EXISTING COMMERCIAL
BUILDING RETROFIT GUIDELINES

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Creating Innovative Solutions for a Sustainable Future

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Foreword

United Technologies (UTC) and The Energy and Resources Institute (TERI) joined hands to establish TERI-UTC Centre of Excellence to promote energy efficient existing buildings in India. The objective of the CoE is to enable policy dialogue for energy efficient buildings based on their energy performance.

Human beings today spend 90% of their time indoors, and are increasingly dependent on mechanical heating, cooling and ventilation and artificial lighting systems. Buildings consume more than 40% of the total energy generated in the country and emit about 19% of the energy related Green House Gas (GHG) emissions. With the increasing demand for habitable spaces for both commercial and residential buldings, it is critical to tap the potential available in existing buildings to respond to the exponentially rising energy demand in this sector.

An energy efficient existing building focuses on increasing the efficiency of the systems used in buildings while minimizing its impact on environment and health and well-being of the occupants.

This collaborative partnership between TERI and UTC will help to put in place enabling policies to mainstream energy efficiency in the existing buildings through tailor made solutions.

I congratulate the teams of UTC and TERI for their efforts in putting together these "Guidelines on Retrofitting Existing Commercial Buildings" and urge upon the building practitioners, facility managers and energy auditors to use these guidelines in optimizing energy use in buildings.

Dr Ajay Mathur

Director General, TERI

Preface

The TERI-UTC Centre of Excellence was established to carry out integrated research on optimizing energy efficiency in existing commercial buildings in India. The objective of the study is to establish validated information on energy use, and provide financial solutions to building managers for enhancing energy efficiency.

Issues related to retrofit existing buildings have been persistent for the last many years and have posed a challenge to facility owners. Strategies to prioritize implementation of energy conservation measures and providing financial resources have been a challenge faced by facility managers.

We, at the TERI-UTC CoE are pleased to introduce a set of "Guidelines on Retrofitting Existing Commercial Buildings" as an integrated approach to optimize energy use in existing buildings through retrofits. These guidelines have been prepared to generate awareness amongst building practisioners, facility owners, finance officers and end users on the importance and benefits of energy efficiency. These encompass step by step approach to developing an energy management portfolio for existing buildings together with commissioning schedule and M&V protocols.

These guidelines have been drafted through a consultative process involving academia, building experts and facilty managers.

I gratefully acknowledge the support of all those associated with the development of these guidelines and look forward to their continued guidance for its enhancement. .

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CHAPTER 1

Overview to Retrofit Guidelines

Background

India is the 7th largest country in the world and home to over 1 billion people living across five different climatic zones. India is a rapidly growing economy with construction sector contributing to around 7.74% to the total GDP of the country [1]. Commercial and residential development remains a priority for the construction industry due to its market potential/market demand/ profit margins?. These sectors also consume a large amount of energy over their life cycle, thus becoming one of the major sources of GHG emissions.

Realising the urban development and need for infrastructure facilities for commercial and residential purposes, the 18th EPS report suggests that the existing building sector in India contributes to 40% of the total energy consumption [2]. The concurrent values for electricity consumption from the residential and commercial sector are 26% and 11% respectively [3]. Where the residential sector has seen a near consistent growth of 9.57% in electricity demand from 1947-50 to 2015-17,the concurrent values for commercial sector is 7.69%.

According to the 17th EPS report published, it was estimated that electricity demand is estimated to increase by 37.5% by 2021-22 over a baseline of 2016-17 [4]. Electricity in both residential and commercial sector is primarily consumed by HVAC, lighting, appliances and entertainment systems.

In the residential sector, lighting consumes up to 28% of the total electricity. The respective values for fans, air conditioning, refrigeration, TV and evaporative cooling are 34%, 7%, 13%, 4% and 4% respectively. The rest 10% accounts for miscellaneous consumption [5]

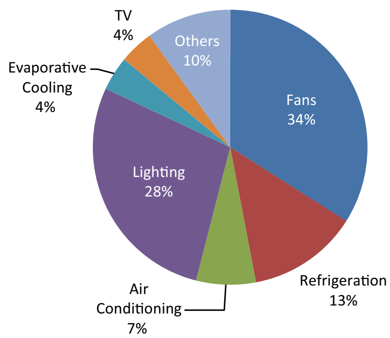


Figure 1 Residential Energy Consumption Breakup
Source: BEE, Figure taken from the Interim Report of the Expert Group on Low Carbon Strategies for Inclusive Growth, Planning Commission, Government of India

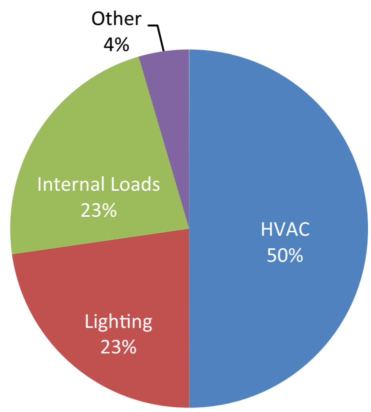


Figure 2 Commercial Energy Consumption Breakup
Source: BEE, Figure taken from the Interim Report of the Expert Group on Low Carbon Strategies for Inclusive Growth, Planning Commission, Government of India

In the commercial sector, HVAC accounts for 55% of the total electricity consumption, lighting contributes to 23%, another 23% is linked with internal plug loads and rest 4% is consumed by other processes [5].

Literature and current policy framework suggest that energy saving and its conservation is of prime importance to the government of India. The government is in a continuous process of suggesting and implementing policy frameworks to manage the energy usage from various sectors including the buildings sector. The government came out with a suggestive list of voluntary and mandatory programs and policies such as Energy Conservation Building Code (ECBC) for commercial buildings, Standards and Labelling (S&L) program for appliances, Star rating program for existing building etc. to monitor and optimize the energy consumption from the sector.

Although the government is working on a proactive approach to monitor and manage the energy consumption from new buildings, sufficient policy push is required to tap the energy consumption and energy saving potential from the existing building.

Need for Commercial Building Retrofit

A building once operational, continues to consume energy and increase its carbon footprint throughout its life. Standard construction in India lasts ranging from 50 to 60 years (source). Hence, retrofitting existing buildings to ensure energy efficiency and mitigate GHG emissions has been identified as one of the most effective mechanism by governments of various countries to reduce their energy consumption and mitigate GHG emissions.

In India major stock of commercial buildings was built before the implementation and access to modern energy saving technologies. Most of the buildings operating as commercial office spaces, hospitals and hotels were inefficiently planned without any attention to passive design strategies, choice of systems and climate responsive building materials. This provides a great opportunity in the commercial building sector to optimize energy consumption.

Previously, case studies from developed countries such as China, U.S, and U.K have proved that

Retrofitting existing buildings can lead up to 15-20 % savings over the benchmark energy consumption. While the building practitioners understand that retrofitting existing buildings presents us with the opportunity to save energy, there is an implementation and financial barrier to the success of the retrofit program.

The guidelines on " Retrofitting Existing commercial Buildings presents a step by step approach to access the saving potential in the existing building and then stimulate implementable options and method to achieve required numbers in term of energy savings and GHG mitigation.

The chapter 2 of the guidelines elaborates on the methodology to estimate the potential of reducing the energy consumption of a building through the implementation of various ECMs. The chapter 2 defines the general energy auditing methodology required to judge the energy saving potential and identify building specific ECMS

The chapter 3 of the guidelines highlights the steps to remember while prioritizing the ECMs for implementation and accessing the financial impact

The chapter4 of the report discusses the need for developing an implementation plan for smooth commissioning and operation of systems while judging the risks and developing mitigation strategy for the same

Chapter 5 of the report focusses on the need for developing M&V protocol and method to evaluate the building performance timely.

CHAPTER 2

Determining the Energy Saving Opportunities in Existing Buildings

Background

A building consists of a group of spaces physically separated by walls, fenestrations and doors. These spaces are supported through electrical, lighting, HVAC and plumbing systems to sustain its functionality and provide occupants with ideal habitat conditions. Designed and planned well, an optimized building can provide thermal, acoustic and visual comfort to its occupants while optimizing its energy consumption and promoting well-being in the built environment. While the need for retrofitting existing building to unlock their energy savings potential is undisputable, the measures recommended should be meticulously assessed and savings should be accurately estimated. The process of identifying and recommending ECMs after a detailed performance evaluation of the building is called a building energy audit and has been summarized in the following figure.

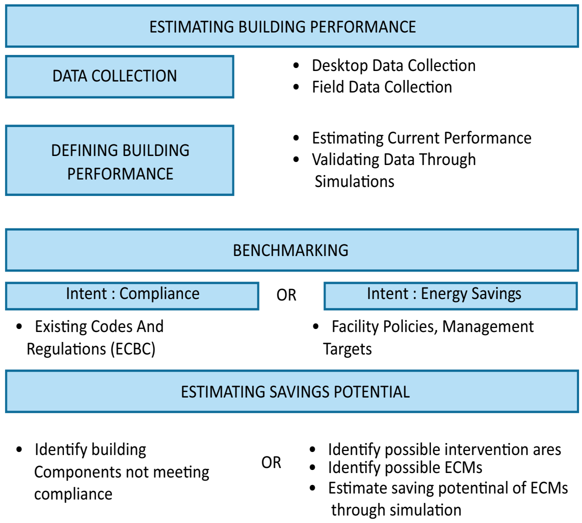


Figure 3 Steps of a Building Energy Audit

Building Energy Audit

In order to assess the energy saving potential of a facility, it is integral to understand and record its current performance through an investigation of operations and building energy use patterns. While there are multiple approaches to perform energy audits in the building, the widely accepted approach is defined by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). ASHRAE has created a set of audit standards – Levels I, II and III – that allow for a common understanding of service levels in the marketplace.[6]

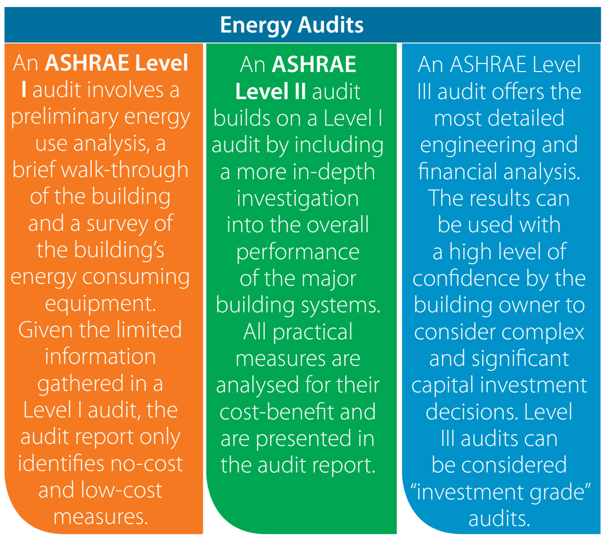


Figure 4 Levels of Energy Audits

Energy audit is the key to a systematic approach to decision-making in the area of energy management. Simple energy audits provide building owners with a list of no-cost or low-cost recommendations and a general road map for future planning. Many of these recommendations are easily implemented by operations and maintenance staff, and energy savings are seen almost immediately.

Many factors such as audit cost, availability of funds for energy efficiency upgrades, long term strategy etc. figure into the choice of adopting an appropriate audit level. For example, a Level I audit could be used to verify that the building portfolio prioritization achieved through benchmarking is indeed reflective of the buildings' energy saving potential while a Level II audit would typically provide enough detail for deeper retrofit measures that involve a longer return on investment and more significant capital outlay. A building owner should complete a Level III audit when it is necessary to estimate energy savings and economic viability accurately.

To ensure a holistic approach to the audit the following aspects of a facility needs to be assessed in detail:

Building Envelope

All components which separate the spaces inside the building from outside environmental conditions are referred to as the building envelope. The building envelope forms a thermal boundary with the exterior through an integrated system of three-dimensional, multi-layer, multi-material assemblies consisting of the following components:

- Roofing system(s)
- Walling system(s) (Above grade)
- Fenestrations
- Base Floor system(s)
- Below-Grade Walling Systems

Electrical Systems

All systems responsible for proper functioning of building and distribution of electricity within the building premises are considered as electrical systems. These includes

- Transformers
- Motors
- Metering and monitoring units
- Automatic power Factor Correctors and
- Harmonic Correctors

Lighting Systems

Good lighting in a building provides sufficient light in the right place. This enables the occupants to see easily and in comfort allowing them to perform their work efficiently without strain or fatigue. The lighting within the building includes

- Artificial indoor lighting
- Outdoor lighting

Heating, Ventilation, Air Conditioning System (HVAC)

It is the prominent head which accounts for most of the building energy demand. Centralized air conditioning system generally consists of Chiller plants, air handling units, fan coil units, cooling tower etc. Figure 5 shows a typical load break – up of HVAC plant where all Chiller, chilled water (CHW) pumps, condenser water (CW) pumps, cooling tower (CT) fans, air handling unit (AHU) fans, fan coil unit (FCUs) and package units aredetailed out.

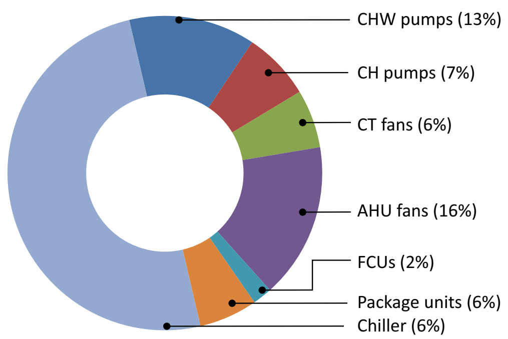


Figure 5 HVAC Load Break up [12]

Data Collection

One of the key tasks of a building energy audit is the collection of data related to the energy demand of the building and current performance of different building systems. The process of data collection needs to be reliable, repeatable and accurate. While sourcing quality data through desktop data collection becomes a challenge due to a lack of monitoring frameworks in existing facilities, field recordings over a limited period of time might also fail to present the annual performance of buildings accurately. Hence to ensure the precision of the audit, it is recommended to follow a robust mechanism to validate both types of data.

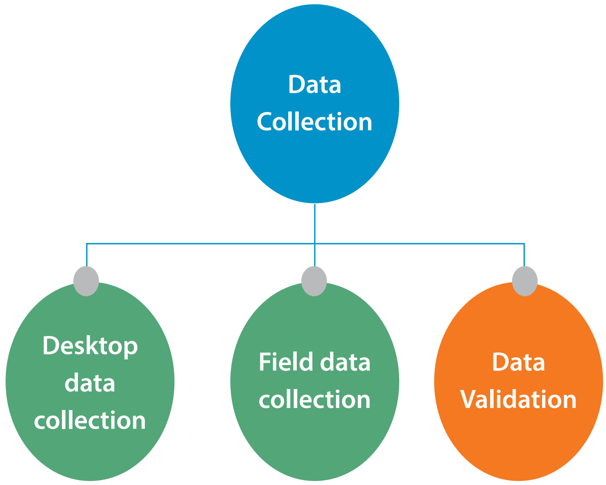


Figure 6 Data Collection Process

Desktop data collection

At this stage, the facility manager should also convey to the audit team, the facility's level of commitment and the extent to which the management is willing to invest.

Field data collection

Field data collection enables auditors to record and observe the performance of each space and equipment. This activity includes field measurements of the electrical,

Table 1 Desktop Data Collection Parameters

Project Details	Building Envelope	Lighting Systems
Location	Architectural Drawings	Lighting Layout
Size	Site Plan and Landscape Plan	Installed lighting typology (CFL, LED, T5 etc.)
Typology	Floor Plans	Wattage of individual lamp type
Number of Buildings	Elevations	Total quantity of lighting fixtures installed
Occupancy	Sections	Usage hours per year
Electrical Systems	Door, Window Schedule	Types of lighting controls installed, if any
Single line diagram (SLD) of power supply	Building Materials	Detail of Timer switch & daylight controls installed, if any
Rating of all the transformers	Load bearing members	Any existing replacement measures going on
Rating of DG sets installed	Non-load bearing opaque wall construction	HVAC System
Design data of Air Handling Unit (AHU)	Roof	Chiller designed technical specification
Historical electricity bill data (for at least one year)	Floor Slabs	Chiller daily log book record
LT log book data (for at least one year)	Fenestration Details	Low side and high side equipment design specifications
Metered data from Energy Management System (if available)	Doors	HVAC floor plans & Plant schematic drawings
UPS inventory	Finishes	Periods of operation and annual plant and equipment operating hours.
Current Monitoring, Reporting and Verification framework		

lighting and HVAC systems and helps validate the data collected previously. The information is used to develop both individual system load profile and overall building load profile. The logged data shall be used to verify the exactness of the estimated building total and end-use energy consumption generated by the desktop data collection.

The energy audit team shall first conduct a site visit to familiarise themselves with the facility's processes and equipment. Following this, the audit team shall use appropriate instruments and methodologies to estimate the following data at site.

- Indoor Air Temperature and Humidity
- Illuminance levels through natural and artificial lighting across all habitable spaces
- Electrical parameters of all major equipment
  a. Voltage
  b. Current
  c. Load (kW)
  d. Power Factor
  e. Voltage Harmonics
  f. Current Harmonics
- Chiller plant performance
  a. Flow Measurement
  b. Inlet and Outlet Temperature
- 5) Cooling Tower Performance
  a. Sump Temperature
  b. Dry-Bulb Temperature and Relative Humidity
  c. Approach
- Pump Efficiency
- Natural and Mechanical Ventilation System Details

The above list is subject to the discretion of the audit team and project objectives.

Benchmarking

The next step in the building energy audit process is to define the performance of a facility through a calculation matrix. The conclusions drawn from the matrix shall help compare the current performance of the facility with similar buildings and identify areas where the building is performing inefficiently. While there are many codes and regulations governing the development and operation of facilities in India, The Energy Conservation Building Code provides a consolidated document for benchmarking building performance. It was released as a voluntary code by the Bureau of Energy Efficiency, Ministry of Power to implement energy efficiency in buildings under the Energy Conservation Act of 2001. The following should be kept in mind during the benchmarking process.

Occupant Comfort

In India, the National Building Code (NBC) prescribes two narrow ranges of comfortable temperature, 23 – 26 °C and 21 – 23 °C for summer and winter, irrespective of variation in building type and climatic conditions (BIS 2005). However, India has a wide variation in geography, climate, culture and household income all of which affect adaptation and thereby also the thermal comfort. More recent models of adaptive thermal comfort like the ASHRAE 55-2010 and CEN Standard EN15251 take into account the climatic context to predict comfortable temperature ranges. These standards can help assess the capability of the building in providing comfortable conditions to its occupants.

Building Envelope

The ECBC lays out mandatory and prescriptive criterions for the optimization of the building envelope to achieve an energy efficient building. The standard is responsive to the varied climatic conditions of India and takes into account the viability of achieving the benchmarks in the Indian context. The ECBC mandatory provisions for the building envelope recommends thermal and physical properties of walling, roofing and fenestration systems. The information collated during data collection needs to be assessed to identify non-compliant components of the envelope which need to be retrofitted.

Electrical Systems

The calculations for electrical system provides with the total annual loading profile of the building along with loading profile of individual systems. The IS codes provides specific requirements for the systems such as transformer and motors. These codes determine the health of the system focusing on the allowable limit of losses. Apart from the IS codes, ECBC lays specific requirement for monitoring, metering, power distribution and power factor correction requirements in the building. Apart from these the harmonics achieved at building LT level should be within the permissible IEEE limits.

Lighting Systems

The lux level measurement identifies the weighted average lux available on the work plane. The same shall be reviewed w.r.t the recommended illuminance levels as per the National Building Code 2016. The Lighting Power Density of a facility needs to be calculated on the basis of data collected and compliance with ECBC needs to be checked. Areas which do not meet the required illuminance level needs to be identified to ensure the visual comfort of all occupants.

HVAC

Using data collected during audit like flow at chilled water lines, inlet and outlet temperature; the audit team shall calculate the performance of chiller i.e. ikW per TR. HVAC in the commercial entities divided into two types. One is generalised air conditioning systems, the standards of which are available with Bureau of Energy Efficiency (BEE) star Labelling scheme based on Indian Seasonal Energy Efficiency Ratio (ISEER). The second is centralised air conditioning systems whose standards are available with Energy Conservation Building Code (ECBC) and ASHRAE 90.1based on their Coefficient of performance (COP) and Integrated Part Load Value (IPLV).

Identifying Energy Conservation Measures

Once the base case for the building performance is established and inefficient aspects of the building are identified, the viability of possible ECMs need to be investigated. The intent of the exercise should be to identify ECMs which could provide the highest savings in energy consumption to meet the facility's requirement while being physically and economically viable. If there is any energy savings target set by the facility manager, the ECMs required to achieve the target needs to identified and scientifically validated.

The accuracy in the estimation of saving potentials for each viable ECM is integral to the success of the project. To make an informed decision, the nuances of a project such as site conditions, building typology, system details, occupant behaviour and schedules need to be considered. Estimation is done through both manual calculations and software simulations.

The advent of simulation tools has made estimating performance of buildings quicker, accessible and more accurate. An array of options exists in the simulation tool industry. The selection of the tool needs to take into account the expertise available and software capability. Before simulating, specific information exchange and input requirements need to be mapped. Once the methodology is validated and energy saving potential for each ECM has been identified, the auditors need to summarize the findings with details regarding their installation requirement, cost, savings, and payback period. Facility managers need to ensure that the ECMs deployed do not hinder the building envelope from providing occupant comfort. For example, the load on systems will change with the use of certain ECMs. If the increase in load is not accounted for, the increase in internal temperature might result in an uncomfortable built environment with detrimental effects on productivity and well-being.

The Table 2 summarizes the possible ECM options and their areas.

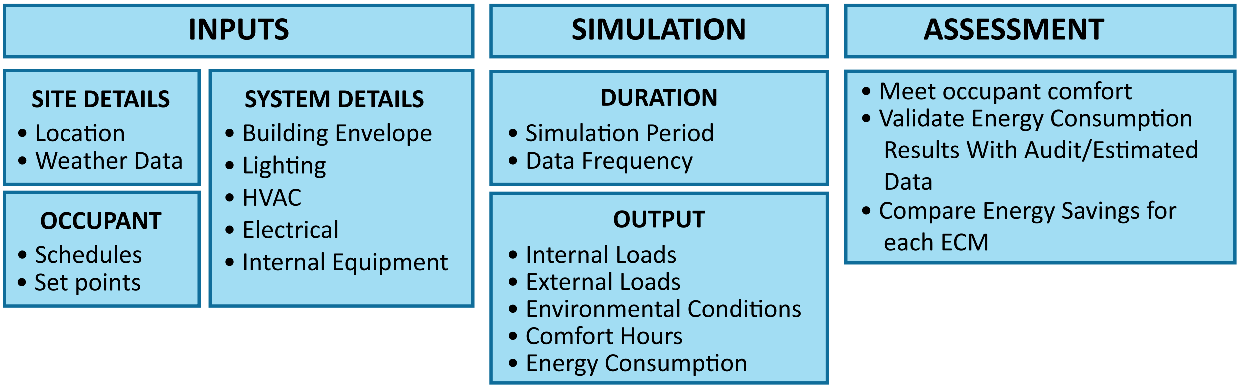


Figure 7 Assessing Energy Savings Potential through Building Simulations

Annexure -I

List of instruments used in energy audits

Annexure II- Reporting and Presentation

The process of identifying ECMs needs to be documented for the perusal of the facility manager. While the report should cover the following topics, the framework is subject to the specifics of the project and the author's discretion.

Executive Summary

The report should begin with a brief description of the methodology used and estimations such as the breakup

Table 2 ECM Strategies

Areas of Retrofit	Possible Retrofit Strategies
Interior walls	Adding insulation to interior walls
External walls	Adding insulation layers to the building exterior Spray-in-place foam insulation Wall colours and shading
Solid ground insulation	Insulation above slab with reinforced screed above Raised floor with rigid or non-rigid insulation
Intermediate floors	Replacing slab with rigid insulation beneath Applying insulation to the underside of the floor Remove deck and apply semi-rigid insulation between joints
Roof	Addition of insulation Replacing the existing roof Cool roof coating Addition of green roof Addition of roof ponds Addition of building integrated photovoltaic
Windows	Introducing new shading or light shelves Using inter-pane shading (roller blinds within the glazing) Internal shading Building integrated photovoltaic for shading or glazing Replacing the window glazing Adding suspended film to the existing window

Areas of Retrofit	Possible Retrofit Strategies
	Replacing the window frames Blocking the openings in the wrong orientation and wrong WWR
External doors	Replacing the existing doors
Daylight	More light integration into the building
Natural Ventilation	Operable panes for ventilation
HVAC System	
Operations	Check Oil Level in Compressor. It should be up to minimum of 1/3 of sight glass.
	Do following sequence of starting as mentioned below: a. Condenser water pumps b. Chilled water pumps c. Cooling Tower fans d. Air handling units e. Chillers
HVAC Plant	Installation of Plant System Manager on HVAC plant
Chiller	Before starting the Chiller plant, make sure there is sufficient water in cooling water tank. Check for sufficient quantity of water in expansion tank/make-up tank and smooth operation of float valves. Chiller Sequencing Increase Chiller set point when outdoor condition are favourable. Replacement of existing Chiller with new efficient Chiller. Use VFD Chiller to get energy savings at Part Load Conditions. Installation of Auto tube cleaning system (ATCS) at Chiller. Install Adiabatic cooling System for Air Cooled Chillers.
Chilled water pumps and motors	The VFDs of secondary pumps should be on auto mode as the system is designed and should not be limited to a fixed frequency. Optimize secondary chilled water pumps Variable Frequency Drive (VFD) operation Replacement of current installed motors with high efficiency motors on HVAC high side Replacement of all AHU motors with high efficiency motors
Cooling Tower	Use CT with Induced Draft Fans Use Low Approach Cooling Tower. Install VFD for CT Fans in Composite and Hot and Dry Climate Zone. Descaling process for the condenser circuit should be done timely to ensure proper heat-transfer by condenser tubes. Only softened water should be used as make-up water in condenser circuit and also chemical treatment/dosing should be done timely in the water circuits.
Electrical System	
Operations & Maintenance	Appropriate energy tariff ensuring Possibility of load shedding Peak demand control by manually shifting of non-critical load
Transformer	Appropriate loading of transformer By proper Location of Transformer preferably close to the load centre, considering other features like centralized control, operational flexibility etc. This will bring down the distribution loss in cables Under fluctuating load condition more than one transformer is used in Parallel Operation of Transformers to share the load & can be operated close to the maximum efficiency range Replacement of existing transformer with energy efficient transformer

Areas of Retrofit	Possible Retrofit Strategies
Harmonics	To use Harmonic filters to reduce distortion of the voltage and current waveform
Power Factor	Installing of Automatic Power Factor Controller
Demand Side Management	Using Demand Side Management (DSM) control to reduce utility cost by increasing/decrease demand, shifting it between high and low peak periods, or managing it when there are intermittent load demands
End Use Equipment	By using minimum 3-star rated energy efficient appliances
Motors	Minimising losses by using Energy efficient motors
AHU, Pumps	Using variable frequency drives to control the frequency
Lighting Systems	
Operations & Maintenance	Cleaning of lighting fixtures
	De-lamping
Timers	Installing timer switches on outdoor lighting
Lighting Fixtures	Replacing inefficient lighting fixtures with energy efficient LED
Occupancy Sensors	Installing infra-red, acoustic, ultrasonic or microwave sensors
Daylight Linked Control	Using Photoelectric cells to either to switch lighting on and off, or for dimming
Localized Switching	To use local switching in large spaces

Table 3 List of instruments used in energy audits*

S.no	Equipment	Parameters to be measured
1	Anemometer	Velocity of air in ducts, AHU and other openings for estimating the amount of air supply
2	Hygrometer (humidity meter)	Outside and inside air humidity
3	Digital Thermometer	Outdoor and indoor dry air temperature
4	Lux meter	Light intensity of lit areas
5	Three Phase Power Analyser	Electrical parameters such as Voltage, Ampere, Load (kW), Power Factor & Harmonics
6	Single Phase Power Analyser	Instant measurement of electrical parameters
7	Infrared Thermal Imager	Leakages & thermal gaps
8	Ultrasonic Flow Meter	Measurement of flow in HVAC pipeline
9	Digital air flow meter	Direction and velocity of air flow
10	Digital air pressure differential meter	Simple and reliable measurement of differential pressure
11	Digital water pressure differential meter	Measure the flow of fluid in a pipe
12	Two – Channel temperature data logger	Measure the Inlet and outlet temperature in a pipe

* From the mentioned list, Three phase Analyser & Single Phase Analyser is used to measure main incoming load of the facility, various end usage such as HVAC, Lighting, UPS, Pumps etc. Logging is performed using three phase analyser and instant measurement is performed by the single phase analyser.

of loads and energy performance Index (EPI) (kWh/ m2 /yr) of the building. The chapter shall summarize the findings of the project and recommend ECMs with their respective cost, savings potential and return on investment period.

Introduction

This chapter should address the following points:

1. Background of the project: The details of the building occupancy, location, size and operation should be summarized.
2. Sources of Data & Information: All data collected through desktop and field audits shall be summarized in this section. The objective of the study and audit tools used shall be mentioned at the end of the chapter.
3. Acknowledgments

Site Description

An overview of the climatic conditions of the site and thermal comfort ranges for occupants needs to be reported. Site conditions affecting the performance of the building such as topology, landscape, weather patterns, urban heat island effect or vegetation needs to be identified. All relevant codes and standards pertaining to the construction or retrofitting of the building need to be highlighted as well.

Energy

The section contains the following project findings:

1. Energy Consumption Trends
2. Annual Energy Consumption
3. Energy Performance Index
4. Energy Costs
5. Observations

Building Envelope

A summary of the building construction details including architectural drawings, building sections, thermo-physical properties of the building envelope, ventilation and air flow study, daylighting and heat ingress patterns

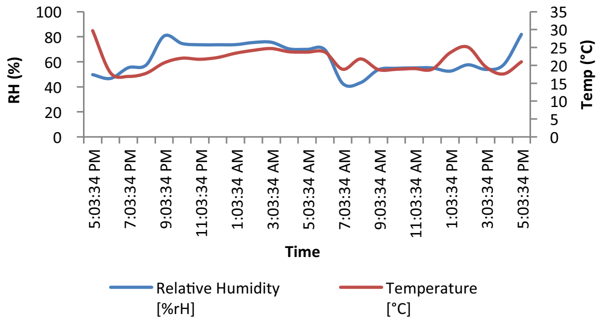


Figure 8 Thermal Comfort profile of a regularly occupied conditioned space

need to be elaborated with calculations and simulation results. Conclusions drawn from this chapter should be summarized in the end.

Electrical Systems

All electrical systems and details such as operation hours, control system, maintenance, the efficiency of equipment and loading need to be summarized in this section. All areas where savings potential has been identified need to be listed with reasons.

Lighting Systems

This section outlines the existing lighting system in the building, its operation and maintenance schedule. The section should focus on the current energy consumption

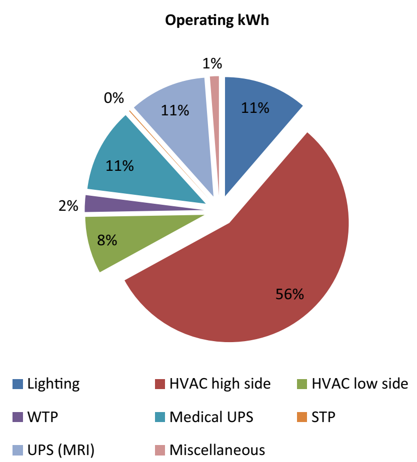


Figure 9 End-use energy consumption break up

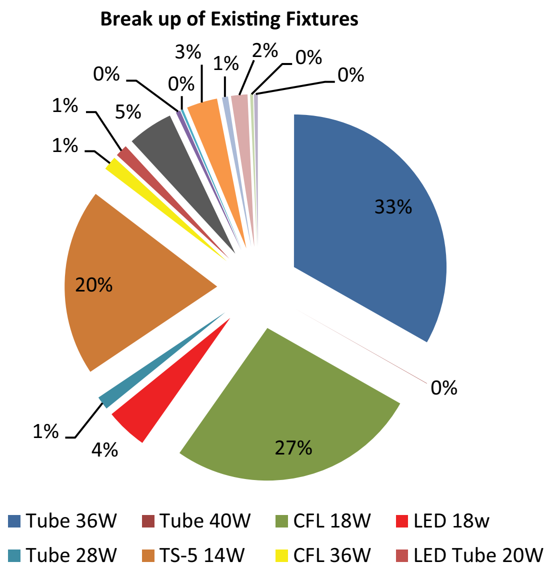


Figure 10 Break up of Existing Lighting Fixtures

due to lighting, lighting power density, visual comfort levels inside the building and opportunities to optimize the system.

Heating, Ventilation and Air-Conditioning Systems

The section shall give an overview of all air-conditioning systems employed in the facility. It should begin with an overview of the plant, system design data, load break up, the efficiency of systems and data collected during audits. The analytics and estimations need to be scientifically validated and referenced. Some of the representations in energy audit report are shown below:

Suggested ECMs

Based on the study, ECMs may be suggested with details regarding their installation requirement, cost, savings, and payback period. The following details need to be covered in this section:

- Assumptions used in estimating savings potential
- Methodology, calculations and references
- Conditions of achieving savings
- ECMs with detailed analysis

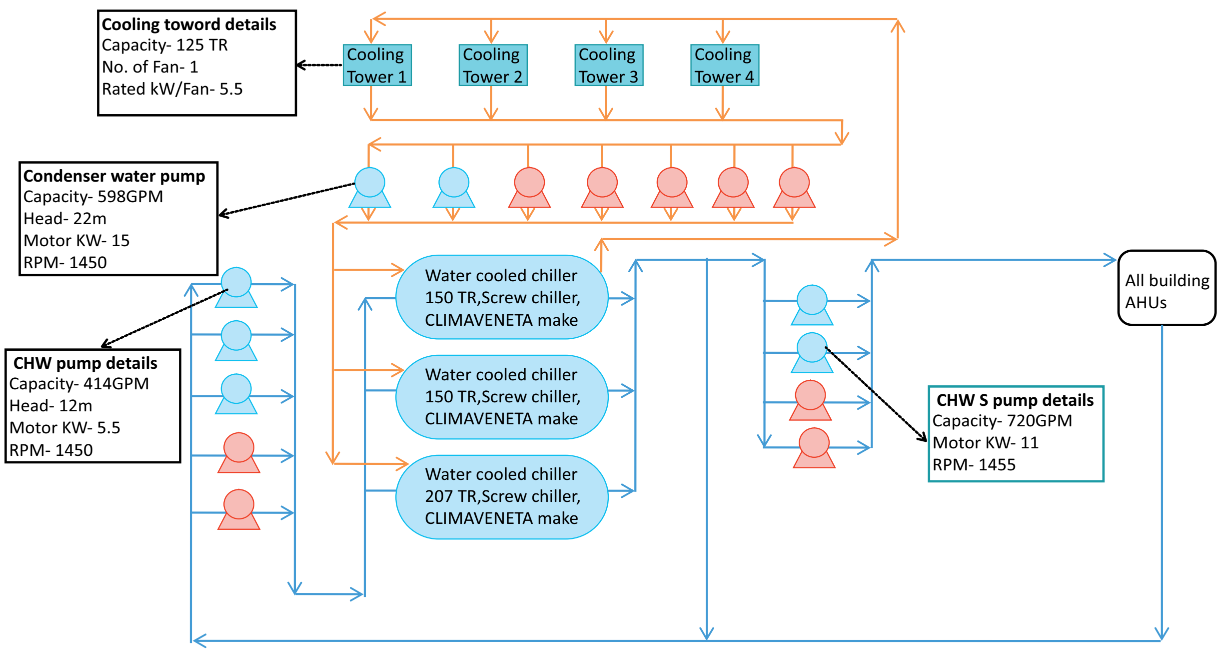


Figure 11 HVAC plant schematic

CHAPTER 3

Energy Management Plan for Buildings

An Energy Management Plan (EMP) is a written plan which describes the steps and approaches to increase energy efficiency and conserve energy in all areas of a building. The typical period of an EMP ranges from three to five year. EMP act as roadmap to improve efficiency, build on progress, and control energy costs.

The previous chapter listed down the energy saving potential different systems hold in the existing building. This chapter will focus on highlighting the requirement for developing an EMP to optimize savings opportunities in a cost effective manner. The plan includes a building profile, short- and long-term energy reduction strategies, reduction targets, staff responsibilities, financial considerations, and the methodology to evaluate the progress. It is a live document that can be changed in response to results, unexpected events, and changing needs.

Staging retrofit plan

In order to understand the requirement of the building, it is firstly required to understand the category of retrofit the suggestive strategy lies into. Energy retrofit projects may be divided into three categories: Minor, Major and Deep.

Minor Retrofits is a good first step and basically include only operational changes.

Major energy Retrofits involve several measures across building systems. It typically lead to savings of 15 to 40%.

Deep Retrofits are generally not driven by the target of energy saving but are driven by the conscious of modification within the space. The savings can result in more than 40% of energy saving.

The retrofit strategy also depends upon the need of the occupant, energy reduction targets and targeted timeline for achieving the retrofitting. Timing and approach are vital factors to synchronize energy efficiency drive with the existing building. Right steps in right sequence, to ensure optimized techno-economical retrofit of building are very important. .

It is preliminary to define an energy saving target based on the assessment done for the building before pursuing with development of EMP. These energy saving targets can be based on the applicable energy conservation codes prevailing in a country. . In countries where national codes does not cater to existing buildings, the EMP is mostly developed based on widely accepted international codes (eg. In India GRIHA, LEED, IGBC cater to the need of the existing building scenario) and energy saving targets are defined accordinlgy.

Prioritizing Building ECMs

The ECMs can vary from low cost measures to high investment measures which may result differently at different times depending on and various parameters such as weather, physical feasibility, equipment age etc. It is essential to prepare a plan and prioritize the retrofit strategy integrating it with the occupant need , Capital plan and Integrated design approach or staged approach so as to say, before engaging for deep or major retrofitting for implementation of the ECMs.

Capital Planning: is a structured approach for managing long-term assets (i.e. a strategic approach to asset management). Effective capital planning allows you to manage capital expenditures associated with your fixed assets, and identify and solve aging asset issues before they become problems. A capital plan categorizes and prioritizes the renewal of your physical assets [7].

Staged Approach: Staged approach is a sequential approach towards achieving best results via the retrofits and hence forth should be incorporated as a part of the comprehensive Energy management Plan for building. The staged approach consists of two phases Reduce, Improve, Optimize and then retrofit.

The first phase mostly refers to enhancing the building operations and maintenance so as to reduce the energy load of the building by eliminating wastage of energy. The reduction includes simple operational changes like turning off the equipment while not in use (eg lights, Pumps) and improvement in use of control equipment so that energy consumption is more precise (setting higher set points, lighting levels). Improvement involves enhancing the building systems by including maintenance schedules and regular processes to make systems achieve best operation efficiency and avoid additional energy demand (eg. Cleaning the filters of AHUs). Optimization involves integrating both the previous steps together and designing a proper schedule of operation and maintenance of different systems within the building to reduce and avoid peak demand (eg. Scheduling regular maintenance process while the equipment is already in turned off state). The second phase is to retrofit the building for which a prioritization shall be done assessing parameters such as Occupant need, Ease of Installation, Investment options and energy reduction opportunities. A priority matrix is made to summarize the results and create retrofit implementation process roadmap along with scheduled timelines.

Occupant Need

Delivering to the requirement of the occupants performing tasks within the building forms the first step of defining the EMP. It is important to cater the needs of the occupant for maintaining the thermal and visual comfort. The feedback received from the occupants acts as control protocol and becomes the first check and verification mechanism for the facility managers.. Depending on the needs of the occupants , niche area which requires modification shall be identified for retrofitting. This becomes the first priority parameter for providing the solution to the occupant of the building. (eg. Occupants can feel uncomfortable because of temperature imbalance in the building at different spaces in the building or not meeting the comfort temperature at all which may arise the need of checking the AHUs or the HVAC Systems for operational performance; too much or too less lighting may result in complaints for visual discomfort which may arise the need for assessing the Lighting fixtures)

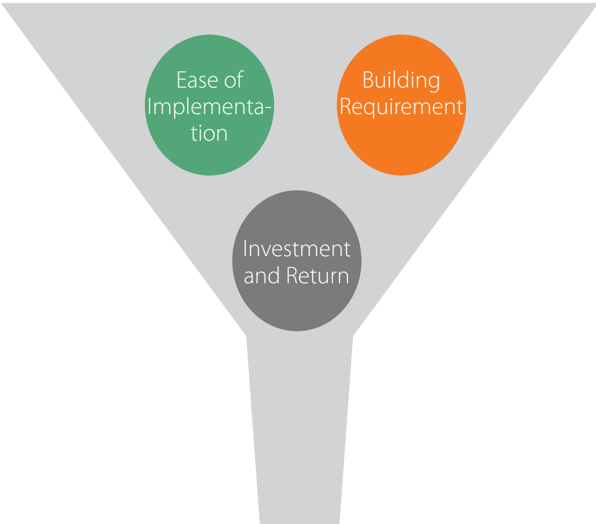
Once the occupant need is determined, the next steps is to prioritize the ECMs identified in the previous chapters in a way that these addresses the issues and challenges raised by the occupants in minimalistic way. These ECM opportunities can be prioritized in accordance with the occupant need mapped with other parameters stated above.

Development of Priority Matrix

Post assessing the opportunities for retrofit. A format is developed to compare the retrofit options present/ available in individual building systems based on parameters discussed earlier, such as: Occupant need, Ease of Installation, Investment

Parameters for Priority Matrix

Defining relevant parameters helps in assessing priority of each ECM in comparison to other building system ECMs. These parameters list presented below is indicative and for the reference of the building manager, a further more extensive list can be developed depending case to case. The paremters detailed in figure below are based on international best practices used world wide for presenting a business case for retrofitting in buildings.



Retrofit priority

Figure 12 Retrofit priority

The parameters have been grouped into three groups based on their applicability:

- **Building Requirement**: Targeting the demand from the building in terms of occupant need, planned or budgeted activity as per the asset management plan or achievement in Energy targets of the building.
- **Ease of Implementation**: Depending on the ease by which the equipment can be physically carried, installed and taking into account time and complexity in Installation
- **Investment & Return**: Caters to the funds involved in the process of implementation from investment to payback period.

Using the priority matrix

This chapter includes a sample priority matrix developed based on the general ECMs widely adopted in the building industry for retrofitting. The listed parameters are compared based on their impact on the building in terms of enhancing energy efficiency of the building. The matrix developed, currently provides a qualitative representation of impact on energy efficiency. The scale is judged based on three impact parameters: Low, Medium, and High. The sample matrix can be filled by the

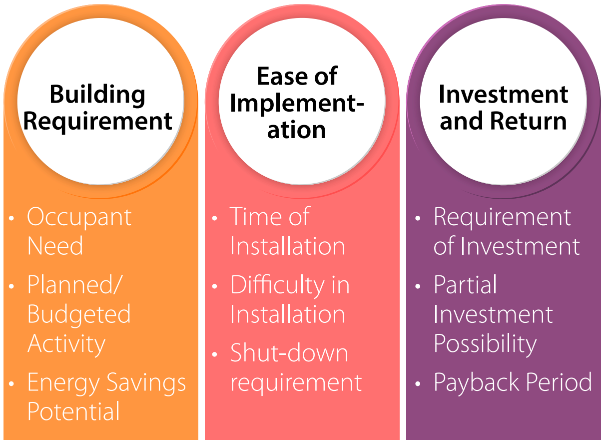


Figure 13 : Parameters to be considered while developing Priority Matrix

Table 4 Definition of Parameters to be considered for Developing Priority Matrix

Parameter	Definition
Occupant Requirement	Occupant requirement refers to the need of the occupant for a particular energy conservation measure, will help them achieve a better comfort scenario or energy savings
Already Planned/ Budgeted	Already planned or budgeted activity refers to a particular ECM which has already been budgeted as per the asset or replacement policy of the company.
Energy Saving Potential	Energy Savings potential can be defined as the energy savings that can be achieved by implementation of a certain energy conservation measure.
Time of Installation	Time of installation refers to the time that is required for the completion of a particular ECM
Difficulty in Installation	Difficulty in installation refers to the difficulty which is faced while installating a particular equipment or ECM
Shut-down requirement	Shut Down requirement refers to the need of shutting the whole building or a particular system down in case of implementation of a ECM
Investment Required	Investment required refers to the investment that is required for the implementation of particular ECM
Partial Installation possibility	Partial installation possibility refers to : if an ECM is to implemented in Phases or stages
Payback Period	The payback period refers to the length of time required to recover the cost of an investment [10]

building manager in consultation with the financial team for coherently assessing and planning technical and financial roadmap of implementation. A combination of responses for high, low and medium may lead to the best prioritization of the ECMs for implementation in a phased manner. The energy saving targets set for the buildings are to be analysed while filling up the priority matrix with maximum weightage being given to the occupant need .

Once the priority matrix has been filled, it becomes easy for the facility manager to draw a time line for the implementation.

Timeline

Timing the implementation of a particular ECM acts as pivotal instrument to increase the impact along with the identified potential.

Development of Capital Plan

It is important to parallel determine a capital investment plan along with the identified ECMs. It is suggested to begin with creating an information repository of Fixed Assets ;which is defined as facilities and equipment, that are economic resources belonging to an organization, these have future economic benefit and are the result of past financial transactions. [7] It is also advised to develop an asset management plan developed post development of the inventory information. The Asset Management Plan; includes activities associated with the acquisition, operation, maintenance, renewal and replacement of an organization's fixed assets. [7] The information collected for asset management plan is required to devise a capital plan. Effective capital planning proves helpful in managing capital expenditures associated with fixed assets, and identifying & solving aging asset issues as well. A capital plan is an effective procedure to categorize and prioritize the renewal process of physical asset.

Assessment using the Capital Plan

The total cost of ownership of an asset includes the purchase costs as well as operation and maintenance (O&M) over time . The lifecycle approach to asset management is a widely accepted methodology that uses an expected useful life for assets and anticipates their replacement on or before the expiry of their operable or serviceable life. However, in some cases, it makes more economic sense to replace an inefficient component, regardless of where it is in its life cycle.

Comparing proposed major retrofit measures with capital plan provides opportunities to analyse priority retrofit options against energy savings It also allows for a strategic asset management decision process, ideally allowing enough lead time to properly evaluate different facility components for enhancement. The comparison can identify projects that would not have been economically viable because of the large capital cost but making them the first priority since the replacement was already scheduled For example, if a replacement of chiller is already budgeted for, and, for a minimal cost premium, operational efficiencies can be gained, such as installation of Plant optimizer. Though achieving these were not a priority. However, the cost involved will only be the premium these efficiencies can be realized.

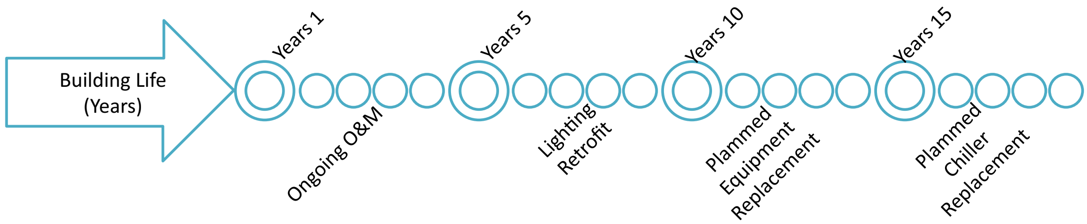


Figure 14: Example of Capital Plan timeline

Table 5: Priority Matrix for Retrofitting in Existing Building

ECM/Staging Parameter				Building Requirement			Ease of Implementation			Investment and Returns		
				Occupant Requirement	Already Planned/ Budgeted	Energy Saving Potential	Time of Installation	Difficulty in Installation	Shut-down requirement	Investment Required	Partial Installation possibility	Payback Period
				High/ Medium/Low	Yes/No		High/ Medium/ Low	High/ Medium/ Low	High/ Medium/ Low	High/ Medium/ Low	High/ Medium/ Low	High/ Medium/ Low
Building Envelope												
Areas of Retrofit		Possible Retrofit Strategies	Type OF ECM									
Wall Insulation	Interior walls	Adding insulation to interior walls	High Cost									
	External walls	Adding insulation layers to the building exterior	High Cost									
		Spray-in place foam insulation	High Cost									
		Wall colours and shading	Low Cost									
floor insulation	Solid ground insulation	Insulation above slab with reinforced screed above	Medium Cost									
		Raised floor with rigid or non-rigid insulation	Medium Cost									
	Intermediate floors	Replacing slab with rigid insulation beneath	High Cost									
		applying insulation to the underside of the floor	Medium Cost									
		Remove deck and apply semi-rigid insulation between joints	High Cost									
Roof Insulation	Roof	Addition of insulation	Medium Cost									
		Replacing existing roof	High Cost									
		Cool roof coating	Low Cost									
		Addition of green roof	Low Cost									
		Addition of roof ponds	Medium Cost									
		Addition of building integrated photovoltaic	High Cost									

ECM/Staging Parameter				Building Requirement			Ease of Implementation			Investment and Returns		
				Occupant Requirement High/ Medium/Low	Already Planned/ Budgeted Yes/No	Energy Saving Potential	Time of Installation High/ Medium/ Low	Difficulty in Installation High/ Medium/ Low	Shut-down requirement High/ Medium/ Low	Investment Required High/ Medium/ Low	Partial Installation possibility High/ Medium/ Low	Payback Period High/ Medium/ Low
Fenestration retrofit	Windows	Introducing new shading or light shelves	Medium Cost									
		Using inter-pane shading (roller blinds within the glazing)	Low Cost									
		Internal shading	Low Cost									
		Building integrated photovoltaic for shading or glazing	High Cost									
		Replacing the window glazing	High Cost									
		Adding suspended film to existing window	Low Cost									
		Replacing the window frames	High Cost									
	External doors	Replacing the existing doors	Medium Cost									
	Daylight	More light integration to the building	Medium Cost									
	Natural Ventilation	Operable panes for ventilation	Medium Cost									
Orientation	North	Blocking the openings in the wrong orientation and wrong WWR	Low Cost									
	South		Low Cost									
	East		Low Cost									
	West		Low Cost									
	N/E		Low Cost									
	N/W		Low Cost									
	S/E		Low Cost									
	S/W		Low Cost									

ECM/Staging Parameter				Building Requirement			Ease of Implementation			Investment and Returns		
				Occupant Requirement High/ Medium/Low	Already Planned/ Budgeted Yes/No	Energy Saving Potential	Time of Installation High/ Medium/ Low	Difficulty in Installation High/ Medium/ Low	Shut-down requirement High/ Medium/ Low	Investment Required High/ Medium/ Low	Partial Installation possibility High/ Medium/ Low	Payback Period High/ Medium/ Low
Electrical												
Areas of Retrofit	Possible Retrofit Strategies	Type of ECMs										
Operations & Maintenance	Appropriate energy tariff ensuring	No cost										
	Possibility of load shedding	No cost										
	Peak demand control by manually shifting of non-critical load	No Cost										
Transformer	Appropriate loading of transformer	No Cost										
	By proper Location of Transformer preferably close to the load centre, considering other features like centralized control, operational flexibility etc. This will bring down the distribution loss in cables	No cost										

ECM/Staging Parameter				Building Requirement			Ease of Implementation			Investment and Returns		
				Occupant Requirement High/ Medium/Low	Already Planned/ Budgeted Yes/No	Energy Saving Potential	Time of Installation High/ Medium/ Low	Difficulty in Installation High/ Medium/ Low	Shut-down requirement High/ Medium/ Low	Investment Required High/ Medium/ Low	Partial Installation possibility High/ Medium/ Low	Payback Period High/ Medium/ Low
	Under fluctuating load condition more than one transformer is used in Parallel Operation of Transformers to share the load & can be operated close to the maximum efficiency range	No cost										
	Replacement of existing transformer with energy efficient transformer	High Cost										
Harmonics	To use Harmonic filters to reduce distortion of the voltage and current waveform	Medium cost										
Power Factor	Installing of Automatic Power Factor Controller	Medium cost										

ECM/Staging Parameter				Building Requirement			Ease of Implementation			Investment and Returns		
				Occupant Requirement High/ Medium/Low	Already Planned/ Budgeted Yes/No	Energy Saving Potential	Time of Installation High/ Medium/ Low	Difficulty in Installation High/ Medium/ Low	Shut-down requirement High/ Medium/ Low	Investment Required High/ Medium/ Low	Partial Installation possibility High/ Medium/ Low	Payback Period High/ Medium/ Low
Demand Side Management	Using Demand Side Management (DSM) control to reduce utility cost by increasing/ decrease demand, shifting it between high and low peak periods, or managing it when there are intermittent load demands	Medium Cost										
End Use Equipment	By using minimum 3-star rated energy efficient appliances	Medium Cost										
Motors	Minimizing losses by using Energy efficient motors	Medium Cost										
AHU, PUMPS	Using variable frequency drives to control the frequency	Medium Cost										
HVAC												
Areas of Retrofit	Possible Retrofit Strategies	Type of ECMs										

ECM/Staging Parameter				Building Requirement			Ease of Implementation			Investment and Returns		
				Occupant Requirement High/ Medium/Low	Already Planned/ Budgeted Yes/No	Energy Saving Potential	Time of Installation High/ Medium/ Low	Difficulty in Installation High/ Medium/ Low	Shut-down requirement High/ Medium/ Low	Investment Required High/ Medium/ Low	Partial Installation possibility High/ Medium/ Low	Payback Period High/ Medium/ Low
Operations	Check Oil Level in Compressor. It should be up to minimum of 1/3 of sight glass.	No cost										
	3. Do following sequence of starting as mentioned below:	No cost										
	a. Condenser water pumps											
	b. Chilled water pumps											
	c. Cooling Tower fans											
	d. Air handling units											
	e. Chillers											
HVAC Plant	Installation of Plant System Manager on HVAC plant	High Cost										

ECM/Staging Parameter				Building Requirement			Ease of Implementation			Investment and Returns		
				Occupant Requirement High/ Medium/Low	Already Planned/ Budgeted Yes/No	Energy Saving Potential	Time of Installation High/ Medium/ Low	Difficulty in Installation High/ Medium/ Low	Shut-down requirement High/ Medium/ Low	Investment Required High/ Medium/ Low	Partial Installation possibility High/ Medium/ Low	Payback Period High/ Medium/ Low
Chiller	Before starting the chiller plant, make sure there is sufficient water in cooling water tank. Check for sufficient quantity of water in expansion tank/ make-up tank and smooth operation of float valves.	No cost										
	Increase chiller set point when outdoor condition are favorable.	No cost										
	Replacement of chiller with new efficient chiller	High Cost										
	Installation of Auto tube cleaning system (ATCS) at Chiller	High Cost										

ECM/Staging Parameter				Building Requirement			Ease of Implementation			Investment and Returns		
				Occupant Requirement High/ Medium/Low	Already Planned/ Budgeted Yes/No	Energy Saving Potential	Time of Installation High/ Medium/ Low	Difficulty in Installation High/ Medium/ Low	Shut-down requirement High/ Medium/ Low	Investment Required High/ Medium/ Low	Partial Installation possibility High/ Medium/ Low	Payback Period High/ Medium/ Low
Chilled water pumps and motors	The VFDs of secondary pumps should be on auto mode as the system is designed and should not be limited to a fixed frequency.	No cost										
	Optimize secondary chilled water pumps Variable Frequency Drive (VFD) operation	Low Cost										
	Replacement of current installed motors with high efficiency motors on HVAC high side	Medium Cost										
	Replacement of all AHU motors with high efficiency motors	Medium Cost										

ECM/Staging Parameter				Building Requirement			Ease of Implementation			Investment and Returns		
				Occupant Requirement High/ Medium/Low	Already Planned/ Budgeted Yes/No	Energy Saving Potential	Time of Installation High/ Medium/ Low	Difficulty in Installation High/ Medium/ Low	Shut-down requirement High/ Medium/ Low	Investment Required High/ Medium/ Low	Partial Installation possibility High/ Medium/ Low	Payback Period High/ Medium/ Low
Cooling Tower	Descaling process for the condenser circuit should be done timely to ensure proper heat-transfer by condenser tubes.	No cost										
	Only softened water should be used as make-up water in condenser circuit and also chemical treatment/ dosing should be done timely in the water circuits.	No cost										
Lighting												
Areas of Retrofit	Possible Retrofit Strategies	Type of ECMs										
Operations & Maintenance	Cleaning of lighting fixtures	No cost										
	Delamping	No cost										
Timers	Installing timer switches on outdoor lighting	Medium cost										

ECM/Staging Parameter				Building Requirement			Ease of Implementation			Investment and Returns		
				Occupant Requirement High/ Medium/Low	Already Planned/ Budgeted Yes/No	Energy Saving Potential	Time of Installation High/ Medium/ Low	Difficulty in Installation High/ Medium/ Low	Shut-down requirement High/ Medium/ Low	Investment Required High/ Medium/ Low	Partial Installation possibility High/ Medium/ Low	Payback Period High/ Medium/ Low
Lighting Fixtures	Replacing inefficient lighting fixtures with energy efficient lighting technology	High Cost										
Occupancy Sensors	Installing infra-red, acoustic, ultrasonic or microwave sensors	Medium cost										
Daylight Linked Control	Using Photoelectric cells to either to switch lighting on and off, or for dimming	Medium cost										
Localized Switching	To use local switching in large spaces	Medium cost										

Investment & Returns

Developing a business case depends upon identifying the opportunities and triggers responsible for implementation of Retrofits in the building. Table below highlights a suggestive list of I triggers which helps is identifying retrofit opportunities and influence the retrofit implementation decisions. It is to note that a retrofit opportunity which is cost effective for one facility may not be for another or even for the same facility at a different stage in its life cycle. Hence, investment in major retrofits opportunities shouldbe in a planned manner integrated with the capital plan. It helps in achieving energy saving targets and lowers costs of operation as well as installation.

Payback and Benefits

Post assessing the option with technical analysis, capital payback calculations are needed to be performed. This helps choosing best retrofit option as per the user requirement and budgetary constraints.

Cost Benefit Analysis can be done using various tools which will helps to rule out cost intensive interventions with very high payback period.

Different payback mechanism [7]

Through analysis and energy data, , peak demand and Energy Cost Index (ECI) (expressed in $ per floor area per year)can be developed [10]. . The attractiveness of an energy retrofit investment is typically assessed using one or more of the following three tools: Simple Payback, Net Present Value (NPV) or Internal Rate of Return (IRR)

Simple payback period: It can be defined as the value of an initial investment divided by the value of all annual cash flows resulting

$P = I/CF$

where: P = payback period (years)

I = value of initial investment ($)

CF = annual cash flow resulting from investment ($/year)

For example, an energy efficiency investment (I) of $100,000, with annual savings (CF) of $40,000 would provide a simple payback (P) of 2.5 years.

Net present value (NPV): It can be defined as the sum of the present value (PV) (the value of an expected cash flow resulting from a project) of all cash flows resulting from a project, including the initial investment (considered a negative cash flow at year zero)

Table 6: Retrofit Triggers and Opportunity [9]

Trigger	Opportunity
Major equipment replacement	Planned replacement of major equipment is an opportunity to right-size and install more efficient technology (e.g. a smaller chiller with better part-load efficiency). After reducing thermal and electrical loads, the marginal cost of replacing the equipment with properly sized, energy efficient equipment can be minimal or even negative.
Major envelope replacement	Planned replacement of major envelope components (roof, windows, etc.) is an opportunity to improve building insulation levels and reduce air leakage at low incremental cost.
Upgrades to meet code	Life safety upgrades require substantial upgrades and cost – enough that the incremental investment and effort to radically improve the building efficiency becomes not only feasible, but profitable. For example, an upgrade to rectify an unsafe electrical system could be coupled with a lighting redesign retrofit project.
New acquisition or refinancing	New acquisition or refinancing includes attractively financed building upgrades (which may not have been possible at other times) as part of the transaction.
Major occupancy change	A company or tenant moving a significant number of people into a building or a major turnover in square footage presents a prime opportunity for a major retrofit for three reasons. First, a major retrofit can generate interior layouts that improve energy and space efficiency and can create more leasable space by downsizing mechanical equipment. Second, ownership can leverage tenant investment in the renovation. Third, tenant disruption can be minimized

$PV = CF/(1+r)^t$

$$NPV = \sum_{0}^{n} CF/(1+r)^t$$

where:

PV = present value ($)

CF = future annual cash flow installment resulting from investment ($)

r = annual discount rate (%)

t = year in which cash flow is received

Internal rate of return: the discount rate, r, which provides an NPV of zero for a given series of cash flows. In other words, to calculate IRR using the formula, one would set NPV equal to zero and solve for the discount rate (r), which is the IRR.

Benefits beyond cost savings [7]

While considering the return on investment and payback, it may also be beneficial to look at opportunities that stand beyond just cost simple cost savings.

Increased property value. The facility may be an income generating asset. In this situation, energy savings may result in both direct cost savings and a higher asset value. One of the most common methods to evaluate a building's asset value

Reduced operations and maintenance expenditures. Many retrofits can be done in a way that reduces required maintenance effort, thus providing additional ongoing savings.

For example, replacing incandescent lamps that are difficult to access with long lasting, efficient light-emitting diode (LED) lamps may lead to ongoing maintenance savings that are comparable to the already attractive energy savings.

Increased rents and occupancy rate. The commercial buildings that efficient may be able to obtain higher rents, while maintaining higher occupancy rates than otherwise comparable buildings.

Qualitative benefits

- Higher productivity and lower employee absenteeism and turnover.
- Progress toward corporate sustainability objectives.
- Marketing and public relations value.
- Reduced environmental impact of corporate operations, e.g. lower greenhouse gas emissions.

While many of these benefits can be difficult to quantify, there is broad agreement that they represent real and positive value

Financial Models

Depending on organization, investment capital, credit line access and retrofit opportunity, several of funding structures (ESCO, Self-financed, Green Bonds) are available. Ideally, the combination of selected funding option and retrofit opportunity shall be in a way, that it should provide the organization with a positive cash flow from energy savings while paying off the capital invested in major retrofit measures. There are a number of options for financing major energy retrofits as listed in table below:

Presenting the business case for the retrofitting

After assessing the retrofitting opportunities in the building for implementation, it is necessary to reach out to right people with the right business case. It becomes important to identify the right people in management responsible for annual budgeting of various projects. The business opportunities both in terms of energy and monetary savings proves to be effective measure to influence the annual budgeting.

For creating a compelling business case and communicating the value of energy savings to the decision makers three primary points should be considered:

- **Understanding the Stakeholder**: Often the decisions and associated benefits does not apply to the same stakeholders. While making a business pitch it should be well thought and prepared taking into con-

Funding	structure Description	Applications
Cash purchase	Cash on hand is used to fund upgrades without outside financing.	• Typically best for inexpensive measures likely to have a short payback period. • Typically not appropriate for organizations with limited cash flow.
Mortgage	Funds are obtained from a lender, secured against the property to be retrofitted.	• Typically best for projects that will provide cost savings sufficient to service the additional debt. • Typically not appropriate for projects that are relatively small. • A number of commercial lenders offer "green" mortgages, which provide more favourable borrowing terms for projects that have an energy efficiency component.
Green loan or lease	New equipment is used as loan security. Security is limited to the value of the equipment and is, therefore, typically viewed as less secure than a mortgage or other loan secured by real property. This may lead to higher financing costs to the borrower.	• Typically best for equipment that will provide cost savings sufficient to service the additional debt. • Typically not appropriate for projects that are relatively small and/or for equipment for which the manufacturer or installer does not offer a financing option.
Energy performance contract	Risk is transferred to a third party (an energy services company [ESCo]) that typically provides turnkey design and installation and secures financing at its own risk. The ESCo verifies energy savings annually and receives a portion of their value. Savings are often guaranteed for a defined period.	• Typically best for organizations unable or unwilling to secure financing or that value risk-mitigation highly. • Typically not appropriate for small projects. ESCos usually take on projects with large commercial or institutional buildings or owners with a portfolio of buildings.
Property-assessed financing	Property tax-based financing offered by municipalities to property owners. The loan is secured by a tax lien on the property and transfers with the property in the case of a sale.	• Limited to facilities in municipalities and provinces that have passed appropriate enabling legislation. • Most appropriate for retrofits with long lifetimes and relatively long payback periods. • In some cases, permission may be required from the owner's mortgage lender.
On-bill financing	Financing through a utility, with repayment of principal and interest included on the customer's energy bill. Repayment schedules are arranged so that loan repayment amounts are less than the value of energy savings. Financing costs may be higher than loans secured by real property.	• Limited to facilities with utility providers that offer such products. • Appropriate for organizations unable or unwilling to take on debt secured against property.
Utility and government grants and incentives	Non-repayable grants and incentives provided by utilities or provincial efficiency organizations for specific measures or comprehensive retrofits.	• Appropriate for eligible project measures. • Grants and incentives are more often available for specific prescriptive projects, but may also be available for comprehensive projects.

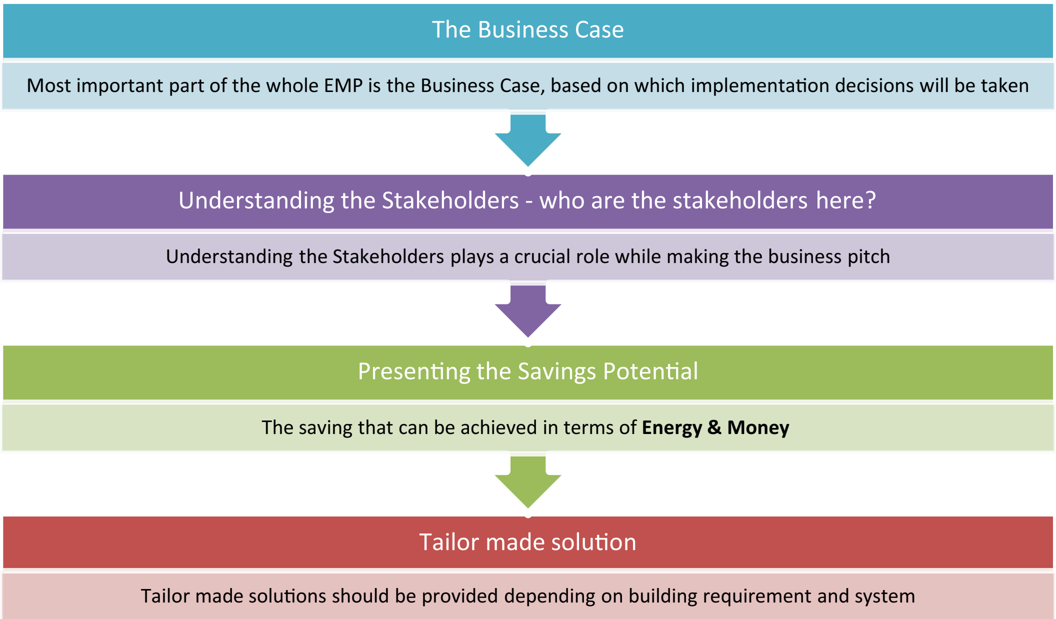


Figure 15: Steps for Presenting the Business Case

sideration the stakeholders who will be making the decisions regarding taking up the implementation.

- **Presenting the Savings Potential**: The savings potential should be presented in a way which clearly indicates the potential Energy and monetary benefits The financial mechanism to check the effectiveness of the proposal , presented together with saving potential generally creates an effective business pitch
- **Tailor Made Solution**: Tailor made solutions as per the preference of the decision maker, building requirement and energy saving targets should be defined and presented to the stakeholders. It should be assured that the value proposition is succinct, straight-forward and easy to understand.

Risk Management and Preparedness

Risk stems everywhere from the efficiency technologies themselves to the process of selecting and implementing efficiency measures. As part of a EMP for implementation of retrofit opportunities it is important to be prepared and have a risk management plan in place. ,. The table below lists the most common risks and the plans that can mitigate them. More details about these mitigation plans can be found in the Managing Deep Energy Retrofits Guide, which details the unique methods and processes of a deep energy retrofit

Once these risks have been assessed and a mitigation strategy is prepared, the building can then move to the next steps of implementation.

Summary of the EMP

The steps identified below can be used as cross check to verify the sincerity of the EMP

Checklist for assessing the Energy Management Plan:

- **Energy Savings Target**: Assessment of Energy Saving Potential pertaining to which energy saving targets shall be set.
- **Prioritizing Building ECMs**: Based on the energy saving targets, building requirement and investment models ECMs should be prioritized

Table 7: Risk Mitigation Strategies [11]

Risk Description	Level	Potential Mitigation Strategy
Predicted Energy Use might be less	High	• Use best-in-class predictive modelling (including peer reviews during the project)
		• Create measurement & verification plan to account for weather variations
		• Consider procurement vehicles such as Integrated Project Delivery and performance contracting
		• Implement post-construction commissioning
		• Engage occupants (see below)
Operation, Maintenance and Verification is not done properly	High	• Implement a standardized measuring and recording protocol throughout the building's lifecycle
		• Development of standard operating procedures
		• Development of maintenance schedule for all the equipment
Occupants may not Cooperate or Behave as you Expected, leading to higher Energy use and Cost	High	• Engage occupants during analysis process via design charrettes and meetings
		• Thoroughly research installed technology and get user testimonials
		• Test improvements among certain groups before full rollout
occupant Impacts, such as Reduced absenteeism and Better test scores, are not Realized	High	• Ensure that the building occupants, their activities, and the implemented retrofit measures are similar to the ones in the studies you referenced
		• Include occupant input for the selection of retrofit measures
Design Is not Constructed accurately; project Is not on time nor on Budget	High	• Consider procurement vehicles such as Integrated Project Delivery and performance contracting
		• Implement post-construction commissioning
Energy prices may BE far Greater or less than Expected	Medium	• Conduct sensitivity analysis to understand how energy prices impact the financial return
		• Obtain long-term energy supply contract (e.g. a power purchase agreement) or technology (e.g. solar panels)
newer, more Cost-effective technology	Medium	• Research all alternatives prior to the go-ahead • Provide flexibility to upgrade during operation
Becomes available During or shortly after Construction		

- **Defining TimeLine**: Once the ECMs are prioritized a timeline should be prepared based on the investment options and retrofit opportunities
- **Selecting Payback mechanism**: A payback option should be selected to calculate the savings potential in consultation with the Financial team
- **Selection of Financial Model**: Selecting a financing option plays a key role, once the technical building EMP has been planned
- **Presenting the Business case**: The monetary and energy opportunities shall be presented to the people responsible for annual budgeting of various projects in the building.
- **Risk Management and Preparedness**: A risk management & mitigation strategy should be planned before proceeding for implementation.

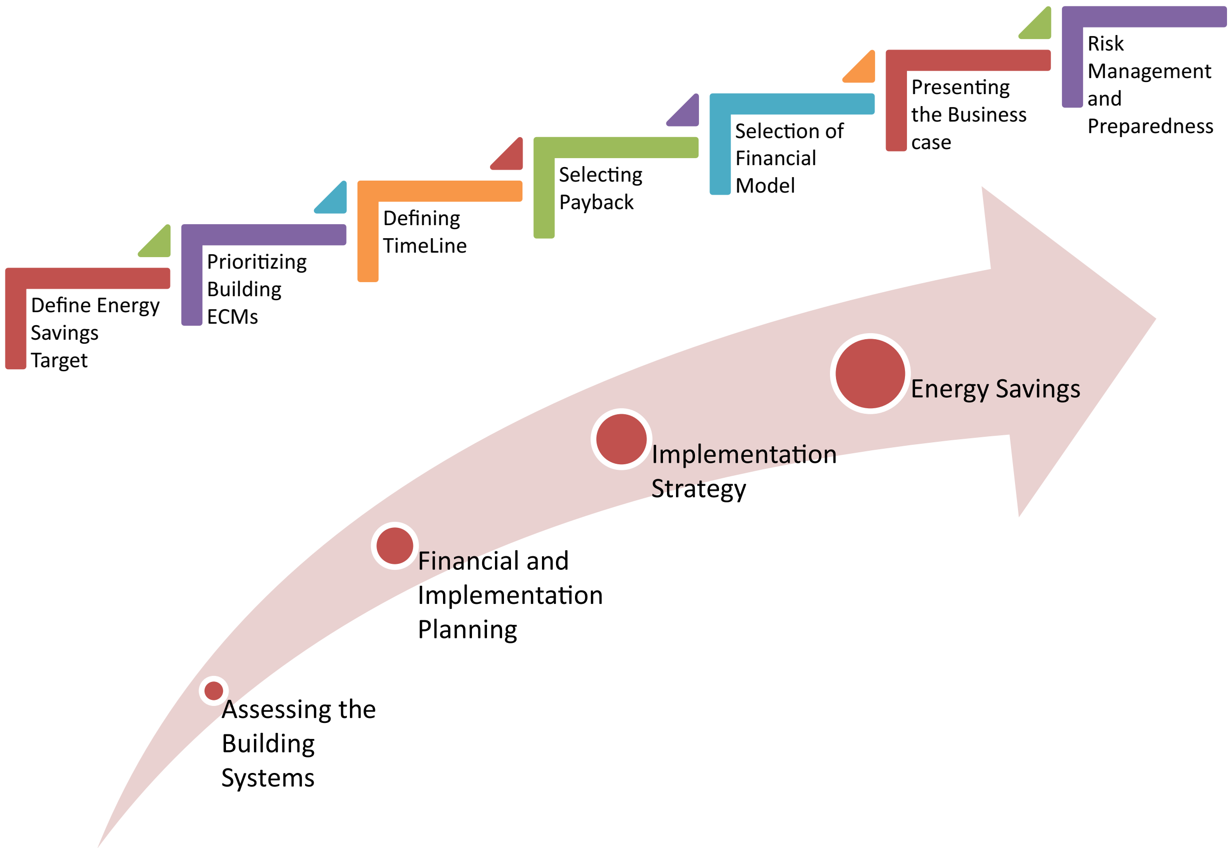


Figure 16 Summary of EMP

CHAPTER 4

Implementation of Building Retrofit

Implementation of Building Retrofits

Once the retrofit plan is finalized after conducting a thorough cost benefit analysis, the team should then work on implementing the retrofit. Proper project planning should be done in terms of assigning appropriate timelines, understanding the commitment and involvement mechanism as well as project finance so that the implementation is seamless. [12]

Project Management

Project management depends on various factors like how large the building is, what kind of systems are installed, what is the building typology and the scope of the project. After analysing all these factors, decision about the execution of the project and project execution partner becomes critical.

A typical implantation process in a project is divided into two parts

- Implementation of no cost and low cost measures
- Cost Intensive retrofit option

Building owners who are willing to implement no cost and low energy saving measure can take the corrective actions internally, but for high cost high energy saving options it becomes important to identify and develop an implementable plan.

If the project is very complex and bigger in size then it may involve managing the multiple contractors (like architect, HVAC contractor, lighting contractor and commissioning agent) simultaneously as well.

Figure 17 project management process

For better implementation of energy efficiency measures, proper coordination is required between building owner, tenant and contractors throughout the project implementation process. Various strategies (like regular project meetings, preparing progress report and sharing project management information like Gantt charts with all the team members) could be used for coordinating with different stakeholders.

The Project Management has five steps

Initiating

In this, project boundaries are defined and permission from relevant authorities are required

Planning

This involves team formulation, defining scope of work, objectives and action plan

Executing

This includes selection of contractors, timely completion of project activity, quality check.

Monitoring and controlling

This activity is performed in parallel with the execution step and includes tracking, reviewing and regulating the project. Identifying the areas where changes are need to be done in the current plan and initiate the corresponding changes.

Closing

This is the process of finalizing all the activities related to the project in order to formally complete the project. The project manager has to ensure that the project work is completed on time and project has met its objective.

Source: Project Management Institute 2013. A Guide to the Project Management Body of Knowledge (PMBOK Guide)-fifth edition

Before starting the retrofit activities following steps should be performed

Team Formulation

In order to ensure the successful implementation of energy efficiency measures in the building a dedicated team of professionals should be formed.

Team should consist of following members:

- Building Owner
- HVAC expert
- Electrical & Lighting expert
- BEE certified Energy Auditor
- Contractor and commissioning agency

Demarcation of area to be affected

It is important to demarcate the particular area where retrofitting activities need to be carried out to avoid any mis-happening.

Occupant sensitization

Keeping occupants in the space while the retrofit is happening is critical. This is not always easy to manage. Keeping occupants informed right from the start, even before the process of implementation begins, will help.

Selecting project execution partner

Selection of expert execution partner is important for the success of the potential retrofit to be implemented. For different components of building different contractors are required. Shortlisting the contracts depends upon the results of the energy audit and EMP developed to execute commissioning of different systems..

It is an established fact that many organisations have their own procurement policies, procedures and guidelines. To successfully complete the implementation process a set of procurement - related documents should be prepared,. The procurement related document prepared should include details such as statement of work, term of reference etc.

The statement of work defines the project scope in detail to help contractors understand the requirement for services to be provided. In addition to this, following set of recommended questions should be prepared and considered while selecting the contractor

- Does the contractor have the technical expertise and enough experience to carry out the retrofit activities?
- Is the contractor licensed and insured?
- Have cost estimates been provided in writing?

Apart from creating a well-defined procurement documents, organising bidder's meeting proves to be constructive approach ensuring that all potential contractors have a clear and same understanding of the project requirements.

Risk Management

Irrespective of the size of the project, risk management is a very important part of project management. Every retrofitting project requires some investment,. The implementation process is complex and is associated with many risks, from retrofit design and implementation to operation and maintenance of the retrofitted buildings. Therefore, it is important that risk associated with the project should be identified beforehand and controlled throughout the course of the project. Some risks may be easily identified by the project team ; others may take more time and effort to uncover, but are still predictable. [13]

To find out the risk, the three factors to be considered are:

1. Scope
2. Schedule
3. Budget

The project team should investigate the above mentioned three areas to check the followings:

- Has the project scope clearly defined in the contract agreement?
- Is there a risk that project might not be completed in time. For example, if some project activities are uncertain, have proper lead times been consider in the project schedule?
- Is there a risk that the project might not be completed within the pre-specified budget and how is this risk shared between client and the contractor?

The different categories of risks associated with a building energy retrofitting project are summarized in Table 8.

All the identified risks throughout the project should be entered in a risk register and always available with the project team.

Commissioning & Project Handover

Process of Commissioning assures that all systems and components of a building retrofit are designed, installed, tested, operated, and maintained according to the operational requirements of the client. Commissioning is the advancement of an installation from the stage of static completion to full working conditions and to meet the performance requirements of the Retrofit. This will include setting into operation and regulation of the installation.

It is very important to verify the operational performance of new equipment and systems. Commissioning process plays an important role in verifying the energy performance of the installed equipment. It also helps in developing the manuals to record crucial information related to operations and maintenance of the equipment. These manuals can be later used to provide training to the new staff. [14]

Table 8 Risk Category

Risk category
Financial risk • Costs associated with the design, construction, certification and maintenance of energy/water efficient buildings is too costly for some companies • Loss of possible financial gain if the building doesn't perform as it was intended to during design stage. • Lack of accurate prediction of return on investment. • Company budgets are not usually structured to track Life Cycle Cost (LCC) for a project making longer term gains harder to record. • Inaccurate investment estimate of retrofitting project
Market risk • Lack of knowledge in financial institutions in regards to green buildings, results lending based on the status quo, • Real estate agents are unable to articulate the benefits of green building • Misconceptions about green buildings' energy efficiency, • Possibility of not reaching the anticipated results for green buildings in the market.
Economic risk • Commodity price volatility such as increase in labour cost, material cost, equipment costs, electricity price, oil price etc. will reduce the profit margin (particularly for energy and water service companies) from an energy efficiency project. • Interest rate volatility in loan market will increase financing cost.
Legislative risk • Tax and regulatory incentives are not uniform and tend to change from state to state, and over time • Tax and regulatory incentives may be complicated and difficult to obtain • As legislation changes risks are introduced that are not yet known and cannot be controlled by decision maker • Uncertain expiration dates on incentives
Social risk • Poor public acceptance • Retrofit is usually performed while existing operations are still running, thus causing substantial disturbance to tenants. Some tenants are uncooperative for fear of losing income and commercial profits during the retrofit process • To maintain the benefits after the retrofit, equipment has to operate at its best efficiency, which requires tenants' continuous cooperation
Industry risk • Lack of relevant knowledge regarding building retrofitting project among the involved parties. • The green building demand may not be satisfied by the supply chain e.g. recycled materials etc. • Lack of green material in the market or delay of delivery to the site. Foreign governments' restrictions on material exports may aggravate the problems • Green building education within the construction industry is not sufficient. • Skilled workers may not be available to handle the specialized design and features in the green retrofitting process.
Project design risk • May result from the lack of sufficient and inaccurate information of the building system. • Inaccurate prediction of baseline and energy/water savings. • Inexperienced and uncooperative team members could result in difficulty in obtaining certification, delays, and budget overruns.

Risk category
Technological risk
• Unstable/poor performance of the retrofitted technologies /materials /equipment • In case of improper equipment sizing, equipment frequently operates at part-load condition which results in reduction of energy/water savings.
Installation risk
• Delay in project completion due to number factors. This results in an increase in project cost and delay in commencement of energy/water savings. • Installation of the retrofit measures may not be done properly which results in risks of not achieving the desired energy/water savings.
Operational risk
• Faster rate of equipment degradation due to poor maintenance. • The retrofitted equipment is not being operated at optimum condition to maximise energy/water savings. • Unexpected consumption patterns. Changes in baseline condition such as weather, operating hours, load requirement etc.
Measurement and verification risk
• Poor quality of the measured data. For example, low-resolution data or missing data. This increases the uncertainty on energy/water savings measurement. • Establishing Improper measurement and verification plan for the retrofitted building which may result in dispute over actual savings. • Measurement error due to the use of inaccurate metering device

Source: Managing risks in complex building retrofit projects for energy and water efficiency. Conference Paper • September 2016

There are certain things which should be look into before going for the commissioning of the project. Systems shall be properly commissioned to demonstrate that all the equipment deliver the designed capacities.

For example commissioning requirements for an AC Plant can be broadly grouped into:

- General requirements, which will include Cleaning and EH&S.
- Electrical Systems pre checks
- Water System checks
- Mechanical Systems / Individual Equipment checks
- Performance Verification for AC System

The Contractor should ensure all General Testing Requirements are followed, as per OEM recommendations.

It is expected that fine-tuning of the commissioned system shall be done by the Contractor to match system performance to the Retrofit Intent.

Important check points to be considered before the project is handed over by the contract ot the project team are:.

- Make sure that all the terms of procurement and the services have been met. [14]
- Make sure that any information related to guaranty or warranty of any equipment has been provided to the client in writing. [14]
- Implementation of a measurement and verification (M&V) plan to make sure that building energy retrofit shall realize the proposed saving and any unexpected change in energy performance can be detected. [14]

CHAPTER 5

Post Implementation Monitoring and Reporting

As the saying goes "Whatever gets measured can be managed". The measurement of building energy performance ensures the continuous improvement in energy performance of building is met. The post implementation monitoring provides the insights to the facility management team on the success of various energy conservation measures and opportunities for future improvements.

The success of any retrofit project depends on many factors; the most important is operation and maintenance of building,. For building retrofit projects the measurement and verification becomes essential to gauge the actual performance of implemented measures and comparison of actual saving achieved with proposed savings. M&V activities include conducting site surveys, metering energy use, monitoring independent variables, executing engineering calculations, and reporting.

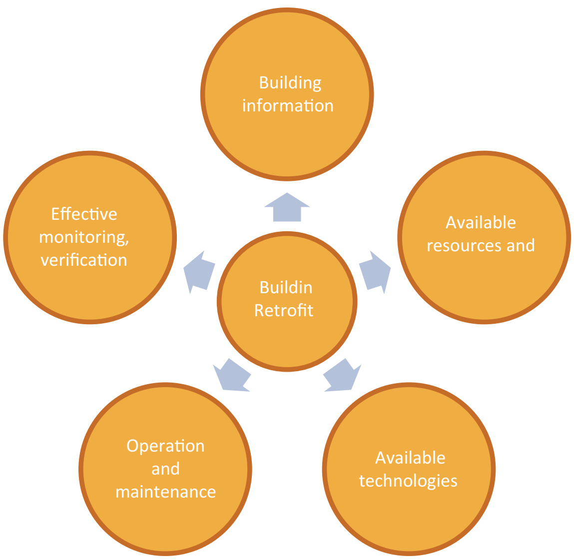


Figure 18 Parameters impacting building performance

The measurement and verification protocols have been defined for building sector by many scholars and practitioners which are based on the International Performance Measurement and Verification Protocol (IPMVP) [15] Since the majority of defined protocols are derived from internationals standards and Indian building subsector is not sufficiently equipped in terms of technical capacity, most of the building retrofit projects does not include the M&V within the scope of the retrofit

According to Efficiency Valuation Organization (EVO), "M&V is the process of using measurement to reliably determine actual savings created within an individual facility by an energy management, energy conservation or energy efficiency project or program. As savings cannot be directly measured, the savings can be determined by comparing measured use before and after implementation of a project, making appropriate adjustments for changes in conditions."

The Efficiency Valuation Organization (EVO) publishes the International Performance Measurement and Verification Protocol (IPMVP) to increase investment in energy and water efficiency, demand management and renewable energy projects around the world. The IPMVP allows building owners, energy service companies, and financiers of energy efficiency projects to quantify the energy savings performance of energy conservation measures (ECMs) programs. The simple reason for omitting the M&V from retrofit program is the cost of proposed measurement systems and lack of technical know-how.

This section of guideline discusses the key factors to be considered for incorporating monitoring and verification protocols while developing a retrofit plan for building.

Post retrofit monitoring within the buildings can be easily established using the existing monitoring framework followed by the facility team to record the regular operating parameters of major energy systems in building.

Defining post implementation measurement approach

There are two essential components of measurement and verification for any building retrofit projects

- Operational Verification
- Saving Verification

The operational verification is generally covered within the project implementation plan. this include the commissioning of installed systems and training of the facility management team .

The post implementation measurement deals with the measurement of key variables associated with the performance of implemented retrofit options.

The process for defining the M&V Approach suitable for the project involves following steps:

Classification of Energy Conservation Measures

The energy conservation measures proposed through the energy audit are classified as per their impact on energy performance of the building. Energy conservation measures such as enhancing equipment efficiency yield energy saving directly and can be monitored easily, whereas measures such as reducing infiltration by envelop sealing yield energy saving in HVAC energy enduse. The basic classification of ECMs helps in defining the key independent variables to be measured.

Defining Independent Variables for Measurement

The metering of the energy consumption and comparison with historical energy consumption of the building simply does not provide the actual energy savings achieved from the retrofits. The building energy consumption is dependent on several factors such as weather, occupancy, operational changes, maintenance activities and expansion of services. To record the actual savings achieved from the retrofit and the improvement in the building energy performance it is important to identify the key parameters. Usually these parameters include units produced ,cooling energy produced , Occupancy , capacity, hours of operation and system efficiency.

The careful selection can be done based on the scope of M&V and level of measurement required.

Defining Measurement Boundary

The M&V for a building retrofit program can be divided into two stages.

- Whole Building performance monitoring
- Verification of individual ECMs implemented

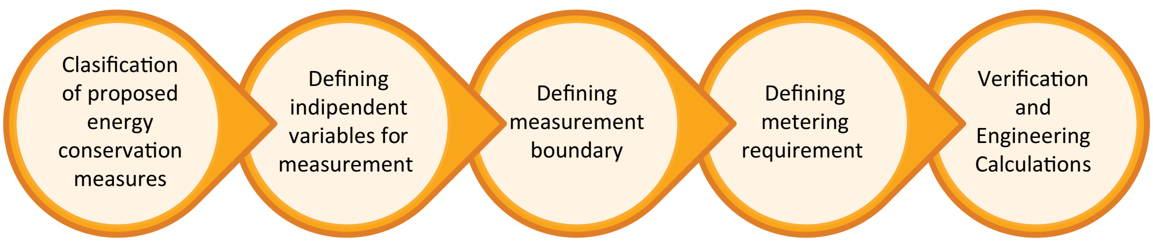


Figure 19 M&V process

In India M&V in building sector is mostly targeted towards recording and, monitoring building energy performance. The basic energy reporting framework followed by the facility management teams in Indian commercial building sector is aptly equipped for recording the parameters needed to assess the post retrofit energy performance of building. This framework can be used effectively for verification of building energy performance with isolating the performance of energy conservation measures implemented. Since the current system works on the manual log-book data entry at fixed time interval, one identified drawback of this system is the logging of reliable and consistent data. This can be ratified using smart metering and digital logging of key performance parameters.

The facility management team in building logs the periodic operational data for all major energy systems (such as transformers, chillers, DG, HVAC auxiliaries, etc.) periodically in log books. The parameters to be logged for equipment are provided by the equipment manufacturer.

These log books are managed by the operating staff and periodic reports are verified by the facility managers.

While performing the energy audit of the building the historical log book data is used for creating the baseline energy consumption pattern for each energy system. The data recorded by the operating staff is verified through onsite measurements conducted by energy auditors and normalized energy consumption data is used for developing baseline for the building.

The measurement boundary is defined based on the intent of M&V plan. In most of the retrofit projects the intent of M&V is to monitor building energy performance and verify energy savings achieved from overall retrofit program act as the key focus. This can be easily achieved using the approach equivalent to whole building option defined in International Performance Measurement and Verification Protocol (IPMVP).

For projects where the intent is to verify savings from energy saving measure, the measurement boundary can be the defined as individual ECMs, however this may result in additional metering requirement and incur additional cost.

The whole building approach coupled with the existing data logging practices can be used to correlate the energy saving achieved from different energy conservation measures using predefined approaches as used during determination of baseline energy performance as described in previous chapters.

Installation of metering system

Based on the approach used for post retrofit measurements and the identified independent variables, the minimum metering requirements identified. In case of whole building performance monitoring the basic metering present in the facility is used for measurement of variables.

Verification and Engineering Calculations

Verification and engineering calculation are defined for correlation of measured data with building energy performance and comparison of baseline energy consumption with measured performance.

As a best practice for continuous performance monitoring of building energy consumption; it is recommended to install basic metering within the building, this involve sub meters dedicated for each major energy consuming service such as lighting, UPS, raw power, HVAC plant, AHUs, Pumps etc. For reference basic metering requirement prescribed in the building rating systems such as GRIHA, IGBC, LEED can be referred. The Energy Conservation Building Code for new constructions can also be referred for metering requirements in buildings and minimum technical requirement for each meter

As described above the performance of building retrofits depend upon several factors which may not be controlled, therefore to compare the energy performance of base year with measured data, basic correlations is developed to estimate the actual savings achieved. This can be done by estimating the changes in the operational and functional parameters. The methodology for estimating annual energy performance of the building used during energy audit should be used with measured deviations in the functional parameters to correct the baseline energy consumption. This can be done by thorough comparison of log-book data for base year and current year. The improvement in the user experience should also be accounted when comparing the performance of retrofit options and baseline energy consumption.

Adoption of M&V approach

Once the measurement and verification approach is finalized the adoption of the approach is required to ensure the reliable measurement. The basic approach for adoption of post implementation measurement require following steps

Training of Staff

Training of staff is required to build the confidence and capacity of the facility management team for operating, measurement and maintenance of the measures implemented..

> Advance metering and automation for operations and M&V protocols should be looked as a strategy for large commercial buildings. An effective building energy management system and HVAC Plant managers for large facilities and buildings with variable operational needs can yield great energy saving. These systems serves the purpose of automating, optimazation ofthe operation through advance algorithm generating the alarms for abnormal behaviour of any system and recording energy consumption patterns for each system at the same time providing continuous monitoring data.

The training should be conducted by the contractor during the handling over and commissioning of the systems. Along with the training the procedures of preventive maintenance and operating sequences should also be demonstrated. The intent of the training exercise is to make the facility team familiar with the design parameters and intended operating requirements of the new appliances.

Standardization of operations and monitoring parameters

The retrofit project implementation team and facility teams should prepare the SOPs for operations and monitoring of implemented energy conservation measures (wherever applicable). The standard operation based on the functional requirement of the building mostly results in least energy consumption as the systems are operated at optimum energy efficiencies.

Defining reporting framework for continuous monitoring

The regular reporting of recorded operational parameters not only help in identification of maintenance needs and fault detection in systems , but also improves the reliability of the monitored data. It also feeds into the management decisions for future target settings and assessment of energy performance of building.

Periodic calibration and energy audits

Periodic calibration of meters is required to record reliable data and eradicate the measurement errors in recorded data. The meters should be calibrated as recommended by the manufacturers. Few metering devices are available with self-calibration options or reference specimens for in-house calibration, these systems can also be used to ensure the accurate measurement of parameters recorded .

Periodic energy audit is also recommended to verify the energy perforemanc eof the building and to assess the opportunities for continuous improvrement in energy performance.

CHAPTER 5

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