



सत्यमेव जयते

Ministry of Power
Government of India



Energy-Efficient Retrofit Manuals: Transforming Existing Buildings

Commercial

Cold

Building
Envelope

Lighting

HVAC

Electrical
Appliances

Water Heating
and Plumbing

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Study by

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Commissioned on behalf of

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India's building sector, accounting for 38% (~208 Mtoe) of total primary energy consumption and 31% (296 TWh) of total electricity use, presents both challenges and opportunities in advancing energy efficiency. While considerable progress has been made in designing energy-efficient new buildings, the potential for retrofitting existing structures remains largely untapped. Retrofitting offers a cost-effective and scalable solution to reduce energy consumption and greenhouse gas emissions, aligning with national sustainability goals. In recognition of this potential, the Bureau of Energy Efficiency (BEE) has developed comprehensive manuals to guide the assessment, planning and implementation of energy-efficient retrofits in both commercial and residential buildings.

The **Energy Efficiency Manuals for Existing Buildings** mark a significant milestone in this effort, offering a robust framework for integrating modern energy-efficient technologies while addressing structural and operational challenges. This manual incorporates industry best practices and technological innovations, providing practical, actionable guidance for enhancing building energy performance across diverse climatic zones.

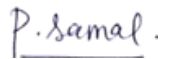
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This manual stands as a testament to collective expertise and a shared commitment to creating sustainable, energy-efficient buildings. It serves as a definitive resource to drive the adoption of retrofitting strategies, fostering a greener, more resilient built environment.



(Pravatanalini Samal)

Director

Bureau of Energy Efficiency (BEE)

Stakeholder Survey Summary

The **Final Stakeholder Survey Report** represents a critical step towards enhancing energy efficiency and sustainability in India's building sector. Commissioned by the Bureau of Energy Efficiency and conducted by The Energy and Resources Institute (TERI), this comprehensive survey provides insights into stakeholder expectations and technical requirements essential for developing energy use benchmarking manuals.

Survey Scope and Objectives

1. Building Aspects: The survey examined a range of building components, including building envelope design, lighting systems, HVAC systems, service water heating, pumping systems, electrical systems, appliances, and renewable energy integration.

2. Pan-India Coverage: The survey covered all Indian states and union territories, capturing diverse regional practices and perspectives to ensure a holistic understanding of the building sector.

2. Pan-India Coverage: The survey covered all Indian states and union territories, capturing diverse regional practices and perspectives to ensure a holistic understanding of the building sector.

3. Willingness for Retrofits: It assessed the willingness of building owners and operators to undertake retrofits aimed at improving energy efficiency, providing valuable insights into the feasibility of proposed measures.

METHODOLOGY

For data collection state wise face-to-face interviews were conducted. The sampling strategy involved:

- Targeting all 36 states and Uts.
- Focusing on state capitals and Tier I towns.

- Employing a Proportionate to Population Size (PPS) sampling strategy.
- Utilizing stratified random sampling to maintain randomness.
- Dividing each city into four zones for a balanced selection of domestic and commercial respondents.

Key Findings and Observations

RESIDENTIAL SECTOR

- 1. Awareness and Knowledge:** Respondents displayed varying levels of familiarity with energy efficiency concepts, with around 64% being familiar or very familiar.
- 2. Implementation of Energy Efficiency Measures:** The implementation levels varied widely, with over 55% of respondents indicating low levels of implementation.
- 3. Energy Audits:** A significant number of homeowners had never conducted an energy audit, highlighting an area for potential improvement.
- 4. Importance of Energy Efficiency:** Energy efficiency was considered important by a majority of respondents, though motivations varied.
- 5. Actions Taken:** Many homeowners had taken steps to improve energy efficiency, but barriers such as financial constraints and lack of information were noted.
- 6. Willingness to Invest:** 60% of respondents were willing to invest in retrofitting measures.
- 7. Factors Influencing Investment:** Key factors included potential cost savings, government incentives, and environmental impact.
- 8. Importance of ROI and Information:** Most respondents emphasized the importance of understanding the expected ROI and having access to reliable information.

COMMERCIAL SECTOR

- 1. Awareness and Interest:** Many commercial buildings lacked load monitoring systems, indicating a need for

- increased awareness and interest in energy efficiency.
- 2. Electricity Bills:** Most respondents reported average monthly electricity bills ranging between ₹20,000 to ₹40,000.
- 3. Current Practices:** A variety of energy efficiency practices were implemented, but there was significant room for improvement.
- 4. Effectiveness Measurement:** Respondents highlighted the importance of measuring the effectiveness of energy efficiency practices.
- 5. Planned Practices:** Many commercial entities planned to implement additional energy efficiency measures in the next 12 months.
- 6. Drivers for Planned Practices:** Cost savings and environmental benefits were primary drivers.
- 7. Willingness to Invest:** Similar to the residential sector, there was a strong willingness to invest in retrofitting measures.

awareness campaigns to bridge gaps in understanding the benefits of energy efficiency measures. Past retrofitting activities positively influence current willingness to invest, indicating a potential learning curve in recognizing the benefits of such measures over time.

Availability of dedicated funds and government incentives could significantly boost the adoption of energy efficiency practices.

CONCLUSION

The survey findings highlight the readiness of commercial building owners and operators in India to embrace energy efficiency and retrofitting measures. There is a notable interest in implementing a wide range of energy-saving practices, driven by the potential for cost savings, environmental impact, and improved occupant comfort. Access to information, financial incentives, and clear ROI calculations are seen as key factors influencing investment decisions.

The survey also reveals opportunities for promoting energy efficiency through education and awareness, tailored incentives, and the sharing of successful case studies. A significant number of commercial buildings lack load monitoring systems, indicating a potential lack of awareness and interest in energy efficiency among building owners or operators. While certain measures like energy-efficient lighting are well-adopted, there is room for improvement in load monitoring and HVAC optimization. The emphasis on tangible benefits such as cost savings indicates a business-oriented approach to energy efficiency.

It was observed that despite awareness of benefits, there is a gap in understanding specific features, which could be addressed through targeted education and information dissemination. The survey highlights a need for targeted

Summary of Final Literature Survey Report

INTRODUCTION

The report highlights the significance of retrofitting existing buildings to reduce energy consumption and greenhouse gas emissions. In 2021, buildings accounted for 30% of global final energy consumption and 27% of total energy sector emissions. The study outlines a systematic approach for selecting optimal retrofit measures for Building Envelope, Comfort Systems & Controls, Lighting & Controls, and Electrical & Renewable Energy systems. The objective is to prepare a comparative matrix of retrofit parameters to better understand how to promote energy conservation and sustainability through effective building retrofits.

OVERVIEW

India's energy consumption is rising, making it the third-largest energy user globally. Buildings in India consume about 34% of the energy produced, with HVAC systems accounting for most of the energy used. The report emphasizes retrofitting existing buildings as they currently consume more electricity than new buildings are projected to use over the next 20 years. India's commitment to improving the environment is reflected in its National Action Plan on Climate Change (2008) and its goal to achieve net-zero emissions by 2070. The "Shunya" Labelling Programme promotes Net Zero Energy Buildings (NZEB) and Net Positive Energy Buildings (NPEB).

INTERNATIONAL GUIDELINES

The report reviews various international guidelines for building retrofits to understand critical areas and overcome barriers:

- 1. Energy Star Building Upgrade Manual (USA):** Focuses on retro-commissioning, lighting, supplemental load reductions, air distribution systems, and heating and cooling systems.
- 2. Major Energy Retrofit Guidelines for Commercial and Institutional Buildings (Canada):** Covers assessing opportunities, energy management planning, implementing major retrofits, and maintaining performance.

- 3. Energy Management Good Practice Guide (Australia):** Highlights benefits of energy management, sources of energy data, identifying improvement opportunities, funding support, and continuous improvement systems.
- 4. Existing Building Retrofit (Singapore):** Outlines steps for determining baseline, reviewing maintenance and energy procurement, and establishing targets and goals.
- 5. ProESCO (Brazil):** Provides guidelines for energy efficiency in public sector buildings, focusing on lighting, motors, compressed air, HVAC, refrigeration, heating, automation, and control systems.
- 6. NOM-020-ENER-2011 (Mexico):** Offers guidelines for retrofitting buildings to enhance energy efficiency, including insulation, windows, lighting, HVAC systems, and renewable energy incorporation.
- 7. Energy Saving Ordinance EnEV (Germany):** Legal requirements for energy efficiency in buildings, including thermal insulation, heating systems, ventilation, and energy performance calculations.

NATIONAL GUIDELINES

India's legislative framework for energy efficiency includes:

- **Energy Conservation Building Code (ECBC) 2017:** Sets minimum energy requirements for commercial buildings.
- **Eco Niwas Samhita (ENS):** Establishes performance requirements for residential buildings.
- **BEE Star Rating for Existing Buildings:** Encourages retrofits to achieve higher energy standards.
- **Perform Achieve and Trade (PAT) for Buildings:** A market-based mechanism to improve energy efficiency in large industries and buildings.
- **Building Energy Efficiency Programme (EESL):** Aims to retrofit 20,000 public and private buildings.

The report concludes by emphasizing the importance of investing in building retrofits to create energy-efficient and decarbonized buildings, thereby supporting India's sustainable development goals and climate action commitments.

Overview of Retrofits

INTRODUCTION

Retrofitting existing buildings offers significant opportunities for reducing energy consumption and greenhouse gas emissions. Retrofit is considered one of the main approaches to achieving sustainability in the built environment at a relatively low cost and high uptake rates. Although a wide range of retrofit technologies is readily available, methods to identify the most cost-effective retrofit measures for projects are still a significant challenge. In 2021 the operation of buildings accounted for

30% of global final energy consumption and 27% of total energy sector emissions. The building sector has a relatively large carbon footprint when both direct and indirect emissions are taken into consideration. These guidelines will provide a proven and comprehensive strategy for assessing, planning, maintaining and implementing energy efficiency retrofits in an existing building.

DETAILED PARAMETERS OF RETROFIT:



FIGURE1 PARAMETERS OF RETROFIT

INITIATE AN ENERGY MANAGEMENT PROGRAM

A dedicated staff team is required to initiate any energy management program. This team ensures that the accurate objectives are set and the right people will implement the plan. Initiating an Energy Management Program requires 6 important steps following as below

1. Identify a core team.
 - Building Owner
 - HVAC expert
 - Electrical & Lighting expert
 - BEE certified Energy Auditor
 - Contractor and commissioning agency
2. Identify and set specific objectives.
3. Develop a plan.
4. Communicate plan
5. Implement measures and monitor performance
6. Motivate staff members
7. Feedback for Improvement

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.

- **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.

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

TABLE 1 DESKTOP DATA COLLECTION PARAMETERS

Determining Energy Performance Indexes (EPI) and Average Annual Hourly EPI (AAHEPI)

$$EPI, kWh/Annum/m^2 = \frac{\text{Building Energy Consumption}}{\text{Total Builtup Area, m}^2}$$

$$AAHEPI, Wh/h/m^2 = \frac{EPI}{\text{Operating Hours}}$$

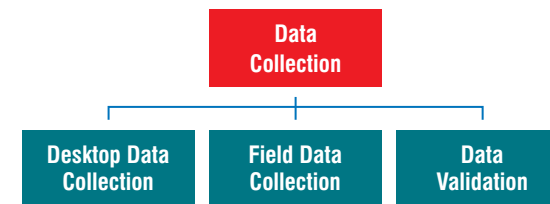


FIGURE 2 DATA COLLECTION

- **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, lighting and HVAC systems, pumping systems, hot water services 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.
- **Benchmarking:** The next step of building energy audit process is to define the performance of a facility through a calculation matrix. The matrix shall help compare current performance of the facility with similar buildings and help in identifying inefficiently performing area. Occupant comfort (BIS 2005, ASHRAE 55-2010 and CEN Standards EN 15251), Building Envelope (Insulation materials, R-Values, SHGC, VLT), Electrical Systems (IS Codes), Lighting Systems (w.r.t illuminance set by NBC 2016), HVAC Systems (w.r.t ECBC and ASHRAE 90.1), these parameters need to be kept in mind during benchmarking.

DETERMINE EFFICIENCY TARGETS

When establishing saving objectives for a commercial building, it's crucial to consider factors such as the building's profitability, operating expenses, and other cash outflows and energy mix. By assessing these elements, an efficient target

can be set and achieved, ultimately reducing the building's energy costs. Identifying both high and low energy consumption areas enables the building occupant to focus on key improvement areas, maximizing returns in the process.

CONDUCT ENERGY ASSESSMENTS

An energy assessment is an essential component of a successful energy management program [9]. This will help to identify the present energy use situation within the building and its energy costs. This assessment helps in developing the energy baseline of the building, for future comparisons of energy use by comparing energy use before and after the program implementation. The energy assessment of the Commercial buildings can be conducted either by a simple walk through energy assessment or a more detailed energy analysis audit.

The first step in this assessment is to examine energy use and associated costs across systems within the building. The steps are as follows,

1. **Energy Planning** – Assists with identification of building statistics, Building Energy source and use, operation schedules of the building and other necessary information to initiate the assessment.
2. **Questionnaire for the Operations and Maintenance (O&M)** – Understanding the present energy policy and building with Operations and Maintenance (O&M) Staff. This includes questions on Operations Procedures, Building Energy Information, School Condition and Operations, O&M Staff Training.
3. **Walk-Through Assessment Checklist** – Identification of energy saving improvements that can be easily implemented. Walk through Assessment Checklist consists of operation, maintenance and usage procedures of HVAC, lighting, services/ amenities, miscellaneous.

Based on the outcomes from the assessment, the buildings are encouraged to follow the implementation of these measures with a more detailed audit to achieve additional savings. Walk through Assessment can act as a first step to identify existing energy saving opportunities and implement the results followed by a more detailed analysis audit to derive more detailed measures for savings including capital intensive energy saving opportunities [9].

IDENTIFY ENERGY SAVINGS OPPORTUNITIES

- **Implement Training Programs for New Employees on Energy Management:** Develop and execute training sessions aimed at educating new staff members on effective energy management practices.
- **Ensure Comprehensive Tracking and Reporting of Energy Consumption to All Employees:** Establish systems to monitor and communicate energy usage data to all staff members, fostering awareness and accountability across the organization.
- **Educate New and Existing Students on the Significance of Energy Management:** Develop educational initiatives targeted at both incoming and current students to raise awareness about the importance of energy conservation and sustainability.
- **Foster a Culture of Continuous Improvement:** Cultivate an environment where ongoing enhancements in energy efficiency are prioritized and embraced throughout the organization.
 - a) **Tracking:** Establish mechanisms for monitoring

energy usage and performance metrics systematically.

- b) **Visibility:** Ensure that energy management efforts and achievements are prominently communicated to all stakeholders.
- c) **Provide Incentives:** Implement reward systems or incentives to motivate individuals and teams to actively participate in energy-saving initiatives.
- d) **Recognition:** Acknowledge and celebrate individuals or groups who demonstrate exemplary commitment to energy conservation and efficiency.

CALCULATING COSTS AND PAYBACKS

Payback period in capital budgeting refers to the time required to recoup the funds spent in an investment, or to reach the break-even point. Payback period measures the duration of investment to pay for itself or break it even. This also helps identify the savings from the investment. The shorter payback periods are preferable to longer payback periods.

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. Determining cost effectiveness of large investments over time would require a life cycle cost or monthly flow calculations. This helps to rule out cost intensive interventions with very high payback period. Higher the cost savings ensures the longevity and success of the program/Energy Conservation Measure. Cost savings and payback period can be calculated through the followings ways. Through analysis and energy data, peak demand and Energy Cost Index (ECI) (expressed in ₹ per floor area per year) can be developed [9]. The attractiveness of an energy retrofit investment is typically assessed using one or more of the following three tools:

1. Simple Payback,
2. Net Present Value (NPV) or Internal Rate of Return (IRR)

IMPLEMENT MEASURES-RETROFIT

After analyzing the energy audit and walk through assessment reports, the Energy conservation measures are devised. Each ECM is shortlisted after conducting a payback analysis to understand cost benefits. Implementation of Energy conservation measures requires proper project planning in

terms of assigning appropriate timelines, understanding the commitment and involvement mechanism and project finance. The primary goal of the implementing the energy conservation measures is to maximize building operational efficiency along with achieving occupant comfort.

MONITOR PERFORMANCE

Regularly monitoring the building's performance is essential, allowing for the introduction of new energy retrofit strategies at set intervals to enhance energy savings. Educating maintenance staff about building efficiency parameters along with financial and non-financial benefits can prove the key measure in the Energy Efficiency in the existing buildings. Collaborative meetings involving the O and M team and other occupants should be held to raise awareness and implement these strategies effectively.

Part –I: Passive Retrofit Solutions

The term '**Passive Retrofit**' refers to the practice of using building materials, insulations, windows, walls, building orientation and other simple techniques, reducing the solar heating and cooling of the building. Passive Retrofitting an existing building can be challenging and requires significant work and investment. However, a well-designed passive retrofit building consumes less energy for heating and cooling, reduces carbon emissions, and improves indoor comfort.

RETROFIT PLAN IN STAGES:

To determine the most suitable retrofit strategy for a building, an initial assessment is required to categorize the project's requirements. Energy retrofit projects can be broadly classified into three categories, Minor, Major and Deep. Minor retrofits, ideal as starting point, primarily focus on operational changes. Major retrofits encompass a wide range of measures implemented across various building systems, typically resulting in energy savings between 15% and 40%. Deep retrofits, on the other hand, are driven less by specific energy-saving targets and more by the desire for significant space modification and optimum utilization of resources. These projects can achieve energy savings exceeding 40%.

Prior to developing an Energy Management Plan (EMP), it is essential to establish an energy saving target based on the building assessment findings. These targets can be derived from applicable national energy conservation code, if available.

BUILDING ENVELOPE RETROFIT

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

CHECKLIST OF ECMs FOR BUILDING ENVELOPE RETROFIT

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 and it is made up of three-dimensional, multi-layer/material assemblies consisting of the following components- External Roofing system, external Walling system, Fenestration (Vertical and Horizontal), Base Floor system, Below-Grade Walling Systems. Heat always flows from the warmer side of the building envelope to the colder side. Conduction, solar radiation and infiltration are the major parameters of heat flowing through a Building envelope. Radiation is the transfer of heat over a distance from a hotter object to a cooler one, such as how the Sun's heat reaches Earth. To maintain thermal and visual comfort, occupants use window shades to block excess radiation

1. EXTERNAL WALL

- **Envelope Air Tightness**
 - o Ensure the walls are sealed without cracks on external envelope
 - o Sealing small cracks in the envelope improves overall comfort in the space.
- **Retrofit through Building Form and Orientation (depending on the availability of space):**
 - o Maximize winter solar gain: Concentrate glazing on the south façade to capture low-altitude winter sun.
 - o Minimize heat loss: Reduction in window area on the north façade to prevent excessive heat loss.

- o Install double glazing with low-emissivity coating to reduce heat loss.

- **Wall Insulation materials**

- o Ensure proper wall insulation materials to increase the thermal mass and minimize heat losses from the envelope.
- o Enhance overall envelope efficiency by addressing external wall heat gains and losses.

- **Trombe Wall:**

- o Paint the external wall with a dark, heat-absorbing material and enclose it with a glass layer to create airspace for effective passive solar heating.
- o Enhance building heating, ventilation, and cooling, reducing heating energy consumption.

- **Thermal Chimneys:**

- o Use thermal chimneys to enhance natural ventilation.
- o Improve passive heating efficiency within the building.

2. FENESTRATION

Heat Transfer through glazing products, encompassing windows, doors, and skylights, share similarities with heat transfer across walls and roofs, primarily occurring through conduction and convection. Analogous to wall assemblies, the U-Factor is employed to quantify the thermal performance of glazing. The ECBC emphasizes three key performance characteristics: U-Factor, Solar Heat Gain Coefficient (SHGC), and Visible Light Transmittance (VLT).

Several areas of building where attention is required to utmost importance:

- Joint around fenestration and doorframes.
- Opening at penetration of utility services through roofs, walls and floors.
- Site-Built Fenestration and Doors.
- Building assemblies used as ducts.
- Joints, seams, and penetration of vapor retarders.
- All other openings in the building envelope.

It is recommended to check junctions between walls and

foundations, between walls and building corners, between walls and structural floor/roofs, and between walls and roofs of wall panels.

- **Air Tightness**

- o Ensure proper sealing around the fenestration avoiding infiltration which can increase the cooling load of a space.
- o Reduces the infiltration and improve thermal comfort without unnecessary drafts inside the space.
- o Reduces the penetration of unwanted particulates, such as dust, into the building.

- **High performance glazing system- Double and triple glazing (Higher SHGC glazing, Low E coating glazing, Lower U value Glazing)**

- o Replacing single glazing windows with energy efficient glazing and profiles can significantly increase the energy performance of the building.
- o Improves indoor thermal as the cold radiation from windows will substantially decrease.
- o Reduces heating load and improve visual and thermal comfort especially for occupants in the perimeter zones.

- **Internal and External Light shelf**

- o Incorporate external light shelves to reflect the incoming sunlight upwards to illuminate the ceiling.
- o Enhances daylight penetration inside the living spaces.
- o Reduces glare and the need for indoor lighting during daylight hours.

- **Solar Reflectors:**

- o Install solar reflectors outside windows to increase the solar gain inside the building.
- o Reduce the building's heating load by 10 to 15%.

Segregation of Measures

An Efficient Building retrofit, material selection and planning demands a nuanced understanding of thermal and visual comfort. Hence, these Energy Conservation Measures (ECMs) are categorized by their capital cost implications. This comprehensive segregation into No Cost, Low Cost, Mid Cost, and Capital-Intensive Cost tiers ensures stakeholders can make informed decisions balancing financial constraints and sustainability objectives. The following detailed breakdown offers extensive insights into the implementation strategies and considerations for each category:

I. NO-COST AND LOW COST ECMs:

1. OCCUPANT BEHAVIOR

- **Description:** Conducting awareness programs to promote energy-efficient practices.
- **Implementation Strategies:** Encouraging active participation from occupants is crucial for the success of behavioral changes. Building managers can facilitate engagement through surveys, feedback sessions, and collaborative initiatives. By involving occupants in the decision-making process and encouraging them to share energy-saving ideas, a sense of shared responsibility is fostered. Occupant engagement extends beyond theoretical understanding to practical implementation. Through interactive workshops, occupants can learn about the energy consumption patterns of common appliances, the impact of lighting on overall energy use, and the potential for behavioral changes to contribute to substantial savings.



FIGURE 3 OCCUPANT BEHAVIOR

2. OPERATION AND MAINTENANCE

- **Description:** Conduct periodic maintenance for optimal functioning of energy integrated shading devices and controls.
- **Implementation Strategies:** Regular cleaning and maintenance of glazing and envelope is essential for maximizing efficiency. Accumulated dirt, dust, and debris on fixtures can significantly reduce their efficiency, leading to increased energy consumption. Cleaning efforts should extend beyond visible surfaces to include lamp covers, reflectors, and diffusers. This attention to detail not only enhances energy efficiency but also contributes to a visually appealing and well-maintained building environment.



FIGURE 4 WINDOW CLEANING- OPERATION AND MAINTENANCE

3. FENESTRATION - AIR TIGHTNESS

- **Description:** Ensure airtightness in envelope to optimize energy efficiency without additional costs without causing increase in heating loads.
- **Implementation Strategies:** Unwanted infiltration can increase the amount of unconditioned air into a space; thereby increasing the cooling requirements. Infiltration can also decrease thermal comfort, and introduce unwanted particulates, such as dust, into the building.



FIGURE 5 WINDOW- AIR TIGHTNESS

II. MID COST ECMs:

1. ENVELOPE - AIR TIGHTNESS

- **Description:** Incorporate adequate sealing for building envelope to protect it from infiltration.
- **Implementation Strategies:** Infiltration is a form of convection in which heat flows via air movement. When the infiltration of the space is higher occupants feel cold when the door is open on a winter day, and why caulking small cracks around windows improves comfort. Unwanted infiltration can increase the amount of unconditioned air into a space; thereby increasing the cooling requirements. Infiltration can also decrease thermal comfort, and introduce unwanted particulates, such as dust, into the building.

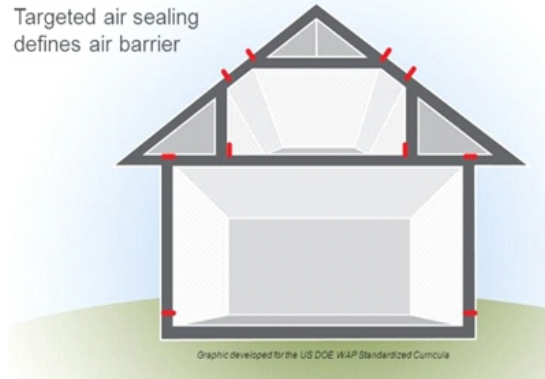


FIGURE 6 ENVELOPE AIR TIGHTNESS

2. INTERNAL AND EXTERNAL LIGHT SHELF

- **Description:** Implement Light shelf to enhance the daylighting inside the building and to reduce the dependency on artificial lighting during daytime
- **Implementation Strategies:** External Light shelves can be used to reflect the incoming sunlight upwards to illuminate the ceiling. The reflected light will have little solar heat content, and can reduce the need for indoor lighting. It is also useful for reducing glare. Daylight penetration can be enhanced through the use of internal light shelves and changing the ceiling profile to bounce light further into the space.

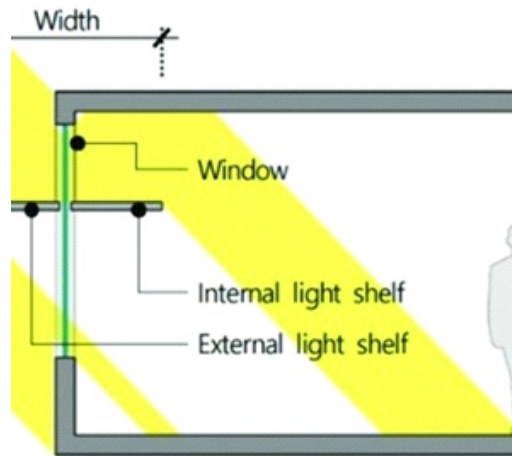


FIGURE 7 INTERNAL AND EXTERNAL LIGHT SHELF

3. SOLAR REFLECTORS:

- **Description:** Use solar reflectors to increase solar gain and reduce heating load.
- **Implementation Strategies:** Solar reflectors are installed outside windows to direct more sunlight into the building, enhancing solar gain. Position these reflectors on windows facing the sun, typically on south-facing windows in the northern hemisphere. They can be fixed or adjustable, depending on the design and seasonal changes. The primary benefit is a reduction in the building's heating load by 10 to 15%, leading to lower energy costs. Additionally, increased natural light improves indoor illumination, reducing the need for artificial lighting and enhancing overall energy efficiency.

4. TROMBE WALL:

- **Description:** Use a Trombe wall for passive solar heating to improve energy efficiency.
- **Implementation Strategies:** A Trombe wall consists of a dark, heat-absorbing wall covered with glass, creating a small airspace that traps heat. Install Trombe walls on the south-facing side of the building to maximize sunlight exposure. Paint the wall with a dark, heat-absorbing color and cover it with a glass panel placed a few centimeters away to create an air gap. This design captures solar energy during the day, storing and slowly releasing it as heat into the building at night. Benefits include enhanced heating, reduced reliance on mechanical heating systems, improved indoor comfort, and lower energy costs.

III. CAPITAL INTENSIVE ECMs:

1. WALL AND ROOF INSULATION MATERIALS

- **Description:** Upgrade adequate wall and roof insulation to shield the building from external heat gains.
- **Implementation Strategies:** Insulating the building envelope helps with retaining warmth in the winter and cool air in the summer, in turn reducing the need for excessive cooling. It also provides protection against weather-induced degradation and physical deterioration, increasing the overall durability of the building. This can be done by adding an air gap in the wall construction or another insulation layer balanced with the provision of cool surfaces.

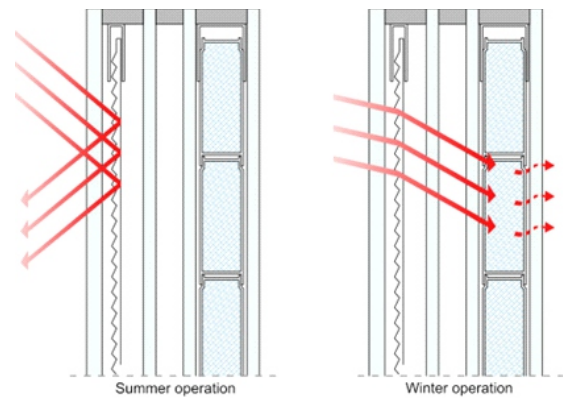


FIGURE 8 WALL AND ROOF INSULATION MATERIALS

2. HIGH PERFORMANCE GLAZING SYSTEM

- **Description:** Upgrade the existing single pane glass with double and triple glazing to reduce the external heat gains through the fenestration.
- **Implementation Strategies:** Incorporating Higher SHGC glazing, Low E coating glazing and Lower U value Glazing contribute to the reduced heat gains through the fenestration resulting in minimized use of artificial light consumption. This reduces heating load on HVAC system

and improves visual and thermal comfort especially for occupants in the perimeter zones.



CONCLUSION:

This elaborate segregation of ECMs based on capital cost involvement serves as a comprehensive guide for stakeholders involved in Envelope retrofit projects in the Indian context for commercial buildings. By delving into intricate details of implementation strategies and considerations, decision-makers can strategically plan and execute retrofits that not only align with budgetary constraints but also contribute to long-term sustainability objectives. This approach ensures a balanced and effective implementation of energy-efficient Envelope retrofits with thermal and visual comfort, tailored to the unique challenges and opportunities presented by the diverse landscape of India.

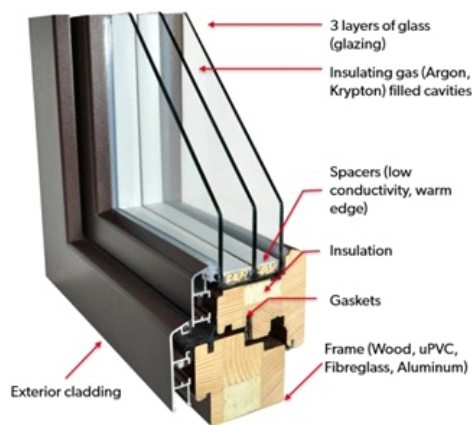


FIGURE 9 HIGH PERFORMANCE GLAZING SYSTEM

Matrix of ECMs (based on cost)

	No cost and Low-Cost ECMs:	Mid-Cost ECMs	Capital-Intensive ECMs
Types of Retrofit	Existing Building Commissioning	Standard Retrofit	Deep Retrofit
Energy Savings	Up to 25% Energy Savings	25-45% Energy Savings	Over 45% energy savings
Benefits of each type	Can be achieved with minimal risk and capital outlay by improving building operation and maintenance procedure	Component level replacement levels of existing equipment for improved energy efficiency.	An integrated whole building approach is used for energy savings. For example, combination of building envelope upgrade with lighting and mechanical system upgrade.
External Wall	High SRI paints	Envelope Air Tightness	Wall Insulation materials
Roof	Cool Roof- Vegetated roof, High SRI paints	Roof Deck Shading	Insulation materials
Fenestration-	Air Tightness	Trombe Wall	High performance glazing system

Part -II Active Retrofit Solutions

The term 'Active Retrofit' refers to the practice of incorporating advanced technologies and systems to improve the energy efficiency of a building. This includes the installation of energy-efficient HVAC systems, smart lighting, renewable energy sources like solar panels, and energy management systems that optimize energy use. Active Retrofitting often requires

significant work and investment, but it can drastically reduce energy consumption, lower carbon emissions, and enhance occupant comfort. A well-executed active retrofit can transform an existing building into a high-performance, sustainable facility.

Lighting Retrofit

Lighting retrofits in existing commercial buildings play a crucial role in enhancing energy efficiency and reducing operational costs. 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. When it comes to office building lighting represents approximately 10%–25% of all electricity consumed. The lighting load is greater for a building with a deeper floor plate or one that operates for evening or night shift hours. This section provides a comprehensive set of technical

guidelines for implementing effective lighting retrofits in commercial buildings across India. The focus is on maximizing energy savings, optimizing lighting quality, and ensuring long-term sustainability. Lighting, constituting a substantial portion of a building's energy consumption, becomes a pivotal area for targeted enhancements. The process of retrofitting lighting systems involves the upgrade or replacement of existing fixtures, controls, and technologies to enhance energy efficiency, reduce operational costs, and foster a more sustainable built environment.

Checklist of ECMs For Lighting Retrofits

All components which separate the spaces inside the building from outside environmental conditions are referred to as the building envelope [8]. The building envelope forms a thermal boundary with the exterior and it is made up of three-dimensional, multi-layer/material assemblies consisting of the following components- External Roofing system, external Walling system, Fenestration (Vertical and Horizontal), Base Floor system, Below-Grade Walling Systems. Heat always flows from the warmer side of the building envelope to the colder side. Conduction, solar radiation and infiltration are the major parameters of heat flowing through a Building envelope. Radiation is heat flow over a distance from hot to cold, the way the Sun's heat reaches Earth. This causes occupants to use window shades to block excess radiation to maintain thermal and visual comfort.

I. NO COST ECMs

No-cost ECMs for lighting retrofits are rooted in the fundamental principle of altering occupant behavior, optimizing operational practices, and implementing proactive maintenance strategies. These measures not only contribute to immediate energy savings but also establish a foundation for a sustainable and energy-efficient lighting environment in the long term. Let us explore each dimension of these measures in detail.

1. BEHAVIORAL CHANGES:

- a) **Energy Awareness Programs:** Creating a culture of responsibility and mindfulness among building occupants is a cornerstone of no-cost ECMs. Energy

awareness programs play a pivotal role in educating occupants about the importance of energy conservation. Through workshops, seminars, and informative campaigns, building managers can instill a sense of ownership and responsibility for energy-efficient practices. A well-designed awareness program should address the environmental impact of energy consumption, the financial benefits of energy savings, and practical tips for reducing energy use. Regular communication channels, such as newsletters, posters, and digital displays, serve as constant reminders, reinforcing the importance of energy conservation.

- b) **Active Occupant Engagement:** Encouraging active participation from occupants is crucial for the success of behavioral changes. Building managers can facilitate engagement through surveys, feedback sessions, and collaborative initiatives. By involving occupants in the decision-making process and encouraging them to share energy-saving ideas, a sense of shared responsibility is fostered. Occupant engagement extends beyond theoretical understanding to practical implementation. Through interactive workshops, occupants can learn about the energy consumption patterns of common appliances, the impact of lighting on overall energy use, and the potential for behavioral changes to contribute to substantial savings.
- c) **Monitoring and Feedback Systems:** Implementing monitoring and feedback systems provides real-time information on energy consumption. This transparency allows occupants to visualize the impact of their behavior on energy use. Web-based platforms, mobile applications, or even simple energy dashboards in common areas can display real-time energy data, fostering a sense of accountability among building occupants. The integration of monitoring and feedback systems enables occupants to track their progress in reducing energy consumption. Recognition programs and incentives can further motivate individuals and teams to actively participate in energy conservation initiatives.

2. OPERATIONAL ADJUSTMENTS:

- a) **Scheduling for Common Areas:** Operational adjustments involve optimizing existing lighting

system settings and schedules to align with usage patterns. One effective strategy is implementing scheduling for common areas and meeting rooms. These spaces often experience intermittent occupancy, making it feasible to strategically control when lights are on or off. By configuring lighting systems to automatically adjust based on scheduled occupancy periods, unnecessary energy consumption during non-operational hours is minimized. Advanced scheduling systems can account for variations in daily and weekly usage patterns, ensuring that lighting aligns with actual occupancy needs.

- b) **Fine-tuning Lighting System Settings:** Regularly reviewing and adjusting lighting system settings is a proactive measure that requires minimal effort but yields significant benefits. Fine-tuning involves optimizing light levels based on occupancy patterns and the specific requirements of different areas within the building. For example, areas with ample natural light may require lower artificial illumination levels. By periodically assessing and adjusting lighting system settings, building managers can ensure that the lighting environment remains conducive to tasks and activities while avoiding unnecessary energy expenditure. This practice also addresses the changing needs of occupants and spaces over time.

3. MAINTENANCE PRACTICES:

- a) **Proactive Maintenance Schedule:** Proactive maintenance practices are integral to the longevity and efficiency of lighting systems. Establishing a proactive maintenance schedule involves routine inspections of lighting fixtures and controls. Regular assessments identify potential issues before they escalate, preventing unnecessary energy loss and extending the life of the lighting system. A comprehensive maintenance schedule includes visual inspections, electrical testing, and assessments of control systems. By addressing issues promptly, building managers can ensure that the lighting system operates optimally, delivering the intended illuminance levels without unnecessary energy waste.
- b) **Cleaning Fixtures and Reflectors:** Regular cleaning of

fixtures and reflectors is essential for maximizing light output. Accumulated dirt, dust, and debris on fixtures can significantly reduce their efficiency, leading to increased energy consumption to achieve desired illuminance levels. Scheduled cleaning routines ensure that fixtures maintain their effectiveness over time. Cleaning efforts should extend beyond visible surfaces to include lamp covers, reflectors, and diffusers. This attention to detail not only enhances energy efficiency but also contributes to a visually appealing and well-maintained lighting environment.

- c) **Addressing Issues Promptly:** Proactive maintenance practices also involve addressing issues promptly when they arise. Rapid response to malfunctioning fixtures, controls, or wiring prevents prolonged periods of energy waste and ensures uninterrupted lighting service. Establishing clear communication channels for reporting issues, along with a responsive maintenance team, is crucial. This proactive approach not only contributes to energy savings but also enhances occupant satisfaction by maintaining a reliable and efficient lighting infrastructure.

II. LOW COST ECMs

Energy efficiency in commercial buildings is a dynamic pursuit, requiring a delicate balance between optimizing performance and managing costs. Low-cost Energy Conservation Measures (ECMs) for lighting retrofits present an opportunity to enhance efficiency without substantial financial investment. This section explores various low-cost ECMs, spanning LED lamp replacements, occupancy sensors, plug load controls, and other strategies designed to achieve tangible energy savings while maintaining budgetary considerations.

1. LED Lamp Replacement:



FIGURE 10 LED LAMP REPLACEMENTS

- a) **High-Efficiency LED Lamps:** The cornerstone of low-cost lighting retrofits is the replacement of traditional incandescent and CFL lamps with high-efficiency LED alternatives. LED lamps offer superior energy efficiency, longer lifespans, and enhanced lighting quality. This simple yet impactful swap reduces energy consumption and maintenance costs, while also contributing to a reduction in the carbon footprint of the building.
- b) **Lumen Output Considerations:** When implementing LED lamp replacements, careful consideration of lumen output is crucial. Opting for LED lamps with a high lumen output ensures that the desired illuminance levels are maintained while still achieving energy savings. This strategic selection enhances both visual comfort and overall lighting efficiency.

2. OCCUPANCY SENSORS:

- a) **Automated Lighting Control:** Integrating occupancy sensors into lighting systems is a cost-effective way to ensure that lights are only active in areas when and where they are needed. These sensors detect movement and occupancy, automatically turning lights on when a space is in use and off when it is vacant. This real-time responsiveness not only reduces energy waste but also aligns lighting with the actual needs of building occupants.

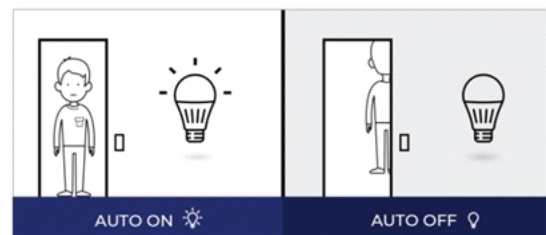


FIGURE 11 OCCUPANCY SENSORS

- a) **Daylight Harvesting:** Daylight harvesting, often included in occupancy sensors, is a low-cost strategy that leverages natural light to modulate artificial lighting levels. By adjusting the brightness of lights based on the availability of natural daylight, daylight harvesting minimizes the need for artificial lighting during well-lit periods. This dual strategy optimizes energy consumption throughout the day.

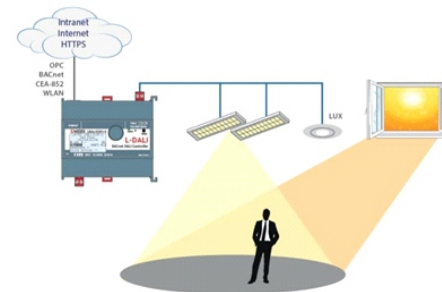


FIGURE 12 DAYLIGHT HARVESTING

3. PLUG LOAD CONTROLS:

- a) **Advanced Power Strips:** Plug load controls, specifically advanced power strips, offer a straightforward solution to managing energy consumption from electronic devices in workstations. These power strips can be programmed to control peripheral devices, such as monitors, printers, and chargers, preventing energy waste when not in use. Educating occupants on the use of these power strips further enhances their effectiveness.
- b) **Power Management Features:** Low-cost ECMs also include encouraging occupants to leverage power management features available in electronic devices. Simple actions, such as enabling sleep mode on computers or turning off monitors during breaks, contribute to incremental energy savings. Educational campaigns and awareness programs play a crucial role in promoting these energy-conscious behaviors.

4. LIGHTING SIGNAGE EFFICIENCY:

- a) **LED Retrofits for Signage:** Exterior lighting signage is often overlooked in retrofits. However, low-cost

measures for signage involve replacing traditional lighting sources with energy-efficient LED retrofits. LED technology not only enhances visibility but also contributes to energy savings. Retrofitting signage lighting aligns with overall energy efficiency goals while maintaining the visual appeal of the commercial building.



FIGURE 13 LED SIGNAGE

- b) **Timing Controls for Signage:** Implementing timing controls for exterior signage ensures that lights are active only during specific hours when visibility is essential. This low-cost measure prevents unnecessary energy consumption during night-time hours when reduced lighting levels may be sufficient. Additionally, incorporating sensors to adjust signage brightness based on ambient light conditions further optimizes energy use.



FIGURE 14 TIMER CONTROLS

III. MID COST ECMs

Mid-cost ECMs for lighting retrofits occupy a crucial position in the spectrum of energy efficiency strategies. While low-cost measures offer immediate benefits, mid-cost solutions introduce a layer of sophistication, incorporating advanced technologies that contribute to both energy savings and enhanced lighting quality. This section delves into the details of mid-cost ECMs, emphasizing their significance in achieving sustainable and efficient lighting systems within commercial buildings.

1. SMART LIGHTING CONTROLS:

- a) **Centralized Building Management Systems (BMS):** One key mid-cost ECM involves upgrading to smart lighting systems with centralized control through Building Management Systems (BMS). BMS facilitates the integration of various building components, allowing for centralized monitoring, control, and optimization of the lighting environment. This advanced level of control enhances operational efficiency and provides building managers with real-time insights into energy consumption patterns.

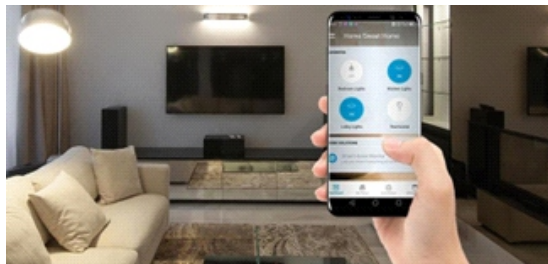


FIGURE 15
CENTRALISED BUILDING MANAGEMENT SYSTEM

- b) **Time-of-Day Controls:** Smart lighting controls include time-of-day controls that enable the automation of lighting adjustments based on specific time periods. This ensures that lighting levels are optimized throughout the day, aligning with occupancy patterns and external lighting conditions. Time-of-day controls contribute to energy savings by avoiding unnecessary illumination during periods of low activity.



FIGURE 16 TOD CONTROLS

2. TASK LIGHTING INTEGRATION:

- a) **Focused Illumination Solutions:** Mid-cost ECMs encompass task lighting integration, which involves the implementation of focused illumination solutions tailored to specific work areas. Task lighting allows occupants to personalize their lighting environment, providing adjustable fixtures that cater to individual preferences. This not only contributes to energy savings by avoiding over-illumination but also enhances occupant comfort and productivity.



FIGURE 17 TASK LIGHTING

- b) **Adjustable Fixtures:** Task lighting solutions often involve the use of adjustable fixtures that can be easily repositioned to suit changing task requirements. The

flexibility of these fixtures ensures that lighting can be directed precisely where it is needed, reducing the need for overall ambient lighting and minimizing energy consumption.

3. ADVANCED LIGHTING FIXTURES:

- a) **High-Efficiency Luminaires:** Mid-cost ECMs include the replacement of outdated fixtures with high-efficiency luminaires. These fixtures are designed to maximize light output while minimizing energy consumption. Upgrading to advanced lighting fixtures ensures uniform illuminance levels across spaces, contributing to both energy efficiency and the visual comfort of occupants.
- b) **Fixture Placement Optimization:** Optimizing the placement of lighting fixtures is another mid-cost strategy. Strategic placement considers the layout of spaces and the intended use of each area, ensuring that lighting is distributed efficiently. Proper fixture placement enhances lighting uniformity and reduces the need for excessive illumination, contributing to energy savings.

4. LIGHTING AUTOMATION SYSTEMS:

- a) **Adaptive Lighting Controls:** Mid-cost ECMs introduce adaptive lighting controls that respond dynamically to occupancy and environmental conditions. These systems use sensors to detect changes in occupancy, adjusting lighting levels accordingly. Adaptive controls contribute to energy savings by ensuring that lighting is active only when and where it is needed, aligning with real-time usage patterns.

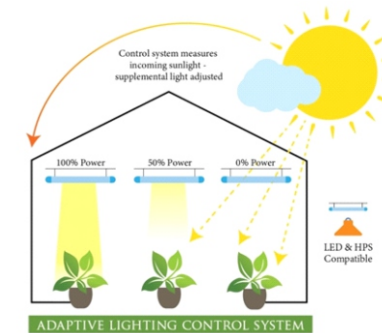


FIGURE 18 ADAPTIVE LIGHTING CONTROLS

- b) **Zoning and Dimming:** Implementing zoning and dimming capabilities enhances the flexibility of lighting automation systems. Zoning allows for the independent control of lighting in different areas, while dimming features enable the adjustment of light levels based on specific requirements. These functionalities optimize energy use by tailoring lighting to the specific needs of each space

IV. CAPITAL-INTENSIVE COST ECMs

As commercial buildings strive to achieve optimal energy efficiency, capital-intensive cost ECMs emerge as transformative solutions that address not only immediate energy savings but also long-term sustainability goals. These measures, while requiring a substantial upfront investment, introduce cutting-edge technologies and advanced strategies that position commercial buildings as leaders in sustainable and energy-conscious practices.

1. FULL FIXTURE REPLACEMENT:

- a) **Modern, Energy-Efficient Fixtures:** One of the core capital-intensive ECMs involves the complete replacement of existing lighting fixtures with modern, energy-efficient alternatives. These fixtures, often based on LED technology, offer higher efficacy, longer lifespans, and improved lighting quality. Full fixture replacements not only contribute to substantial energy savings but also align with sustainability goals by reducing the overall environmental impact of lighting systems.
- b) **Compatibility with Advanced Controls:** When undertaking full fixture replacements, it is essential to ensure compatibility with advanced lighting controls. This integration allows for enhanced control over lighting levels, color temperatures, and other parameters. The compatibility ensures that the investment in modern fixtures is maximized through comprehensive control and customization capabilities.

2. DAYLIGHT HARVESTING SYSTEMS:

- a) **Advanced Daylight Harvesting Controls:** Capital-intensive ECMs include the implementation of advanced daylight harvesting systems. These systems use sensors and controls to modulate artificial lighting based on the availability of natural daylight. By dynamically adjusting lighting levels in response to changing daylight conditions, daylight harvesting systems optimize energy consumption and provide a seamless integration of natural and artificial light.
- b) **Automated Shading Systems:** To complement daylight harvesting, automated shading systems can be integrated to control glare and optimize daylight utilization. These systems adjust the positioning of blinds or shades based on the sun's position, preventing excessive glare while allowing for the maximum use of available natural light. This dual approach enhances occupant comfort and energy efficiency.



FIGURE 19 AUTOMATED SHADING SYSTEMS

3. ADVANCED LIGHTING CONTROLS INTEGRATION:

- a) **Color-Tunable Lighting:** Capital-intensive ECMs involve the integration of color-tunable lighting controls. This technology allows for the adjustment of color temperature, mimicking natural daylight variations throughout the day. Color-tunable lighting not only enhances visual comfort but also has potential benefits for occupant well-being and productivity by supporting circadian rhythms.
- b) **Adaptive Lighting Systems:** The adoption of adaptive lighting systems represents a transformative strategy. These systems use sensors, occupancy data, and machine learning algorithms to adapt lighting conditions based on user preferences, occupancy patterns, and environmental factors. Adaptive lighting enhances energy efficiency by providing personalized illumination, responding in real-time to changing needs.

4. BUILDING INTEGRATED SOLAR PHOTOVOLTAIC::

- a) **Description:** The term “building integrated photovoltaics” is applied to any application of photovoltaics mounted on or withing a building envelope. Additionally, it refers to projects where the photovoltaics are used to enhance the design concept of a building and where there is consideration of integration at physical, environmental and aesthetic levels. This technology enables the integration of PV on or withing roofs, glazing, skylight and shading devices.
- b) **Implementations:** Building Integrated Photovoltaics (BIPV) offers a dual-purpose approach to energy conservation and retrofitting by seamlessly integrating photovoltaic modules into the building envelope. This innovative strategy not only generates clean electricity but also enhances the building's aesthetic appeal and potentially improves its thermal performance. Exploring available government incentives, subsidies, and regulations to optimize the BIPV project's financial viability and compliance.

HVAC Retrofit

INTRODUCTION

In the dynamic landscape of building management, the role of HVAC systems (Heating, Ventilation, and Air Conditioning) has become pivotal in shaping energy-efficient practices. HVAC retrofitting, characterized by strategic upgrades and modernization of climate control systems, has emerged as a cornerstone in the journey towards sustainability within the built environment. This introduction serves as a gateway to comprehensively explore the nuances of HVAC retrofitting in India, traversing through regulatory compliance, industry trends, the pressing need for energy savings, meticulous checklists of Energy Conservation Measures (ECMs), and the transformative potential of technological innovations.

As the world increasingly grapples with the challenges posed by climate change, the significance of retrofitting existing HVAC systems comes to the forefront. The energy consumed by HVAC systems in commercial buildings constitutes a substantial portion of the overall consumption. Retrofitting offers a strategic avenue to enhance the efficiency of these systems, thereby reducing operational costs, mitigating environmental impact, and aligning with global sustainability objectives.

CHECKLIST OF ECMs FOR HVAC RETROFITS

Efficient HVAC retrofit planning demands a nuanced understanding of Energy Conservation Measures (ECMs) categorized by their capital cost implications. This comprehensive segregation into No Cost, Low Cost, Mid Cost, and Capital-Intensive Cost tiers ensures stakeholders can make informed decisions balancing financial constraints and sustainability objectives. The following detailed breakdown offers extensive insights into the implementation strategies and considerations for each category:

- **High-Efficiency Boilers:**
 - o Upgrade boilers to high-efficiency models for effective heating in cold climates.
 - o Optimize combustion efficiency to minimize heat loss.

- **Underfloor Heating Systems:**

- o Implement underfloor heating systems for localized and efficient space heating.
- o Distribute heat evenly across the floor surface for enhanced comfort.

- **Triple Glazed Windows:**

- o Install triple glazed windows to improve insulation and reduce heat loss.
- o Minimize cold drafts and enhance thermal comfort in cold climates.

- **Snow Melting Systems:**

- o Integrate snow melting systems for outdoor areas to enhance safety and reduce the load on heating systems.
- o Optimize the use of energy for snow melting during cold weather conditions.

Efficient HVAC retrofit planning demands a nuanced understanding of Energy Conservation Measures (ECMs) categorized by their capital cost implications. This comprehensive segregation into No Cost, Low Cost, Mid Cost, and Capital-Intensive Cost tiers ensures stakeholders can make informed decisions balancing financial constraints and sustainability objectives. The following detailed breakdown offers extensive insights into the implementation strategies and considerations for each category:

I. BUILDING TYPOLOGIES:

- **Occupancy Sensors:**

- o Install occupancy sensors for intelligent HVAC control based on real-time occupancy levels.
- o Optimize energy usage by adjusting HVAC settings in unoccupied zones.

- **Advanced Building Management Systems (BMS):**

- o Upgrade to advanced BMS for centralized control and monitoring of HVAC operations.
- o Implement predictive analytics and fault detection for proactive system management.

- **Demand-Controlled Ventilation:**
 - o Implement DCV strategies in commercial buildings to adjust ventilation rates based on occupancy.
 - o Optimize indoor air quality while conserving energy during unoccupied periods.
- **Energy-Efficient Lighting Integration:**
 - o Coordinate HVAC retrofits with energy-efficient lighting solutions for a holistic approach.
 - o Implement integrated controls for both HVAC and lighting systems.
- **Timers and Scheduling Controls:**
 - o Utilize timers and scheduling controls for HVAC systems to align with operational hours.
 - o Optimize system performance during peak occupancy periods
- **High-Efficiency Air Filtration Systems:**
 - o Install high-efficiency air filtration systems to maintain optimal indoor air quality.
 - o Address specific air quality requirements in healthcare settings.
- **Temperature and Humidity Control in Sensitive Areas:**
 - o Implement precise temperature and humidity control measures in areas with sensitive medical equipment.
 - o Ensure compliance with healthcare standards for environmental control.
- **Energy Recovery Ventilation (ERV) in Common Areas:**
 - o Incorporate ERV systems in common areas to recover and utilize energy from exhaust air.
 - o Improve overall HVAC efficiency while addressing
- **Duct Sealing and Insulation:**
 - o Ensure proper sealing and insulation of ductwork to minimize energy losses.
 - o Enhance overall system efficiency by addressing duct-related heat gains and losses.
- **Regular HVAC System Maintenance:**
 - o Establish a routine maintenance schedule to ensure the ongoing efficiency and longevity of HVAC systems.
 - o Conduct periodic inspections, filter replacements, and system optimization.
- **Occupant Awareness Programs:**
 - o Implement programs to raise awareness among occupants about energy-efficient practices.
 - o Foster a culture of energy conservation through education and engagement.

Segregation of Measures

Efficient HVAC retrofit planning demands a nuanced understanding of Energy Conservation Measures (ECMs) categorized by their capital cost implications. This comprehensive segregation into No Cost, Low Cost, Mid Cost, and Capital-Intensive Cost tiers ensures stakeholders can make informed decisions balancing financial constraints and sustainability objectives. The following detailed breakdown offers extensive insights into the implementation strategies and considerations for each category:

I. NO-COST ECMs:



FIGURE 20 THERMOSTAT CONTROLS

1. OPTIMIZED HVAC SYSTEM SETTINGS:

- **Description:** Adjusting temperature setpoints and ventilation rates to optimize energy efficiency without additional costs.
- **Implementation Strategies:**
 - Conducting periodic energy audits to identify optimal setpoints and control parameters.
 - Utilizing predictive analytics tools for continuous system optimization.
 - Implementing a proactive maintenance schedule to ensure controls operate optimally.

2. EQUIPMENT OPTIMIZATION:

- **Description:** Optimizing the operation of HVAC systems,

lighting, and other equipment through scheduling, zoning, and load shedding.

• **Implementation Strategies:**

- Track energy consumption to identify areas for improvement and measure the impact of implemented measures. Explore options for basic automation, such as timers or simple controllers, to streamline equipment operation.

3. OPTIMIZED SETPOINTS:

- **Description:** Adjusting thermostat settings for heating and cooling systems to maximize energy efficiency.
- **Implementation Strategies:** Seasonal adjustments modify setpoints based on the time of year. Lower heating setpoints during milder months and raise cooling setpoints during cooler periods. Provide clear guidelines on recommended setpoint temperatures for different seasons and occupancy levels. Implement setpoint changes gradually to allow occupants to adapt to new temperature levels.

4. COLD RECOVERY VENTILATION (CRV) SYSTEM:

- **Description:** Installing CRV systems to recover heat from exhaust air and transfer it to incoming fresh air.
- **Implementation Strategies:** Installing CRV systems in conjunction with ventilation systems to improve indoor air quality and reduce energy consumption.

5. OCCUPANCY-BASED SCHEDULING:

- **Description:** Implementing HVAC scheduling based on building occupancy patterns.
- **Implementation Strategies:**
 - Deploying advanced occupancy sensors and machine learning algorithms for predictive scheduling.
 - Collaborating with building occupants to gather data on occupancy patterns for refined scheduling.

- Integrating scheduling strategies into a centralized Building Management System (BMS) for seamless operation.

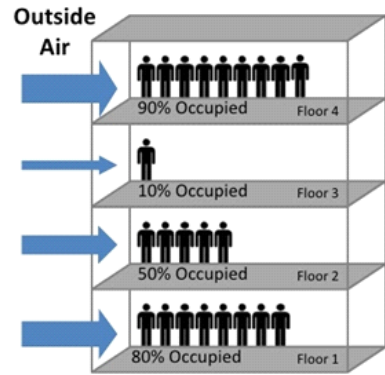


FIGURE 21 OCCUPANCY BASED SCHEDULING

6. AIR FILTER MAINTENANCE:



FIGURE 22 AIR FILTER MAINTENANCE

- Description:** Establishing a proactive air filter maintenance schedule.
- Implementation Strategies:**
 - Employing real-time monitoring systems to track filter health and schedule replacements.
 - Introducing predictive maintenance tools that use data analytics to forecast optimal replacement times.

- Conducting regular training for maintenance staff to enhance filter replacement efficiency.

7. BEHAVIORAL CHANGES:

- Description:** Conducting awareness programs to promote energy-efficient practices.
- Implementation Strategies:**
 - Developing interactive campaigns utilizing multimedia channels to engage building occupants.
 - Introducing incentive programs for energy conservation.
 - Establishing a continuous feedback loop for occupants to share energy-saving suggestions.

II. LOW-COST ECMs:

1. VARIABLE REFRIGERANT FLOW (VRF) CONTROLS:

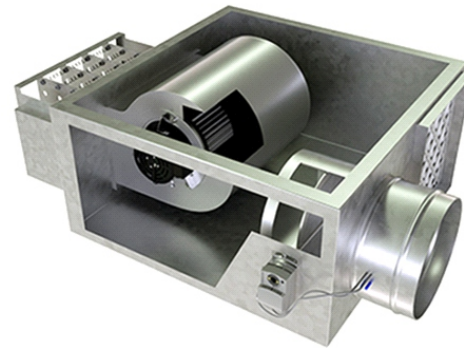


FIGURE 23 VARIABLE AIR VOLUME (VAV) CONTROLS

- Description:** Installing VRF controls to optimize airflow and enhance zoning capabilities.
- Implementation Strategies:**
 - Conducting a detailed HVAC system assessment to identify zones suitable for VRF controls.
 - Integrating real-time monitoring systems to adjust VRF settings dynamically.
 - Implementing control algorithms that consider occupancy, temperature, and airflow requirements.

2. PROGRAMMABLE THERMOSTATS:

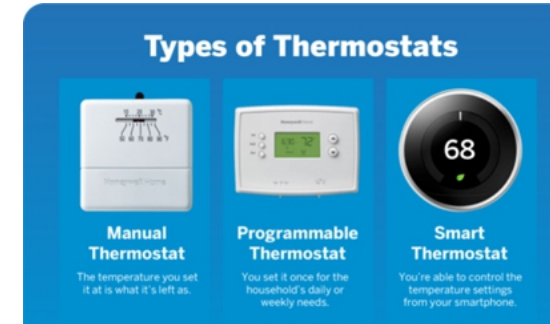


FIGURE 24 PROGRAMMABLE THERMOSTATS

- Description:** Upgrading to programmable thermostats for better control and scheduling.
- Implementation Strategies:**
 - Deploying smart thermostats that can be remotely controlled and programmed.
 - Integrating thermostats with occupancy sensors for adaptive temperature control.
 - Conducting training sessions for building occupants to maximize thermostat usage.

3. DUCT SEALING:



FIGURE 25 SEALING OF DUCT

- Description:** Sealing and insulating ductwork to minimize air leakage.
- Implementation Strategies:**
 - Conducting a comprehensive ductwork inspection using thermal imaging and pressure testing.

- Utilizing advanced sealing materials and techniques, such as aerosol-based sealing.
- Integrating insulation materials that align with the specific needs of the ductwork.

4. HVAC SYSTEM TUNING:

- Description:** Conducting regular HVAC system tuning and optimization.
- Implementation Strategies:**
 - Implementing a proactive maintenance plan that includes regular system tuning.
 - Utilizing advanced diagnostic tools for comprehensive system analysis.
 - Incorporating continuous commissioning processes to ensure ongoing system optimization.

III. MID-COST ECMs:

1. ENERGY RECOVERY VENTILATION (ERV) SYSTEMS:



FIGURE 26 ENERGY RECOVERY VENTILATION (ERV) SYSTEMS

- Description:** Installing ERV systems for efficient heat and moisture exchange.
- Implementation Strategies:**
 - Conducting a thorough ventilation system assessment to determine ERV feasibility.
 - Introducing demand-based control strategies to optimize ERV performance.
 - Integrating ERV units with air-handling systems for seamless operation.

2. DEMAND-CONTROLLED VENTILATION (DCV):

- **Description:** Implementing DCV strategies based on real-time occupancy.
- **Implementation Strategies:**
 - Deploying advanced occupancy sensors and CO2 monitors for precise control.
 - Utilizing machine learning algorithms to predict occupancy trends and adjust ventilation rates.
 - Integrating DCV systems with centralized BMS for coordinated operation.

3. LIGHTING SYSTEM UPGRADES:



FIGURE 27 LIGHTING UPGRADE

- **Description:** Integrating energy-efficient lighting systems to reduce overall heat gain.
- **Implementation Strategies:**
 - Collaborating with lighting retrofit projects to synchronize efforts for cumulative energy savings.
 - Implementing advanced lighting controls, such as daylight harvesting and occupancy sensing.
 - Utilizing smart lighting solutions that integrate seamlessly with HVAC controls.

IV. CAPITAL-INTENSIVE COST ECMS:

1. HIGH-EFFICIENCY HVAC SYSTEMS:



FIGURE 28 INSTALLING HIGH-EFFICIENT HVAC SYSTEM

- **Description:** Complete replacement or major upgrade to high-efficiency HVAC equipment.
- **Implementation Strategies:**
 - Conducting a comprehensive lifecycle cost analysis to justify the long-term benefits.
 - Exploring innovative financing models, such as performance-based contracting.
 - Collaborating with manufacturers and suppliers to customize systems based on building needs.

2. RENEWABLE ENERGY INTEGRATION:

- **Description:** Incorporating renewable energy sources, such as solar panels, to power HVAC systems.
- **Implementation Strategies:**
 - Conducting feasibility studies and energy modeling to optimize renewable energy system sizing.
 - Exploring government incentives, grants, and subsidies to offset initial capital costs.
 - Integrating smart grid technologies for efficient energy distribution and storage.



FIGURE 29 RENEWABLE ENERGY INTEGRATION

3. ADVANCED BUILDING MANAGEMENT SYSTEM (BMS):

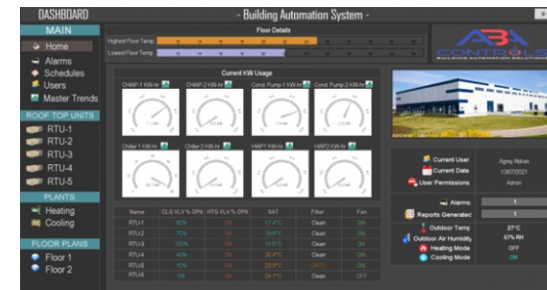


FIGURE 30
ADVANCED BUILDING MANAGEMENT SYSTEM (BMS)

- **Description:** Installing a sophisticated BMS for centralized control, monitoring, and optimization.
- **Implementation Strategies:**
 - Collaborating with experienced BMS vendors to tailor the system to the facility's specific needs.
 - Providing comprehensive training programs for facility management staff to maximize BMS utilization.
 - Integrating BMS with other building systems, such as lighting and security, for seamless control

4. DUAL AC:

- **Description:** Use dual AC units to efficiently heat and cool specific areas.
- **Implementation Strategies:** Dual AC units are designed to provide targeted heating and cooling, saving energy by only conditioning the spaces in use. Install dual AC units in larger homes or offices where different zones require separate temperature control. Regular maintenance ensures they operate efficiently. Benefits include lower energy bills, improved comfort, and enhanced control over indoor temperatures, leading to a more efficient and comfortable living environment.

5. HEAT TRAP:

- **Description:** Use heat traps to improve heating efficiency by preventing heat loss.
- **Implementation Strategies:** Heat traps are devices installed in heating systems to prevent heat from escaping, thereby improving energy efficiency. Install heat traps on both hot and cold water lines of water heaters to minimize heat loss. This is especially useful in colder areas where maintaining water temperature is crucial. Benefits include reduced heating energy consumption, lower utility bills, and improved efficiency of the heating system, ensuring consistent and efficient space heating.

CONCLUSION:

This elaborate segregation of ECMS based on capital cost involvement serves as a comprehensive guide for stakeholders involved in HVAC retrofit projects in the Indian context. By delving into intricate details of implementation strategies and considerations, decision-makers can strategically plan and execute retrofits that not only align with budgetary constraints but also contribute to long-term sustainability objectives. This holistic approach ensures a balanced and effective implementation of energy-efficient HVAC retrofits, tailored to the unique challenges and opportunities presented by the diverse landscape of India.

Retrofit Service Water Heating & Plumbing

Service water heating and plumbing systems play a pivotal role in the functionality of commercial buildings. Retrofitting these systems is a strategic approach to enhance energy efficiency, reduce water consumption, and contribute to overall sustainability.

CHECKLIST OF ECMs FOR RETROFITTING OF SERVICE WATER HEATING AND PLUMBING

a) Optimized Hot Water System Settings:

- **Description:** Adjusting temperature settings based on climatic demands ensures comfort without unnecessary heating. Occupancy-based adjustments cater to varying usage patterns, optimizing energy consumption.
- **Implementation Details:** Utilize smart controls or programmable thermostats to dynamically adjust hot water temperatures based on real-time occupancy and external temperature conditions.

b) Leaks and Drips Maintenance:

- **Description:** Regular inspection and timely repair of leaks are crucial, especially in humid climates prone to accelerated wear. Swift leak detection in multi-story buildings prevents extensive water damage and promotes water conservation.
- **Implementation Details:** Conduct routine inspections, implement leak detection systems, and educate maintenance staff and occupants about the importance of reporting leaks promptly.

c) Water Fixture Upgrades:

- **Description:** Installing water-saving fixtures with aerators, particularly in water-scarce regions, significantly reduces water consumption. Upgrading fixtures in high-density areas ensures maximum water savings without compromising user comfort.
- **Implementation Details:** Replace traditional fixtures with low-flow alternatives, consider sensor-operated faucets, and incorporate aerators to regulate water flow and maintain user satisfaction.

d) Behavioral Changes:

- **Description:** Promoting water-saving practices through awareness programs is essential, particularly in arid and semi-arid regions. Behavioral changes among occupants contribute significantly to water conservation efforts.
- **Implementation Details:** Conduct workshops, distribute educational materials, and implement signage to encourage responsible water use. Engage building occupants in water conservation initiatives.

e) Insulation for Hot Water Pipes::

- **Description:** Prioritizing insulation in colder climates minimizes heat loss during transit. Focus on multi-story buildings where hot water travels longer distances, reducing the need for excessive heating.
- **Implementation Details:** Use appropriate insulation materials to cover hot water pipes, paying special attention to exposed sections in colder climates. Regularly inspect and replace insulation as needed.

f) Water Heater Timer Installation:

- **Description:** Implementing timers on water heaters aligns heating schedules with fluctuating temperature patterns, optimizing energy consumption. Timers can be adjusted based on occupancy variations in different seasons.
- **Implementation Details:** Install programmable timers or smart controls on water heaters to match heating schedules with demand patterns. Educate occupants on timer usage and benefits.

g) Faucet and Pipe Sealing:

- **Description:** Sealing gaps in faucets and pipes prevents water leaks and ensures the efficient functioning of the plumbing system. This is particularly important in humid climates prone to accelerated corrosion.
- **Implementation Details:** Use weather-resistant sealants and caulks to seal gaps in faucets and pipes. Regularly inspect and maintain seals to prevent water wastage and potential water damage.

h) Low-Flow Fixture Replacements:

- **Description:** Choosing low-flow fixtures balances water conservation with user comfort in all climatic zones. Replacing outdated or inefficient fixtures is essential for optimizing water use.
- **Implementation Details:** Install low-flow toilets, faucets, and showerheads with the WaterSense label. Consider user satisfaction and ensure proper maintenance to avoid any impact on performance.

i) Hot Water Recirculation Systems:

- **Description:** Emphasizing recirculation in regions with cold temperatures minimizes waiting times for hot water, improving user experience and reducing water wastage.
- **Implementation Details:** Install recirculation systems with temperature-controlled pumps to circulate hot water efficiently. Optimize settings based on building occupancy and usage patterns.

j) Greywater Systems:

- **Description:** Implementing greywater systems in water-scarce regions maximizes reuse and reduces the demand on fresh water supplies.
- **Implementation Details:** Design and install greywater collection and treatment systems. Ensure compliance with local regulations and educate occupants on the proper use of greywater.

k) Pipe Insulation Upgrade:

- **Description:** Upgrading insulation materials for hot water pipes ensures better performance, especially in extreme climates.
- **Implementation Details:** Use advanced insulation materials that are resistant to wear and tear. Focus on upgrading insulation in buildings with older or deteriorating infrastructure.

l) Smart Water Metering:

- **Description:** Utilizing smart meters for real-time monitoring in regions prone to water scarcity enhances water management capabilities.
- **Implementation Details:** Install IoT-enabled water meters to collect real-time data. Integrate data with Building Management Systems for centralized monitoring and analysis.

m) High-Efficiency Water Heaters:

- **Description:** Consideration of high-efficiency heaters in regions with extreme temperature variations optimizes energy consumption.
- **Implementation Details:** Conduct a lifecycle cost analysis to justify the long-term benefits of high-efficiency water heaters. Explore financing models and government incentives.

n) Solar Water Heating Systems:

- **Description:** Use solar energy to heat water efficiently. Leveraging solar systems more extensively in regions with abundant sunlight reduces dependency on traditional energy sources.
- **Implementation Strategies:** Solar water heating systems use sunlight to heat water, reducing reliance on electricity or gas. Install solar panels on rooftops or other areas with maximum sun exposure, connecting them to a water storage tank. This setup is ideal for regions with ample sunlight. Benefits include significant energy savings, reduced utility bills, and an environmentally friendly solution to water heating. Solar water heating also contributes to a sustainable lifestyle by harnessing renewable energy sources.

o) Plumbing System Redesign:

- **Description:** Redesigning plumbing systems ensures efficiency and prevents issues such as freezing in colder climates.
- **Implementation Details:** Collaborate with plumbing engineers to optimize piping layouts. Upgrade to efficient piping materials and configurations based on the building's needs.

p) Water Recycling Infrastructure:

- **Description:** Prioritizing advanced water recycling in water-scarce regions enhances sustainability efforts.
- **Implementation Details:** Install treatment systems for greywater and blackwater recycling. Collaborate with water management experts for system optimization and compliance with regulations.

Implementing these ECMs requires a strategic approach, collaboration with experts, and a commitment to long-term sustainability. Stakeholders should conduct thorough assessments, prioritize measures based on their context, and educate occupants for successful implementation and sustained impact.

Segregation of Measures

Water heating and plumbing retrofits in India demand a multifaceted strategy, intricately woven with the country's diverse climatic zones and varied building typologies. To provide a comprehensive roadmap for implementation, we present a detailed segregation of measures based on capital cost involvement, encompassing four distinct categories: No Cost, Low Cost, Mid Cost, and Capital-intensive Cost ECMs.

1. NO-COST ECMs:

No-cost measures form the foundational layer of the retrofit strategy, involving adjustments and behavioral changes that necessitate minimal to no financial investment.

- **Behavioral Changes:** Initiating water conservation awareness programs to instigate a shift in occupant behavior.



FIGURE 31 SAVE WATER

- **Optimized Hot Water System Settings:** Implementing dynamic temperature adjustments based on climatic conditions and occupancy patterns.

Benefits:

- **Immediate Implementation:** No extensive planning or financial approvals required.
- **Cultural Shift:** Fosters a culture of responsibility and environmental consciousness among building occupants.



FIGURE 32 OPTIMISING TEMPERATURE OF HOT WATER

2. LOW-COST ECMs:

Low-cost measures strike a balance between efficiency gains and budget considerations, offering tangible benefits without substantial financial implications.

Examples:

- **Faucet and Pipe Sealing:** Sealing gaps in faucets and pipes to prevent water leaks and optimize system performance.
- **Low-Flow Fixture Replacements:** Installing water-saving fixtures with aerators for improved water efficiency.



FIGURE 33 SEALING IN FAUCETS AND PIPES



FIGURE 34 LOW FLOW SHOWER HEAD

3. MID-COST ECMs:

Mid-cost measures represent a moderate financial investment, offering more substantial efficiency gains and sustainability benefits.

Examples:

- **Hot Water Recirculation Systems:** Introducing systems to minimize waiting times, enhancing user experience and water conservation.
- **Greywater Systems:** Implementing systems to capture and reuse greywater, reducing demand on fresh water supplies.

Benefits:

- **Significant Improvement:** Offers a meaningful impact on water management and sustainability.
- **Balanced Investment:** Presents a reasonable upfront cost with substantial long-term gains.

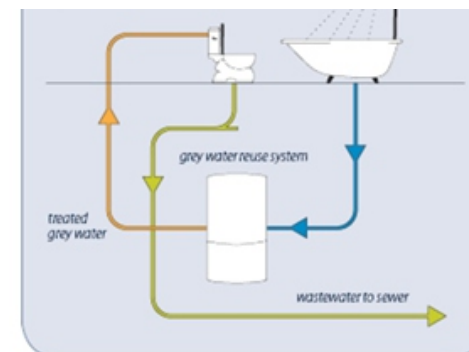


FIGURE 35 REUSING OF GREYWATER

4. CAPITAL-INTENSIVE COST ECMs:

Capital-intensive measures, while requiring a higher initial investment, bring transformative changes and long-term benefits to water heating and plumbing systems.

Examples:

- **Solar Water Heating:** Solar energy can be effectively used to heat water, particularly in regions with abundant sunlight. Solar water heating systems are highly efficient, capable of converting up to 80% of the sunlight that strikes the collector into usable heat energy. These systems reduce reliance on conventional water heating methods and contribute to energy savings and environmental benefits.

Implementation:

- **System Selection:** Choose the appropriate solar water heating system based on the building's hot water demand and local climate conditions. Options include flat-plate collectors and evacuated tube collectors, both of which are efficient in capturing solar energy.
- **Optimal Installation:** Install solar panels on rooftops or other areas that receive maximum sunlight exposure for optimal heat capture. Proper orientation and tilt of the panels are crucial for maximizing efficiency.
- **Integration with Existing Infrastructure:** Connect the solar panels to a water storage tank to store heated water for later use. The system can also be integrated with the existing water heating infrastructure, allowing for seamless operation and additional energy savings.



FIGURE 36 SOLAR WATER HEATER

- **Water Recycling Infrastructure:** Implementing advanced systems for efficient water recycling and resource optimization.
- Benefits:**
- **Revolutionary Sustainability:** Presents revolutionary improvements in water and energy sustainability.
 - **Long-Term Cost Savings:** Despite higher upfront costs, delivers significant savings over the lifecycle.

CONCLUSION:

Strategically segregating water heating and plumbing retrofit measures based on capital cost ensures a systematic and sustainable approach. By aligning measures with specific building needs, objectives, and financial considerations, stakeholders can optimize water and energy efficiency while ensuring a prudent allocation of resources. This approach not only addresses immediate concerns but also establishes a foundation for long-term sustainability and resilience, fostering a holistic and resilient water management system.

Retrofit Electrical Systems & Appliances

CHECKLIST OF ECMs FOR ELECTRICAL SYSTEMS AND APPLIANCES RETROFITTING

POWER DISTRIBUTION	APPLIANCE UPGRADATION	SMART METERING AND AUTOMATION
<p>Energy-Efficient Transformers:</p> <ul style="list-style-type: none"> • Replace outdated transformers with newer, more energy-efficient models. <p>Power Factor Correction Devices:</p> <ul style="list-style-type: none"> • Implement power factor correction devices to enhance system efficiency. <p>Smart Meters:</p> <ul style="list-style-type: none"> • Integrate smart meters for real-time monitoring and effective load management. 	<p>Energy Star-rated Appliances:</p> <ul style="list-style-type: none"> • Replace old appliances with Energy Star-rated models for improved efficiency. <p>Smart Appliances:</p> <ul style="list-style-type: none"> • Integrate smart technologies for automated control and energy optimization. <p>Load Management:</p> <ul style="list-style-type: none"> • Implement load shedding strategies to balance electricity demand during peak hours. 	<p>Power Factor Improvement:</p> <ul style="list-style-type: none"> • Enhance power factor through capacitor banks or other devices. <p>Energy Optimizer:</p> <ul style="list-style-type: none"> • Implement energy optimization solutions to ensure peak efficiency. <p>Harmonic Mitigation:</p> <ul style="list-style-type: none"> • Address harmonics in the electrical system to enhance stability and efficiency.

FIGURE 36 CHECKLIST OF ECMS

SEGREGATION OF MEASURES

NO-COST ECMs:

1. BEHAVIORAL CHANGES:

- Encourage occupants to adopt energy-conscious behavior, such as turning off lights and appliances when not in use.



FIGURE 37 ENCOURAGE ENERGY CONSCIOUS BEHAVIOUR

- Promote awareness campaigns on energy conservation and encourage responsible energy usage.



FIGURE 38 AWARENESS CAMPAIGNS FOR ENERGY CONSERVATION

2. OPTIMIZED SCHEDULING:

- Adjust operating hours of non-essential appliances based on occupancy patterns and usage requirements.
- Implement a schedule that aligns with peak and off-peak energy demand periods.

MID-COST ECMs:

1. VARIABLE FREQUENCY DRIVES (VFDs):



FIGURE 39 INSTALLING VFDs

- Integrate VFDs to regulate fan and pump speeds, optimizing energy consumption.
- Moderate upfront investment with considerable energy savings and improved control over HVAC systems.

2. ENERGY-EFFICIENT TRANSFORMERS:



FIGURE 40 REPLACING OLD TRANSFORMERS

- Replace outdated transformers with newer, more energy-efficient models.
- Moderate capital cost with long-term benefits in reduced energy losses and improved transformer efficiency.

3. POWER FACTOR CORRECTION DEVICES:



FIGURE 41 INSTALL POWER FACTOR CORRECTOR

- Implement power factor correction devices to enhance system efficiency.
- Moderate investment to improve power factor, resulting in reduced energy wastage and potential utility cost savings.

CAPITAL-INTENSIVE COST ECMs:

1. SMART METERS:



FIGURE 42 INTEGRATING SMART ENERGY METERS

- Integrate smart meters for real-time monitoring and effective load management.
- Considerable upfront investment, providing detailed insights into energy usage patterns for informed decision-making and long-term efficiency gains.

2. ENERGY STAR-RATED APPLIANCES:

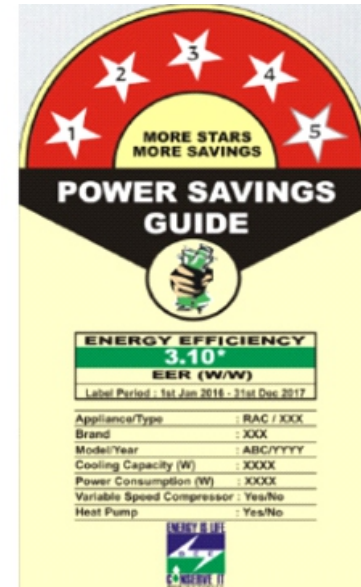


FIGURE 43 INSTALLING STAR RATED APPLIANCES

- Replace old appliances with Energy Star-rated models for improved efficiency.
- Capital-intensive due to the need to replace existing appliances, but significant energy savings and environmental benefits over their lifecycle.

3. SMART APPLIANCES:

- Integrate smart technologies for automated control and energy optimization.
- Higher initial cost, but the automation capabilities contribute to precise energy management, leading to long-term operational efficiency and energy savings.



FIGURE 44 INTEGRATE SMART CONTROLS AND AUTOMATION

4. LOAD MANAGEMENT:

- Implement load shedding strategies to balance electricity demand during peak hours.
- Capital-intensive due to the need for advanced control systems, but effective in reducing peak demand charges and improving overall grid stability.

5. POWER FACTOR IMPROVEMENT:

- Enhance power factor through capacitor banks or other devices.
- Capital-intensive upfront investment with long-term benefits in reduced reactive power demand, enhanced system efficiency, and potential utility cost savings.

6. ENERGY OPTIMIZER:

- Implement energy optimization solutions to ensure peak efficiency.
- Capital-intensive, but the advanced optimization capabilities contribute to significant energy savings and improved overall system performance.

7. HARMONIC MITIGATION:

- Address harmonics in the electrical system to enhance stability and efficiency.
- Capital-intensive due to the need for specialized equipment, but critical for ensuring the reliability of sensitive electronic equipment and improving power quality.

Part -III

Renewable Integration

Renewable energy, derived from natural and constantly replenished sources, plays a crucial role in sustainable development. Integrating renewable energy systems, such as solar panels, wind turbines, biomass energy, and geothermal energy, into buildings enables the generation of clean energy on-site.

This helps meet a portion of the building's energy needs while reducing reliance on conventional, non-renewable sources. Generating energy from renewable sources not only lowers energy costs but also helps reduce air pollution and carbon emissions. However, the availability of renewable energy can depend on time and weather conditions, which may affect energy generation.

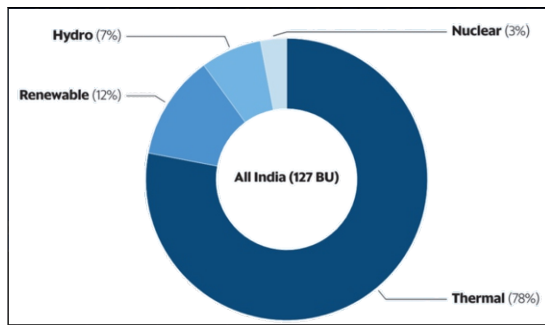
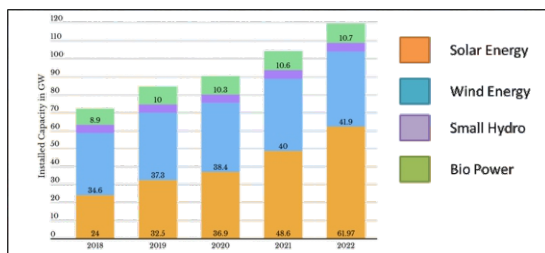


FIGURE 45 SOLAR, BIOMASS AND BAGASSE, WIND AND SMALL HYDRO CONSTITUTES RENEWABLE ENERGY



CHECKLIST OF ECMs FOR RENEWABLE ENERGY INTEGRATION

1. SOLAR ENERGY

Solar energy can be generated through photovoltaic (PV) panels and solar heaters, serving dual purposes: electricity generation and water heating. Photovoltaic panels convert sunlight into electricity, while solar water heaters use the sun's thermal energy to heat water. These systems provide efficient, renewable energy solutions that reduce dependency on traditional energy sources.

APPLICATIONS OF SOLAR ENERGY:

- **Heating:** Solar water heaters for domestic or commercial use.
- **Generating Electricity:** Solar PV systems to power electrical appliances and reduce grid dependency.

ENERGY CONSERVATION MEASURES:

- **Solar Photovoltaic Panels:** For electricity generation.
- **Solar Water Heating Systems:** For efficient water heating.
- **Energy-Efficient Lighting:** Using solar-powered lights to reduce energy consumption.

BUILDING INTEGRATED PHOTOVOLTAICS (BIPV):

Building integrated photovoltaics (BIPV) refers to the seamless incorporation of photovoltaic (PV) modules within the building envelope, including roofs, glazing, skylights, and shading devices. This integration not only generates clean electricity but also enhances the design of the building on physical,

environmental, and aesthetic levels, providing an energy-efficient and visually appealing solution.

Design Concept: The integration of PV modules can enhance a building's design by improving thermal performance, adding architectural value, and contributing to sustainable energy generation. BIPV systems can be creatively incorporated into various elements like facades and shading devices while maintaining the building's aesthetic integrity.

IMPLEMENTATION:

- **Seamless Integration:** Photovoltaic modules can be incorporated into the building's structure, reducing the need for additional mounting systems.
- **Multifunctional Benefits:** In addition to generating clean energy, BIPV systems can enhance the building's appearance and improve thermal insulation.
- **Financial Optimization:** Government incentives, subsidies, and regulations should be explored to maximize financial viability and ensure compliance with energy standards.

THUMB RULES FOR SOLAR PV INSTALLATION:

- **Area Required:** 10 m² per kW of installed capacity.
- **Energy Generation:** 3 to 4 kWh per day per kW of capacity.
- **Cost:** ₹ 70,000 to ₹ 1,00,000 per kW of installed capacity.

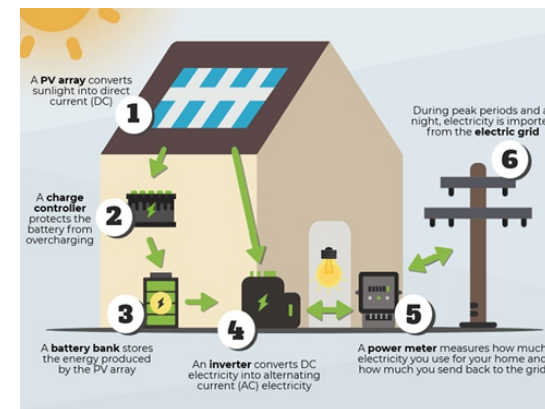


FIGURE 46 SOLAR PHOTO VOLTAIC

SOLAR LIGHTS SYSTEM:

Solar lighting systems provide an efficient and sustainable solution for lighting pathways, terraces, and other outdoor spaces, reducing the building's operational energy demand. These systems harness solar energy during the day, storing it in batteries for use at night, offering an eco-friendly and cost-effective alternative to conventional lighting.

IMPLEMENTATION AND MAINTENANCE

- **USAGE-BASED SELECTION:** Choose the type of solar lights that suit your needs, such as path lights for walkways, floodlights for larger areas, or wall-mounted lights for accent lighting.
- **Optimal Placement:** Install solar lights in locations with maximum sunlight exposure, ideally on south-facing surfaces, to ensure the solar panels receive enough energy for storage.
- **Maintenance Guidelines:** Regularly clean the solar panels to ensure they operate at maximum efficiency. Additionally, check the battery performance periodically to ensure reliable nighttime lighting.



FIGURE 47 Solar LIGHTING (RESIDENTIAL)

SOLAR COOKER:

Solar cookers harness solar energy to cook food, offering a clean and renewable alternative to traditional cooking methods. These cookers utilize the sun's rays to generate heat, making them an efficient solution in regions with abundant sunlight. Solar cookers come in various types, including box, panel, and parabolic designs, each offering unique advantages for different cooking needs.

KEY CONSIDERATIONS:

- **Fuel-Free Cooking:** Solar cookers eliminate the need for conventional fuels like firewood or LPG, reducing fuel costs and minimizing carbon emissions.
- **Environmental Benefits:** Utilizing solar energy for cooking helps decrease pollution and contributes to reducing global warming by cutting down greenhouse gas emissions.

ADVANTAGES OF SOLAR COOKERS:

- No fuel costs and minimal pollution.
- Long-lasting and low maintenance.
- Simple and safe to use for everyday cooking.



FIGURE 48 SOLAR COOKER

2. WIND ENERGY

Small-scale wind turbines can be installed on rooftops to generate and store electricity at a community scale, offering a decentralized and renewable energy solution. Wind energy generation primarily depends on wind speed, the area swept by the turbine blades, and air density, making location and environmental factors crucial for efficiency.

KEY CONSIDERATIONS:

- **Wind Speed:** Wind speed is the main determinant of energy generation efficiency. Ideal wind conditions for small-scale turbines range from 50 to 60 km/h, although a minimum speed of 12-14 km/h is required for basic operation. Maximum wind speeds should not exceed 90 km/h to avoid potential damage to the turbine.

THUMB RULES FOR SMALL-SCALE WIND TURBINES:

- **Minimum Wind Speed:** 12-14 km/h for basic energy generation.
- **Ideal Wind Speed:** 50-60 km/h for optimal energy output.
- **Maximum Wind Speed:** 90 km/h for safety and equipment protection.



FIGURE 49 ROOF TOP WIND TURBINE

3. BIOMASS

Biomass energy can be harnessed at a community scale by converting organic waste, such as food scraps and animal excreta, into biogas. This process not only reduces waste but also generates a renewable source of energy that can be used for cooking, electricity generation through combustion engines and pyrolysis, or as an alternative fuel like ethanol.

KEY CONSIDERATIONS:

- **Biomass Availability:** The production of biogas depends on the consistent availability of organic biomass, including food waste and animal excreta.
- **Versatile Uses:** Biogas can serve as a cooking fuel, while processed biomass can be used to generate electricity or produce alternative fuels, contributing to local energy independence.

THUMB RULES FOR BIOGAS PRODUCTION:

- **Biomass Requirement:** 20 to 30 kg of biomass is required to produce 1 kg of biogas.

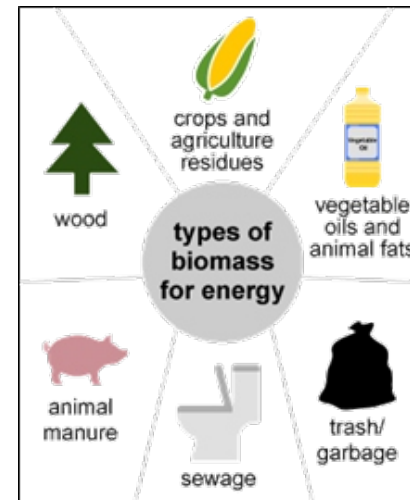


FIGURE 50 BIOMASS

4. Geo Thermal

Geothermal energy leverages the Earth's natural heat sink properties to provide passive space conditioning, offering both cooling and heating solutions. By tapping into the consistent temperatures below the Earth's surface, geothermal systems help maintain comfortable indoor conditions, making them an effective and sustainable choice for energy-efficient buildings.

KEY BENEFITS:

- **Efficient Temperature Control:** Geothermal systems utilize the stable temperatures of the Earth's subsurface to heat and cool buildings, reducing the need for conventional HVAC systems.

- **Energy Source:** This renewable energy comes from the Earth's core, where temperatures are extremely high, providing a reliable source for space conditioning.
- **Significant Energy Savings:** Geothermal systems can achieve up to 50% energy savings compared to traditional heating and cooling methods.
- **Cost-Effective and Reliable:** Geothermal energy is cost-effective, operates year-round, and maintains high capacity factors, making it a dependable solution for sustainable building design.

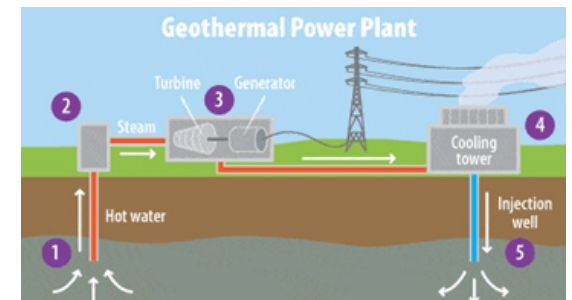


FIGURE 51 GEOTHERMAL POWER PLANT

5. OPERATION AND MAINTENANCE OF RE

- Ensure regular cleaning of solar PV panels to ensure maximum efficiency.
- Get an AMC for installed renewable energy system.
- Ensure cleaning of biogas plant such as removal of debris and organic matter.
- Checking for corrosion and worn out turbine blades.
- Checking and tightening bolts and electrical connections...

Case Studies

1. EXPANSION & MODIFICATION OF TERMINAL BUILDING AT JAMMU AIRPORT



Climate	Cold
Type	Commercial
Total carbon offset	6.82 tons/year (By planting native saplings & preserving existing trees)
Site Area	24,446 sq.m.
Built-up Area	14,500 sq.m.
Year of completion	2017
Client (Operation and Maintenance)	Airport Authority of India

A. PASSIVE DESIGN STRATEGIES

1. NATURAL VENTILATION

- Strategies to improve cross-ventilation were integrated.

2. BUILDING ENVELOPE OPTIMIZATION

- Shading strategies were introduced to reduce heat gain.
- 38% of the total site area has been shaded using soft paving, trees, and solar panels to mitigate the urban heat island effect.

3. FENESTRATION IMPROVEMENTS

- Window shading devices installed to reduce heat ingress.
- Improved daylight penetration to reduce artificial lighting demand.

B. ACTIVE DESIGN STRATEGIES

1. ENERGY-EFFICIENT LIGHTING UPGRADE

- Transitioned to energy-efficient lighting systems.
- Smart lighting controls and occupancy sensors installed to optimize energy usage.

2. HVAC SYSTEM OPTIMIZATION

- Existing HVAC system upgraded for better energy efficiency.
- Improved temperature control strategies to enhance operational efficiency.

3. SMART METERING AND MONITORING

- Installed a smart metering system to track real-time energy consumption.
- Implemented energy monitoring strategies to optimize consumption patterns.

4. WATER EFFICIENCY MEASURES

- Building water consumption reduced from 33,551.67 kL/annum to 13,321.98 kL/annum through efficiency upgrades.
- Landscape water consumption reduced from 7,385 kL/annum to 2,260 kL/annum.
- Installed a 200 kLD soil-biotechnology-based sewage treatment plant (STP) to improve water reuse.

5. ENHANCING HUMAN HEALTH & COMFORT

- Daylighting improved to create a healthier indoor environment.
- Provision of ramps, lifts with braille, dedicated parking, and toilets for differently abled persons to improve accessibility.

6. CARBON REDUCTION STRATEGIES

- 14% of total energy offset by renewable energy from an on-site solar photovoltaic system.
- 60.29% reduction in overall building water demand.
- Tree plantation drive conducted to further enhance carbon sequestration.

C. RENEWABLE ENERGY

1. **Solar Photovoltaic System Installed:** 300 kWp capacity
2. **Annual Renewable Energy Generation:** 4,33,469 kWh

D. ADDITIONAL SUSTAINABILITY INITIATIVES

1. **Environmental Awareness Campaigns:** Posters displayed in common areas to educate occupants.
2. **Smart Transportation:** Dedicated parking spaces for electric vehicles.

2. ADMIN BUILDING, KASHMIR UNIVERSITY, J&K (OFFICE)



Climate	Cold
Type	Commercial
Total carbon offset	6.82 tons/year (By planting native saplings & preserving existing trees)
Built-up Area	3,085 sq.m.
Np. of Floors	G+ 1
Award	B.E.E. Super 2022 Award

A. PASSIVE DESIGN STRATEGIES

1. BUILDING FORM AND FENESTRATION OPTIMIZATION

- The building is developed in two distinct blocks, based on security levels, and centered around a central atrium.
- The atrium serves as an "all-weather" space for gatherings, meetings, and temporary exhibitions.
- A fir tree at the center of the design enhances aesthetics and natural shading.
- The main entrance is defined using a glass partition, making it the warmest naturally lit space in the building.
- Linear corridors direct movement towards administrative and meeting functions, keeping service areas away from sunlight.

2. ENVELOPE AND CONSTRUCTION MATERIAL EFFICIENCY

• FACADE & WINDOWS DESIGN

- Ample daylighting achieved through an extensive glass

facade, reducing dependence on artificial lighting.

- Trombe walls integrated within service areas (pantries and toilets) to pre-heat air during winter, reducing heating loads.
- Trombe walls can be sealed off in summer to prevent overheating.

• CONSTRUCTION MATERIALS & TECHNOLOGY

- All toilet pipes (including drain pipes) are insulated to prevent freezing and cracking in winter.
- High-performance prismatic glass glazing optimizes solar gain:
 - ☞ Allows solar radiation in winter (when sunlight angles are low).
 - ☞ Blocks solar heat in summer, preventing overheating.
- Factory-fabricated steel structure used for:
 - ☞ Façade panels
 - ☞ Insulated roofing

☞ Beams and columns

B. ACTIVE DESIGN STRATEGIES

1. LIGHTING OPTIMIZATION

- Daylighting design reduces artificial lighting demand.
- High-efficiency lighting fixtures installed to minimize energy consumption.

2. HEATING SYSTEM EFFICIENCY

- Trombe wall-based passive heating significantly reduces reliance on conventional heating systems.

3. SMART METERING AND MONITORING

- Smart metering systems implemented to track and optimize energy performance.

4. WATER EFFICIENCY MEASURES

- Insulated piping systems prevent water loss due to freezing.

5. ENHANCING HUMAN HEALTH & COMFORT

- Atrium acts as a natural social and interaction space, improving user experience.
- Optimized daylight penetration enhances occupant well-being.

6. CARBON REDUCTION STRATEGIES

- Reduction in heating energy demand through passive solar techniques.
- Optimized glazing and insulation further reduce reliance on conventional energy sources.

3. PUBLIC LIBRARY, KARGIL, LADAKH



Climate	
Type	Commercial
Total carbon offset	6.82 tons/year (By planting native saplings & preserving existing trees)
Site area	362.72 sq.m.
Built-up Area	1743.37 sq.m.
Total No. of Floors	B+G+3
Energy Performance Index (EPI)	89.09 kWh/m ² /year
Total Renewable Energy Installed Capacity	154,910 kWh
Energy Savings	14.83%

A. PASSIVE DESIGN STRATEGIES

1. BUILDING FORM & FENESTRATION OPTIMIZATION

• ORIENTATION:

- The rectangular form with symmetrical elevations allows for windows on all sides, maximizing daylighting and natural ventilation.
- A central cutout with a skylight further enhances natural light penetration, reducing dependence on artificial lighting.
- The longer sides are oriented northwest-southeast, while the shorter sides face northeast-southwest, optimizing solar gain in winter.

- **VENTILATION:** Cross-ventilation enabled in all regularly occupied spaces, ensuring fresh air circulation and thermal comfort.

2. BUILDING ENVELOPE & CONSTRUCTION MATERIALS

• Building Envelope:

- Walls: Constructed with AAC blocks, rock wool insulation, and 12mm thick wooden panelling, ensuring high thermal performance and minimal heat loss during winter.
- Roof: Composed of RCC structure with exterior tiles, PUF insulation, and interior wooden panelling, providing protection against extreme cold and reducing indoor temperature fluctuations.

- **Construction Materials:** AAC blocks and wooden panelling are low-carbon materials, contributing to a lowered carbon footprint while maintaining energy efficiency.

B. ACTIVE DESIGN STRATEGIES

1. LIGHTING & ENERGY EFFICIENCY

- Maximized daylight penetration reduces the need for artificial lighting.
- Energy-efficient lighting fixtures installed to optimize power consumption.

2. HVAC OPTIMIZATION

- Highly insulated building envelope reduces heating demand, minimizing the need for mechanical heating systems.

3. SMART METERING AND MONITORING

- Energy monitoring system integrated to track and regulate power usage efficiently.

C. RENEWABLE ENERGY

- **Roof-top solar photovoltaic system:** 14 kWp capacity
- **Annual energy generation:** 22,778 kWh/year
- **Grid dependency reduced by:** 14% energy savings.



Bureau of Energy Efficiency

BEE is statutory body under the Ministry of Power. It assists in developing policies and strategies with the primary objective of reducing energy intensity of the Indian economy. BEE co-ordinates with designated consumers, designated agencies and other organizations to identify and utilize the existing resources and infrastructure performing the functions assigned to it under the Energy Conservation Act.

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KNOWLEDGE PARTNERS

