasons. In order to maintain a reasonable level of quality, it is necessary to identify the disturbance causing a particular type of power quality problem and to locate the sources of that disturbance in the power system so that corrective action can be taken.

Existing methods of analyzing and identifying power disturbances are laborious since they are based on visual inspection of disturbance waveforms. Due to the complexity of power quality problems and the lack of reliable techniques to analyze these problems, power utilities are unable to ensure the required level of power quality without a considerable increase in cost. An automated system for disturbance recognition and classification will have many advantages over a manual system. These advantages include the speed of processing, amount of data that can be processed, ease of data collection and storage, reliability and cost [9-10].

Power quality can be defined as any problem manifested in voltage, current, or frequency deviation that results in failure or mal-operation of electric equipment [11].

Currently in JUST, there is a reliable automatic system exists to measure Harmonics for make an indicator to power quality.

The THD of voltage and current can be implemented as a function of time, where the value of THD took every 5 seconds on each line of source, also we can see that the THD curve for each line likes to be a sine wave.

The revisions to IEEE 519-1992 establish recommended guidelines for harmonic voltages on the distribution system as well as harmonic currents within the industrial distribution system. The standard defines the voltage distortion limits below 69 KV by 5%, and proposes a limit on the harmonic in transformer 5% at rated current, which mean that all measured values, were within the range [12].

4.5 Office Equipments

The office equipments were classified into 8 types. Multi-function devices (MFDs) fall into several different categories, and although good energy data on these product categories are not available, all indications are that the energy use of each type behaves similarly to a conventional single-function type (copier, laser printer, or inkjet printer) [13].

4.6 Monitors and Display Terminals

Monitors and display terminals are actually distinct entities. A display merely presents a visual image seen by the user, while a monitor includes the display and the circuitry that converts an electrical signal from the computer to the monitor into a visual image. Conventional monitors resemble and are very similar to televisions, but without an antenna or the components needed to receive a broadcasting signal. Both use a Cathode Ray Tube (CRT) to convert electrical signals to the visual display seen on the screen. CRT’s project electrons onto a screen by using an electron gun to emit electrons. Anodes accelerate the electrons, which are then “steered” by a varying electromagnetic field onto different parts of the screen, where they interact with a coating of phosphor compounds that convert the electron signal into a visual signal. In essence, the CRT paints an image on the phosphor layer. In contrast to monochrome displays, which use a single electron gun, color monitors use three different electron guns (red, blue, and green) to create color images. Laptop and portable computers also have displays but they are not CRT-based, instead they use liquid crystal displays, or LCD’s. LCD’s consume a fraction of the energy and space of CRT’s, making them the solution for portable (and battery powered) devices, driven by a desire to conserve space in some applications where space is limited, flat screen monitors have recently entered the market. LCD’s also often appear as control display panels or displays for copiers, facsimile machines, telephones, and handheld computers, sometimes incorporating interactive capabilities (i.e., the user can touch the screen to control the device). Instead of projecting light onto a screen, LCD’s reflects useable light, typically in conjunction with additional light sources to “back light” the screen.

Power management has been more successful in monitors and displays than in PCs, even though the PC must be the initiator. Compared to power managing PCs, screens are usually simpler, have much more energy savings potential, power manage more reliably, and are less likely to interfere with operation or network connections. Because of this, it is even more important to enable screens for power management than it is to enable PCs.

Monitor power management is in most cases independent of PC power management in that the monitor can power down even if the PC doesn’t, and vice-versa. However, the monitor is still dependent on the PC for power management initiation; this is necessary since the monitor does not directly receive the activity information needed to know when to begin and end power management. Once the first low-power mode is entered, however, the monitor has an internal timer and will shift to succeeding low-power modes even if the PC doesn’t send additional signals. While delay times may differ, for the most part, the screen and PC are driven by the same activity for beginning and ending low-power modes.

4.7. Measuring and surveying

According to statistics in June last year for example, JUST have 2586 personal computers. There monitors distributed according to their type and size as shown in Figure 8. [14].

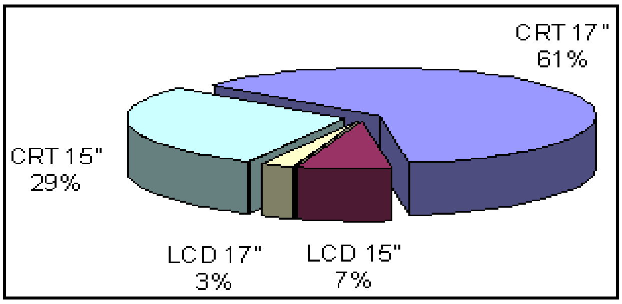

Fig.8. Screens distribution according to the type

The electrical quantity measured for each type of Monitor at 220 volt, then the results obtained in Figure 9 shows a comparing in the power consumption between the different kinds of monitors during the active, screen saver, and turn off modes. A case study was performed in a laboratory in Engineering building (E1, L2) at JUST which consists of 13 computers, to determine the energy consumption under the stochastic student usage when screen saver controlling with different times. The screens used were CRT 15". This study took 1۳ weeks, We left screens without any setting neither turn off nor screen saver for one week, then the energy consumption was measured to be 242320 Wh.

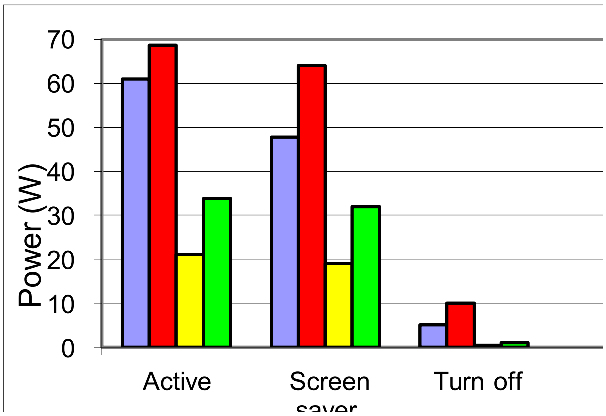

Fig.9. Analysis and recommendation

Setting the power management screens

If we compare the two modes of power management (turn off and screen saver), they are indicating to that turn off mode is less energy consumption. The optimum case is to set the screen on turn off is between 15 to 30 minutes, otherwise the energy consumption will be larger or annoying for users, since the screen will turn off during the work many times.

At the case of 15 minutes setting to turn off, we can calculate the time that the screen goes to turn off weekly:

$E_{Case} + E_N + E_A + E_{OFF} = E_{Comp.}$ (4)

Plug in equation (4) to have:

(168 h x 50 W) + (128 h x 5.1 W) + (Active time x 61 W) + (Off time x 5.1 W) = 148512 Wh / 13.

(Active time x 61 W) + (Off time x 5.1 W) = 2371.2 Wh (4*)

We can make nearly the same equation for screen saver mode:

$E_{Case} + E_N + E_A + E_{Saver} = E_{Comp.}$ (5)

Plug in equation (5) to have:

(168 h x 50 W) + (128 h x 47.8 W) + (Active time x 61 W) + (Off time x 47.8 W) = 220288 Wh / 13.

(Active time x 61 W) + (Screen saver time x 47.8 W) = 2426.8 Wh (5*)

If we suppose that screen saver time is equal to off time in the period of day time, we can solve the two equations (4*) and (5*) to find that, off time = 1.3 hours per screen per week.

The yearly useless time at daytime = 1.3 hour/screen / week x40 weeks (in the academic year) = 52 hour / screen / year.

The yearly useless time at nights and weekends = 128 hour / screen / week x 48 weeks (in a year) = 6144 hour / screen / year.

So, the total yearly useless time = 52 + 6144 = 6196 hour / screen / year.

According to this calculation, let us take three cases applied on the total different screens at the university:

First case: screen saver mode,

Yearly energy consumption = energy consumed by (CRT 17" + CRT 15" + LCD 17" + LCD 15")

Yearly energy consumption = (52 hour / screen / year x 1562 screens x 64W) + (52 hour / screen / year x 782 screens x 47.8W) + (52 hour / screen / year x 69 screens x 32W) + (52 hour / screen / year x 173 screens x 19.1W)

Yearly energy consumption = 7428714.8 Wh / year.

Since the each electrical kilo-watt costs 85 Fils including the country Fils and the addition penalty, then

Yearly energy cost = 7428.7148 KWh x 0.085 JD / KWh = 631.4 JD.

Second case: turn off mode,

Yearly energy consumption = energy consumed by (CRT 17" + CRT 15" + LCD 17" + LCD 15")

Yearly energy consumption = (52 hour / screen / year x 1562 screens x 10W) + (52 hour / screen / year x 782 screens x 5.1W) + (52 hour / screen / year x 69 screens x 1W) + (52 hour / screen / year x 173 screens x 0.5W)

Yearly energy consumption = 1027712.4 Wh / year.

Yearly energy cost = 1027.7124 KWh x 0.085 JD / KWh = 87.4 JD.

Third case: active mode,

Yearly energy consumption = energy consumed by (CRT 17" + CRT 15" + LCD 17" + LCD 15")

Yearly energy consumption = (52 hour / screen / year x 1562 screens x 68.7W) + (52 hour / screen / year x 782 screens x 61W) + (52 hour / screen / year x 69 screens x 33.8 W) + (52 hour / screen / year x 173 screens x 21.1W)

Yearly energy consumption = 8371682.8 Wh / year.

Yearly energy cost = 8371.6828 KWh x 0.085 JD / KWh = 711.6 JD.

Table 2 shows the reduction yearly cost.

Table 2: Summery of potential saving in different operation modes.

Mode	Reduction in energy (KWh)	Reduction in cost (JD)	Investment (JD)	Payback period (Years)
Screen saver	942.97	80.2	0	Immediate
Turn off	7343.97	624.2	0	Immediate

Turn off the monitors from the power button

If we turn off the screens from the power button after working hours, there will be a saving in energy of 121428172.8 Wh/year which results into an annual saving of an amount of 10321.4 JD.

Replacement of monitors

Another recommendation was to replace all the CRT screens by others of LCD, where JUST can sell the old screens to reduce the cost of investment. This approach has three scenarios:

First scenario,
Replace all CRT screens by another of LCDs of size 17", which will cost 480530 JD as an investment. To calculate the energy saving cost, we should calculate the annual energy consumption before and after replacement.
Annual energy consumption before replacement = energy consumption by 1562 screens of CRT 17" + energy consumption by 782 screens of CRT 15". The Total energy consumption of CRTs = 361450054.4 Wh. Whereas the Annual energy consumption of the new 2344 LCDs 17" is 137167129.6 Wh. As a result the Annual energy saving was 224282924.8 Wh with an annual energy saving cost of 19064 JD with a payback period of 25.2 years.
Second scenario,
Replace all CRT screens by another of LCDs of size 15", with an Investment cost of 363330 JD. The Total energy consumption of CRTs was 361450054.4 Wh, as calculated before. The annual energy consumption of the new 2344 LCDs 15" is 83823315.2 Wh. As a result the annual energy saving is 277626739.2 Wh and the annual energy saving cost of 23598.3 JD with a payback period 15.4 years.
Third scenario,
Replace CRT screens of size 17" by another LCDs of the same size, and CRT of 15" by LCDs of 15", The investment cost of this scenario is 441430 JD. As described before the annual energy saving in consumption is 242079368 Wh and the annual energy saving cost is 20576.7 JD with a payback period of 21.45 years.

5.1 Lighting System

Lighting system is considered as one of the major electricity consumers in JUST. Table 3 shows the number and capacity for different existing types of lighting luminaries.

Table 3: Types and quantities of lighting fixtures in JUST.

Type of fixture	Wattage	No.	Total KW
Fluorescent	36 x 2	10000	720000
Fluorescent	18 x 4	4000	288000
Fluorescent	13 x 2	500	13000
Fluorescent	10 x 2	500	10000
Fluorescent	8 x 2	500	8000
Fluorescent Circular	40	7000	280000
Fluorescent Circular	32	3000	96000
Mercury lamps	250	800	200000
Mercury lamps	150	800	120000
Mercury lamps	125	600	75000
Sodium lamps	400	600	240000
Sodium lamps	250	800	200000
Incandescent lamps	75	2000	150000

5.1.1 Electronic Ballast

Fluorescent lamps require a ballast to apply starting voltage to the lamp and establish current flow – an "arc" – between the lamp electrodes. Once the lamp is operating, the ballast also regulates lamp current and power.
Ballasts are integral parts to fluorescent luminaries, since they provide the voltage level required to start the electric arc and regulate the intensity of the arc. Before the development of electronic ballasts in early 1980's, only magnetic or "core and coil" ones were used to operate fluorescent lamps. While the frequency of the electrical current is kept at 50 Hz (or 60 Hz in US) by the magnetic ballasts, electronic ballasts use solid-state technology to produce high-frequency (20- 60 MHz) current, which increases the energy-efficiency of the fluorescent luminaries since the light is cycling more quickly and appear brighter.
Other advantages that electronic ballasts have relative to their magnetic counterparts include:
1- Higher power factor: The power factor of electronic ballasts is typically in the 0.9 to 0.99 range. Meanwhile, the conventional magnetic ballasts have low power factor (less than 0.80) unless a capacitor is added,
2- Less flicker problems: Since the magnetic ballasts operate at 50 Hz current, they cycle the electric arc about 120 times per second. As a result, flicker may be perceptible, especially if the lamp is old during normal operation or when the lamp is dimmed to less than 50% capacity. However, electronic ballasts cycle the electric arc several thousands of times per second and flicker problems are avoided, even when the lamps are dimmed to as low as 5% of capacity.
3- Less noise problems: The magnetic ballasts use electric coils and generate audible hum, which can increase with age. Such noise is eliminated by the solid-state components of the electronic ballasts.
Ballast types fall into two broad categories:
1- Magnetic: a simple device that uses a core and coil assembly transformer to perform the minimum functions required to start and operate a lamp. Magnetic ballasts are often found in Metal Halide Lamps (HID) systems, as well as older fluorescent systems.
2- Electronic: a more complex device that substitutes electronic components for the core
and coil assemblies found in magnetic ballasts. Electronic ballasts are significantly smaller, lighter and quieter than their magnetic counterparts and offer distinct advantages in energy efficiency and lamp operation.
Ballasts, particularly for fluorescent systems, can be further categorized by their lamp starting and operating method. Starting and operating methods now available are balances between lamp life, energy consumption, and overall system costs that allow the user to select the system best suited for their application. The THDs for current and voltage were in the range of IEEE (Std 519-1992) recommends a maximum allowable voltage THD of 5% at the building service entrance. Verderber and others in 1993 showed that the voltage THD reaches the 5% limit when about 50% of the building electrical load has a current THD of 55% or when 25% of the building electrical load has a current THD of 115%, and according to this it is preferable to change magnetic ballasts with electronics ones [15].
Also the PF improved in clearly way spatially in circular Fluorescent 32 (W) and 40 (W).
The most important opportunity to save energy in lighting system is to replace magnetic ballasts with electronic ones.
The emergency lamps (8W, 10W, 13W) are already have electronic ballasts, so the other Fluorescents type shown in Table 4 will be replaced only. The calculated total saving power consumption for all fixtures is 540,000,000 Wh with an annual saving in cost of 45,900 JD.

Table 4: Summery of power saving by using electronic ballast in different type of lamps.

Type of fixture	Wattage	Saving power for a fixture (W)	Total saving power (W)
Fluorescent	36 x 2	100 - 76 = 24	10,000 x 24 = 240,000
Fluorescent	18 x 4	101 – 75 = 26	4,000 x 26 =104,000
Fluorescent Circular	40	54 – 44 = 10	7,000 x 10 =70,000
Fluorescent Circular	32	47 – 35 = 12	3,000 x 12 =36,000

In this process two types of electronic ballasts were needed, the first one is for 2 x 36 watt or 4 x 18 watt fluorescent lamps, and the second for 32 watt or 40 watt fluorescent lamps. Table 5 shows the investment to implement this suggestion. As a result the payback period is 4.67 years.

Table5: Summery of investment costs of electronic ballasts.

Ballast type	Number	Unit price (JD)	Total investment (JD)
2 x 36 watt	10,000	10	100,000
4 x 18 watt	4,000	10	40,000
40 watt	7,000	7	49,000
32 watt	3,000	7	21,000
Total			210,000

5.1.2 Light intensity levels

Energy can be saved by reducing illumination levels and eliminating lighting that is not needed. If several tasks that require different levels of illumination occur within a space, you can rearrange the area while reducing illumination levels to the appropriate level for each task.

The illumination level for a residential premise is different from that of commercial, industrial or educational premises [16]. There are many samples of light intensity measurements taken at JUST and can be shown in Table 6 compared with recommended according to Jordanian Lighting Code [17].

Table 6: Measured and recommended illumination levels in different places.

Place	Measured illumination level (Lux)	Recommended illumination level (Lux)
Registration office	170-250	300
Lectures hall (E2,113)	335	300
Cafeteria	250	100
Student activity building	264 (without lamping)	300
Financial office	130	300
Library	320	300
Machine Lab.	550	500

The results show that in registration office the level was under the recommended despite of it taken before and after open the widow curtain. The purpose of this low level is the dirty cover of lamps, and the financial office also has the same case. In the other places the light intensity was over range, and can be explained by the time of the experiment done (12:00 pm to 2:00 pm) where the day light is nearly the maximum. Students and employers should take care to turn off lights when their no need. The recommendation here goes toward human resources, where it depends on their culture of energy auditing. Also we need to clean and maintain the lamp covers where the levels of light are over recommended.

5.1.3 Occupancy sensors

Occupancy sensors turn off the lights when they detect that no occupants are present. The occupancy sensor includes a motion sensor, a control unit and a relay for switching the lights. The sensor and control unit are connected to the luminaries by low voltage wiring, with a transformer stepping down the current. There are four basic types of occupancy sensors, defined by how they detect motion: ultrasonic, passive infrared, acoustic and dual-technology [18]. In JUST buildings, there are 98 lecture halls. So, occupancy sensors may be installed in these halls. As an example, the hall (E2,113) is observed for one day 25/6/2005 and we calculate the total time where no one in the hall despite of the lights still turned on, the time was nearly 3 hours, and this hall contains 18 fluorescent lamps of 36 watt. In a walk-through survey 18 lamps was nearly the minimum number of fixtures.

Suppose that 3 hours of 18 (36 watt) lamps are the dissipated time for each hall daily, and as before suppose 5 days in a week, where there are 40 weeks in the academic year, and then the dissipated energy yearly is:

Annual dissipated energy = Power in a hall x No. of halls x Yearly time = (18x50) x (98) x (3x5x40) = 38102.4 KWh.

Where the 50 watt consumed by each lamp was measured in the laboratory.

If we installed the occupancy sensors in halls the saving cost will be:

Annual cost saving = 38102.4 KWh x 0.085 Fils / KWh = 3238.704 JD

Investment cost = occupancy sensor cost x number of halls = 20 JD x 98 = 1960 JD

Payback period (in years) = Investment cost / Annual energy saving cost = 1960 / 3238.704 = 0.6 year.

5.1.4Compact Fluorescent Lamp (CFL)

Compact fluorescent lamps work in the same way as fluorescent lamps but take up much less space. An electrical charge is passed through mercury vapor between two electrodes, causing the vapor to emit invisible ultraviolet (UV) radiation.

A phosphor applied to the inside of the glass tube converts the UV radiation into visible light. Different phosphors give the light different color appearances. In comparison to incandescent light bulbs, CFLs have a longer rated life and use less electricity, also a quick, easy replacement for typical screw-base incandescent lamps.

A 13-watt compact fluorescent lamp (about 15 watts with electronic ballast) provides the same illumination as a 75-watt incandescent lamp and lasts up to 15,000 hours [19-20].

In JUST buildings, there are 2000 incandescent lamps. If they replaced by CFLs, then the saving power will be:

Saving power = saving power in each lamp x number of lamps = (75 - 15) x 2000 = 120,000 watt

As we suppose before, six hours daily operation in five days a week during 40 weeks yearly, then:

The total annual energy saving = 120,000 x 6 x 5 x 40 = 144,000,000 Wh.
The annual saving in cost = 144,000 KWh x 0.085 Fils / KWh = 12240 JD
Investment cost = a CFL cost x number lamps = 3 JD x 2000 = 6000 JD
Payback period (in years) = Investment cost / Annual energy saving cost = 6000 / 12240 = 0.49 year.

5.2 Mechanical system

5.2.1 Boilers

JUST facilities have four main boilers of type water-tube, in these boilers the water flows inside tubes surrounded by flue combustion gases. The density variation between cold feed water and the hot water mixture in the riser generally maintain the water flow. These four boilers are similar in specifications with a capacity of 65 million Btu/hr for each one. Just one boiler works in the time. The central heating network can be described as shown in Figure 10. The temperatures of water leaving the heat exchanger to the internal network measured in 13/3/2006, and they are shown in Table 7.

Table 7: Temperatures of water leaving heat exchanger

Pump station	Mechanical room	Temperature (° C)
P.S.1	Veterinary clinic	---
	Central kitchen	68
	Maintenance workshop	56
	Car maintenance	60
	Movement	62
	Civilian defense	58
	Store 1	70
	Store 2	65
	Needs	70
P.S.18	D3	54
	D5	44
	D7	56
	D9	48
	335	58
	341	78
	342	68
	344	58
P.S.16	D5	60
	B7	60
	B9	62
	B11	60
	B13	60

There are two alternative methods for the evaluation of boiler efficiency, direct method and indirect method. It is preferable to use the indirect method in measuring boiler efficiency while conducting the energy audit.
This method was defined by the American Society of Mechanical Engineers (ASME) in their Performance Test Code (PTC). The indirect method is also called the heat loss method, and it is based on accounting for all the heat losses of the boiler. The actual measurement method consists of subtracting from 100 percent the total percent stack (combustion), radiation, and convection losses. The resulting value is the boiler's fuel-to-water efficiency.
Radiation losses are the losses represent heat radiating from the boiler body, and can be calculated according to Stefan-Boltzmann law [21-23]:
$Q_R = \sigma \times \varepsilon \times A \times [(Ts)^4 - (Ta)^4]$
The boilers located in a room (7m x 2.5m x 3.35m) with the areas and temperatures shown in Table 8.

$Q_{Rad,\ total} = Q_{Front} + Q_{Back}\ Q_{Right}\ Q_{Left}\ Q_{Ceiling} = 310.26 + 1020.21 + 184.325 + 92.64 + 1744.42 = 3351.855$ W
And heat lost due to air flowing across the boiler called convection losses, where can also be calculated:
$Q_C = C \times A \times (Ts - Ta)^{1.25}$
$Q_{Conv,\ total} = Q_{Front} + Q_{Back}\ Q_{Right}\ Q_{Left}\ Q_{Ceiling} = 257.19 + 1015.44 + 109.87 + 46.2 + 2592.44 = 4021.14$ W

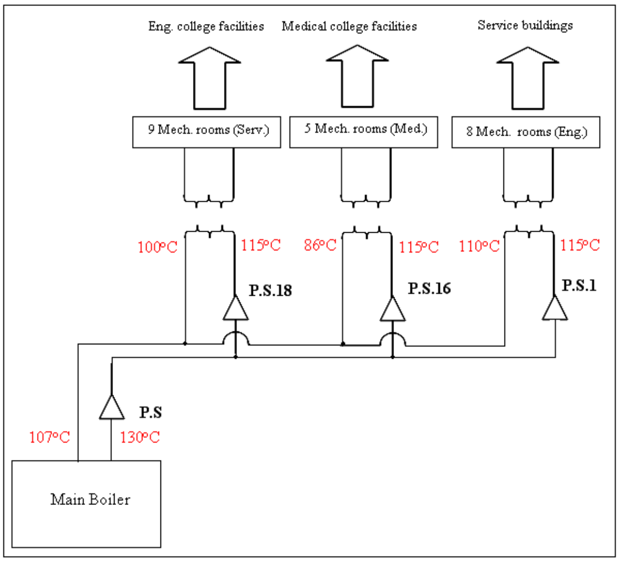

Fig.10. Central heating network.

About the combustion losses, we can say that the stack temperature is a measure of the heat carried away by dry flue gases and the moisture loss. It is a good indicator of boiler efficiency. The stack temperature is the temperature of the combustion gases (dry and water vapor) leaving the boiler and reflects the energy that did not transfer from the fuel to the steam or hot water. The lower the stack temperature, the more effective the heat exchanger design, and the higher the fuel-to-water efficiency. Some measurements were performed on a boiler number 3 to calculate its efficiency. By using Gas analyzer, the results shown in Table 8:

Table 8: Results from Gas analyzer experiment

Ambient temperature	17° C
Gas temperature	243° C
O_2 percentage	14.3%
CO_2 percentage	6.26%
Combustion efficiency	74.6%
Excess air percentage	205.5%

The combustion losses % = 100% - Combustion efficiency % = 100% - 74.6% = 25.4%
In order to have the percentage of radiation and convection losses we need to calculate the input power.

$Q_{input} = \dot{m} \times CV$

And from data sheet we have the consumption rate: 6.6 (gal / min.)
Consumption rate = 6.6 (gal / min.) x (1 min. / 60 sec.) x (3.7854 Liter / 1 gal) = 0.4164 (Liter / sec.) (6)
Remember that the diesel density is 0.84 (Kg / Liter), then:

Q_{input} = [0.4164 (Liter / sec.) x 0.84 (Kg / Liter)] x [43 x 10^6 (J / Kg)] = 15040368 (J / sec) or (W)
Percentage of radiation losses (%) = Q_R / Q_{input} = 0.022 %
Percentage of convection losses (%) = Q_C / Q_{input} = 0.027 %
Boiler efficiency (η) = 100% - (R_L% + C_L% + CO_L %)
Boiler efficiency (η) = 100% - (0.022 % + 0.027 % + 25.4%) = 74.55 %

This shows that the convection and radiation losses are low and the most losses were centered in combustion losses, so the access air should be calibrated.

The accepted values of the stack components can be described as the following:

1) CO2 level:
The higher this level, the more efficient is the combustion. The low limits acceptable for CO_2 level is 10% for gas fired boilers and 14% for oil fired boilers. If the CO_2 levels are lower than these limits, the combustion is most likely incomplete. The air-to-fuel ratio should be adjusted to provide more excess air.

2) CO level:
No CO should be present in the flue gas. Indeed, any presence of CO indicates that the combustion reaction is incomplete, thus there is not enough excess air. The presence of CO in the flue gas can be detected by the presence of smoke that leads to soot deposit in the boiler tubes and chambers.

3) O2 level:
The lower the O_2 level, the more efficient is the combustion. High level of O_2 is an indication of too much excess air. The high limit acceptable for O_2 level is 10%. When greater levels are found, the excess air should be reduced.

4) Minimum exit flue gas temperatures to avoid stack corrosion is 200°C [6].

In order to increase the boiler efficiency we can calibrate the excess air on its optimum value which is 10% in order to have nearly complete combustion, with the same stack temperature (243° C = 470° F), the new boiler efficiency is found to be η_{new} = 84.5 %. To calculate the saving in fuel use, ΔFU related to the change in boiler efficiency, the following equation can be used:

$$\Delta FU = \frac{\eta_{new} - \eta_{old}}{\eta_{new}} \times FU_{old}$$

And take care of that the annual consumption is one million liter of diesel.

$$\Delta FU = \frac{84.5\% - 74.55\%}{84.5\%} \times 1{,}000{,}000$$

ΔFU = 117751.5 Liter / year.

Annual saving cost = 117751.5 (Liter / year) x 0.315 (JD / Liter) = 37091.7 JD / year

Another way to increase the overall efficiency of the boiler is to use the economizer which transfers energy from stack flue gases to incoming feed-water. The stack temperature should not be lowered below the limits in order to avoid corrosion problems. Since the flow is water, then formula can be expressed the heat recovered will be [24]:

$Q_{rec.}$ = 500 x gpm x ΔT

Take care that the volume flow rate of water from the boiler is 1460 gpm. If the temperature of water rises just one Celsius degree (ΔT = 1.8 ° F), then:

$Q_{rec.}$ = 500 x 1460 x 1.8 = 1314000 (Btu / hr) = 1314000 (Btu / hr) ÷ 3413 = 385 (KJ / sec.), 3413 is a factor.

But the period of operation is nearly for five months (from Nov. to Mar.), and nearly in average four hours daily.

The annual recovery heat = $Q_{rec.}$ (KJ / sec.) x (5 months) x (30 days) x (4 hours) x (3600 sec) = 831.6 x 10^9 (J)
The annual recovery amount of diesel is:

$$\text{Diesel(Liter)} = \frac{\text{Heat energy (J)}}{\text{diesel density (Kg / Liter)} \times \text{diesel calorific value (J / Kg)}} \quad (9)$$

$$= \frac{831.6 \times 10^9 \text{ (J)}}{0.84 \text{ (Kg / Liter)} \times 43 \times 10^6 \text{ (J / Kg)}} =$$

23023 Liter

The annual cost saving = 23023 (Liter) x 0.315 (JD / Liter) = 7252 JD

The economizer will cost nearly 10,000 JD, so the payback period will be:

Payback period (in years) = 10,000 (JD) / 7252 (JD / year) = 1.379 year.

But the effective year here is the five months (operation period equals 150 days), which means that the payback period is:Payback period (in days) = 1.379 x 150 = 207 days. The results of changing ΔT from 1°C to 10°Care shown graphically in Figure 11.

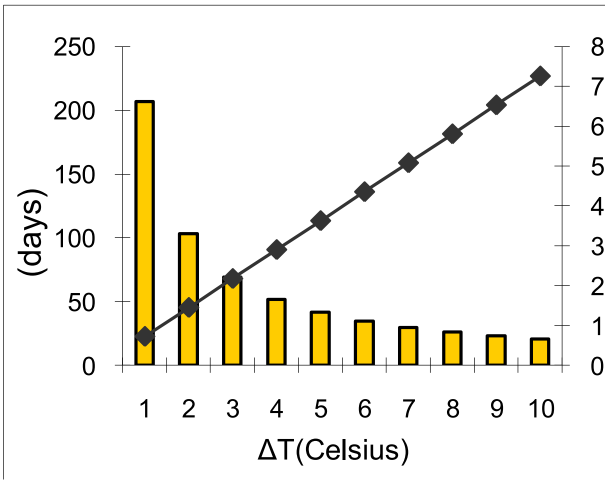

Fig11. Annual saving and payback period with changing in water temperature in boiler.

5.2.2 Chillers

The chiller is a refrigeration machine using mechanical energy input to drive a compressor to generate chilled water. The chiller efficiency is expressed as COP (Coefficient of Performance). The COP normally ranges from 2.8 to 4, and it can be calculated by measuring the power input to the compressor and fans and comparing with the chilled water entering and leaving water temperature [6]. The formula is:

COP = heat removed/ power input =

$$\frac{500 \times \text{gpm} \times (T_{in} - T_{out})}{\text{Input power} \times 3413}$$

The library chiller is the sample has taken to study, its specifications shown in Table 9.

To calculate the COP, measurements were taken as and given in Table 10. So, the input power is the total power consumed by the compressor and the four fans:Input power = (4 x 1.678) + 110.6 = 117.312 KW.

Table9: Specifications of library chiller

Brand name	York.
Model	YCAR 11 -50 C
Source	380 V / 50 Hz.
Number of fans condenser	4

Table10: Measurements were taken from library chiller

T_{in}	$14^oC = 57.2\ ^oF$
T_{out}	$9^oC = 48.2\ ^oF$
Compressor power	110.6 KW
Fan power	1678 W

And by referring to the chiller data sheet at measurable values, the gpm = 251.7

Substitute in equation (13), then:

$$\text{COP} = \frac{500 \times 251.7 \times (57.2 - 48.2)}{117.312 \times 3413} = 2.83$$

Raise the chilled water

A ways to increase the COP of the chiller is to raise the chilled water leaving temperature, if it is acceptable. The ambient and chilled water temperatures affect on COP, by using the data sheet of this chiller find the COP by using this formula [16]:

$$\text{COP} = \frac{Q_{ext.}}{P_{in}} = \frac{CAP(T.R.) \times 3.516(KW/T.R.)}{P_{compressor}(KW) + P_{fans}(KW)}$$

The calculated COP at three leaving chilled water temperatures, 4.4° C , 7.78° C and 8.89 ° C respectively.

Figure 12 shows the COP versus ambient temperature at different chilled water temperatures, these curves show that if the chilled water temperature increases, then the COP will increase.

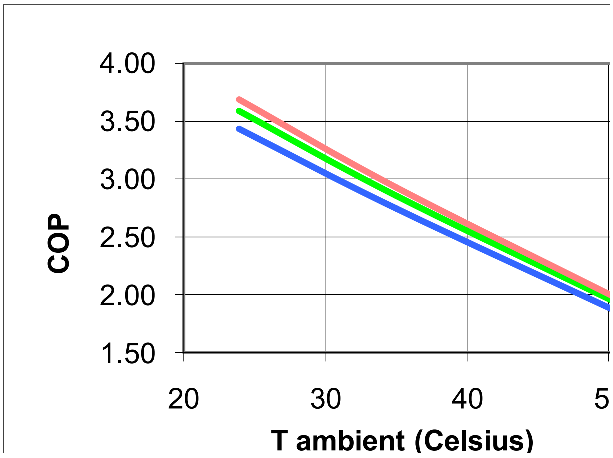

Fig.12. COP variation according to the ambient temperatures at different temperatures of chilled water.

For example at ambient temperature 35° C, the COP = 2.89 when the chilled water temperature is 8.89° C. The increasing of water temperature to 10 ° C makes COP = 2.93, which means increasing in the efficiency. The energy savings calculations from increasing the energy efficiency of cooling system can by estimated using the following equation [6]:

$$\Delta E_C = \dot{Q}_C \times N_{h.C} \times LF_C \times \left(\frac{1}{COP_B} - \frac{1}{COP_A}\right)$$

The rated capacity of this chiller took from data sheet is 93.8 (T.R), and in the (KW) unit:

$\dot{Q}_C$ = 93.8 x 3.516 = 329.8 (KW).

$N_{h.C}$ = 8 (hours) x 5 (days) x 4 (weeks) x 4 (summer months in a year) = 640 (hours / year).

LF_C = 1, it is assumed that the chiller sized correctly. Substitute in equation (15), then

$$\Delta E_C = 329.8 \times 640 \times 1 \times \left(\frac{1}{2.89} - \frac{1}{2.93}\right) = 997$$

(KWh / year)

Annual saving in cost = 997 (KWh) x 0.085 (JD / KWh) = 84.7 JD

Reduce the ambient temperature

Also, we can see from COP versus ambient temperature curves the direct effect of ambient on the COP of chillers, and this effect comprises all chillers' components which exposed to direct sun especially in the summer (June, July, August, and September) where the temperature under the sun can be reach to 40 °C or more.

The recommendation here is to reduce the ambient temperature in summer (35°C as an average) to the shade temperature (30°C in an average). But this is the static temperature of air in shade, so the air surrounding air temperature may be reduced just 1°C.

When the chilled water temperature is 8.89 °C, the COP at ambient temperature 35 °C = 2.89, but at 34 °C, it will be calculated as before using formula 14:

$$\text{COP}_{34^oC} = \frac{104 \times 3.516}{109.1 + 6.712} = 2.91$$

The saving in energy will be depends on equation (15):

$$\Delta E_C = 329.8 \times 640 \times 1 \times \left(\frac{1}{2.89} - \frac{1}{2.91}\right) = 502 \text{ (KWh / year)}$$

Annual saving in cost = 502 (KWh) x 0.085 (JD / KWh) = 42.7 JD

The investment cost will be nearly 400JD by constructing a simple drapery cover.

Payback period (in years) = 400 (JD) / 42.7 (JD / year) = 9.4 year.

Replace the pumps

There are two parallel pumps in the chiller system, and they work at the same time. The two pumps are similar with the properties as shown in Table 11 and 12. From the first view we recommend to operate just one pump and leave the other standby. Measurements were taken, and the results shown in Table 13: When we operate the second pump during the first one is working, we measured 12.5 (KW) consumed by the first pump. This means that when the two pumps operating, the power consumption is:

Total power = 12.5 x 2 = 25 (KW).

But when we apply this recommendation (turn off one pump), the control system gave alarm say there is a low suction. So, the solution is to replace one pump by another has a suitable suction and let one of the old pumps as a standby pump. The specifications of the new pump shown in Table 11. To calculate the power consumption of this pump we should determine the operating point on characteristic curve. At first remember that the pumps at measured values give 251.7 gpm, which equals 57.2 m^3/h.

Table 11: Specifications of the new pump

Brand name	LOWARA, SFC series.
Maximum delivery	180 m^3/h.
Maximum operating pressure	4.5 bar.
Motor power	18.5 KW
Speed	2940 rpm.

Table 12: Specifications of chiller pumps

Type	Centrifugal
Volume flow rate	204 (gpm)
Speed	1455 rpm
Rated voltage	380 V
Rated current	30 A
Suction pressure	2 bar
Discharge pressure	4.1 bar

Table13: Measurements on chiller pumps

Power	14.68 (KW)
Voltage	379 V
Current	27.65 A
PF	0.81

Referring to the operating characteristic curve for this pump at pressure 4.1 bars and 57.2 m^3/h, then the power consumption will be 11.8 KW [25].

Saving power = Old pumps power – The new pump power
= 25 KW – 11.8 KW = 13.2 KW

As we suppose before, the chiller operates 640 (hours / year) So,

The total annual energy saving = 13.2 KW x 640 hours = 8448 KWh.

The annual saving in cost = 8448 KWh x 0.085 Fils / KWh = 718 JD

Investment cost = 1300 JD

Payback period (in years) = Investment cost / Annual energy saving cost = 1300 / 718 = 1.8 year.

6. Conclusion

there is a good opportunities to save energy in JUST facilities, starting from the electrical distribution system where the Power World Simulator program used, it was found that all wires are normally loaded and transformers losses may be reduced by separating the primary when there were no loads on secondary.

Also it can see from our measurements that the PF is in good range in both summer and winter. The power quality is accepted since the harmonic distortions locate in the allowable range according to the IEEE 519-1992 establish recommended guidelines.

In setting the screens, the optimum case is to set the screen on turn off mode between 15 to 30 minutes, and the screens should be turned off from the power button at the end of day and in the weekends. Also all scenarios to replacement the CRT screens with others of LCDs have a long payback period, which means it is not economical, so the suggestion is replacing any CRT will be defected by another of LCD, and if JUST needed any new screens then LCDs must be purchased.

Replacing magnetic ballast with electronic ballast is profitable way to save energy with acceptable payback period. The recommendation about the light intensity levels in JUST building facilities is to make a survey on all fixture covers to clean or replace them. Also we recommend installing occupancy sensors in lecture halls since the study showed good opportunity to save energy with accepted payback period. And replacing incandescent light bulbs with CFLs is so benefit.

The efficiency of all boilers in JUST facilities should be calculated to decide if there is any way to increase boiler efficiency or not, and access air regulation should be done using Gas analyzer. It found by this study that economizers are so effective to install on main boilers.

In chillers, COP should be calculated and then try to increase the chilled water temperature in order to increase the chiller efficiency. And decreasing the ambient temperature by putting a simple cover on the chiller was a good idea to increase the COP and then save in the energy consumption. In sampled chiller, replacement one of the two parallel pumps with another one showed a good result in energy saving with accepted payback period, so we recommend to apply this suggestion.

Table 14 shows a summary of all suggestions and their economic calculations.

Finally there are many recommendations appear after this study, and can be summarized by:

1- Establish an energy auditing team includes members of different specializations, electrical, mechanical and architectural.
2- Culture students and other employees in JUST facilities about energy auditing.
3- Make a detailed energy auditing in all JUST facilities.
4- Purchase some computer programs needed during work like full version of Power World Simulator program.

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Table14: Summary of potential saving

Area	Annual saving (Quantity / year)	Saving in cost (JD / year)	Investment (JD)	Payback period (Year)
Profitable suggestions				
Disconnect the primary of Lake transformer	1944 KWh	165.24	0	Immediate
Setting the screens on Turn-Off mode	7343 KWh	624.2	0	Immediate
Turn-Off the screens from the power button	121428 KWh	10321.4	0	Immediate
Install electronic ballasts	540 MWh	45900	210000	4.67
Install occupancy sensors	38102 KWh	3238.7	1960	0.6
Replace Incandescent lamps by CFLs	144 MWh	12240	6000	0.49
Increase the boiler efficiency by tuning excess air	117752 Liter	37092	0	Immediate
Install economizer on the boiler, just 1^o C	23023 Liter	7252	10000	1.379
Raise the chilled water 1^o C	997 KWh	84.7	0	Immediate
Replace the chiller pump	8448 KWh	718	1300	0.568
Un-profitable suggestions				
Replace all CRT by 17" LCD	224283 KWh	19064	480530	25.2
Replace all CRT by 15" LCD	277627 KWh	23598.3	363330	15.4
Replace CRT by LCD of same size	242079 KWh	20576.7	441430	21.45
Covering the chiller	502 KWh	42.7	400	9.4