ENERGY MANAGEMENT OF THE INSTITUTE OF ENVIRONMENTAL SCIENCES & ENGINEERING (IESE) - SCEE - NUST

by

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This thesis is dedicated to my Mom and Wife

For their endless affection, support and encouragement

List of Abbreviation

kW	Kilo Watt
kWh	Kilo Watt Hour
MW	Mega Watt
RFO	Residual Fuel Oil
HSD	High Speed Diesel
LCD	Liquid Crystal Display
LED	Light Emitting Diode
CRT	Cathode Ray Tube
CFL	Compact Fluorescent Light
ENERCON	National Energy Conservation Center
UPS	Uninterrupted Power Supply
PMO	Project Management Office
HVAC	Heating, Ventilation and Air-Conditioning
GHG	Green House Gases
tCO_2	Tons of Carbon Dioxide
ECOs	Energy Conservation Opportunities
EA	Energy Audit
EAT	Energy Audit Team
EMS	Energy Management System
TL	Tube Light
CCAR	California Climate Action Registry
EE	Energy Efficiency
RE	Renewable Energy

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ABSTRACT

Modern energy services are a powerful engine of economic and social development. On one side if it is the obligation of government to supply energy to every individual; at the same time judicial use of energy is the responsibility of every consumer. Pakistan where major proportion of power generation is dependent on fossil based thermal resources is facing a shortfall of more than 5,500 MW. Universities, as research and education centers of the world, should set positive social, environmental and economic examples for their societies to follow. This study is a fair attempt to identify energy saving potential at National University of Science & Technology (NUST) Pakistan. IESE building was considered as a model for investigating the available potential for saving energy. The areas considered were lighting, building envelops (only Windows) and CRT monitors. Tri-phosphor T5 lights were found the most suitable option to replace existing lights with saving potential of 19 MWh annually. Existing windows once replaced with double glazed uPVC windows would indirectly save 33 MWh annually whereas replacing 34 number of CRT type computer monitors with LCDs can save 11 MW. Thus a collective saving of about 64 MWh or Rs. 1.3 million and net GHG reduction of 26.5 tCO_2 annually, with total investment of Rs. 8.1 million and payback period of 6.3 years.

INTRODUCTION

1.1 BACKGROUND

Energy is the key component of economic development and prosperity of society. It also provides a thrust for keeping sustainability in economic growth. Pakistan being developing country has been facing an extraordinary energy crisis for more than a decade as the gap between demand and supply is getting wider. Presently this gap has touched a figure of 5,500 MW resulting into a load-management of 16-20 hrs/ day in rural and 8-12 hours/ day in urban areas. Most of the electricity production in the country depends on expensive imported oil i.e., about 40 % power generation is from expensive thermal fuel sources either Residual Fuel Oil (RFO) or High Speed Diesel (HSD). While remaining 60 % is produced from natural gas & hydel sources in almost equal ratio with small share of nuclear. Weak infrastructure, poor human resource management, huge theft rate and a highly inefficient transmission & distribution system are additional causes of energy losses and high rates. Based on fuel mix including transmission and distribution charges, average cost of power generated ranges Rs. 16-18 per unit. While the transmission and distribution losses further add Rs. 2-3 Per unit; making it Rs. 20-22 per unit. Which is supplied to end users at different rates depending on consumer category i.e., at subsidized rates to domestic, while on actual rates to commercial and on higher rates to industrial consumers. Domestic sector is in fact cross subsidized through industrial sector consumers. But now Government has almost withdrawn this subsidy from domestic tariff (except life line consumers, i.e., up to 200 units).

The primary energy sources such as crude oil, natural gas and other conventional fuels are limited. These are formed by geological processes through solar energy accumulation into the earth over millions of years. Depleting natural resources are one of the major causes for the increasing gap between demand and supply of energy as well as its unit cost. The technology for utilizing non-conventional energy resources is still in the infancy stage. To handle this problem, a combination of supply side management (enhancing generation capacity intelligently) with demand side management (i.e., energy management on consumption side through energy conservation programs) is a best possible solution. But there is a clear financial as well environmental edge of saving one unit in comparison to its production. According to Environment Australia, One unit saved at the shop-floor saves 4.2 units at power house. Knowing the importance of energy conservation both developed and developing countries have to consider new measures to take maximum advantage of it. Energy conservation can be defined as an approach applied to energy consumption without compromising quality of life. Energy conservation will not only save huge foreign investment but will help allot in boosting the economy of the nations. (A. Al-Mofleh et al. 2009, ECC Japan 1996).

Government of Pakistan in its Power Policy (2013) highlighted not only current challenges of power sector but has also termed the goals very ambitious ones. In fact in such a situation we need to have supply as well as demand side management simultaneously. Meaning that since the gap is very high and we have to cater for future demand as well, thus on one side we need to increase our power supplies and on the other hand, we have to go for energy efficiency and conservation so that the existing resources can be utilized optimally. This can be carried out step wise in three strategic levels whereas steps to be taken are categorized accordingly. Immediate possible remedies through short term planning (by energy conservation & efficiency, solar photovoltaic, controlling theft and losses), existing gap through medium term power projects (this includes small hydel plants, alternate energy projects, coal and nuclear based projects), while future demand is met through long term planning (it includes mainly larger hydel and coal fired thermal power projects). Thus energy conservation comes under short term planning that is what can be contributed on immediate basis. And this is in fact the most feasible part of the solution in all aspects whether it is time, cost or its adverse effect on our environment. Now, if we look around us, one can simply observe how callously we are wasting energy in our daily usage at houses, offices or elsewhere.

1.2 WHAT IS ENERGY MANAGEMENT?

As mentioned earlier Pakistan's poor economy is dependent on imported fuel and thus large import bill i.e., equivalent to 50% of export earning, is creating serious economic crisis. It is the responsibility of every individual to play its role in reducing unnecessary consumption and increase energy efficiency, thus help the country not only to overcome energy crisis but also contribute to reduce environmental pollution caused by power generation through conventional fuels.

While keeping educational institutions as exception, they should not only play their role by managing their own energy consumption but to educate and motivate others for it.

The term “Energy management” has different meaning to different people but a simple one is narrated here as: *“The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions”* (Cape Hart, Turner and Kennedy, 1997)

The purpose of Energy Management is to attain and sustain best possible source of energy and its consumption throughout the entity and:

- To minimize energy cost/ waste with no effect on quality of services
- To minimize environmental effects

The primary connection between energy conservation programs and environmental initiatives is the benefit of reduction in pollution caused by energy generation. When electricity is generated, three principle pollutants are emitted from the power plant: sulfur dioxide, nitrogen oxides, and carbon dioxide. In the US, electricity generation accounts for 35% of all US emissions of carbon dioxide, 38% of nitrogen oxides and 75% of all sulfur dioxide. If less electrical energy is used, fewer emissions are produced.

Energy management starts with an energy audit. Energy audit is basically nothing but a systematic approach for measuring energy consumption in a way to balance input with outputs (uses) and indentify all energy consumptions routes in a facility thus helps in finding out losses and identifies/ suggest improvements that leads to a comprehensive energy management program.

Energy Audit is defined by Pakistan Energy Efficiency & Conservations Act (2013) as “*an examination of any energy consuming project about the way the energy is generated, transmitted, distributed or used there and identification of areas where* *energy waste can occur for improving energy efficiency and where scope for improving energy use efficiency may be possible*".

1.3 THE PRESENT STUDY

Present study is a small initiative not only to help the Govt. to achieve its targets to overcome energy crisis in the country but also to reduce campus own energy consumption as well as reduction in carbon foot prints. Institute of Environmental Sciences and Engineering (IESE) of National University of Science and Technology, H-12 Campus, Islamabad was selected as focus of this study.

To bring this important issue in the notice of the management so that in future, research work in this area should be given prime importance and funds should be allocated for the same. An effort was made to identify areas for potential savings in the energy consumption. Economical recommendations and simple but proven approaches were suggested, to show the management how to take action to tackle energy issues and adopt best practices in future planning. This will help to bring a change in mindset of students and employees and will convey the message to the society for a change in behavior regarding energy use. It will also improve the environment while enjoying significant financial benefits.

The data collected was assessed with the combination of two approaches i.e., on one side Microsoft Excel based self developed model was designed as per nature of the project, scope of the study and limitation of the data available. And where appropriate, an international software tool "RETScreen" was used to analyze the energy performance. RETScreen is a clean energy software package developed by the Government of

Canada that includes particular energy management (Window’s based) software “RETScreen Plus” that helps in finding out a facility ongoing energy performance.

At the same time the RETScreen integrates multiple databases to help out user. This includes a global database of climatic conditions obtained from near 7000 ground stations and NASA’s satellite data, product database, benchmark database and hydrology database along with clean energy policy legal toolkits.

1.4 OBJECTIVES

The purpose of this study was to determine energy saving potential at IESE. Specific objectives were to:

- Reduce consumption of energy with consequent financial benefits.
- Raise awareness of environmental due diligence through energy saving.

Goal of the study was identification of energy wastages & inefficiencies by measuring the actual energy consumption and comparing with minimum energy requirement. And to find out technically and economically feasible options to take energy consumption to lower level without compromising services.

1.5 ORGANIZATION OF THIS THESIS

First chapter of this thesis is the introduction of the topic. It includes in general about energy, current situation of energy in Pakistan, basic definitions of energy management, energy audit and about present study.

Chapter 2 is literature review that covers updated status of Pakistan’s current energy situation and similar work carried by other universities.

Chapter 3 is about the experimental work & the data collected generated during the research work and the methodology.

Chapter 4 is about analysis and results. It describes the quantum of monetary and environmental savings that can be achieved through effective energy management.

Whereas Chapter 5 is the last one that strongly recommends for immediate implementation of energy management program throughout the campus and suggest for devising Campus Sustainability Policy.

1.6 METHODOLOGY

A good energy management plan starts with a comprehensive energy audit. The purpose of energy audit it is to estimate energy efficiency of entire facility. Right from the entry point of the energy into a facility; the energy auditor starts at the energy meters, tracing all sources of incoming energy, assesses their efficiency and point out energy reduction and financial benefits without compromising recommended comfort level. In this study the whole process was done in three phases as explained below:

PHASE – I: Studied all Energy Systems and Baseline Data Collection:

Walk through visit of the institute's building to observe and find out potential target areas based on general experience and common sense. Once the potential areas were identified the next step was to collect existing data i.e., necessary data for identifying energy conservation opportunities. This included types of energy, its sources, quantities, consumption and load of the building, types and quantities of appliances etc.

Also considering building energy codes of Pakistan, observed type of building construction, its design, features, location of windows and doors and type of material used, level of insulations, temperature setting during occupancy etc.

PHASE – II Energy Saving Opportunities:

Studied the applicable components like building envelop, heating/ cooling (HVAC), lighting, fans and other energy consuming appliances from energy efficiency/ conservation point of view. Identified energy saving opportunities on technical grounds; suggested various workable options for retrofitting measures (both in terms of equipment and techniques). RETScreen software was used to analyze the data collected.

PHASE – III Results and Recommendations:

A detailed analysis of the building was made with determination of retrofit measures; both in technical and monetary terms with payback periods. Based on the results most cost effective, easy and environment friendly solutions were recommended to reduce the building energy consumption.

1.7 EXPECTED OUTCOME

- Reduced Energy Bills
- Increased Competitiveness
- Improved Quality
- Reduced GHG and other Emissions

1.8 SCOPE AND LIMITATION OF THE STUDY

This research was limited to IESE Building at National University of Science & Technology, Islamabad in the following areas:

- Lighting & Fans
- Space Heating & Cooling
- Computer monitors

LITERATURE REVIEW

2.1 NATIONAL POWER POLICY OF PAKISTAN – 2013

Ministry of Water & Power (Govt. of Pakistan) has highlighted the current challenges being faced by power sector in the country are huge supply-demand gap of up to 5500 MW, high generation cost, transmission and distribution system losses up to 25%, theft, subsidies and circular debt.

To overcome these challenges government has a very clear vision and has set nine ambitious goals. Knowing its importance "demand side management" has been placed second most important goal on priority basis. It aims to develop sense of responsibility & a culture of energy conservation. The policy also sets some targets with clear time lines e.g. to cut the current supply-demand gap to zero, unit cost to 10c from existing 12c, decrease losses to 16% and increase collection to 95% by 2017.

Targeting three important areas including product labeling, time wise power usage and improvement in energy efficiency, Govt. will pass legislation for energy conservation. This will help to strategize standardization and energy conservation by encouraging local industry to produce energy efficient products. To make it possible local manufacturers will be granting an exception for three years and import of inefficient products will be banned. Also it aims to prepare and implement Green energy building codes throughout the country and to introduce energy services companies in the private sector to conduct energy audits and improve energy efficiency in residential, commercial and industrial sectors.

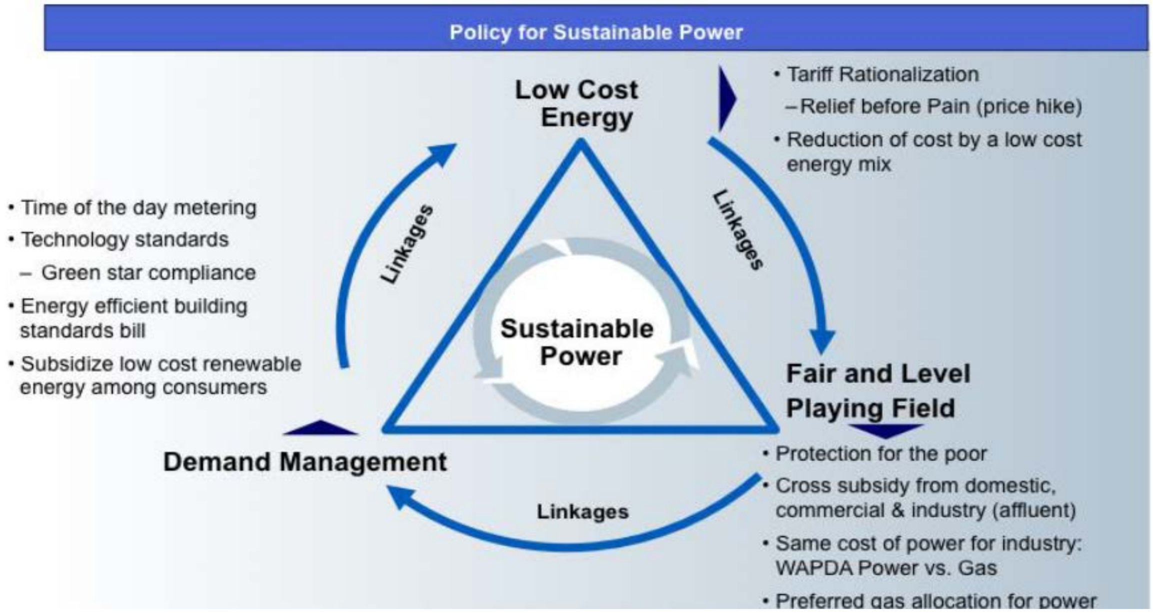


Figure 2-1: The three pillars of Efficiency (National Power Policy – 2013)

The government may also impose timing restrictions for evening commercial activities and introduce 'time of use' metering to discourage utilization during the peak hours by charging different rates for on- and off-peak timings.

2.2 NEED FOR ENERGY MANAGEMENT

Energy conservation programs that burst forcefully on the scene with the oil crises of 1970s, only to be significantly scaled down after 1985 collapse of oil prices, are again enjoying a renaissance. The renaissance is driven partly by environmental concerns, but also because new energy efficiency technologies developed in the 1990s have enabled the significant cost savings (D. Skoric 2000, Haugland, 1996).

Despite the fact that new energy efficient technologies were not always supported, the energy conservation programs have been very successful. As a result of such programs, in United States in 2000 total primary energy consumption per capita was almost same as that was in 1973. But gross domestic product per capita increased by 74% in these 27 years. This is really a big achievement for a nation to reduce its energy consumption and to save at least 430 billion dollars only in the year 2000 that would have been otherwise spent in purchasing more energy. (D. Skoric 2000, Nadel and Geller, 2001).

Turner and Capehart (2001) concluded that it has been proved again and again, that energy management is not only cost effective but also vital to national security, environmental friendly and economic productivity. Although energy efficiency in United States has improved allot as it was 25 years ago, yet there is huge potential for more economical energy savings (D. Skoric 2000, Nadel and Geller, 2001).

All energy conservation actions have been considered as always beneficial option, it benefit both the consumer and society with a cost effective energy savings. The guaranteed benefit is drawn based on many studies that shown at least 20% of energy savings in a cost effective manner (D. Skoric 2000, Haugland, 1996).

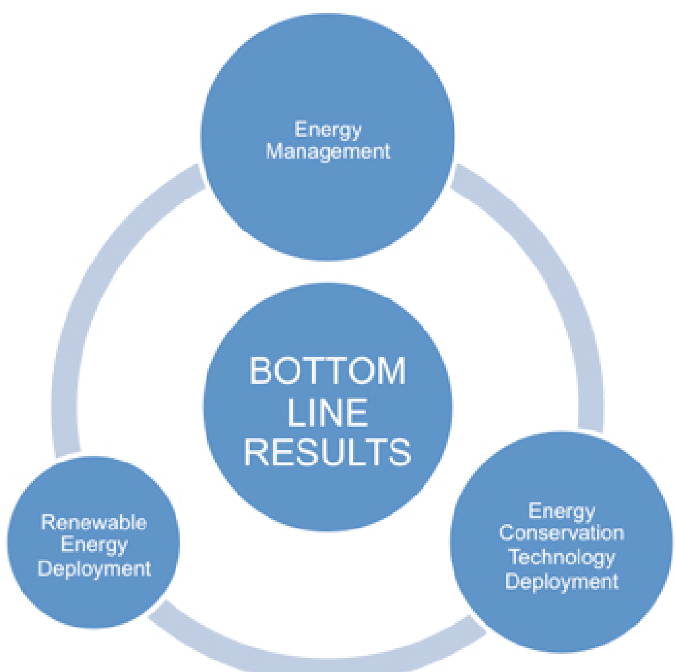


Figure 2-2: Energy Management (Source: http://www.bisbee-associates.com/)

According to an estimate by U.S. Department of Energy, better implementation of energy efficiency throughout the country could cut national energy consumption by 10% or greater in 2010 and approximately 20% in 2020, with net economic benefits for consumers and businesses (D. Skoric 2000, Nadel and Geller, 2001).

During 2009-2010 Pakistan's economy suffered allot due to issues and development in energy sector. The sharp rise in the international oil prices in 2009 put huge upward pressure on costing in the power generation and transport sector and indirectly resulted in gas and power supply shortages. The energy issues had an estimated collective effect of about two per cent of GDP on the economy just during 2009-10 (Asif, 2010).

Energy crisis in Pakistan needs immediate actions to improve energy efficiency in all sectors particularly residential, commercial and industrial sector where lot of potential exists for improvement. Energy Efficiency programs must be linked with awareness amongst the end user. However, attempts in this respect have demonstrated the need for a more vigorous, systematic and long term multi-stakeholder approach (Asif 2010).

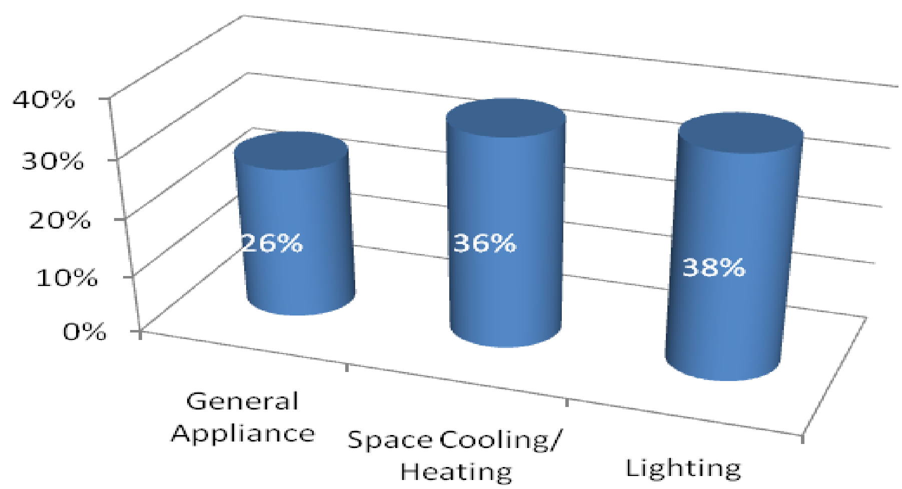


Figure 2-3: Power Consumption Pattern of Commercial Sector in Pakistan (PEYB 2009)

Out of total 74,348 GWh electricity consumption in Pakistan in the year 2009-10 alone domestic sector consumed 46 %, industrial sector 26%, agriculture sector 13% and commercial sector consumed 7.5%. Through product labeling standards considerable amount of electricity can be saved with highly efficient equipment and machinery in industrial sector, through efficient tube-wells and preferably with gradual introduction of solar photovoltaic energy & with energy efficient lighting, fans and other domestic gadgets. (Pakistan Energy Year Book, 2010).

Demand side management is often a very cost effective option as the investment is relatively low which translates in a relatively high return on capital at the house hold or enterprise levels. However despite the relatively low investment in these technologies, financial mechanisms and communication strategies are necessary to promote the new equipment and policies. As far as electricity is concerned, the major challenge remains access of rural population which are still far from the grid and do not have a sufficient purchasing power to implement decentralized energy options particularly from Renewable Energy (Smail, 2012).

With the help of concept and frame analysis of Energy Management System, a method can be outlined for how to launch and run Energy Management System. In this method first step is to identify all energy consuming areas, then to evaluate and highlight the area to be treated with priority, then to chart out investment grade project for management and finally develop the system document. In the system document all the energy consuming areas should be measurable. By noting and evaluating each energy consuming area of the whole process, run Energy Management System to achieve the goal (Fu et al. 2011).

Figure 2-4: Energy Management Cycle (Source: http://frontlineenergy.ie/)

Energy Audit is a process to identify energy conservation potential without compromising comfort level of the user, and optimize energy consumption of existing buildings (Sterling, et al. 1994, Rahman 2009, Ali 2012). Energy Audit is a cyclic process, it analyses changes in energy usage of already installed equipment and scope for new energy efficient replacements. American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHARE), has set energy audit standards and methodology for conducting energy audit explaining how it is effective in reducing energy consumption of a facility (ASHRAE, ANSI/ASHRAE Standard 100-2006, Ali, 2012).

The Energy Audit (EA) process starts with forming an appropriate Energy Audit Team (EAT) that clearly specifies the audit scope. It is crucial for the team to look at the available resources to frame the time and budget for the audit and to gather all necessary building information before starting the audit (Ali, 2012).

Depending on the time and budget limitations the complexity of the building energy audit can be classified in three different levels. As defined by ASHRAE (100-2006) standard, the three levels of energy audits are as:

Level 1: “walk-through audit” or “preliminary audit;

Level 2: “energy survey and analysis”; and

Level 3: “detailed analysis of capital intensive modifications”.

A list of energy conservation opportunities should come out in the result of conducting any level of energy audits (Ali, 2012).

2.3 ENERGY MANAGEMENT IN UNIVERSITIES

Everybody, on all levels starting from government or society as whole down to a single individual can benefit from conserving energy. Somewhere in the middle of this pyramid of users we find the user of interest; “Universities” that represent microcosms of society and as such consume vast amounts of resources (UBC, 2004).

The reason for this particular interest is that universities, being hub of research and education, have unlimited achievements. With medical developments they have saved thousands of lives, improved quality of life and contributed in establishment of a healthy society. At the same time it is also the responsibility of universities and should take remedial initiatives against the adverse effects of these developments. The most important one is the severe and direct impact on our global environment. Thus universities have to set positive examples in social, environmental, and economic segments to be followed by the societies (UBC, 2003b).

As large commercial institutions filled with computer labs, libraries, offices and research labs, universities are major consumers of energy. However, universities have the potential to engender individuals who could be passionate about sustainability issues, through both formal and informal educational initiatives. In 2011, 284 campus energy conservation initiatives were announced in the online bulletin for the Association for the Advancement of Sustainability in Higher Education (AASHE). This was an increase of 28% against 2010, which had posted 129 initiatives. The initiatives of 2011 included 97 solar installations, 34 energy overhauls, 21 wind initiatives, 19 renewable energy research centers, 17 campus energy competitions, 13 campus monitoring efforts, 12 renewable energy plans, and 9 geothermal projects (AASHE, 2011). The Massachusetts Institute of Technology saved 13 million kilowatt-hours after 1 year of initiating its Efficiency Forward Program, a campus-wide energy conservation and efficiency initiative and 24 million kilowatt-hours after 2 years (AASHE, 2011).

In China 200 plus educational institutions had enjoyed the benefits of energy conservation program by the year 2011. The overall per student water consumption in comparison to the year 2010 for the selective 25 institutes was reduced by 6.5% & in the same way power consumption per unit area was reduced by 23.3%.Thus proving that there is a tremendous potential available for energy saving in educational institutes in China (Xuan Zhou et al., 2013).

The case for energy management and conservation is especially strong in recent years for public universities. State and federal budgets are running at a deficit and so the state universities are faced with choice either to increase the tuitions and fees or make cuts and eventually lower the quality of service. While struggling to make more out of less the question is, will the universities rely mainly on multiple tuition increases or will they look for creative ways to provide the same or better services at lower cost? Energy management is one such area that produces dramatic savings without decreasing user comfort (D. Skoric 2000, Zeloznicki, 2000).

The benefits of energy conservation in universities not only includes saving of state tax money, positive cash flow, healthier indoor air quality, better lighting, more comfortable working and learning conditions, but also reduces various negative environmental and social impacts. These impacts include air pollution, acid rain and global warming, oil spills and water pollution, loss of wilderness areas, construction of new power plants, foreign energy dependence and the risk of international conflict over energy supplies. (Green College, 2002).

Ever since the sharp rise in the cost of energy over the past few years (2005 in particular), the University of Georgia (UGA), Athens, Georgia, USA has been in search of ways to curb energy consumption in an effort to reduce this drain on the annual budget. To determine the most efficient and most cost effective measures that can be taken. UGA is implementing a program to conduct energy audits on buildings around campus (Drifmier Energy Audit Report UGA–2006).

The American Association for Sustainability in Higher Education reports some 30 institutions who have formalized their sustainability programs by initiating a permanent office of sustainability or its equivalent.

Harvard University has initiated a program for campus sustainability being the largest in USA. It is termed as The Harvard Green Campus Initiative (HGCI) with 20 full time professional staff and 40 student interns. Among many of their services and achievements includes a revolving $12 million Green Campus Loan Fund. A considerable energy saving was achieved through effective behavioral change programs.

University of California also has taken multiple steps on campus sustainability that could be termed one of the biggest initiatives taken by any university system. The president of the university has signed the Presidents Climate Commitment and a University Policy on Sustainable Practices. A steering committee look after system wide policy for sustainability, whereas its working groups are established in the areas of sustainable transportation, green building renovations, waste reduction, recycling sustainable operations, sustainable food systems, and climate change. In addition to sustainability staff each campus has an advisory committee. Whereas four campuses have joined the California Climate Action Registry (CCAR) and are cataloging greenhouse gas emissions; other campuses are exploring joining the CCAR.

Similarly Arizona State University has completed a carbon emissions inventory. President Crow is a co-founder of the President's climate commitment. It will be used to develop a strategic plan to reach carbon neutral status. Based on its superior energy efficiency the new cogeneration plant on Arizona State University received an award from the EPA. Four megawatt solar system has already been developed whereas another two solar arrays are currently under construction. Arizona State has developed then nation's first School of Sustainability (IUB, 2008).

Due to huge dependence on electricity our demand is increasing day by day, it is important that it should be used efficiently. In order to manage the power consumption, it is important to measure and monitor the electrical systems. Monitoring can provide advanced visualization and data analysis tools which can help us to achieve energy savings and peak power optimization. In this work, we present a power monitoring system developed for the campus buildings at the University of León (ULE) in Spain. This system is based on a three-layer structure. In the server layer, data are acquired from meters installed in the campus buildings. In the middle layer, data are stored and processed. In the client layer, monitoring interfaces, accessible remotely through the Internet, provide both traditional and advanced monitoring tools, based on statistical and data mining techniques. These techniques exploit data in order to find electrical patterns, detect faults and deviations, predict future power consumption, optimize peak power, etc. The data acquired by the monitoring system during 2010 are analyzed. The results from the visualization and data analysis tools, implemented in the monitoring system led to economic savings of around 15% (Manuel Domínguez et al., 2012).

Experimental, numerical and simulation studies were performed to evaluate the energy efficiency performance, develop energy conservation measures (ECMs), and conduct overall energy analysis of a medium-size data center at the campus of the University of Maryland, College Park. Based on the analysis, the PUE (power usage effectiveness) of the data center was found to be 2.73, suggesting ample opportunity for energy saving measures. The IT cooling and electrical loads consume 36.6%, 32.9% and 21.7% of the total data center energy consumption, respectively. Four ECMs are suggested to reduce energy consumption by optimizing the thermo-fluid flow in the data center: (1) eliminate unnecessary CRACs (computer room air conditioning units); (2) increase the return air temperature at the CRACs; (3) add cold aisle containment; (4) implement fresh air cooling. In addition, a transient analysis was performed under a total power failure scenario of all cooling systems, as well as failure of individual CRACs as a separate analysis, to predict the corresponding temperature increase with time in the data center and electronics. (Kyosung et al., 2014).

Maged et al., (2014) analyzed a competition between 6500 students living in 20 residences across six university campuses in British Columbia to reduce energy consumption from a baseline level. Using a mixed methods approach, we sought to determine the overall effectiveness of the competition in reducing short and medium-term energy reduction and sought to uncover the motives for participation. We found that students tended to join the competition because multiple pathways of participation were available to them. Participants were motivated by the actions and stories of their friends and did not pay attention to the actions or competition scores of strangers. Our findings suggest that employing entertainment engagement that enables multiple pathways for participation with mechanisms for knowing the behavior of peers may be effective in shifting long-term energy consumption.

Eight different types of higher education institutions of China's were examined in Changchun, Jilin. The results revealed that most of the initiatives adopted by those institutions for conservation of electricity were non-technical. These included usage limitations and prolonged winter breaks with little bit technical initiatives. Due to financial constraints the higher education institutions are less interested in conserving energy. Overall hindrances in energy conservation are also known, that includes less support from government, lack of own investment by that institute, quality issues of energy consuming products and misunderstandings among student welfare and energy conservation (Kevin, 2012).

Table 2-1: Comparative Table of others universities Energy Audit Outcome

S#	University	Location	Areas Explored for Energy Audit	Action Taken	Benefits	Payback (Years)	Reference
1.	University of King's College	Coburg Road, Halifax, NS, Canada	Computers (57 Nos.)	Reduced brightness, sleep mode set for 10 min., turned off when not in use	2336 - 2448 kWh of energy savings, or $247 – 259, over the course of two terms	Immedia te	A Study of the School of Journalism Computer Labs ENVS/SUST 3502: Campus as a Living Lab. Dr. Tarah Wright (Apr13)
2.	Northeastern Illinois University	Chicago	Lighting, HVAC system up gradation, Pumps, Control systems up gradation, Renewable energy initiatives, Water efficiency up gradation, New Heating Boilers etc	Up-gradation/ addition	Energy savings 3,916,780 KWh or $ 478,292	15.6	Energy Performance Contracting Project, Energy Audit Report 2010
3.	Mechanical Engineering Department (MED) in the College of Technological Studies (CTS)	Kuwait	Complete Energy Audit	Overall Energy Conservation Opportunities (ECOs) - Both non-retrofitting & retrofitting	6.5% saving for non retrofitting ECOs & 49.3% for retrofitting ECOs (Total 52%)	0.5	Ali Alajmi (2012)

Table 2-1: Continued….

4.	National Autonomous University of Mexico (UNAM).	Mexico	Lighting, Refrigeration and water heating	Up gradation to T-5 and LED, hybrid system (solar - electric - LPG) for water heating	7.5 % saving in electricity and 11.3 % in CO_2 emission	Annually	Azucena Escobedo 2014
5.	University of Malaya	Kuala Lumpur, Malaysia	Lighting	Retrofitting/ replacement by T5	40% savings	1.95 Years	T.M.I. Mahlia et. Al 2011
6.	Technical University of Catalonia (UPC)	Barcelona, Spain	space heating	management measures	44.5 kWh/m^2 i.e. 40 %	1 year	E´. Mata 2009
7.	Saga University	southern island of Japan	greening for improving the outdoor thermal environment	Quantity of trees was increased by 20%.	air temperature decrease with an average and maximum of 0.24C and 2.29 C, respectively	5-8 Years	Manat Srivanit 2013

(1) – Heating, Ventilation and Air Conditioning

(2) *– Domestic Hot Water*

METHODOLOGY

3.1 SELECTION OF BUILDING

The Institute of Environmental Sciences and Engineering (IESE) was selected for this study since the researcher as well as the supervisor both belonged to the same it was assumed that it would allow better control on variable of interest.

3.2 WALK THROUGH SURVEY

A walk through audit as known from its name was conducted in Feb 2013, in order to know the broader sources of energy, inflows and outflows, its routes, types of energy use, major consumption areas, past consumption history, building envelop and possible potential for energy saving etc.

Walk through audit at IESE building had following findings:

- Electric power (Either supplied by local distribution Co. or through standby power generator) was the only source of energy for all kind of usage including lighting, heating, cooling, cooking etc.
- There was no meter installed to monitor the energy inflow into the building.
- A 75 KVA diesel power generator is installed as backup source during power shut downs
- Most of the important systems mainly computers, some low consuming special lab equipments and emergency lighting are backed up by locally installed Uninterrupted Power Supply (UPS)

- Central HVAC plant was out of order and split air conditioners were used for space cooling in summers and electric heaters (blower type) were used for space heating in winter
- In addition ceiling fans were used for air circulation to provide comfort in summers being used with or without air conditioners
- For cooking purpose (very rare) or for heating food/ making tea again electricity was the only source being used through microwave oven or electric kettle/ plate heaters.
- Also since there is no use of hot water for bathing/ washing clothes or dishwashing the limited need of hot water was again met through instant electric geysers installed within the washrooms
- 34 monitors used with computers are CRT while rest are LCD type
- Mostly T-12 tube lights or otherwise CFLs are used for indoor lighting
- No water pumps are installed to uplift water to over head water tanks, rather water flows from central water tanks in campus that supplies water to the building through gravity
- Need for cold drinking water in summers is met through water dispensers installed at various places with the department being run by electricity
- Another energy consuming area is a large number of various lab equipments installed in different laboratories of the institute that are powered by electricity and used whenever required
- No special considerations given to insulation in building construction, traditional nine inch brick walls with plaster is used all around

- A fair attempt was made to catch natural light through windows and up to some extent through glass doors, but on the other side considerable amount of energy is lost in heating/ cooling due to 3-5 mm single layers glasses used. Also frames of windows and doors are made of Aluminum that itself causing additional loss of heating/ cooling
- No special treatment was given to roof for reduction of heat transfer

This gave a very clear road map for how to move and where to focus for potential energy savings. The only major hurdle was non availability of previous consumption history due to the absence of separate electricity meter for the building.

Based on walk through audit it was concluded that this would be a pilot project, we would focus on few major areas with practical approach and suggest for other areas based on past experience or desktop studies. The selected areas were:

- ❖ Lighting
- ❖ Fans
- ❖ CRT Display Monitors
- ❖ Windows (the only part selected from building envelop to indirectly cater for savings in heating/ cooling consumption through electric heaters and air conditioners)

3.3 COLLECTION OF DATA

Building drawings/ plans were collected from PMO (Project Management Office) NUST. Though these plans did not completely match the actual building due to modifications during construction or at later stages, still an estimated floor area was extracted. It also helped in marking position and counting of lights, fans, heaters, air conditioners and other appliances installed within the building. Also area of doors and windows was estimated with the help of these drawings in addition to actual measurements.

Since no separate metering was available in the building, it was not possible to estimate exact energy consumption in terms of units and monthly costs, the estimated installed load data was collected from PMO (Project Management Office) on the basis of their day to day estimations. In addition daily shut downs and fuel consumption of backup power generator was extracted from the log book (maintained for backup generator by PMO staff).

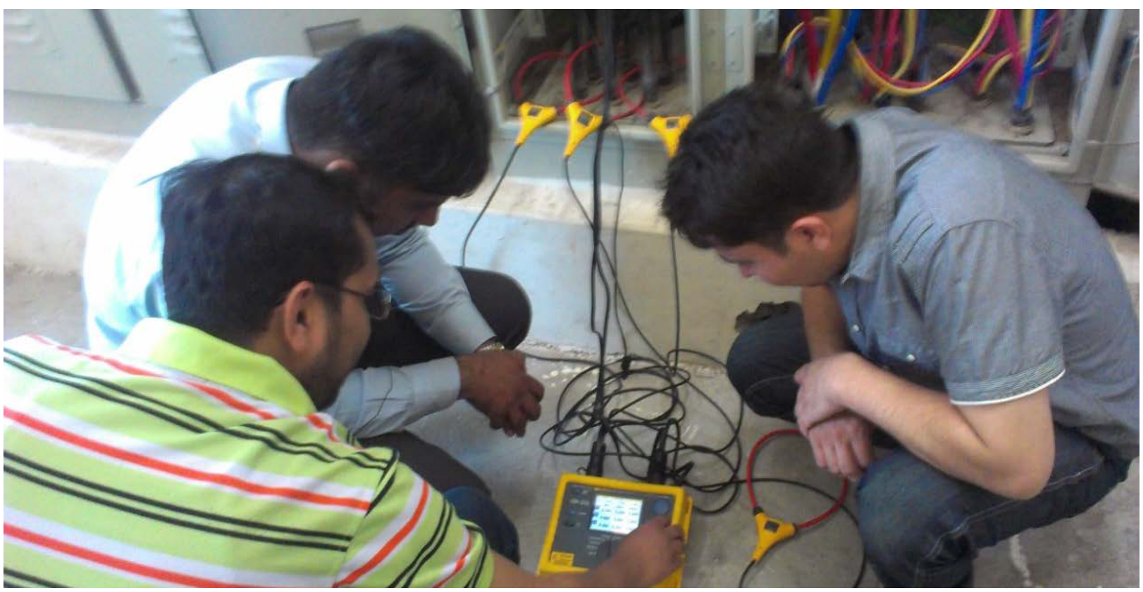


Figure 3-1: Estimation of overall load & energy consumption

At the same time to cater for this deficiency the tools borrowed from ENERCON's including data Logger were involved. Total load and estimated power consumption data was collected from main panels of electric distribution system of the building. The electrical engineers from the Project Management Office were also involved in this activity in order to avoid any mishap.

In next phase, all type of appliances and equipments were counted in each individual area i.e., in class rooms, offices, laboratories, corridors etc., Lights and computers were given special attention, counted type wise separately and recorded properly. Load for each type of appliance was measured and documented as given in Table 3-1.

Figure 3-2: Monitoring building load

Table 3-1: Location and Appliance wise load of the building

Appliances / Location	CFL	Tube Lights (Electronic Ballast)	Tube Lights (Magnetic Ballast)	Tube Lights - 2Ft (Electronic Ballast)	Ceiling Fan	Bracket Fan	A/C 1 Ton	A/C 1.5 Ton	LCD Monitor	CRT Monitor	Water Dispenser	Printer	Scanner	LCD TV (42")	Photocopier	Fridge	Electric Heaters	A/C Vertical (Ton)	Overhead Projector
Ground Floor																			
Corridor (Main Entrance)	20					2									1				
Corridor (Right Side)	18					1					1								
Corridor (Opposite Side)	10																		
Corridor (Left Side)	20					1					1								
Reception (116)	7					1		1	1			1					1		
Office HD Env. Sc. (115)		6			2			1	1		1	1					1		
Electric Room # 1			2																
Kitchen	1					1													
PhD Cubical (111)		12			4			1	10								1		
Adv. Analytical Lab (112)		20			7			2	3	5	1	3					2		
Waste Water Lab (114)	4	14	4		6		1	2	1	1	1	1				2	2		
Washrooms	10		2																
Env. Biotech Lab (113)		12		12	4	2		3	1	2	1	1				1	2		
Imran Hashmi Office (101)				8		1		1	1			1					1		
Sher Jamal Office (102)				8		1		1	1			1					1		
Washroom Staff	2			1															
Dr. Saud (103)		4			1				1			1					1		

Table 3-1: Continued …

Appliances / Location	CFL	Tube Lights (Electronic Ballast)	Tube Lights (Magnetic Ballast)	Tube Lights - 2Ft (Electronic Ballast)	Ceiling Fan	Bracket Fan	A/C 1 T on	A/C 1.5 Ton	LCD Monitor	CRT Monitor	Water Dispenser	Printer	Scanner	LCD TV (42")	Photocopier	Fridge	Electric Heaters	A/C Vertical (Ton)	Overhead Projector
Room 104		4			1				1			1							
Seminar Hall (105)				180		8			1					1			4	2	1
Room 109		4			2												1		
Computer Lab		25				8			28	22		5	2				4	2	1
Classroom # 2 (106)		12	2		8			3	1								2		1
Classroom # 1 (107)		18	2		8			3	1								2		1
Girls Washroom	11		2																
Girls Lounge (108)		4			2		1		3								1		
First Floor																			
Corridor (Main Entrance)																			
Corridor (Right Side)	12										1								
Corridor (Opposite Side)	10																		
Corridor (Left Side)	14					2					1								
Administrator Office (222)		4			2			1	1			1					1		
Electric Room # 3			2																
Kitchen	2					1													
Strong Room (217)			3			4		2									2		
Admin and Finance (218)			5			4		1	7			1			1		2		
Air, Noise & S.W. Lab (219)		18			4	1		1	3	1							2		
Env. Chemistry Lab (221)		22	1		7			2	1	1						1	2		

Table 3-1: Continued …

Appliances / Location	CFL	Tube Lights (Electronic Ballast)	Tube Lights (Magnetic Ballast)	Tube Lights - 2Ft (Electronic Ballast)	Ceiling Fan	Bracket Fan	A/C 1 T on	A/C 1.5 Ton	LCD Monitor	CRT Monitor	Water Dispenser	Printer	Scanner	LCD TV (42")	Photocopier	Fridge	Electric Heaters	A/C Vertical (Ton)	Overhead Projector
Washroom Staff	6		2																
Env. Microbiology Lab (220)		18	2		5	2		3	4	1							2		
Classroom # 4 (208)		16	2		5			2	1								2		1
Classroom # 3 (209)		16	2		5			2	1								2		1
Associate Dean Office (201)				16	2		1		1			2			1		1		
PA to Associate Dean (223)		4			1			1	1			1					1		
HOD Env. Engg (203)				8		1	1		1		1	1					1		
PA to HOD Env. Engg (202)			1		1	1				1							1		
Room 204		4				1			2			2							
Room 205		4				1						1							
Conference Room (216)		12				4		2	1								2		1
Faculty Lounge (215)			6			6		2			1						2		
Library (206)		16			8				41			2		1	1		2	2	
Room 213			3		1			1				2							
Room 214			2		1			1											
Store (212)			1																
Mosque (211)		4			1												1		
Electric Room (210)			1																
Washroom Faculty	7		2																
TOTAL	154	273	49	233	88	54	4	39	120	34	10	29	2	2	4	4	2	6	7

Table 3-2: Estimated Installed Load of IESE Building

Estimated LOAD of IESE Building NUST										
Appliance	Qty	Rating (kW)	Total Load (kW)	Avg. Daily Hrs Winter	Avg. Daily Hrs Summer	Avg. Units (kWh)/Month Winter	Avg. Units (kWh)/Month Summer	Avg. kWh/ Year	Avg. Unit Rate (PRs.) *	Est. Cost/Year
CFLs	154	0.02	3.54	16	16	1473.47	1473.47	17681.66	18	318269.95
Tube Lights (E.B)*	273	0.04	12.01	16	16	4996.99	4996.99	59963.90	18	1079350.27
Tube Lights (M.B)*	49	0.05	2.30	16	16	958.05	958.05	11496.58	18	206938.37
Tube Lights - 2Ft (E.B)	233	0.03	6.99	16	16	2180.88	2180.88	26170.56	18	471070.08
Ceiling Fan	88	0.08	6.60	-	12	-	1742.40	10454.40	18	188179.20
Bracket Fan	54	0.04	2.16	-	12	-	570.24	3421.44	18	61585.92
A/C 1 TOR	4	1.16	4.64	-	12	-	1224.96	6124.80	18	110246.40
A/C 1.5 TOR	39	1.60	62.40	-	12	-	16473.60	82368.00	18	1482624.00
A/C Vertical (4 Ton)	6	4.40	26.40	-	10	-	5808.00	29040.00	18	522720.00
Electric Heaters	48	1.00	48.00	12	-	12672.00	-	63360.00	18	1140480.00
LCD Monitor	120	0.05	5.40	16	16	1900.80	1900.80	22809.60	18	410572.80
CRT Monitor	34	0.11	3.74	16	16	1316.48	1316.48	15797.76	18	284359.68
Water Dispenser	10	0.60	6.00	-	12	-	1056.00	6336.00	18	114048.00
Printer	29	0.50	14.50	2	2	638.00	638.00	7656.00	18	137808.00
Scanner	2	0.30	0.6	2	2	26.40	26.40	316.80	18	5702.40
LCD TV (42")	2	0.08	0.16	6	6	21.12	21.12	253.44	18	4561.92
Photocopier	4	1.00	4.0	2	2	176.00	176.00	2112.00	18	38016.00
Fridge	4	0.60	2.40	8	8	422.40	422.40	5068.80	18	91238.40
Oven	4	1.00	4.0	4	4	352.00	352.00	4224.00	18	76032.00
Overhead Projector	7	1.00	7.0	4	4	616.00	616.00	7392.00	18	133056.00
Misc	1	2.00	2.0	2	2	88.00	88.00	1056.00	18	19008.00
Total Load			**224.85**			**27838.59**	**42041.79**	**383103.74**		**6,895,867.39**

Assumptions: Working Hours per Day: 12 Hrs (0900 – 2100), Working Days per Month: 22 Days (5 Days/Week)

Summer Months/ Year: 6 (Averaging Spring and autumns), Winter Months/ Year: 6 (Averaging Spring and autumns)

Rate per Unit Electricity: Rs. 18/- (Taking rough avg. of IESCO unit rate and cost of diesel consumption of Generators during Load Shedding)

Average Load Shedding Duration: 4-6 Hours

* E.B = Electronic Ballast, M.B: Magnetic Ballast

This also helped in estimating the overall load of the building. At the same time it provided load of each component separately i.e., for lighting, air conditioning, fans, computers etc.

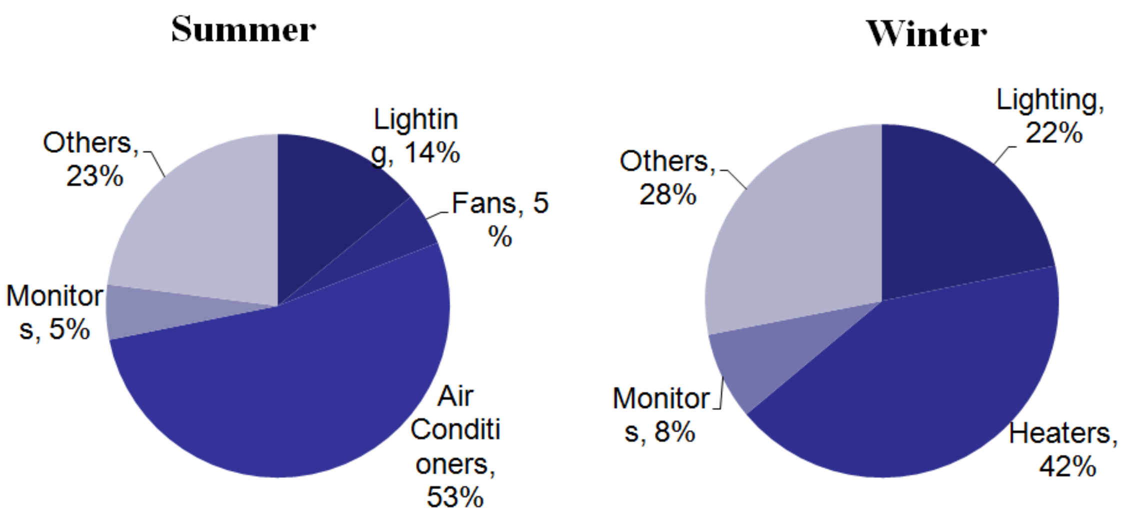


Figure 3-3: Load Distribution at IESE

Based on both approaches (i.e., measuring load through data logger and calculating from installed appliances/ equipment) as well as data from Project Management Office, total installed load at IESE was estimated 230 KW whereas running load in winters as 70-80 KW and in summers it goes to 120-130 KW. Since only lighting, air conditioning and computer monitors are considered in this study, it is important to note that the total installed load of these gadgets/ equipments was estimated 180 KW.

Experimental Work:

3.3.1 Lighting

It was revealed during the walk through audit that mainly three types of lights are used in the building for lightings purpose:

- T8 Tube light with magnetic ballast
- T8 Tube light with electronic ballast
- Compact Fluorescent Lights (CFLs)

Figure 3-4: LED light on Testing Board

A test display board was installed with each sample of existing lighting fixtures along with a sample of each type of lighting fixture available in the market with the claim of being the most efficient lighting. Purpose was to study these options not only from efficiency point but also to compare economics and life span of these lights. And thus prepared a comparison chart. The lights studied in this work included:

- T8 Tube light with magnetic ballast
- T8 Tube light with electronic ballast
- CFL 20 Watts
- CFL 30 Watts

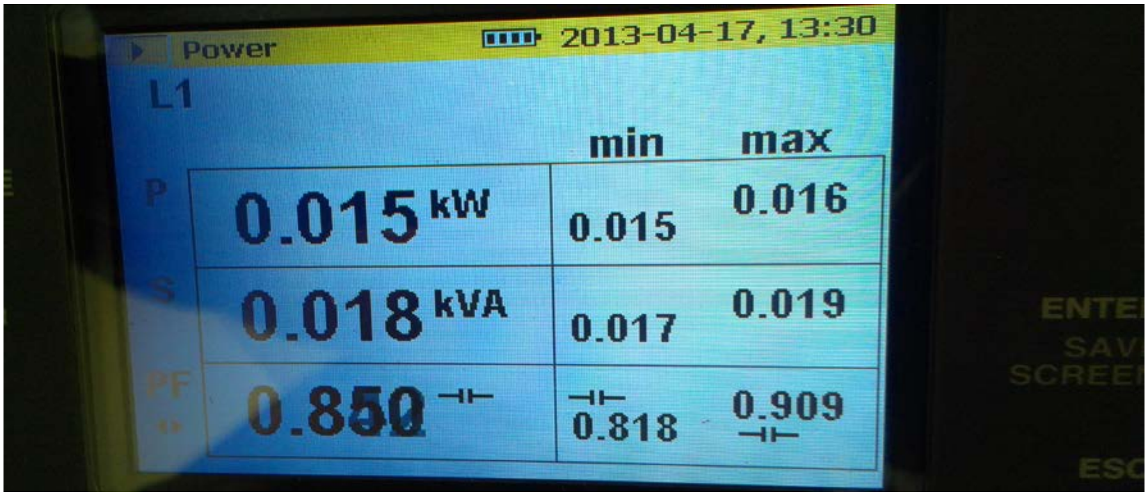


Figure 3-5: Readings for LED light

- T5 (Philips) with user friendly fittings (Patti), replaceable ballast and tube
- T5 Chinese brand with built in fixture but replaceable tube
- LED bulb (9 Watts)

All items to be tested were fixed on a display board installed in a fully dark room. Each light was monitored with data logger for energy consumption, load and power factor by keeping all other parameters e.g. source of power, frequency and voltage fixed. Whereas light intensity (Lumens) was measured with the help of Lux-meter (by keeping distance and angle of lux-meter constant for all readings).

Figure 3-6: T8 Tube Light on Test

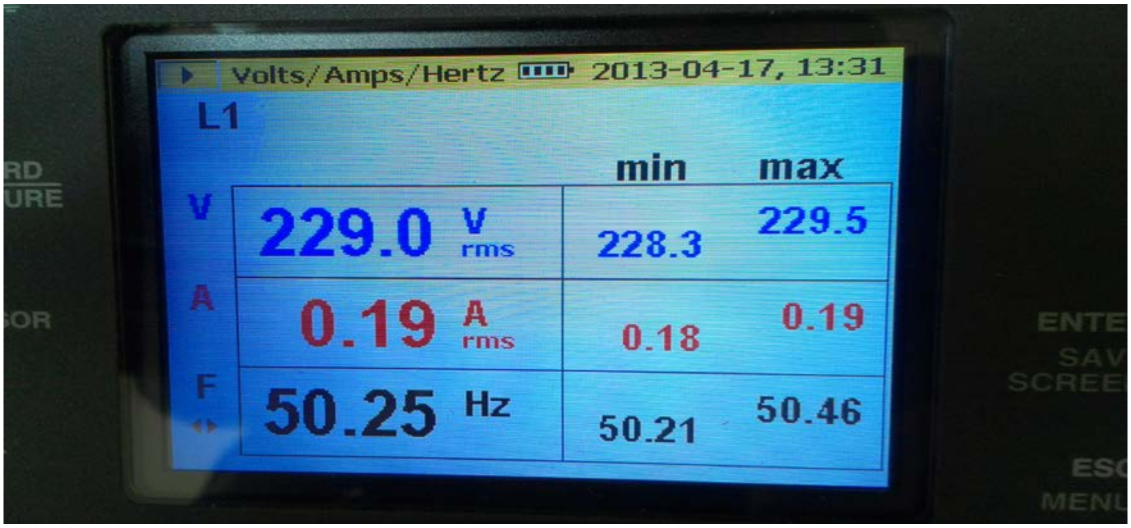


Figure 3-7: Results of T8 Tube Light

The detailed comparison of different lights (Table 3-4), shows that both type of T5 tube lights are not only consuming lesser power but also has very high power factor and high lumens (Figure 3-8). In addition it was found that tube lights with magnetic ballast (M. B.) have very poor power factor but higher consumption than tube lights with electronic ballast (E. B.).

On above grounds it was concluded that considering the use pattern and other local factors T5 is the best suitable option to go with.

Table 3-3: Comparison of various lighting sources

Type	Claimed Load (W)	Actual Load (W)	KVA	Power Factor	Current (Amps)	Lumens (from a distance of 11 Ft)
CFL - 20	20	23	0.031	0.78	0.14	23
CFL - 30	30	32	0.045	0.716	0.21	41.9
LED Bulb - Philips	9	15	0.018	0.85	0.08	27.4
Tube Light (M. B)	44	47	0.082	0.582	0.36	69
Tube Light (E. B)	40	44	0.044	0.997	0.19	73
T5 (Built-in fixture) Chinese	27	34	0.35	0.981	0.15	62.5
T5 (Mounted E. B.) Philips Pak.	27	37	0.37	0.994	0.16	81

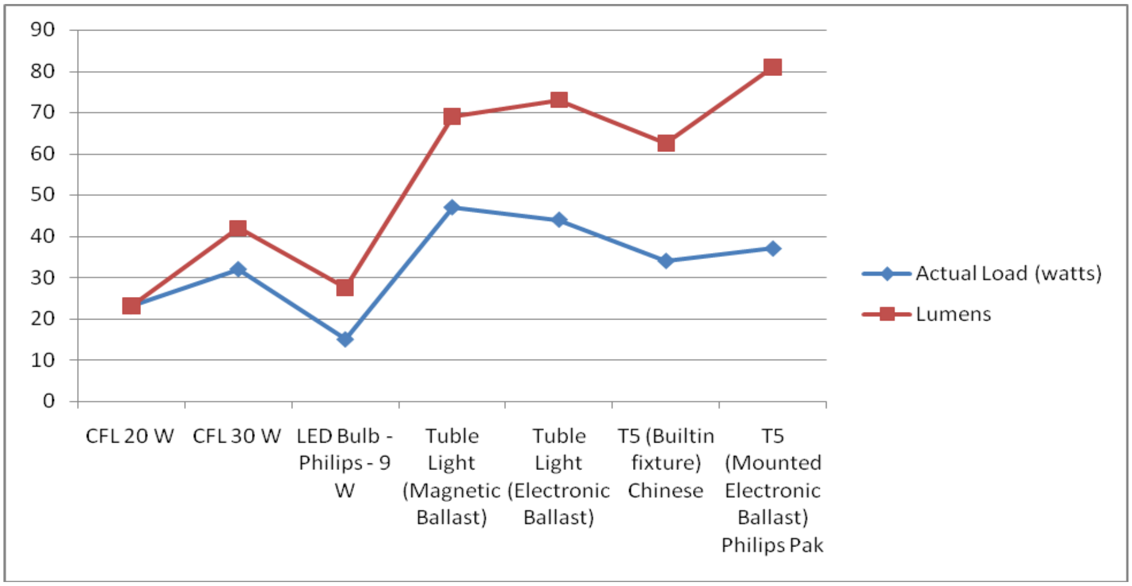


Figure 3-8: Power Vs Lumens of each light under consideration

In next phase, two similar and adjacent rooms were selected to find out practical comparison by keeping one room with existing lighting while lights in the other room were replaced with same number of T5 tube lights (installed on same positions). Rooms were selected very intelligently by considering similarity in size, use pattern, average number of occupants, number of lighting fixtures etc. Also to bring uniformity, lights in both rooms were connected to power source directly so that users can not interfere in to usage pattern and the lights stay lit round the clock or in case of shut down go for equal duration. Then only lighting of each room was connected to individual energy meters and turned on at once by noting down date and time. Both the meters as well lights were monitored on daily basis and observed for three consecutive months. In addition the lighting intensity was also noted in Lumens at the start of experiment and repeated every week for any possible variation till the last day of third month. Details are provided in Table 3-5.

Table 3-4: Energy consumption and luminosity of T5 vs. Existing T8 Tube Lights

Room #	Type of Light	No. of Fixtures	Lumens at same level			Operation Hrs/day	Observation period	Units Consumed
			Max	Min	Avg			
204	T5 (4Ft)-Chinese	4	241	235	238	24	30 days	24.48
205	T8 (4Ft)	4	289	253	265	24	30 days	38.84
Units Saved								14.36
Energy Saved								23%

This helped in confirmation of the decision to opt for T5 tube light to replace existing lighting.

3.3.2 Fans

Similar exercise was repeated for fans. Existing fans of the building are mainly of a specific local brand (i.e., Pak Fan) and common standard size i.e., 56 inches Ø. One Pak fan and two other brands were purchased from the local market and were installed and analyzed for energy consumption and air flow.

Table 3-5: Comparison of various ceiling fan brands

Brand and Size	Claimed Load (Watts)	Actual Load (watts)	KVA	Power Factor	Current (Amps)
Pak Fan – 56” Ø (with claim for 99.9% copper)	75	78	0.087	0.88	0.36
Younus Fan – 56” Ø	70	82	0.093	0.85	0.39
Ravian – 56” Ø	75	88	0.098	0.90	0.43

Figure 3-9: Testing different fans for energy consumption

3.3.3 Computer Monitors

Although there is a clear understanding in common and in particular at NUST about energy consumption of Cathode Ray Tube (CRT) monitors vs. Liquid Crystal Display (LCD) monitors that why majority of monitors with computers at IESE are LCD based technology still a small ratio at IESE are CRT type i.e., relatively high energy consuming ones. There are 154 desktop computers in use at IESE out of which 34 are connected with CRT monitors. These can also help in reducing energy consumption at IESE if replaced with LCD monitors. Then at some later and appropriate stage these desktop computers may be replaced with high efficiency laptops.

3.3.4 Heating and Cooling

IESE building does have a centralized heating/ cooling system but it is not functional. At present, the only source for space cooling is air conditioners (Split unit type) in summers and electric heaters (mostly blower type) for space heating in winter. Electric power is again the only source of energy being used for heating and cooling.

Since these are direct sources for heating or cooling there is less possibility of losses in the form of leakages and insulation of piping. Still some measures can improve efficiency including regular servicing/ maintenance, good insulation of piping/ ducting between indoor and outdoor units, keeping thermostat of air conditioners on 26° C and cleaning air filter regularly.

In addition, before installing new air conditioners, the ideal way is to calculate heating load (an engineering approach to estimate the size/ capacity of air conditioner for a particular space) of a specific space that results in efficient consumption of energy.

Yet there is a large potential of reduction in energy consumption for space heating and cooling through improving building envelop. In this study mainly windows and some doors (glass based) were considered to support reduction of energy consumption in space heating and cooling.

3.3.5 Windows and Doors

Window and glazing plays an important role in building energy management. From thermal insulation point of view, window is most vulnerable. So glazing plays an important role. In this regard, glazing technology has gone through rapid evolution. Numerous research and development in glazing fabrication techniques have led to a wider range of design options. So, the desired criteria of a glazing system from energy saving point of view is that it should possess higher transmittance in visible spectrum and lower transmittance in infrared region (S. Ghoshal 2014).

According to ENERGYWISE™ a program for energy efficiency and conservation by the Govt. of New Zealand in “Double glazing” two panes of normal glass are fixed in parallel in such a way that an insulating layer is build among the two panes. That layer can be a noble gas such as Argon or can be normal air. The beauty of Double glazing is that it restricts heat transfer across but at the same time allows same amount of sunlight as single-glazed windows. An ideal window system should possess the following optical properties for cooling demand applications:

- Effective transmittance is numerically one (i.e., there is no absorption or reflection) within visual range (0.4-0.7 μm) for best utilization of daylight.
- Effective back reflectance is numerically one in infrared range (0.7-50μm).

It was always a try to make window insulation prominent. As a result, glazing systems have been modified from single glaze to double glaze and recently developed multilayer evacuated glazing. Heat losses (U) through single glazed units were significantly high (U-value of 5.3 W m^{-2}K-1). To acknowledge this heat loss, double glazed units were manufactured. Initially, double glazed units were air filled. But due to conductive nature of stagnant air, significant heat loss was observed. Gradually noble gas filled double glazing units have been developed. With this modification, conductive heat loss was reduced, but not eliminated; as any noble gas possesses very small conductivity (0.016 W m^{-1}K-1 for argon). Heat transfer through such glazing units was reduced to U-value 1.1 Wm^{-2}K-1 and was further reduced to 0.8Wm^{-2}K-1 by applying night insulation (ASHRAE 1993, Liu. M. et. Al. 2013, Smith. N. 2009, Chow T.T. 2010).

Double glazed windows reduce fifty percent heat loss through that window. It reduces condensation building in winter and external noise. Based on the results of previous studies; windows accounts for 15-20 % of entire heat transfer in a building either in summer or winter. Now point is that the windows at IESE are single glazed with average thickness of 5 mm and fitted in aluminum frame. Approximate total area of about eighty windows of various sizes is 21600 ft^2 including aluminum frames and structures. While according to findings of this study; 42% of the energy consumed at IESE building goes to cooling in summer and 22% goes to heating in winter (Figure 3-3: Load Distribution at IESE). This means that 15 % of the energy consumed in cooling and heating goes to waste or in other words 8-12 % of the total energy consumed at IESE is wasted just by heat loss through windows and doors.

Past studies shows that replacing of single glazed windows with double glazed windows and uPVC frame can reduce energy loss by one third. This means that in IESE it can reduce 5 % of the total energy consumption. Best available options for double glaze windows with proven quality, experience and prices were evaluated from local market and analyzed for replacement in IESE.

3.3.6 Motion Sensors in Washrooms and Corridors

There is enough potential to save energy in washrooms and corridors by using occupancy or motion sensors. As known from its name, a motion sensor is a switch that turns on/ off lights against movement and thus reduces energy consumption.

A sample motion sensor was installed in one of the office in the institute for more than six months just to observe its performance and identify any problems/ hindrances. Finally it was concluded that installation of motion sensors in washrooms and corridors can avoid considerable amount of useless consumption of energy in lighting. Although savings through installations of motion sensors are not incorporated in the calculations but a rough estimate is given here for future consideration:

Table 3-6: Cost benefit analysis of motion sensors

	CFLs	TL (MB)	TL (EB)	TL – 2 Ft (EB)	Bracket Fan
Corridors + Washrooms	150	8		3	6
Avg. Load. (KW)	4.5	0.4		0.1	0.24
Total Load (KW)	5.24				
Avg. No. of motion sensors required*	35				
Avg. reduction in usage per day (Hours)	4				
Total Energy saved per year (KWh)	52, 500.00				
Saving in Rs. Per year	83, 000/-				
Total cost of installing motion sensors Rs.	22, 500/-				
Pay Back time (Years)	0.64				

(*) per area i.e., one for each washroom section (150 ft^2, and a corridor section (30-40 ft long)

3.3.7 Use of Master Switch outside Each Room

A main switch was installed outside a classroom to make it easy to switch off all appliances installed in the room at once. The purpose was to avoid forgetting of switching off all or some of the appliances before leaving the room. It also proved to be a good and easy step with almost negligible cost to help improving energy efficiency.

RESULTS AND DISCUSSION

The most significant problem with investigating energy saving potential at IESE/ NUST was that, once the energy is distributed into the campus, it disappears. Meaning that there is no sub meter installed for measuring power consumption neither on school level nor at institute level, thus we have no record of where the energy is consumed and in what quantity. For that reason random readings were taken with electrical data logger at various load peaks and off peaks from main electrical control panel as well as from sub panels for overall load and individual appliances group loads. Based on these readings and further analysis, results are established mainly for lighting, air conditioning, heating and monitors. Accordingly potential savings were estimated on the basis of suggested modifications or replacements.

4.1 ANALYSIS OF DATA

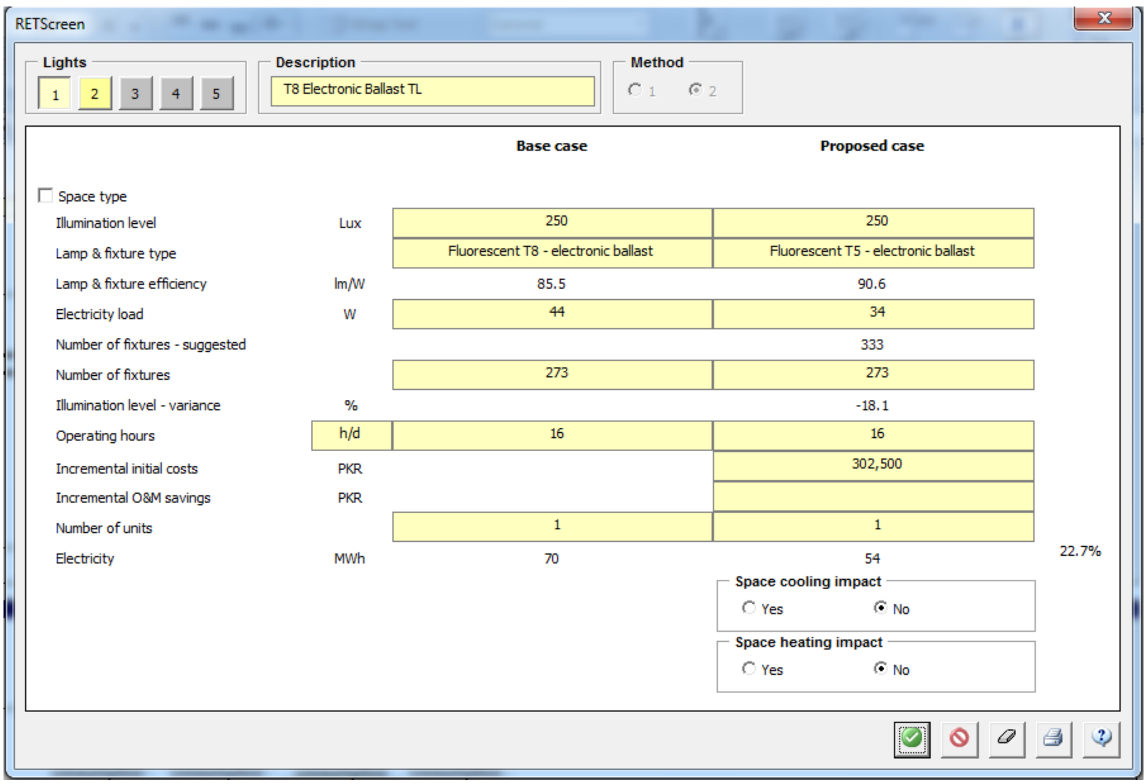
The data collected was assessed with the combination of two approaches i.e., on one side Microsoft Excel based self developed simple model being designed as per scope of study and limitation of the data available. While where appropriate, “RETScreen plus” was used to analyze the energy performance. Detailed results of each target areas are given and discussed one by one.

4.2 LIGHTING

The results of experimental work i.e., by comparing different types of lighting available in the market with high energy efficiency claim to the existing installed lighting and the practical comparison of selected T5 lights to the existing lights by monitoring performance of both type of lights through energy meters in similar environments and keeping rest of the conditions fixed; The decision to opt for alternate lighting while feeding all available data in to “RETScreen plus” software was very clear.

First we processed for the replacement of T5 against Tube Lights with Electronic Ballasts with following results:

Table 4-1: Outcome of replacing T8 Electronic Ballast TL with T5


RETScreen

Lights: 1 2 3 4 5 — Description: T8 Electronic Ballast TL — Method: 1 / 2

		Base case	Proposed case	
Space type				
Illumination level	Lux	250	250	
Lamp & fixture type		Fluorescent T8 - electronic ballast	Fluorescent T5 - electronic ballast	
Lamp & fixture efficiency	lm/W	85.5	90.6	
Electricity load	W	44	34	
Number of fixtures - suggested			333	
Number of fixtures		273	273	
Illumination level - variance	%		-18.1	
Operating hours	h/d	16	16	
Incremental initial costs	PKR		302,500	
Incremental O&M savings	PKR			
Number of units		1	1	
Electricity	MWh	70	54	22.7%

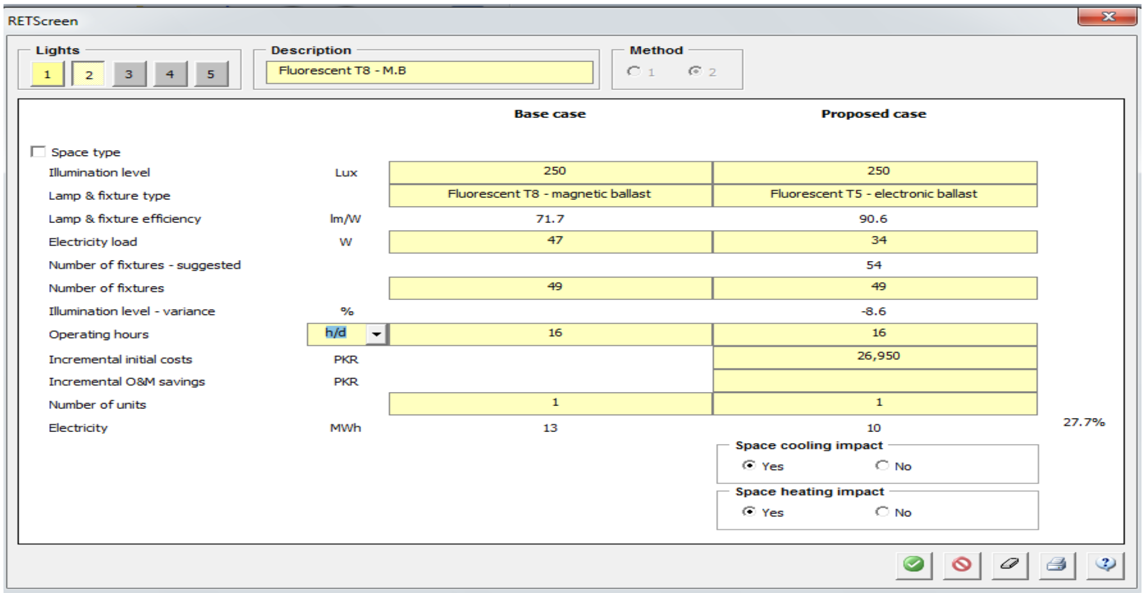
Space cooling impact: Yes / No

Space heating impact: Yes / No

Overall 273 number of T8 Tube Light (Electronic Ballasts) were replaced with same number of relative high efficiency T5 (Electronic Ballasts). It clearly reflecting the difference of energy (electricity) saved in one year i.e. 16 MWh which is 22.7 % of the total consumption.

Then the same exercise was repeated for Tube Lights with Magnetic Ballast with following results (Table 4-2).

Table 4-2: Outcome of replacing T8 Magnetic Ballast TL with T5


RETScreen

Lights: 1 2 3 4 5 | Description: Fluorescent T8 - M.B | Method: 1 2

		Base case	Proposed case	
Space type				
Illumination level	Lux	250	250	
Lamp & fixture type		Fluorescent T8 - magnetic ballast	Fluorescent T5 - electronic ballast	
Lamp & fixture efficiency	lm/W	71.7	90.6	
Electricity load	W	47	34	
Number of fixtures - suggested			54	
Number of fixtures		49	49	
Illumination level - variance	%		-8.6	
Operating hours	h/d	16	16	
Incremental initial costs	PKR		26,950	
Incremental O&M savings	PKR			
Number of units		1	1	
Electricity	MWh	13	10	27.7%

Space cooling impact: Yes / No

Space heating impact: Yes / No

Total 49 Tube Light (Magnetic Ballast) fixtures replaced with same number of relative high efficiency T5 (Electronic Ballasts). It clearly reflecting the difference of energy (electricity) saved in one year i.e., 3 MWh which is 27.7 % of the total consumption.

4.3 BUILDING ENVELOP

As mentioned in earlier chapters, only windows and few doors (glass based) were selected out of building envelop being the easily achievable retrofitting option with relatively considerable energy saving potential and a well defined success ratio worldwide. The performance of improved insulation in buildings can be well gauged through reduction in the consumption of energy in space cooling and heating.

After gathering details of Air conditioners in summers and Heaters in winters, the estimated base case load and consumptions were fed into the "RETScreen plus" with certain assumptions of average daily, monthly and seasonal consumption.

Table 4-3: Energy saving in cooling load after replacing Double Glaze windows

RETScreen

Electrical equipment: 1 2 3 4 5

Description: Air Conditioners

	Base case				Proposed case				
		Operating hours	Electricity load	Duty cycle		Operating hours	Electricity load	Duty cycle	Incremental initial costs
Description	Quantity	h/d	kW	%	Quantity	h/d	kW	%	PKR
Air conditioners (1 TON)	4	12	1.5	33	4	10.2	1.5	33	77,522.56
Air conditioners (1.5 TON)	39	12	1.8	33	39	10.2	1.8	33	93,027.07
Air conditioners (4 TON)	6	10	4	33	6	8.5	4	33	206,726.83
Total									5,178,507

		Base case	Proposed case	
Incremental initial costs	PKR		5,178,507	
Incremental O&M savings	PKR			
Electricity	MWh	139	118	15.0%

Space cooling impact: Yes / No (No selected)

Space heating impact: Yes / No (No selected)

Table 4-4: Energy Saving in Heaters after replacing Double Glaze windows

RETScreen

Electrical equipment: 1 2 3 4 5

Description: Electric Heaters

	Base case				Proposed case				
		Operating hours	Electricity load	Duty cycle		Operating hours	Electricity load	Duty cycle	Incremental initial costs
Description	Quantity	h/d	kW	%	Quantity	h/d	kW	%	PKR
Electric Heaters	48	12	1.2	33	48	10.2	1.2	33	49,614.44
Total									2,381,493

		Base case	Proposed case	
Incremental initial costs	PKR		2,381,493	
Incremental O&M savings	PKR			
Electricity	MWh	83	71	15.0%

Space cooling impact: Yes / No (No selected)

Space heating impact: Yes / No (No selected)

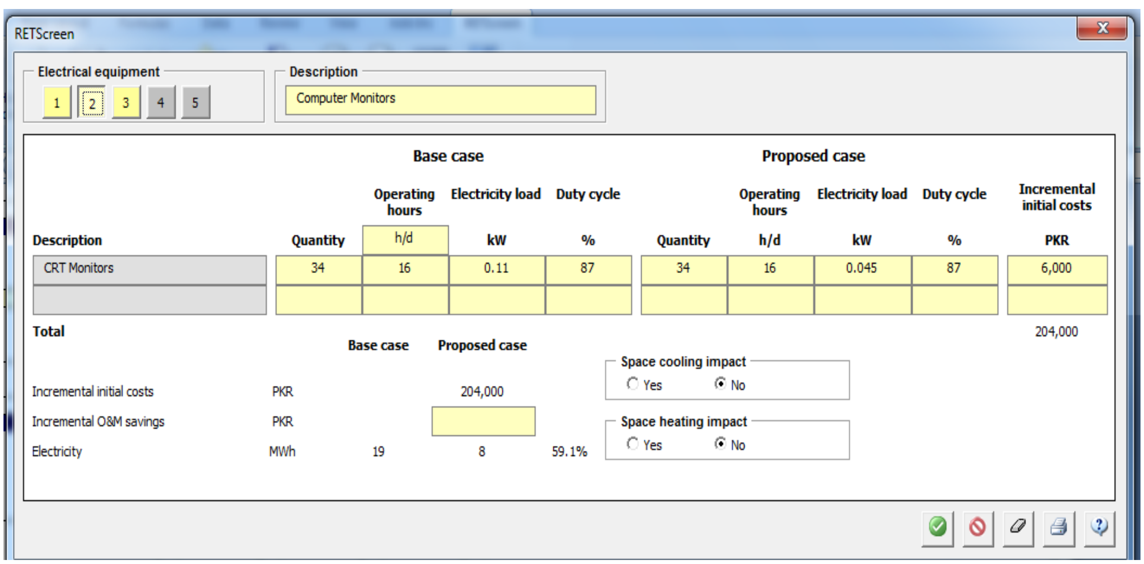
Once all the windows were replaced with double glaze, it was revealed that about 33 MWh of energy could be saved annually at IESE; whereas cost of retrofitting could be recovered within a period of 12 years. With the existing trend of regular increase in power prices payback time can further be reduced.

4.4 COMPUTER MONITORS

Although IESE has a limited number of CRT monitors, still it matters to be replaced with energy efficient LCD monitors. Thirty four number of CRT monitors if replaced with LCDs can save 11 MWh annually with a payback period of just 9-10 months.

Further by lowering down the automatic computer sleep time to 10 minutes of all computers, change the monitor brightness to the lowest possible setting, deactivate screen savers, and turn off computers at night we can save additional handsome amount of energy.

Table 4-5: Outcome of replacing CRT monitors with LCD monitors



RETScreen

Electrical equipment: 1 2 3 4 5

Description: Computer Monitors

	Base case				Proposed case				
		Operating hours	Electricity load	Duty cycle		Operating hours	Electricity load	Duty cycle	Incremental initial costs
Description	Quantity	h/d	kW	%	Quantity	h/d	kW	%	PKR
CRT Monitors	34	16	0.11	87	34	16	0.045	87	6,000
Total									204,000

		Base case	Proposed case	
Incremental initial costs	PKR		204,000	
Incremental O&M savings	PKR			
Electricity	MWh	19	8	59.1%

Space cooling impact: Yes / No (selected)

Space heating impact: Yes / No (selected)

4.5 OVERALL ENERGY SAVINGS

Now, if we consider the collective effect of these limited measures i.e., lighting, cooling, heating and replacement of CRT monitors, 64 MWh can be saved annually in IESE. This means saving of Rs. 1.3 million annually. To apply all these measures, it will take approximately 6-8 months and an investment of Rs. 8.1 million. This investment can be recovered within 6.3 years.

Table 4-6: Overall Energy Savings

Facility characteristics ☑ Show data

Show:	Heating	Cooling	Electricity	Incremental initial costs	Fuel cost savings	Incremental O&M savings	Simple payback	Include measure?
Fuel saved	MWh	MWh	MWh	PKR	PKR	PKR	yr	☑
Heating system	0	-	-	0	0	0	-	☑
Cooling system	-	0	-	0	0	0	-	☑
Building envelope	0	0	-	0	0	0	-	☑
Ventilation								
Lights								
T8 Electronic Ballast TL	-	-	16	302,500	318,864	0	0.9	☑
Fluorescent T8 - M.B	-	-	4	26,950	74,402	0	0.4	☑
Electrical equipment								
Air Conditioners	-	-	21	5,178,507	417,142	0	12.4	☑
Computer Monitors	-	-	11	204,000	224,571	0	0.9	☑
Electric Heaters	-	-	12	2,381,493	249,765	0	9.5	☑
Hot water								
Heat recovery								
Other								
Total	0	0	64	8,093,450	1,284,745	0	6.30	

Summary ☑ Show data

	Fuel		Base case		Proposed case		Fuel cost savings	
Fuel type	Fuel consumption - unit	Fuel rate	Fuel consumption	Fuel cost	Fuel consumption	Fuel cost	Fuel saved	Fuel cost savings
Electricity	MWh	PKR 20,000.000	324.9	PKR 6,498,086	260.7	PKR 5,213,342	64.2	PKR 1,284,745

4.6 ENVIRONMENTAL SAVINGS

Since the approximated overall consumption of energy considered in this study is about 325 MWh annually whereas after taking these retrofitting measure the consumption will come down to about 261 MWh with clear energy saving of 64 MWh.

Based on the fuel mix of power generation in Pakistan approximately 65 % thermal (Fossil fuels), 34 % Hydel resources and 4 % nuclear, RETScreen has calculated a GHG emission factor for electricity consumption. Upon processing our data it was revealed that saving 64 MWh can help us in reducing 26.5 tons of CO_2 every year i.e., equivalent to 6 Acers of Forest absorbing CO_2 (RETScreen).

Table 4-7: Environmental Benefit after implementing the project

Base case electricity system (Baseline)

Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Pakistan	All types	0.413		0.413

☐ Baseline changes during project life

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission tCO2/MWh	GHG emission tCO2
Electricity	100.0%	325	0.413	134.1
Total	100.0%	325	0.413	134.1

Proposed case system GHG summary (Energy efficiency measures project)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission tCO2/MWh	GHG emission tCO2
Electricity	100.0%	261	0.413	107.6
Total	100.0%	261	0.413	107.6

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission tCO2
Energy efficiency measures project	134.1	107.6	26.5		26.5

Net annual GHG emission reduction 26.5 tCO2 is equivalent to 6.0 Acres of forest absorbing carbon

4.7 PROJECTED SAVINGS BY NUST, ISLAMABAD

Following the consumption pattern at IESE it can easily be estimated that the overall power consumption at NUST in the three main areas (i.e. Lighting, Air-conditioning and Computer Monitors) is about 80% of the total energy consumption.

As per IESCO (service provider) electricity bill of NUST, total electricity consumption of NUST for the month of June 2013 is 704,000 units. Now by assuming that 80% of the energy goes to Lighting, Space cooling and Monitors it will become 563,200 units for these three target areas. Whereas electricity bill for a typical month in winter is 624,000 units (Ref: Jan 2013) that will become 499,200 for the targeted load i.e., Heating, Lighting & computer monitors.

Based on the results of this study and by assuming 15% (on lower side) saving in the three selected areas, the energy saved would be 84,480 units i.e., equivalent to the saving of Rs. 1,520,640.00 in a typical summer month. Similarly for a winter month it is 74,880 units and equivalent to Rs. 1,347,840.00.

Thus considering an average monthly saving of 1,434,240.00 will lead us to a total saving of Rs. 17 Million annually with an approximate retrofitting cost of Rs. 60 Million and a payback period of 6.5 Years.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This attempt at the institute IESE building revealed that substantial energy saving potential exists in our educational institutions. Following conclusions can be drawn from this study:

- Only few measures accumulatively resulted in 64 MWh annually against approximate total load of 180 KW and yearly consumption of about 325 MWh (considered load only), which is 19.8 % of the considered load and roughly 12-14 % of total load of the institute.
- With this IESE can reduce 26.5 tons of Carbon Dioxide annually and contribute in global effort of GHG reduction.
- Thus the same once practiced for whole campus can result in annual saving of Rs. 17 million after a payback period of 6.5 years.

5.2 RECOMMENDATIONS

- It is highly recommended is to install sub-meters in each building at school or institute level so that individual performance could be monitored in terms of energy consumption and its own profitability. This will help in identifying energy wasting areas and create a competition for reduction in energy consumption between schools and institutes.
- Once energy meters are installed, findings of this study should be verified before implementation.
- Work out the feasibility of converting at least soft and critical loads (mainly computers, important lighting and critical low load laboratory equipments) on solar Photovoltaic systems instead of UPS (Uninterrupted Power Supply).
- Energy audits should be carried out at other institutes and schools after installations of sub-meters and for that complete set of Energy Management tools should be purchased so that self dependence could be achieved and the procedure can give accurate findings for decision making.
- NUST should device a “Campus Sustainability policy” with a define vision and high goals such as zero energy, zero waste and zero emissions.

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