A SUSTAINABLE DRIVE WITH ENERGY EFFICIENCY- AN EVALUATION OF BUILDINGS AND INDUSTRIES

A Project Report

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DECLARATION

I hereby declare that this submission is my own and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other Degree or Diploma of the University or other Institute of Higher learning, except where due acknowledgement has been made in the text.

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CERTIFICATE

This is to certify that the thesis titled **A SUSTAINABLE DRIVE WITH ENERGY EFFICIENCY- AN EVALUATION OF BUILDINGS AND INDUSTRIES** submitted by MUHAMMED THASLIM K A (R660214019), to the University of Petroleum & Energy Studies, for the award of the degree of **MASTER OF TECHNOLOGY** in Energy Systems is a bonafide record of project work carried out by him under my supervision and guidance. The content of the thesis, in full or parts have not been submitted to any other Institute or University for the award of any other degree or diploma.

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NOMENCLEATURE

AHU	Air Handling Unit
APFC	Automatic Power Factor Controller
BD	Billing Demand
BFP	Boiler Feed Water Pump
CFM	Cubic Feet per Minute
DG	Diesel Generator
ECM	Energy Conservation Measure
FTL	Florescent Tube light
GCV	Gross Calorific Value
HP	Horse-Power
HT	High Tension
LED	Light Emitting Diode
LT	Low Tension
kCal	kilo Calorie
kWh	kilo Watt Hours
kV	kilo Volt
MD	Maximum Demand
MH	Metal Halide
MWh	Mega Watt Hour
PF	Power Factor
SEC	Specific Energy Consumption
SLD	Single Line Diagram
SPB	Simple Payback Period
TR	Tonnes of Refrigeration
THD	Total Harmonics Distortion
V & A	Voltage and Ampere
Yr.	Year

ABSTRACT

Today we witness rising concerns about GHG emissions and climate change mitigation. Energy production and conversion cycles are observed to be the main sources of emissions, developing from the inefficient processes and unavoidable losses. With a share of 40% each of the total energy end use and 39% & 41% respectively of the total electricity end use (IEA 2015), buildings and industry sector are the main consumers of energy in India. . The high dependency on coal based power generation to meet the electricity demand made the situation more vulnerable. Any methodology to trim the energy consumption can contribute to the global climate mitigation goals.

Among the different mitigation technologies present today, energy efficiency has arisen as a multi-benefit-cost-effective option. Energy efficiency measures can be implemented in a process, be it building or industry, only after a detail examination of its energy consumption pattern. Energy audits are a powerful tool for energy efficiency, uncovering operational and equipment improvements that will save energy, reduce energy costs, and lead to higher performance. Whether looking for simple retrofits or a long-term investment project, an energy audit is the first step toward reducing energy use and improving the performance of facilities. More complex energy audits provide a comprehensive energy efficiency capital investment plan in line with the financial goals. This type of rigorous energy audit is typically part of a larger energy management program.

This project is an attempt to identify the major consumers of energy in a process-building and industry, to identify the energy saving opportunities with the help of detailed energy audit at the facilities. The key performance indicators coupled with different processes will be identified and compared to understand the behavior of general saving opportunities. Each energy conservation measure will be evaluated for their economic feasibility to value the degree of acceptability.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The term 'Sustainability' no longer needs an introduction. Now a days we see people, delegates and governments talking about their plans for sustainable development frequently. Sustainability can be associated with anything, be it a process, a technology, a company, or a country itself. Sustainable goals are painted to achieve the same. In brief sustainability encompasses three verticals – the triple bottom line concept – Social, Economic and Environment. It is undoubtedly necessary to meet all these three verticals in order to sustain here for a long time.

Today, the rising demand for energy and the global pledge for climate change mitigation has brought the environment concerns to intensified attention, which previously were neglected by some or many around the globe. Now as the environment verticals of the triple bottom line is gaining as much importance as the other two verticals, the reasons for environment related threats and climate change are examined in detail. Without much debate it is globally accepted that the rising energy consumption and energy production are proved to be the main contributors to pollution and climate change. The increased dependency on fossil fuels for energy production have made the situation more vulnerable with high level of GHG emission and global warming. A study shows that the mean annual surface temperature has increased by 0.4°C over the Indian subcontinent alone during the past 100 years (Hingane et al., 1985). The realization for a sustainable future has demanded prompt and effective methods to bring the climate change under control. Various climate change mitigation tools and green growth technologies are developed and implemented to offset the damages human has already done to the environment. Among the climate change mitigation tools existing the prominent ones are Renewable energy technologies, Carbon capture and sequestration, Energy Efficiency etc.

Unquestionably all of the climate mitigation technologies have gained high level of responses, and are delivering effectively, but all of them have different merits and demerits. Demerits of the mitigation tools may not necessarily be the technological limitation, but rather the geographical and political limitations. Energy efficiency has perceived as an effective mitigation tool with multiple benefits, also a prominent tool deployed in the Indian market. Though, it is still a concern that the inception of energy efficiency in India is far below the milestones the developed countries has achieved. Today, the point of worry is exponential as India is the second largest populated nation in the world, which is directly effecting the needs for basic facilities and energy. With growing population and its associated demand for facilities has resulted in sectors like buildings and industries to rise as the major consumers of energy in global level and in India. Thus sector wise policies and technological support for energy efficiency is highly necessitated.

This project is an attempt to identify the sector wise major consumers of energy in buildings and industries, and to identify the energy saving opportunities with the help of detailed energy audit at the facilities. Comprehensive energy audits will be carried out at buildings and industry as case examples to understand the energy consumption pattern and the feasibility of energy efficiency implementation. Additionally the project also evaluates the benefits of energy efficiency projects over other mechanisms as a climate mitigation tool.

1.2 ENERGY EFFICIENCY

Technology has experienced continuous changes throughout the years. Development of technology is an integral part of business, also increasing the competitiveness in the market. Today we see equipments and technologies which are well advanced than their pioneers. All or most of the new development is towards energy efficiency technologies, since it is an important factor that defines the life and cost factor of the product. Moreover, the advancement in technology and energy efficiency has proved as a reason to increase market presence. Energy efficiency can be seen in every energy conversion links of the chain: from exploration and production of primary resources, conversion to the secondary grade energy and till the end use at industry, building or in transportation.

Energy efficiency is considered as an alternative energy resource, since it is the energy which would otherwise have gone wasted. Moreover, energy efficiency helps to decrease the demand for primary energy resources and thus helps in achieving considerable savings. There is tremendous scope of energy efficiency along all the energy cycle chains. However energy efficiency is not alone dependent on the technology, yet the major deciding factor is the economy behind energy efficiency implementations. Hence a detailed feasibility study has to be run for identifying the technological and economical bottlenecks associated with each conservation opportunities. These studies can either be at equipment level, process level, industry level or national level. Thus it is evident that energy efficiency technologies will only be used when it is economically viable within their lifetime, and technologically feasible as well.

1.2.1 ENERGY AUDIT

Energy audit is the tool for energy efficiency. It is the first step towards energy efficiency which uncovers the operational and equipment energy conservation opportunities. Energy audits are carried out for the existing facilities, which identifies the losses occurring in energy chain and conversion cycles, quantifies it, and evaluates saving opportunities associated. Energy audits comes with recommendations including simple retrofits and long-term investment projects depending upon the economic viability and availability of investments. The general approach of any energy audit is pointed below:

- Identify areas of opportunity for energy saving and recommend an action plan to bring down total energy cost
- Conduct energy performance evaluation and process optimization study
- Conduct efficiency test of equipments and make recommendations for replacement (if required) by more efficient equipment with projected benefits
- Suggest improved operation & maintenance practices
- Provide details of investment for all the proposals for improvement
- Evaluate benefits that accrue through investment and payback period
- Analyze various energy conservation measures and to prioritize based on the maximum energy saving & investment i.e. short, medium and long term.

1.3 SECTORIAL ENERGY EFFICIENCY

The energy scenario of the starting years of industrialization is no more the same. The nations which were developing that time, are now the ‘developed’ countries. And amazingly only 20% of world population is living in those countries. The developed countries have already exploited the environment during their development process. While the developing countries today are experiencing energy shortages with high growth of population and increased demand of facilities. The earlier exploitation cannot be replicated for the 80% population, which would lead to environment catastrophes, with increased demand of facilities, all the sectors are expanding, which includes buildings, industries and transportation. The energy consumption pattern, equipments and process are different in different sectors. So it is the need of time to understand sector specific energy consumption pattern, the major consumers of energy and the possible conservation opportunities. Though there are many cross sectorial technological and policy initiatives are observed to be effective, sector wise energy conservation and climate mitigation policies has to be implemented to increase the pace of this process. An effective energy efficiency implementation plan can cut down the energy demand to desired levels.

1.3.1 BUILDING

Today, buildings are responsible for more than 40 percent of global energy used, and as much as one third of global greenhouse gas emissions, both in developed and developing countries.

The main source of GHG emission from buildings are undoubtedly its energy consumption. But it is noted that buildings are major emitters of other non-CO_2 greenhouse gases such as Halocarbons. It is observed that the rate of growth of emission from buildings, between 19971 and 2004, carbon dioxide emission has increased at a growth rate of 2.5% per year for commercial buildings, and 1.7% per year for residential buildings (Levine et al, 2007. What particularly worrying is that building sector also contribute to significant non-CO_2 GHG emissions such as halocarbons, CFCs, and HCFCs and hydro fluorocarbons (HFCs), which causes the damage of ozone layer and thereby increasing global warming. The reason being the use of refrigerant containing these substances in HVAC systems and incase of halocarbons insulation materials. Although certain rules have implemented to reduce the use of CFCs and HCFCs in HVACs, the replacement of older implementations are not complete.

While historically the majority of emissions emanated from developed countries, it is expected that the emission from buildings in developing countries will surpass that in the developed countries with increased population growth.

Most of the developed countries and many of the developing countries have already step forwarded towards greening the buildings, but certain limitation has arisen as a gap between the expected and the realistic. Unquestionably it is accepted that there is a huge potential of energy saving in building sector, though the practicality of achieving is same has many hurdles in its path. Building sector is spread across many stakeholders, which includes small residential buildings to large commercial or hospital buildings. The choice for energy efficiency implementation in buildings are entirely upon the owners choice, since there are very less numbers of governments who have put mandates for buildings related to energy efficiency. The volunteerism decision in building sector is mainly dependent on the economics behind the energy efficiency implementation. Lack of practical knowledge about energy efficiency implementation is another concern which has to be addressed in national level to increase the participation.

1.3.2 INDUSTRY

From the phase change from developing to developed, the inception of industries in global market was immense. In order to meet the requirements of a civilized world, the extent of development required in industry sector was huge. The main input to this change were human and energy. While it provided job opportunities for lakhs of people, it has severely damaged the ecological system with emission of carbon into living atmosphere. Today industry account for 40% of world's total energy consumption and 40% of India's total energy consumption. And the recent trends shows that there is a steep increase in the consumption pattern.

Most of the developed countries after understanding the severity of industrial operation on climate change has implemented energy efficient technologies in their industries to cut down the energy requirement. While on the other side, fast evolving developing countries are finding difficulties for a sudden shift to energy efficiency technologies considering the heterogeneous behavior of industries.

Countries like China and India, have risen as the main contributors to climate change GHG emissions, though their per capita energy consumption rates are well below the international and developed country rates. However, in track with the global motives, several policies are implemented to cut down the energy wastage and cut down the dependency on fossil fuels.

In India, one such policy has been developed under the under the National Mission on Enhanced Energy Efficiency (NMEEE). The mechanism was named 'Perform, Achieve & Trade (PAT)' which was launched by was launched by Bureau of Energy Efficiency (BEE) under Ministry of Power on 4^{th} July, 2012 at New Delhi. The mechanism identifies the energy intensive sectors in the country, and has mandated to conduct periodic energy audits to identify energy conservation opportunities and improve systems to reduce the energy demand. During first cycle of PAT, 9 industrial sectors were classified under energy intensive sectors which are

- Thermal Power
- Aluminium
- Cement
- Fertilizer
- Iron & Steel
- Pulp & Paper
- Textiles
- Chlor-Alkali

Additionally 3 new industry sectors has been classified as energy intensive from the second cycle of PAT starting from 2016. The 3 new entrants in the mechanism are:

- Railways
- DISCOMS
- Refinery

It is noted that these sectors alone are not responsible for rising energy demand in the nation. The role of MSME sector in India in its development is well noted who are the largest employers of the nation. They are also holding a major share of energy consumption of the country.

CHAPTER -2

LITERATURE REVIEW

2.1 THE RISING DEMAND FOR ENERGY EFFICIENCY

While arguments on the reserve of primary energy source are still going on, it is undoubtedly agreed that the energy resources are abundant for next 5-10 decades and can meet the growing demand in upcoming decades. The urge to reduce the consumption of energy are thus not limited to the fear of losing the existing reserves, but rather major implication caused by increased energy consumption such as climate change, and increased life cycle cost of equipments does plays a bigger role. With world striving to cleanse the energy and energy conversion cycles in order to achieve the global target of limiting the temperature rise within 2˚C, energy efficiency is most prominent solution.

The major driving forces of Energy Efficiency implementations are:

1. **Rising energy demand –** Due high growth rate of population, the demand for energy and commodities has increased.
2. **Demographic reasons-** Major share of primary energy sources are limited to only certain percentage of countries in the file. Many countries are dependent on very volatile gulf countries which are prone to war and political issues. This affects the energy security of the consumer countries.
3. **Climate change –** Evidentially the main reason for unlinking from dirty energy to a cleaner one, as the global strive for limiting the temperature rise within 2.5˚C has become more stringent.

Energy efficiency has risen as a promising option to reduce the energy demand, as well as a climate mitigation tool. The potential of energy efficiency projects have made it more attractive. Some examples are noted below:

- Irrespective of technology, process, or size and effective energy management system can increase the energy efficiency by at least 5%.
- Electric systems efficiency of Oil & Gas exploration can be increased up to 50% from current 20%.

- Coal fired power plants are giving an overall efficiency of 32-36%, which can be increased upto 46% with the help of Best Available Technology (BAT) implementations.
- An energy saving between 20-40% can be achieved in buildings.

2.2 THE ENERGY SCENARIO

2.2.1 GLOBAL

The global energy scenario has witnessed drastic changes during the last two decades. From the start of industrialization, there is a steep increase in demand for energy. Moreover the improved electrification has also became a reason for the increased demand for energy. From 1990 to 2010, a 25% of growth in global primary energy consumption was observed, and this is expected to rise in the upcoming year but at a lower pace than the previous decades.

Recent demand for green energy has brought new investments in renewable energy sector, though the current percentage of overall energy supply share from renewable energy is very low. Research and developments in the renewable energy sector is remarkable. However above all these coal remains as the major primary source of energy till date and is projected to maintain its position after two decades also. The dependency on coal based power generation from rising economies like China and India is considered to be the main reason for the same. The energy markets of China and India will be deciding the future trends of world energy consumption.

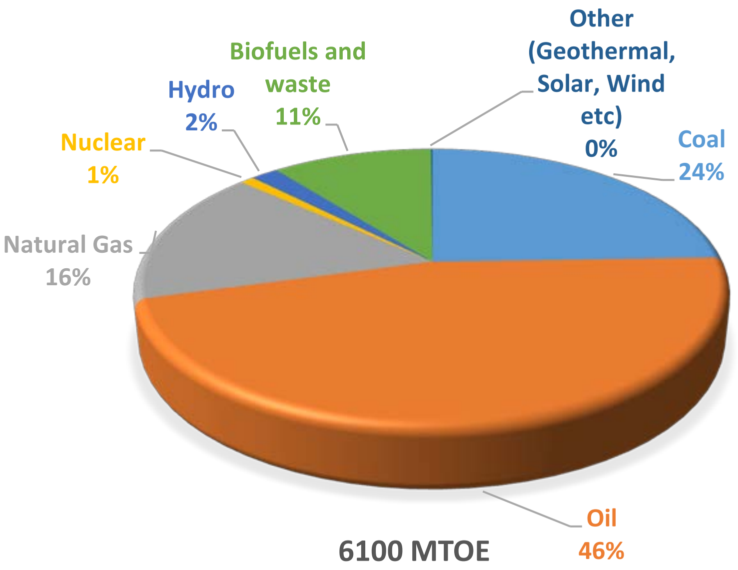


Figure 2.1: World energy supply share 1973

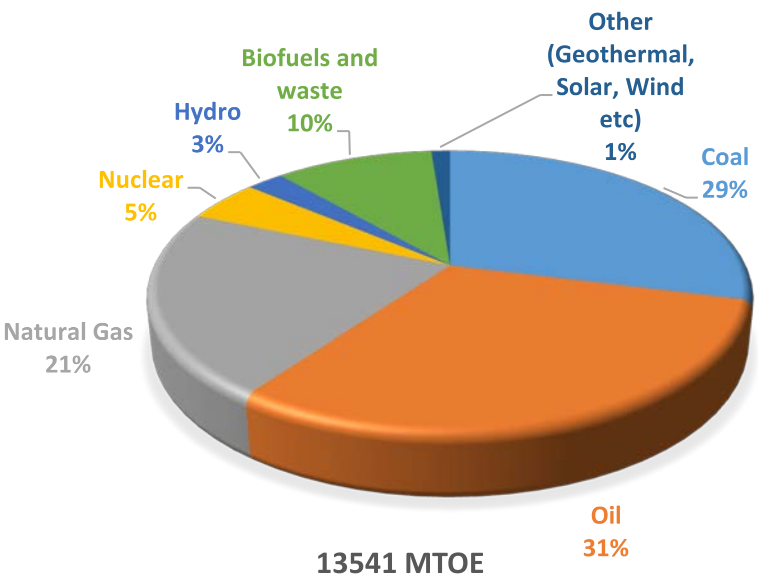


Figure 2.2: World energy supply share 2013

Oil based products haven't found any threat to its market, as transport sector is still waiting for a technological change. Natural gas, especially from unconventional sources, is finding more importance in power generation as it is considered as a green product. The recent fall of crude oil prices have relaxed the efforts to shift from the oil based products.

Forecasts shows that in the upcoming decades global and regional energy demand will be a challenge. There no single solution in the global level, rather the individual consumers has to reduce the demand from the demand end for a sustainable future. Effective policies at national levels could frame the energy consumption pattern of the future. International initiatives like COPs and Montreal Protocol have set global targets to limit the climate change factors, thus imposing national level targets.

2.2.2 INDIA

India has been responsible for almost 10% rise in energy demand globally since 2000. The energy demand has almost doubled in this period with an increase in global energy demand to 5.7% which was previously 4.4%. The concern is that this accounts for only 18% of India’s population share, which indicates that there will be a huge rise in demand with strengthening of Indian economy.

The rise in energy demand during this period is the result of economic growth and targeted policy interventions which has lifted millions out of extreme poverty. However this accounts for only one third of global average in energy consumption, and about 240 million people doesn’t have access to electricity. The situation is considered to get worsen, as increased energy efficiency implementations and subsidy reform can’t alone offset the rising demands for energy.

The major share of India’s energy demand is still met by fossil fuels, mainly coal for power generation. Recent trend indicates that the electricity demand has been increasing due to gradual move away of households from use of traditional solid biomass towards electricity for cooking.

Coal remains as the main source of primary energy for India with 70% power generation met by coal based thermal power plants. And recently the import of coal for power generation has increased from Indonesia and Australia. Furthermore the expansion plans in coal based power generation and extraction of Indian coal mines has put a question mark over the targets for climate change mitigation. Though the oil based and gas based power generation in India is very less, India was the world’s third-largest importer of crude oil in 2014. The increased refining capacity of India made it one the largest importer of crude oil, and at the same time one of the largest exporter of refined petrochemical products. Power generation capacity has increased over recent years, trying to reduce the supply gap, but the sector is facing serious threats due to high level of AT&C losses.

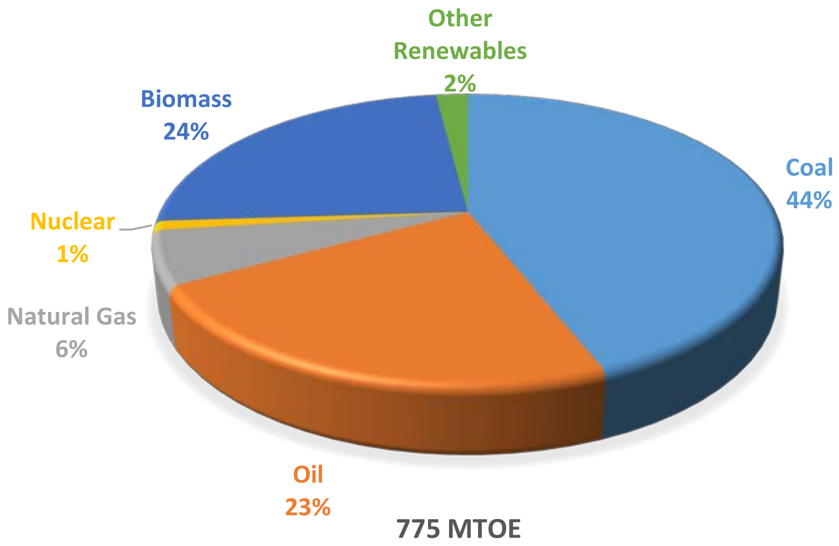
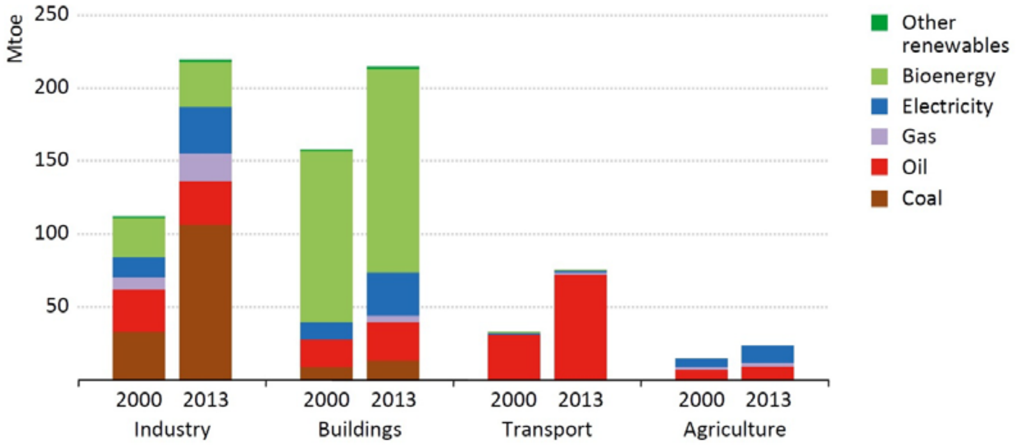


Figure 2.3. Primary energy demand India 2013

India's renewable energy sector is promising with high potential for hydro, solar and wind projects, but yet most of these are untapped. The data has shown that India has around 45GW of hydropower and 23GW of wind power. However India is aiming at a renewable energy installation of 175GW by year 2022, which is a steep increase from the current installation of 37MW. Solar is always one of the key element in India's renewable energy dreams, with certain solar missions already existing, like (Jawaharlal Nehru National Solar Mission).

Energy demand had historically been dominated by building sector (including both service and residential), which has been recently crossed by industry consumption. A rise of 8% in electricity demand from 2000 to 2013 is observed in building sector in India after the increased ownership of electrical equipments like fans, television, fridge, and increased demand of HVAC systems in urban areas. A notable shift from traditional biomass based cooking and heating, to electrical and oil based cooking systems have also added to the demand rise. The previous share of bioenergy in building sector has reduced from 75% to two third during 2000 to 2013.



Notes: Other renewables includes solar photovoltaics (PV) and wind. Industry includes energy demand from blast furnaces, coke ovens and petrochemical feedstocks.

Figure 2.4. Energy demand by fuel in selected end-use sectors in India

In 2000-2013 period, the industrial energy demand has almost doubled. One of the component is the large growth of energy-intensive sectors, including a tripling in steel production. In India, the consumption levels of cement and steel are still comparatively low: consumption of cement is around 220 kilograms (kg) per capita, well behind the levels seen in other fast-growing economies and a long way behind the elevated levels seen in China in recent years (up to 1 770 kg per capita). A small part of energy demand, the agricultural sector is a very important source of employment and after more farmers shifted to usage of electric pumps for irrigation purposes, the total final electricity demand is increased by 15 % since 2000.

Energy production and trade: Lack of very strong policy push in favour of alternative fuels, fossil fuel supply around three-quarters of India's primary energy demand and decrease in the traditional use of biomass, this share will tend to increase over time. The large and highly growing- reliance on fossil fuels have two major-drawbacks. India's domestically produced fossil fuels per capita is by far the lowest among the major emerging economies, meaning that India has a structural dependence on imported supply. In addition, combustion of coal and oil materials results to pressing air quality problems in many areas, as well as to global greenhouse gas (GHG) emissions.

More interestingly, In India, 18% of the world's populations uses only 6% of the World’s primary energy. Since 2000 India's energy utilization is almost doubled and have a great potential for the rapid growth.

India is set to contribute to the projected rise in global energy demand, more than any other country, around one quarter of the total: In 2040, the energy demand per capita is still 40% below the world average. India’s total energy demand more than doubles in our main scenario, propelled higher by an economy that is more than five times larger in 2040 and a demographic expansion that makes India the world’s most populous country. Because of the decreased use of energy in many developing countries and the less intensive phase in development scenario of China, India emerges as a major driving force in global trends, with all modern fuels and technologies playing a part. The largest source of growth in global coal use is because of the surging consumption of coal on power generation.

2.3 BUILDINGS AND INSUTRIES – AN ENERGY PERSPECTIVE

2.3.1 BUILDINGS

Buildings use about 40% global resources and global energy and 25% of global water and emit almost 1/3 of GHG emissions. Residential and commercial buildings consume approximately 60% of the world’s electricity. Performance levels of existing buildings is frequently far below current efficiency potentials so that they represent significant energy saving opportunities. Undoubtedly the building sector is the largest contributor to global GHG emissions.

A new study on energy efficiency in buildings (EEB) indicates that in 2050 the global building sector needs to cut energy consumption in buildings 60 percent to help meet global climate change targets. Buildings account for 40 percent of the world’s energy use with the resulting carbon emissions according to WBCSD, more than those in the transportation sector. The organization recommends that individuals, business and government start to aggressively decrease the use of energy in new and existing buildings in order to reduce the planet’s energy-related carbon footprint by 48 Giga tons or 77 percent (against the 2050 baseline) to stabilize CO_2 levels to reach the level called for by the Intergovernmental Panel on Climate Change (IPCC).

India’s urbanization is a key driver of energy trends: In 2040, an additional 315 million people- almost the population of the United States today, are expected to live in India's city. This change surely had wide ranging and fluctuating effects on energy use, accelerating the switch to modern fuels, the rise in appliance and vehicle ownership and pushing up demand for construction materials. In residential buildings comes from urban areas have three-quarters of the projected increase in energy demand which is driving the sector’s energy use away from solid biomass (two-thirds of the total today) and towards electricity and oil (45% and 15% of the 2040 total, respectively). There is a tremendous opportunity for India to expand and tighten efficiency standards and ensure that future demand for energy services – notably for cooling – is met without putting undue strain on energy supply because since most of the 2040 building stock has yet to be constructed. The scope of other efficiency measures for buildings and appliances, while expanding, is still far from comprehensive apart from the successful. Successful initiatives include a huge and cost-effective programme to replace old, inefficient light bulbs with LEDs. In 2015, a “Smart Cities” programme is launched, it puts a welcome emphasis on integrated planning and provision of urban services which includes power, water, waste and mass transportation, although faces the considerable challenge of coordinated delivery across different branches and levels of government.

2.3.2 INDUSTRIES

Undoubtedly energy is a very important key feature of industrial productivity growth. It is an important production input in industrial processes. On average, energy represents between 1% and 10% of total production costs. The share of energy costs is higher, that is between 15% and 40% on average for some energy intensive industries, such as steel, chemical, paper, pharmaceutical, cement and construction sectors.

The industrial sector consuming about half of the world’s total delivered energy and global estimate is that energy efficiency could reduce industrial energy use by more than 25% according to the global Institute for Industrial Productivity. Industrial Sector uses more energy than any other end-use sector.

The 60% of industry's total final energy consumption is only by developing countries and the economies in transition account. In recent decades, industries has significantly improved its energy efficiency. But as an outcome of continuing large increases in the volume of production, industry's total energy use continues to grow. In the coming decades, production is expected to continue to expand very substantially, particularly in developing countries. But as a result the modest energy efficiency improvement rates will not sufficient to stabilize or decrease the sector's energy demand in absolute terms. For making significant decrease the sector's energy demand in absolute terms, several energy savings measures need to be implemented.

Realizing that there is a reduction of 3% to 4% in the total costs of production after implementing the energy saving measures. The total current energy cost savings potential in industry is estimated to be around USD 230 billion a year (excluding the cost of the investments required to upgrade current levels of technology to BPT) in worldwide. Industrialized countries have the potential to save around USD 65 billion in energy costs. More than 70% of the global potential cost savings, i.e, around USD 165 billion can potentially save by developing countries and economies in transition which are equivalent to 2% of current industrial value added worldwide.

Potential energy savings of up to 34% by 2030 which is equivalent to an energy efficiency improvement rate of 1.7% a year is offered by implementing Best Available Technology (BAT). From country to country and from industry to industry, the drivers of energy efficiency varies. Energy efficiency is partly driven by high energy prices in some sectors. But in some other sectors, the high capital cost of investment in new and efficient plants is a major limitation on the rate of efficiency improvement in industry. This case is particular in some countries where interest rates are high and economy is unstable.

2.3.2.1 PULP AND PAPER SECTOR

During the project a comprehensive energy audit was conducted to understand the energy saving opportunities in a paper industry. Thus a brief about the Indian Paper industry sector is drawn below.

One of the fast growing industrial sectors in India is paper sector. In India, Paper industry in India is one of the 35 highest priority industries having a bearing on the socio-economic development of the country.

In Indian economy, Indian paper industry plays an important role with a contribution of with the contribution of Rs 300 million million (USD 0.7 billion) contribution to the exchequer and its contribution to the GDP is approximately Rs. 3000 million (USD 7 billion). The demand of paper in India has been in the of 8% for some time. Over last few years, the growth of an average of 6-7 percent in the GDP which is the reflection of the growth of Paper industry. In 2020, the paper consumption will estimated to catch 20 million tons, so that India is the fastest growing market for paper globally and it presents an exciting scenario.

Pulp & Paper industry is one of the major energy related industry. For paper production in India the consumption of steam and electricity per tonne is about 11-15 tonne and 1,500-1,700 kWh. The average specific energy is placed at 52 GJ per tonne of paper, which are nearly twice the North American and Scandinavian standards. The energy cost component has been increased at 16-25% of the total production cost of paper, and this is expected to increase over other inputs in the near future.

Important factors that affect energy consumption in the Pulp & Paper Industry in India are:

- Low level of capacity utilization
- Quality and type of paper produced
- Number and multiplicity of machinery
- Paper machine runnability and down time
- Finishing losses
- Boiler type & pressure levels
- Level of cogeneration
- Power generation

The Pulp & Paper sector in India is competing several developmental challenges to rise the global competitiveness on the following fronts - Capital expenditure, Energy Cost, Availability of raw materials, Green technologies & Quality improvement.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 MORPHOLOGY OF PROJECT

This project is an attempt to identify the major consumers of energy in a process-building and industry, to identify the energy saving opportunities with the help of detailed energy audit at the facilities. The key performance indicators coupled with different processes will be identified and compared to understand the behavior of general saving opportunities. The project has been divided into four phases. In the first phase, a detailed analysis of the benefits of energy efficiency and its significance in present scenario is studied from previous reports. This also evaluates the general energy conservation opportunities associated with buildings and industries.

In the second and third phase a detailed energy audit is conducted at a building and an industry to understand the energy saving opportunities of the same. The final phase consists of a detailed analysis of economical and technological feasibility study of energy efficiency implementation in the facilities. The direct and indirect benefits associated with energy efficiency are also discussed.

Figure 3.1 Phases of project

3.1.1 ENERGY EFFICIENCY – THE SOLUTION

To reduce the production cost in industry, providing the same output with a lower energy input is called energy efficiency. Consequences of high energy costs can be decreased and increase competitiveness while at the same time addressing security of supply and environmental concerns by improving the energy efficiency. Furthermore, energy efficiency is important in order to attain a sustainable energy future based on a variety of more intermittent energy sources.

Industry accounts for one-third of global final energy demand. As per International Energy Agency (IEA) a large potential remains untapped even tough industrial energy efficiency is improving at good pace. Industrial processes are heterogeneous which remains as the main challenge for industry energy efficiency. There are countless industrial processes and ways in which energy efficiency projects can be designed and implemented – ranging from replacing one piece of equipment to complete facility retrofit and modernization.

The impacts of industrial energy efficiency measures are calculated only in terms of greenhouse gas abatement, and sometimes in terms of energy demand reduction.

The different advantages associated with energy efficiency are:

- Improved productivity and competitiveness
- Reduced costs for environmental compliance, O&M and waste disposal
- Extended equipment lifetime
- Enhanced process and product quality
- Enhanced work conditions and decreased liability

While energy efficiency policy makers may see a certain logic in distinguishing between general projects and energy efficiency projects, this is not necessarily the case within industry, which is an important consideration. Enhanced energy efficiency leads to be viewed by industry as a by-product of initiatives undertaken for business reasons; it is rarely a targeted aim. When energy efficiency projects are linked to energy efficiency reporting requirements, in which case they may be viewed by industry as a burden on time, resources and finances or specific government targets, an exception has occurred.

It is often claimed that energy efficiency is not of strategic importance to companies and not part of core business. Considering a wider range of advantages from energy efficiency, and demonstrating their direct impact on business processes and productivity, can improve the business case for energy efficiency investments.

KEY DRIVERS FOR BUSINESS-LED ENERGY EFFICIENCY

For improving the bottom line- i.e. delivering a return on investment by improving profit margins, contributions are needed from company's investment. It can contribute to the strategic priorities of businesses in three key ways:

- Reduce costs: Energy efficiency can lead to lower expenses for water, materials, equipment repair and maintenance, etc. in addition to reducing the amount of money spent on energy
- Increase value (including improved value through diversification and innovation): energy efficiency can help companies win supplier contracts and access new markets in some cases, it can help companies generate value by improving product quality; Companies can also gain market share by highlighting their commitment to energy efficiency in advertising and branding.
- Mitigate risk: Energy efficiency can help mitigate energy price volatility (one of several risks) as energy and fuel prices influence the cost of products, lower energy consumption can help to keep down costs and create competitive advantage. Energy efficiency projects can also contribute reducing the risk of downtime and to improving processes. Some energy efficiency projects can reducing risks of negative health impacts or accidents so that improve worker safty. At present, energy efficiency implementation is sometimes associated with increased risk – for example, risks stemming from the need to change processes or impacts of equipment replacement on processes. More well-calculated assessments will contribute to better management of such risk and help dispel unfounded risk perceptions.

In fact, research indicates companies typically demand shorter payback periods for energy efficiency investments than for other investments. In many cases, the payback periods for energy efficiency is two years or less, equivalent to a discount rate of considerably more than 50% (McKinsey Global Institute, 2007).

3.1.2 BUILDING ENERGY EFFICIENCY OPPORTUNITIES

Building energy efficiency starts right from the planning stage. A properly designed and located building can offset many energy requirements. Located at proper place with rightly designed to balance the light intrusion and reduce heat infiltration according to the sun path is the most effective energy efficient measure. Regulating a building's temperature and illumination, its location and surroundings plays a key role. For example, trees, landscaping, and hills can provide shade and block wind. Designing buildings with south-facing windows increases the amount of sun (ultimately heat energy) entering the building in cooler climate minimizing the use of energy maximizing passive solar heating. Energy-efficient windows, well-sealed doors, and additional thermal insulation of walls, basement slabs, foundations and such tight building design can reduce heat loss by 25-50%. Dark roofs may become up to 39 C° (70 F°) hotter than the most reflective white surfaces, and could transmit some of this additional heat inside the building. Lightly colored roofs use 40% less energy for cooling than buildings with darker roofs according to US Studies. During sunnier climate, white roof system saves more energy. Advanced electronic heating and cooling systems can moderate energy consumption and improve the comfort of people in the building. We can reduce the need of artificial lightening by proper placement of windows and skylights as well as the use of architectural features that reflect light into a building.

Increased use of natural and task lighting has been shown by one study to increase productivity in schools and offices. Comparing incandescent light bulbs, Compact fluorescent lights use two-thirds less energy and may last 6 to 10 times longer. Newer fluorescent lights produce a natural light, and in many applications they are costly, despite their higher initial cost, with payback periods as low as a few months. low cost Passive Infra Reds (PIRs) uses in effective energy-efficient building design to switch-off lighting when areas are not contain toilets, corridors or even office areas out-of-hours. In addition, daylight sensors can use to measure the lux levels linked to the building's lighting scheme to switch on/off or dim the lighting to pre-defined levels to take into account the natural light and thus reduce consumption. All of this together linked in one centralized computer to control the whole building's lighting and power requirements by Building Management Systems (BMS) . The choice of space heating or cooling technology in buildings can have a significant impact on energy use and efficiency. we can use city wastes by district heating and cooling systems. For example, replacing an older 50% efficient natural gas furnace with a new 95% efficient one will dramatically reduce energy use, carbon emissions, and winter gas bills. Ground source heat pumps can be even more energy efficient and cost effective. In order to "pump" heat against its natural flow from hot to cold, for the purpose of transferring heat into a building from the large thermal reservoir contained within the nearby ground systems use pumps and compressors to move refrigerant fluid around a thermodynamic cycle The end result is that heat pumps typically use four times less electrical energy to deliver an equivalent amount of heat than a direct electrical heater does. Ground source heat pump can be reversed in summertime and operate to cool the air by transferring heat from the building to the ground which is another advantage of ground source heat pump. The disadvantage of ground source heat pumps is their high initial capital cost, but this is typically recouped within five to ten years as a result of lower energy use. Smart meters are slowly being adopted by the commercial sector to focus staff on energy issues and for internal monitoring purposes the building's energy usage in a dynamic presentable format. The use of Power Quality Analyzers can be introduced into an existing building to assess usage, harmonic distortion, peaks, swells and interruptions amongst others to ultimately make the building more energy-efficient. Often such meters communicate by using wireless sensor networks.

3.1.3 INDUSTRY ENERGY EFFICIENCY OPPORTUNITIES

A large amount of energy to power a diverse range of manufacturing and resource extraction processes uses by industry for various purposes. Large amounts of heat and mechanical power are required by many industrial processes and most of which is delivered by natural gas, petroleum fuels and as electricity. Some industries generate waste streams that can be recovered to provide additional energy. Industrial processes are so diverse from the cold or low temperature required process to the high temperature required process, so that it is impossible to describe the multitude of opportunities for energy efficiency improvements in industry. A lot of processes and energy services that are widely used in many industries. Mostly depend on the specific technologies and processes in use at each industrial facility. However effective energy management in industry, irrespective of size, technology or process, will increase energy efficiency by at least 5%. Reduced process heat level and amount or recover the waste heat from process or utilities provides important Energy Efficiency opportunities in many countries by implementing co-generation. Various industries co-generate steam and electricity for subsequent use within their own facilities. The heat that is produced as a by-product when electricity is generated and it can be captured and used for process steam, heating or other industrial purposes. 90% of fuel can be converted into usable energy by co-generation. Advanced boilers and furnaces can operate at higher temperatures while burning less fuel. These technologies are more efficient and produce fewer pollutants. Over 45% of the fuel used by US manufacturers is burnt to produce steam. The typical industrial facility can reduce its energy usage by 20% (according to the US Department of Energy) by insulating steam and condensate return lines, stopping steam leakage, and maintaining steam traps.

Electric motors are by far the most important type of electric load in industry using about 70% of the consumed electricity. In the tertiary sector, electric motor systems use about one third of the consumed electricity. Electric motors usually run at a constant speed, but a variable speed drive allows the motor's energy output to match the required load. This achieves energy savings ranging from 3 to 60%, depending on how the motor is used. Motor coils made of superconducting materials can also reduce energy losses. Moreover, motors can also benefit from voltage optimization. Industry uses a large number of pumps and compressors of all shapes and sizes and for a wide variety of applications. The efficiency of pumps and compressors depends on many factors but often improvements can be made by implementing better process control and better maintenance practices.

According to the US Department of Energy, optimizing compressed air systems by installing variable speed drives, along with preventive maintenance to detect and fix air leaks, can improve energy efficiency by 20 to 50%.Compressors are commonly used to provide compressed air which is used for sand blasting, painting, and other power tools.

3.2 CASE STUDY ANALYSIS

3.2.1 ENERGY AUDIT OF BUILDING

A comprehensive energy audit was carried out at a commercial building facility as part of their energy conservation program. The aim of the energy audit was to bring out opportunities for energy savings, and to reduce the overall operational cost of the facility.

3.2.1.1 **PROJECT BACKGROUND**

Energy audit was carried out at a commercial building located in Gurgaon. The overall area of the building was 59363 m^2. The scope of the audit was limited only to the facility's common area. The audit was performed in the month of January 2016, and the calculations are based on the data analyzed for the time period January 2015 to December 2015. The performance test under energy audit was carried out for the below tabled equipment.

Table 3.1: Systems Covered Under Study

INVENTORY	
PARTICULARS	INSTALLATION
Transformers	3
DG	6
Chiller	5
CHW primary pump	5
CHW secondary pump	3
Condenser pumps	5
STP system	1
WTP system	1
BMS system	1
AHU	78
Lighting (Common area)	

The total estimated power & energy consumption of the facility for the last year is shown below:

Table 3.2: Energy Consumption by the Different Systems

PARTICULARS	POWER	ENERGY
	KW	KWH/YR
Chillers	399.3	2346500
Primary pumps	20.7	144900
Secondary pumps	41.7	249500
Condenser pumps	103	672100
CT fans	36.95	227950
STP plant	29.5	109654
WTP plant	24	124000
AHUs	252	1765526
Lighting system	53.097	279190
Fire fighting system	144	0

3.2.1.2 PRESENT ENERGY SCENARIO

<u>E2NERGY SOURCES</u>

Energy for the building operation is conceived from 2 sources in this facility

1. Electricity from Haryana State Electricity Board
2. Electricity from DG operation during power fails from the grid

Table 3.3: Energy source distribution

PARTICULARS	ELECTRICITY (LAKH KWh)	COST (LAKH Rs)
EB	114.07	982.9
DG	17.54	249.55
Total	**131.61**	**1295.04**

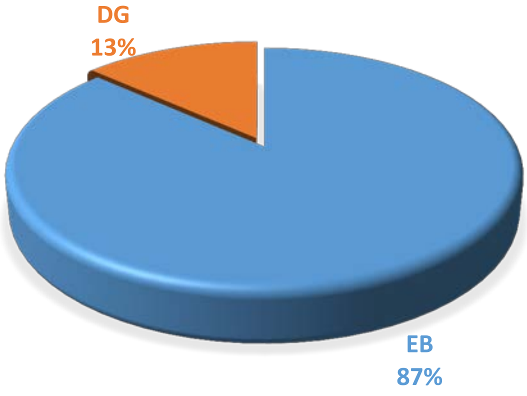


Figure 3.2: Energy consumption distribution

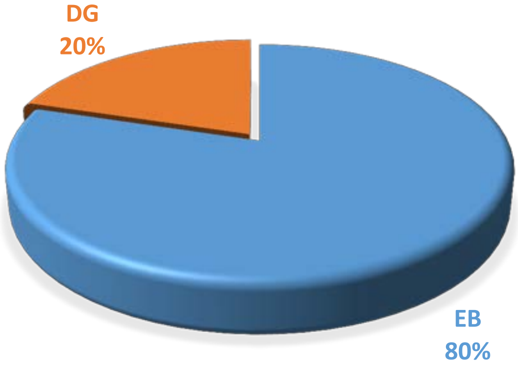


Figure 3.3: Energy cost distribution

ENERGY PERFORMANCE INDEX (EPI)

Energy performance index of a building is indicated as the electricity consumption by building in a year. It shows in terms of kWh/yr/m^2. It gives an indication that how much energy is being consumed per unit area per year. The EPI of the building was calculated on the basis of electricity consumption and area provided during the energy audit and shown below:

Table 3.4: Energy Performance Index (EPI)

PARTICULARS	UNITS	VALUE
Building ID		SP Infocity
Climatic Zone		Composite
Electricity consumption	kWh	13159257
Area	m^2	59363
Operating hrs/day	Hrs/day	24
No of operating days	Day/week	7
AAhEPI		25
Star rating		5

3.2.1.3 ELECTRICAL SYSTEM

Electricity is consumed from Dakshin Haryana Bijli Vitaran Nigam (DHBVN) through 3no.s of transformers. As per the Tariff scheme electricity bills are generated on monthly basis. Following is an analysis of the last year's electricity bill.

Table 3.5: Electricity bill analysis

Month	Electricity Consumption		PF	Total Cost	Electricity Cost
	kWh	kVAh		Rs	Rs/kWh
Nov-14	1115472	1138080	0.98	8773216.00	7.9
Dec-14	1026096	1039344	0.99	8890932.00	8.7
Jan-15	810432	814320	1.00	6949288.00	8.6
Feb-15	790848	797808	0.99	6811932.00	8.6
Mar-15	730848	734640	0.99	6371051.00	8.7
Apr-15	674064	675120	1.00	5977686.00	8.9
Jun-15	767280	770976	0.99	6642004.00	8.7
Jul-15	846336	848736	1.00	7212001.00	8.5
Aug-15	1044816	1050048	1.00	8643042.00	8.3
Sep-15	1017792	1023456	0.99	8448200.00	8.3
Oct-15	1271568	1277856	1.00	10913709.00	8.6
Nov-15	1309104	1320432	0.99	12657582.00	9.7
	11404656.00	**11490816.00**	**0.99**	**98290643.00**	**8.6**

Following graph is shows the trend of electricity consumption during the year.

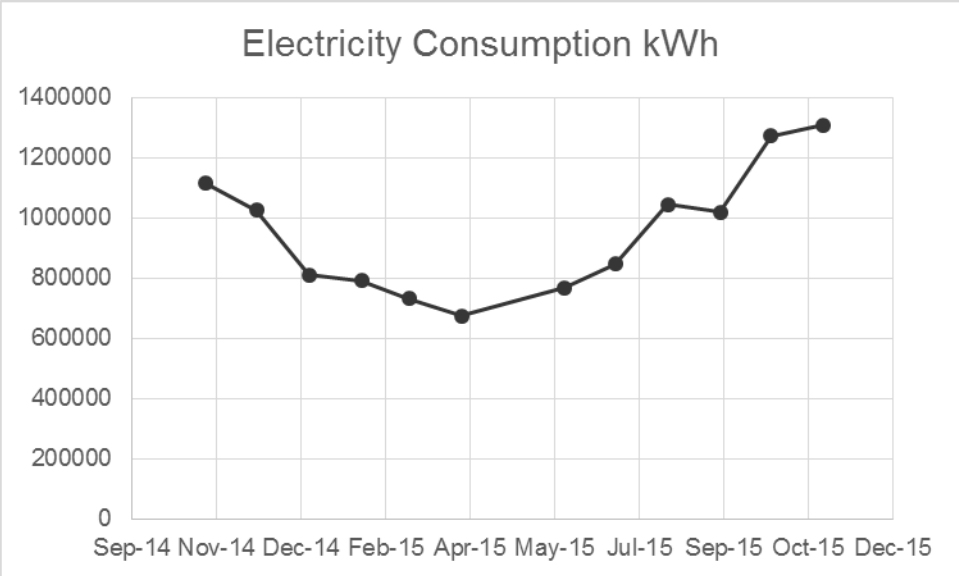


Figure 3.4: Electricity consumption behaviour

- The variation of energy consumption in graph (Apr- Sept) indicates the more operating hours of HVAC system like chillers and associated pumps and accessories.
- Total electricity consumption of the facility in 12 months is 114.4 Lakh kWh with a corresponding cost of Rs 982 Lakh.
- The average estimated landed energy cost (Rs/kWh) is calculated as Rs 8.6/kWh for the use of saving calculation in report.
- The power factor of the unit is being maintained near to unity and due to good maintenance of power factor the facility is enjoying a PF incentive of Rs. 70 Lakh for the period of last 12 months.

TRANSFORMER

Three Numbers of transformers (2 operational) are allocated to fulfill the electricity demand for the building. The transformers are the capacity of 2000 kVA each and out of these three transformers 2 are in operational condition.

Table 3.6: Transformer Specification & Loading Measurement

Particulars & Unit	Values	
Transformer ID	1	2
Make	Universal	Universal
Rated KVA	2000	2000
Primary Voltage, V	11000	11000
Secondary Voltage, V	433	433
Primary current, A	105	105
Secondary current, A	2782.5	2782.5
Measured KVA	800	856
Measured KW	794	852
% Loading	40%	43%

The load profiling on each transformer was established by using a three phase power analyzer. The result is shown below:

VOLTAGE PROFILE

Following figure shows the voltage variation with respect to time.

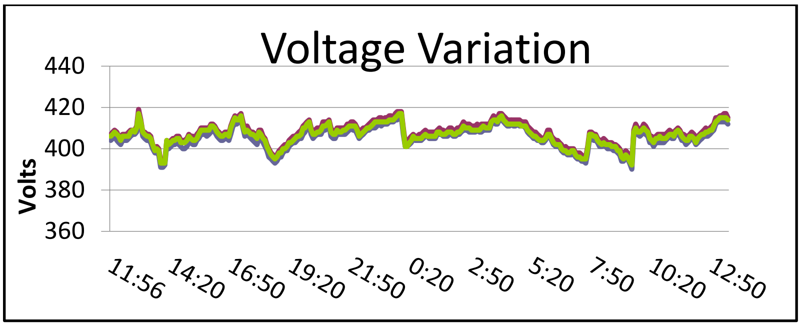


Figure 3.5: Voltage Profile (LT Panel -1)

- The graph indicates that there is less voltage variation in the circuit.
- The maximum line voltage in the circuit is 419 V while the min. is 393 V it is within range of 5%.

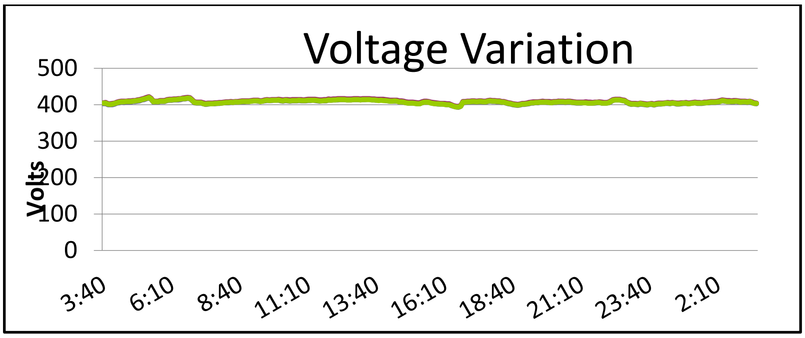


Figure 3.6: Voltage Profile LT Panel -2

- The graph indicates that there very less voltage variation in the circuit.
- The maximum line voltage in the circuit is 405 V while the min. is 400 V.

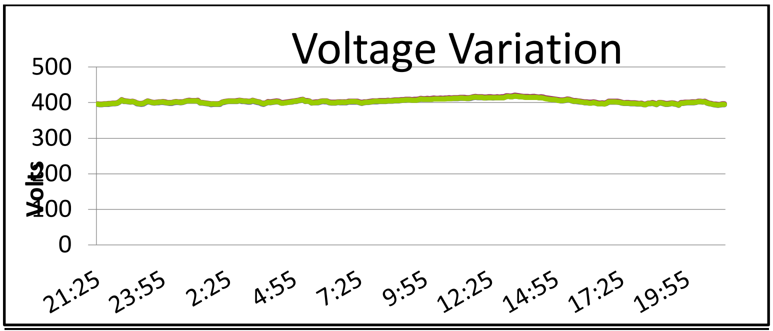


Figure 3.7: Voltage Profile LT Panel -3

- The graph indicates that there is very less voltage variation in the circuit.
- The maximum line voltage in the circuit is 405 V while the min. is 400 V.

LOAD PROFILE

Following figure shows the profile of power.

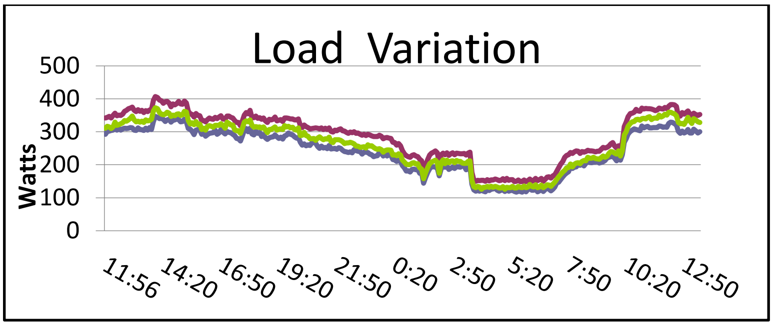


Figure 3.8: Load Profile LT Panel -1

- More load observed in Y- phase in all condition.
- The load on phase-B need to be checked for balancing the load.

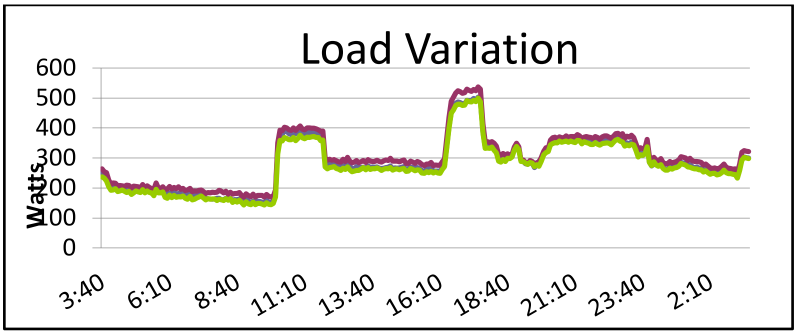


Figure 3.9: Load Profile LT Panel -2

- Good load balancing in all phases of the circuit.
- Variation of load with time depends on the requirement of the client side.

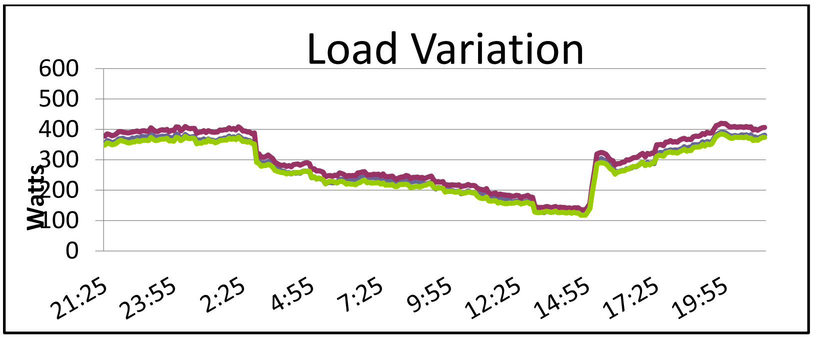


Figure 3.10: Load Profile LT Panel -3

- Good load balancing in all phases of the circuit.
- Variation of load with time depends on the requirement of the client side.

POWER FACTOR PROFILE

Following figure shows the profile of power factor.

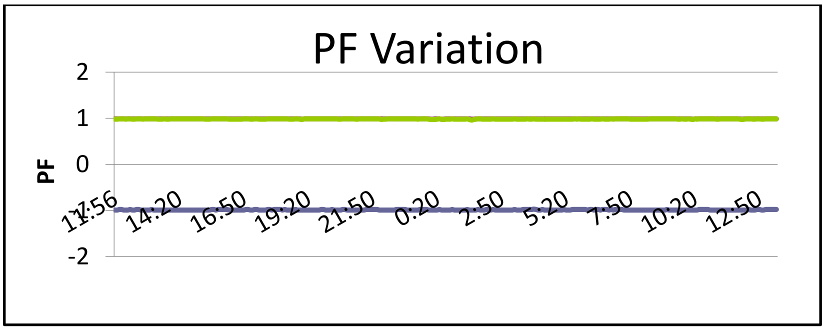


Figure 3.11: Profile of Power Factor LT Panel -1

- Loading power factor observed in R-phase of the circuit.
- It is required to check the connected capacity of capacitor in the phase.

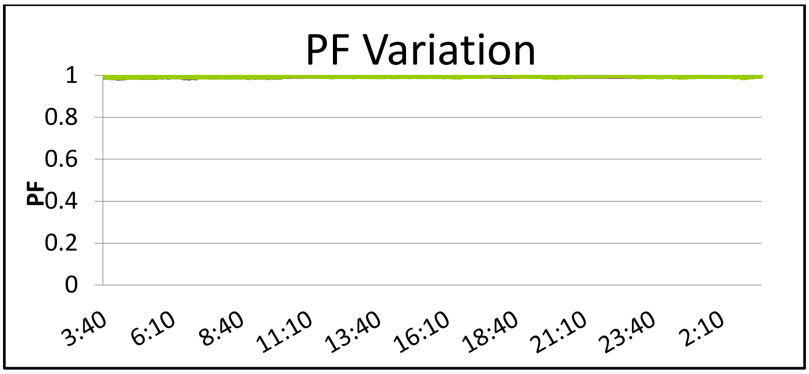


Figure 3.12: Profile of Power Factor LT Panel -2

- Power factor in the circuit is maintained good and near to unity.

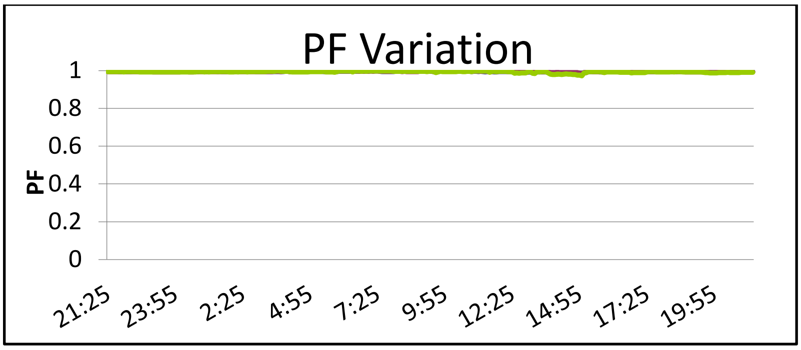


Figure 3.13: Profile of Power Factor LT Panel -3

- Power factor in the circuit is maintained good and near to unity.

TOTAL HARMONICS DISTORTION (%VTHD) PROFILE

Following figure shows the profile of voltage harmonics.

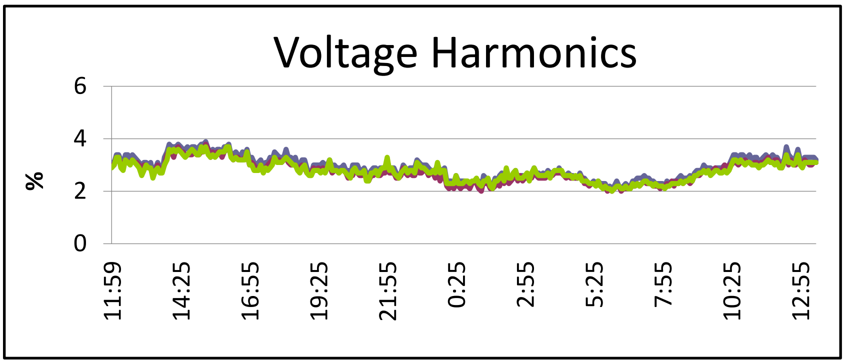


Figure 3.14: Voltage Harmonics LT Panel-1

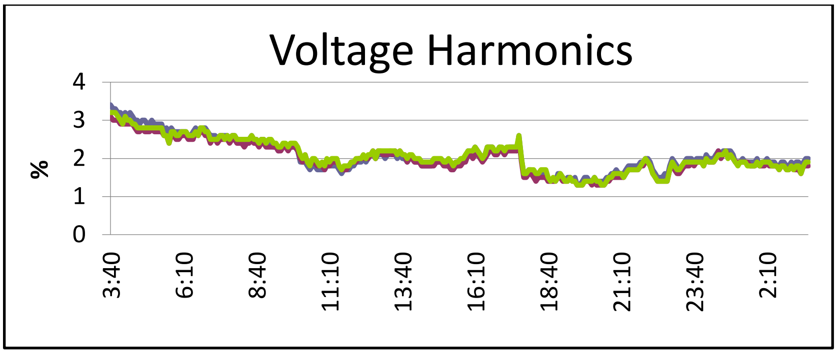


Figure 3.15: Voltage Harmonics LT Panel -2

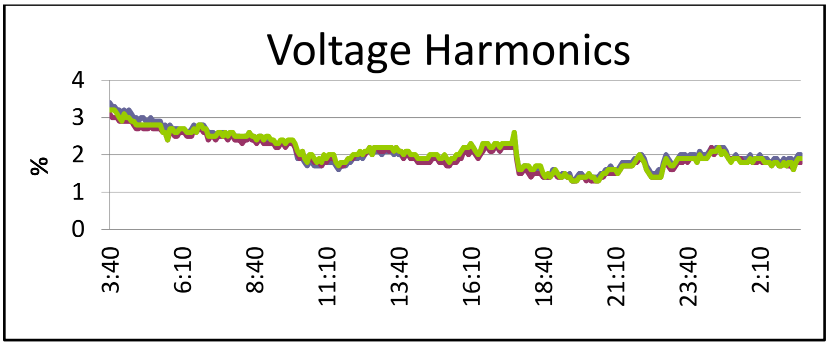


Figure 3.16: Voltage Harmonics LT Panel -3

- As per IEEE-519 1992 for below bus voltage less than 69 kV VTHD should less or 5%.
- Voltage harmonics in all three LT panel circuit is less than 5% & within permissible limit.

<u>TOTAL HARMONIC DISTORTION (% ITHD) PROFILE</u>

Following figure shows the profile of current harmonics.

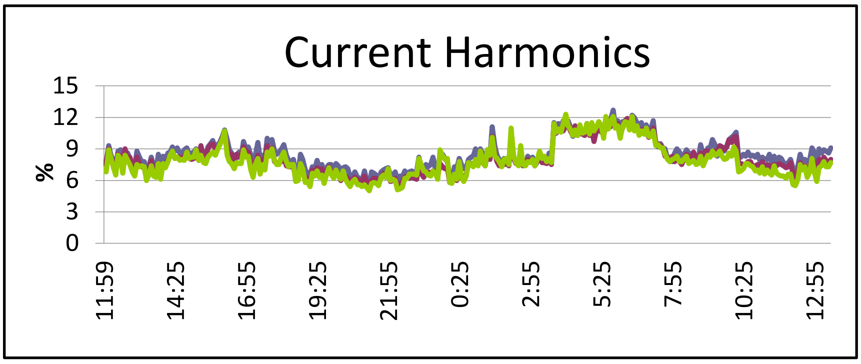


Figure 3.17: Current Harmonics LT Panel -1

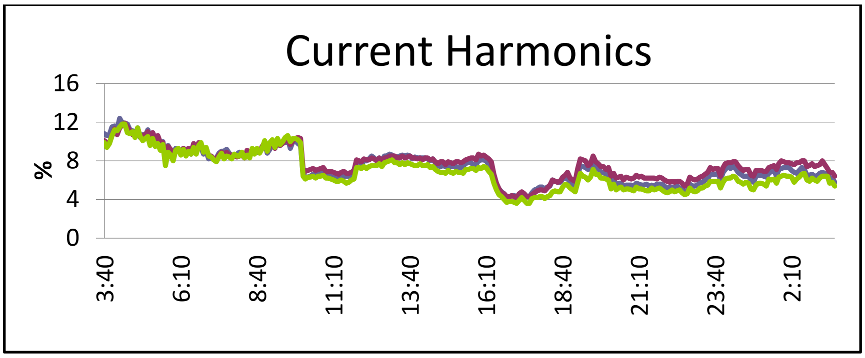


Figure 3.18: Current Harmonics LT Panel -2

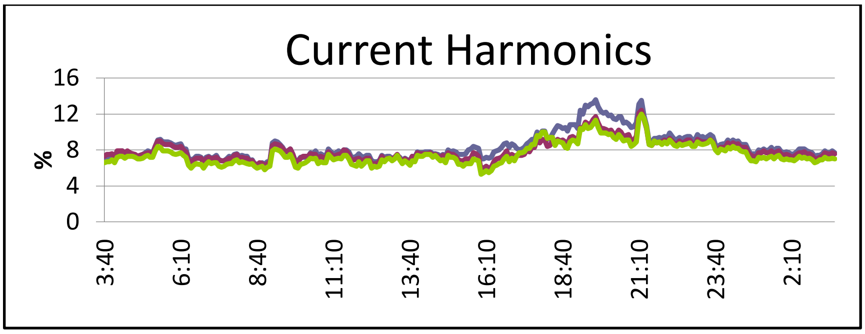


Figure 3.19: Current Harmonics LT Panel -3

- As per IEEE-519 1992 for current harmonics limit and 15%-20% in circuit.
- Current Harmonics in all three LT panel circuit is within permissible limit.

3.2.1.4 PERFORMANCE EVALUATION OF UTILITIES

HVAC SYSTEM

HVAC system in the facility consisted of 5 numbers of chillers which is supplying the chilled water to AHUs of the building. In general two chillers are in operating condition and in peak time three/four chillers are required to run. The chillers are running in alternatively to maintain all the chillers in running condition and reduce the maintenance due to idle condition of chillers. The chillers are receiving water from primary pumps as high temperature water and supplies to secondary pumps to further provide chilled water to AHUs in the facility.

Design details of chillers were collected and chiller performance measurement of operating chillers was performed. To measure the performance flow of chilled water in individual chiller, inlet & outlet temperature of chilled water, and compressor power measurement was taken and performance in terms of specific power consumption of chiller (kW/TR) was calculated and the result is shown below:

Table 3.7: Chiller performance calculation

CHILLER CALCULATION			
S. NO	DESCRIPTION	CHILLER-4	CHILLER-5
1	Type of Chiller		
2	Make	CLIVET	Daikin McQay
3	Model Number	NA	PFS4653DARY0000109
4	No of compressor	3	
5	Type of Chiller	WDH/33.53	
6	Refrigerant	R 134a	R 134a
7	Power consumption	487	263
9	Chilled water flow (m3/hr)	328	380
10	Chilled water inlet temperature (^{O}C)	10.8	12.7
11	Chilled water outlet temperature (^{O}C)	7.9	9.5
12	Chilled water ” T, (^{O}C)	2.9	3.2
13	Chilled water set point (^{O}C)	6	7
14	No of compressors in operation	2	2
15	Net refrigeration capacity (TR)	314.55	402.12
16	Compressor power (kW)	224	175
17	Specific energy consumption (kW/TR)	0.71	0.44

- Out of 5 chillers installed performance measurement of two (operational) chillers was done. During the audit period only 2 chiller were in operation.
- The total instantaneous refrigeration load during the audit was measured 718 TR. However due to weather condition variation takes places in the capacity.
- The total yearly energy consumption for the chiller 4 & 5 is 2027060 kWh in normal condition.
- The specific power consumption of both chiller (ranging from 0.44 to 0.71 kW/TR) is good and out of both chiller 4 & 5 SEC of chillers 5 is very good compared to SEC of chiller-4. It was also observed that chiller -5 is running always as a saving/good engineering practice.

CHILLED WATER PUMPING SYSTEM

There are two types of chilled water pumping system and condenser water system associated with chiller system. Primary pumps are receiving the chilled water (return from AHU) and supplies to chillers for further cooling. The chilled water after chillers is supplied to secondary pumps which further supplies the chilled water to

AHUs. Condenser pumps are receiving water from cooling tower and supplying water to condenser before returning to cooling tower in a close loop.

There are 5 nos of primary pumps, 3 nos of secondary pumps and 5 nos of condenser pump were installed in the facility. The design details of the pumps were collected and performance measure like flow measurement and power measurement was performed and result is shown below:

Table 3.8: Primary and Secondary Pump Design Details

DESIGN DETAILS				
	UNIT	PRIMARY	SECONDARY	CONDENSER WATER
No of pumps installed	Nos	5	3	5
Make		Beacon	Grundfos	Beacon
Flow	m^3/hr	183	295	385
Head	m	15	19.5	26
Power	kW	11	22	37

The secondary pumps were connected with VFDs. And the performance measurement was taken when two pumps of both systems were running (as a process requirement). Therefore the flow & power were measured combine and the result is shown below:

Table 3.9: Primary, Secondary and condenser Pump Analysis

PARTICULARS	UNIT	PRIMARY PUMP		SECONDARY PUMP	CONDENSER PUMP		
Measurement		2	3	1 & 2	2	3	4
Pump flow	m^3/hr	190	190	380	366	320	317
Suction Head	m	NA	NA	NA	NA	NA	NA
Discharge Head	m	NA	NA	NA	NA	NA	NA
Power consumption	kW	28.6	29.2	28.1	39.1	40.2	23.04
Specific water flow	m^3/kW	6.6	6.5	13.5	9.4	8.0	13.8
VFD Frequency	Hz	No VFD	No VFD	45	No VFD	No VFD	No VFD

- It was observed that the none of the installed pressure gauges are working andon condenser pump no pressure gauges are available on either side (suction & discharge).
- It was also observed that the valves of condenser water line in other chiller (2 nos in chiller-3 and 1 in chiller-1) is not being closed and water is being

circulated even the chiller is not in operation. As a result more nos of pump are being required to run to get the sufficient amount of cooling. The water flow was measured in non-working valve pipe line and it was found that one condenser pump can be stopped if all the valves will be operated properly.

AIR HANDLING UNITS

AHUs are being used to cool the air which is being supplied to cool work station area, passage area, and canteen area. A total of 48 numbers of air handling unit are installed in the unit to fulfil the cool air demand of the unit. 5 nos of AHUs on each floor are installed to fulfil the cooling demand of respective area. The maintenance of all AHU is coming under the facility management team's scope. The performance study of all AHU of occupied floors was carried out during the audit inroder to understand the cooling status of the facility.

The performance of operating (during audit) AHUs were measured and measured air flow, humidity & temperature, power consumption and TR calculation for the same is shown below

Table 3.10: AHU Performance Measurement & Calculation

Floor ID	Tower ID	AHU ID	Design Parameters			Measured Parameter			CFM Loading %
			CFM	kW	CFM/kW	CFM	kW	CFM/kW	
Ground Floor	**A**	**1**	19000	7.50	2533	14427	8	1803	76
	A	**2a**	8000	3.75	2133	7333	3.7	1982	92
	A	**2b**	8000	3.75	2133	6317	3.4	1858	79
	A	**4**	15000	7.50	2000	14671	7.8	1881	98
	B	**5**	22000	7.50	2933	10004	7.5	1334	45
	B	**6**	15000	7.50	2000	14421	7.49	1925	96
	B	**7**	15000	7.50	2000	6173	3.75	1646	41
Third Floor	**B**	**5**	20000	7.50	2667	5317	7.36	722	27
	B	**6**	20000	7.50	2667	11809	8.96	1318	59
	B	**7**	22000	7.50	2933	11745	8.5	1382	53
Fourth Floor	**A**	4	16000	7.50	2133	14913	9.5	1570	93
	A	3a	8000	3.75	2133	3891	3.25	1197	49
	A	3b	8000	3.75	2133	6292	3.25	1936	79
	B	5	20000	7.50	2667	11331	7.31	1550	57
	B	6	20000	7.50	2667	10692	10.7	999	53
	B	7	20000	7.50	2667	6632	5.81	1141	33

Fifth Floor	**A**	1	17000	7.50	2267	8107	3.2	2533	48
	A	2a	8000	3.75	2133	6042	2.3	2627	76
	A	4	16000	7.50	2133	12345	10.6	1165	77
	B	5	20000	7.50	2667	12656	7.52	1683	63
	B	6	20000	7.50	2667	12885	7.7	1673	64
	B	7	20000	7.50	2667	9869	5.45	1811	49
Sixth Floor	**A**	1	17000	7.50	2267	11772	7	1682	69
	A	2a	8000	3.75	2133	6435	3.7	1739	80
	A	4	20000	7.50	2667	16857	7.5	2248	84
	B	5	21000	9.38	2240	18002	4.7	3830	86
	B	6	21000	7.50	2800	17953	7.4	2426	85
	B	7	20000	7.50	2667	12413	6.04	2055	62
Seventh Floor	**A**	1	17000	7.50	2267	9555	7.34	1302	56
	A	2	8000	3.75	2133	4901	3.6	1362	61
	A	4	14000	5.63	2489	12211	5.5	2220	87
	B	5	22000	9.38	2347	11006	6.89	1597	50
	B	6	21000	9.38	2240	13955	6.14	2273	66
	B	7	21000	9.38	2240	15005	6.27	2393	71

- It was observed that 28% of all measured AHUs are working at less capacity (<60% CFM) when compared to design capacity (CFM) indicated as shaded colour in table. The less loading of motors will results in reduction of motor efficiency and further leads to loss of energy.
- It was also observed that material was stored in few AHU rooms. It leads to increase more electrical load on chiller to provide sufficient cooling.

LIGHTING SYSTEM

The common area (Indoor & Outdoor) of facility is equipped with different types of lighting like 4X18 W FTL fixture (with electronic ballast), 36/28 W FTL (with EB) and 9/18 W CFL. 4x18 W FTL fixtures are installed in lift lobby area and 36/28 W FTL are installed in parking area in basement, LT panel /DG room, chiller room etc. 9 W CFL is installed in area of stair case and roof top. The outdoor lighting is equipped with 150 W mercury vapour lights. The inventory of lighting was collected and total operational load was calculated 53 kW. The inventory table and calculation is shown below:

Table 3.11: Common Area Lighting summary (indoor & outdoor)

TYPE OF LIGHT	NOS	POWER KW	ANNUAL ENERGY KWH/YR
36 W FTL	353	12.7	75613
28 W FTL	330	9.2	54978
4x18 W FTL	303	21.8	114970
150 W MVL	27	4.3	12852
9 W CFL	122	2.0	11727
18 W CFL	169	3.0	9050
Total		**53**	**279190**

- The total operating lighting load is calculated as 53 (includes outdoor lighting) kW of common area.

LUX MEASUREMENT

LUX measurement in common area was performed as sample basis and the result is shown below:

Table 3.12: Lux measurement in Common Areas

Tower ID	Floor ID	Area ID	Lux	Remarks
	Basement	CBRE office	170	All light 'ON'
		Chiller room	102	
		Panel room	114	
		WTP room	64	
		STP room	36	
Tower A	7th Floor	Main Lift lobby	87	With light 'OFF
			351	With light 'ON'
	6th Floor	Main Lift lobby	143	With light 'OFF
			285	With light 'ON'
	5th Floor	Main Lift lobby	83	With light 'OFF
			359	With light 'ON'
	4th Floor	Main Lift lobby	70	With light 'OFF
			320	With light 'ON'
	3rd Floor	Main Lift lobby	80	With light 'OFF
			288	With light 'ON'
	2nd Floor	Main Lift lobby	195	With light 'ON'
	1st Floor	Main Lift lobby	240	With light 'ON'
Tower B	4th Floor	Main Lift lobby	96	With light 'ON'
			261	With light 'OFF
	5th Floor	Main Lift lobby	93	With light 'ON'
			255	With light 'OFF

3.2.2 ENERGY AUDIT OF INDUSTRY

A comprehensive energy audit was carried out at a paper industry as part of the PAT cycle mandatory energy audit under the compliance of energy conservation act of Government of India. The aim of the energy audit was to establish the specific energy consumption of the industry, and to bring out opportunities for energy savings in order to reduce the overall operational cost of the facility

3.2.2.1 PROJECT BACKGROUND

This paper industry is one among the oldest in the country with more than 70 years of presence in the Indian market. It produces a wide range of industrial, packaging and cultural papers catering to almost all segments of the consumers.

The primary energy consumption in the plant includes coal, furnace oil, agro based fuels and pet coke. The electricity power requirement for the plant operations has been imported and internally generated. Coal is utilized for process heating in paper plant as well as source of energy in captive power plant. Furnace oil purchased is used in recovery boiler and the rotary lime kiln. And recently due to the fall of oil prices the main energy source after captive power generation is DG sets which are run with furnace oil.

Table 3.13: Products and Annual production rates 2014-15

SL NO:	PARTICULARS	UNIT	ANNUAL PRODUCTION QUANTITY
1	Writing printing paper	MT	29288
2	Paper board and Kraft paper	MT	33164
3	Speciality paper	MT	9520

3.2.2.2 COMPONENTS OF PRODUCTION COST

Pulp and paper industry is one of the most energy intensive and polluting sectors. The sector largely employs conventional technologies. These are highly intensive in terms of consumption of raw material, chemicals, energy and water thereby generating higher levels of effluents.

The pulp and paper industry comprises companies that use wood as raw material and produce pulp, paper, board and other products. The facility have consumed the following cost components (on yearly basis) for manufacturing of their products:

Table 3.14: Components of production

SR. NO.	DESCRIPTION	% COST
1	Raw material cost	0.48
2	Power and fuel cost	0.27
3	Finance cost	0.02
4	Other	0.24

- Power and fuel charges are around 27% of total production cost.
- Major cost of Raw material is around 48% of the total cost.

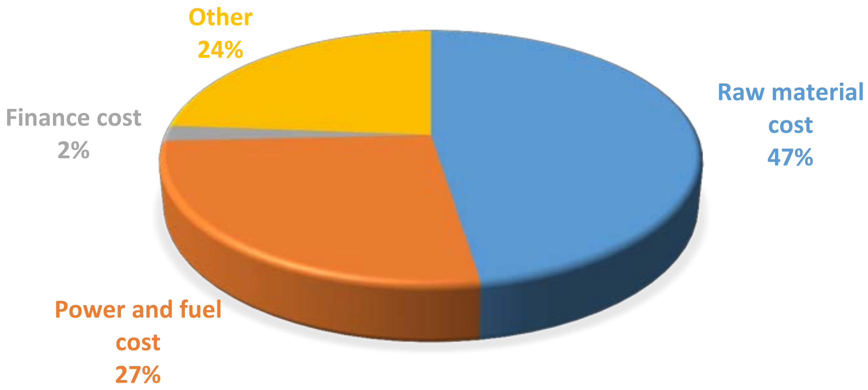


Figure 3.20: Component of production cost (%)

Following are the raw material consumed in year (2014-2015) for the production of pulp and paper in the facility:

Table 3.15: Raw material consumption

SL NO:	NAME OF THE RAW MATERIAL	QUANTITY MT/ANNUM
1	Eucl. wood	73914.89
2	Eucl. Wood-UPFC/UFDC	1555.742
3	Poplar wood	7506.19
4	P. Indus. Waste (peels)	20030.3
5	P. Indus. Waste (chips)	105721.35
6	Chammak	919.25
7	Saw mill dust	2294.07
8	Bamboo	46.345
Total Raw Material		**211988.137**

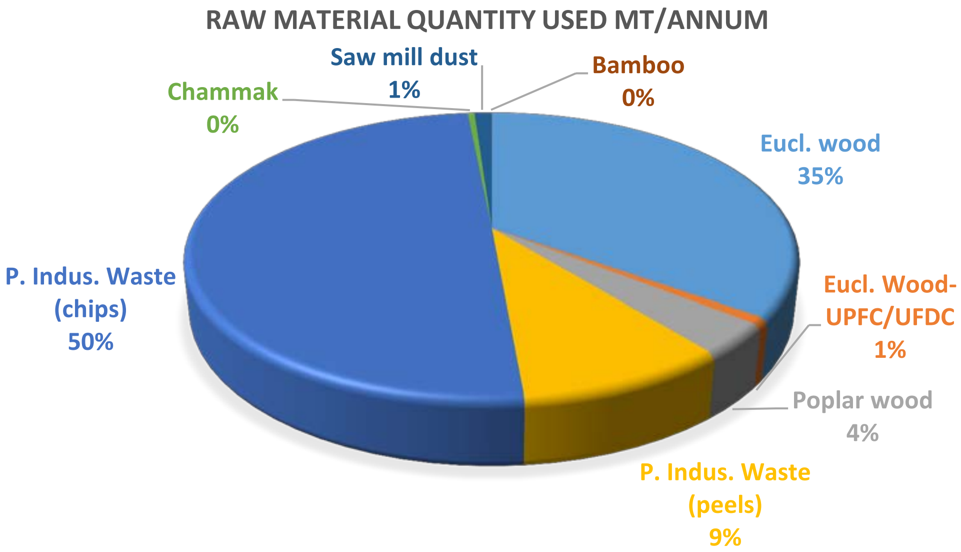


Figure 3.21: Raw material quantity used

3.2.2.3 MAJOR ENERGY USAGE AREA

The major forms of energy used in the plant are electricity and heat. The heat is used in the form steam. The heat and electricity are generated from the co-generation plants. Major electrical energy usages areas:

Table 3.16: Area wise electricity consumption

Sl no:	Particular	Average running load (MW)
1	Paper machines	3.7
2	Soda recovery	1.2
3	Stock preparation	1
4	Water supply	0.5
5	Boiler	0.4
6	ETP	0.3
7	Digester	0.2

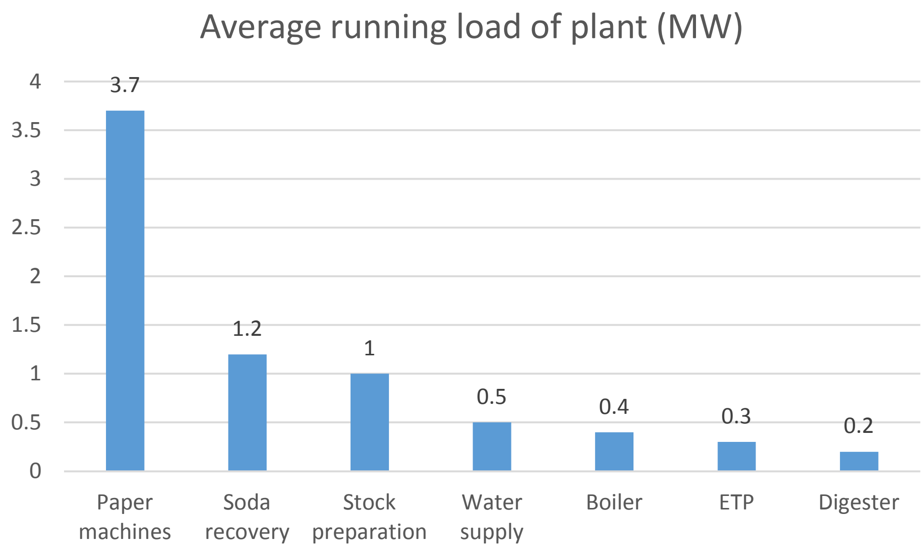


Figure 3.22: Electricity consumption share

Following table is given for major steam consumption areas (as verified during Energy Audit):

Table 3.17: Area wise steam consumption

Sl no:	Particular	Average steam consumption (MT/Day)
1	China 6MW turbine	1361
2	Evaporator	398
3	Paper machines	467
4	Digesters	279
5	Enmas deaerator	61
6	Causticizer	60
7	Enmas soot blower	40

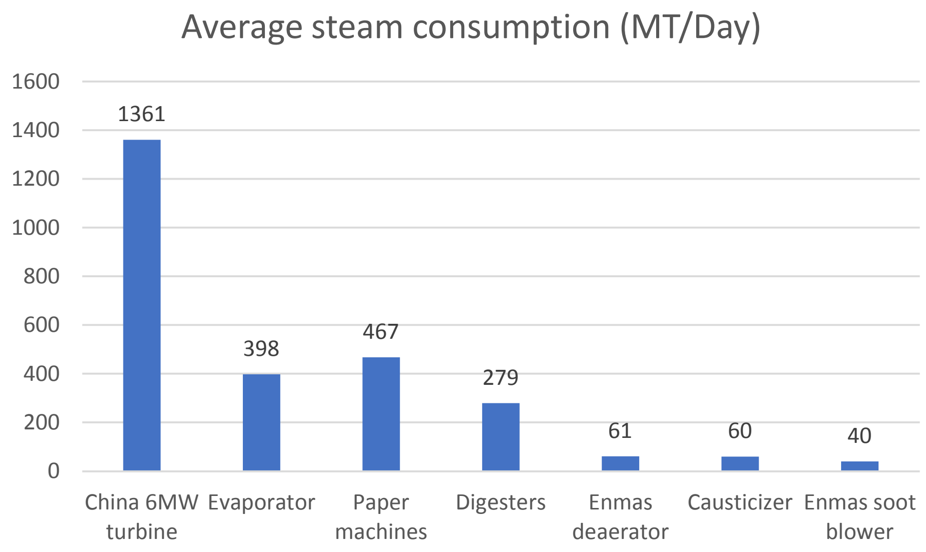


Figure 3.23: Steam consumption share

3.2.2.4 PRODUCTION PROCESS DESCRIPTIONS

The company is producing writing, printing paper, paper board and specialty paper. The plant has 4 paper machines. The main raw materials for the plant are wood and waste chips.

3.2.2.4.1 RAW MATERIAL PREPARATION

In India, most of the mills are not doing debarking as they receive either debarked wood or use them with bark due to difficulty in debarking of some hardwoods. The logs at *paper mill* are chipped to size suitable for pulping using chippers. Disc and drum chippers are used for chipping. The oversized chips are re-chipped, as under sized chips (pin chips) are rejected and used in the boiler to partially offset the fuel consumption.

Figure 3.24: Chipper plant

3.2.2.4.2 COOKING / DIGESTION PROCESS

The *paper mill* prepares pulp by the chemical pulping process using chemicals called as Kraft or sulphate (alkaline) process. In any chemical process, the cellulose fibres of the wood are separated from the non cellulose components by chemical action.

In this (Kraft or sulphate) process, the raw material is fed into digesters, reacted with white liquor (80:20 NaOH and NaS) and streamed for about two to three hours at high temperatures and pressure (162-168 deg. C and 7-8 kg/sq.cm). Digesters at *paper mill* are of batch type, which offers advantages such as increased flexibility in cooking process.

The pulp is then washed to make the pulp free from soluble impurities and removal of black liquor through 4 stages of counter current washing using rotary drum filters. The washed pulp is sent to Oxygen de-lignifications before sent for bleaching to increase the brightness of the pulp and the dilute black liquor is sent to evaporators. The treated pulp then goes for stock preparation. The black liquor after concentration is fired in recovery boiler. The residue ‘green liquor’ is treated with lime to get white liquor for reuse.

Figure 3.25: Digester

3.2.2.4.3 BLEACHING PROCESS

Pulp when it comes from digester, contains residual colouring matter. The unbleached pulp may be used for making heavy wrapping paper or bags. However, paper to be used for printing, writing or paper which is to be dyed, must first be bleached. The main object in bleaching is to remove residual lignin from the wood pulp fibres as well as to destroy or remove remaining colouring matter.

The industry uses bleaching agents that are used to bleach the pulp such as chlorine, hydrogen peroxide, Oxygen and calcium hypochlorite.

3.2.2.4.4 STOCK PREPARATION

Stock preparation is undertaken to give the pulp various desired qualities through refining. It is mostly accomplished in either double disk or conical refiners. The stock then undergoes addition of sizing, filling and colouring agents. A final screening and centri-cleaning is carried out prior to paper making for removing the contaminants as they may lead to defects in paper.

Paper machines: The *paper mill* has 4 paper machines operating to produce around 300TPD of paper. These machines have the following sections.

The feed to the paper machine consists of combination of refined pulp and broke, together with additives such as fillers and wet end chemicals, having requisite stock consistency. Either fourdriner or cylindrical mould machines form the feed into sheet. At wet end of paper machine, water is first removed by gravity, then by suction, then by pressing the sheet and lastly by steam heated cylinders.

Figure 3.26: Paper Machine 1

3.2.2.4.5 HEAD BOX / FAN PUMP

The paper stock at this point in the process is 99% water and 1% fibre. The fan pump forces the paper stock through a set of nozzles in the head box onto the 'wire' mesh. The fan pump speed is a major factor in the basis weight (calliper) formation of the sheet of paper.

3.2.2.4.6 FORMING SECTION

A typical flat former is a continuous rotating wire (today this is plastic) mesh that removes water from the paper by sucking it out of suspension. Initially the water is allowed to drain through the pores of the wire and towards the end light vacuum is applied in the flat boxes.

3.2.2.4.7 PRESS SECTION

Rolls are nipped (pressed) together to squeeze the water out of the sheet of paper. Multiple rolls are used with a felt (blanket) supporting the sheet and accepting the water from the sheet. Vacuum is applied for the felt to remove the water absorbed by them before the felt comes back to the press again.

3.2.2.4.8 DRYER SECTIONS

Typical dryer sections consist of quantity four to ten cylinders 5 to 6 ft. (1.5 – 1.8 m) in diameter. These cans are filled with steam that evaporates water from the sheet as it passes around the cylinders.

3.2.2.4.9 STEAM AND CONDENSATE SYSTEM

Steam and condensate system of the paper machine dryer forms the major part of the dry end section. The control system of the steam and condensate system governs the moisture content of the paper at the pope reel (end of paper machine).

The objective of the steam and condensate system in the paper machine is to provide the steam for the drying. In the dryer part the moisture is evaporated as the sheet is pressed between a fabric and the hot drying cylinder.

The steam and the condensate system is a part of paper machine. Past the press section, the paper sheet has a water content of about 60%. The final drying achieved in the drying section. This is achieved by means of several steam heated dryers (cylinders). These are driven in groups of few together. The temperature of each of the dryer surfaces must be exactly controlled. In the first group this might be 70 deg. C (160 deg. F) and rise then slowly to 105 deg. C (220 deg. F) in the later groups at the dry end.

3.2.2.4.10 UTILITIES

<u>Waste water treatment</u>

The main pollutants in the effluent discharged are suspended solids, B.O.D. and C.O.D. etc. The waste water from the mills is treated in Effluent Treatment Plant consisting of Primary treatment to remove the suspended solids and secondary treatment (activated sludge process) to remove B.O.D. and C.O.D. and then treated by land treatment process to remove even the colour of effluent. The *paper mill* discharges effluent downstream and drawing water from upstream.

Primary treatment

Waste water is passed through bar screens and perforated screens to remove any foreign material and pumped to primary clarifiers. The settle-able solids are removed from the bottom and clarified effluent from the top of clarifier is taken to secondary treatment.

Secondary treatment (Activated sludge process)

The effluent from the primary treatment is taken to an aeration tanks. There are 13 nos. of mechanical surface aerators, each of 55 HP. Nutrients like Urea and SSP (single super phosphate), are dosed into the aeration tank as food to the bacteria. From the aeration tank the effluent is taken to the secondary clarifiers each.

The details of the equipments of the paper machines and finishing house are furnished in figure. The process flow diagrams for stock and paper machines are furnished below:

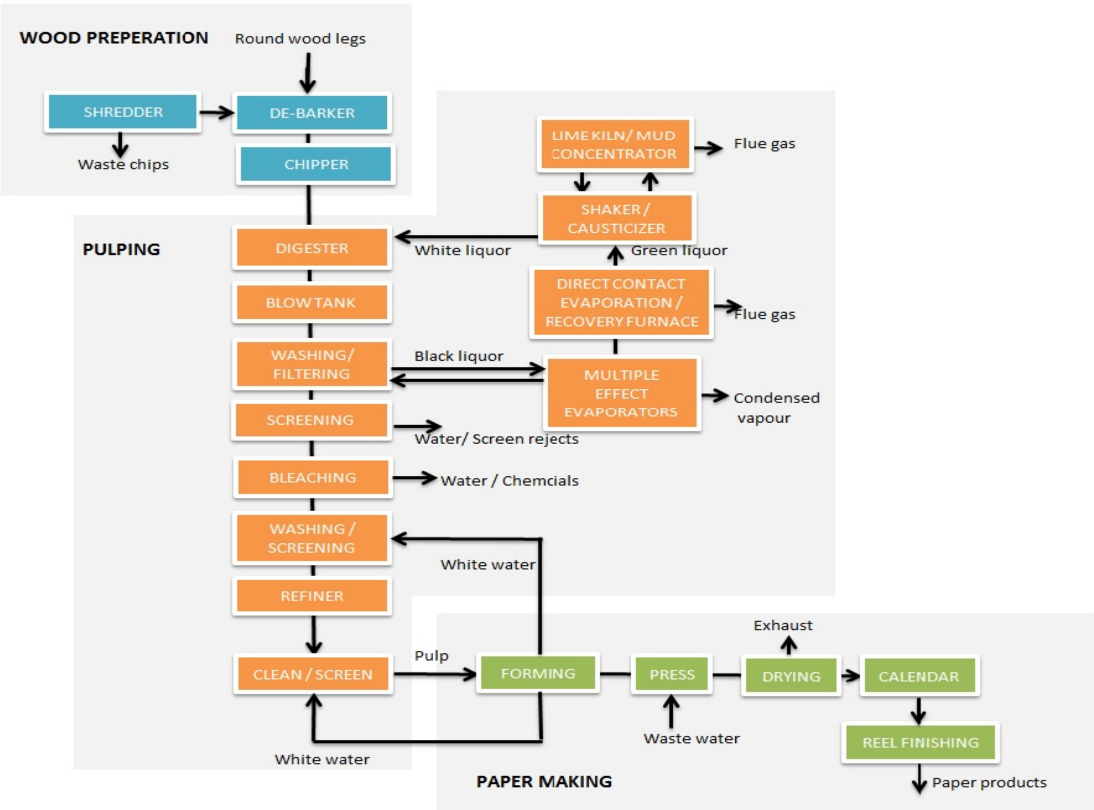


Figure 3.27: Process flow diagram of Pulp & Paper industry

3.2.2.5 MAJOR RAW MATERIAL INPUTS, QUANTITY AND COSTS

The main raw material for the *paper mill* is wood and chips and the details of the consumption is furnished below (figures are verified in last financial year)

Table 3.18: Raw materials and cost

Sl no:	Name of the raw Material	Quantity MT/annum	Cost of material (Cr.)
1	Eucl. wood	73914.89	31.72
2	Eucl. Wood-UPFC/UFDC	1555.742	1.02
3	Poplar wood	7506.19	3.87
4	P. Indus. Waste (peels)	20030.3	7.02
5	P. Indus. Waste (chips)	105721.35	40.89
6	Chammak	919.25	0.34
7	Saw mill dust	2294.07	1.21
8	Bamboo	46.345	0.01
	Total Raw Material	**211988.137**	**86.11**

- The industry is presently using Bamboo and chips as raw material for the paper production for all types like writing and printing paper and specialty papers.
- Major Eucalyptus wood and waste chips used as raw material in year are 73914 Tonnes and 105721 Tonnes respectively.

3.2.2.6 ENERGY AND UTILITY SYSTEM DESCRIPTION

There are several main energy using systems in pulp and paper manufacturing facilities. These include compressed air, electric motors, process steam, lighting, and heat. There were many similarities among the plants with respect to the types of energy-using equipment operated. All of the plants had a significant amount of compressed air and electric motors driving their operations, as well as lighting throughout the facility.

In the pulp and paper industry, electricity and heat drive processes. Their cost drives profitability. That is why these vital elements need to be reliable and effective. Followings are the major utility systems:

- Electricity
- Steam
- Water
- Compressed Air
- Lighting System

3.2.2.6.1 ELECTRICITY

The major source of electricity for the plant is from captive co-generation plants. The unit has two co-generation plants of 6 MW each and one is in standby mode. The plant has contract demand of 9500 KVA from state electricity board.

Table 3.19: Electricity supply share

Sl no:	Item	Unit	Year (2014-2015)
1	Total Electricity Purchased from Grid/Other Source	Million kWh	42.9
2	Total Electricity Generated	Million kWh	39.7
3	Total Electricity Exported	Million kWh	0
4	Total Electrical Energy Consumption	Million kWh	82.6

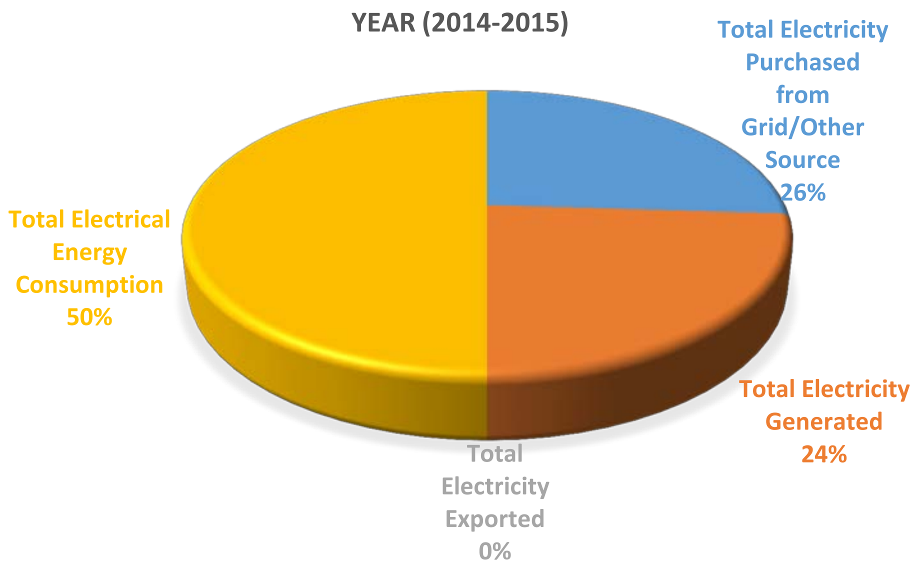


Figure 3.28: % share of electricity

Table 3.20 Monthly electricity generation and import

Month	6 MW TG Set MWH Power Generation	UPPCL MWH Power Import (Grid Supply)	4.2 MW DG Set MWH Power Generation
Apr-14	2948	3902	46
May-14	2826	3798	23
Jun-14	2151	2485	245
Jul-14	2424	3368	73
Aug-14	3355	4583	47
Sep-14	3400	4044	95
Oct-14	3140	3870	85
Nov-14	2603	3892	0
Dec-14	2976	3868	86
Jan-15	3147	4133	41
Feb-15	2719	2104	1620
Mar-15	3299	1948	2280
Apr-15	2974	1688	2152
May-15	3001	2396	1618
Jun-15	2759	3128	741
Jul-15	2755	1526	2189
Aug-15	1772	1315	3817
Sep-15	836	1742	3381

- Graphical representation of 6 MW TG set power generation

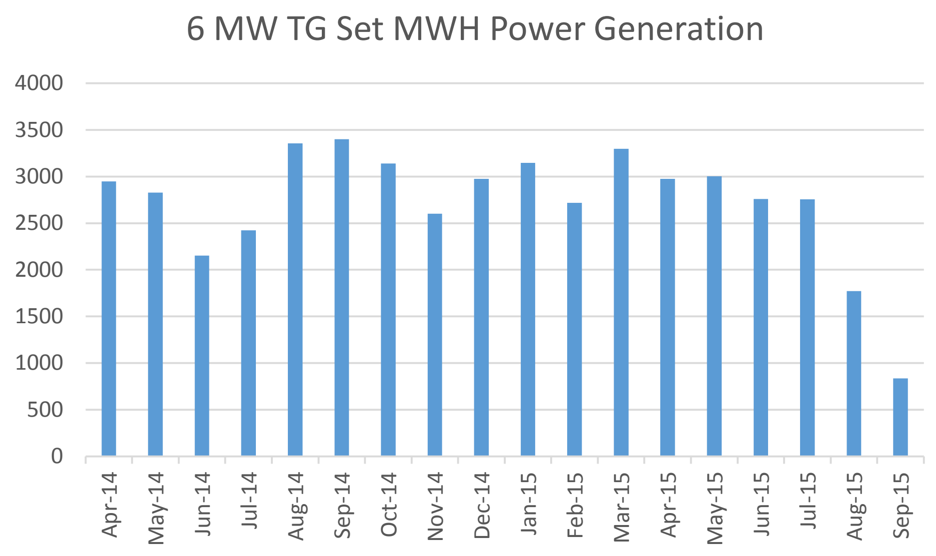


Figure 3.29: 6 MW TG Set MWH Power Generations

- Graphical representation of Grid supply import

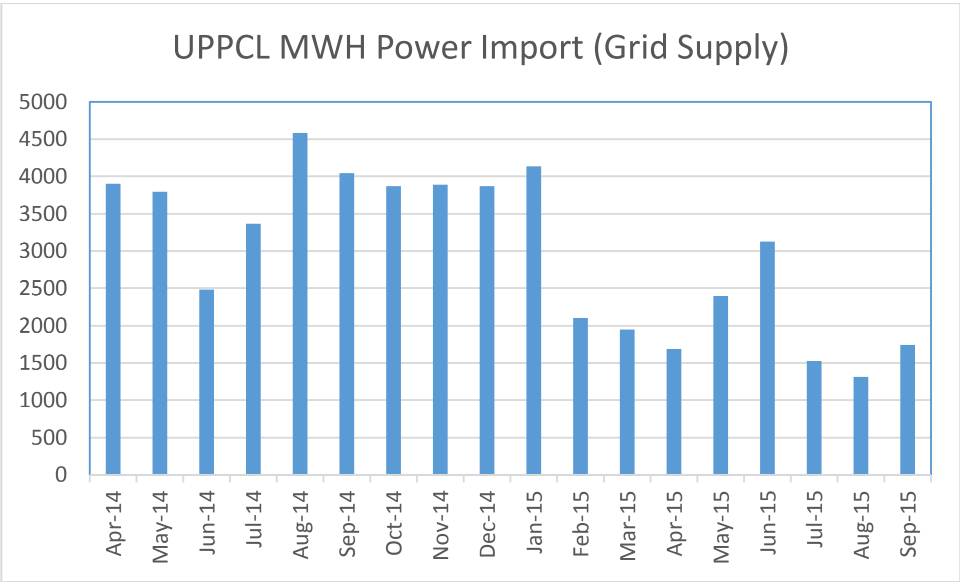


Figure 3.30: Grid supply power import

- Graphical representation of 4.2 MW DG set power generation

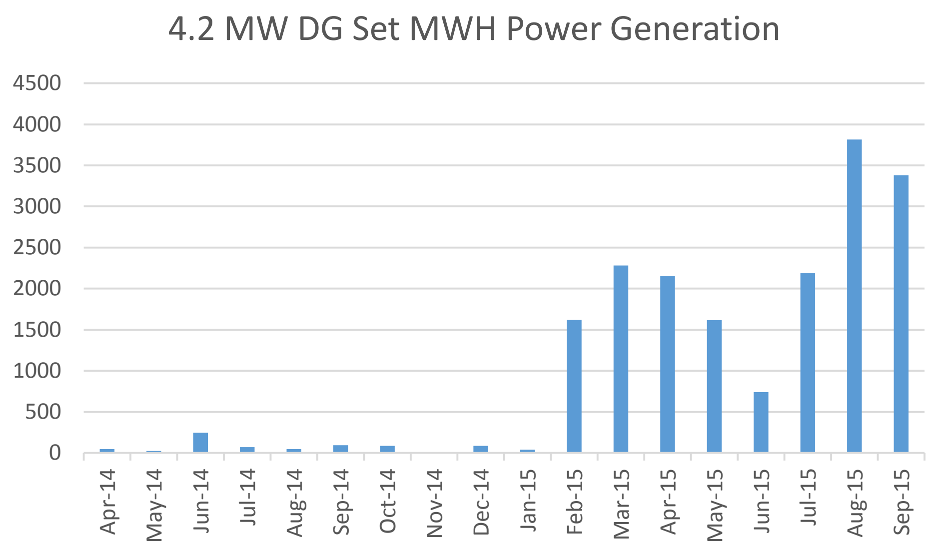


Figure 3.31: 4.2 MW DG Set MWH Power Generations

3.2.2.6.2 STEAM

The major thermal energy source for the plant is steam. The plant has four boilers as follows:

1. Cheema boiler FBC – 45 TPH
2. Stoker fired boilers – 2 nos. – 18.5 TPH each (both are standby)
3. Enmas Recovery boiler – 40 TPH

FBC and Recovery boiler are operating continuously as per requirement. The steam from FBC is generated at 42.5 kg/sq.cm and 420^{O}C. The steam from Stoker fired boilers is generated at 17 kg/sq.cm and 320^{O}C. The Enmas Recovery boiler is generating steam at 42.5 kg/sq.cm and 420^{O}C.

China turbine of 30MW is extraction cum back pressure type. The other BHEL turbine of 6 MW is extraction cum condensing type. There are two extractions from this turbine, 1st extraction is at 80 psi and 2nd extraction is at 40 psi. But this turbine is in standby mode.

Table 3.21 Steam generation share

Month	Total steam generation by B-9	Total steam generation by B-10	Recovery Boiler	Cheema FBC Boiler
Apr-14	0	0	24777	22215
May-14	0	0	24173	19696
Jun-14	1211	1107	17612	14594
Jul-14	297	226	18212	17556
Aug-14	225	234	25428	25013
Sep-14	0	150	26351	24231
Oct-14	0	0	23931	23410
Nov-14	0	278	20868	21370
Dec-14	417	552	23846	21928
Jan-15	631	823	26587	22977
Feb-15	0	90	23234	18868
Mar-15	0	0	28291	20818

3.2.2.6.3 WATER

The *paper mill* uses bore well water. The waver is delivered to water treatment plant. After purification of water it is then delivered to mills and colony.

Table 3.22 Pumps used for water pumping

Sl no:	Pump	HP	RPM	Rated current (A)	Rated discharge (m^3/hr)	Actual discharge (m^3/hr)	Actual current (A)
1	Pump 1	45	1440	55	160	75	32
2	Pump 2	45	1440	55	175	140	41
3	Pump 3	62.5	2900	90	175	135	83
4	Pump 4	45	1440	55	160	60	36
5	Pump 5	40	1440	52	175	150	42
6	Pump 6	45	1440	55	175	135	42
7	Pump 7	45	1440	55	175	140	41
8	Pump 8	45	1440	55	175	140	42
9	Pump 10	45	1440	55	175	125	41

Table 3.23: Major water consuming areas

Sl no:	Areas	Unit	Average consumption /day
1	Colony	K. Ltr.	600
2	Bleach pulp	K. Ltr.	3500
3	Unbleached Pulp	K. Ltr.	
4	Paper making	K. Ltr.	5500
5	Recovery boiler	K. Ltr.	1500
6	Boiler	K. Ltr.	1000
7	Miscellaneous	K. Ltr.	3000

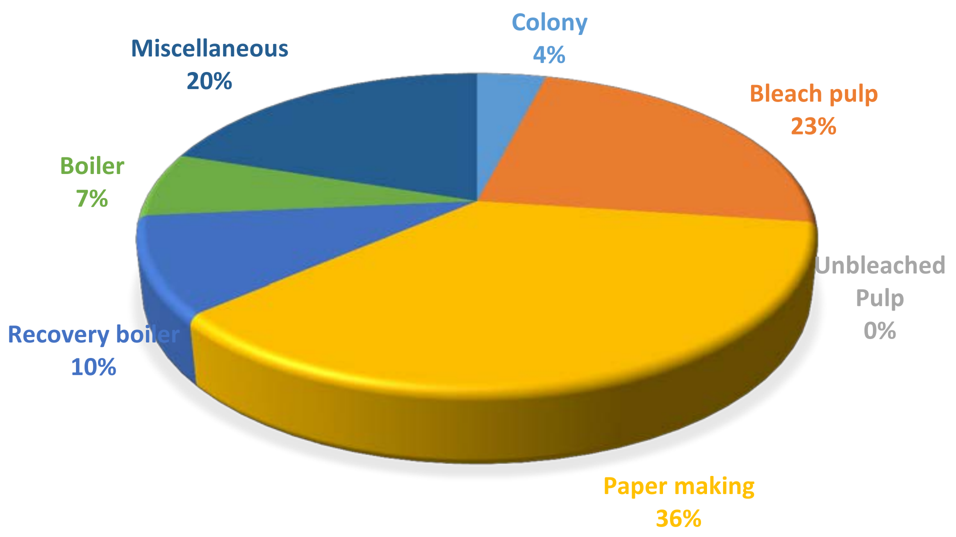


Figure 3.32: Area wise water consumption share

3.2.2.6.4 COMPRESSED AIR

Following table is given indicating compressors details:

Table 3.24: Installed compressors and its application

Sl no:	Type of compressor	Rated capacity (CFM)	Operating pressure (kg/cm^2)	Motor rating (HP)	Application
1	Reciprocating	400	4.5	100	Instruments of machine house & power house
2	Reciprocating	400	4.5	100	Instruments of machine house & power house
3	Reciprocating	400	4.5	100	Paper feeding, cleaning
4	Reciprocating (standby)	400	4.5	100	Paper feeding, cleaning
5	Reciprocating	110	6	30	Reel packing machine

6	Reciprocating (standby)	110	6	30	Reel packing machine
7	Reciprocating	109	10	15	Stretcher and rewinder rider roll
8	Reciprocating	109	10	15	Stretcher and rewinder rider roll
9	Reciprocating (standby)	109	10	15	Stretcher and rewinder rider roll
10	Reciprocating	-	5.5	146	Instruments of pulp plant
11	Reciprocating (standby)	-	5.5	146	Instruments of pulp plant

3.2.2.7 DETAILED PROCESS FLOW DIAGRAM AND ENERGY AND MATERIAL BALANCE

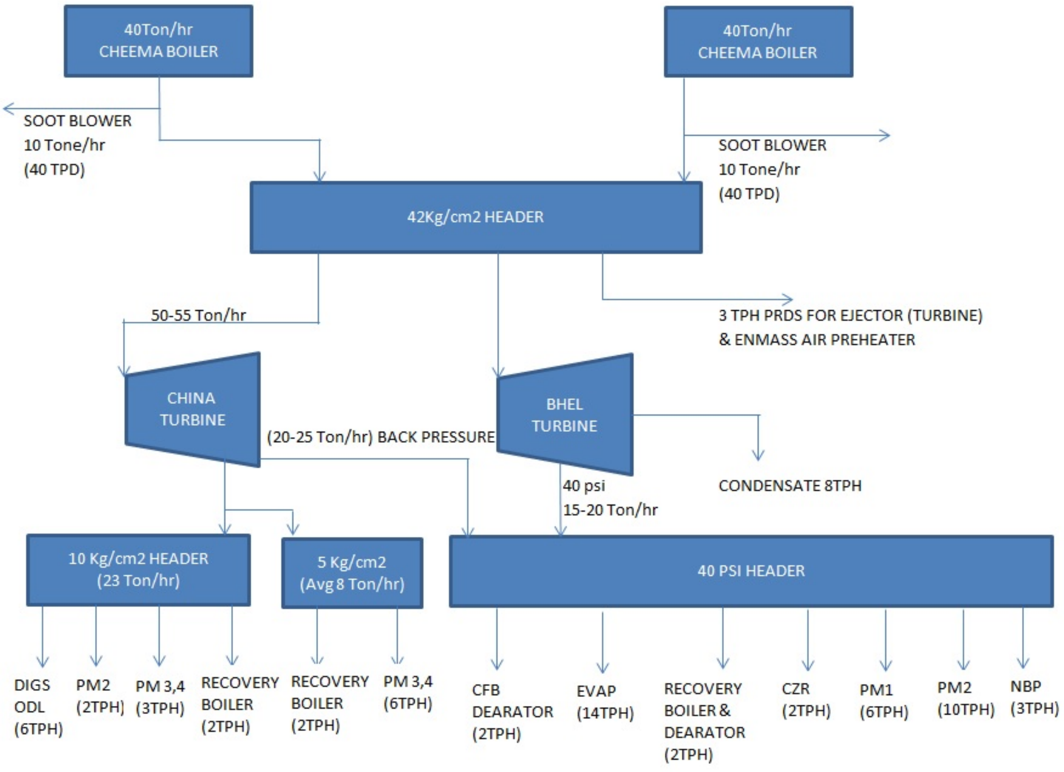


Figure 3.23: Steam flow diagram

ELECTRICAL ENERGY BALANCE

Power Generation		
Particulars	Unit	Quantity
6 MW Steam Generation Turbine	MW	2.8
4.2 MW DG set	MW	4.9
Grid Power (UPPCL)	MW	1.8
Total		**9.5**
Power Consumption		
Vico chipper	MW	0.004
Norman chipper	MW	0.01
Drum chipper	MW	0.06
Digester	MW	0.1
Hot stock screening	MW	0.27
Washing	MW	0.63
ODL	MW	0.34
New bl. Plant	MW	0.52
New screening plant	MW	0.06
Stock preparation	MW	0.92
Paper machines	MW	3.4
Rewinder and cutter	MW	0.07
General office	MW	0.02
Guest house	MW	0.04
Lime kiln	MW	0.05
Water supply	MW	0.4
Boiler	MW	0.4
Turbine	MW	0.22
DG set	MW	0.26
Soda recovery	MW	1.04
Worksop	MW	0.02
Central lab	MW	0.02
ETP	MW	0.26
Lighting	MW	0.12
Total		**9.5**

STEAM BALANCE

Steam Generation		
Particulars	Unit	Quantity
Boiler-9	MT	0
Boiler-10	MT	0
Cheema FBC Boiler	MT	745
Enmas Recovery Boiler	MT	887
Total		**1632**
Steam Consumption		
Paper machines	MT	484
Digesters	MT	243
Enmas air heater	MT	158.35
ODL & EOP	MT	78
NBP	MT	69
FBC deaerator	MT	45
Enmas deaerator	MT	57.66
Causticizer	MT	52
evaporators	MT	321
Lime kiln sludge	MT	2
Exhaust	MT	39
Bark feeding	MT	6
Enmas path	MT	15
Enmas soot blower	MT	40
FBC soot blower	MT	10
Balance steam	MT	12
Total		**1632**

3.2.2.8 SPECIFIC ENERGY CONSUMPTION

- The specific energy consumption of the plant is calculated based on the equivalent production of major product and the total GTG energy consumption of the plant.
- The major product is writing & printing paper and all other products are converted to equivalent of writing & printing paper production by taking the ratio of specific energy consumption of other product to major product and ratio multiplied by production of other product.
- The equivalent production figures with conversion factors and specific energy consumption for all products are given in table below.

Table 3.25: Specific Energy Consumption Calculation

Sl no:	Description	Unit	Year (2014-2015)
1	Writing Printing Paper	Tonne	20555
2	Specialty Paper	Tonne	8054
3	Paper Board & kraft Paper	Tonne	26583
Specific energy consumption of each product			
4	Writing Printing Paper	kcal/Tonne	2822970
5	Specialty Paper	kcal/Tonne	3668521
6	Paper Board &kraft Paper	kcal/Tonne	1805388

- The energy consumption of the whole plant is considered based on the total energy used for Co-Gen. and process.

3.2.2.9 BOILER EFFICIENCY ASSESSMENT

$$\begin{aligned} Boiler\ efficiency \\ &= Steam\ generated \\ &\times (\,Steam\ enthalpy - feed\ water\ enthalpy) \\ &\div (\,Coal\ supplied\ \times GCV\ of\ coal) \end{aligned}$$

Boiler efficiency assessment is done using the direct method for recovery boiler.

Steam enthalpy at 42 kg/cm^2 – 770

Feed water enthalpy at 130^{o}C – 130

Steam generated – 24832 T

Coal supplied – 7989 T

Gross calorific value of fired liquor – 3250 kcal/kg

Recovery boiler efficiency – 61.2%

3.2.2.10 COOLING WATER SYSTEM PERFORMANCE ASSESSMENT

Cooling tower effectiveness is the ratio of range to the ideal range.

$$Cooling\ tower\ effectiveness = \mathrm{Udqjh} \div (\mathrm{Udqjh} + \mathrm{Dssurdfk})$$

Parameter	Unit	Value
Hot water inlet temperature	Deg C	35
Cool water outlet temperature	Deg C	30
Wet bulb temperature	Deg C	25
Effectiveness	%	0.5

Cooling water pump (150 m^3/hr) is in continuous operation for CPP and for evaporator.

The details of cooling towers are as follows:

- The evaporation ratio is 194 m^3/day
- It has induced draft
- Holdup volume is 150 m^3

3.2.2.11 LIGHTING SYSTEM

The industry has installed different types of lighting system to cater to its lighting requirement. Most of the lighting system present during the audit were old and inefficient. Below given is the inventory of lighting system of the industry.

Table 3.26: Light inventory

Particulars	No.s	Present
		W
Tube light	3000	40
HPMV	20	125
HPMV	29	250
HPSV	14	150
HPSV	1	250
MH	35	150
MH	19	70

3.2.2.12 EXISTING ENERGY PROFILE AND PRODUCT WISE SPECIFIC ENERGY CONSUMPTION FOR FUTURE MONITORING

Table 3.27: Energy profile and SEC calculation

Particulars	Unit	Value
Writing Printing Grades		
Production	Tonne	18363
Steam Consumption-MP	Tonne-MP	24153
Steam Consumption-LP	Tonne-LP	24913
Power Consumption	kWh	15441739
Steam-MP	**T/Tonne**	**1.3**
Steam-LP	**T/Tonne**	**1.4**
Power	**kWh/Tonne**	**840.9**
Paper Packaging Grades		
Production	Tonne	32790
Steam Consumption-MP	Tonne-MP	9224
Steam Consumption-LP	Tonne-LP	48141
Power Consumption	kWh	17070090
Steam-MP	**T/Tonne**	**0.3**
Steam-LP	**T/Tonne**	**1.5**
Power	**kWh/Tonne**	**520.6**
Speciality Grades		
Production	Tonne	4039
Steam Consumption-MP	Tonne-MP	11463
Steam Consumption-LP	Tonne-LP	267
Power Consumption	kWh	5741468
Steam-MP	**T/Tonne**	**208**
Steam-LP	**T/Tonne**	**0.1**
Power	**kWh/Tonne**	**1421.5**

CHAPTER 4

RESULTS AND DISCUSSION

4.1 ENERGY CONSERVATION ANALYSIS OF CASE STUDIES

A detailed evaluatuation of the data obtained from the energy audit and the observations were concluded as energy conservation opportunities. Techno-commercial feasibility of each conservation measures have been examined, and are noted below as different projects.

4.1.1 BUILDING AUDIT ANALYSIS

PROJECT – 1: CORRECTION OF CONDENSER PIPELINE VALVES IN CHILLERS

Present Scenario

It is observed that few of the valves in different chillers condenser are not working and water is being circulated even the chiller is not working condition. This leads to operate extra condenser water pump to provide the required cooling. The calculated extra yearly consumption is 242420 kWh/yr with a corresponding cost of Rs 20.9 Lakh/yr.

Proposed Measure

It is recommended to correct the valves to save unnecessary energy being wasted.

Saving Calculation

CORRECTION OF CONDENSER WATER LINE VALVES				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Power consumption	kW	39.1	0	39.1
Energy consumption	kWh/yr	242420	0	242420
Monetary cost	Rs Lakh	21	0	20.9
Investment	Rs Lakh	Nil		
Payback period	Months	Immediate		

- Annual electricity saving : 242420kWh/yr
- Annual Monetary Saving : Rs. 20.9 Lakh

Investment & Payback Period

- Investment : NIL
- Payback Period : Immediate

PROJECT – 2: REPLACEMENT OF 36 W FTL W FIXTURE WITH LED

Present Scenario

A total of 353 nos of 36 W FTL is installed and in operation in the facility. The estimated yearly energy consumption is 91427 kWh/yr with a corresponding cost of Rs 7.9 lakh per year.

Proposed Measure

It is proposed to install energy efficient lighting (20 W LED) replacing the conventional lighting. The estimated energy saving is 42007 kWh/year with a corresponding cost of Rs 3.6 Lakh per year.

Saving Calculation

REPLACEMENT OF 36 W FTL W FIXTURE WITH LED				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
No of lights	Nos	353	353	0
Power consumption	kW	13	7	6
Energy consumption	kWh/yr	91427	49420	42007
Monetary cost	Rs Lakh	7.9	4.3	3.6
Investment	Rs Lakh	7		
Payback period	Months	23		

- Annual electricity saving : 42007 kWh/yr
- Annual Monetary Saving : Rs. 3.6 Lakh

Investment & Payback Period

- Investment : Rs. 7 Lakh
- Payback Period : 23 months

PROJECT – 3: REPLACEMENT OF 28 W FTL W FIXTURE WITH 20 W LED

Present Scenario

A total of 330 numbers of 28 W FTL is installed to fulfil the lighting demand of parking area and staircases. The estimated consumption of electricity is 66990 kWh per year with a corresponding cost of Rs 5.8 Lakh per year.

Proposed Measure

It is proposed to install energy efficient lighting system like 20 W LED to save energy. The expected energy saving is 20790 kWh per year with a corresponding cost of Rs. 1.8 Lakh.

Saving Calculation

REPLACEMENT OF 28 W FTL W FIXTURE WITH LED				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
No of lights	Nos	330	330	0
Power consumption	kW	10	7	2.97
Energy consumption	kWh/yr	66990	46200	20790
Monetary cost	Rs Lakh	5.8	4.0	1.8
Investment	Rs Lakh	7		
Payback period	Months	47		

- Annual electricity saving : 20790 kWh/yr
- Annual Monetary Saving : Rs. 1.8 Lakh

Investment & Payback Period

- Investment : Rs. 7 Lakh
- Payback Period : 47 months

PROJECT – 4 : REPLACEMENT OF 4X18 W FIXTURE IN LIFT LOBBY WITH 40 W LED

Present Scenario

A total of 303 numbers of 4x18 W FTL fixture is installed to fulfil the lighting demand of lift lobby (main lift lobby and service lift lobby) area. The estimated consumption of electricity is 135259 kWh per year with a corresponding cost of Rs 11.6 Lakh per year.

Proposed Measure

It is proposed to install energy efficient lighting system like 40 W LED fixture to save energy. The expected energy saving is 60115 kWh per year with a corresponding cost of Rs. 5.2 Lakh.

Saving Calculation

REPLACEMENT OF 4X18 W FIXTURE WITH LED IN LIFT LOBBY				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
No of lights	Nos	303	303	0
Power consumption	kW	22	12	9.696
Energy consumption	kWh/yr	135259.2	75144.0	60115
Monetary cost	Rs Lakh	11.6	6.5	5.2
Investment	Rs Lakh	15		
Payback period	Months	35		

- Annual electricity saving : 60115 kWh/yr
- Annual Monetary Saving : Rs. 5.2 Lakh

Investment & Payback Period

- Investment : 15 Lakh
- Payback Period : 35 months

PROJECT – 5: REPLACEMENT OF 2X9 W CFL FIXTURE WITH 8 W LED FIXTURE IN STAIR CASE

Present Scenario

A total of 97 numbers of 2x9 W PL lighting fixture is installed in staircases to fulfil the lighting demand of area. The estimated consumption of electricity is 12222 kWh per year with a corresponding electricity cost of Rs 1.1 Lakh per year.

Proposed Measure

It is proposed to install energy efficient 8 W LED fixture to save energy. The estimated electricity saving is 6790 kWh per year with a corresponding cost of Rs. 0.58 Lakh per year.

Saving Calculation

REPLACEMENT OF 2X9 W CFL FIXTURE WITH LED ON STAIR CASE				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
No of lights	Nos	97	97	0
Power consumption	kW	1.7	0.8	0.97
Energy consumption	kWh/yr	12222	5432	6790
Monetary cost	Rs Lakh	1.1	0.5	0.58
Investment	Rs Lakh	1.0		
Payback period	Months	20		

- Annual electricity saving : 679 0 kWh/yr
- Annual Monetary Saving : Rs. 0.58 Lakh

Investment & Payback Period

- Investment : Rs. 1 Lakh
- Payback Period : 20 months

PROJECT – 6: INSTALLATION OF LIGHT SENSOR IN MAIN LIFT LOBBY

Present Scenario

It was observed that the lighting are in 'ON' condition even the sufficient day light is available in the main lift lobby area and the illumination level is good. The estimated yearly energy consumption after replacement to 40W LED would be 46376 kWh per year with a cost of Rs. 3.99 Lakh per year.

Proposed Measure

It is proposed to install lighting sensor 'Lux' sensor which will switch light 'ON' & 'OFF' to maintain the sufficient illumination level in the area. The estimated electrical saving is 13913 kWh per year with a corresponding cost of Rs 1.2 Lakh per year.

Saving Calculation

INSTALLATION OF LIGHTING SENSOR IN MAIN LIFT LOBBY				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
No of lights	Nos	187	187	0
Power consumption	kW	7	7	0
Energy consumption	kWh/yr	46376	32463	13913
Monetary cost	Rs Lakh	3.99	2.79	1.2
Investment	Rs Lakh	1.4		
Payback period	Months	14		

- Annual electricity saving : 16278 kWh/yr
- Annual Monetary Saving : Rs. 1.2 Lakh

Investment & Payback Period

- Investment : Rs. 1.4 Lakh
- Payback Period : 14 months

PROJECT – 7: SWITCHING 'OFF' PARKING LIGHTS ON WEEKENDS

Present Scenario

The lights are switched 'ON' at weekends when the building occupancy is very less on weekends. The estimated yearly energy consumption is 34254 kWh per year with a corresponding cost of Rs 2.9 Lakh per year.

Proposed Measure

It is proposed to start a practice of switch 'ON' only 70% or less (depending on occupancy)of total parking lights to save energy. The estimated electrical saving is 24289 kWh per year with a corresponding cost of Rs 2.09 Lakh per year.

Saving Calculation

SWITCHING 'OFF' OF PARKING LIGHT ON WEEKENDS				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
No of lights	Nos	519	156	363
Power consumption	kW	17	5	12
Energy consumption	kWh/yr	34254	9984	24270
Monetary cost	Rs Lakh	2.9	0.9	2.09
Investment	Rs Lakh	Nil		
Payback period	Months	Immediate		

- Annual electricity saving : 24289 kWh/yr
- Annual Monetary Saving : Rs. 2.09 Lakh

Investment & Payback Period

- Investment : NIL
- Payback Period : Immediate

4.1.2 INDUSTRY AUDIT ANALYSIS

PROJECT – 1: OPTIMIZATION OF DEAERATOR PUMP OF ENMASS BOILER

Present Scenario

The installed deaerator pumps have a rated head of 45m, which is now supplying against a head of maximum 30m only. The overrated pumps thus is causing the underperformance of the pumping system. The rated specifications of the pump are 60m^3/hr , 45m, 30HP.

Proposed Measure

It is recommended to optimize the size of the pump in order to avoid energy loss by under loading. A new pump with head matching to the required 30m is suggested which can supply the required flow.

Saving Calculation

OPTIMIZATION OF DEAERATOR PUMP OF ENMASS BOILER				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Power consumption	kW	22	15	7
Energy consumption	kWh/yr	192720	131400	61320
Monetary cost	Rs Lakh	8.67	5.91	2.76
Investment	Rs Lakh	3.75		
Payback period	Months	16.31		

- Annual electricity saving : 61320 kWh/yr
- Annual Monetary Saving : Rs. 2.76 Lakh

Investment & Payback Period

- Investment : Rs. 3.75 Lakh
- Payback Period : 17 months

PROJECT – 2: OPTIMIZATION OF DEAERATOR PUMP OF CHEEMA BOILER

Present Scenario

The installed deaerator pumps have a rated head of 62m, which is now supply against a head of maximum 30m only. The overrated pumps thus are causing the underperformance of the pumping system. The rated specifications of the pump are $132m^3$/hr, 62m, 40HP.

Proposed Measure

It is recommended to optimize the size of the pump in order to avoid energy loss by under loading. A new pump with head matching to the required 30m is suggested which can supply the required flow.

Saving Calculation

OPTIMIZATION OF DEAERATOR PUMP OF CHEEMA BOILER				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Power consumption	kW	30	22	8
Energy consumption	kWh/yr	262800	192720	70080
Monetary cost	Rs Lakh	11.83	8.67	3.15
Investment	Rs Lakh	5.5		
Payback period	Months	20.93		

- Annual electricity saving : 70080 kWh/yr
- Annual Monetary Saving : Rs. 3.15 Lakh

Investment & Payback Period

- Investment : Rs. 5.5 Lakh
- Payback Period : 21 months

PROJECT – 3: OPTIMIZATION OF COOLING WATER CIRCULATING PUMP TO SUIT THE PIPELINE CAPACITY

Present Scenario

The cooling water circulating pump is equipped with a pump of rated flow 1500m3/hr and rated head of 18m. The pump has been provided with a 12” line for the cooling water circulation as well as a 6” bypass line. It is observed that the 12” line is closed and the pump is delivering a circulation of 280-298m^3/hr through the 6” pipeline.

Proposed Measure

The 6” pipeline is designed with another pump of smaller size, which is not in position. It is recommended to install the smaller pump for the delivering the required current flow of 280-298m^3/hr.

Saving Calculation

OPTIMIZATION OF COOLING WATER PUMP SIZE TO SUIT THE PIPELINE CAPACITY				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Power consumption	kW	80	38	42
Energy consumption	kWh/yr	700800	332880	367920
Monetary cost	Rs Lakh	31.54	14.98	16.56
Investment	Rs Lakh	10		
Payback period	Months	7.25		

- Annual electricity saving : 367920 kWh/yr
- Annual Monetary Saving : Rs. 16.56 Lakh

Investment & Payback Period

- Investment : Rs. 10 Lakh
- Payback Period : 8 months

PROJECT – 4: REPLACEMENT OF HYDRAULIC GOVERNOR WITH NEW ELECTRONIC GOVERNOR FOR TURBINES

Present Scenario

The industry has two no.s of turbines installed running on the steam generated by the boilers. At present one turbine of 5MW capacity is under operation for the entire hours, supplying to the electricity demand of the plant. Currently hydraulic governors are used to stabilize the electricity generated at a frequency of 49.5 to 50 Hz.

Proposed Measure

From the national best practices, it is identified that reducing the frequency by 2% can result in reduced energy consumption by 4% due to connected centrifugal and linear loads.

Saving Calculation

REPLACEMENT OF HYDRAULIC GOVERNOR WITH NEW ELECTRONIC GOVERNOR FOR TURBINES				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Power consumption	kW	4500	4320	180
Energy consumption	kWh/yr	39420000	37843200	1576800
Monetary cost	Rs Lakh	1773.90	1702.94	70.96
Investment	Rs Lakh	60		
Payback period	Months	10.15		

- Annual electricity saving : 1576800 kWh/yr
- Annual Monetary Saving : Rs. 70.96 Lakh

Investment & Payback Period

- Investment : Rs. 60 Lakh
- Payback Period : 11 months

PROJECT – 5: USE OF VENT STEAM TO PREHEAT BOILER FEED WATER

Present Scenario

It is observed that a high quantity of steam, around 5TPH, is vented through the steam vent for an average of 5 hours in a day, due to reduce consumption of steam. Reduction in steam production is not feasible as this would also affect the power production through turbine resulting in increased dependency on grid power.

Proposed Measure

In order to reduce the steam losses, it is suggested to use the vent steam for preheating the boiler feed water inside the feed water tank before deserter, as this can reduce the energy requirement to heat the feed water. A direction injection type heat exchanger system can meet the requirement, which would also have an in tangent benefit of reducing the water requirement.

Saving Calculation

USE OF VENT STEAM TO PREHEAT BOILER FEED WATER				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Energy from steam recovery	kCal/hr	-	2448000	2448000
Energy saving	kCal/yr	-	3672000000	3672000000
Monetary cost	Rs Lakh	-	27.00	27
Investment	Rs Lakh	40		
Payback period	Months	17.78		

- Annual energy saving : 3672000000 kCal/yr
- Annual Monetary Saving : Rs. 27 Lakh

Investment & Payback Period

- Investment : Rs. 40 Lakh
- Payback Period : 18 months

PROJECT – 6: USE OF VFDS IN PRODUCT CIRCULATION PUMPS OF EVAPORATOR 1A, 1B & 1C (3NO.S)

Present Scenario

The product weak black liquor from the digester is processed in evaporator section to convert it into thick black liquor before burned in the Enmass boiler. Circulation pumps are provided for the circulation of black liquor through evaporators, which is observed to have serving for varying demand according to the load factor of the plant.

Proposed Measure

It is recommended to install VFDs to optimize the power consumption of circulating pumps. Three circulating pumps of 90kW each id identified for VFD installation. VFD can provide a minimum of 10% saving from the current operation.

Saving Calculation

USE OF VFDS IN PRODUCT CIRULATION PUMPS OF EVAPORATOR 1A, 1B & 1C (3NO.S)				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Power consumption	kW	189	170.1	18.9
Energy consumption	kWh/yr	1655640	1490076	165564
Monetary cost	Rs Lakh	74.50	67.05	7.45
Investment	Rs Lakh	9		
Payback period	Months	14.50		

- Annual electricity saving : 165564 kWh/yr
- Annual Monetary Saving : Rs. 7.45 Lakh

Investment & Payback Period

- Investment : Rs. 9 Lakh
- Payback Period : 15 months

PROJECT – 7: REPLACEMENT OF VACUUM PUMPS WITH VACUUM BLOWERS (17NO.S)

Present Scenario

Vacuum pumps are used in the industry to facilitate the vacuum demand for the paper machines. During the energy audit field study, under normal operation, it is identified that 17nos of vacuum compressors accounting to a total kW of 1613 were in operation. Vacuum compressors operate on a low efficiency of 40% which is observed to be a main loss in paper machine energy consumption.

Proposed Measure

The efficiency of vacuum pumps are very low 40% compared to that of vacuum blowers which has its efficiency around 60%. It is recommended to replace the vacuum pumps with vacuum blowers in the paper machines.

Saving Calculation

REPLACEMENT OF VACCUM COMPRESSORS WITH VACCUUM BLOWERS (17NO.S)				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Power consumption	kW	1613	1290.4	322.6
Energy consumption	kWh/yr	14129880	11303904	2825976
Monetary cost	Rs Lakh	635.84	508.68	127.17
Investment	Rs Lakh	250		
Payback period	Months	23.59		

- Annual electricity saving : 2825976 kWh/yr
- Annual Monetary Saving : Rs. 127.17 Lakh

Investment & Payback Period

- Investment : Rs. 250 Lakh
- Payback Period : 24 months

PROJECT – 8: PROVIDE MECHANICAL SEAL IN DIGESTER CIRCULATION PUMPS RESULTING IN WATER SAVING 200 CU.M PER DAY

Present Scenario

Digester circulation pumps requires continuous supply of water for the sealing purpose. The seal water is supplied using a seal water pump which is running continuously. This seal pump has measured to be drawing an energy at average of 4kWh per hour for 24 hours a day. The system also costs for waste of water, as the water is not recovered after the sealing purpose.

Proposed Measure

It is recommended to provide mechanical seal for the circulating pumps in digester. This would reduce the consumption of water, and the sealing pump can be stopped. Energy saving and water saving can be observed from tis alteration.

Saving Calculation

PROVIDE MECHANICAL SEAL IN DIGESTER CIRCULATION PUMPS RESULTING IN WATER SAVING 200 CU.M PER DAY				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Power consumption	kW	-	4	4
Energy consumption	kWh/yr	-	35040	35040
Monetary cost	Rs Lakh	-	1.58	1.58
Investment	Rs Lakh	3		
Payback period	Months	22.83		

- Annual electricity saving : 35040 kWh/yr
- Annual Monetary Saving : Rs. 1.58 Lakh /yr

Investment & Payback Period

- Investment : Rs. 3 Lakh
- Payback Period : 23 months

PROJECT – 9: IMPROVING STEAM PIPE LINE INSULATION NEAR PAPER MACHINE DRYER SECTION AND AT JOINTS

Present Scenario

High quantity of steam is supplied to the paper machines for the processing of pulp inside the paper machine. During the field study it is observed that the insulation of steam lines are old and damaged. This causes heat losses and thereby causing extra load on steam generation.

Proposed Measure

It is recommended to provide effective insulation for the steam pipelines near the paper machine. An effective insulation can reduce the heat loss in the pipe, and thus reduces the required steam production. The temperature of the steam pipe was measured to around 130^{O}C.

Saving Calculation

IMPROVING STEAM PIPE LINE INSULATION NEAR PAPER MACHINE DRYER SECTION AND AT JOINTS				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Energy from steam recovery	kCal/hr	-	216381.28	216381.28
Energy saving	kCal/yr	-	1895500000	1895500000
Monetary cost	Rs Lakh	-	11.15	11.15
Investment	Rs Lakh	10		
Payback period	Months	10.76		

- Annual energy saving : 1895500000 kCal/yr
- Annual Monetary Saving : Rs. 11.15 Lakh

Investment & Payback Period

- Investment : Rs. 10 Lakh
- Payback Period : 11 months

PROJECT – 10: REPLACEMENT OF LIGHTING SYSTEM TO HIGH EFFICIENT LIGHTS

Present Scenario

The industry lighting system is old and inefficient compared to the present lighting systems available. The operating hours for lighting systems in the industry is taken as 10hours/ day for 365 days. Major inefficient lightings are identified and tabled as below.

Particulars	No.s	Present	
		W	kWh
Tube light	3000	40	438000
HPMV	20	125	9125
HPMV	29	250	26462.5
HPSV	14	150	7665
HPSV	1	250	912.5
MH	35	150	19162.5
MH	19	70	4854.5

Proposed Measure

It is recommended to replace the he existing lightings with LEDs of different ratings according to the lux requirement.

Saving Calculation

REPLACEMENT OF LIGHTING SYSTEM TO HIGH EFFICIENT LIGHTS				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Power consumption	kW	138.68	61.5	77.18
Energy consumption	kWh/yr	506182	224475	281707
Monetary cost	Rs Lakh	22.78	10.10	12.68
Investment	Rs Lakh	25.18		
Payback period	Months	23.84		

- Annual electricity saving : 281707 kWhl/yr
- Annual Monetary Saving : Rs. 12.68 Lakh

Investment & Payback Period

- Investment : Rs. 25.18 Lakh
- Payback Period : 24 months

PROJECT – 11: REPLACEMENT OF STEAM TRAPS TO ARREST WASTAGE OF STEAM AND CONDENSER RECOVERY

Present Scenario

Steam traps are installed in the industry to trap the condensate after steam consumption. Due to the age of the plant it is observed that most of the steam traps are not function and high amount of steam/condensate leakages are observed.

Proposed Measure

It is recommended to replace the malfunctioned steam traps, plug the leakages, maintain the steam trap lines, and recover condensate to feed water tank.

Saving Calculation

REPLACEMENT OF STEAM TRAPS TO ARREST WASTAGE OF STEAM AND CONDENSOR RECOVERY				
PARTICULARS	UNIT	PRESENT	PROPOSED	SAVINGS
Energy from steam recovery	kCal/hr	-	733.13	733.13
Energy saving	kCal/yr	-	6422222.222	6422222.22
Monetary cost	Rs Lakh	-	0.04	0.04
Investment	Rs Lakh	0.1		
Payback period	Months	31.76		

- Annual energy saving : 6422222.22 kCal/yr
- Annual Monetary Saving : Rs. 0.04 Lakh

Investment & Payback Period

- Investment : Rs. 0.1 Lakh
- Payback Period : 31 months

4.2 MUTIPLE BENEFITS OF ENERGY EFFICIENCY

Along with the direct benefits of energy efficiency- such as reduction in energy demand and GHG emissions, it is observed that other indirect benefits are also influencing energy efficiency implementations. The multiple benefits of energy efficiency is thus the main reason why it is different from other climate change mitigation tools.

Some of the multiple benefits incurred from energy efficiency is detailed below from the experience of energy audits and study of previous research papers.

Energy Systems Security

Energy security: Energy efficiency can help in reducing the total energy demand, thus increasing the dependency.

Energy delivery: Energy efficiency enables the utilities to provide better service to the customers with less expense. The reduction in demand from user side can help the utility to provide uninterrupted supply without any shortage.

Energy prices: Decreased energy demand at national level can bring down the energy costs.

Economic Development

Industrial productivity: In an industrial level energy efficiency can bring increased productivity and capacity utilization. It also helps the industry to reduce the manpower and O&M costs.

Improvement in national economy: The reduced energy demand can bring down the production cost, helping to increase the productivity at a national level, thus increasing the GDP of the nation.

Social development

Health and well-being: The improved environment quality of the living space after energy efficiency implementations helps the occupants to improve their health and well being.

Employment: Energy efficiency is a new market which can bring new job opportunities, thus helping to reduce the unemployment issues.

Environmental sustainability

Reduction in air pollution: Together with the reduction in GHG emissions, it provides a good working environment for the employees.

Resource management: The energy less used is the energy less generated. In turn this is the fossil fuel that has been saved from exploration, and less the carbon emitted to the environment. Thus it helps to use the resource efficiently and reduce the costs involved for the same.

4.3 HURDLES IN THE GROWTH OF ENERGY EFFICIENCY IN INDIA

Though the benefits from energy efficiency are plenty, there are certain factors coming across the path of its implementation. Several financial, technical, behavioral and institutional barriers constrained the deployment of energy efficient technologies and processes. A key barrier is a lack of both strategic priority of energy efficiency at company level and willingness to invest in energy efficiency measures. There is a need for improved knowledge and experience regarding energy saving potentials. There are several factors that influence the differences in energy efficiency and energy intensity between countries.

Energy intensity are expressed in terms of energy per cost. The energy intensity of an end product and sector differs enormously. Moreover the energy intensity of same products at different nations also differs in many terms. Certain factors influence these differences- depending on the end product, sector and country of production.

- Energy efficiency sometimes reduces the scrap produced during the process, which were previously supplied as a raw material within the process or to any other process outside. The economics behind these decides the implementation of energy efficiency in such cases.
- Energy efficiency fits perfect when the fossil fuel prices are high. The recent trend of fall in fossil fuels (especially crude oil) has reduced the prices of Diesel, Petrol, Furnace oil etc. This is increased the payback period of energy efficiency implementations.
- The relative return of investment of energy efficiency implementations from new plant is observed to be slow from that of an old plant. The reason behind being old plant is equipped with old technologies, but new plants are usually equipped with relatively new technologies. So a technological improvement in these plants doesn’t usually fit in for payback within their life cycle.

- Capital investments for energy efficient technologies are high due to the high costs of efficient technologies. This has made companies opting for capacity expansion over energy efficiency thus generating more revenue.
- Many companies don’t have proper information on their energy efficiency pattern or monitoring, thus restricting themselves from research and developments on their bottlenecks in energy demand reduction.
- Increased benefits from other climate change mitigation options restrict companies to invest on less benefited energy efficiency, unless there is a mandate from government. Moreover lack of strict implementation and corruption worsen the scenario.

CHAPTER 5

CONCLUSION

Energy efficiency is considered as an easy solution for reducing energy demand. Presently there are many energy efficient technologies available for improvement, and it is expected to be available in future also with more R&D in this field. But the prioritization in selection is not only depended on technology, there are certain barriers – organizational, financial and behavioural factors.

The effectiveness of energy efficiency as a climate mitigation tool was evaluated for the case example energy audits and are tabulated as below:

Building Energy Audit

Table 5.1: GHG Mitigation through energy saving in building case study

Greenhouse Gas Mitigation through Major Energy Efficiency Projects						
Sl No	Projects	Energy saved(Yearly)		Sustainability (Years)	First year ton of CO_2 mitigated	Expected Tons of CO_2 mitigated through out life cycle
		(kWh)	MWh	Years		
1	Correction of Condenser Pipeline Valves in Chillers	242420	242.42	10	198.78	1987.84
2	Replacement of 36 W FTL W fixture with LED	42007	42.01	5	34.45	172.23
3	Replacement of 28 W FTL W fixture with 20 W LED	20790	20.79	5	17.05	85.24
4	Replacement of 4x18 W fixture in Lift lobby with 40 W LED	60115	60.12	5	49.29	246.47
5	Replacement of 2X9 W CFL fixture with 8 W LED fixture in stair case	6790	6.79	5	5.57	27.84
6	Installation of Lighting Sensor in main Lift Lobby	13913	13.91	5	11.41	57.04
7	Switching ‘OFF’ Parking Lights on Weekends	24270	24.27	10	19.90	199.01
Total		410305.0	410.31		336.45	2775.68

Industry Energy Audit

Table 5.2: GHG Mitigation through energy saving in industry case study

Greenhouse Gas Mitigation through Major Energy Efficiency Projects						
Sl No	Projects	Energy saved(Yearly)		Sustainability (Years)	First year ton of CO_2 mitigated	Expected Tons of CO_2 mitigated through out life cycle
		(kWh)	MWh	Years	Tonne	Tonne
1	Optimization of Deaerator Pump of Enmass Boiler	61320	61.32	5	50.28	251.41
2	Optimization of Deaerator Pump of Cheema Boiler	70080	70.08	5	57.47	287.33
3	Optimization of cooling water circulating pump to suit the pipeline capacity	367920	367.92	5	301.69	1508.47
4	Replacement of hydraulic governor with new electronic governor for turbines	1576800	1576.80	10	1292.98	12929.76
5	Use of vent steam to preheat boiler feed water	4269767	4269.77	10	3501.21	35012.09
6	Use of VFDs in product circulation pumps of evaporator 1a, 1b & 1c (3no.s)	165564	165.56	5	135.76	678.81
7	Replacement of vacuum compressors with vacuum blowers (17no.s)	2825976	2825.98	5	2317.30	11586.50
8	Provide mechanical seal in digester circulation pumps resulting in water saving 200 cu.m per day	35040	35.04	5	28.73	143.66
9	Improving steam pipe line insulation near paper machine dryer section and at joints	2204070	2204.07	5	1807.34	9036.69
10	Replacement of lighting system to high efficient lights	281707	281.71	5	231.00	1155.00
11	Replacement of steam traps to arrest wastage of steam and condenser recovery	7468	7.47	5	6.12	30.62
Total		9789591.9	9789.59		8027.47	57643.37

From the figures it is inferred that energy efficiency as a climate mitigation tool has a bright future ahead. Moreover energy efficiency is unavoidable as in without which the energy scarcity in the upcoming years couldn't be addressed completely. It is also observed the multiple behavior of energy efficiency has to be showcased and quantified to boost the market presence.

Identifying multiple benefits of energy efficiency can enhance the business market of energy efficiency. But the constraint is identification and quantification of multiple benefits corresponding to each industry. It is necessary to classify the multiple benefits sectorial wise and country wise to provide proper attention to relevant industries. Creation of such general categories and showcasing the relevant benefits to industries can minimize the complexity.

Measuring multiple benefits of energy efficiency can give a new and clear angle for the financiers and policy makers. Taking into account these benefits can give relaxation in the current way of ROI calculations. Assessing industrial benefits can help increasing the participation of industries, thus ensuring the success of the program. A better understanding of the expectations from the industries can help the policy makers to design the policies accordingly considering the locational and sectorial behaviours.

A strict mandate of government over the industries and buildings, considering cutting down of energy demand as well as a climate mitigation tool can be an effective way forward for Indian market. The CO_2 mitigation from the case example audits are calculated and tabulated as shown below.

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