GUIDELINES FOR ENERGY EFFICIENCY AND ENERGY CONSERVATION

COMMERCIAL SECTOR

MAURITIUS

MAY 2025

Energy Efficiency Management Office

This page is intentionally left blank.

GUIDELINES FOR ENERGY EFFICIENCY AND ENERGY CONSERVATION

COMMERCIAL SECTOR

MAURITIUS

MAY 2025

Energy Efficiency Management Office

Suggested Citation:

Energy Efficiency Management Office (2025). Guidelines for Energy Efficiency and Energy Conservation Guideline for Commercial Sector. Mauritius.

Disclaimer:

All the information in this report has been put together by the authors from public sources, reports of various institutions, and correspondence with different government ministries and departments, multilateral and bilateral agencies. All references are given where taken from public sources. However, the authors do not guarantee the accuracy, adequacy or completeness of any information and are not responsible for errors or omissions or for the results obtained from the use of such information in this report. The EEMO accepts no liability for the content of this document, or for the consequences of any action taken on the basis of the information provided.

Consultants and Development Team:

Deloitte

Organization:

The Energy Efficiency Management Office (EEMO) was established in 2011 under the Energy Efficiency Act 2011 and operates as a department of the Ministry of Energy and Public Utilities. As provided in the Energy Efficiency Act, the objectives of the EEMO are to (i) Promote the efficient use of energy; and (ii) Promote national awareness for the efficient use of energy as a means to reduce carbon emissions and protect the environment.

FOREWORD

The Commercial Sector, primarily the Services Sector comprising financial services, retail trade and professional services, by virtue of its contribution to employment (43.4%) and GDP (46.7%), stands as a major pillar of our economy. As per the Energy and Water Statistics 2023, the Commercial and Distributive Trade Sector has a significant energy footprint, consuming approximately 113.9 ktoe annually - accounting for 11.8% of the nation's total final energy consumption and a remarkable 37.5% of all electricity generated in 2023.

Office buildings, retail outlets, data centres and cold storage facilities together contribute substantially to national peak demand and overall grid load. As the largest electricity-consuming sector and the fourth-largest energy-consuming sector overall, commercial energy use has a direct bearing on our energy security and wide-ranging implications for national development.

Government is committed to achieving a successful transition to a low-carbon economy. In this context, the Commercial Sector has a pivotal role to play. It presents some of the most promising opportunities for cost-effective energy savings through investments in efficient systems, smart technologies, and behavioural changes that promote sustainable consumption.

Energy efficiency is not only the most cost-effective but also the most immediate solution to reduce operational costs. It also creates space for a greater integration of renewable energy sources, thereby reinforcing our energy security and supporting national efforts to reduce greenhouse gas emissions.

The Energy Efficiency and Energy Conservation Guidelines for the Commercial Sector have been developed to support this national transition. These guidelines offer a practical and structured roadmap for building owners, facility managers, consultants, auditors to design, retrofit and operate commercial buildings with energy performance in mind. Drawing upon international best practices while being tailored to the local context, they aim to cultivate a culture of energy efficiency that is measurable, verifiable, and scalable.

I extend my appreciation to the Energy Efficiency Management Office (EEMO) and the consultant, Deloitte, for their dedication and professionalism in producing this important report. I also urge all stakeholders, across both the public and private sectors, to engage deeply with the content of this document and apply its recommendations with commitment and purpose.

Energy efficiency is not only about cost savings - it is about investing in a more sustainable, competitive and resilient Mauritius for generations to come.

Hon. Patrick Gervais ASSIRVADEN

Minister of Energy and Public Utilities

This page is intentionally left blank.

SUMMARY

The commercial sector of Mauritius is one of main pillar of country's economy and a key driver for inclusive socio-economic development, significantly contributing to the country's economic growth. In 2023, this sector accounted for 64.9 % of GDP[1] and consumed 37.5 % of the total electricity generated[2], highlighting the urgent need to review energy use in this sector to optimise energy efficiency and to identify decarbonisation initiatives. As part of its climate actions, the Mauritius government has set ambitious energy efficiency targets, including a 10 % improvement in energy efficiency by 2030, related to 2019 levels[3]. These targets are part of country's Nationally Determined Contributions (NDCs), focusing on reducing greenhouse gas (GHG) emissions and enhancing resilience in key sectors such as buildings and infrastructure.

Mauritius has enacted key regulations on energy efficiency and energy conservation, however the implementation of policies to promote energy efficiency needs to be strengthened. The energy efficiency and energy conservation guidelines prepared for commercial buildings sector is a key step for supporting implementation of energy efficiency.

The Energy Efficiency and Energy Conservation guidelines prepared by the Energy Efficiency Management Office (EEMO) under the Ministry of Energy and Public Utilities (MEPU) may serve as a reference guide and a complementary document to other national energy policies and may guide key stakeholders while adopting energy efficient technologies and solutions in new and existing commercial buildings across the country.

Purpose of Guidelines

This guideline is prepared to help policymakers, department officers and building professionals to better understand the basics of energy efficiency for commercial buildings in tropical climates. This guideline offers recommendations for various building types, including Wholesale & retail trade (Shopping complexes) , Storage (Cold storage), Information and communication (Offices), Financial and insurance activities (Financial services), Professional, scientific and technical activities (Office & pharmaceuticals), Education (Educational institutions), Human health and social work activities (Healthcare facilities), Arts, entertainment and recreation (Entertainment), aiming to achieve cost savings through optimisation of energy consumption and GHG emission reduction. The guideline outlines how building owners, management, and facility staff can enhance energy performance by implementing energy efficiency measures.

The guideline is structured to provide a clear, actionable framework for the efficient use of energy across various building systems and operational practices. The key attributes of the guideline are:

- The guideline emphasizes the importance of energy efficiency and conservation in commercial buildings, aiming to reduce environmental impact and enhance energy management practices. It provides actionable steps for improving energy performance, thus contributing to both economic and environmental sustainability in Mauritius.

[1] Statista, Mauritius: Share of economic sectors in gross domestic product (GDP) from 2013 to 2023.
[2] Statistics Mauritius (2024). Economic and Social Indicators - Energy and Water Statistics. Issue No. 1791. Ministry of Finance, Economic Planning and Development, Port Louis.
[3] Nationally Determined Contribution of the republic of Mauritius (2021)

- The guideline covers all aspects of energy efficiency, including strategies for the design, and optimization of HVAC systems, lighting, building envelopes, equipment, and appliances. It also integrates smart energy management, ensuring commercial buildings in Mauritius are prepared for future energy challenges.
- The guideline outlines critical steps for implementing energy management practices in commercial buildings, including roles and responsibilities of energy management team and steps for data collection to begin with.
- The guideline provides detailed instructions of benchmarking of any building's energy efficiency and steps to conduct a benchmarking assessment to compare their performance with similar facilities, helping to identify areas for improvement.
- The guideline provides detailed instructions for conducting energy audits, including site inspections, identifying inefficiencies, estimating energy savings, and preparing action plans. It highlights key Energy Conservation Measures (ECMs) such as optimizing building orientation, using energy-efficient materials, optimizing lighting, improving HVAC systems, and leveraging Internet of Things-based smart technologies for better performance and energy savings.
- The guideline includes cost-benefit analysis tools such as Simple Payback Calculators and Life Cycle Cost analyses, allowing building owners and managers to evaluate the financial viability of implementing ECMs. This ensures informed decision-making about investments in energy efficiency improvements.
- The guideline emphasizes the importance of proper building commissioning and Measurement & Verification (M&V) and explain the process for verifying that energy-saving measures are working as expected. The guideline provides a clear M&V plan and methodologies to ensure that the energy performance of buildings is continually optimized.
- The guideline includes a structured approach for energy planning, with clear steps for goal setting, implementation, and progress evaluation. The role of various stakeholders in the energy planning process is also outlined, ensuring collaborative efforts toward energy efficiency.

Additionally, this guideline is an important step in supporting implementation of current regulations and policies on energy efficiency by encouraging stakeholder engagement through awareness-raising, clarifying technical aspects of energy-saving measures, and providing resources for capacity-building and operational checklists.

In conclusion, the Energy Efficiency and Energy Conservation Guideline provides a roadmap for improving energy performance in commercial buildings across Mauritius. By implementing the strategies outlined in the document, commercial buildings may be able to optimise their energy consumption, lower operational costs, and comply with local energy regulations. These actions will contribute to Mauritius' broader sustainability objectives, promote green building practices, and ensure long-term energy security.

This document provides guidance regarding energy performance index, potential energy conservation measures (for select building typologies) and other aspects, which may require an update in future due to advancement of technology in building construction and appliances, introduction (or amendment) of any building related regulations (for example: building codes) and other relevant factors. Therefore, these guidelines are planned to be updated periodically to capture mentioned updates. For latest version of energy efficiency guidelines for commercial buildings please refer EEMO website.

Applicability of the Guideline

This energy efficiency guideline for commercial and public buildings is a practical handbook with relevant recommendations for new and existing commercial and public buildings to achieve significant cost savings by improving efficiency of energy use. The guideline provides inputs about how building owners, building management and Operation & Maintenance (O&M) staff may improve energy performance and reduce operating costs of the building.

The proposed measures also include energy conservation initiatives that requires minimal or no initial investment. Such initiatives include smart technologies and low-cost solutions for building envelope, cooling (Air-conditioning and refrigeration), appliances and lighting systems. Additionally, the guidelines encourage stakeholder participation by raising awareness, clarifying the technical relevance of energy-saving measures, and offering resources for capacity-building trainings and operational checklists.

The guidelines are applicable for both new and existing commercial buildings, covering the following sub-categories mentioned in Table 1:

Table 1: Commercial Building Sub-Categories Applicable for Guidelines

Building sub-categories	Building Subcategories terminology used in guidelines	Description
Wholesale & retail trade	Shopping Complex	This category focuses on the centres dedicated to wholesale and retail trade, featuring stores and outlets for various products. It includes supermarkets, distributors, as well as different types of service providers (such as office equipment, consumer goods, paint, etc.)
Storage	Cold Storage	This category includes facilities designed for the storage of perishable goods, typically maintained at controlled temperatures. For example, cold rooms for seafood products, storage of vegetables and consumer foods.
Information and communication	Office	The category covers spaces used for communication-related work such as IT services, administrative tasks, and collaboration. It includes companies with highest employed people such as call centres.
Financial and insurance activities	Financial service sector	This category includes buildings used for financial activities, including banking, insurance, and investment-related services.
Professional, scientific and technical activities	Office, Pharmaceuticals	This category comprises both office spaces such as consultancy, IT sector, public relations, communication, and advertising along with facilities for pharmaceutical research, development, and technical such as laboratories.
Education	Educational Institution	This category includes buildings like schools, colleges, and universities focused on education and learning environments.
Human health and social work activities	Healthcare	This category comprises of facilities providing health services, including hospitals, private clinics, and wellness centres for medical care.
Arts, entertainment and recreation	Entertainment	This category focus on the spaces dedicated to recreation and leisure activities such as casinos, conference halls and cinemas, and gaming zones.

Structure of the Guideline

The guideline is divided into certain chapters which are briefly explained below:

01 **Introduction** covers the overview of the rationale, of developing the energy efficiency and energy conservation guidelines for commercial sector along with their aim and objectives, while highlighting the importance and benefits of energy efficiency and conservation and their alignment with national goals such as NDC targets and Sustainable Development Goals.

02 **Energy Efficiency and Energy Management Implementation in Commercial Buildings** provides the step-by-step process for energy management implementation in new and existing commercial buildings, such as data collection, conduction of energy audits, recommendations of ECMs, cost benefit analysis, commissioning, and establishment of M&V process.

03 **Benchmarking of Commercial building** focuses on the need for and benefits of establishing a benchmarking process, outlining the approach and methodology, and identifying a building's energy performance as expressed by the Energy Utilisation Index (EUI).

04 **Energy Audit in Commercial building** focuses on the basics of energy audit, different types of audits, steps of walk-through energy audits followed by the data collection template and walk-through energy audit checklist.

05 **Guidelines for Identification of Energy Conservation Measures in Commercial Buildings** provides the list of energy conservation measures (ECMs) considering different categories including site measures, building envelope, lighting measures, comfort systems and controls, equipment, and appliances with due consideration to energy efficiency improvement through advanced/ IoT based smart technologies.

06 **Cost Benefit Analysis** defines the methodology to calculate the simple payback period, life cycle cost analysis and its related parameters to evaluate the energy cost saving. It also provides a simple payback calculator.

07 **Building Commissioning, and Measurement & Verification Plan)** provides the basic of building commissioning and its process, post-implementation assessment of energy conservation measures i.e., various M&V options and plan along with their approach and process.

08 **Energy Planning Ledger and Checklist** provides the overview of the energy planning process and key steps involved based upon the building energy use statistics along with energy management checklist to establish opportunities for energy efficiency in buildings as well as the role of stakeholders in the energy planning process.

References provide the list of reference documents and links used to develop the guidelines.

Annexure provides Case studies, Energy audit checklist, Energy planning ledger and additional water saving measures for commercial buildings.

TABLE OF CONTENTS

CHAPTER - 6

CHAPTER - 7

CHAPTER - 8

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AAC	Autoclaved Aerated Concrete
AC	Air Conditioner
AFRC	Australian Fenestration Rating Council
AFUE	Annual Fuel Utilization Efficiency
AHU	Air Handling Unit
AMCA	Air Movement and Control Association
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	Building Automation System
BUA	Built up Area
BAU	Business-as-usual
BAMS	Building Automation and System
BCA	Building and Construction Authority
BEE	Bureau of Energy Efficiency
CFLs	Compact Fluorescent Lamps
CFM	cubic feet per minute
CF	Commercial Refrigeration
COP	Coefficient of Performance
CSPF	Cooling Seasonal Performance Factor
DR	Demand Response
EC	Energy Conservation
ECBC	Energy Conservation Building Code
ECM	Energy Conservation Measure
EEMO	Energy Efficiency Management Office
EE	Energy Efficiency
EER	Energy Efficiency Ratio
EESL	Energy Efficiency Services Limited
EDGE	Excellence in Design for Greater Efficiencies
EIS	Energy Information System
EPA	Environmental Protection Agency
EPEAT	Electronic Product Environmental Assessment Tool
EPC	Energy Performance Contract
EPI	Energy Performance Index
EPS	Expanded Polystyrene
ETC	ETC Solar Heat Pump Hybrid
EU	European Union

EUI	Energy Use Intensity
FDD	Fault Detection and Diagnosis
FUE	Fuel Utilization Efficiency
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
kVA	Kilovolt-Ampere
kW	Kilowatt
LBNL	Lawrence Berkeley National Laboratory
LCC	Life Cycle Cost
LED	Light Emitting Diode
Low-E	Low Emissivity
LPD	Lighting Power Density
M&V	Measurement & Verification
MEPS	Minimum Energy Performance Standards
MEPU	Ministry of Energy and Public Utilities
MERV	Minimum Efficiency Reporting Value
MUR	Mauritian Rupee
NDC	National Determined Contributions
NEMA	National Electrical Manufacturers Association
O&M	Operations and Maintenance
PC	Personal Computer
Pes	Percentage energy savings
PVC	Polyvinyl Chloride
SDGs	Sustainable Development Goals
SHGC	Solar Heat Gain Coefficient
SRI	Solar Reflectance Index
sqm	Square Meter
TJ	Terajoule
TR	Ton of Refrigeration

TV	Televisions
UMC	Uniform Mechanical Code
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UPVC	Unplasticized Polyvinyl Chloride
UPS	Uninterruptible Power Supply
VAV	Variable Air Volume
VFDs	Variable Frequency Drives
VLT	Visual Light Transmission
VRF	Variable Refrigerant Flow
VSD	Variable Speed Drives
VVVF	variable voltage variable frequency
WERS	Window Energy Rating Scheme
WWR	Window-to-Wall Ratio

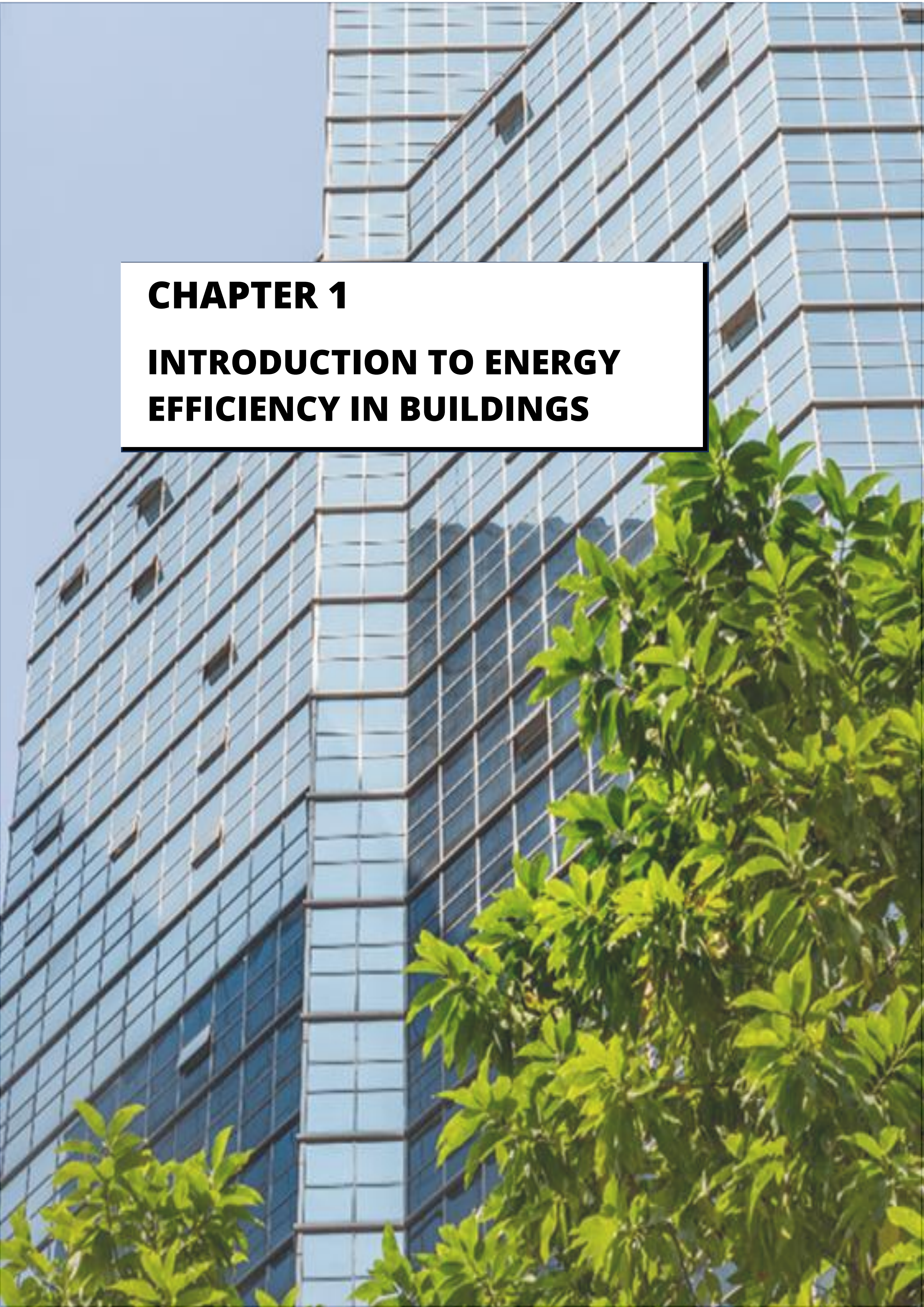
DEFINITIONS

Terms	Definitions
ACC Blocks	Autoclaved Aerated Concrete (AAC) block is a low-maintenance precast building material with excellent thermal insulation and durability. The heat-insulating properties of AAC blocks keep the building cooler and prevent outside heat from entering, resulting in significant savings on air conditioning costs.
Built-up area (BUA)	Sum of the covered areas of all floors of a building, other than the roof, and areas covered by external walls and parapet on these floors.
Building Envelope	The exterior and semi-exterior portions of a building, that separates the interior of a building from the exterior environment, such as walls, roof, window, floor, etc.
Connected load	The sum of the rated wattage of all equipment, appliances, and devices to be installed in the building or building complexes, in terms of kilowatt (kW) that will be allocated to all applicants for electric power consumption. Demand factor is the ratio of the sum of the maximum demand of a system to the total connected load and is always less than one.
Contract demand	The maximum demand in kilo Volt Ampere (kVA) agreed to be supplied by the electricity provider or utility in the agreement executed between the user and the utility.
Cooling Seasonal Performance Factor (CSPF)	It refers to the ratio of the total annual amount of heat that the equipment can remove from the indoor air when operated for cooling in active mode to the total annual amount of energy consumed by the equipment during the same period.
Cool roof	Roof with top layer of material that has high solar reflectance and high thermal emittance properties, typically light-colored to reject heat.
Correlated Color Temperature	It is a measure of how yellow or blue the color of light emitted from a light bulb appears. It is measured in the Kelvin unit and the lower the number, the warmer the white light appears, while a higher Kelvin will appear cooler.
DG sets	Diesel generators are diesel fuel based prime mover which convert mechanical energy to electrical energy
Energy Performance Ratio (EER)	The ratio of net cooling capacity in kW to the total rate of electric inputs in Watts under design conditions.
Energy Use Intensity (EUI)	EUI is used to measure the energy efficiency of a building. It expresses the amount of energy consumed by a building relative to its size, typically in terms of energy per square meter per year.
Fenestration	All areas (including frames) in the building envelope that let in light, such as windows, skylights, clerestories, and glass doors. Includes skylight and vertical fenestration classifications.
Fly Ash Blocks	These are made by mixing fly ash (a waste product from coal-fired power plants), cement, and water, and then compressing the mixture into molds. They are a cost-effective and eco-friendly alternative to traditional clay bricks and are commonly used for load-bearing structures.

Terms	Definitions
Gross Floor Area	The Gross Floor Area is the total floor area, as measured from the principal exterior surfaces of the enclosing fixed walls. It is the sum of all the building’s property uses reported on the application, and it should represent the whole building, excluding the basement areas
Illuminance	It is the measure of the amount of light (luminous flux) falling on a surface area. Its unit is lux (lx) = Lumen per square meter.
Lighting Power Density (LPD)	Maximum lighting power per unit area of a space or building, based on its function or classification.
Lumen	The lumen is the unit of luminous flux, measuring the total light output of a lamp.
Luminaires	A complete lighting unit including a lamp or lamps with the housing, which distributes, positions, protects the lamps, and connects them to power.
Luminous efficacy	It is a measure of how well a light source produces visible light. It is basically the ratio of luminous flux to power, measured in Lumens/Watt.
Luminous flux	Luminous flux refers to the total amount of light emitted by a light source, and the most common unit of measurement for luminous flux is the lumen (lm).
Lux	It is the metric unit of measure for illuminance of a surface. One lux is equal to one lumen per square meter.
Process load	Building loads from energy consumption or release due to industrial or other non-HVAC/non-lighting processes.
Solar Heat Gain Coefficient (SHGC)	The ratio of solar heat gain entering through fenestration to incident solar radiation, including transmitted and re-radiated heat.
Solar Reflectance Index (SRI)	A measure (0 to 100) of a material's ability to reflect solar heat, where 0 is black and 100 is white.
Color Rendering Index (CRI)	A quantitative measure of a light source's ability to accurately reproduce object colors compared to a reference light source.
Thermal resistance (R-value)	A measure of a material's resistance to heat flow; higher values indicate better insulation.
Thermal transmittance (U-value)	The rate of heat transfer through a material under steady-state conditions, expressed in W/m^2K. Lower values mean better insulation.
Visible Light Transmission (VLT)	Measures the percentage of visible light that passes through a material, influencing visibility and daylight access.
Window Wall Ratio (WWR)	The ratio of vertical fenestration area to gross exterior wall area. Gross exterior wall area is measured horizontally from the exterior surface; it is measured vertically from the top of the floor to the bottom of the roof.

CHAPTER 1

INTRODUCTION TO ENERGY EFFICIENCY IN BUILDINGS



CHAPTER 1

INTRODUCTION TO ENERGY EFFICIENCY IN BUILDINGS

This chapter covers the overview of the rationale, of developing the energy efficiency and energy conservation guidelines for commercial sector along with their aim and objectives, while highlighting the importance and benefits of energy efficiency and conservation and their alignment with national goals such as NDC targets and Sustainable Development Goals.

Mauritius is a subtropical country composed of a group of Islands, situated in the south-western part of the Indian ocean, just over 1,130 km east of Madagascar, off the south-eastern coast of Africa. The economy of the country is largely driven by the service sector, which account for about 64.9 % of the GDP, while industry sector accounts for 18.5 % of the GDP respectively[4]. With its diversified economy, Mauritius has a significant need for energy, which is largely reliant on fossil fuels. In 2023, fossil fuels accounted for approximately 82% of the energy used electricity production, highlighting the country's heavy dependence on imported sources of fossil fuel. There has not been a significant increase in the contribution of renewable energy, contributing to approximately 18 % of the total electricity generation share of the country in 2023[5].

As a small island developing state, Mauritius is vulnerable to the impacts of climate change and faces significant energy challenges due to its dependence on fossil fuels. To address these issues, the Mauritian government has set ambitious energy efficiency targets, as outlined in the 2021-2022 budget, including a 10 % improvement in energy efficiency by 2030, related to 2019 levels[6]. These targets are closely linked to the country’s Nationally Determined Contributions (NDCs), which prioritize reducing greenhouse gas (GHG) emissions and enhancing resilience across key sectors, including buildings and infrastructure. They aim to achieve this by promoting energy conservation and efficiency measures to strengthen energy security and sustain efforts against climate change.

1.1 Importance of Energy Efficiency and Energy Conservation

Energy efficiency and conservation are essential for optimizing energy use and GHG emission, while ensuring sustainable economic growth. Adopting energy-efficient technologies and practices in Mauritius can optimize energy demand, leading to reduced operational costs and enhanced energy security by decreasing reliance on imported fuels. These measures not only support climate resilience but also promote healthier and more sustainable living environments. In addition, energy efficiency and conservation drive innovation, create job opportunities, and contribute to achieving global sustainability goals, particularly in sectors like buildings and infrastructure.

Energy efficiency and energy conservation in buildings play a crucial role in achieving national energy strategy targets by providing several benefits illustrated in Figure 1:

[4] Statista, Mauritius: Share of economic sectors in gross domestic product (GDP) from 2013 to 2023.
[5] Ministry of Energy and Public Utilities (2024). Annual Report 2023-24. https://publicutilities.govmu.org/.
[6] Advancing Energy Efficiency in Mauritius: A Collaborative Effort for Sustainable Urban Development (2024). UNEPCCC.

Promote national security	Reduce dependency on imported fossil fuels	Reduce energy consumption	Substantial cost savings on utility bills
Lower carbon footprints	Improved indoor environment and thermal comfort	Better occupant comfort and health	Economic growth and job creation

Figure 1: Benefits of Energy Efficiency and Energy Conservation in Buildings

1.2 Energy Efficiency in Commercial Buildings for Mauritius

The commercial sector is one of the main pillars of the economy of Mauritius and a key driver of inclusive socio-economic development, significantly contributing to the economic growth of the country. Over the years, this sector has witnessed sustained growth and accounted for 64.9% of GDP in 2023[7], consuming 37.5% of the total electricity generated[8], which highlights urgent need to reduce energy consumption in the commercial sector. Below Figure 2 illustrates the significant evolution of electricity consumption in the sector over the past 10 years in Mauritius[9]:

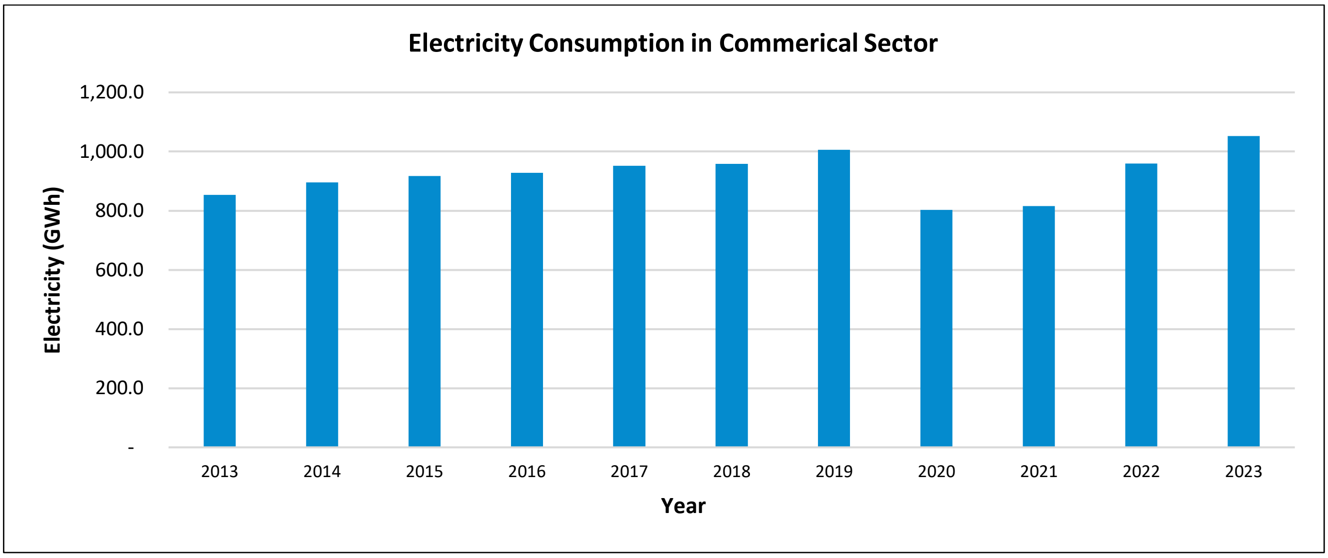


Figure 2: Evolution of electricity consumption in the commercial sector in Mauritius

The country's NDC goals emphasizes the integration of energy efficiency and energy conservation criteria into building codes to lower energy consumption. There is a focus on training architects and stakeholders to design energy-efficient and sustainable infrastructure that aligns with climate resilience goals[10]. The efforts to improve energy efficiency in buildings directly support Mauritius's NDC commitments and advance the Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action), which helps strengthen its path toward a more sustainable and energy-resilient future.

[7] Statista, Mauritius: Share of economic sectors in gross domestic product (GDP) from 2013 to 2023.
[8] Statistics Mauritius (2024). Economic and Social Indicators - Energy and Water Statistics. Issue No. 1791. Ministry of Finance, Economic Planning and Development, Port Louis.
[9] Ibid
[10] Update of the Nationally Determined Contribution of The Republic of Mauritius, 2021

Synergy between Energy Efficiency and Carbon Emission Mitigation

Improving energy efficiency in buildings is a critical strategy for reducing carbon emissions. In Mauritius, where a significant portion of energy is generated from fossil fuels, buildings are major contributors to the national carbon footprint due to their high energy consumption. Enhancing energy performance, particularly in commercial buildings, directly reduces the demand for carbon-intensive energy sources, leading to measurable emission reductions.

Energy-efficient buildings also present a strategic opportunity to benefit from carbon credit mechanisms. A carbon credit represents the reduction of one metric ton of carbon dioxide (CO_2) emissions and can be traded or used to offset emissions. Implementation of certified energy-saving measures and registering them under approved carbon credit programs, building developers and owners can earn credits for verified emission reductions.

These carbon credits can be sold in carbon markets or retained to offset the entity's own emissions, providing both environmental and financial returns. Furthermore, participation in carbon credit programs aligns projects with national and international sustainability goals, enhances the building's environmental profile, and may unlock additional economic advantages.

1.3 Status of Legal and Regulatory Frameworks for Mauritius

Mauritius has established a robust legal and regulatory framework to promote energy efficiency, ensuring sustainable energy use and contributing to climate resilience. The Ministry of Energy and Public Utilities (MEPU) is the main apex body, with an objective to highlight the initiatives in energy in the domestic, industrial, transport and services sector in view of sensitizing and creating a synergy around an effective management of energy, and establishment of a responsible legal framework to govern the development of these sectors. The existing legal and regulatory framework in the country are explained below:

Energy Efficiency Act 2011

- The act promotes energy audits, sets minimum energy performance standards, and regulates energy labeling for appliances and equipment. It also emphasizes capacity-building, awareness campaigns, and the integration of energy efficiency measures across sectors.

Energy Efficiency (Energy Consumer and Energy Audit) Regulations 2017

- The regulation classify an energy consumer based on its average annual energy consumption and made it mandatory for large energy consumers to have at least level 2 energy audit conducted (as per ISO: 50002 standard) by a certified energy auditor/ auditing firm registered with EEMO.

Energy Efficiency (Registration of Energy Auditors) Regulations 2016 (amended in 2019 and 2021)

- The regulation outlines the schedule/ forms for the application for registration as energy auditor/ energy auditing firm with EEMO, list of certification bodies and registration fees.

Energy Efficiency (Labelling of Regulated Machinery) Regulations 2017 (amended in 2018, 2022 and 2023)

- The regulation defines the energy efficiency standards and labeling of domestic appliances like refrigerators, dish washers, electric ovens, TVs, ACs, etc.

Energy Efficiency (Minimum Energy Performance Standards for Regulated Machinery) Regulations 2025

- The regulation defines the minimum performance value for air-conditioners. It defines that importer and local manufacturer must be register with EEMO and comply with the MEPS specified in the regulation.

Mauritius has enacted key regulations on energy efficiency and energy conservation, however the implementation of policies to promote energy efficiency needs to be strengthened, a critical step to promote energy conservation practices, particularly within the commercial building sector. Below Figure 3 provides a comprehensive summary linking energy efficiency guideline to key energy efficiency regulations in Mauritius:

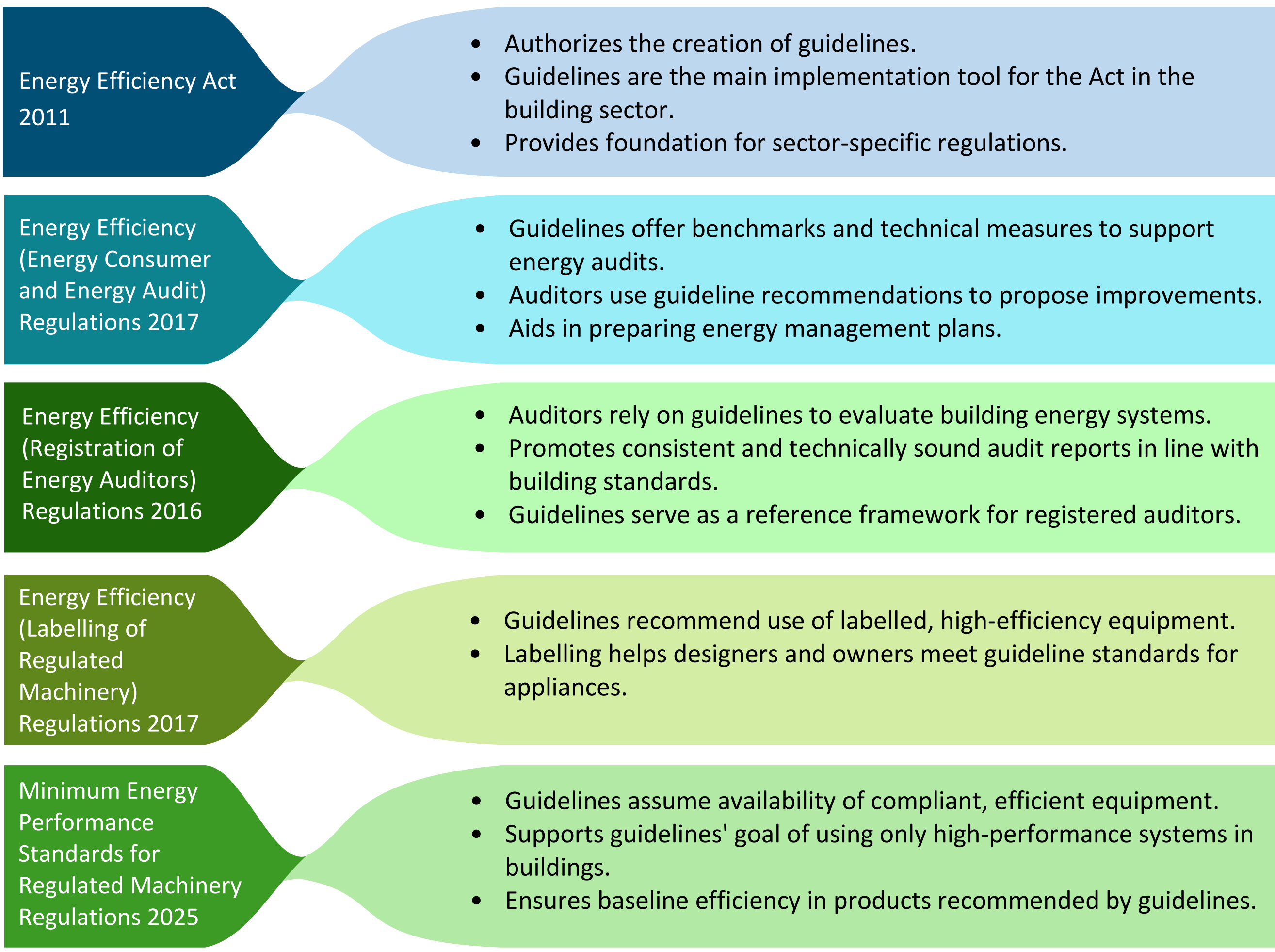


Figure 3: Linkage between energy efficiency guideline and regulatory frameworks

1.4 Need for Energy Efficiency and Energy Conservation Guidelines

Recognizing the urgent need for energy efficient and sustainable solutions, the Mauritian government has initiated several key initiatives across various sectors including buildings. These include updated national determined contributions (NDCs), energy efficiency act, energy efficiency regulation 2016 and 2017 and other important energy efficiency and energy conservation programs.

The UNEP Copenhagen Climate Centre, in collaboration with the Energy Efficiency Management Office (EEMO) of Mauritius, is driving efforts to implement energy efficiency measures in the country's building sector to meet the national target of 10% improvement in energy efficiency by 2030[11]. Furthermore, as part of mitigation actions, there is a critical need to establish monitoring procedures for energy efficiency and consumption, with the goal of reducing electricity usage in public institutions by at least 5%[12].

This guideline is an important step in supporting implementation of current regulations and policies on energy efficiency by encouraging stakeholder engagement through awareness-raising, clarifying technical aspects of energy-saving measures, and providing resources for capacity-building and operational checklists.

[11] UNEPCCC (202). Advancing Energy Efficiency in Mauritius: A Collaborative Effort for Sustainable Urban Development
[12] Ministry of Environment, Solid waste Management and Climate Change (2024). Mauritius first biennial transparency report

CHAPTER 2

ENERGY EFFICIENCY AND ENERGY MANAGEMENT IMPLEMENTATION IN COMMERCIAL BUILDINGS

CHAPTER 2

ENERGY EFFICIENCY AND ENERGY MANAGEMENT IMPLEMENTATION IN COMMERCIAL BUILDINGS

This chapter covers the energy management implementation in commercial buildings though critical steps such as data collection, conduction of energy audits, recommendations of ECMs, cost benefit analysis, commissioning, and establishment of M&V process.

2.1 Critical Steps to Implement Energy Management Practices in Buildings

Before investing in energy efficiency improvements, it is crucial to assess whether the process will yield positive benefits for both the organization and the building. Effective energy management and enhancement of existing commercial and public buildings require implementing the steps outlined in the following Figure 4:

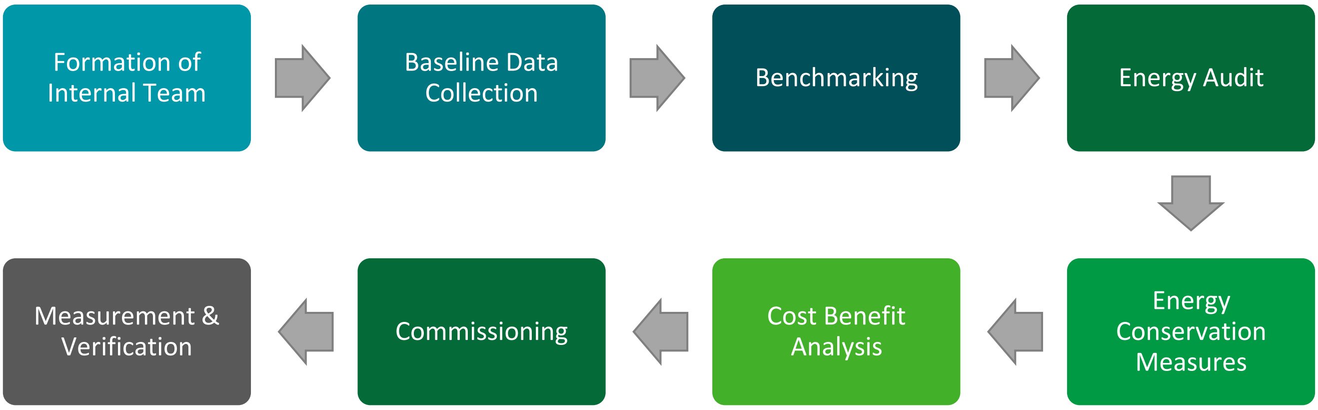


Figure 4: Steps for Implementing Energy Efficiency in Commercial Buildings

2.1.1 Formation of Internal Team

The formation of an internal team is a critical first step in managing energy efficiency in commercial buildings. This team typically representatives from top-level management, building management, facilities operations, maintenance team and energy experts. In the team, the roles and responsibilities of each team personnel should be clearly defined to ensure that energy management becomes a priority, and any individual is not overloaded in day-to-day operations of the building.

The roles and responsibilities of team members are explained in the Table 2 below:

Table 2: Roles and responsibilities of team members

Team members	Roles	Responsibility
Top level management	Provides leadership, sets energy efficiency goals, and allocates resources	• Set clear energy efficiency goals and integrate them into the organization's overall business strategy. • Develop and enforce energy efficiency policies and procedures across the organization. • Advocate for energy-saving initiatives and sustainability at the executive level. • Collaborate with stakeholders to identify new energy-saving opportunities and secure incentives or rebates.
Energy Manager	Oversees the energy efficiency initiatives and ensures that energy management practices are followed across the facility.	• Develop and implement energy management strategies. • Set goals for energy reduction and track performance. • Ensure compliance with energy-related regulations and standards. • Lead energy audits and assess areas for improvement. • Report on energy performance to senior management or stakeholders.
Energy auditor	Conducts energy audits to identify inefficiencies and recommend improvements	• Assess building systems (HVAC, lighting, insulation, etc.) for energy performance. • Identify areas where energy is wasted or used inefficiently. • Provide actionable recommendations for improvements and upgrades. • Analyze and report findings from energy audits to guide decisions.
Facility manager and operator	Oversees daily operations of the facility and ensures integration of energy efficiency into overall management practices.	• Coordinate energy efficiency efforts with other facility management duties. • Ensure that building staff follows energy-saving protocols. • Act as a liaison between the energy team and senior management. • Address any operational challenges that may impact energy performance.
O&M Staff	Ensures the proper functioning of building systems and equipment to support energy efficiency goals.	• Maintain and repair energy-consuming systems like HVAC, lighting, and water heating. • Implement energy-efficient technologies and upgrades. • Ensure equipment operates according to energy-saving protocols. • Monitor and troubleshoot system performance to prevent energy wastage.
Financial Specialist	Manages budgets, funding, and financial aspects of energy efficiency projects	• Analyze the cost-effectiveness of proposed energy-saving measures. • Explore and secure funding, grants, or incentives for energy efficiency projects. • Track financial savings generated by energy improvements. • Prepare cost-benefit analyses for potential energy upgrades.
Project Manager (for Energy Efficiency Projects)	Manages specific energy efficiency projects from conception to implementation.	• Plan, execute, and oversee energy efficiency projects like HVAC upgrades or lighting retrofits. • Ensure that projects meet timelines, budgets, and performance goals. • Coordinate with contractors, vendors, and the energy team. • Monitor the success of implemented measures and resolve any challenges.

Effective energy management in any facility requires a collaborative approach, where the energy efficiency team works closely with other departments to integrate energy-saving practices throughout the building. The following cross-functional responsibilities mentioned in the Figure 5 highlight the importance of collaboration, continuous improvement, and innovation within an energy management framework:

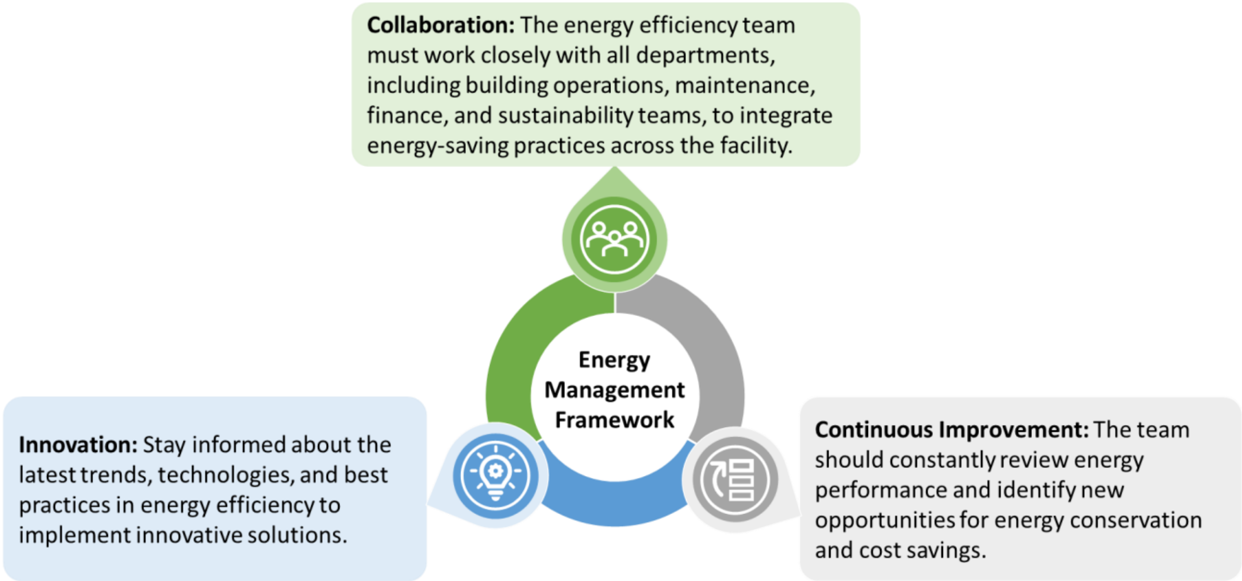


Figure 5: Cross-functional responsibilities of energy management framework

2.1.2 Baseline Data Collection

The next step is to gather preliminary data related to the building and its energy consumption. This data is a key requirement for energy audit process, can be collected using a walk-through data collection template. Preliminary data collection helps establish an energy baseline, serving as a reference point to measure the impact of energy efficiency initiatives. This baseline enables monitoring and evaluation of EE measures, ensuring their effectiveness in reducing energy consumption over time.

A simplified formula for energy saving calculation is represented below:

$$\begin{pmatrix}\text{Energy}\\ \text{Savings}\\ \textbf{kWh}\end{pmatrix} = \begin{pmatrix}\text{Baseline Energy}\\ \text{Consumption}\\ \textbf{kWh}\end{pmatrix} - \begin{pmatrix}\text{Actual Energy}\\ \text{Consumption}\\ \textbf{kWh}\end{pmatrix}$$

A preliminary data collection template is presented in the below Table 3:

Table 3: Preliminary Building Data Collection Template

No.	Details		Data /Value
1	Type of building		
2	Year of building construction		
3	Numbers of floors in the building		
4	Area of the building (exclude parking, lawn area, roads, etc.)	Total built up area (sqm)	
		Carpet area (sqm)	
		Conditioned area (sqm)	
		Unconditioned area (sqm)	
5	Total number of employees		
6	Average number of employees present at a time in office		
7	Working hours		
8	Working days per week		
9	Connected load (kW)		
10	Contract demand (kVA)		
11	Peak demand or Maximum demand indicated (kW)		
12	Installed capacity of Diesel Generator Sets (kVA of kW)		
13	Installed lighting load (kW)		
14	Equipment load (kW)		
15	Installed capacity of HVAC system (BTU)		
16	Type of HVAC system		
17	Annual electricity consumption from Utilities (kWh)		
18	Annual electricity consumption from DG sets (kWh)		
19	Annual electricity cost purchased from Utilities (MUR)		
20	Annual electricity cost generated through DG sets (MUR)		
21	Whether sub-metering of electricity consumption for Air Conditioning, Lighting, Plug Loads, etc. done: Yes/No		
22	High Speed Diesel (or any other fuel oil used, specify)/Diesel/Gas Consumption in DG/GG Sets (cubic meters) in the year		
23	Fuel (e. g. Fuel Oil, Light Diesel Oil, Liquid Petroleum Gas, Natural Gas) consumption for generating steam/water heating in the year		
24	Water consumption in building (cubic meters per year)		
25	Estimated hot water consumption (cubic meters per year)		

2.1.3 Benchmarking

Benchmarking is the process of analysing the energy performance of a commercial building and comparing it to similar buildings within the same climate and operational category. Energy consumption levels vary based on building type, size, occupancy, and function. Therefore, commercial buildings are typically classified by floor area, occupancy levels, and operational usage (e.g., office buildings, shopping malls, hotels, or mixed-use developments).

Facility managers can calculate building energy consumption and assess how their building performs relative to others with similar characteristics. If a building's energy consumption is higher than the industry average, it indicates an opportunity for energy efficiency improvements. Benchmarking helps identify present level of performance and helps prioritizes the implementation of ECMs to reduce operational costs and enhance sustainability.

Detailed benchmarking process is explained in **Chapter 3** of this guideline.

2.1.4 Energy Audit

An energy audit is a thorough assessment of a building's energy systems to understand energy usage pattern, evaluate performance of building envelope (and appliances), identify opportunities for energy conservation, and suggest improvements. It examines key components like HVAC systems, lighting, insulation, water heating, and overall building performance. The audit carefully analyzes the building's energy flow to identify areas of energy waste. For instance, it might uncover inefficient lighting or inefficiencies in HVAC systems that contribute to excessive energy consumption. The audit's findings form the foundation for creating a focused energy management plan, detailing specific measures to reduce energy use and enhance efficiency.

The type of energy audit and methodology for walk-through energy audit is explained in the **Chapter 4** of this guideline.

Further, the detailed energy audit checklist for energy audit and energy planning ledger checklist is provided in the subsequent sections of this guidelines.

2.1.5 Energy Conservation Measures

Energy Conservation Measures (ECMs) are the practical steps or strategies implemented to optimize energy consumption. After identifying inefficiencies during the audit, ECMs are put in place to address these issues. The goal of ECMs is to implement changes that may reduce energy use without compromising comfort or functionality. ECMs are often selected for their advantages or returns, and they helps achieve sustainable energy saving while improving the building overall environmental impact. The ECM can be broadly classified into below two options:

- **Low- or No-Cost Measures**: Simple actions such as optimizing HVAC settings, improving envelope insulation, and scheduling equipment maintenance can reduce energy consumption significantly without requiring major investments.
- **Technology Upgrades**: Replacing outdated appliances, lighting, and HVAC systems with energy-efficient alternatives may require capital investment but can lead to substantial energy savings. The typical payback period for such upgrades ranges from **2 to 5 years**, depending on the building type and the ECMs implemented.

ECM's to be implemented in the commercial building of Mauritius is discussed in the **Chapter 5** of this guideline.

Some of the proven case studies related to the implementation of the energy efficiency conservation measures are showcased in **Annexure-1.**

2.1.6 Cost-Benefit Analysis

After identifying long list of potential ECMs, it is important to evaluate the financial feasibility of these measures through a cost-benefit analysis. This analysis involves comparing the upfront costs (or investment) of implementing each measure to the anticipated energy and cost savings over time. For example, upgrading to LED lighting may require an initial investment, but the energy savings over the useful life of the bulbs will result in a positive return on investment. The cost-benefit analysis helps prioritize ECMs based on their financial viability, payback period, and the overall impact on energy savings.

A template for simple payback calculator is provided in the **Chapter 6** of this guideline.

The calculator will help user to estimate the return on investment and analyze the feasibility of the ECM.

2.1.7 Building Commissioning

Building commissioning is a process of verifying that newly implemented systems and energy-efficient measures are properly installed and functioning as intended. It involves ensuring that HVAC systems, lighting, insulation, and other energy-saving devices are performing optimally and delivering the expected energy and cost savings. Commissioning ensures that all equipment is calibrated, adjusted, and tested to meet the design specifications.

A building commissioning is very crucial because even the most efficient systems will underperform if they are not installed or maintained as per supplier standard operating procedure (SOP).

The basics of commissioning, process of commissioning, and details of M&V along with its different methods have been explained in **Chapter 7** of this guideline.

2.1.8 Measurement and Verification

Measurement and Verification (M&V) is a continuous process that tracks and evaluates the effectiveness of energy conservation measures. M&V helps confirm that the anticipated energy savings are being realized. By continuously monitoring energy consumption and comparing it to the baseline data collected earlier, building managers may assess whether the building's energy performance aligns with the goals set during the implementation of energy conservation measures. M&V also offers important insights to refine energy management strategies, ensuring long-term efficiency.

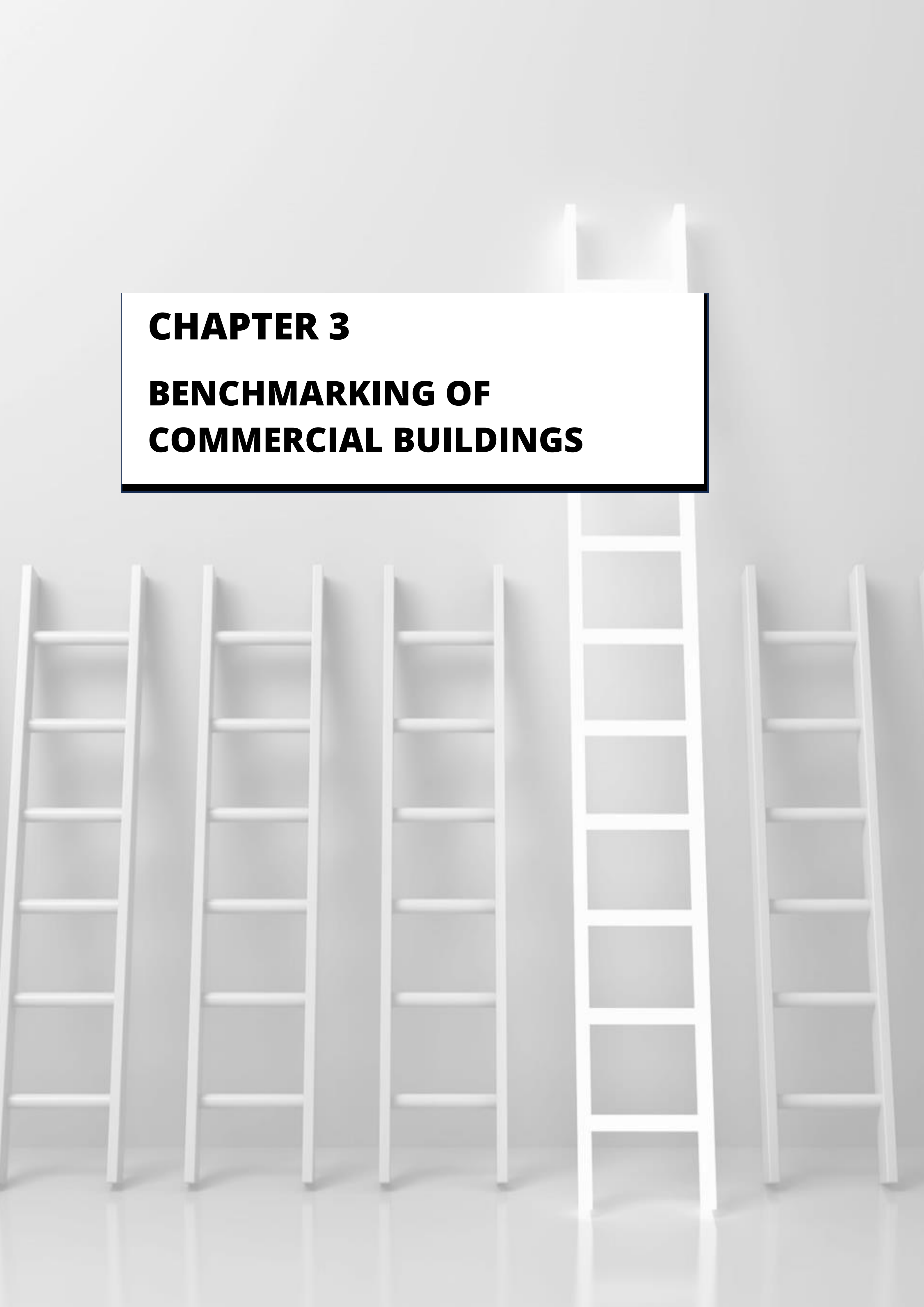
Summary

The successful implementation of energy efficiency and energy management practices in commercial buildings requires a systematic approach that integrates advanced technologies, data-driven strategies, and collaboration. Organizations may optimise energy consumption and operational costs by thorough energy audits and utilizing energy management systems for real-time monitoring.

The process of implementing energy efficiency in Commercial and buildings has been explained and simplified through this guidelines document, which also provides ready to use templates and checklists in the following **Chapters** and **Annexures**.

CHAPTER 3

BENCHMARKING OF COMMERCIAL BUILDINGS



CHAPTER 3

BENCHMARKING OF COMMERCIAL BUILDINGS

This chapter covers brief about energy benchmarking, provides detailed instructions of benchmarking of any building's energy efficiency and steps to conduct a benchmarking assessment to compare their performance with similar facilities, helping to identify areas for improvement.

3.1 Need for Benchmarking

Energy benchmarking is a process of evaluating and comparing the energy performance of commercial buildings against standardized metrics. This comparison helps identify areas for improvement and informs decisions to optimise overall building performance. As a fundamental aspect of effective energy management, energy benchmarking is required for the following reasons:

1. Establish Performance Standards
2. Identification of Operational Inefficiencies
3. Building Performance Monitoring and Evaluation
4. Cost Optimization and Resource Management
5. Comparative Performance Analysis
6. Optimization of Building Energy Performance

Hence, benchmarking is the first and most critical step in defining energy efficiency for commercial buildings. Although Mauritius developed the Energy Efficiency Guidelines for hotels in 2021, which provide benchmarks for energy consumption in kWh/m^2 of serviced area for luxury service hotels only, and energy consumption benchmarks for commercial buildings were not included.

Considering Mauritius' predominant tropical rainforest climate with minimal climatic variations, it is essential to develop and implement benchmarking based on the different building types. This approach ensures that the unique characteristics and energy consumption patterns of various commercial building typologies are accurately represented, allowing for more effective and relevant energy efficiency standards.

3.2 Benchmarking of Commercial Building in Mauritius

The commercial sector is defined as non-manufacturing business establishments for the purpose of this guideline, and the sub-categories was considered as Shopping Complex, Cold Storage, Office, Banks, Data Centre and Laboratories, Educational Institutions, Healthcare, and Entertainment.

A survey for benchmarking exercise was carried out by Energy Efficiency Management Office[13] for sample commercial buildings on energy use and energy efficiency in the services sector. The survey results provide data for EUI per built area for different building typologies relevant for commercial sector. The EUI provided in the survey document is based on the data collected from an average of 10 existing commercial buildings. The established EUI for eight sub-categories of commercial buildings is shown in the Table 4 below:

Table 4: Established EUI for Benchmarking of Commercial Buildings

S. N.	Commercial building sub-categories	Energy Use Intensity (EUI) per built area (kWh/m²/year)
1	Shopping Complex	233.3
2	Cold Storage	203.1
3	Office	80.5
4	Banks	203.5
5	Data Centre and Laboratories	1308.6
6	Educational Institutions	23.2
7	Healthcare	93.7
8	Entertainment	118

Energy benchmarking for any building is a crucial tool for assessing and improving a building's energy performance. It helps identify inefficiencies, reduce operational costs, and enhance sustainability. The benchmarking should be updated periodically to consider new construction and energy efficiency measures. The following section elaborate on the approach that may be used to update the benchmarking values in future.

3.3 Approach for Benchmarking of Commercial Buildings

Different approaches can be used depending on the focus and the metrics to assess for building energy performance.

[13] Survey on Energy Use/Consumption and Energy Efficiency in the Services Sector (2019). Energy Efficiency Management Office (EEMO)

As per the EU energy performance in buildings, there are two major approaches for developing building energy benchmarks[14] are explained below in Figure 6:

Modelled Benchmarks

- These benchmarks are obtained using an energy simulation model to determine the performance of a building, typically at design or refurbishment stage.
- The energy model calculates the energy required based on the building's usage, indoor environment, climate, and its properties.
- This approach helps calculate the asset or design performance, which is later confirmed upon the building's completion, comparing the initial design with the actual outcomes, including the quality of installation, commissioning, and control systems.

Empirical Benchmarks

- These benchmarks are obtained from statistical data from detailed studies of 20-100 buildings. per sector.
- The minimum information required for benchmarking is how much energy has been used over the last year, which is best obtained from meter readings and energy bills. This majorly covers the operational performance of the building, and takes into account its actual efficiency, occupation, management, and fuel consumption.

Figure 6: Broad approaches for Benchmarking as per EU Energy Performance in Buildings

The empirical benchmarking approach is considered for benchmarking as it is highly relevant for the initial development and provides a data-driven method to establish performance standards and identify energy efficiency opportunities from the initial stage. The below statistical methodology presented in Figure 7 provides a step-by-step procedure to define the empirical benchmark for commercial buildings, covering all the required sub-categories:

1. Define Objective and Scope
2. Data Collection
3. Determine Benchmarking Metrics
4. Define Benchmarking Building
5. Comparison against Benchmarking

Figure 7: A five-step Methodology for Developing Benchmarking through Empirical Approach

Step 1. Define objectives and scope

The first step is to determine the specific objectives and scope of the benchmarking exercise. This could involve reducing energy costs, improving sustainability, or complying with regulations. The scope should include identifying the relevant building typologies along with building systems (HVAC, lighting, insulation, etc.) and areas (common areas, office spaces, etc.), which will be included in the assessment.

[14] EU Energy Performance in Buildings - Directive Implementation Advisory Group: Methodologies in support of the Energy Performance of Buildings Directive: The UK approach to implementation for buildings other than dwellings.

Step 2. Data collection

Developing an appropriate and robust benchmarking process depends upon accurate, consistently measured, and verifiable data that will enable performance and progress to be measured, monitored, and managed. The following is a suggested data collection process for building surveys:

Establish support for data collection process

- Letter from relevant government agency to provide support and credibility to the data collection process

Preparation of data collection questionnaire

- A comprehensive questionnaire should be designed to gather essential data parameters for calculating EUI of various building types.
- The questions are customized to be practical and answerable by building users, relying on commonly accessible data. Key terms should be clearly defined to ensure clarity and consistency.

Define sampling design

- The data collection should be based on a good sample design ensuring maximum coverage in terms of location, cities, urban-rural continuum, building types, and subtypes.
- It should try to cover the maximum variation in key parameters covering the entire range of key parameters, such as built-up area, gross floor area, annual energy consumption (kWh), etc.

Develop survey methodology

- The online and offline survey should be done with real time checking to ensure data quality.
- The surveyors should be familiarized with the technical contents and should have a knowledge to see discrepancies in collected data.

Regularized data collection activity

- The data collection exercise should be repeated often and at least every four years.
- Repeat data collection to control for variations in weather, which directly affect the performance label.

Verification of collected data

- The quality of the data should be verified by a third-party consultant.
- The relevant agency should have ownership rights of data and ensure full privacy of data collected.

A sample questionnaire form for data collection for benchmarking is provided in the **Annexure-2.**

Step 3. Determine Benchmarking Metrics

Choose the appropriate benchmarking metrics based on the building type, purpose, and location. Common metrics include Energy Use Intensity (EUI), Energy performance Index (EPI), Energy Star Score, etc. For Mauritius, EUI has been selected as appropriate benchmarking metrics.

Energy Use Intensity: Energy benchmarking for buildings is normally expressed in Energy Use Intensity (EUI) and is helpful in comparing the energy performance of similar buildings. EUI is the key metric considered for energy efficiency benchmarking of commercial buildings in Mauritius due to its ability to accurately measure energy consumption relative to building size, providing a standardized method for assessing performance.

EUI measures the total energy consumed in a building in a year, expressed as kilowatt hour (kWh) per gross floor area (m^2), and is calculated from the formula given below:

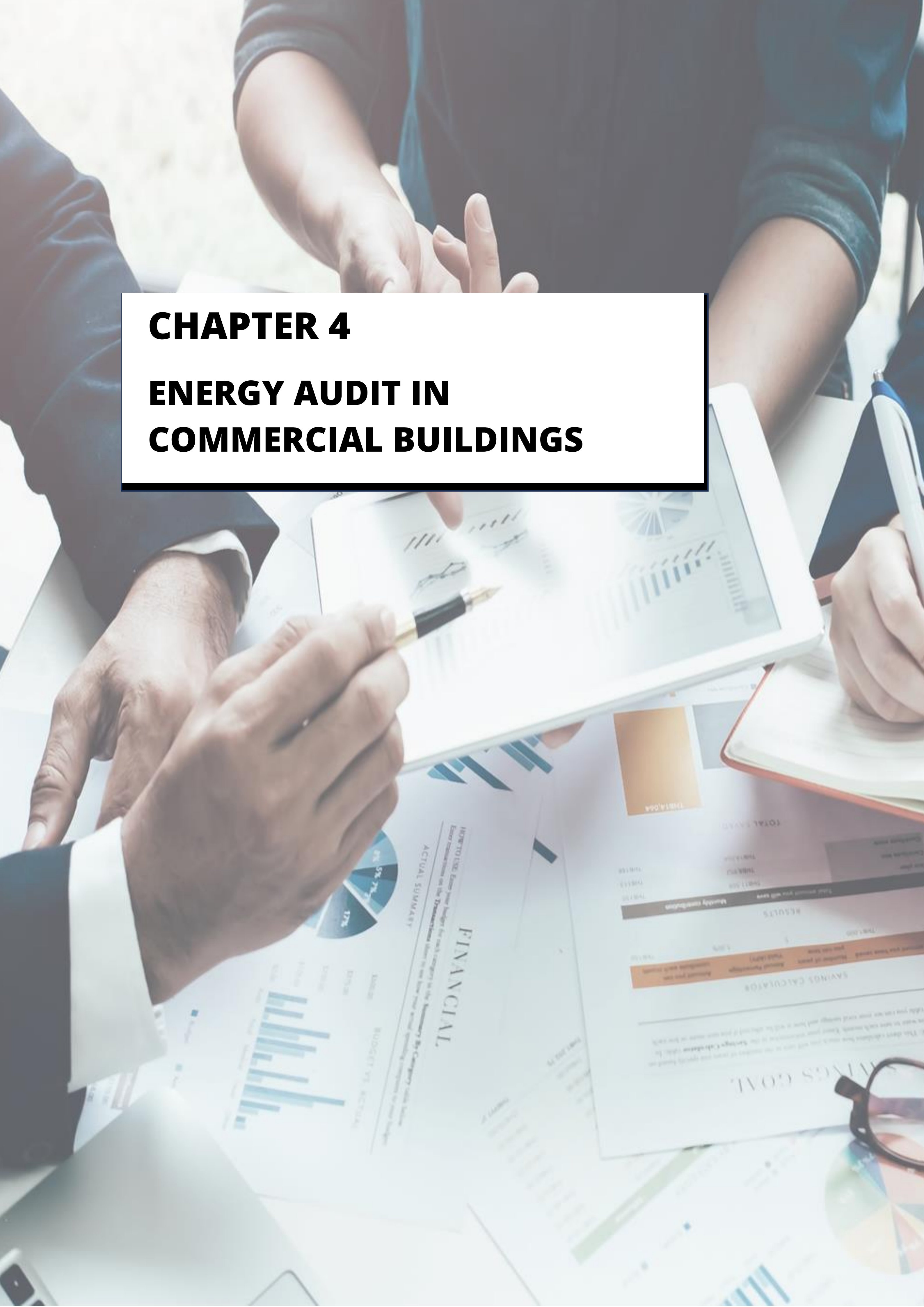
$$Energy\ Use\ Intensity\ (EUI) = \frac{Annual\ energy\ consumption\ of\ new\ building\ (kWh)}{Total\ gross\ floor\ area\ (m^2)}$$

Step 4. Define Benchmark Building

A benchmark building serves as a comparative reference point in energy performance assessments. It is a hypothetical model that represents a typical building with similar characteristics (such as climate zone, building category, area, operating characteristics and energy consumption pattern). This method helps compare how a similar building would perform in terms of energy usage and other important factors. Based on this analysis, improvement strategies are developed and implemented to enhance energy performance.

Step 5. Comparison against Benchmark

Once data is collected from step 2, calculate the EUI of building and compare it with the benchmark building defined in the Step 4 for the specific building sub-category. The data collected for building energy use and gross floor area will be used for determining the EUI. This information should be compared with other energy efficient buildings for achieving improved energy performance.



CHAPTER 4

ENERGY AUDIT IN COMMERCIAL BUILDINGS

CHAPTER 4

ENERGY AUDIT IN COMMERCIAL BUILDINGS

This chapter covers brief about basics of energy audit, how to identify opportunities for energy conservation and recommending strategies for energy conservation. An energy audit is essential for identifying energy saving opportunities in a building's energy systems and making informed decisions on its improvements.

4.1 Introduction of Energy Audit

An energy audit study aims to identify measures to optimize energy losses in a system through fine-tuning of operating parameters, retrofitting of the existing system (to operate it close to the design efficiency level), or through technology upgradation.

An energy audit is a systematic process of evaluating a building's energy use through inspection, survey, and analysis of actual energy flows/ use for the identification of energy saving opportunities. The goal of energy audit is to optimise energy consumption, lower utility costs, and minimize the environmental impact of a building's operations by optimizing energy systems and implementing energy-saving measures.

The objectives of carrying out energy audit includes the following:

- Improve energy performance and minimize the environmental impacts of building operations.
- Gain a greater understanding of building's energy usage patterns.
- Identify behavioral change opportunities by evaluating current operations and maintenance practices.
- Identifying technical opportunities by evaluating significant process energy-using components or utilities including boilers, refrigeration plant, ventilation systems, building performance and fleet efficiency.
- Provide clear financial information regarding energy savings opportunities to prioritize them for the buildings decision-making process.
- Identify potential for using renewable energy supply technologies.
- Inform a strategic plan aimed at minimizing the building's carbon footprint.

4.2 Types of Energy Audit

While there are multiple approaches to performing energy audits in the building, the widely accepted approach is defined by ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers). As per the procedure[15] defined by ASHRAE, a commercial building energy analysis can generally be classified into three types:

15 ASHRAE (2011). Procedure for commercial building energy audit (2011). ASHRAE Manual.

- **Level 1 energy audit** provides walk-through analysis of building recording observable sources of energy loss or deficiencies that may be corrected with no-cost or low-cost measures such as, replacing incandescent bulbs with LEDs, insulating ductwork, and pipeline, lowering hot water temperature, arresting compressor leakages etc.
- **Level 2 energy audit** entails a more detailed building survey and includes computer-generated energy modelling used to develop an energy action plan. Some of the systems and components analyzed in a level 2 audits are chillers, piping, pumps, ventilation controls, and insulation. The energy action plan in such audit outlines no/ low-cost measures that improve energy efficiency. The plan also recommends adjustments and basic capital improvements that can be made to major building systems, such as HVAC, electrical, and plumbing, to optimize their operational performance.
- **Level 3 energy audit** expands on the review and analysis of the building systems and components performed in level 1 and 2. In addition to listing no-cost and low-cost measures and minor adjustments to improve operating efficiency, the energy action plan in a Level 3 audit includes detailed recommendations for major capital improvements, such as plant upgrade, roof replacement, re-piping program, etc., that would provide the greatest measures of energy savings.

As a preliminary audit activity, the premises and the energy auditor shall establish the availability of data for the energy audit and determine whether the data are sufficient to enable more detailed type of audit. If additional measurement is required, the premises and the energy auditor should typically agree on the extent of required measurements before undertaking the audit. The level of energy audit as per Level 1, Level 2 and Level 3 is explained in Figure 8:

Level 1

Time required for Level 1 energy audit for Small-Medium building:
1 day on site
1 week report writing
For Large Building:
2 days on site
2 weeks report writing

Data collection: Facility energy data including sub-meters and daily load profiles.

Analysis: Energy use, equipment data to prepare preliminary energy balance and identify significant energy uses (SEUs).

Opportunity identification: Walk-through to visually inspect energy uses. Identify and quantify no/ low-cost measures.

Output: Identification and basic evaluation of no/low-cost measures.

Level 2

Time required for Level 2 energy audit for Small-Medium building:
1 week on site
2 weeks report writing
For Large Building:
2 weeks on site
4 weeks report writing

Data collection: Overall available energy data including daily load profiles.

Analysis: Analysis of current and historical energy data and detailed energy balance profile.

Opportunity identification: Specific and implementable EnPIs measures.

Output: Detailed understanding of energy consumption and use.

Level 3

Time required for Level 3 energy audit is determined by detail required or complexity of a sub-system

Data collection: Operating/ load profile of the site.

Analysis: Analysis of current and historical energy data and energy perf. indicators (EnPIs) at plant area and for SEUs.

Opportunity identification: Quantification of range of specific and implementable EnPIs including short, medium and long-term actions with energy savings.

Output: Detailed understanding of energy consumption and use.

Figure 8: Summary of Different types of Energy Audit

This guideline covers the checklist and data collection template for walk through energy audit, which is explained in the subsequent section.

4.3 Walk-through Energy Audit

A walk-through energy audit is a basic level of energy audit that involves a systematic visual inspection of a building/ facility to assess energy consumption, identify energy saving measures and accordingly recommend improvements. The walk-through energy audit methodology covers the following steps provided in Figure 9:

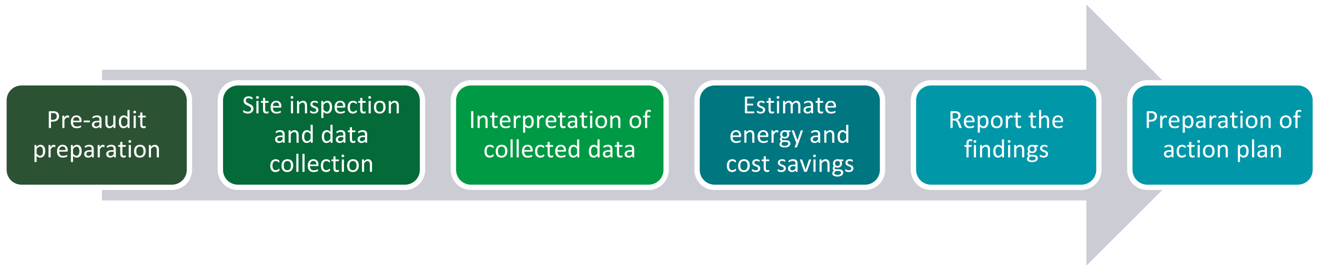


Figure 9: Methodology for Process of Walk-through Energy Audit

4.3.1 Pre-audit Preparation

The initial step in the energy audit is to define the purpose of the walkthrough audit, whether it is to optimize energy costs, improve energy efficiency, or comply with regulations. Before conducting the energy audit, preliminary data contains the information regarding building characteristics, building area, construction details, occupants etc., inventory of the equipment installed in the premises, energy and fuel consumption related data, utility bill records for a minimum period of one-year, operational knowledge such as heating and cooling practices, and equipment and systems in use and other information related to lighting controls, hot water usage, plug loads etc.

4.3.2 Site Inspection and Data Collection

This step involves physically inspecting the building and its systems to identify energy inefficiencies. Areas to focus on include Building envelope, Lighting systems, HVAC systems, Water heating, Equipment and appliances and occupant behavior. The data collection helps the user to understand how energy is used in the building with respect to energy-using systems, identify areas of energy wastage, provide the benchmark for managing the energy, and developing the energy baseline. The data collection template for walk through energy audit checklist covers below aspects and information provided in Figure 10:

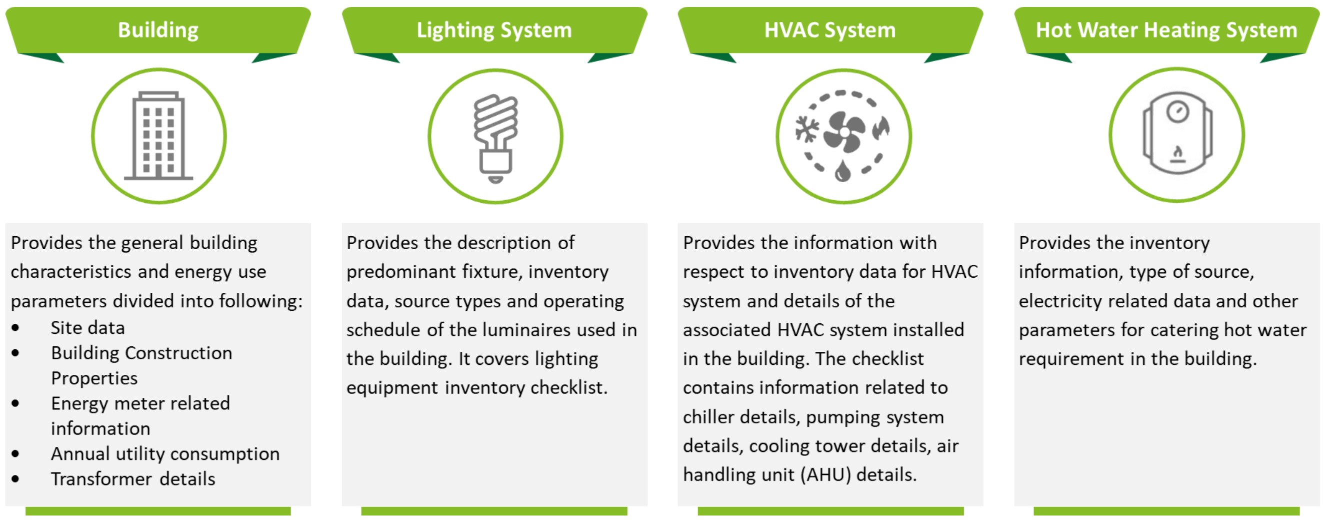


Figure 10: Summary of Information to be Collected during Site-visit

The detailed information covering the above categories have been explained in the preliminary walk-through energy audit data collection template, which is described in **Annexure-3** of this guideline**.**

4.3.3 Identify Inefficiencies and Interpretation of Collected Data

The data analysis in a walk-through energy audit involves preliminary analysis of energy use and performance of technical systems installed in the building. It helps energy auditors to assess how energy is used in the building, and help identifying the energy consumption patterns such as, peak usage times or areas with unusually high energy use. The key action points of collected data can be grouped together as:

Lighting waste: Identify lights that are operating (switched on) when not needed. Pay attention to the age of the bulbs-older, inefficient lighting systems can be easily replaced with LED lighting, which consumes significantly less energy.

HVAC in-efficiencies: Look for HVAC systems that are running when not required or poorly maintained, such as systems running in empty spaces. Check for inefficiencies like faulty thermostats, unsealed ducts, or poorly calibrated systems that may lead to energy waste.

Air leaks: Inspect windows, doors, and any gaps in the building's envelope. These leaks can lead to air infiltration, causing the HVAC systems to work harder than necessary. Drafty windows or poorly sealed doors should be noted for repair or upgrading.

Water heating waste: Hot water systems that are not well-maintained or that are set to unnecessarily high temperatures can waste a significant amount of energy. Leaking pipes or inefficient water heaters should be flagged for replacement or repair.

Inefficient equipment: Identify outdated office equipment, refrigerators, or appliances that consume excessive amounts of energy. Additionally, observe whether equipment is left on when not in use or is operating inefficiently.

Behavioral Issues: Sometimes, energy waste comes from human behavior, such as leaving lights on, failing to turn off equipment, or adjusting thermostats without consideration for energy efficiency. While these issues may not always be directly fixable through physical upgrades, addressing them through awareness programs and staff training can significantly reduce waste.

4.3.4 Estimate Energy and Cost Savings

Based on the findings during the walkthrough audit, a list of actionable recommendations (ECMs) aimed at reducing energy consumption should be prepared. After identifying the ECMs, the energy auditor calculates associated cost savings for each measure. These recommendations typically fall into short-term improvements, medium-term and long-term investments.

4.3.5 Report the Findings

Once the audit is complete, a report that summarizes the findings, energy waste observations, and recommended energy conservation measures including the cost benefit analysis should be prepared. The report clearly prioritizes each recommendation based on its potential impact on energy savings, ease of implementation, and cost.

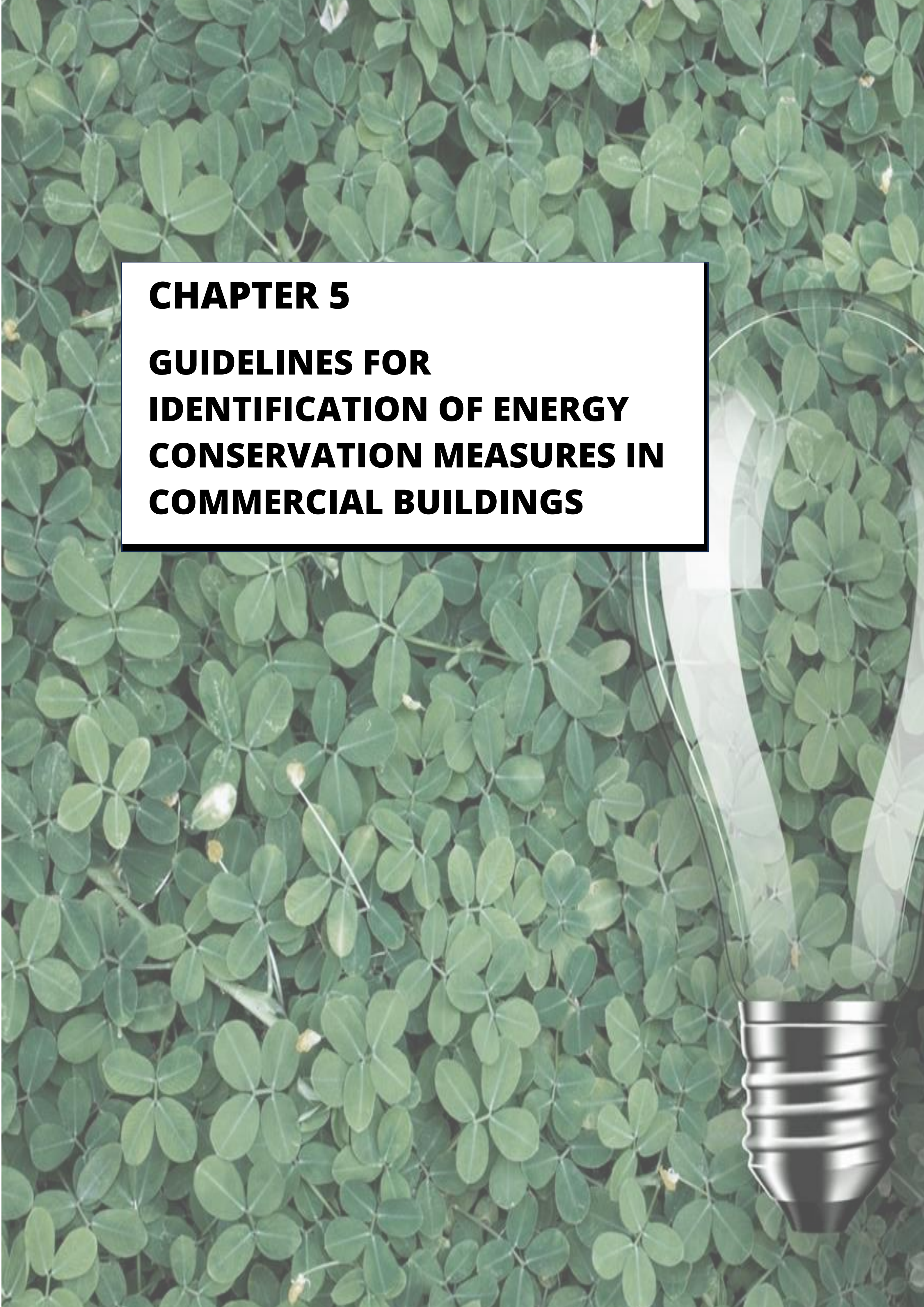
4.3.6 Preparation of Action Plan

After the findings and recommendations have been shared, it's important to create an actionable plan for implementing the suggested improvements. This action plan should be realistic, with clear timelines and assigned responsibilities. The action plan contains key actions as implementation timelines, budget considerations, roles and responsibilities, and schedule follow-ups.

!

The walk-through energy audit data collection template is designed to gather preliminary information about the building, which will support the subsequent detailed energy audit process. An energy audit checklist in spreadsheet format is provided with this guideline and includes detailed instructions for completing the required data fields.

A summary of the types of data included in the checklist is provided in **Annexure 3** of this guideline; however, users are advised to refer to the spreadsheet for the complete and detailed data collection template.



CHAPTER 5

GUIDELINES FOR IDENTIFICATION OF ENERGY CONSERVATION MEASURES IN COMMERCIAL BUILDINGS

CHAPTER 5

GUIDELINES FOR IDENTIFICATION OF ENERGY CONSERVATION MEASURES (ECM) IN COMMERCIAL BUILDINGS

This chapter provides the list of energy conservation measures (ECMs) considering different categories including site measures, building envelope, lighting measures, comfort systems and controls, equipment, and appliances with due consideration to energy efficiency improvement through advanced/ IoT based smart technologies.

Heating, Ventilation, and Air Conditioning (HVAC) systems are major energy consumers in commercial building, often accounting for 40% to 60% of total energy use. In regions like Mauritius, where cooling demand is high, HVAC systems can lead to significant energy waste if not optimized. Implementing Energy Conservation Measures (ECMs), such as upgrading insulation, using energy-efficient components, and improving control systems, can significantly reduce HVAC energy consumption. A generic breakdown of energy consumption for different appliances for commercial buildings is represented in the Figure 11 below[16]:

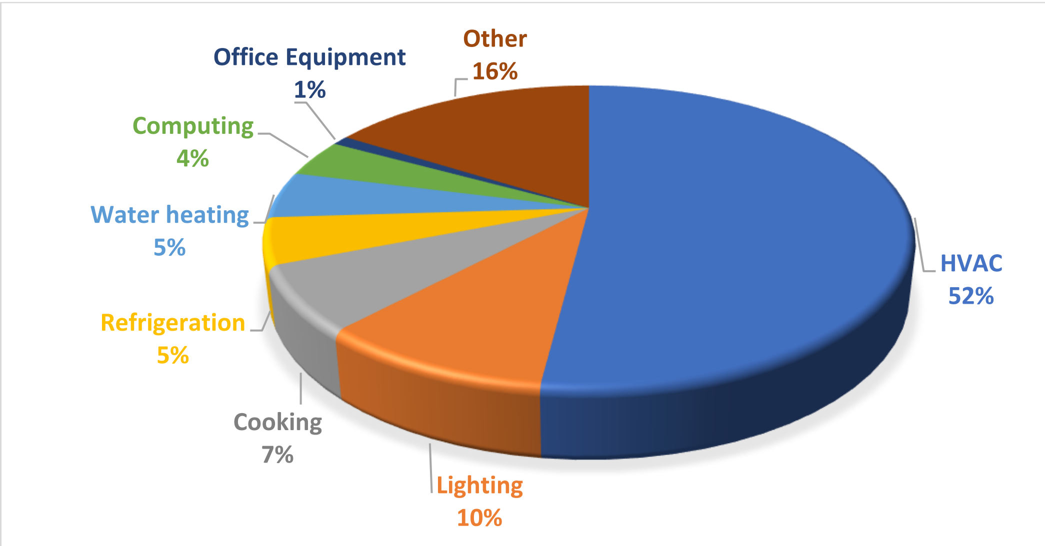


Figure 11: Share of Energy Consumption by Appliances in Commercial buildings

[16] U.S. Energy Information Administration, 2018, Source: https://www.eia.gov/energyexplained/use-of-energy/commercial-buildings.php

ECMs are the upgrades and retrofits that can be implemented on the buildings to improve energy efficiency of the building. General practice in retrofit projects is to evaluate and select energy conservation measures, ECMs, individually based on cost-benefit. Basis the building type and mechanical system used in Mauritius, a set of recommendations for ECMs are broadly divided into the following six categories:

Lighting Measures

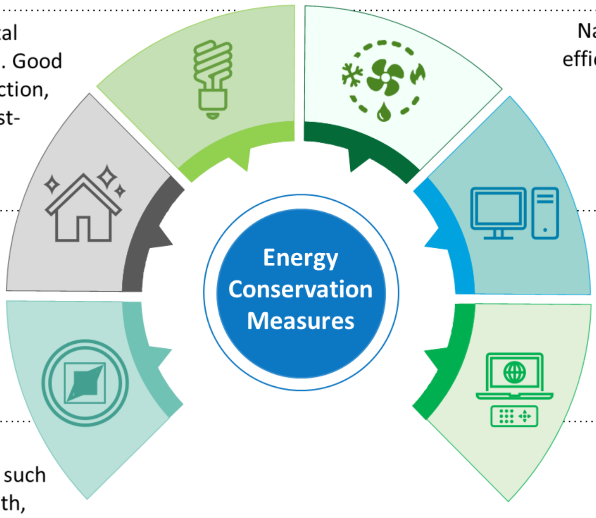
Lights are a significant part of the total energy use and demand in a building. Good electrical lighting design, fixture selection, and control are some of the most cost-effective ways to save energy

Envelope Measures

Increasing the envelope's thermal resistance to block unwanted heat loss and gain from the outside reduces the energy required for heating and cooling.

Site Measures

Adapting the building to the outdoor environment and climatic conditions such as orientation of the building, sun path, prevailing winds, and shape of the building.



Comfort Systems and Controls

Natural ventilation and use of energy-efficient HVAC equipment and controls.

Equipment and Appliances

Use of efficient office equipment, refrigeration, service hot water systems to reduce and optimize the building energy use.

IoT-based smart technologies

Use of smart lighting control, daylighting sensors, building automation systems and energy efficient appliances with IoT integration

The below sections define each energy conservation measure allocated to each subcategory and gives recommendations for each category to improve the energy efficiency of the building.

1. Site Measures

Category	Subcategory	Measure	Benefit
Site Measures	Building orientation and layout	Longer side towards North-South	Reduces direct exposure to the harsh afternoon sun, minimizing heat gain
		Prevailing wind direction	Facilitates efficient ventilation and reducing cooling demand
	Building form	Open and elongated shape with shallow rooms	Provides more cross ventilation, suitable for tropical rainforest climate
		Raised foundation	Mitigate the risk of flooding
		Sloped Roofs	Facilitate the rapid drainage of rainwater, thereby preventing moisture buildup and leaks

2. Building Envelope Measures

Building Envelope Measures

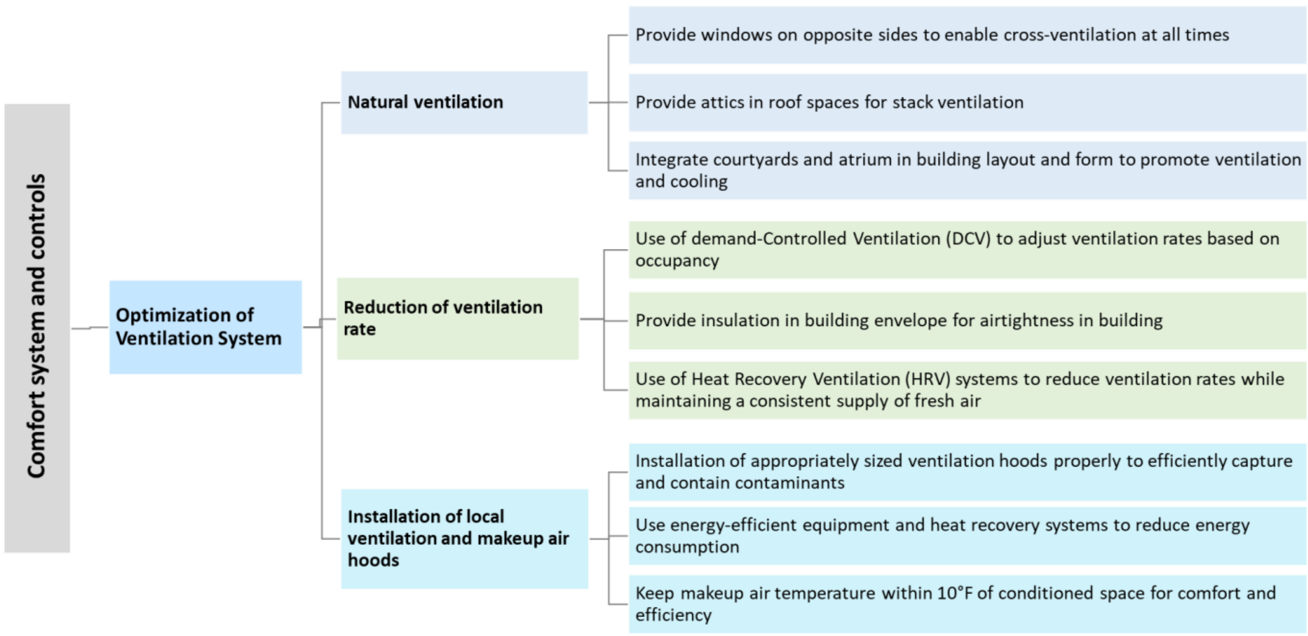
- **Walls**
  - **Use of Building Materials with High Thermal Mass** — U-value reduction with use of efficient building material
  - **Provision of Insulation for exterior walls** — Additional Wall Insulation by using expanded polystyrene (EPS), polyurethane foam, etc.
- **Roof**
  - **Provision of Insulation for roof** — Additional roof Insulation by using expanded polystyrene, Extruded Polystyrene, etc.
  - **Use of cool roof** — Mitigates urban heat island effect by using high Solar Reflectance Index paint and materials
  - **Use of green roofs** — Acts as an insulation, mitigates urban heat island effect and manage storm water management
- **Fenestration**
  - **Provide appropriate WWR** — Recommended 20% for E-W and 40% S-N orientation to manage heat ingress
  - **Use of energy efficient glazing** — Selection of efficient glazing type with low SHGC and high VLT(single glazed / double glazed)
- **Shading Devices**
  - **Fixed vertical and horizontal** — Provision of fixed vertical louvers and horizontal shading devices
  - **Internal louver blinds** — Additional adjustable shading with horizontal or vertical slat with provision of tilts
- **Minimized Air Leakage / Infiltration**
  - **Proper design of building envelope components** — Design building envelope elements to meet testing and certification standards that reduce air infiltration
  - **Seal building openings and joints** — Seal openings and joints with suitable caulking or gasketing for effective air barriers

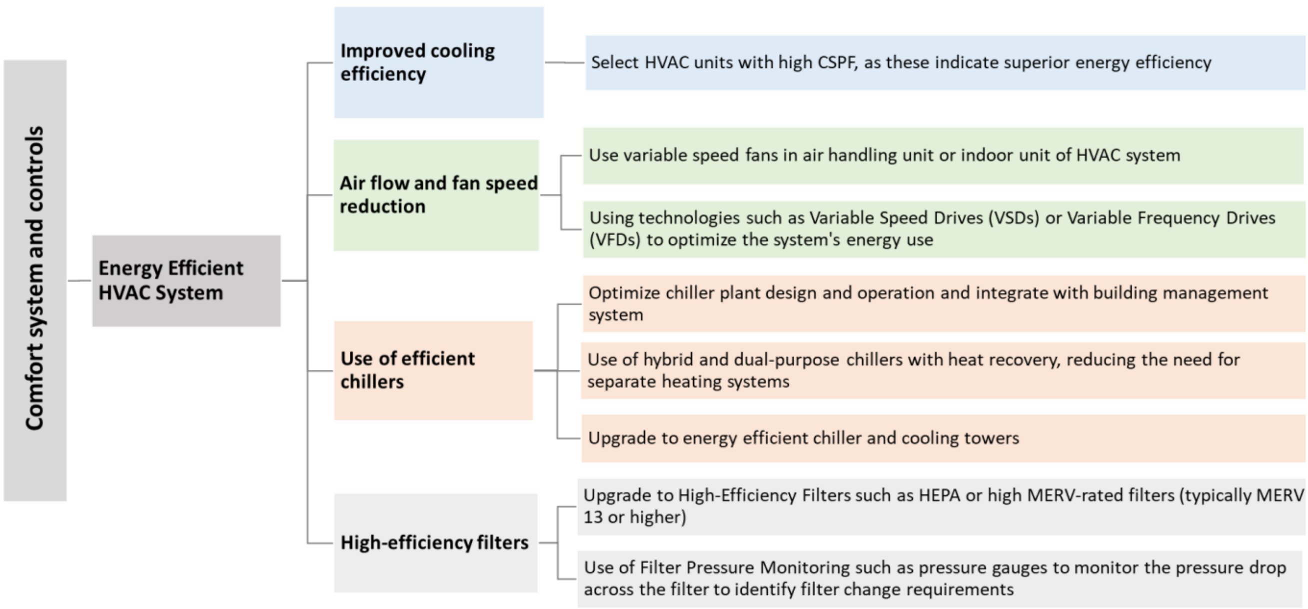
3. Lighting Measures

Lighting Measures

- **Efficient Lighting**
  - **Optimize Lighting power density**
    - Using task lighting in office spaces and LED lights in the building interior
  - **Efficient Exterior Lighting Fixtures**
    - Use of LED lights and solar power lighting
    - Integrate motion sensors and timer along with smart lighting controls
- **Daylighting strategies**
  - **Maximize Use of Daylighting**
    - Properly designed windows in occupiable spaces
    - Use of skylights in spaces where windows cannot be provided
    - Provision of light shelves on south and north facing windows in deep and low height buildings
    - Use of daylight responsive lighting controls

4. Measure for Comfort System and Control





- **Comfort system and controls**
  - **Energy Efficient HVAC System**
    - **Pumps**
      - Improving performance with the use of variable speed drives (VSD)
      - Periodic Maintenance to reduce pump energy consumption
    - **Heat recovery system**
      - Integrate Heat Recovery Ventilators (HRVs) and Energy Recovery Ventilators (ERVs) in building such as hotels, offices, and public buildings
    - **Energy-Efficient Motors**
      - Use motors with minimum efficiency class of IE3
      - Install Variable-Speed Drives (VSDs) or Variable Frequency Drives (VFDs) to optimize motor speed based on demand
      - Ensure regular monitoring and maintenance and integrate with energy management systems to optimize energy usage
    - **Green Refrigerants**
      - Use of green refrigerant which have low GWP (less than 100) and ODPS such as R-32, R-290 (propane), R-1234yf, and CO2 (R-744)

5. Measure for Equipment and Appliances

- **Efficient Equipment and Appliances**
  - **Refrigeration and Green Refrigerants**
    - **Reducing refrigeration load**
      - Use of energy-efficient refrigerators with an efficiency class of E or higher on the EU energy label
      - Use authorized service providers for repairs and maintenance to keep efficiency high
    - **Use of green Refrigerants**
      - Using refrigerant which have low GWP (less than 100) and ODPS or natural refrigerants such as carbon dioxide, ammonia, etc.
  - **Use of Positive Cold Rooms for Cold storage**
    - **Optimize the design of positive cold room**
      - Maintain optimal temperature control through high accuracy thermostats and temperature control sensors
      - Use high efficiency insulation materials such as polyurethane panels (80–100 mm thick) to prevent heat ingress
    - **Ensure adequate operation, and maintenance of positive cold room**
      - Implement a preventive maintenance schedule for regular checks on compressor performance, evaporator and condenser coils, fan motors, and door seals
      - Regularly inspect and clean drain pans and coils to ensure cooling efficiency

- **Efficient Equipment and Appliances**
  - **Office Equipment**
    - **Energy- efficient office appliances**
      - Use of monitors and computers with Energy Efficiency Labelling and other energy efficient power saving devices such as printers and photocopies
      - Use of smart thermostats, smart power strips and timers
    - **Energy Management System**
      - Use of integrated control systems and building automation systems to integrate office equipment and reduce energy usage
    - **Establishment of policy for use and awareness**
      - Encourage employees to turn off office equipment when not in use and use energy-saving modes on computers
      - Enable energy-saving features such as standby modes further support efficiency
    - **Equipment Maintenance and Upgrades**
      - Establish maintenance procedures to ensure periodic servicing and routine maintenance of equipment
      - Develop equipment procurement policies to encourage suppliers with a record of energy efficient products
  - **Boiler Service Hot-Water**
    - **Use of retrofitting boilers**
      - Enhance efficiency and safety, extending the life of older but functional systems
    - **Efficiency of equipment**
      - Use of gas or oil-fired boilers with minimum Fuel Utilization Efficiency (FUE) of 80%
    - **Insulation practices for hot water pipes**
      - Use of insulation such as metal-coated fiberglass, rockwool, mineral wool, polyurethane foam, aerogel, calcium silicate, etc. for steam and hot water pipes
  - **Elevators**
    - **Efficiency of equipment**
      - Use of regenerative drives, energy-efficient motors, standby mode and smart elevator systems

6. Energy Efficiency improvement measures via IoT-based smart technologies

- **Energy Efficiency improvement measures via IoT-based smart technologies**
  - **IoT-integrated technologies to analyze and reduce energy consumption**
    - Use of IoT-enabled smart lighting systems with sensors for occupancy, and dimming control
    - Use of smart window technologies and automated blinds that adjust based on external weather conditions or internal occupancy patterns
    - Use of IoT sensors to monitor temperature, humidity, and occupancy to adjust HVAC operation in real-time
    - Use of IoT-based smart meters and energy sensors across building systems to provide real-time energy consumption data
    - Use IoT devices to automatically respond to peak demand signals from the grid and adjust building energy consumption accordingly
    - Use IoT technology to optimize energy consumption of elevators by adjusting operations based on peak usage patterns
    - Use of appliances (such as refrigerators and office equipment) with IoT connectivity to allow remote monitoring and energy optimization.
    - Use of IoT-based Building Automation Systems to optimize lighting, HVAC, security, and other systems in a coordinated manner

The subsequent sections elaborate each of the energy conservation measures and best practices, wherever applicable.

5.1 Site Measures

Site measures are one of the most essential strategies implemented to optimize energy performance at early design stage for new commercial buildings. These measures focus on the overall building's relationship with its immediate environment, incorporating innovative technologies and design practices to ensure long-term energy efficiency. For new buildings, especially in regions like Mauritius where tropical climates present unique challenges, integration of passive design from the design stage is essential. The two most crucial parameters for building design are building orientation and form, which are explained in detailed in this section.

5.1.1 Building Orientation

The first step in building design is determining the orientation of the building on the site, which is one of the most important passive design strategies for reducing energy consumption and improving thermal comfort for occupants.

The proper orientation of a building, with respect to its position and direction, plays a key role in optimizing wind patterns and sun exposure. In Mauritius, an ideal orientation is North-South (with the longer sides facing north and south), which reduces direct exposure to the harsh afternoon sun, minimizing heat gain. This orientation also aligns the building’s spaces with the prevailing wind direction, facilitating efficient ventilation and reducing cooling demand. Furthermore, it decreases the need for electrical lighting during the day and allows for effective natural cooling in the evening, thus minimizing reliance on air conditioning.

Additionally, strategically placing windows at the right locations and angles can help capture sunlight and heat during cooler months (if applicable) while minimizing heat gain during warmer months, especially in tropical climates. The below Figure 12 describe the summer and winter sun path[17] for tropical climate and the benefit from selecting the façade orientation.

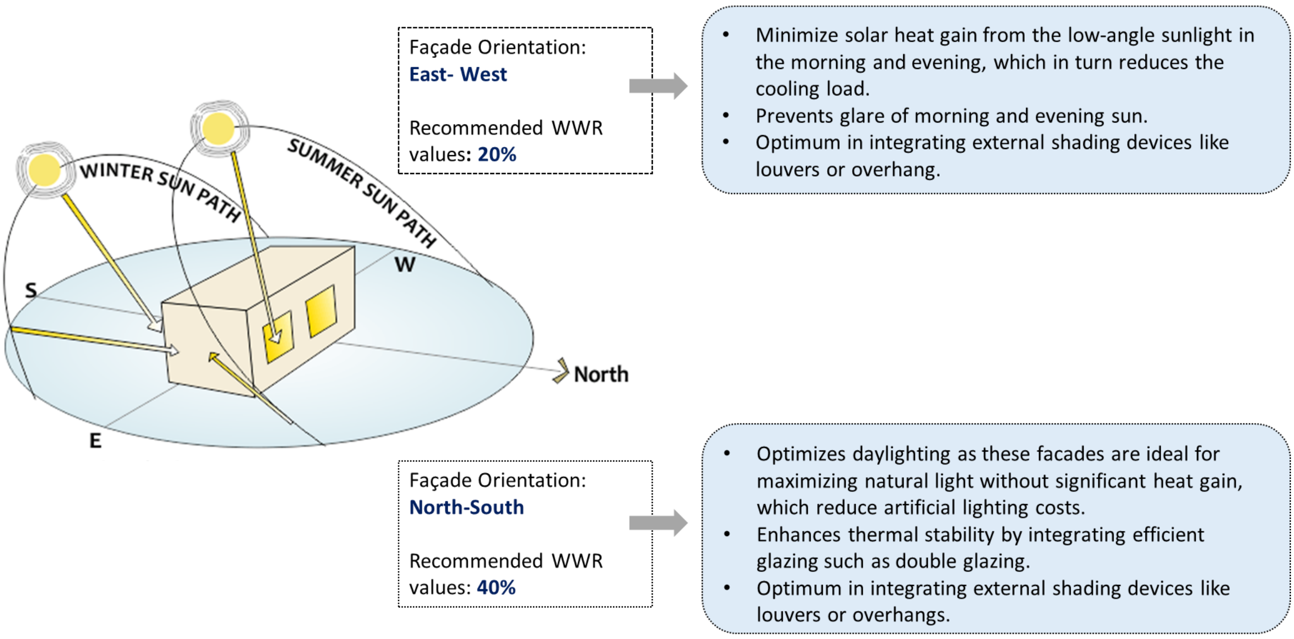


Figure 12: Building orientation to reduce heat gain and maximise ventilation in tropical climate

[17] Net Zero Energy Buildings, https://nzeb.in/knowledge-centre/passive-design/form-orientation/

5.1.2 Building Form

The building form determines the volume of space inside a building that needs to be cooled. Thus, more compact the shape, the less wasteful it is in gaining/losing heat. Given the tropical rainforest climate of Mauritius, open and elongated building shapes with U-shaped plans, strategically positioned for natural ventilation and cross-breezes, are generally considered most appropriate, along with features like large openings and shading.

In consideration of Mauritius' frequent rainfall, elevating buildings slightly on stilts or raised foundations can effectively mitigate the risk of flooding. Furthermore, sloped roofs are essential as they facilitate the rapid drainage of rainwater, thereby preventing moisture buildup and leaks.

To manage the strong sun and frequent rains, extended roof overhangs, balconies, and shading elements protect walls from overheating while keeping outdoor spaces comfortable. Apart from reducing the reliance on air conditioning and lighting, the building form also determine the thermal and visual comfort to a large extent.

5.2 Measures for Building Envelope

The building envelope is a key physical and thermal barrier that separates the interior from the exterior environment, which includes elements such as walls, roofs, windows, doors, and other openings. The design features of the envelope strongly affect the visual and thermal comfort of the occupants, as well as energy consumption of the building. According to studies, an energy effective building envelope design can save 35 % of annual energy consumption and even reach up to 60 % in some cases.[18]

In Mauritius, selection of energy efficient building envelope is crucial due to its tropical climate, characterized by high temperatures, humidity, and significant rainfall. Key building envelope measures include high-performance insulation to minimize heat gain, efficient shading devices like overhangs and louvers to block direct sunlight, and placement of efficient windows to reduce solar heat gain while maintaining natural light. The summary of applicable measures is provided in the Figure 13 below:

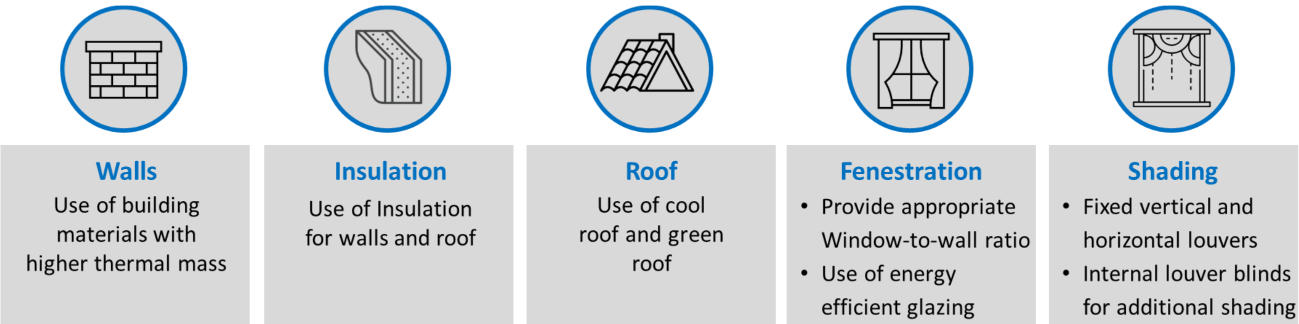


Figure 13: Summary of ECM for building envelope

5.2.1 Use of Building Materials with High Thermal Mass

The building materials with high thermal mass are highly beneficial for the tropical climate of the country. The key characteristics of high thermal mass materials are as follows:

- **Thermal Mass Effect:** Materials having high thermal mass exhibit high volumetric heat capacity, enabling them to absorb and store significant amounts of heat during the day and release it at night. This reduces the need for constant, energy-intensive HVAC operation, which in turn reduce energy consumption.

[18] V. Gupta, C. Deb, Envelope design for low-energy buildings in the tropics: A review (2023). Renewable and Sustainable Energy Reviews

- **U-Values (Building Envelope):** Materials with high thermal mass offer excellent thermal insulation due to their cellular structure, resulting in low U-values (heat transfer coefficient). For example, a typical AAC block wall can achieve a U-value significantly lower than a conventional concrete block wall with same thickness.

Mass and density of a building material affects heat storing capacity in buildings. High density materials such as concrete, bricks and stone have high thermal mass, while materials such as wood or plastics have low thermal mass.

Materials having high thermal mass includes Autoclaved Aerated Concrete (AAC) blocks, lightweight bricks, concrete blocks, clay-fired bricks, fly ash blocks and hollow concrete blocks. Each material offering unique thermal performance characteristics to suit different building needs. The properties of these materials are provided in the below Figure 14:

AAC Block

- Lightweight, precast blocks made from a mixture of cement, lime, sand, water, and aluminum powder.
- Thermal conductivity range typically between 0.09 to 0.14 W/m·K.

Lightweight Brick

- Produced using materials like expanded polystyrene or clay aggregates, which reduce their density.
- Thermal conductivity ranging from 0.5 to 1.2 W/m·K

Concrete Blocks

- Made from cement and aggregates,
- Thermal conductivity ranging from 1.4 to 1.8 W/m·K.

Clay Fired Bricks

- Dense and provide good mass for heat storage but have moderate thermal insulation properties.
- Thermal conductivity ranging from 0.7 to 1.0 W/m·K

Fly Ash blocks

- Made from fly ash, cement, and lime. Provide good insulation.
- Thermal conductivity ranging from 0.35 to 0.60 W/m K

Hollow Concrete Block

- Made from concrete with hollow cavities within them for better insulation.
- Thermal conductivity ranging from 0.45 to 1.1 W/m·K.

Figure 14: Typical Example of Materials having High Thermal Mass

5.2.2 Use of Insulation for Wall and Roof

Insulation in buildings is a very important factor to achieve thermal comfort to the building occupants. The external surfaces of a building such as walls, roof, which are exposed to the direct solar radiation, get heated up and transfer the heat inside the building through thermal conduction. Given the high temperatures and regular humidity in Mauritius, well-insulated walls and roofs are essential for keeping indoor temperatures more stable and minimizing the need for air conditioning in buildings.

Insulation material such as expanded polystyrene (EPS), polyurethane foam can be used for wall insulation to effectively block heat while also providing soundproofing benefits. In the case of roofs, which are particularly vulnerable to solar heat gain, Extruded Polystyrene (XPS) significantly reduces the amount of heat absorbed by the building.

The below Figure 15 and Figure 16 explain the different type of insulation types for wall and roof.

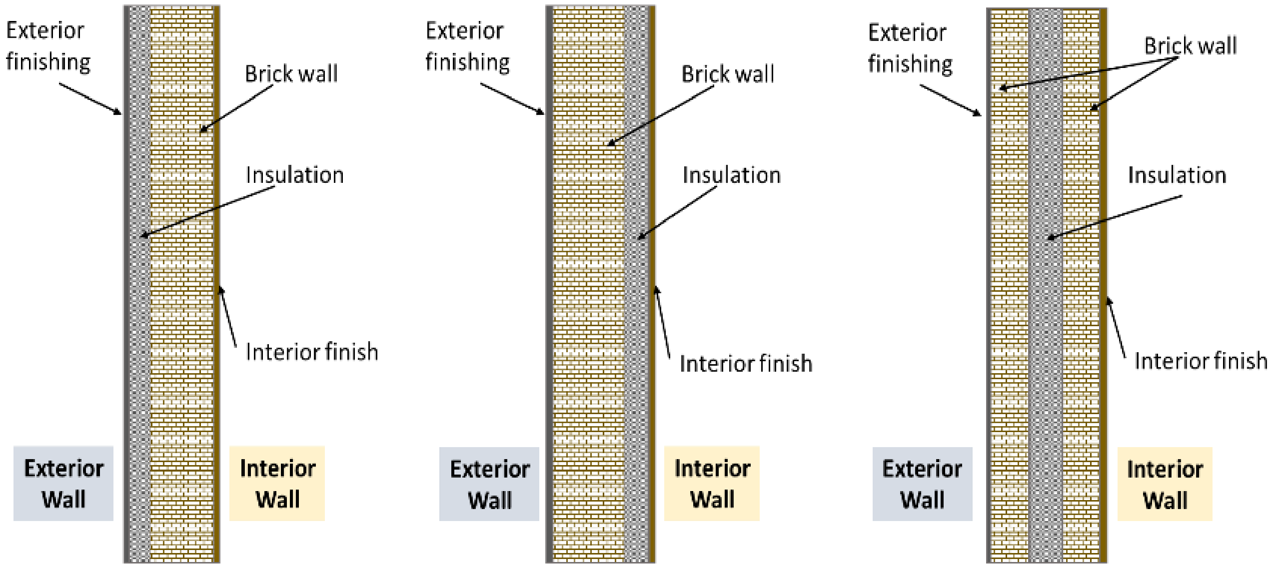


Figure 15: Wall Insulation - External, Internal and Cavity

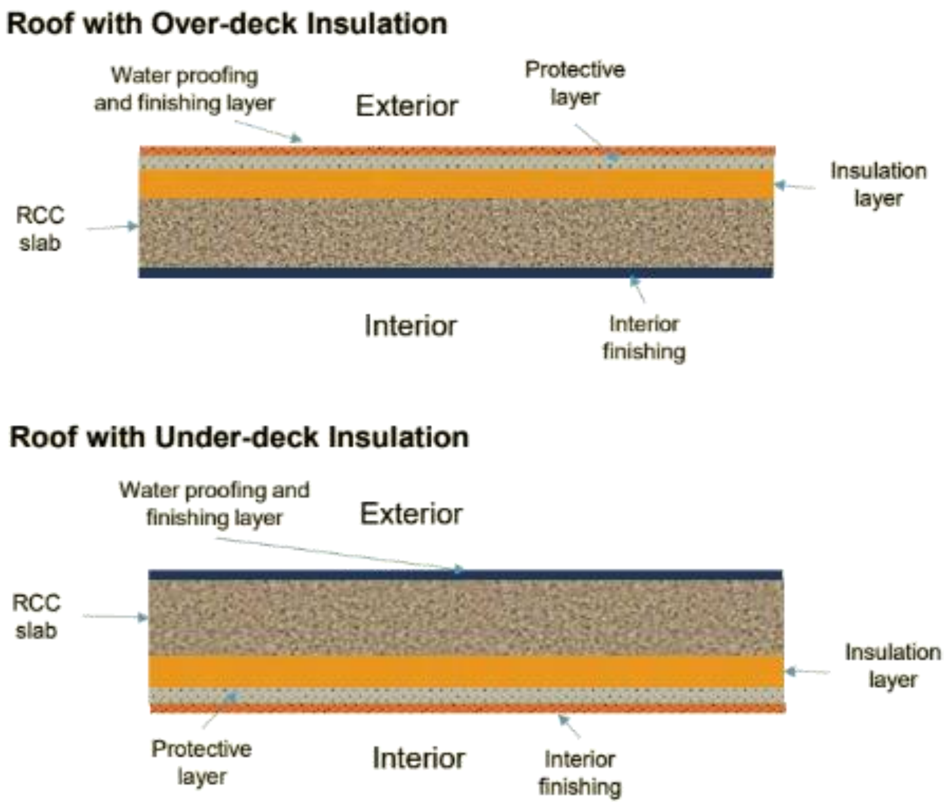


Figure 16: Over-deck and Under-deck Insulation for Roof

Various types of insulation materials along with its characteristics are summarized below in the Table 5 :

Table 5: Characteristics of Insulation Materials

S. N.	Insulation Materials	Characteristics	Advantages	Disadvantages
1	Glass wool insulation	• Good thermal resistance (R-2.9 to R-3.8 m^2·K/W) • Available in loose fill and blankets type • Non-flammable • Can be applied to uneven structure	• Low cost • Easily available • Can be acquired in any thickness. • Environment friendly	• No water resistance • Itchy and irritating properties while applying – need special protection equipment. • No resistance to compression or traction
2	Mineral wool insulation	• Contains average of 75% recycled content • Good thermal resistance (R-2.8 to R-3.5 m^2·K/W) • Available in loose-fill, blanket, and fibre type • Non-flammable	• Moderate cost • Does not need additives to make it fire resistant. • Environment friendly • Does not melt	• Water repellent but dries quickly. • No resistance to compression or traction
3	Cellulose	• Made from recycled paper products. • More than 82% recycled content • Good thermal resistant (R-3.1 to R-3.7 m^2·K/W) • Available in loose-fill and blown-in	• Most eco friendly • Moderate cost • Requires no moisture barrier. • Very compact structure so inhibits airflow thus fire resistant	• Can generate allergies. • Required skilled labour for installation.
4	Expanded Polystyrene (EPS)	• Made of small plastic beads fused together. • High thermal resistance (up to R-4.0 m^2·K/W) • Available in loose fill, foam board, structure insulating panels • Can be applied to low slope roofs	• Low cost • Lightweight • Can be applied in any required thickness. • East to cut, fix and lay.	• Surface protection is required as soon after application. • Flammable • Due to absorption properties, it can absorb water and melt or drip
5	Extruded Polystyrene (XPS)	• Made of molten material pressed into sheets. • Very high thermal resistance (up to R-4.0 m^2·K/W) • Available in loose fill, foam board, structure insulating panels • Can be applied to low slope roofs	• Low cost • Lightweight • Good mechanical strength • Highly water resistant • Excellent sound insulation • Have smooth surface	• Degrades on exposure to ultraviolet light. • Combustible in nature • Limited range of size in market • Thermal ageing occurs over time
6	Foamed Polyurethane	• Foam based insulation used with a foaming agent. • Hight thermal resistance (up to R-5.3 m^2·K/W) • Contains low conductivity gas in its cells.	• Available both in solid board and liquid form • Great sound insulator • Highly water resistant • Very good mechanical strength	• High cost • Thermal ageing occurs over time. • Combustible in nature • Liquid type needs special skills to apply

Insulation should be selected based on the two most important factors:

(1) Thickness of insulation
(2) Cost of insulation

The Figure 17 shows that the cost of insulation increases linearly with thickness, while the cost of heat loss decreases exponentially.

Initially, the total cost decreases and then increases, with a minimum point corresponding to the optimum insulation thickness.

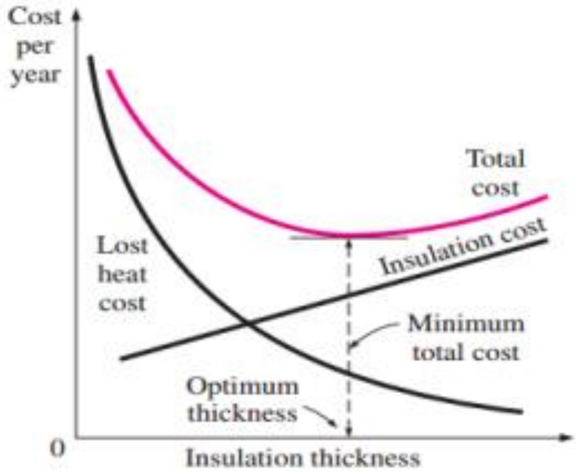


Figure 17: Relation between insulation thickness and cost

It is imperative to select insulation material based on specific requirements and its suitability for the building, ensuring unnecessary costs and physical limitations are avoided. The following factors must be considered when choosing insulation:

Table 6: Factors need to be Considered while Selecting an Insulation

S. N.	Factors	Description
1	Type of insulation	In certain projects, a single type of insulation may not give the desired R-value, therefore a combination of different insulation material can be used based on the usage. For an example, if there are some small spaces, attic spaces, then loose fill insulation will be the best suited choice as board insulation will be harder to cut and fix.
2	R- value	The R-value is the amount of resistance of the indoor heat flow through a certain material. It varies with the type of insulation materials, thickness, and its density. An insulation material with higher R-value always better than the one with a lower value. For tropical regions like Mauritius, insulation with a lower R-value might suffice because the focus is often on preventing excessive heat from entering, rather than retaining indoor heat.
3	Durability	The insulation should be resistant to external factors such as insects, rodent, external weather, and humidity but should also not settle over time such as loose-fill insulation.
4	Acoustic Performance	Although, the thermal insulation would be the first choice, but some types of insulation material have good acoustic properties as well which minimizes the noise pollution in the building. For an example, the injection foam insulation provides a very good acoustic insulation sue to its high density.
5	Humidity Control	The humidity control of an insulation material is its ability to absorb and release humidity efficiently without deteriorating. Insulation with good humidity control ensures dry and healthy indoor air for the occupants
6	Flammability	Some insulation materials are considered flammable material which can easily set on fires while some are non-flammable and can even protect against fire by slowing the spread of flames.
7	Allergens	There are some insulation materials which produce allergies such as glass wool, mineral wool, cellulose. These kinds of material have very small particles toxic in nature and can cause respiratory problem when inhaled.

5.2.3 Use of Cool Roof and Green Roof

Cool Roof reflects most of the incident sunlight (about 80 % on a clear day) and efficiently emits some of the absorbed radiation back into the atmosphere, instead of conducting it into the building. As a result, the roof stays cooler - maintains a lower surface temperature, keeping the building below at a cooler and more constant temperature. Cool roofs are known to stay 10-16 °C cooler than a normal roof under a hot summer sun[19]. This greatly reduces heat gain inside the building and the cooling load that needs to be met by the HVAC system. Below Figure 18 represent the fundamental concepts of cool roof with respect to solar radiation[20]:

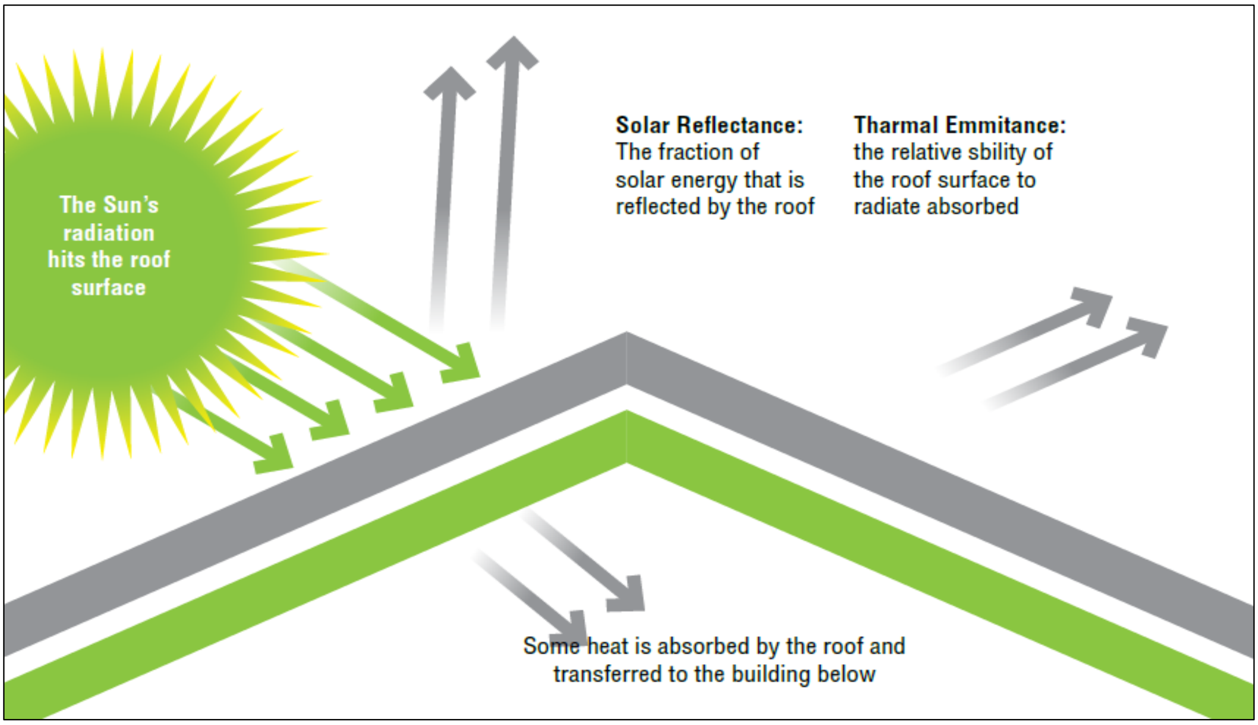


Figure 18: Principle of a cool roof

Conventional dark or medium-coloured roofs and wall materials readily absorb solar heat and transfer it into the building, increasing indoor temperatures. In contrast, light-coloured surfaces have been used in hot climates since ancient times to help keep interiors cooler. For example, traditional dark roofs can reach temperatures of 66 °C (150 °F) or more under the summer sun, whereas a cool roof under the same conditions can remain over 28 °C (50 °F) cooler.

Surfaces with high solar reflectance typically come in lighter shades, such as white, light grey, and light tan, that reflect sunlight more effectively. The Solar Reflectance Index (SRI) combines solar reflectance and thermal emittance into a single value, indicating the relative steady-state temperature of a surface. An SRI of 100 represents the performance of a standard white surface, while an SRI of '0' represents a standard black surface under specified solar and ambient conditions.

Cool roofs are a viable option for both new construction and retrofits. In most climates, roofs and walls can be upgraded with light-coloured paints or materials featuring high SRI values. These materials vary in their reflectivity, emissivity, lifespan, and upfront cost. Common types of cool roofing materials include broken China

[19] LBNL (2011). Using Cool Roofs to Reduce Energy Use, Greenhouse Gas Emissions, and Urban Heat-island Effects.
[20] Sustainable and Smart Space Cooling Coalition (2017). Thermal Comfort for All - Sustainable and Smart Space Cooling. New Delhi: Alliance for an Energy Efficient Economy.

mosaic coatings, high-SRI paints, modified bitumen (asphalt or tar enhanced with plastics and reinforced, then topped with a reflective surface), slate or tile, metal, and shingles.

Below Table 7 shows various colors with their corresponding solar absorptance and Solar Reflectance Index (SRI) values. It helps to understand the user to select the high SRI paint for cool roof[21].

Table 7: Color with their solar absorptance and solar reflectance index

Colour of Paints		Solar Absorptance	Solar Reflectance Index (SRI)
Standard White		0.20	100
Off-White		0.32	82
Cream		0.32	82
Medium Grey		0.47	61
Dark Red		0.69	31
Dark Charcoal		0.73	26
Dark Green		0.75	23
Dark Blue		0.75	23
Standard Black		0.95	0

Radiant Barriers can reduce summer heat gains and reduce cooling costs. The barriers consist of a highly reflective material that reflects radiant heat rather than absorbing it. This principle can be used by covering the roof with a highly reflective cover during the day and withdrawing it at night, thus exposing the roof for cooling by radiation to the sky. The highly reflective shade prevents heating of the roof during the day and once removed after sunset promotes cooling by sky radiation at night. The combined effect leads to a slab bottom temperature consistently below 30 °C.

For an industrial building, energy simulation showed a **38.8 % reduction** in the roof load (from 25.8 TR to 15.8 TR), when a radiant barrier material (4 mm XLPE + 0.2 mm aluminium foil) was used as underdeck insulation.

Green Roof is a roof, also known as 'vegetated roof', are of a building that is partially or completely covered with vegetation, consist of a waterproofing membrane, growing medium (soil) and vegetation (plants) overlying a traditional roof. Green roofs serve several purposes for a building such as absorbing rainwater, providing insulation, and helping lower urban air temperatures and mitigating the urban heat island effect. Green roofs are cooled primarily by the evaporation of water from plant surfaces rather than by reflection of sunlight. The soil layer also provides additional insulation as well as thermal mass. The primary reasons for using this type of roof include managing storm water and creating an attractive and enjoyable rooftop open space.

[21] CSIRO (2021). Solar Reflective (Cool) Coatings. Building Technology Resources.

A review study[22] assessed the performance of green roofs in Mauritius and found that green roofs increase thermal mass, reduce indoor temperature fluctuations, and lower daily peak indoor temperatures compared to conventional roofs. It was found that the maximum heat flux on each day for a conventional roof varied from 0.47 W/sqm to 2.5 W/sqm; whereas for the green roof, it varied from 0.21 W/sqm to 0.53 W/sqm, shown a significant reduction of 55-80 %.

Point to Note: *When designing or installing a green roof, it is crucial to exercise caution to ensure both safety and long-term performance. Proper assessment of the building's structural capacity is essential, as green roofs add significant weight due to soil, plants, and retained water. Waterproofing membranes must be meticulously installed and protected to prevent leaks that can cause costly damage. Attention should be given to drainage systems to avoid waterlogging, which can harm plants and strain the roof structure.*

5.2.4 Fenestration

Choosing energy efficient windows, and skylights is one of the most important ECM for any high-performance project. The use of high-performance fenestration can reduce energy consumption by decreasing the cooling/ heating loads in buildings. Some of the best practices or methods to reduce the heat gain through windows are explained below:

i) Provide appropriate window-to-wall ratio

Windows are integral components of building designs, influencing aesthetics, ventilation, daylighting, and energy efficiency. The window-to-wall ratio (WWR) is the percentage of a building's wall area covered by windows, and is calculated by the formula given below:

$$Window\ Wall\ Ratio\ (WWR) = \frac{Net\ glazing\ area\ (sqm)}{Gross\ wall\ area\ (sqm)}\ X\ 100$$

WWR is an essential factor in energy performance analysis, daylighting design, and visual comfort for building. The recommended or standard value of WWR varies with the façade orientation. For tropical climatic countries such as Mauritius, the following WWR are recommended (Figure 19):

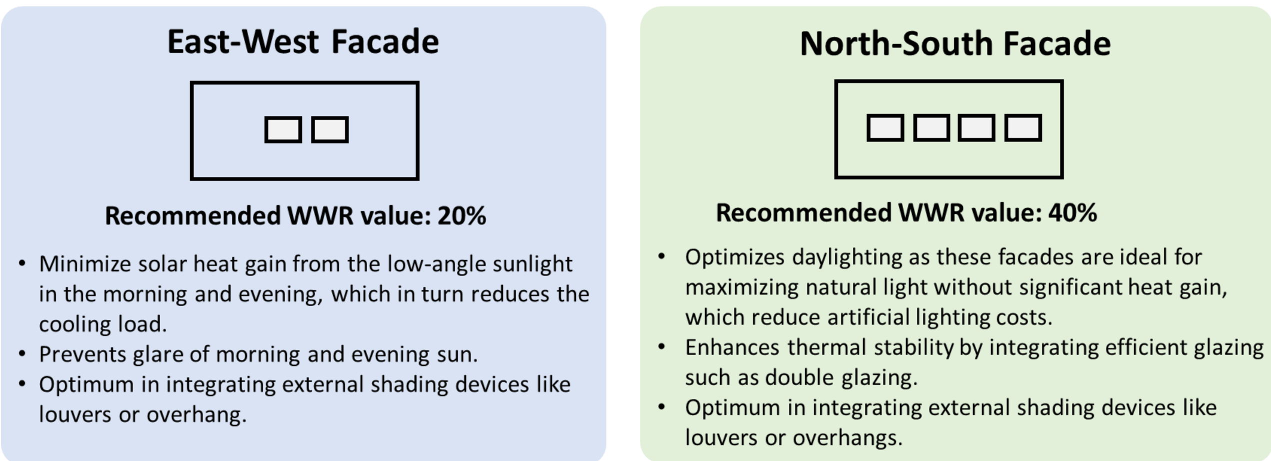


Figure 19: Recommended values for WWR based on facade orientation

[22] Maheshsingh Mungur et al (2020). "A numerical and experimental investigation of the effectiveness of green roofs in tropical environments: The case study of Mauritius in mid and late winter". Energy. Volume 202. https://doi.org/10.1016/j.energy.2020.117608

ii) Use of energy efficient glazing

Glazing plays a critical role in commercial building energy efficiency, influencing thermal insulation, daylight penetration, and occupant comfort. It significantly enhances insulation, reduces energy consumption, and maintains stable indoor temperatures.

Double-glazed windows with Low-E (Low emissivity) coatings are highly effective in Mauritius, as they reduce solar heat gain while allowing ample natural light to penetrate. In relation to the window frame, the UPVC (Unplasticized Polyvinyl Chloride) frame is well known for its good insulating properties, helping to further reduce heat loss compared to metal frames. The main design feature of this frame is thermal bridge break which interrupts the flow of heat through the frame, minimizing heat loss at the points where the frame connects to the glass pane. Below Figure 20 provides cross sectional details of different glazing units highlighting the structural layers and materials.

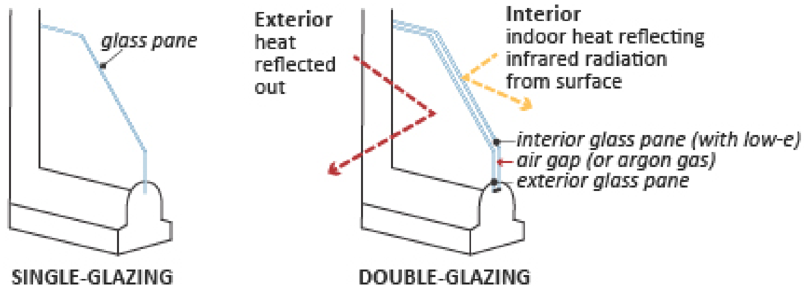


Figure 20: Cross Section Details of Different Glazing Units

As per the Window Energy Rating Scheme (WERS), accredited by the Australian Fenestration Rating Council (AFRC)[23], the Table 8 below provides several glazing configurations. The optimal combination should be selected on a case-to-case basis based upon the factors such as size of the window, level of direct exposure with the sun and daylight requirements.

Table 8: Characteristics of Common Window types based on WERS

Glazing type along with frame	SHGC	VLT	U-value (W/sqm-K)
Single glazed, 3mm clear glass with Aluminium frame	0.77	0.80	6.9
Single glazed, 3mm clear glass with Timber of UPVC frame	0.69	0.72	5.5
Double glazed, 3mm clear glass and 6mm air gap with Aluminium frame	0.69	0.72	4.2
Double glazed, 3mm clear glass and 6mm air gap with Timber of UPVC frame	0.61	0.65	3.0
Triple glazed, 4mm Low-e glass and 16mm Argon gap with Timber aluminium composite window	0.25	0.36	1.00

[23] https://www.yourhome.gov.au/passive-design/glazing

5.2.5 Shading Devices

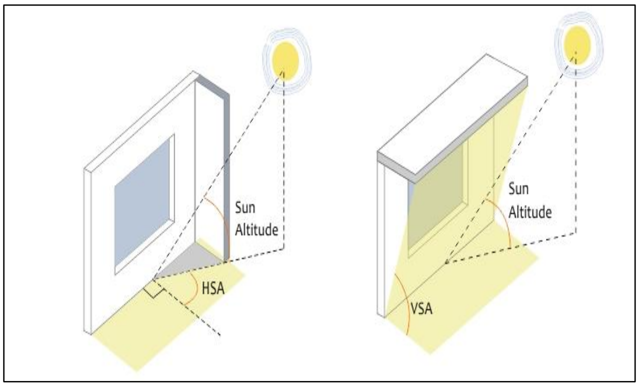


Figure 21: Angles used for designing shading devices

Shading is a crucial passive design strategy that helps regulate indoor temperatures by minimizing unwanted solar heat gain by reducing internal heat gain through coincident radiation. There are various methods to shade windows such as overhangs, awnings, louvres, vertical fins, and light shelves. The shading mechanism can be fixed or movable (manually or automatically) for allowing varying levels of shading based on the sun's position and movement in the sky. In tropical climates, where excessive heat is a concern year-round, effective shading prevents overheating while still allowing ample natural daylight. Effectiveness of shading as a cooling load reduction strategy can be gauged from the fact that shading alone resulted in a 22% reduction in cooling energy consumption[24]. The Figure 21 shows the use of horizontal shadow angle and vertical shadow angle while designing shading devices.

Shading, in combination with high-performance glass with low solar heat gain coefficient (SHGC), can reduce cooling energy consumption even further by cutting down on heat gain through radiation. The different methods to provide shading is explained below:

i) Fixed vertical and horizontal louvers

In warm, sunny climates, excessive solar gain can lead to high cooling energy consumption. Fixed vertical and horizontal louvers on East and West facades effectively mitigate direct sunlight, reducing peak heat gain and cooling demands. Additionally, shading elements contribute to architectural aesthetics, adding depth and character to building facades. The following Figure 22 shows the visual representation of different type of shading louvers.

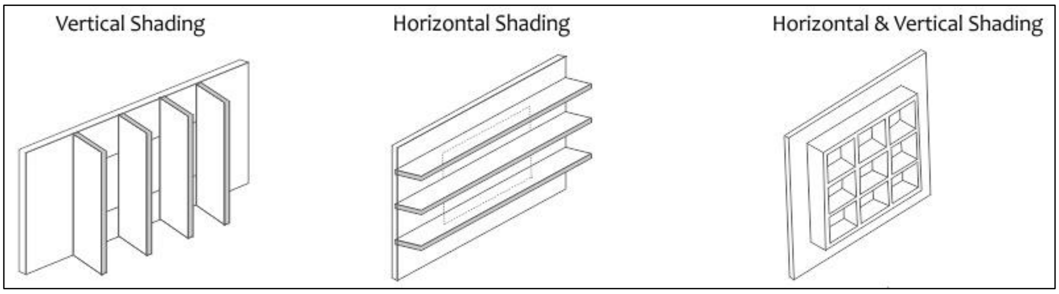


Figure 22: Visual representation of different type of shading louvers

Properly designed shading enhances visual comfort by minimizing glare and improving daylight distribution. However, it is essential to first understand the sun's position in the sky during the cooling season to design the shading devices for any building.

ii) Internal louver blinds for additional shading

Internal louver blinds are adjustable shading devices designed to control daylight, glare, and solar heat gain within the buildings. These blinds consist of horizontal or vertical slats that can be tilted to regulate the amount of sunlight entering a space, offering flexibility in managing indoor lighting and thermal comfort. These blinds

[24] NREL (2000). Impacts of Shading and Glazing Combinations on Residential Energy Use in a Hot Dry Climate

often come in white color as the white color enhances their reflective properties, further reducing heat absorption and improving energy efficiency.

These blinds are installed on the interior side of windows and are typically made from lightweight materials such as aluminum, PVC, or coated wood. They can be manually adjusted or motorized for automated control, responding to external weather conditions and user preferences. When fully closed, they act as a barrier against excessive sunlight, minimizing heat gain. When adjusted to an optimal angle, they diffuse daylight evenly into the room, reducing glare while maintaining outside views.

5.2.6 Minimize Air Leakage / Infiltration

The cooling load of an air-conditioned space can be significantly reduced by minimizing air infiltration. Uncontrolled outside air can enter the building through cracks, gaps, and openings in various building elements such as doors, windows, walls, and ceilings, which not only increases cooling demand but also compromises energy efficiency. The following are several methods to minimize air leakage or infiltration within a building:

Proper design of building envelope components

- Various building elements, such as windows, door assemblies, curtain walls, and storefronts, are subject to specific testing and certification standards designed to limit air infiltration. These components should ideally meet performance criteria to ensure they do not contribute excessively to air leakage.

Seal building openings and joints

- All openings in the building envelope should be sealed using appropriate caulking materials or gasketing systems to provide effective and durable air barriers. Joints between construction materials should be sealed similarly, using caulking, tapes, or moisture-vapor permeable wrapping materials to prevent air leakage.

Design for expansion and contraction

- Sealing materials used for joints between construction elements should be designed to accommodate the expansion and contraction of the materials. This flexibility ensures that the seal remains effective over time, even with temperature fluctuations or structural movements.

To address air leakage, various energy codes have established limitations and prescriptive requirements that regulate the maximum amount of unconditioned outdoor air that can infiltrate the building through its envelope. Table 6 provides the maximum allowed infiltration rates according to ASHRAE 90.1-2010[25]:

Table 9: Maximum air infiltration rate for fenestration assembly as per ASHRAE 90.1-2010

Fenestration Assembly	Maximum Rate (CFM/ sqft)	Maximum Rate (CFM/ m^2)	Test Procedure
Windows	0.20[a]	2.15	AAMA/ WDMA/ CSA101/ I.S.2/ A440 Or NFRC 400
Sliding doors	0.20[a]	2.15	
Swinging doors	0.20[a]	2.15	
Skylights- with condensation weep holes openings	0.30	3.23	
Skylights- all others	0.20[a]	2.15	
Curtain walls	0.06	0.65	NFRC 400 Or ASTM E 283 at 1.57 psf (75Pa)
Storefront glazing	0.06	0.65	
Commercial glazed swinging entrance doors	1.00	10.76	
Revolving doors	1.00	10.76	
Garage doors	0.40	4.31	ANSI / DASMA 105, NFRC 400 Or ASTM E 283 at 1.57 psf (75Pa)
Rolling doors	1.00	10.76	

For S.I. unit: 1 cubic foot per minute=0.47 L/s, 1 square foot= 0.093 sqm

[a] The maximum rate for windows, sliding and swinging doors, and skylights is permitted to be 0.3 cfm per square foot of fenestration or door area when tested in accordance with AAMA/ WDMA/ CSA101/ I.S.2/ A440 at 6.24 psf (300 Pa).

5.3 Measures for Lighting

A typical commercial building has many lighting requirements, and each has its own set of options for improving lighting efficiency. Since lighting contributes significantly to the overall energy demand, it presents a major opportunity for energy savings. Energy-efficient lighting solutions can deliver substantial savings, often achieving a payback period of less than two years. Efficient lighting refers to solutions designed to use less energy than traditional systems while providing equal or better illumination quality. This includes technologies like Light Emitting Diodes (LEDs), Compact Fluorescent Lamps (CFLs), task lighting, and advanced lighting controls such as automation and dimming systems. Efficient lighting significantly reduces energy consumption, lowers operational costs, making it a key strategy for sustainability in commercial buildings.

For optimal energy efficiency and long-term reliability, it is recommended to select LED lighting products that are supported by a manufacturer warranty. This ensures consistent performance and protects against potential defects or operational issues.

[25] ASHRAE 90.1 (2022). ANSI/ASHRAE/IES Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings

The Table 10 below compares the different types of lighting appliances[26] from least efficient to highly efficient Light Emitting Diode (LED) lamps.

Table 10: Characteristics of Different Types of Lighting Appliances

Lamp Type	Characteristics					
	Luminous Efficacy (lm/W)	Lamp Life (hours)	Color Rendering Index	Cost of Installation	Cost of Operation	Application
Halogen	12-35	2,000-4,000	Very Good	Low	High	General lighting
Mercury Vapor	40-60	12,000	Poor to Good	Moderate	Moderate	Outdoor lighting
CFL	40-65	6,000-12,000	Good	Low	Low	General lighting
Fluorescent Lamp	50-100	10,000-16,000	Good	Low	Low	General lighting
Induction Lamp	60-80	60,000-100,000	Good	High	Low	Places where maintenance is difficult
Metal Halide	50-100	6,000-12,000	Good	High	Low	Shopping malls, commercial buildings
High Pressure Sodium	80-100	12,000-16,000	Fair	High	Low	Outdoor, streets lighting, warehouse
LED	20-120	20,000-100,000	Good	Low	Low	All

In addition to choosing the right lighting fixtures, maintaining the appropriate illuminance level is crucial for achieving optimal lighting design. This approach helps prevent over-lighting which may result in higher energy consumption and ensures that lighting systems provide the required amount of light for each space without over-illumination, thereby minimizing energy wastage. The table below provides the specified lux levels for various standard spaces, in accordance with the European Standard EN 12464: Lighting of Indoor Workplaces[27].

Table 11: Space wise recommended Illuminance Levels in Lux

Standard Spaces	Illuminance Level (Lux)
Public areas	20 - 50
Corridors, Stairways, Escalators, Lifts and Storage space	100
Working areas	100 - 150
Warehouse, Homes, Theatres	150
Office areas	250
Classrooms	300
Library, Groceries, Laboratories, Kitchens, Auditoriums	500
Supermarkets, Mechanical Workshop, Office landscape	750
Operation theatres	1,000
Detailed drawing work, mechanical work, electronic workshops	1,500 - 2,000

[26] International Institute for Energy Conservation (2015). "Energy Efficiency Guidelines for Commercial & Public Buildings in the Pacific: Promoting Energy Efficiency in the Pacific (Phase 2)"
[27] European Standard EN 12464: Lighting of Indoor Workplaces

Example 1: Calculating Number of LED Bulbs for an office

Consider an office area of 100 sqm. that requires new LED lighting.

The recommended lighting level for office work is 250 lux (*provided in the table above*). One lux is equal to one lumen per square meter.

Therefore, the total lumen (lm) requirement for the office = 250 lux x 100 sqm. = 25,000 lm

Considering a typical LED light has 120 lm/W.

Therefore, the total wattage of LED required for office = 25000 lm /120 lm ≈ 210 W

To achieve 210 W of LED lighting requirement, the following three combinations, can be selected:

- 6 LED bulbs of 36 W each
- 12 LED bulbs of 18 W each
- 24 LED bulbs of 9 W each

Any option can be considered for installation based on the design of the office space and there should be no zone remains in dark.

Example 2: Replacing CFL with LED in a room

A 40W CFL light is installed in a room, producing 2,200 lm. To improve energy efficiency, it needs to be replaced with an LED light that provides same brightness.

Considering a typical LED light has 120 lm/W

Therefore, the total wattage of LED required for the room = 2200 lm /120 lm ≈ 18W

Hence, an 18-watt LED bulb can replace the 40W CFL light, resulting in an energy saving of 22W (= 40-18) per bulb, while maintaining the same lighting level.

The correct illuminance levels contribute to creating an optimal, comfortable, and safe environment for occupants. Some effective lighting strategies for better lighting quality and significant energy savings are explained further in detail.

Best Practice: Integration of IR reflective films in interior lighting

An Infrared (IR) reflective film selectively reflects infrared (heat) radiation while transmitting visible light. To enhance LED and interior lighting efficiency and lifespan, incorporate IR reflective films that reflect infrared radiation while allowing visible light to pass through. These films should be applied to fixture covers or enclosures to redirect heat away from critical components, reducing thermal stress and preserving lumen output. Choose IR films that are compatible with the fixture type, ensure efficient visible light transmission, and do not compromise safety. This integration improves thermal management, reduces energy consumption, and lowers maintenance costs of the equipment.

5.3.1 Optimizing Lighting Power Density

Efficient lighting design plays a crucial role in reducing energy consumption while maintaining optimal illumination levels in commercial spaces. Lighting Power Density (LPD) is a measure of the amount of electrical power (in watts) consumed by lighting per unit area of a building, typically expressed in watts per square meter (W/sqm). A lower LPD value depicts the efficient lighting system in the building, or the building uses less energy from the lighting consumption. There are several effective approaches to reduce LPD, as outlined in the below sub-section:

i) Utilize Task Lighting in office spaces

Task lighting enhances workplace efficiency by providing focused illumination for specific activities, reducing eye strain and improving visual comfort. It allows flexibility in lighting levels, minimizing overall energy consumption while ensuring optimal brightness where needed. Task lighting directs illumination to specific areas, such as desks or workstations, rather than lighting the entire room uniformly. This targeted approach reduces the need for excessive overhead lighting, leading to significant energy savings.

ii) Using efficient fixture

Using LED lighting is one of the most effective ways to reduce Lighting Power Density (LPD) in buildings. LED lights are highly energy-efficient compared to traditional lighting technologies, such as incandescent and fluorescent bulbs. LED provides same or higher levels of illumination while consuming significantly less power, which directly lowers LPD. Some of the key benefit of using LED are highlighted below:

Lower Power Consumption

- LEDs use up to 80% less energy than traditional bulbs reducing the overall energy required for lighting in a building.

Longer Lifespan

- LEDs last much longer than traditional bulbs, reducing the frequency of replacements and maintenance costs, while also ensuring consistent lighting performance over time.

Improved Luminous Efficacy

- LED have a higher luminous efficacy (lumens per watt) than most conventional light sources. This means they provide more light with less energy without sacrificing the quality of lighting.

Dimming Capabilities

- LEDs can be easily integrated with dimming controls, allowing further reduction of lighting power during low occupancy or when natural daylight is sufficient.

Instant Lighting

- Unlike fluorescent lights, LEDs reach full brightness immediately, avoiding the energy waste associated with the warm-up time of older technologies.

5.3.2 Efficient Exterior Lighting Fixtures

Exterior lighting is essential for security, safety, and aesthetic purposes, but it can also contribute significantly to a building's overall energy use. By upgrading to energy-efficient lighting fixtures, buildings can reduce energy consumption, minimize light pollution, and enhance sustainability while maintaining effective outdoor lighting. Some of the strategies for implementing efficient exterior lighting fixtures are provided below:

Adopt LED lighting

By replacing traditional exterior lighting with LED fixtures, buildings can drastically reduce energy consumption, often by 50-80%, and lower maintenance costs due to their long lifespan.

Utilize Solar-Powered Lighting

Solar-powered exterior lighting systems harness sunlight during the day to power outdoor fixtures at night, eliminating the need for grid electricity and are perfect for illuminating walkways, gardens, or parking lots in commercial centers

Incorporate Motion Sensors and Timers

Installing motion sensors and timers ensures that exterior lights are only in use when necessary. Motion sensors detect movement and activate lighting when someone is present, while timers can control lighting based on time-of-day schedules.

Implement Smart Lighting Controls and Dimming

Smart controls enable the automation of lighting systems, adjusting light levels based on environmental factors or occupancy. Dimming systems can reduce light intensity during off-peak hours, such as late at night, or when natural light is available.

Choose High-Performance Fixtures with Reflective Surfaces

The use of high-performance lighting fixtures equipped with reflective surfaces or light diffusers enhances the effectiveness of outdoor lighting. These fixtures direct light precisely where it's needed, reducing the need for multiple light sources while improving light distribution.

Best Practice: Use of Solar Lighting for Exterior Lighting

Solar-powered lighting is an eco-friendly and energy-efficient solution for exterior lighting. By using solar lights, energy consumption is reduced, electricity costs are lowered, and the carbon footprint is minimized. To ensure optimal performance, it is important to place solar lights in areas that receive sufficient sunlight during the day. This allows the lights to charge properly and provide adequate illumination at night.

Regular maintenance, such as cleaning the solar panels, helps in maintaining their efficiency. In solar lighting systems, maintenance involves cleaning solar panels to prevent dust buildup, checking battery performance, inspecting internal wiring, and ensuring that sensors and timer function correctly. Proper upkeep extends the lifespan of solar lighting systems, reduces energy consumption, and minimizes the need for costly repairs.

5.3.3 Maximize Use of Daylighting

Optimizing the use of daylight in buildings can reduce reliance on artificial lighting, lower energy consumption, and create healthier, more comfortable indoor environments. Properly implemented daylighting strategies not only contribute to energy savings but also improve the quality of the indoor space by enhancing the natural atmosphere.

Humans have an intrinsic preference for natural light, and research suggests that exposure to daylight enhances mood, focus, and overall satisfaction. In commercial spaces, daylighting has been linked to higher productivity among employees and improved customer experiences. For instance, retail chains like Walmart observed that departments illuminated by natural light achieved higher sales per square foot, demonstrating both environmental and economic benefits. Some of the common strategies to maximize the use of daylighting are explained below:

Strategic Window Placement

Proper placement of windows and glass doors ensures that natural light is maximized while minimizing direct heat gain. In tropical climates, windows should be oriented to take advantage of northern and southern exposures, which provide the most consistent natural light throughout the day without excessive solar heat. Large windows on these facades allow daylight to penetrate deep into the building, reducing the need for artificial lighting

Use of Skylights

Skylights are excellent solutions for introducing daylight into deeper or interior spaces that may not receive adequate natural
light from windows. Skylights, when properly designed and shaded, can flood the building with daylight, reducing the need for artificial lighting even in large spaces.

Daylight-Responsive Lighting Controls

Integrating daylight-responsive lighting controls (also known as daylight sensors) can automatically adjust the level of artificial lighting based on the available natural light in a space. When there is enough daylight, the system dims or turns off artificial lights.

Use of Light Shelves and Reflective Surfaces

Light shelves are horizontal surfaces placed above eye level to reflect sunlight deeper into the building, helping to distribute daylight more evenly across a room. They can be particularly effective in spaces with high ceilings or deep floor plans

Open Floor Plans and High Ceilings

Open floor plans and high ceilings allow daylight to reach deeper into the interior of the building. By reducing internal partitions and increasing vertical space, more natural light can penetrate further into the building, reducing the need for artificial lighting during the day

5.4 Measures for Comfort Systems and Controls

Enhancing energy efficiency and occupant comfort within buildings, ventilation and HVAC systems play a critical role as key ECM. These systems, responsible for regulating air quality, temperature, and humidity, offer significant opportunities for optimization. By implementing advanced control strategies such as demand-controlled ventilation (DCV), variable air volume (VAV) systems, and high-efficiency HVAC units, buildings can reduce energy consumption while maintaining a comfortable indoor environment. These ECMs not only improve energy performance but also contribute to better air quality, ensuring that both energy savings and occupant well-being are prioritized. This section discusses about ECMs for comfort systems and controls in buildings:

5.4.1 Optimization of Ventilation System

Ventilation systems are essential for maintaining indoor air quality and occupant comfort. However, they can also be a significant source of energy consumption if not properly optimized. Buildings can improve their air quality by implementing efficient ventilation strategies. Below are several ECMs designed to optimize the performance of ventilation systems:

i) Natural Ventilation

Mauritius has a tropical maritime climate, with warm and humid conditions for much of the year. While the temperature is relatively constant, humidity levels can make the air feel warmer. Natural ventilation in such climates can be highly beneficial, as it allows for passive cooling by bringing in fresh, cooler air and expelling hot, stale air from the building without relying on energy-intensive systems.

A well-designed natural ventilation strategy can improve occupant comfort by providing access to fresh air as well as reducing cooling energy requirements, resulting in lower capital and maintenance costs. There are several natural ventilation strategies that can be implemented in buildings in Mauritius:

Cross Ventilation

This method relies on having openings (such as windows, vents, or louvers) on opposite sides of a room or building to create a flow of air that moves from one side to the other. Buildings can benefit from natural airflow by strategically placing these openings and aligning them with prevailing wind directions.

Stack Ventilation

This technique uses the natural tendency of warm air to rise. By having high-level vents or openings at the top of a building, warm air can escape while cooler air enters from lower openings, creating a vertical flow of air. This method is especially effective in multi-story buildings.

Ventilated Roof Space

In tropical climates like Mauritius, roofs can be designed to facilitate the escape of hot air and allow fresh air to flow through the attic or upper floors. This can be particularly useful for preventing heat buildup in buildings.

Courtyards and Atriums

The use of open courtyards or atriums within buildings allows air to circulate freely, promoting ventilation and cooling. In densely built areas, incorporating these spaces can improve airflow and reduce reliance on air conditioning.

Design Considerations for Natural Ventilation

- ***Building Orientation:*** The orientation of the building should take advantage of prevailing wind directions to maximize natural airflow. In Mauritius, the trade winds typically come from the southeast, so buildings should be designed to capture and direct these winds into the interior.
- ***Window Placement:*** The placement and size of windows are crucial for effective natural ventilation. Windows should be positioned to allow for the cross flow of air while ensuring privacy and security. Additionally, windows with operable vents enable occupants to control ventilation.
- ***Building Layout:*** Open floor plans with minimal obstructions enhance airflow and natural ventilation. Rooms that require more cooling, such as kitchens or bathrooms, should be strategically placed to promote the escape of heat and moisture.
- ***Landscaping:*** The surrounding landscape can influence airflow and provide shading. Planting trees and vegetation around the building can act as windbreaks, provide shade, and reduce heat absorption, which in turn can improve the building's overall natural ventilation performance.

ii) Reduction of ventilation rate

Ventilation rate refers to the volume of air exchanged in a space over a given period, typically measured in cubic meters per hour (m^3/h) or cubic feet per minute (CFM). In Mauritius, building ventilation requirements are governed by local regulations to ensure occupant health and safety. The Building Control Act mandates that any new building or existing building accommodating more than 20 persons must be inspected by the relevant authority. While specific guidelines detailing minimum ventilation rates are not explicitly provided in the available Mauritian regulations, international standards ASHRAE 62.1[28] may serve as a reference and reliable benchmark.

Strategies to reduce ventilation rates:

Demand-Controlled Ventilation (DCV)

- DCV systems adjust ventilation rates based on real-time occupancy levels and indoor air quality. For example, CO_2 sensors in an office building can detect when the space is unoccupied or when fewer people are present, automatically reducing the ventilation rate accordingly. This approach ensures that energy isn't wasted on excessive ventilation when it's not needed.

Optimized Ventilation Based on Occupancy

- Reducing ventilation rates in low-occupancy periods (e.g., evenings, weekends, or holidays) can help save energy without compromising air quality. This can be done by programming the ventilation system to provide lower air exchanges during off-peak times or by using occupancy sensors to adjust the airflow dynamically.

Nighttime Ventilation

- In certain climates (such as in tropical regions), nighttime ventilation can be an effective strategy. During cooler evening hours, outdoor air can be brought into the building to cool it naturally, while reducing the need for mechanical cooling. Once the building reaches a certain temperature, the ventilation rate can be reduced or adjusted to maintain comfort.

Improving air tightness of building

- A well-insulated building envelope reduces need for mechanical ventilation, as it helps maintain stable indoor temperatures, prevent building up of heat or humidity that would typically require excessive ventilation. In some cases, reducing ventilation rate during cooler months can be achieved without sacrificing comfort by ensuring good insulation and airtightness in the building.

Heat Recovery Ventilation (HRV)

- HRV systems can allow buildings to reduce ventilation rates while maintaining a consistent supply of fresh air. These systems recover heat from the outgoing stale air and use it to preheat incoming fresh air, thus reducing the need for additional heating or cooling. This method ensures energy efficiency while still providing sufficient ventilation.

Point to Note:

Reducing ventilation rate must be implemented carefully to balance energy savings with maintaining healthy indoor air quality. A mechanical ventilation consumes significant amounts of energy, so reducing the rate at which air is exchanged can reduce energy consumption. However, it's important to ensure that the ventilation rate still meets the required standards for occupant comfort and health.

[28] ANSI/ASHRAE Standard 62.1-2022, Ventilation and Acceptable Indoor Air Quality. The American Society of Heating, Refrigerating and Air-Conditioning Engineers.

iii) Installation of local ventilation and makeup air hoods

In Mauritius, the installation of local ventilation and makeup air hoods in commercial buildings is governed by several regulations aimed at ensuring safety, health, and environmental standards. The key regulations include Building Control Act, Fire Code, Building Regulations 1919 etc. The key consideration for installation involves balanced airflow, proper placement of diffusers and maintaining temperature control.

Following points may be considered to ensure the compliance with regional requirements and international best practices:

- Ensure that ventilation hoods are appropriately sized for the specific application. The design should facilitate efficient capture and containment of contaminants, preventing their spread into occupied spaces.
- Ensure the makeup air volume matches the exhaust volume to maintain neutral pressure. The Uniform Mechanical Code (UMC)[1] specifies that "The make-up air quantity shall prevent negative pressures in the commercial cooking area(s) from exceeding 0.02-inch water column".
- Utilize energy-efficient equipment and consider heat recovery systems to minimize energy consumption. Regular maintenance ensures that systems operate at peak efficiency, reducing operational costs.
- Maintain a slight negative pressure in areas like kitchens to prevent the spread of contaminants to other parts of the building. This requires careful coordination between exhaust and makeup air systems.
- The temperature differential between makeup air and the conditioned space should not exceed 6°C to ensure occupant comfort and system efficiency.

iv) Reduce infiltration in HVAC Systems

Air infiltration is the unintentional entry of outdoor air into a building through cracks, gaps, or poorly sealed openings. It is a major contributor to increased HVAC energy loads. Reducing infiltration helps maintain desired indoor temperatures, reduces energy waste, and improves indoor air quality and comfort. Common source of infiltration includes gaps around doors and windows, poorly sealed electrical and plumbing penetrations, cracks in walls or foundations, unsealed ductwork or ventilation shafts, and elevator shafts and stairwells.

Reducing infiltration is a low-cost ECM which improves building performance and HVAC efficiency. It is especially beneficial in climates with extreme outdoor temperatures or high humidity (tropical climates). There can be a reduction of 5 % - 20 % of HVAC energy use, depending on leakage in the envelope or system.

Some of the best practices to reduce the infiltration are provided in the Figure. These best practices can be applicable while designing the HVAC system ductwork and during construction stage with respect to the envelope.

5.4.2 Energy Efficient HVAC Systems

An energy-efficient HVAC system is a critical component of any building's strategy to reduce energy consumption while maintaining occupant comfort. Implementing energy-efficient HVAC systems not only reduces operational expenses but also contributes to sustainability goals by lowering the building's carbon footprint. Below are several ECMs designed to enhance the energy efficiency of HVAC systems in buildings:

i) Improved cooling efficiency

Mauritius experiences a very warm and humid climate during summer (October-April) season and therefore, making air conditioning in public and commercial buildings a major energy consuming appliance. The energy audits and surveys have revealed that air conditioners accounts for approximately 40 % to 60 % of the total energy use[29] in these buildings. On a national scale, it's estimated that air conditioners contribute to about 15 % of the country's total electricity consumption.

EEMO has developed the Energy Efficiency regulations (Minimum energy performance standards for regulated machinery)[30] for the procurement of energy-efficient air-conditioned. These MEPS regulations is mandatory for certain type of air-conditioner units right now and define the minimum efficiency in terms of EER or CSPF. The energy efficiency standards value and type of air-conditioner is provided below in the Table 12:

Table 12: Minimum energy performance standards and type of air-conditioner

Type of air conditioner	Energy Efficiency parameter
Self-contained[31]	CSPF ≥ 4.5
Ductless split	CSPF ≥ 4.5
Double duct portable	EER ≥ 3.1
Single duct portable	EER ≥ 3.1

Selecting Energy Efficient Equipment

Energy efficiency of air conditioners is reported in terms of Cooling Seasonal Performance Factor (CSPF) Replacing old and inefficient air conditioners offers high energy saving opportunities. Higher efficiency HVAC system can be identified and recommended based upon their energy-rating labels.

Most of the countries have developed standards and labelling programs for consumers to make informed decisions while selecting air conditioners. It is therefore important to note how the rating scheme corresponds to the product's efficiency. These labels offer a simple identification method for consumers to select more efficient products in the market. In line with the EU regulations on labelling and various other regulations and communications developed by EEMO along, some of the best practices may be considered with respect to energy-efficient air conditioners in the commercial buildings:

- Choosing HVAC units with the energy efficiency labels to ensure high energy efficiency and lower carbon emissions.
- Select HVAC units with high CSPF or, EER ratings, as these indicate superior energy efficiency.

The EU Energy labelling ranks all models of certain type of products within certain energy class range, typically from A+++ (most efficient) to D (least efficient). It covers the energy efficiency classes for air conditioners (except double ducts and single ducts).

ii) Air flow and fan speed reduction

In traditional HVAC systems, fans often operate at constant speeds regardless of the heating or cooling demand. However, most modern HVAC systems can benefit from adjusting fan speeds according to real-time requirements. By using technologies such as Variable Speed Drives (VSDs) or Variable Frequency Drives (VFDs), the fan speed can be modulated to match the demand for airflow, optimizing the system's energy use.

[29] https://eemo.govmu.org/Pages/Awareness/Awareness-Campaign-on-Air-Conditioner
[30] Energy Efficiency (Minimum Energy Performance Standards for Regulated Machinery) Regulations 2025. Regulations made by the Minister under section 23 of the Energy Efficiency Act, The Energy Efficiency Act 2025.
[31] **Self-contained** refer to window-type air conditioners.

The fan laws are a set of principles that explain the relationship between fan speed, airflow, and energy consumption. One important principle is that the energy required by a fan is proportional to the cube of the speed. This means that a slight reduction in fan speed can result in a significant reduction in energy consumption. For example:

- Doubling the fan speed can increase the energy consumption by eight times.
- Reducing the fan speed by 20% can lead to up to 50% energy savings.

Implementation strategies for air flow and fan speed reduction:

Install Variable Speed Drives (VSDs) or Variable Frequency Drives (VFDs):

VSDs and VFDs are devices that control the speed of electric motors by varying the frequency of the electricity supplied. Installing these drives on HVAC fans allows the system to adjust fan speed based on the actual demand, which can result in significant energy savings. They are particularly effective for systems that experience fluctuating loads, such as those in commercial and industrial buildings.

Install Demand-Controlled Ventilation (DCV):

Demand-controlled ventilation systems adjust the airflow based on real-time occupancy or indoor air quality levels. By integrating sensors to detect CO2 levels or occupancy, DCV systems ensure that ventilation rates are reduced when the building is not fully occupied, further optimizing energy use.

Optimize System Design:

When designing or retrofitting HVAC systems, it's important to plan for variable airflow requirements. This can involve properly sizing fans and ducts to ensure that the system can adjust airflow when necessary. Additionally, using energy-efficient fans designed for variable speeds can improve system performance and energy efficiency.

Regular Monitoring and Adjustment:

Implementing monitoring systems to track airflow and fan performance is essential for ensuring optimal operation. By continuously monitoring key metrics such as energy consumption, airflow, and temperature, facility managers can adjust as needed to optimize fan speeds for efficiency. For instance, system performance can be adjusted in response to seasonal changes, occupancy patterns, or operational requirements.

Building Automation Systems (BAS):

Integrating fan speed control into a Building Automation System (BAS) can help manage airflow and fan speed in real time. A BAS can automatically adjust fan speeds based on factors such as time of day, occupancy, or changes in outdoor temperature, ensuring that the HVAC system operates efficiently and effectively.

Regular Maintenance:

Ensure that HVAC systems, particularly fans and motors, are regularly maintained to operate efficiently. Regular inspection of components like fan belts, filters, and motors can help identify issues before they lead to reduced efficiency or increased energy consumption.

iii) Use of efficient chillers

In tropical climates, where cooling demands are consistently high due to year-round high temperatures and humidity, HVAC chillers are essential to maintaining comfortable indoor environments. However, the energy consumption of chillers in these climates can be substantial. Below are some energy-saving opportunities while using chillers as HVAC system.

Upgrade to Energy-Efficient Chillers

- Replacing older chillers with high-efficiency models, such as centrifugal or screw chillers, can reduce cooling energy consumption by 20-30 %. These models are designed to handle the demands of tropical climates, offering improved performance and reduced operational costs due to advanced refrigerants and variable-speed drives.

Optimizing Chiller Plant Design and Operations

- Implementing smart controls with variable-speed drives for compressors, pumps, and cooling towers ensures that the chiller plant operates efficiently by adjusting to actual building load demands and changing external conditions, reducing energy waste and improving system responsiveness in tropical climates.

Integration with Building Management Systems (BMS

- By integrating chillers into a Building Management System (BMS), real-time data can optimize cooling output based on factors like temperature, humidity, and occupancy, ensuring efficient operation. This integration helps detect inefficiencies early and adjust cooling settings dynamically, reducing energy consumption and preventing overcooling.

Use of Free Cooling

- During cooler periods, airside and waterside free cooling strategies can be used to bypass the chiller system, leveraging outdoor air or cooler water sources to reduce the load on chillers. This significantly cuts energy consumption, especially during the night or in seasons when external temperatures are lower than the internal cooling demand.

Chiller System Load Shedding and Demand Response

- Implementing demand-side management techniques like load shedding can reduce chiller output during peak energy demand periods, either automatically or through manual control. This reduces electricity costs by minimizing peak load demand, which is especially beneficial in tropical climates with high daytime cooling loads.

Hybrid and Dual-Purpose Chillers (Heat Recovery):

- Heat recovery chillers can repurpose waste heat from the cooling process for other building needs, such as domestic hot water. This reduces the need for separate heating systems, improving energy efficiency and lowering overall energy consumption in tropical climates where cooling demands are high.

Efficient Cooling Towers

- Optimizing cooling towers with variable-speed fans helps improve heat rejection efficiency, especially in tropical climates where ambient temperatures and humidity are high. This reduces the workload on chillers, resulting in lower energy use and more effective system performance.

Best Practices for Operation & Maintenance of HVAC System

- Clean evaporator and condenser coils regularly to prevent dirt and debris buildup, which can reduce heat transfer efficiency. This ensures optimal cooling performance and avoids overloading the HVAC system.
- Replace or clean air filters to maintain proper airflow, which is essential for maintaining cooling efficiency and preventing the system from working harder than necessary.
- Inspect and clear condensate drains to prevent blockages and ensure proper drainage, avoiding water buildup and potential system issues.
- Regularly evaluate and adjust temperature setpoints to maintain comfort without excessive energy use. In tropical climates, ensure the system is not set to too low of a temperature, which increases the load on HVAC system.
- Implement nighttime temperature setbacks, where cooling is reduced during off-hours when the building is unoccupied or less active, reducing unnecessary energy consumption.
- Regularly check for unusual vibrations or noise that could indicate mechanical issues, such as worn-out bearings or misalignment, which can affect performance and lead to costly repairs.
- Regularly check the refrigerant charge levels to ensure they are within the manufacturer's recommended range. Low refrigerant levels can lead to reduced cooling efficiency, higher energy consumption, and system damage.
- Preventive Maintenance on Motors and Compressors
- Motor Check: Inspect and clean motors regularly to prevent overheating, which could lead to motor failure. Ensure proper lubrication of moving parts to reduce wear and tear.
- In tropical climates, the cooling load may vary slightly with the seasons. Adjust system settings to optimize efficiency during the peak cooling season. For example, consider adjusting temperature setpoints based on higher outdoor temperatures during peak months.
- Encourage building operators to identify energy waste, such as overcooling or improper setpoint adjustments, and implement corrective actions.

Best Practices for Operation & Maintenance of Chiller

- Chiller Temperature and Coil Reset: Regularly check and adjust the chilled water setpoint temperature. Avoid overcooling by resetting the temperature based on actual building needs rather than fixed schedules.
- Ensure the temperature differential between supply and return water is within the recommended range. A large differential indicates the chiller is overloaded, while a small differential shows insufficient cooling capacity.
- Based on cooling demand and outdoor conditions, reset the chiller's temperature controls to match actual requirements, improving energy efficiency and reducing excess power consumption.
- Utilize smart thermostats and building management systems (BMS) to optimize AC and chiller operation. Set temperature levels to match occupancy and operational schedules, preventing the system from cooling unnecessarily when rooms are empty.
- Implement chiller sequencing, where multiple chillers are staged to operate in sequence depending on the cooling load. This ensures that the system doesn't operate with more capacity than necessary, minimizing energy waste.
- Use data from Building Management Systems (BMS) to adjust chiller setpoints dynamically based on real-time cooling needs, occupancy, and environmental conditions. This ensures that chillers don't run unnecessarily or provide more cooling than needed.
- Ensure that maintenance staff and building operators are trained in the latest chiller technologies, energy-saving practices, and troubleshooting techniques. Proper knowledge can significantly reduce operational inefficiencies.
- Water Flow and Fan Speed: Ensure the cooling tower's water flow rate and fan speed are optimized for the building's cooling load. Variable-speed drives on fans can help adjust fan speed to outdoor conditions, improving energy efficiency.
- Regularly clean and treat cooling tower water to prevent scale, algae, and bacteria buildup, which can reduce heat exchange efficiency and lead to equipment damage.

iv) High-efficiency filters

HVAC systems rely on filters to trap particles and prevent them from circulating throughout the building. Traditional filters can become clogged quickly, increasing the resistance to airflow and forcing the system to work harder, consuming more energy. High-efficiency filters, such as HEPA (High-Efficiency Particulate Air) or MERV (Minimum Efficiency Reporting Value) rated filters, are designed to trap smaller particles with greater efficiency, which reduces the frequency of filter changes, enhances system performance, and can lower the overall energy consumption. Below are some implementation strategies for buildings in Mauritius:

Upgrade to High-Efficiency Filters

- Replacing standard filters with HEPA or high MERV-rated filters (typically MERV 13 or higher) can provide better filtration while maintaining adequate airflow. Depending on the building's requirements and existing HVAC system specifications, selecting the right level of filtration is key.

Regular Maintenance and Monitoring

- It's important to regularly monitor and maintain high-efficiency filters to ensure that they are functioning properly. Over time, even high-efficiency filters can become clogged, which may reduce airflow and energy savings. Scheduling periodic checks and replacements is essential for maintaining the system's efficiency.

Use of Filter Pressure Monitoring

- Installing pressure gauges to monitor the pressure drop across the filter can help determine when filters need to be changed. This ensures that the HVAC system is not forced to work harder than necessary due to clogged filters.

Customized Filtration for Specific Needs

- Depending on the building's requirements (e.g., healthcare facilities, laboratories, offices, or commercial spaces), selecting the appropriate filter rating (e.g., MERV 13, HEPA) can help to balance air quality, system performance, and energy efficiency. Some environments may require the highest levels of filtration, while others may benefit from less restrictive options that optimize both filtration and airflow.

v) Pumps

Pumps play a crucial role in reducing energy consumption and operational costs across various sectors, including industrial processes, water and wastewater management, and HVAC systems. Every pump is designed to operate at a specific range of duty point (i.e. a specific range of flow and head) and within this range the operational efficiency of the pump is highest. Therefore, it is quite essential to select optimum pump size, as the operating efficiency may reduce if the pump is operated outside the high efficiency range (of flow and head). It is advised to refer the pump curves (provided with technical specifications by manufacturer) while selecting a pump.

Key Features of Energy Efficient Pumps

- Optimized Hydraulic Design: Improved impeller and volute designs enhance flow dynamics, reducing friction losses and increasing overall pump efficiency.
- High-Efficiency Motors: Modern pumps often incorporate premium efficiency motors (such as IE3 or IE4 class), which reduce energy losses during operation.
- Variable Frequency Drives (VFDs): VFDs adjust motor speed to match system demand, preventing over-pumping and reducing energy waste.
- System Integration: Smart pump systems can monitor operating conditions in real time and adjust performance for optimal efficiency, minimizing downtime and unnecessary energy use.

Best Practices for using Pumps

- Avoid oversizing and perform accurate load calculations to analyze system head and flow requirements.
- Install VFDs to modulate pump speed based on actual system demand (e.g., chilled water or hot water flow).
- Reduces energy consumption during part-load conditions, which dominate in HVAC systems.
- Use high efficiency motors that meet or exceed IE3 (Premium Efficiency) or IE4 (Super Premium Efficiency) standards, which leads to reduced losses in motor windings and improved design deliver long-term savings.
- Integrate pumps into a Building Management System (BMS) or Energy Management System (EMS) to continuously monitor temperature, pressure, and flow.
- Implement Variable Primary Flow (VPF) Systems for chilled water systems, which will reduce the need for secondary pumping.
- Use differential pressure sensors across the system to enable pumps to modulate speed precisely. It helps maintain constant flow in variable flow systems with dynamic load profiles.
- Perform regular maintenance and monitoring for motor seal integrity, bearing lubrication, impeller wear, and motor alignment.
- Monitor energy use and performance with sub-metering or smart monitoring tools.
- Use predictive maintenance tools (e.g., vibration sensors) to avoid downtime and inefficiencies.
- Ensure proper pipe sizing to reduce friction losses and pump energy use.
- Optimize piping layout to minimize elbows, reducers, and restrictions that raise system resistance.
- Select pumps with optimized hydraulic profiles (e.g., computational fluid dynamics [CFD] optimized impellers) or choose pumps that meet high energy rating scores.
- Ensure proper setup of pumps during installation with functional testing/balancing.
- Periodically re-commission systems to align pump operation with current load profiles and occupancy patterns.

vi) Heat recovery system

Heat recovery can significantly enhance the energy efficiency of buildings in Mauritius due to its tropical climate. This technique involves capturing and reusing waste heat from processes, HVAC systems, or other operations, reducing the need for additional heating or cooling energy. The most common type of heat recovery system includes heat recovery ventilator, energy recovery ventilator, and waste recover ventilators. A brief about different type of heat recovery system is presented in Figure 23:

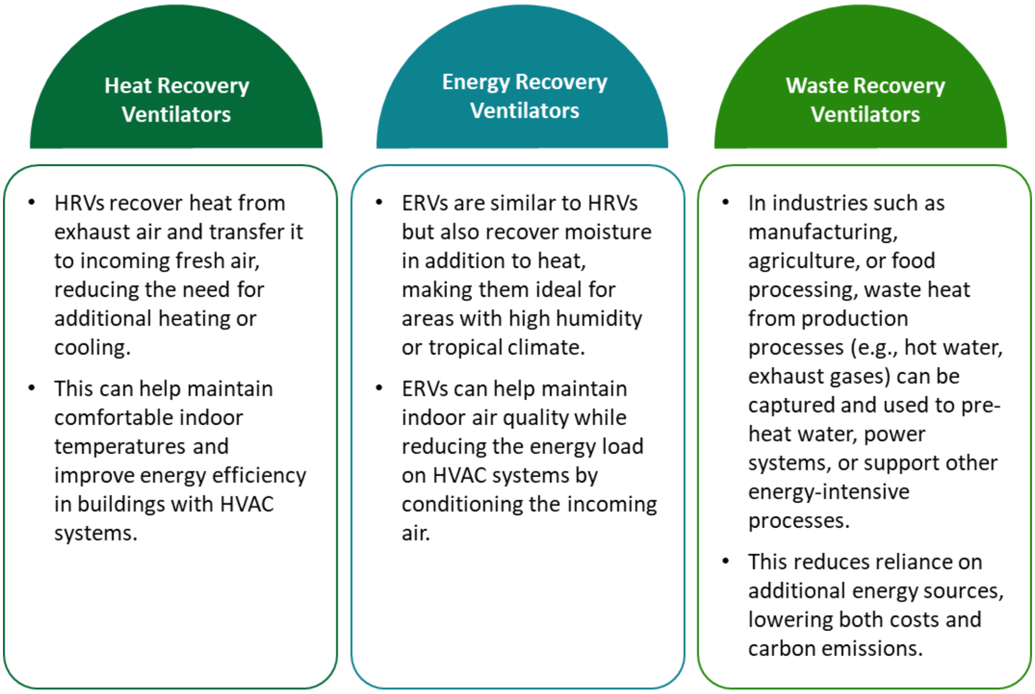


Figure 23: Different type of heat recovery systems

In the context of tropical climate country, below are some of the implementation strategies for heat recovery systems:

- **Building Integration (HRVs and ERVs):** In both residential and commercial buildings in Mauritius, integrating HRVs and ERVs into HVAC systems can be an efficient way to recover heat. These systems are particularly useful in buildings that require continuous ventilation and air quality management, such as hotels, offices, and public buildings. ERV systems offer a solution by transferring both sensible and latent energy between incoming and outgoing airstreams, significantly reducing HVAC energy demand.
- **Industrial Heat Recovery:** In industrial sectors like sugar production, food processing, and manufacturing, where high-temperature processes generate waste heat, capturing and using this heat for preheating or generating power can result in considerable energy savings. The use of heat exchangers and heat recovery boilers can be explored for this purpose.
- **District Energy Systems:** Large-scale heat recovery could also be integrated into district heating systems. By collecting waste heat from power plants, large buildings, or industrial facilities, this heat can be redistributed to nearby buildings for heating water or air. This method is especially viable in urban areas in Mauritius to reduce overall energy demand.

In tropical climates like Mauritius, where high temperatures and humidity levels are constant, ventilation systems face the dual challenge of maintaining indoor air quality while minimizing cooling and dehumidification loads.

vii) Energy-Efficient Motors

The motors are an integral part of the HVAC system as the HVAC system uses motors to drive key component such as Fans for air circulation, Pumps for water circulation, and compressor for refrigeration. In traditional systems, motors often operate at a constant speed, consuming more energy than necessary for varying load conditions. Energy-efficient motors (such as premium efficiency motors or variable speed motors) are designed to consume less power and adjust their operation based on the actual needs of the system.

The key performance parameter for an electric motor is typically measured using the International Efficiency (IE) class. In Mauritius, the efficiency standards for electric motors in commercial buildings are guided by IEC 60034-30 standard. This standard classifies motor efficiency into several classes, with IE1 being Standard Efficiency, IE2 as High Efficiency, and IE3 as Premium Efficiency. The Figure below shows the different IE class for 4-pole motors according to IEC 60034-30-1:2014 standard[32].

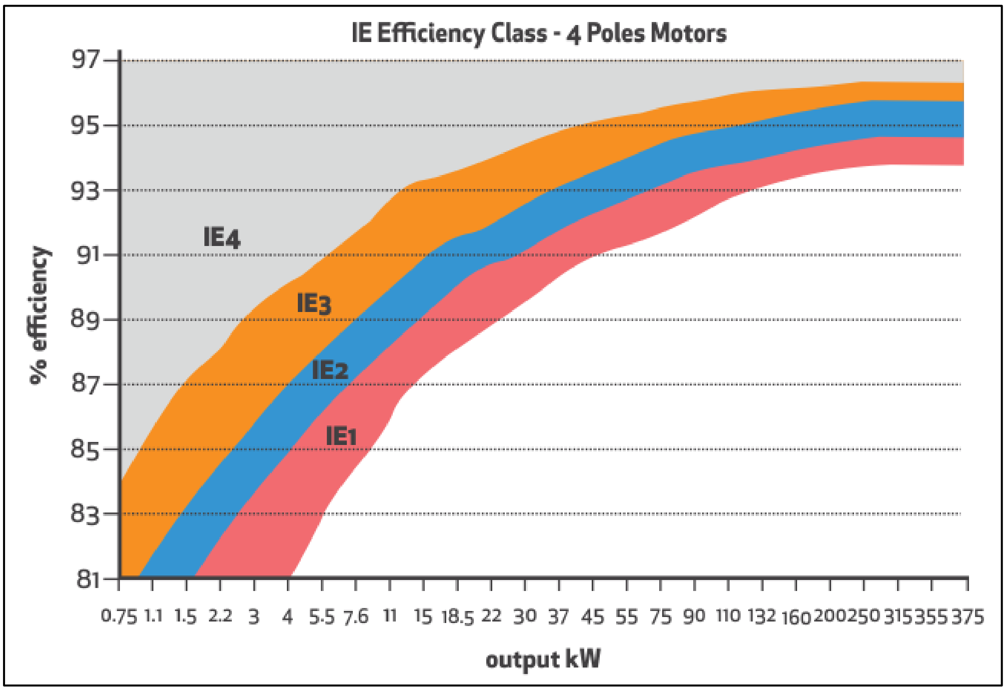


Figure 24: Efficiency and output relation for 4-pole motors

Following strategies for energy efficient motors can be implemented in the HVAC systems:

- **Motor Selection:** Choose premium efficiency motors or high-efficiency motors that meet or exceed the efficiency standards set by organizations like the International Electrotechnical Commission (IEC) or the National Electrical Manufacturers Association (NEMA). These motors are designed to provide better performance while consuming less energy.
- **Variable-Speed Drives (VSDs):** Install Variable-Speed Drives (VSDs) or Variable Frequency Drives (VFDs) to optimize motor speed based on demand. VSDs allow motors to run at speeds that match the actual needs of the system, reducing energy consumption during periods of low demand (e.g., at night or during off-peak hours). For example, fans and pumps can slow down when full capacity is not needed, leading to substantial energy savings.
- **Retrofit Existing Motors**: In buildings with older HVAC systems, consider retrofitting existing motors with energy-efficient versions. This can be more cost-effective than replacing the entire system, especially when

[32] Int. Electrotechnical Commission (IEC), Standard for Efficiency classes of line operated AC motors (IE code), no. 60034-30-1:2014, 2014.

upgrading to motors that are compatible with existing components. Retrofit kits, such as variable-speed drives, can also be installed on existing motors to make them more efficient.

- **Regular Monitoring and Maintenance:** To ensure energy-efficient motors continue to perform optimally, implement regular monitoring and maintenance programs. This can include routine inspections, lubrication, and cleaning, as well as monitoring energy consumption to ensure that motors are operating efficiently.
- **Energy Management Systems (EMS):** Integrate energy-efficient motors with Energy Management Systems (EMS) that track energy use and optimize HVAC operations. An EMS can provide real-time data on energy consumption and system performance, helping facility managers make informed decisions to further reduce energy usage.

vi) Green Refrigerants

Globally, stationary AC systems account for nearly 700 million metric tons of direct and indirect CO_2-equivalent emissions ($MMTCO_2e$) annually. Indirect emissions from electricity generation account for approximately 74 % of this total, while direct emissions of hydrofluorocarbon (HFC) and hydrochlorofluorocarbon (HCFC) refrigerants account for 7 % and 19 %, respectively. Direct emissions can occur from leakage during use and/or release at end-of-life due to poor deconstruction and recycling practices. Addressing direct emissions is a crucial step in significantly reducing GHG emissions. Additionally, the use of green refrigerants or low-GWP refrigerants presents an opportunity for efficiency improvements in equipment, which can also lead to reductions in indirect emissions.

Reducing direct emissions presents a crucial opportunity to significantly mitigate overall greenhouse gas (GHG) emissions in the HVAC sector. One of the most effective strategies is the adoption of low-GWP refrigerants, which have a GWP of 100 or less, compared to traditional high-GWP refrigerants. These low-GWP alternatives, such as R-32, R-290 (propane), R-1234yf, and CO_2 (R-744), can reduce direct emissions by up to 75 % or more. By using refrigerants that are less harmful to the environment, HVAC systems can contribute to the global effort to reduce the impact of climate change.

Additionally, improving the efficiency of HVAC systems plays a significant role in reducing overall emissions. Though the upfront cost of adopting low-GWP refrigerants and redesigning systems to accommodate them may be higher, these initial expenses can be offset over time through lifecycle energy savings. Energy-efficient systems consume less electricity, reducing the associated indirect emissions. Over time, the reduced operational costs and energy consumption can lead to lower total costs for consumers, making the transition to green refrigerants both economically and environmentally beneficial in the long run.

5.5 Measures for Equipment and Appliances

In modern building design and management, the integration of efficient and sustainable equipment and appliances is essential to reduce operational costs, ensure safety, and minimize environmental impact. Whether it's in residential, commercial, or industrial spaces, selecting the right equipment and appliances can greatly influence energy consumption, water use, and the overall environmental footprint of a building. This section discusses about the different measures for equipment and appliances in the building and how it can be used as ECMs to enhance the energy efficiency of the building.

5.5.1 Refrigeration and Green Refrigerants

The main areas of electricity use in commercial sector in Mauritius are refrigeration, air conditioning and decorative and security lighting[33]. In 2024, the total energy consumption of commercial refrigeration was close to 70 GWh in the country[34]. The refrigeration load in commercial buildings varies based on the building type and utilization. For example, an office building will have a lower refrigeration load than a retail store for grocery and food products. Modern refrigerator models feature improved insulation, high-efficiency heat exchanger coils and advanced compressors, significantly enhancing their energy performance. Some of the benefit of energy efficient refrigeration are:

- Energy-efficient refrigerators consume less power, reducing operational costs.
- Advanced technology reduces wear and tear, leading to fewer repairs and longer appliance life.
- Generates less heat, reducing the strain on air conditioning systems and lowering cooling expenses.
- Lowers carbon footprint by reducing energy consumption and using eco-friendly refrigerants.
- Maintains stable temperatures, ensuring better food preservation in hotels, supermarkets, and hospitals.

Status of Energy Efficiency Labelling for Refrigerators in Mauritius

Mauritius has established stringent energy efficiency standards for refrigerating appliances under the Energy Efficiency (Labelling of Regulated Machinery) Regulations 2017 (GN 11/2017), issued under the Energy Efficiency Act for domestic refrigerators. These regulations mandate that refrigerating appliances must comply with the Commission Delegated Regulation (EU) 2019/2016, requiring an efficiency class of E or higher on the EU energy label for only public institutions. Refrigerating appliances with a direct sales function (formerly Commercial Refrigeration (CF) are those used to display refrigerated or frozen foods or drinks. Typically, they can be accessed directly by consumers in e.g. supermarkets, public indoor spaces, and offices. Following Figure 25 represent an energy label for EU commercial refrigerator.

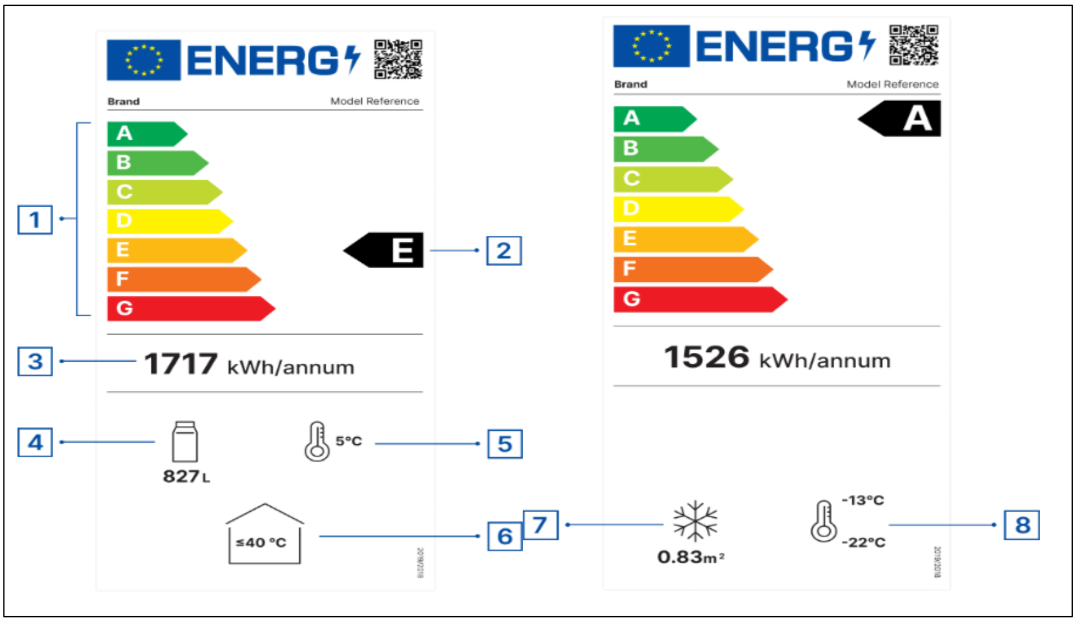


Figure 25: EU Commercial Refrigerator Energy Label

[33] Energy Efficiency Management Office (2022). Energy Observatory Report 2020
[34] United for Efficiency (2024). Mauritius Savings Policy Assessment. https://united4efficiency.org/country-assessments/mauritius/

Best Practices for Refrigeration

- Set the Right Temperature: Maintain 3-5°C for refrigerators and follow the manual for cooler settings.
- Optimal Placement: Keep away from heat sources like ovens, dishwashers, radiators, and direct sunlight.
- Ensure Proper Ventilation: Leave at least 6 inches behind the unit for airflow; blocked condensers can increase operating costs by up to 5%.
- Check and Replace Door Seals: Worn-out seals cause leaks, increasing energy use by up to 10%. Use a slip of paper or flashlight test to check for gaps.
- Avoid Overloading: Ensure proper air circulation inside the refrigerator by not overfilling with food items.
- Cool Food Before Storage: Allow hot food to cool before placing it inside; use airtight containers to reduce energy use and condensation.
- Defrost Regularly: Ice buildup in manual defrost models acts as insulation, reducing cooling power.
- Clean Condenser Coils: Dust buildup makes the compressor work harder. Clean the coils regularly using a brush or vacuum after unplugging.
- Schedule Maintenance: Use authorized service providers for repairs and maintenance to keep efficiency high.
- Consider Replacement: If an older refrigerator requires major repairs, it may be more cost-effective to replace it with an energy-efficient model.

Green Refrigerants

Addressing direct emissions due to the use of conventional refrigerants (HFCs and HCFCs), offers an important path to substantially reducing GHG emissions. Many available low-GWP alternative refrigerants having GWPs of 100 or less, can potentially reduce 75% or more of all direct emissions. Efficiency improvements can help offset the higher upfront purchase costs for consumers associated with more expensive refrigerants and system redesigns by delivering significant energy savings over the lifecycle of the equipment.

A few examples of green refrigerants include R-32, R-290 (propane), R-1234yf, and CO2 (R-744). These eco-friendly refrigerants help optimize energy efficiency, lower operating costs, and meet environmental regulations, supporting the shift toward more sustainable and responsible energy use in building climate control.

Natural refrigerants offer several significant advantages, including a zero-ozone depletion potential (ODP), an extremely low global warming potential (GWP), and the fact that they are part of natural biogeochemical cycles. These substances do not persist in the atmosphere, water, or biosphere. Examples of natural refrigerants include carbon dioxide, ammonia, and hydrocarbons such as propane, propene, and isobutane. These refrigerants are commonly used in various refrigeration and air-conditioning (RAC) applications, with isobutane frequently used in household refrigerators and ammonia in large-scale cooling systems.

A "green" refrigerant would combine the environmental benefits of natural refrigerants while also being energy efficient.

5.5.2 Use of Positive Cold Rooms for Cold Storage

Positive cold rooms are temperature-controlled storage environments typically maintained above 0 °C (32 °F), usually in the range of +1 °C to +15 °C. These rooms are designed to store products that require cool but not freezing conditions, making them ideal for preserving the freshness, quality, and safety of perishable goods.

Positive cold rooms use standard refrigeration systems with moderate insulation, usually 80–100 mm thick polyurethane panels, and are built to withstand frequent access, making features like airtight doors, air curtains, or PVC strip curtains essential for maintaining temperature stability. These rooms consume a significant amount of energy due to continuous refrigeration, insulation losses, and frequent access. Optimizing the design, operation, and maintenance of positive cold rooms offers a high-impact ECM that reduces energy consumption, operational costs, and carbon emissions, while preserving product quality and safety.

Best Practices for Positive Cold Room

- Maintain Optimal Temperature Control: Set and maintain the temperature between +2 °C to +8 °C based on the specific needs of the stored goods.
- Use high-accuracy thermostats and temperature sensors to ensure consistent conditions. Avoid large temperature fluctuations by setting narrow deadbands to minimize compressor cycling.
- Use high efficiency insulation to Insulate walls, ceilings, and floors with high-quality materials such as polyurethane panels (80–100 mm thick), which help prevent heat ingress from the external environment.
- Regularly inspect insulation for damage or wear that could result in thermal leaks.
- Seal air leaks effectively around doors, vents, and penetrations as improper seals lead to energy wastage and increased cooling loads.
- Regularly check door gaskets for wear and replace them when needed.
- Ensure that refrigerant lines, electrical conduits, and other penetrations are properly sealed.
- Install automatic door closers and air barriers to minimize the risk of air infiltration.
- Air curtains or PVC strip curtains can be used near doors to create a barrier that reduces warm air from entering during frequent access.
- Select high-efficiency compressors, evaporators, and condensers to reduce energy consumption.
- Consider low-GWP refrigerants to meet sustainability goals and reduce environmental impact.
- Install VFDs on evaporator and condenser fans, as well as on compressors, to adjust motor speeds based on real-time cooling needs.
- Implement a preventive maintenance schedule for regular checks on compressor performance, evaporator and condenser coils, fan motors, and door seals.
- Clean coils regularly to remove dust and debris, ensuring that heat exchange efficiency remains optimal.
- Regularly inspect and clean drain pans to prevent ice buildup, which could affect cooling efficiency.
- Store products strategically to avoid blocking air vents or obstructing airflow, which can lead to uneven cooling.
- Avoid overcrowding the cold room, as this restricts airflow and increases the load on the refrigeration system.
- Educate staff on best practices for operating cold rooms, such as minimizing door openings, proper loading, and ensuring doors close properly.

PVC strip curtains are used in cold storage to minimize cold air loss and prevent warm air infiltration during door openings, thereby maintaining temperature stability and reducing energy consumption. For optimal performance, strips should be transparent, flexible, and of appropriate thickness (2-4 mm) with sufficient overlap (50-70 %) to create an effective barrier.

Regular cleaning and timely replacement of damaged strips are necessary to maintain hygiene and durability. Training staff to move carefully through the curtains and manage door use efficiently further enhances the cold room's operational efficiency and safety.

5.5.3 Office Equipment

Office equipment is the fastest growing energy user in the business world, consuming 15 % of the total electricity used in offices. This category includes commonly used office equipment such as computers, monitors, printers, fax machines, and photocopiers, as well as less frequently used but high-energy-consuming devices like projectors, computer servers, scanners, and tele-conferencing systems. Given their integral role in daily operations within commercial spaces, it is essential to monitor their energy consumption and enhance energy efficiency. There are several measures which can be implemented as part of an overall energy management strategy are explained below:

i) Energy- efficient office appliances

- **Monitors & Computers:** Select energy efficient models that are compliant with Energy Efficiency Labelling standards or other relevant energy efficiency certification. This includes energy-saving features such as automatic sleep modes and low-power settings for both desktops and laptops. The adoption of low-energy equipment with automatic standby features enhances overall efficiency. Reducing operational time extends equipment lifespan, lowers maintenance costs, and decreases the risk of breakdowns.
- **Printers and Photocopiers:** Choose printers, copiers, and multifunction devices that are energy-efficient, have duplex printing capabilities to reduce paper waste, and feature power-saving modes.
- **Smart Thermostats:** Install programmable or smart thermostats that adjust heating and cooling based on occupancy, time of day, and outdoor temperature, optimizing the energy used by HVAC systems.
- **Smart power strips and timers:** Use smart power strips or surge protectors that cut power to devices when they are not in use. Many office devices draw power even when they are turned off, known as "phantom load" or "standby power." These power strips can reduce this wasted energy. **Timers** can be used for office equipment such as printers, copiers, or coffee machines to ensure they are only operating during necessary times, and turned off when the office is closed, or equipment is not in use[35].

ii) Energy management system

- **Integrated Control Systems:** Use energy management systems to monitor and control the energy consumption of office equipment. EMS allows for centralized management of equipment, including lighting, HVAC, and office electronics, making it easier to identify areas where energy can be saved.
- **Building Automation:** Implement a building automation system that integrates office equipment and systems to ensure that energy usage is optimized across all devices and appliances. For example, the system can shut down devices when not in use or adjust settings based on usage patterns.

iii) Establishment of policy for use and awareness

Small and medium-sized companies often let employees manage their own PC settings, while larger firms have centralized control. Encouraging both IT departments and users to activate standby modes can save energy. Establishing a policy that includes energy efficiency tips and procurement guidelines ensures smarter equipment choices, Standardizing equipment setup, maintenance, procurement, considering running costs. Some practices which can include are:

- Encourage employees to turn off office equipment when not in use, use energy-saving modes on computers, and be mindful of energy consumption in their workstations.
- Offer training sessions on energy conservation techniques and provide incentives for employees who actively contribute to reducing energy consumption.

[35] Guidelines for the procurement of Energy Efficient equipment in the public sector, MEPU

- Optimizing printing settings, such as selecting reduced quality, black-and-white, and double-sided printing, improves energy efficiency. Promoting responsible printing practices helps minimize both energy use and paper waste.
- Enabling energy-saving features such as standby modes further support efficiency. Encouraging batch copying minimizes operational time and power usage, while reducing unnecessary photocopying contributes to overall sustainability efforts.

Best Practice: Promoting Energy Awareness and Behavioural Change

Fostering behavioural change through regular awareness initiatives is an essential strategy for reducing energy consumption within the workplace. These cost-effective measures not only promote a culture of accountability but also contribute to long-term energy conservation goals:

- **Periodic communication**: Regular communication with employees through emails, posters or workshops reinforces energy-saving practices and keeps sustainability objectives at the forefront of workplace priorities.
- **Encourage energy-conscious behaviour:** Employees should be actively encouraged to turn off lights, computers, and other electrical equipment when spaces are unoccupied or at the close of the workday, thereby preventing unnecessary energy consumption.
- **Monitoring and displaying energy use**: Implementing a system to track and display a daily electricity usage profile can provide valuable insights into consumption patterns, identify peak usage times, and drive collective efforts towards improving energy efficiency.

iv) Equipment Maintenance and Upgrades

- **Chart daily electricity use profile** to track and visualize electricity consumption throughout the day to identify inefficiencies and optimize energy use.
- **Establish maintenance procedure:** A maintenance policy should specify, which equipment requires periodic servicing; the type of routine maintenance is needed. For example, cleaning filters on air conditioners, and keeping computers and printers free of dust.
- **Equipment procurement policies:** Clear guidelines for purchasing new equipment are essential, especially when multiple individuals are involved in the process. The equipment purchasing policies may include details of suppliers and manufacturer with a proven record of energy efficient products.

Ensuring the procurement of EU Energy Efficiency Labels certified devices for Mauritius will lead to significant energy savings, reduced operational costs, and lower environmental impact.

5.5.4 Boiler-Service Hot Water

A commercial hot water boilers heat water and distribute it throughout a building. They are commonly used in larger residential and commercial buildings and can be fuelled by natural gas, oil, or electricity. The hot water is circulated through pipes to radiators or other components that distribute heat. Common types of commercial boilers include water tube, electric, steam, oil, and condensing boilers. In commercial buildings, hot water boilers are commonly used in hospitals, office buildings, and shopping malls.

Retrofitting Boiler

Boilers can be retrofitted to enhance efficiency and safety, extending the life of older but functional systems. However, the cost of retrofits should be carefully compared to the investment in a new boiler. Upgrading to a new heating system provides an opportunity to incorporate the latest energy-efficient technologies.

Best Practices for Service Hot Water Boiler

- Check the physical integrity of the heat exchanger. Boiler heat exchangers may leak water and are easy to spot.
- Adjust the controls on the boiler to provide optimum water and air temperature settings for both efficiency and comfort.
- If you're considering replacing or retrofitting your existing heating system, have the technician perform a combustion-efficiency test first.

Enhancing the energy efficiency of boiler systems that provide service hot water presents a valuable opportunity to lower both energy consumption and operational costs in commercial buildings. This can be achieved in following ways:

- **Use of Waste Heat Recovery:** In conventional boiler operations, a considerable amount of heat is lost through flue gases or mechanical equipment. By implementing waste heat recovery systems, this residual heat can be captured and reused for preheating boiler feed water or for other heating needs within the facility. This reduces the boiler's overall energy demand, increases its operational efficiency, and results in notable fuel savings while also contributing to lower greenhouse gas emissions.
- **Reduction of Surface Losses**: Surface heat losses from boiler bodies, steam distribution lines, and hot water tanks can be substantial, especially in older systems with inadequate insulation. Applying high-performance thermal insulation to exposed surfaces and regularly maintaining these components can significantly reduce heat loss. Minimizing surface losses not only enhances system efficiency but also improves safety and prolongs the service life of equipment.
- **Installation of Energy-Efficient Boilers**: Replacing outdated boilers with high-efficiency models is a critical step in improving overall energy performance. Modern boilers, particularly those with condensing technology, achieve higher thermal efficiency by extracting more heat from the combustion process. Features such as modulating burners and improved heat exchangers further contribute to reduced fuel consumption and emissions. The installation of energy-efficient boilers ensures better reliability, compliance with energy standards, and alignment with sustainability goals.

Upgrading boiler systems through waste heat recovery, improved insulation, and the adoption of high-efficiency technologies can significantly enhance the energy performance of service hot water systems. Mauritius can consider adopting India's Energy Conservation Building Code (ECBC) standards for commercial hot water boilers, ensuring a minimum Fuel Utilization Efficiency (FUE) of 80% for gas or oil-fired boilers, which will support in the sustainable energy use in commercial buildings.

Use of Solar Water Heater

The use of solar water heaters is an effective energy-saving measure that utilizes solar energy to heat water, reducing reliance on electricity. This environmentally friendly solution is especially beneficial in tropical climate like Mauritius with high solar irradiance and can be used across various, commercial building sub-categories. Incorporating thermal storage tanks improve reliability and performance of solar water heaters during low solar availability. The use of solar water heaters supports sustainability goals by reducing GHG emissions, lowering energy bills, and contributing to long-term energy savings.

Insulation practices for hot water pipes

Insulating hot water piping is a simple yet highly effective energy conservation measure that minimizes heat loss as water travels through the system. Properly insulated pipes help maintain water temperature, reducing the need for reheating and improving overall system efficiency. This leads to lower energy consumption, faster delivery of hot water at outlets, and increased user comfort.

Additionally, insulation helps prevent condensation and prolongs the lifespan of piping systems, making it a cost-effective and sustainable choice for both new and existing buildings. Some common materials that recommended for steam and hot water pipes are metal-coated fiberglass, rockwool, mineral wool, polyurethane foam, aerogel, calcium silicate etc.

Best Practice: Reduce Hot Water Usage and Minimize Heat Loss from Water Heater Tanks

Reducing hot water usage and heat loss from water heater tanks improves energy efficiency and lowers operating costs. This can be achieved by installing low-flow fixtures to reduce water demand and insulating water heater tanks to minimize standby heat loss. Additionally, insulating water heater tanks with appropriate thermal insulation materials helps retain stored heat, reducing standby losses and the frequency of reheating cycles. For maximum effectiveness, use factory-insulated tanks or retrofit existing tanks with external insulation blankets rated for high-temperature applications extends system lifespan of hot water system.

5.5.5 Elevators

Elevators are a vital component of modern buildings, but they can also be a significant source of energy consumption. Enhancing Energy Efficiency in Elevators. with technological advancements, elevators are becoming more energy-efficient than ever before. Modern innovations help reduce energy consumption while improving performance and sustainability in buildings. Here are keyways elevators contribute to energy efficiency:

Regenerative Drive

- Regenerative drives capture energy typically lost during braking and redirect it into the building's electrical system. This reduces energy costs and increases overall efficiency. By recycling energy instead of wasting it, regenerative drives significantly enhance the sustainability of elevator operations.

Energy-Efficient Motors

- Gearless motor technology improves the efficiency of elevator hoisting machines, leading to lower energy consumption. Upgrading to energy-efficient motors not only enhances performance but also reduces operational costs. Traction elevators, which often feature efficient motors, consume less energy than hydraulic elevators while providing a quieter and smoother ride.

Smart Elevator Systems

- Smart elevators leverage IoT connectivity and sensors to optimize performance and reduce energy use. These systems analyse data in real time and make intelligent decisions to improve efficiency. Advanced controls and compact hardware further contribute to energy savings and operational reliability.

Standby Mode

- Energy-saving elevators automatically switch to standby mode during idle periods, such as nights, weekends, or low-traffic hours. This reduces unnecessary energy consumption while ensuring elevators remain ready for use when needed.

By integrating these energy-efficient technologies, modern elevators not only fulfil the vertical transportation needs of buildings but also contribute significantly to sustainability and cost reduction.

Available rating systems for elevators:

- **European Union - ISO 25745 Energy Performance Classification:** The ISO 25745 standard provides energy efficiency classification for Lifts (elevators) and Escalators & moving walks. It assesses energy consumption in different operation modes (idle, standby, and running) and provides efficiency classes (A to G), with Class A being the most efficient.
- **Singapore - BCA Green Mark for Lifts & Escalators:** The Green Mark certification by the Building and Construction Authority (BCA) evaluates energy efficiency for elevators based on use of variable voltage variable frequency drives, standby mode power reduction, and regenerative braking technology.

5.5.6 Energy Metering

Energy metering involves the installation of meters to monitor and record energy consumption at various points within a building. These systems track electricity usage, providing detailed data on energy consumption across different zones, equipment, or systems. This information is crucial for assessing energy use, identifying inefficiencies, and implementing corrective actions to reduce overall consumption.

An energy meter, also known as an electricity meter or watt-hour meter, is a device used to measure and record the consumption of electrical energy in buildings. There are various types of meters available, which are briefed in the Figure 26:

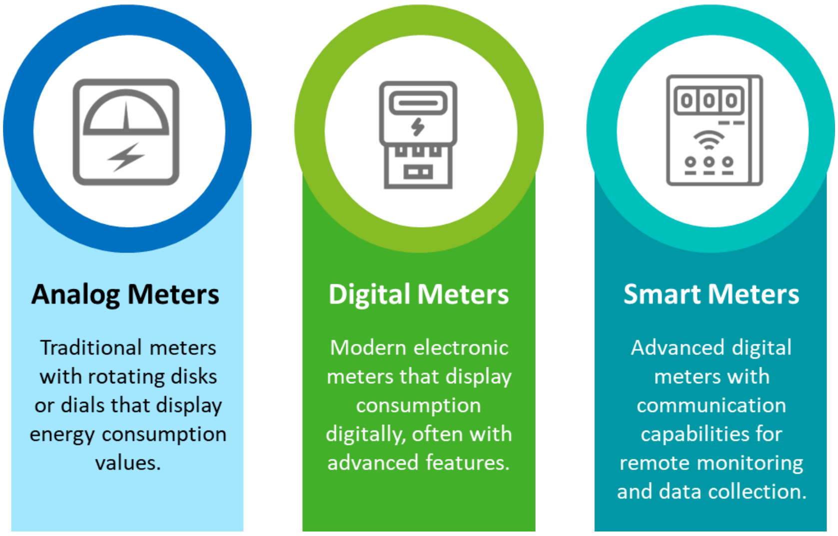


Figure 26: Type of energy meters used in commercial buildings

The benefits of installing energy meters are as follows:

- **Real-Time Monitoring**: Energy meters provide immediate feedback on energy consumption, enabling the quick detection of anomalies such as excessive usage or system inefficiencies. Regular monitoring of the data allows for the identification of unusual consumption patterns or peaks in energy demand.
- **Enhanced Building Performance:** The data collected through energy meters supports informed decision-making regarding energy-saving measures, such as optimizing heating, ventilation, and air conditioning (HVAC) systems, as well as adjusting lighting and equipment usage. This facilitates the optimization of systems to achieve peak efficiency, thereby improving the overall performance of the building.

- **Benchmarking and Performance Tracking:** Energy meters enable benchmarking against industry standards or historical consumption data, allowing buildings to track improvements over time and set realistic energy reduction goals.
- **Reduction in Energy Bills:** By identifying areas of energy wastage and inefficiency, building managers can take targeted actions to lower energy costs, resulting in significant long-term savings.

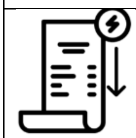
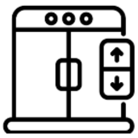
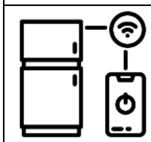
Energy meters should be installed at key locations within the building, such as electrical panels, individual equipment, or major systems like HVAC and lighting. In larger buildings, sub-metering by floor or zone is recommended to provide more detailed insights into energy usage. Measuring energy consumption at the sub-building level is essential for identifying current energy usage patterns and potential inefficiencies. This data enables a comprehensive understanding of consumption patterns and supports data-driven adjustments that reduce waste, lower operational costs, and promote environmental sustainability.

5.6 Energy Efficiency Improvement Measures via IoT-based Smart Technologies

The integration of Internet of Things (IoT) technologies plays a pivotal role in advancing energy efficiency by enabling real-time monitoring, automation, and optimization of energy use across various systems and devices. These technologies integrate sensors, data analytics, and connectivity to create intelligent systems that adapt to user needs and environmental conditions. From smart thermostats and lighting systems to automated HVAC and energy monitoring platforms, IoT solutions are revolutionizing energy management in commercial buildings. There are various types of IoT based smart technologies which can be adopted in the building to enhance the energy efficiency of the building, are tabulated below:

Table 13: Summary of various types of IoT-based smart technologies

Type	Components	Characteristics	Applicability
 Smart Lighting Control Systems	• Occupancy Sensors • Daylight Sensors • Dimming control	• Integrate advanced features such as occupancy detection, daylight harvesting, and dimming controls to optimize energy usage and enhance user convenience. • Adjust lighting based on real-time data, such as detecting room occupancy to turn lights on or off, utilizing natural daylight to reduce artificial lighting needs, and offering adjustable brightness for personalized settings. • With IoT connectivity, users can manage lighting remotely via apps or voice assistants, schedule usage patterns, and integrate with other smart building systems.	Applicable across diverse spaces and various commercial building types including offices, banks, shopping complex, healthcare facilities and conference halls.
 Energy-efficient Smart Windows and Blinds	• Smart Glass • Motorized Blinds • Light Sensors	• Adjust automatically based on sunlight, temperature, or occupancy, reducing heat gain and glare, while lowering energy consumption. • IoT integration allows remote control and scheduling for added convenience, making them sustainable and efficient solutions for modern buildings.	Applicable for various commercial building types including offices, banks, educational institutes and healthcare facilities.

Type	Components	Characteristics	Applicability
 Smart HVAC systems	• Sensors • IoT-enabled air Conditioners • Smart thermostats (wi-fi enabled)	• Use IoT-enabled sensors to monitor temperature, humidity, and occupancy across building zones, enabling real-time adjustments through scheduling and monitoring for optimal performance. • Enhance energy efficiency, personalized comfort, and predictive maintenance while offering remote management and data insights. • Regulate heating and cooling based on real-time occupancy and time-of-day patterns with remote controls	Applicable for commercial buildings, where energy efficiency and comfort are key priorities such as hospitals, laboratories offices, shopping complex, educational institutions and cinemas
 Energy Monitoring and Analytics	• IoT Sensors, Dashboards • Smart meters • Analytics Software	• Utilize IoT-based smart meters and sensors to provide real-time energy consumption data. • Track and analyze energy usage, identify inefficiencies, reduce costs, and promote sustainability through actionable insights and predictive analytics, making them ideal for efficient energy management.	Applicable for various commercial building types such as educational institutions, hospitals, laboratories offices, shopping complex and cinemas
 Demand Response and Load Shedding	• IoT Controllers • Smart Meters	• Use IoT devices to automatically adjust energy consumption during peak demand periods, prioritizing essential loads while reducing non-essential usage. • Optimize energy costs, support grid stability, and promote efficient resource utilization through real-time monitoring and automated responses.	Applicable for large commercial buildings that are part of smart grid initiatives
 Energy-efficient Elevators	• Regenerative Drives • IoT Monitoring Systems	• Use IoT technology to optimize energy consumption by adjusting operations based on real-time building traffic and peak usage patterns. • Incorporate energy recovery systems, standby modes, and smart scheduling to enhance efficiency, reduce wastage, and support sustainable building management.	Applicable for high-rise commercial buildings such as offices, shopping complex and entertainment facilities.
 Energy Efficient Appliances with IoT Integration	• IoT-enabled Appliances (Refrigerators, Washers)	• IoT integration allow remote monitoring, energy optimization, and smart scheduling. • Provide usage insights, enable predictive maintenance, and promote interconnectivity with other devices, enhancing convenience and reducing energy usage.	Applicable for various commercial building types including offices, banks, educational institutes, cold storage, laboratories and healthcare facilities.

Type	Components	Characteristics	Applicability
 Building Automation Systems (BAMS)	• Sensors, Controllers • Centralized Dashboards	• Use IoT technology to integrate and optimize lighting, HVAC, security, and other systems in real-time. • Enhance energy efficiency, streamline building operations, provide centralized control, and support remote accessibility.	Applicable for modern commercial buildings such as offices, banks, educational institutes, shopping complex and healthcare facilities

Example of IoT based smart daylighting controls and impact on load reduction and energy saving

Control Type	2 level + off	3 level + off	2/3on/0ff
Step Control	lights in 2-steps (1, 0.5) then 0	lights in 3-steps (1, 0.66, 0.33) then 0	lights in 3-steps (1, 0.66, 0.33)
Load Reduction	4.8%	4.8%	3.2%
Energy Reduction	4.0%	4.2%	2.8%

CHAPTER 6

COST BENEFIT ANALYSIS

CHAPTER 6

COST BENEFIT ANALYSIS

This chapter defines the methodology to calculate the simple payback period, life cycle cost analysis and its related parameters to evaluate the energy cost saving. The simple payback calculator has been provided as a supporting document along with this guideline.

The cost-benefit analysis helps to prioritise the energy conservation measure option based on financial indicators (payback) thresholds and other user requirement. Cost-benefit analysis needs to be carried out for all the practical measures and recommendations to categorise them in short-, medium- and long-term priority. This guideline emphasizes the use of the simple payback period and allows energy managers to quickly assess potential projects and aids in budget planning.

6.1 Simple Payback Calculator

The simple payback period is the amount of time (in years) it would take for the additional cost of implementing an energy savings measure to be realized through cost savings due to efficient functioning of the measure.

The simple payback method involves calculating the simple payback by dividing the cost of the improvement by the annual energy savings. The result is the number of years to payback the investment from the energy savings. It is calculated by the following formula:

$$Simple\ Payback\ Period\ (in\ years) = \frac{Total\ initial\ cost\ of\ energy\ conservation\ measure}{Net\ Annual\ Energy\ Savings}$$

This method comprises of a basic calculation and is utilized primarily for low investment measures. It provides a good initial assessment of the viability of any energy efficiency project. The simple payback calculator considers the total energy cost savings over a year due to equipment replacement, costs of new energy-efficient procurement and installation.

<u>Point to Note:</u>

The simple payback calculation does not consider time value of money, unlike other methods of capital budgeting such as Net present value (NPV), or Internal rate of return (IRR), or energy cost changes tax effects if any, including the expected life of the equipment.

The energy improvement simple payback period calculator is illustrated below:

Simple Payback Calculator			
Description	**Unit**	**Existing System**	**Proposed System**
Type of equipment/system	-		
Power consumption of equipment/system (A)	kW		
Quantity (B)	Nos.		
Operating hours per day (C)	hrs/day		
Electricity consumption per day (D)	kWh/day	D = A * B * C	D = A * B * C
Number of days in operation in a year (E)	Days		
Operating hours per year (F)	hrs/year	F = C * E	F = C * E
Annual electricity consumption (G)	kWh/year	G = D * F	G = D * F
Annual savings in consumption (H)	kWh		$G_{Existing} - G_{Proposed}$
Electricity tariff rate (I)	MUR/kWh		
Total annual electricity cost (J)	MUR	J = G * I	J = G * I
Annual cost saving in electricity (K)	MUR		$J_{Existing} - J_{Proposed}$
Cost of single equipment/system (L)	MUR		
Cost of installation of EE equipment/system (M)	MUR		
Total Cost of equipment/system (N)	MUR	N = (L + M) * B	N = (L + M) * B
Simple Payback period (P)	Years		**P = N / K**

Where

	Non-editable
	User input
	System calculated

!

A simple payback calculator in spreadsheet format is provided with this guideline separately. It includes built-in formulas and instructions to help users input data and calculate the payback period. A demonstration of the calculator, along with the formulas used, is included above in this section. However, users are advised to use the spreadsheet calculator directly to ensure accuracy and avoid calculation errors.

Example of Payback Period for an Energy Conservation Measure: Using energy efficient air conditioner in office

Description	Unit	Existing System	Proposed System
Type of equipment/system	-	Air conditioner	Energy-efficient air conditioner
Power consumption of equipment/system (A)	kW	2.4	2.0
Quantity (B)	Nos.	5	5
Operating hours per day (C)	hrs/day	8	8
Electricity consumption per day (D)	kWh/day	D = A * B * C	
		96	80
Number of days in operation in a year (E)	Days	250	250
Operating hours per year (F)	hrs/year	F = C * E	
		2,000	2,000
Annual electricity consumption (G)	kWh/year	G = D * F	
		192,000	160,000
Annual savings in consumption (H)	kWh		$H = G_{Existing} - G_{Proposed}$
			32,000
Electricity tariff rate (I)	MUR/kWh	8	8
Total annual electricity cost (J)	MUR	J = G * I	
		1,536,000	1,280,000
Annual cost saving in electricity (K)	MUR		$K = J_{Existing} - J_{Proposed}$
			256,000
Cost of single equipment/system (L)	MUR		25,000
Cost of installation of EE equipment (M)	MUR		1,000
Total Cost of equipment/system (N)	MUR	**N = (L + M) * B**	
			1,30,000
Simple Payback period (P)	Years		**P = N / K**
			0.5 years

6.2 Life Cycle Cost of Equipment

The Life Cycle Cost (LCC) of equipment/system refers to the total cost of owning, operating, maintaining, and disposing of the equipment over its entire lifespan. LCC Analysis is particularly suitable for the evaluation of building design alternatives that without compromising performance have a different initial investment cost, different operating and maintenance costs, different lifecycles and that perform differently in terms of energy savings. It considers all the cost of owning, operating, maintaining, and eventually disposing of a building, with all the costs adjusted (discounted) to reflect the time-value for money. The key factors that contribute to calculating the life cycle cost of equipment are:

- **Initial purchase cost**: The initial purchase cost includes all the expenses paid at the time of buying an equipment or material. This not only covers the basic price but also any additional charges such as taxes, delivery fees, and setup or installation costs. These are one-time expenses that occur at the beginning and are often the most visible.
- **Operating cost**: Operating costs are the regular, ongoing expenses needed to use the equipment effectively. These may include the cost of energy or fuel, materials, and other daily inputs required for operation. Depending on the situation, operating costs might also involve the wages of workers directly involved in its use. These costs can add up over time and have a big impact on the total amount life cycle cost of the equipment.

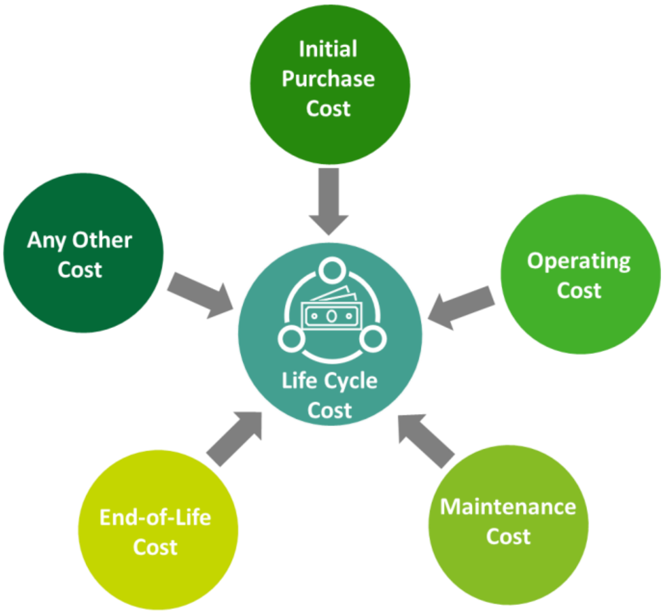


Figure 27: Components of Life cycle cost

- **Maintenance cost**: Maintenance costs cover all expenditures needed to ensure the equipment continues operating efficiently and reliably throughout its life. This includes routine maintenance such as cleaning, calibration, and inspections, as well as unexpected repair costs due to breakdowns or component failures. Additionally, spare parts, replacement of worn-out components, and service agreements with external vendors also fall under this category. Regular and preventive maintenance not only helps extend the equipment's lifespan but also minimizes downtime and costly repairs in the long run.
- **End-of-Life cost**: End-of-life costs are the expenses associated with decommissioning and disposing of the equipment once it has reached the end of its usable lifespan. Depending on the nature of the equipment, these costs may include dismantling, transporting the equipment for disposal, recycling, or environmental handling fees to comply with local regulations. In some cases, the cost may also involve data wiping, safe disposal of hazardous materials, or penalties for improper disposal. These costs can often be overlooked during initial planning but should be included to gain a full understanding of long-term ownership.
- **Any other associated cost:** This includes various indirect or less obvious costs that may be incurred throughout the equipment’s lifecycle. Examples include the expense of training personnel to operate and maintain the equipment safely and effectively, the cost of productivity loss during equipment downtime, and insurance or extended warranty premiums. Additionally, compliance with health, safety, or environmental regulations may require further investment. These miscellaneous expenses, though sometimes harder to quantify upfront, can significantly influence the total cost and operational success of the equipment.

The below Figure 28 shows a sample distribution of such costs associated with key components. It can be seen from the distribution that the operating cost and all other cost surpasses the initial purchase cost in HVAC lifespan, therefore, it is very important to consider the life cycle cost of equipment for cost benefit analysis.

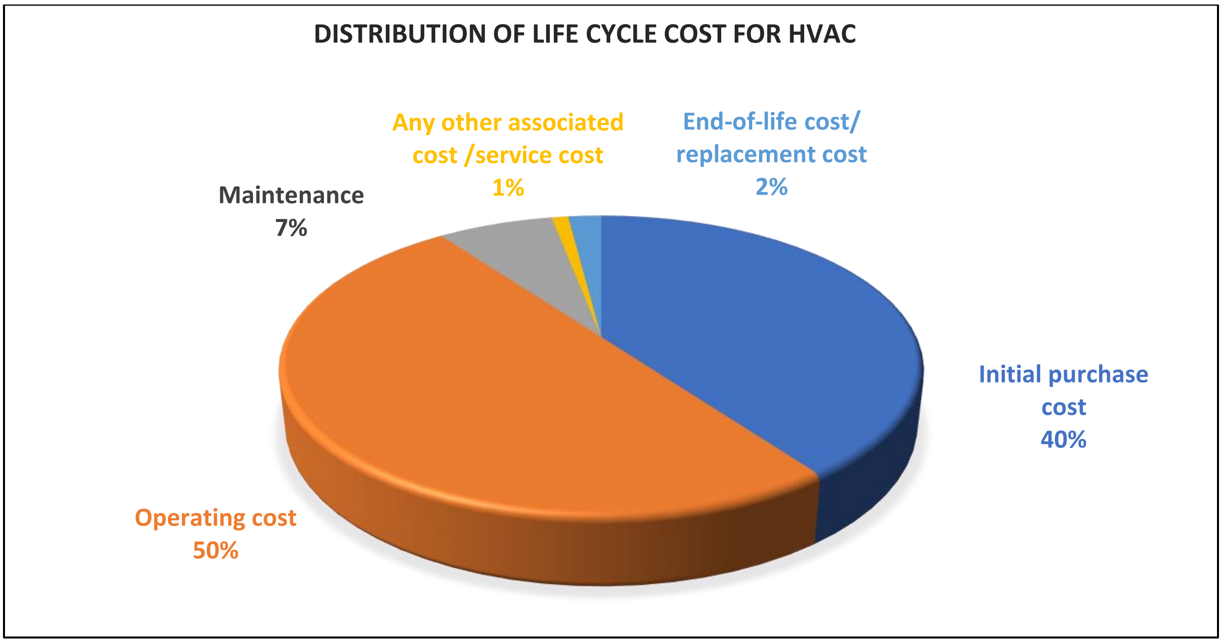


Figure 28: Distribution of various cost components in a life cycle cost of 30 years

The life cycle cost analysis should be performed early in the design process to refine the design to ensure reduction in life cycle cost. The formula to calculate the life cycle cost is following:

$$\left\{\begin{matrix}\textbf{Total Life Cycle}\\ \textbf{Cost of}\\ \textbf{Equipment}\end{matrix}\right\} = \left(\begin{matrix}\text{Initial}\\ \text{purchase}\\ \text{cost}\end{matrix}\right) + \left(\begin{matrix}\text{Operating}\\ \text{Cost}\end{matrix}\right) + \left(\begin{matrix}\text{Maintenance}\\ \text{Cost}\end{matrix}\right) + \left(\begin{matrix}\text{End of}\\ \text{Life}\\ \text{Cost}\end{matrix}\right) + \left(\begin{matrix}\text{Any other}\\ \text{Associated}\\ \text{Cost}\end{matrix}\right)$$

Example to Calculate Lifecycle Cost for an Energy Conservation Measure: Using Energy-Efficient Air Conditioning (AC) in an Office

Cost Component	Description	Estimated Cost (MUR)
Initial Purchase Cost	Price of the AC unit, including taxes, shipping, and installation	40,000
Operating Cost	Electricity consumption over 10 years (average 3,600 kWh/year × 10 years × MUR 10/kWh)	360,000
Maintenance Cost	Annual servicing, repairs, and part replacements over 10 years (MUR 3,000/year × 10 years)	30,000
End-of-Life Cost	Disposal and recycling fees at the end of 10 years	2,000
Other Associated Costs	Staff training on usage, downtime costs during repairs, and miscellaneous expenses	8,000
Total Life Cycle Cost (MUR)		**440,000**

CHAPTER 7

BUILDING COMMISSIONING AND MEASUREMENT & VERIFICATION

CHAPTER 7

BUILDING COMMISSIONING AND MEASUREMENT & VERIFICATION

This chapter provides the basic of building commissioning and its process, post-implementation assessment of energy conservation measures i.e., various M&V options and plan along with their approach and process.

Building Commissioning and Measurement & Verification (M&V) Plan is a critical component of an effective energy management strategy, ensuring that building systems and energy-saving measures operate as intended and deliver the expected performance. Commissioning involves the systematic process of verifying and optimizing the installation and functionality of building systems; while M&V provides a structured approach to monitor and evaluate the actual energy savings resulting from energy conservation measures implemented during the commissioning phase.

7.1 Basics of Building Commissioning

Building commissioning is a systematic and designed process coordinated by a commissioning authority or team which included documentation, verification procedure, functional performance tests, validation, and training. Commissioning is critical for ensuring that the building design is successfully constructed and operated and is fundamental to the success of the whole-building design process.

The commissioning activities vary for existing and new buildings because of the factors namely, differences in the accessibility of building systems, occupancy etc. In existing buildings, owners can begin existing building commissioning projects to save energy while maintaining design intent[36]. On the other hand, new buildings are commissioned against design intent, and commissioning new buildings is about meeting this design intent and ensuring that a space is ready to meet occupant requirements and applicable standards.

The commissioning uncovers the issues or, anomalies including faulty design, or construction and reveals any leakage/wastage in energy consumption and accordingly identifies the root cause. The studies[37,38] show that the commissioning process in existing buildings can save up to 10 % to 15 % energy savings and up to 25 % or more in new buildings. Whereas the commissioning process costs up to 0.6 USD per square foot for existing and 1.0 USD per square foot for new construction with payback period up to 2.5 years and 4.8 years respectively.

[36] It is the description of how designer envision a building or system to perform. e.g., design intent may consist of a building narrative that describes a building that is comfortable for its occupants in every season. It may also consist of a document stating the HVAC system will not simultaneously heat and cool more than three hours in a given day.

[37] Mills, Evan (2011). "Building commissioning: a golden opportunity for reducing energy costs and greenhouse gas emissions in the United States". Energy Efficiency. Volume 4, pages 145–173.

[38] Bourassa, Norman (2005). "The Cost-Effectiveness of Commissioning New and Existing Commercial Buildings: Lessons from 224 Buildings,"

7.2 Process and Steps for Building Commissioning

The commissioning process of any existing building involves the following four phases depicted in the Figure 29 namely, planning, investigation, implementation, and hand-off. The process provides a tasks checklist to be completed in each phase of the commissioning.

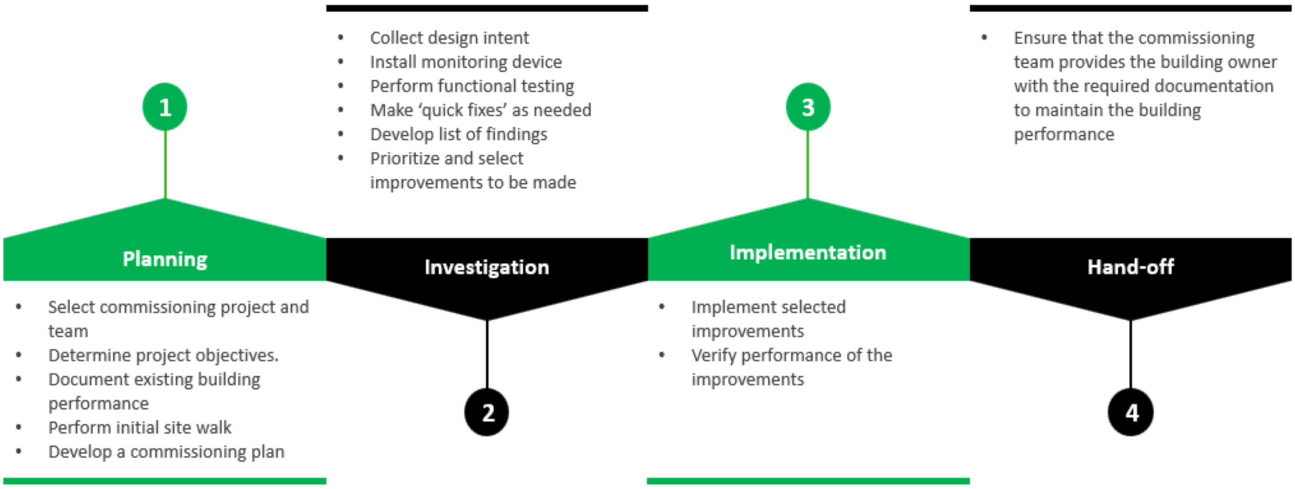


Figure 29: Four step process of building commissioning

Depending upon the building size and project scope, the above four phases can require a time frame of a couple of months up to two years. Further, before commissioning can begin, the team shall be provided with set of documents that include as-built drawings, operating sequence performed by the building owner and desired operating performance, and any other data/ document related to procedures that verify the readiness of building systems for building operations.

Moving forward, the following flowchart in Figure 30 shall be followed to decide which commissioning project is right to perform, based upon the existing or new building:

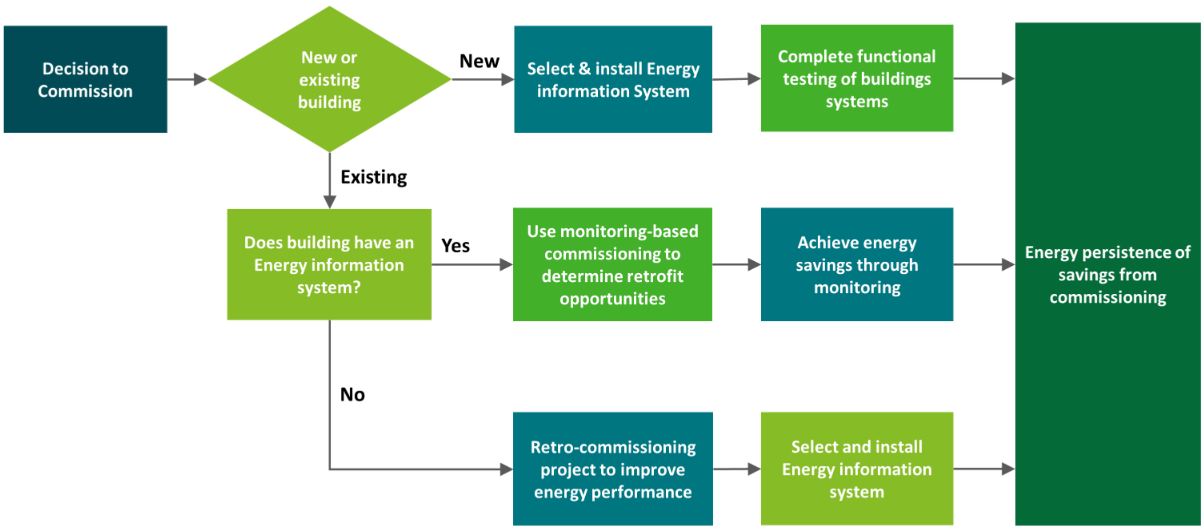
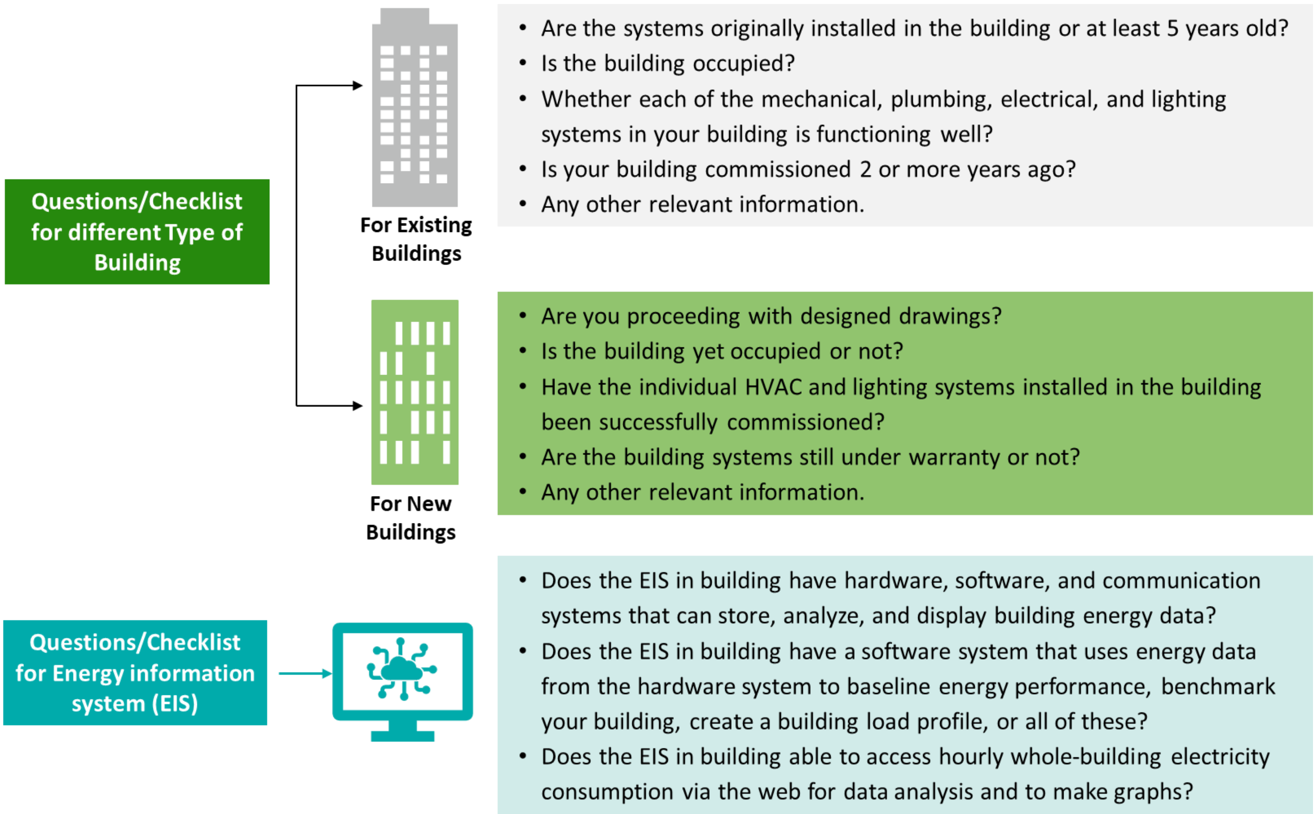


Figure 30: Flow chart for building commissioning process

Once the type of building is selected, the next step is monitoring of building performance using energy information systems (EIS). Energy monitoring requires both the technology to monitor energy consumption as well as a process to review the data. This step helps the builder owners to select a technology to monitor energy consumption in the building.

The EIS systems combine visualization, reporting, and analysis, and at a minimum integrate whole building electric data collected at 15-minute, hourly, or daily intervals. Depending on the level of monitoring at the site, EIS may integrate gas, sub metered system, electric loads and along with integrating building automation system (BAS), utility demand response (DR) information. In a nutshell, EIS combines the features of BAS, fault detection and diagnosis, tracking, and benchmarking tools.

Following set of questions/ checklist can be considered and answered to decide whether the commissioning to be performed is for an existing building or new building and is there any energy information system[39] or not?



For new buildings, the next sub-step is to select and install EIS. However, for existing buildings, the following two scenarios arise and then EIS is selected and installed.

[39] Energy Information Systems (EIS) are the software, data acquisition hardware, and communication systems used to analyze and display building energy performance.

Scenario 1

- If energy information systems is already installed, use of monitoring-based commissioning to determine the retrofit opportunities and achieve energy savings is to be performed.

Scenario 2

- If EIS is not in place, then retro-commissioning resources to improve energy performance shall be carried out.
- It includes commissioning guidelines, protocols, and standards, toolkits, checklists, specifications and templates for building owners, including training resources and best practice guides.

However, in case of new building, next step is performing functional testing[40] of the building systems. It is required to ensure that building systems operate according to their design intent and offer an opportunity to evaluate system performance and compare it to the intended performance. The functional testing process is carried out as a 6-step procedure, illustrated as under Figure 31:

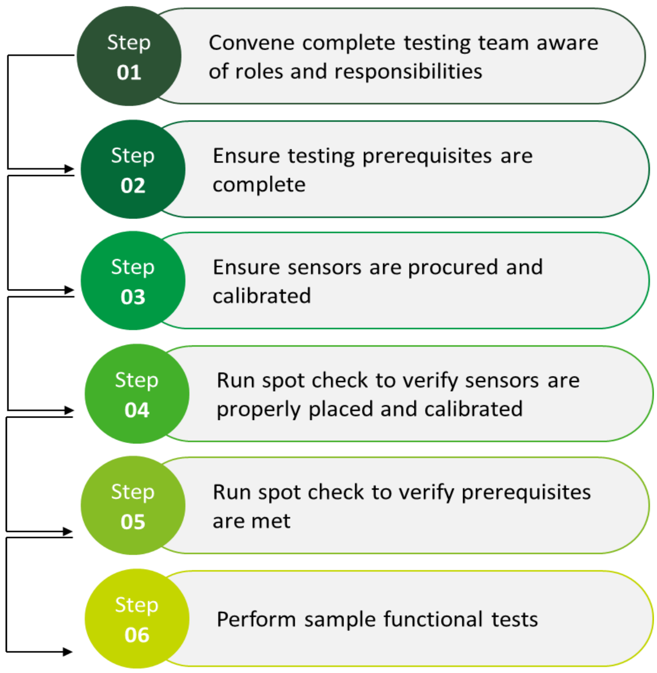


Figure 31: Functional testing process for building commissioning

Once the steps of commissioning building and monitoring is completed, the last step is to maintain the building performance and ensure persistence of the energy savings from commissioning. It is a general phenomenon that commissioning savings often erode over time if building and system energy performance is not continuously tracked. Hence, it is critical to maintaining persistent energy savings is knowing what are were the "corrections" made during the commissioning, ensuring that they remain in place, and new problems shall be avoided.

Therefore, various analysis methods namely, applying cost accounting and tracking based on utlity-bills/interval-meterd data, the benchmarking of a building or any system, defining baseline, tracking operational efficiency of the system, use of energy anomaly detection algorithms automated algorithms for the quantification of aggreate difference between metered and baseline values.

[40] Functional testing is a series of procedures that verify the readiness of building systems for building operation.

7.3 Basics of Measurement and Verification (M&V)

Measurement and Verification (M&V) is a concept which helps in estimating the savings from an intervention (including energy efficiency) in an entity. M&V is a set of rules and procedure for estimating the level of resource usage, before and after the implementation of the energy efficiency intervention. M&V rules are generally finalised before undertaking the energy efficiency interventions to prevent any ambiguity and conflict of understanding in estimation of energy savings.

Measurement and Verification (M&V) is the process of planning, measuring, collecting, and analysing data for purpose of verifying and reporting energy savings within an individual facility resulting from the implementation of energy conservation measures.

Measurement refers to the collection of information to monitor the progress of the implementation and impacts related to an energy saving action, with an impact on mitigating GHG emissions.

Reporting: Once the measured information has been delivered, it needs to be reported in a defined and transparent manner to the corresponding authorities.

Verification means an evaluation of the information that is presented, in terms of its completeness, coherence and reliability by a third party.

The illustration of M&V concept through energy consumption in pre and post intervention scenario is provided in Figure 32 below:

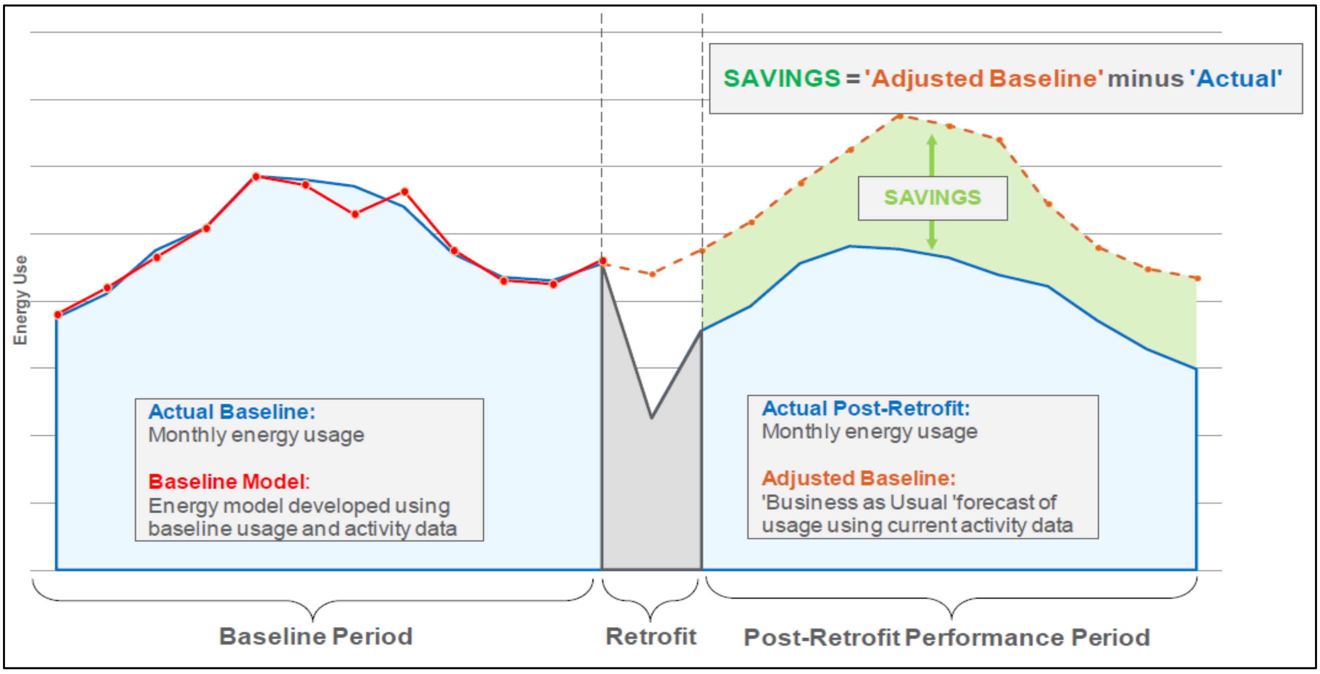


Figure 32: Measurement and verification (M&V) concept[41]

[41] Measurement and Verification Operational Guide – Best Practice M&V Processes. Office of Environment and Heritage NSW (2012).

To understand the process described in the Figure above:

Before the ECM is implemented

- A period of time prior to the ECM implementation is selected and measured – this is the 'baseline period'.
- During the baseline period, data is also collected for 'independent variables', which change on a regular basis, and have a direct effect on baseline energy usage patterns. Examples of such variables include changes in weather.
- An energy model is developed to describe the relationship between baseline energy use, and the independent variables affecting energy use.

After the ECM is implemented

- Once the ECM is implemented, data over a suitable period is once again selected and measured. This is called the 'post-retrofit' performance period.
- Data is also collected for the same independent variables for the post-retrofit period.

Calculating savings

- A 'business as usual' forecast of energy use or demand is determined by adjusting the developed baseline energy model with data for independent variables from the post-retrofit period. This is known as the 'adjusted baseline'.
- Finally, savings are determined by subtracting the measured actual usage from the adjusted baseline.

Energy consumption in building depends upon numerous factors such as occupancy, climatic conditions, set point of air conditioners etc. Hence, there are chances that the baseline estimated during baseline period may change due various factor such as change in occupancy, climatic conditions including external climate or environment change, operating schedule, and others. To incorporate these factors and to estimate the realistic savings, baseline adjustment factors are defined during baseline period. These adjustment or correction factors used in reporting period to adjust baseline, in case of deviation in any of the above-mentioned parameters.

7.4 Measurement & Verification Plan

The M&V plan is the single most important item in an energy savings "guarantee." It is central to proper savings determination and is the basis of verification and developed during contract negotiations. A plan is essential to assure the transparency of processes and the quality and credibility of achieved outcome. The amount of detailing required for a M&V plan depends on the scale of the project and costs associated with it. For all practical purposes, the M&V plan should stipulate the following in detail:

- Details of baseline and data collected.
- Documentations of all sources of data
- What will be verified?
- Who will conduct M&V activities?
- Discussion on risk and savings uncertainty
- Details if energy conservation measures performed.
- Detail on baseline energy consumption.
- How energy and cost savings will be calculated?
- How and why baseline may be adjusted.
- Define preventive maintenance responsibilities.
- What will be the cost of measurement vs savings?
- Complexity of ECM to be installed.

Before developing an effective M&V plan or approach, it is important to understand the nature of the project being implemented; basic approach and design for conducting M&V, desired outcomes, and limitations (e.g. budget). Further, it is important that the premises, and the implementing agency agree upon general M&V approaches to be used prior to starting the technical energy audit. The suggested M&V planning process listed below in the Table 14 can be used as a basis for developing a M&V plan:

Table 14: Comprehensive Overview of the M&V Planning Process

Measurement & Verification Plan Contents	
ECM intent	• The desired outcome or benefit expected to be achieved by implementing the ECM.
Measurement boundary	• The measurement boundary which best suits the size (in terms of expected savings) and complexity of the project. ○ A narrow boundary simplifies data measurement, but variables driving energy use outside the boundary (interactive efforts) will need to be accounted for. ○ A wide boundary will minimize interactive effects and increase accuracy; however, M&V costs may vary. • Static factors (document important static factors in case conditions change).
Required data for energy baseline development	The data that will likely be required to substantiate the intended benefits: • Energy data: • Performance factors: • Usage data: • Static factors: • Interactive efforts: • Independent variables:
Measurement tools	• What measurement devices are required? • Where to install these devices for measurement? • Accuracy requirements • Measurement period/ duration
Data collection	• Software • Manual data collection – Metering/ Sub-metering • Utility bills
Analysis	• Which independent variables will be used to create energy model • What software will be used (Metrices)? • Validation of model with baseline data
Responsibility	• Who will collect and record the data? • Who will provide oversight and ensure M&V plan is followed?

7.5 Purpose for Developing M&V Plan

M&V is a key element of NDCs, an instrument that can assess the efforts made by countries in addressing GHG emissions in such a way as to facilitate reviews of the collective efforts of all countries. The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) requires all countries to periodically report information and data related to national climate actions following some principle of Measurement, Reporting and Verification.

The M&V plan is developed because energy savings cannot be measured directly, instead savings are determined by comparing energy use before or after implying the project, making appropriate adjustments for change in conditions. M&V techniques can be used by facility owners or energy efficiency project investors to quantify the savings. A good M&V plan includes the following purpose:

- **Increase energy savings –** Accurate estimation of energy savings using ECMs can help them adjusting ECM designs, changes in operations in achieving energy savings.
- **Enhance financing for efficiency projects –** A good M&V plan increases the credibility of the report and thus enhance the options for financing. It also increases the credibility of projections for the outcome of ECM and its related investments.
- **Improve facility operation and management –** A good M&V plan helps the facility to discover and reduce maintenance related issues so they can run the facilities more efficiently. Good plan also provides insights for the future projects.
- **Increase public understanding of energy management –** M&V increases public acceptance of the related emission reduction. Such public acceptance encourages investment in energy projects or the emission credits they may create. Good M&V plan highlights the public benefits provided by good energy management, such as improved community health, reduced environmental degradation and increased employment.

As a best practice for continuous performance measurement and verification of building energy consumption; it is recommended to install basic metering within the building, this involves sub meters dedicated for each major energy consuming service such as lighting, UPS, raw power, HVAC plant, AHUs, Pumps etc.

7.6 Measurement & Verification Process

The M&V Process focuses on the execution of the M&V Plan, ensuring that the energy savings are monitored, measured, and verified over time. The below Figure 33 outline a typical M&V process flowchart.

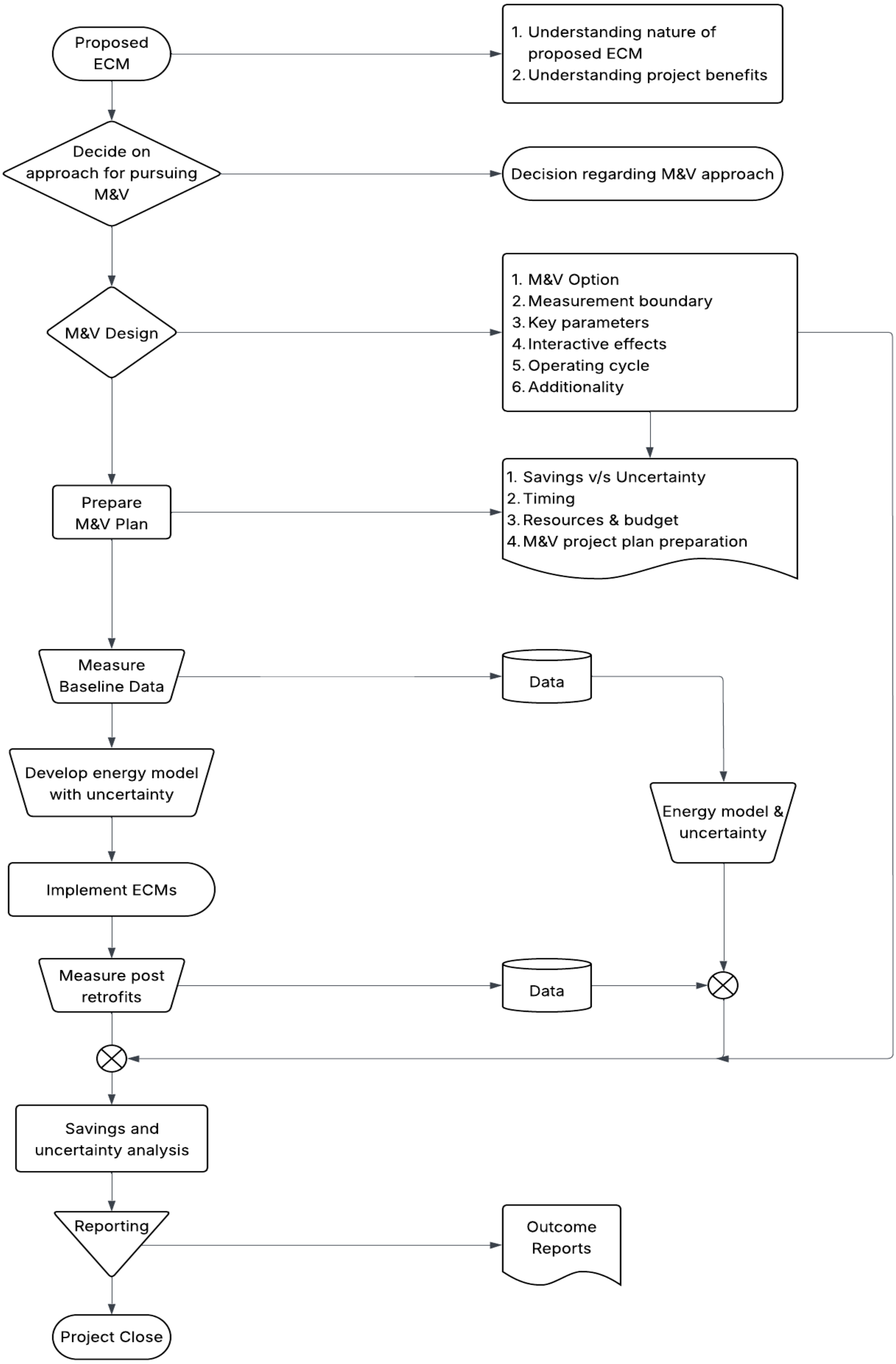
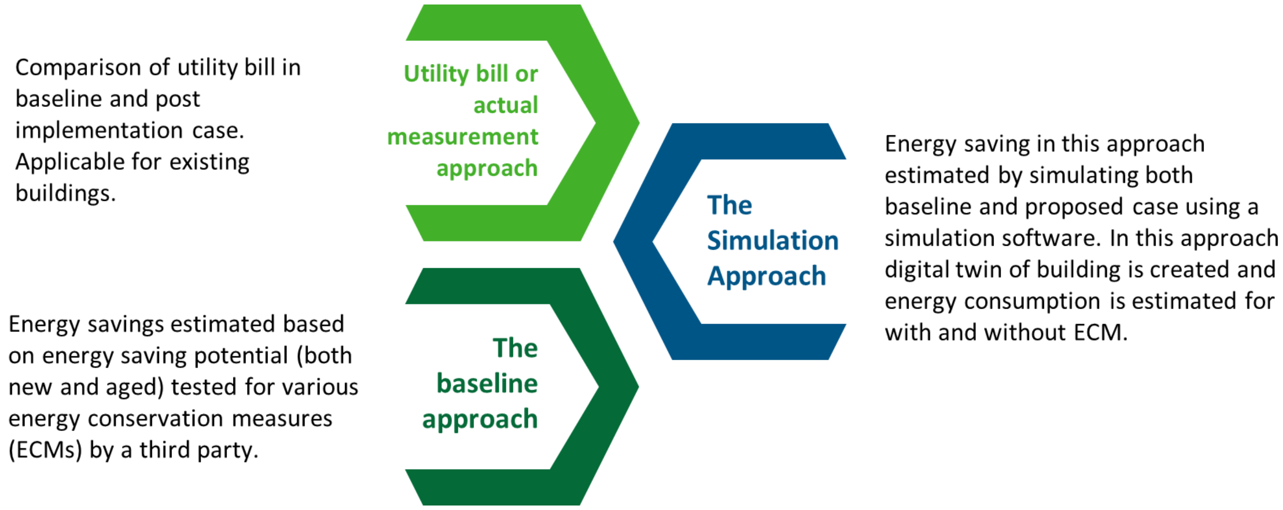


Figure 33: Measurement & Verification process flowchart

7.7 Measurement & Verification Approach: Potential Options for Buildings

The M&V Approach refers to the method or strategy used to measure and verify the energy savings for a particular project. It specifies the general methodology or technique used for data collection and verification, and it may involve one or more of the available options in the M&V standard. Three potential approach suggested for M&V of the building are listed below:



Brief about each of above mentioned approaches are provided in subsequent sections.

7.7.1 Utility Bill or Actual Measurement Approach

This method of M&V can be used and is most suited for existing buildings. In this approach, the actual energy consumption measured using utility meter or any meter installed (specially installed for M&V). The measurement of energy consumption is done twice, one before installation of ECM and another after installation of energy-efficient measure. The equation of annual energy saving, and GHG emission reduction is provided below:

$$\textbf{Annual Energy Savings (in kWh)} = ((EC_{Baseline}) - (EC_{Proposed}))$$

Emission reduction (in kg of CO_2 Equivalent) = Annual Energy Savings (in kWh) X Grid emission factor[42]

where,

- $EC_{Baseline}$ is the energy consumption of baseline scenario (in kWh)
- $EC_{Proposed}$ is the energy consumption post implementation scenario (in kWh)
- Grid Emission factor is the quanity of emissions (in CO_2 Equivalent terms) produced for generation of 1 kWh of electricity.
- Emission reduction (in kg of CO_2 Equivalent) is the annual emission reduction due to installation of ECM.

[42] As per the Clean Development Mechanism under the United Nations Framework Convention, the grid emission factor (Combined Margin) was provided as 0.95 tCO2/MWh and was used in the Energy Observatory Report 2019 by EEMO. The new grid emission factor is currently being developed by the Ministry of Energy and Public Utilities, in collaboration with the Central Electricity Board and the Energy Efficiency Management Office.

Important Considerations for this Approach:

- In measurement approach the scheduling and duration of measurement is an important and as far as possible, the measurement should be done when building is operating at its normal load (or in business-as-usual (BAU) scenario). The duration of measurement depends upon variability of electricity load in target building. For example, in case measurements are being conducted on a commercial building, the occupancy, schedule of office, and operational set point of HVAC system, should be like any usual day.
- This approach is more suitable for existing building, where the measurement can be undertaken. For new building, where ECM is applied as default, there will be no baseline to compare.
- The utility bill generally provides energy consumption of complete facility. To estimate energy savings on a specific floor of the building, installation of a separate measuring instrument seems more pragmatic.
- Before undertaking any M&V exercise, defining the baseline adjustment factors (which includes factor such as change in occupancy, climatic conditions including external climate or environment change, operating schedule, etc.) is most important. This process envisages most of the possible scenarios or factor where the consumption of building may get affected. Therefore, to nullify the impact of such varriations on the result, adjustment factor are defined.

7.7.2 The Baseline Approach

In this “baseline Approach” the energy saving potential of various ECM may be measured by a third party agency as per standard testing conditions for a sample number of buildings in local environment. The third party measurement, one time or periodic activity on sample building, will provide:

- Energy performance index (EPI) i.e. energy used in building per square meter per year for a specific building typology. This will act as baseline for new building.
- Percentage energy savings (P_{es}) in EPI from application of different ECMs.

Above mentioned baseline EPI and P_{es} should be estimated on perodic basis to incorporate changes of energy usage pattern and changes of climatic conditions.

Important Considerations for this Approach:

- This approach is suitable for both existing and new building.
- The savings are estimated based on pre-estimated percentage energy savings, therefore, the total energy savings can be calculated in advance, i.e., before implementation of ECMs.
- The Error in estimation of energy savings is dependent on accuracy of measurements done by third party and the sample size of buildings considered.
- In this approach, higher accuracy or low margin of error would require large sample size and which may result in higher cost of M&V. Therefore, it is important to select sample size carefully considering available budget and level of accuracy required.

7.7.3 The Simulation Approach

In this approach, using building energy software, a digital twin of the building is created and energy consumption is estimated by simulation of baseline case and proposed case (with ECMs). The equation of total this approach is provided below:

Annual Energy Savings (in kWh) = Total annual energy consumption in baseline case (simulated) - Total annual energy consumption in proposed case (simulated)

Emission reduction (in kg of CO_2 Equivalent) = Annual Energy Savings (in kWh) X Grid emission factor[43]

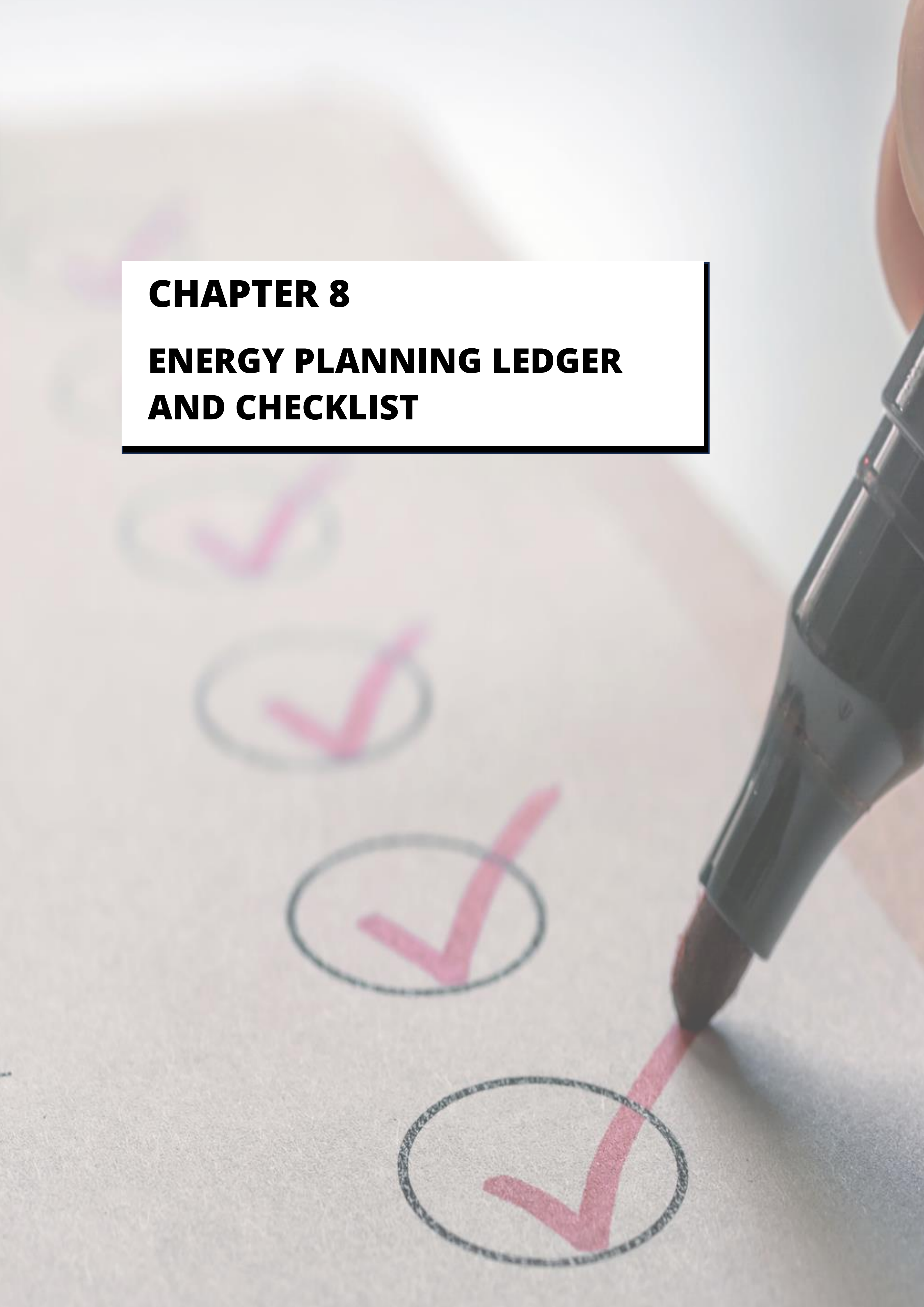
where,

- Emission reduction (in kg of CO_2 Equivalent) is the annual emission reduction due to installation of ECM
- Grid Emission factor is the quanity of emissions (in CO_2 Equivalent terms) produced for generation of 1 kWh of electricity.

Important Considerations for this Approach:

- This approach is suitable for both existing and new buildings.
- This approach of simulation requires special technical skills and knowledge about simulation softwares and more information about building material and local weather.
- The savings are estimated based on simulation, therefore, the total energy savings can be calculated in advance, i.e before implementation of ECMs.
- The Error in estimation of energy savings is dependent on accuracy of parameters considered in simulation software such as properties of building material, weather data of location, operating hours of the appliances etc.
- The cost of simulation varies across different geographies depending upon extent of use of simulation in building performance assessment and availalbility of local service providers.

[43] As per the Clean Development Mechanism under the United Nations Framework Convention, the grid emission factor (Combined Margin) was provided as 0.95 tCO2/MWh and was used in the Energy Observatory Report 2019 by EEMO. The new grid emission factor is currently being developed by the Ministry of Energy and Public Utilities, in collaboration with the Central Electricity Board and the Energy Efficiency Management Office.



CHAPTER 8

ENERGY PLANNING LEDGER AND CHECKLIST

CHAPTER 8

ENERGY PLANNING LEDGER AND CHECKLIST

This chapter provides the overview of the energy planning process and key steps involved based upon the building energy use statistics along with energy management checklist to establish opportunities for energy efficiency in buildings as well as the role of stakeholders in the energy planning process.

Energy Planning Ledger and Checklist are essential tools for organizing and tracking the energy management process within a building or facility. The Energy Planning Ledger serves as a comprehensive record that documents energy usage, goals, and strategies, providing a clear overview of current energy performance and future objectives. aired with a detailed checklist, it ensures that energy-saving actions, maintenance tasks, and upgrades are properly planned, executed, and monitored. It also gives details about the energy management team responsible for identifying inefficiencies, recommending actionable solutions, overseeing implementation, and monitoring outcomes to ensure alignment with established goals.

8.1 Energy Planning

Energy Planning is the process of envisioning a desired future state of sustainable energy supply and consumption based upon existing conditions. In other words, energy planning is a long-term roadmap to focus and guide efforts and actions towards a defined energy vision. It is a key step in putting an energy management system in place and translate the commitment and energy policy into objectives, targets, and action plans. It is fundamental to know how much energy is being used, where, and for what purpose and answers the following questions:

- How much energy building is using?
- What is the trend of energy usage?
- Where the energy is being consumed in building and which are the most significant usage areas?
- What is the driving factor of the energy usage?
- What are the indicators that the buildings can use to measure and manage energy performance?
- What opportunities do the buildings have to improve the premises energy performance?
- What are the buildings energy performance improvement, objectives, target, and action plans?

8.1.1 Objective of Energy Planning

The energy planning process encompass the procedures and strategies that governments and organizations employ to manage energy production, distribution, and consumption. Through thoughtful energy planning, building owners and stakeholders can improve energy efficiency, and ensure that energy production aligns with environmental conservation and sustainable practices. The broader aim of energy planning is:

- ✓ Basis for the policy framework, setting energy goals and making energy decisions.
- ✓ Help in finding and allocating the resources for meeting the specific energy requirements.
- ✓ Encourage reduction in energy consumption and costs through energy audit and investments in energy efficiency opportunities.
- ✓ Encourage planning, design, and construction of energy-efficient buildings.
- ✓ Assessing the scope and extent of energy use efficiency.
- ✓ Increasing the use of cleaner energy alternatives.
- ✓ Providing information to energy management team to implement energy plans.

8.1.2 Benefits of Energy Planning

Energy planning offers a wide range of benefits, from cost savings and environmental protection to improved operational efficiency and long-term sustainability in buildings. By focusing on reducing energy consumption, optimizing energy use, and adopting sustainable energy practices, organizations and governments can realize both immediate and long-term advantages in terms of financial performance, regulatory compliance, and environmental responsibility. Some of the benefits includes the following:

Lower energy costs
- Through optimizing energy useby efficient system and practice
- Help identify inefficiencies
- Strategic planning allows for more targeted investments

Reduced environmental impact
- Reduced carbon footprint due to use of renewable energy
- Helps transition to sustainable energy solutions reducing reliance on fossil fuel
- Reducing the energy demand contribute to flight climate change

Improved energy security
- Diversify energy sources, reducing reliance on a single source and enhancing energy security
- Anticiptae and adapte to market volatility including fluctuations in energy price

Enhanced operational efficiency
- Helps in balancing energy demand with supply and minizime peak demand load
- Proper plannign ensures that energy systems are well designed

Long term sustainability
- Promote sustainable use of natural resources
- Anticipate future energy needs and trends and help create resilient systems for future challenges

Regulatory compliance
- Ensure to meet regulatory standards for energy efficiency and renewable energy
- Helps to take advantage of government funded financial incentives, grants and rebates.

8.2 Key Activities of Energy Planning for Effective Energy Management

Energy planning is a continuous iterative process having the following key activities that form important steps a building premises/ organizations can take to begin or make progress on their energy planning journey. The process and the steps involved in the energy planning process is illustrated as under Figure 34:

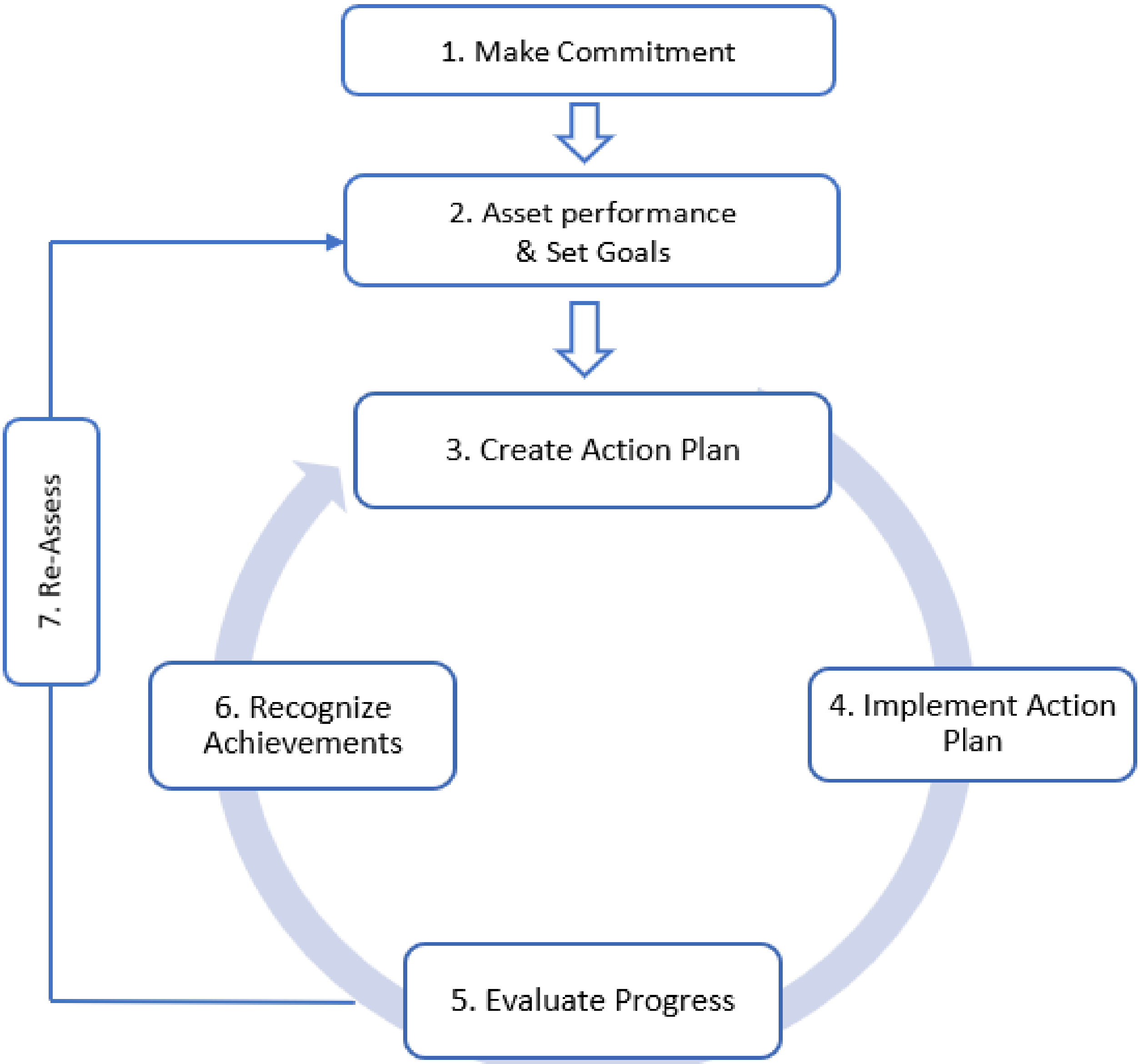


Figure 34: Steps of energy planning process

Step 1: Make commitment

The first and foremost step is to establish a requirement and scope for energy management plan followed by the creation of a dedicated energy team reflecting a cross-sectional key stakeholder that will provide guidance on the development of plan.

Step 2: Asset performance and set goals.

Asset Performance

The next step involves the understanding of current and past energy use to identify opportunities for improving the energy performance and gain financial benefits. Assessing the performance is the periodic process of evaluating energy use for all major facilities and functions in the building premises and establishing a baseline for measuring future results of efficiency efforts. The key aspect in this step includes:

Data Collection and Management

- Gather and track data – Collect energy use information and document data over time.

Baselining and Benchmarking

- Establish baselines – Determine the starting point from which to measure progress.
- Benchmark – Compare the energy performance of various building facilities, peers and over time to prioritize which premises to focus on for improvements.

Analysis and Evaluation

- Analyze – Understand the energy use patterns and trends.
- Technical assistance and audits – Evaluate the operating performance of facility systems and equipment to determine improvement potential.

The assessment of energy performance would help to answer the following:

- ✓ Categorize current energy use by fuel type, operating division, facility, etc.
- ✓ Identify high performing facilities for recognition and replicable practices.
- ✓ Prioritize poor performing facilities for immediate improvement.
- ✓ Understand the contribution of energy expenditures to operating costs.
- ✓ Develop a historical perspective and context for future actions and decisions.
- ✓ Establish reference points for measuring and rewarding good performance.

Setting Goals

Setting the clear and measurable goals drive the energy management activities and promote continuous improvement and helps in understanding intended results, developing effective strategies, and obtaining financial gains. Further, well-settled goals guide daily decision-making and form the basis for tracking and measuring progress. Hence, to develop effective performance goals, following shall be covered:

Determine scope → **Estimate potential for improvement** → **Establish goals**

- **Determine scope:** Identify organizational and time parameters for goals.
- **Estimate potential for improvement:** Review baselines, benchmark to determine the potential and conduct feasibility assessments and audits.
- **Establish goals:** Create and express clear, measurable goals with target timelines for the entire organization, facilities, process, or equipment.

Setting the goals would help in understanding the following:

- ✓ Set the tone for improvement throughout the organization.
- ✓ Measure the success of energy management program.
- ✓ Help the energy management team to identify the progress and setbacks at the facility level.
- ✓ Foster ownership of energy management, create a sense of purpose and motivate staff.
- ✓ Demonstrate commitment of reducing environmental impacts.
- ✓ Create schedules for upgrading the activities and identify key milestones.

Step 3: Create action plan.

After the goals setting, building premises can now develop a roadmap to improve energy performance of their facilities. A detailed action plan would help in ensuring a systematic process to implement performance measures wherein, action plan is regularly updated on an annual basis to reflect recent achievements, changes in performance and shifting priorities. This step would help in designing the following:

Defining technical steps

- Identify gaps between current performance and goals by reviewing the results of technical assessments or energy audits and based upon that take necessary steps to take the organization to the desired level of performance.

Defining technical targets

- Create performance targets for each facility, to track progress towards achieving goals
- Set timelines to evaluate progress, completion milestones and expected outcome.
- Creation of a system to track and monitor the progress of energy use and related project activities.

Determine roles and responsibilities

- Identify internal and external roles to determine who should be involved and what are their responsibilities.

Step 4: Implement action plan.

The next step for the energy management team is to establish policy and program recommendations to meet the goals. The recommendations include the development of detailed action plan and milestones for implementation. The implementation of action plan shall include the following steps:

Creation of communication plan

- Develop targeted information for stakeholders and other key officials about energy management plan.
- It includes developing variety of communication resources that an organization can customize to help spread the activities across stakeholders.

Raise awareness

- Communication strategies and materials for raising awareness of energy use, goals and impacts shall be tailored to the needs of intended stakeholders.
- Increase general energy awareness to build management support for energy management activities and programs.

Build capacity

- Investing in training and systems to share successful practices helps ensure the success of the action plan by building the overall organizational capacity.
- Capacity building training programs help staff to understand the importance of energy performance that provides the necessary information to make informed decisions.

Motivate

- Offering incentives by means of internal competition, recognition, financial bonus, environmental sustainability and tying performance standards to energy goals for energy management

Track and monitor

- A centralized tracking system is how an energy program's activities are monitored and available for all to use in gauging progress toward established targets, milestones, and deadlines.

Step 5: Evaluate progress.

This step evaluates the progress that includes formal review of both energy use data and the activities carried out as part of the action plan as compared to the performance goals. The evaluation results and information gathered during the formal review process is used by organizations to create new action plans, identify best practices, and set new performance goals. The key steps involved are:

Measure results

Gather energy use data and compare results to established goals to determine the accomplishments

- Reviewing energy use and cost data.
- Organize reports and data from tracking and monitoring efforts.
- Analyze energy efficiency achievements based on established performance metrices.

Review action plan

Understand factors affecting the results as well as additional benefits of improved energy performance

- Get feedback on the plan from the energy management team and other departments.
- Identify critical factors that has led to miss or surpass the targets.
- Identify and quantify benefits arising from the implementation of energy management activities and programs i.e. reduced O&M expenses, productivity improvement, etc.

Step 6: Recognize achievements.

The last step is providing internal recognition to individuals, teams and facilities within the organization as well as receiving external recognition from government agencies, or any other third-party organizations for supporting and successfully implementing the energy management activities and programs.

8.3 Role of Stakeholders in Energy Planning Process

Stakeholders are individuals or groups with a vested interest in the outcome of a plan, and their role in energy planning is to help ensure that policies are relevant, effective, and supported by a wide range of stakeholders.

The key stakeholders and program participants could help drive the development, implementation, and success of any energy efficiency policy or program. It further, play a critical role in the energy planning process by helping to identify potential challenges, propose solutions, and ensure that policies are relevant and effective. The role of various stakeholders in the energy planning process is summarized below in Table 15:

Table 15: Role and Responsibilities of different types of Stakeholders in Energy Planning Process

Stakeholder	Role and Responsibilities
National/ State Govt.	• Formulating the energy policy and setting energy goals for national development. • Framing regulations to facilitate fulfilment of energy goals. • Providing funds and resources for the energy efficiency. • Encouraging the departments and organizations to adopt the regulations that reflect good energy planning principles. • Setting up monitoring mechanisms, developing, and disseminating tools and methods for monitoring energy performance and implementing energy policy. • Distributing information on energy options and financing to developers, builders • Commissioning energy surveys in accordance with the ongoing energy planning scenario as well as the near-term projections. This will help to ascertain the willingness of the target group to share energy driven responsibilities. • Monitoring energy use and enforcing energy performance standards.
Organizations/ Departments/ Building premises	• Identifying energy resources. • Participating in energy planning exercises to influence staff, employees, and plant officials towards energy efficiency. • Identifying energy options and incorporating them into internal strategic and operational plans (such as Integrated Resource Plans). • Identifying potential design changes and design standards to improve service quality and cost-effectiveness.

Stakeholder	Role and Responsibilities
Developers	• Becoming familiar with current energy opportunities, public preferences, potential market trends and using them. • Working with local planners to identify preferred development standards or design features that can be practically implemented. • Constructing buildings on the basis of their long-term costs and performance and conforming to standards. • Using cost-saving or cost-neutral energy options and adopting designs and features that recognize and mitigate infrastructural and environmental constraints or costs. • Facilitate easy financing mechanisms devoid of bulky documentation practices of past.

8.4 Energy Planning Ledger

The energy planning ledger and assessment checklist assist the building owners in highlighting the required information/ data to initiate the energy assessment. The energy planning ledger and assessment checklist can be used while conducting energy assessment of the building premises and record the information on energy use. The structure of energy planning ledger prepared for commercial buildings is tabulated below and provide the insights on the following questions:

- How much energy does the building use?
- Collect the electricity bills for past 1 year and use them to fill out the energy planning ledger.
- What are the various sources of energy use in the building?
- What is the cost of various energy sources?
- Other relevant information/data.

The energy planning ledger will help to ascertain an energy use baseline that will allow buildings to measure the success of energy management program at regular intervals.

8.5 Energy Assessment Checklist

An energy assessment checklist is a list of items and steps that an energy assessor follows when evaluating a building or system for energy efficiency. The checklist assists the building staff and O&M personals in the identification of energy saving improvements that can be easily implemented and make necessary observations against each action item. It helps to ensure that all key areas are reviewed and that nothing is overlooked by using checklist boxes to check the progress on energy conservation, mark necessary observations and take corrective actions.

The energy planning ledger and energy assessment checklist for existing building systems provided under **Annexure-4** of this guideline.

REFERENCE

REFERENCE

In addition to the references provided in the guidelines (as footnotes), the following documents were also referenced in the preparation of the energy efficiency and energy conservation guidelines for the commercial sector:

Energy Efficiency Management Office, Energy Efficiency and Energy Conservation in Hotels", Mauritius, 2021.

Ministry of Energy and Public Utilities: Energy Efficiency Management Office, "Guidelines for the reduction of electricity consumption in Public Institutions", Mauritius, 2021.

Government Gazette of Mauritius, "The Building Control Act", 2012.

Government Gazette of Mauritius, "Energy Efficiency Act", 2011.

Energy Efficiency Management Office, "Survey on Energy Use/Consumption and Energy Efficiency in the Services Sector", Mauritius, 2019.

Government Gazette of Mauritius, "Energy Efficiency (Energy Consumer and Energy Audit) Regulations", 2017.

Building Sector Energy Efficiency Project (BSEEP), "Building Energy Efficiency Technical Guideline for Passive Design", Malaysia, 2013.

Singh R, Ravache B, Sartor D, "Building Innovation: A Guide for High-Performance Energy Efficient Buildings in India", Lawrence Berkeley National Laboratory, 2018.

Bureau of Energy Efficiency, "Energy Conservation Building Code", India, 2017.

International Institute for Energy Conservation (IIEC), "Energy Efficiency Guidelines for Commercial & Public Buildings in the Pacific", 2015.

The Energy and Resources Institute, "Existing Commercial Building Retrofit Guidelines", New Delhi, 2019.

Green Building Council of South Africa (GBCSA), "Green Star A Mauritius Local Context Report: Applying Green Star SA in Mauritius", 2017.

Energy Conservation of Nigeria: Japan International Cooperation Agency, "Energy Audit of Selected Buildings in Abuja", 2017.

Economic Research Institute for ASEAN and East Asia (ERIA), "Technical Guidelines for Energy Efficiency and Conservation in Commercial Buildings", Indonesia, 2021.

Energy Conservation and Commercialization (ECO-III), "Envisioning the National Building Star Rating Program," India, 2010.

ASHRAE Technical Committee 7.6, Building Energy Performance, "Procedures for Commercial Building Energy Audits Second Edition", Atlanta, 2011.

Indian Standard IS/ISO 50002:2014, "Energy audits requirements with guidance for use", 2017.

Construction Industry Development Board, "A Strategy Paper for the Construction Industry", 2013.

Bureau of Energy Efficiency, "Guidelines for Energy-Efficient and Thermally Comfortable Public Buildings in Karnataka", India, 2016.

Ministry of Science, Energy, Telecommunication, and Transport, "Energy Efficiency and Conservation Policy and Guidelines for Public Facilities, Specifically for School, and Hospitals", India, 2023.

Juha Forsstrom, Pekka Lahti, Esa Pursiheimo, Miika Rämä, "Measuring energy efficiency: Indicators and potentials in buildings, communities and energy systems", 2011.

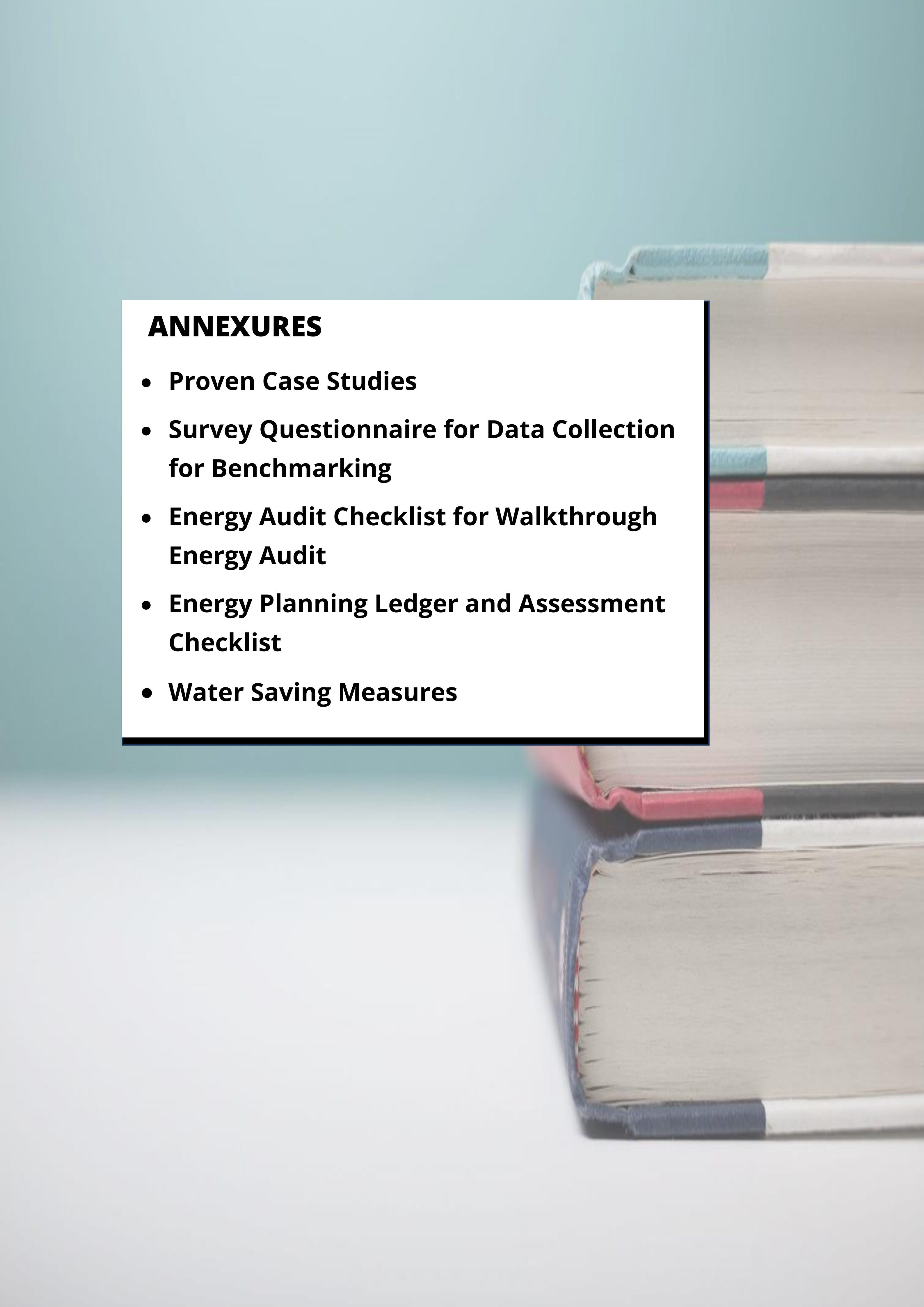
European Standard, “EN 12464-1: Light and lighting - Lighting of work places - Part 1: Indoor work places”, 2002

United Nations Framework Convention on Climate Change, “Standardized baseline: Mauritius Grid Emission Factor” Version 1.0, 2019

Int. Electrotechnical Commission (IEC), Standard for Efficiency classes of line operated AC motors (IE code), no. 60034-30-1:2014, 2014

Stanford University, Guidelines for Life Cycle Cost Analysis, 2005

Department of Sustainable Development of the General Secretariat of the Organization of American State, “Energy Efficiency Guidelines for Office Buildings in Tropical Climates”, 2013.



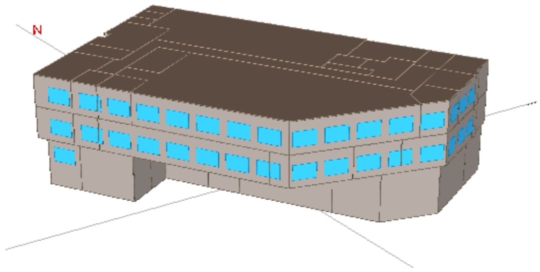
ANNEXURES

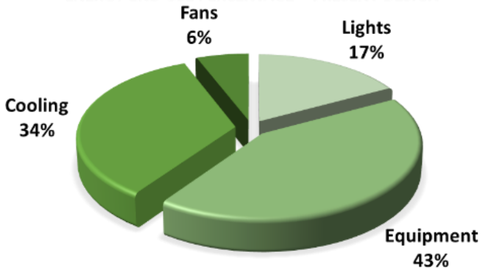
- **Proven Case Studies**
- **Survey Questionnaire for Data Collection for Benchmarking**
- **Energy Audit Checklist for Walkthrough Energy Audit**
- **Energy Planning Ledger and Assessment Checklist**
- **Water Saving Measures**

Case Study-1: Application of ECMs in an Office Building

This case study highlights the potential energy savings and load reduction achieved through the implementation of various energy conservation measures in a new office building for warm and humid climate. The building characteristics are following:

Building Parameters	
Climate	Warm and Humid
Building typology	Office building
Area	6,500 sqm
Building WWR	21 %
Wall	200mm common brick + Cement plaster
Roof	150mm RCC
Glazing	Single clear glass with SHGC of 0.87
Interior lighting power density	10.0 W/sqm
Lighting Controls	No
HVAC system type	Packaged terminal AC
System efficiency	COP of 3.2
Fan control	Constant volume





The estimated annual energy consumption of the building without any design interventions is 26,75,312 kWh/year with an EPI (Energy Performance Index: Electricity Usage per area per year) of **225 kWh/Sqm/Yr**. The following ECMs were incorporated in the building which provided significant cooling load reduction and energy savings as given in the table below:

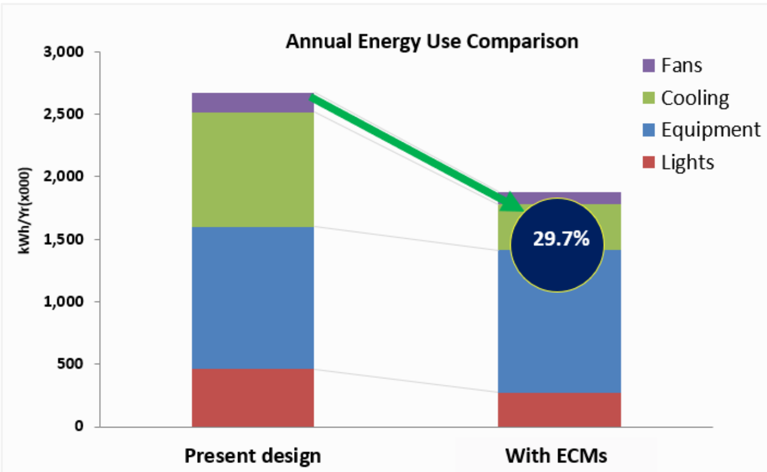
Category	Base / Design Case	Proposed Energy Conservation Measures	Energy savings
Site Measures	Building with orientation 45 degrees between North and South.	**ECM-1:** Building orientation with largest side towards North and South.	Annual energy consumption reduction of 1.3%.
Building Envelope	150 mm RCC roof	**ECM-2:** Roof insulation of 50mm XPS insulation	Load reduction of 4.4 % Energy reduction of 1.2 %
		ECM-3: Roof insulation of 75mm XPS insulation	Load reduction of 7.8 % Energy reduction of 1.7 %
	200 mm common brick with cement plaster on both sides	**ECM-4:** Use of AAC block	Load reduction of 7.1 % Energy reduction of 0.8 %
		ECM-5: Use of AAC block with 50mm XPS insulation	Load reduction of 8.9 % Energy reduction of 1.0 %
	Single clear glass with a U-value of 8.34 W/sqm.K and SHGC of 0.87	**ECM-6:** Use single glazed glass with a U-value of 6.1 W/sqm.K and SHGC of 0.62.	Load reduction of 4.8 % Energy reduction of 2.4 %
		ECM-7: Use single glazed glass with a U-value of 6.1 W/sqm.K and SHGC of 0.50.	Load reduction of 9.7 % Energy reduction of 3.8 %
		ECM-8: Use double glazed glass with a U-value of 2.8 W/sqm.K and SHGC of 0.39.	Load reduction of 13.1 % Energy reduction of 4.4 %

Category	Base / Design Case	Proposed Energy Conservation Measures	Energy savings
		ECM-9: Use double glazed glass with a U-value of 2.6 W/sqm.K and SHGC of 0.30.	Load reduction of 15.5 % Energy reduction of 4.9 %
	No shading	**ECM-10:** Shading of windows with overhang of 1 feet depth	Load reduction of 5.1 % Energy reduction of 1.6 %
Building Lighting and Controls	Lighting power density of 10.0 W/sqm	**ECM-11:** Use of efficient interior lighting with 10 % reduced LPD.	Load reduction of 2.6 % Energy reduction of 2.5 %
		ECM-12: Use of efficient interior lighting with 20 % reduced LPD.	Load reduction of 5.2 % Energy reduction of 5.0 %
		ECM-13: Use of efficient interior lighting with 30 % reduced LPD.	Load reduction of 7.9 % Energy reduction of 7.5 %
	No use of daylighting controls	**ECM-14:** Use of Daylighting controls	Load reduction of 4.8 % Energy reduction of 4.2 %
Building HVAC System	Packaged terminal AC with COP of 3.2	**ECM-15:** VRF system with COP of 3.2	Energy reduction of 12.5 %
		ECM-16: VRF system with COP of 3.5	Energy reduction of 14.4 %
		ECM-17: VRF system with COP of 3.8	Energy reduction of 16.0 %
		ECM-18: VRF system with COP of 4.0	Energy reduction of 16.9 %

With the incorporation of combined ECMs listed below, the estimated annual energy consumption is 18,80,744 kWh/year resulting in overall energy savings of 29.7% with a reduction of EPI of 151 kWh/sqm/year.

Combined ECM

- 50mm XPS Roof insulation
- High performance Wall with AAC block and 50mm XPS insulation
- High-performance double-glazed glass with SHGC 0.3
- Overhang 1 feet depth
- 30% reduced LPD
- VRF system of 4.0 COP

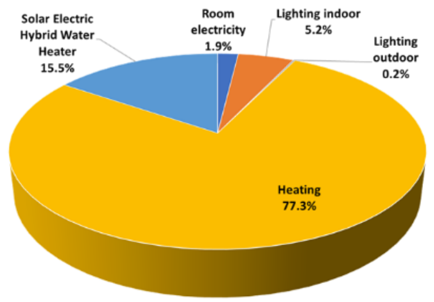


Case Study-2: Retrofitting of a Hostel Building

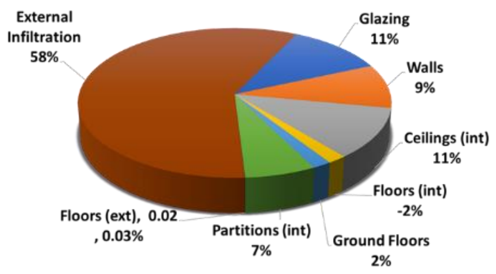
This case study highlights the potential energy savings achieved through the implementation of various energy conservation measures in an existing residential building in cold climate. The purpose of highlighting this case study to showcase that by using proper planning and ECM's, the energy can be saved up to 80% of the total energy consumption.

Building Parameters	
Climate	Cold
Building typology	Residential building
Building WWR	16 %
Wall	230mm hollow blocks + Cement plaster
Roof	10mm particle board with timber frame support and 3mm Corrugated galvanised iron (CGI) sheets
Floor	100mm RCC floor with cement screed and plaster
Glazing	Single clear glass with wooden frame and SHGC of 0.85
Interior lighting power density	4.0 W/sqm
Lighting Controls	No
Boiler type	Solar and electric hybrid
System efficiency	69 % medium efficiency

Distribution of Energy Use in Building



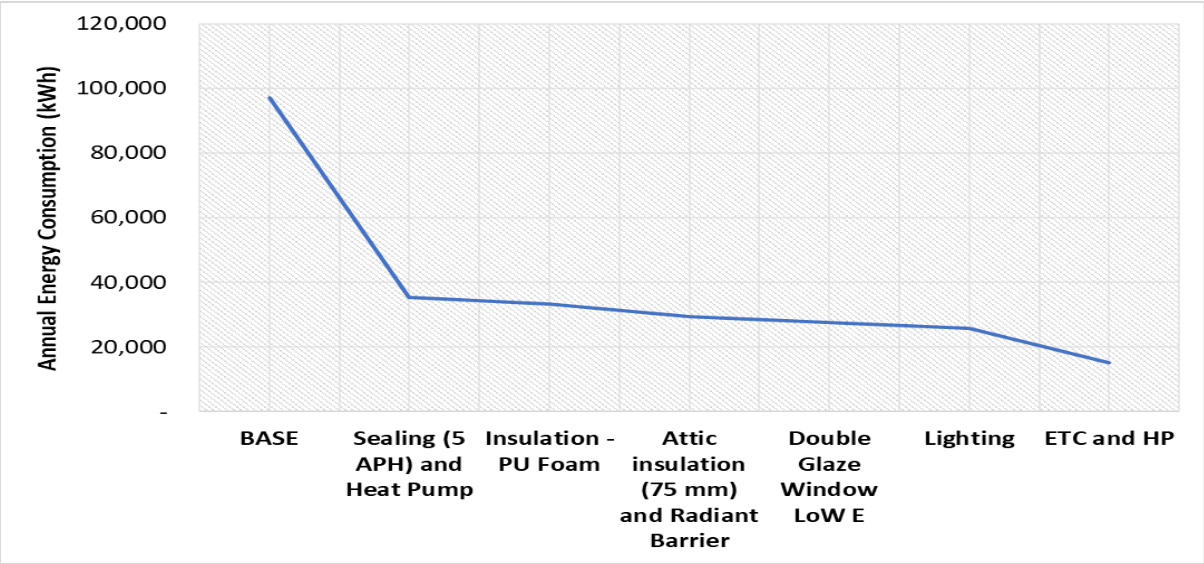
Heat Loss from Existing Building



Annual electricity consumption of existing building is estimated to be 97 kWh per annum. Following ECMs were suggested as a retrofit in the building to increase the energy efficiency:

- Reduce air infiltration.
- Use of heat pump-based heating system
- External wall insulation
- Attic insulation and radiant barrier
- Installation of double-glazed window
- Installation of LED Tube light
- Installation of ETC Solar Heat Pump Hybrid

The following figure illustrate the energy saving at each level of ECM.

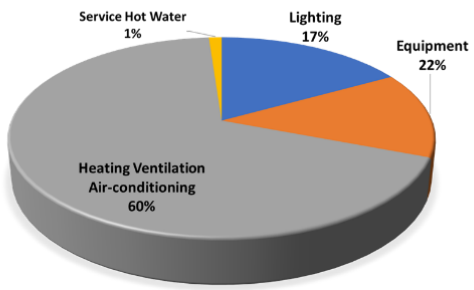


Case Study-3: Path to Net Zero for Educational Building

This case study of a school building in Tropical climate, highlights a path to net zero for a building through the implementation of various energy conservation measures and find out the potential of renewable energy to make the building net zero.

Building Parameters	
Climate	Tropical Climate
Building typology	Educational building
Building WWR	24 %
Wall	230mm bricks + Cement plaster
Roof	200mm RCC + China mosaic tiles
Floor	150mm RCC floor with cement screed and plaster
Glazing	Single clear glass with SHGC of 0.64
Interior lighting power density	5.4 W/sqm
Lighting Controls	No
Cooling type	Chiller of 2.3 COP
Pump type	Constant volume
Current EPI	102 kWh/sqm/year
Existing solar PV	260 kWp

Distribution of Energy Use in Building



The total energy usage of the building is 27,90,428 kWh/year with an EPI of 102. The following ECMs were suggested for incorporation which provided significant energy savings as given in the table below:

S. No	Alternative	Description and Type of ECM
1	ECM 01	Add 50 mm Polystyrene insulation to the As Built wall
2	ECM 02	Add 50 mm Polystyrene insulation over the As Built Roof Assembly
3	ECM 03	Replace existing glazing to reduce SHGC from 0.64 to 0.25
4	ECM 04	Reduce lighting power density 30% below the As Built
5	ECM 05	Reduce lighting power density 40% below the As Built
6	ECM 06	Replace existing 2.3 COP chillers (2 Nos.) with 3.3 COP chillers
7	ECM 07	Replace existing AHU fan motors with Electronically Commutated (EC) motors
8	ECM 08	Reduce the fan power of FCU (0.4 W/CFM)
9	ECM 09	Install VFD on primary and secondary Pumps
10	ECM 10	ECM evaluates impact of distributing 50% of service hot water load on solar hot water
11	ECM Package 01	ECM 04 + ECM 06 + ECM 07 + ECM 08 + ECM 09

The energy savings have been measured individually and payback period have been calculated for each ECM considering lifecycle cost.

Alternative	Annual Energy Savings (kWh/Yr)	Annual Energy cost Savings (USD/Yr)	Incremental Capital Cost (USD)	Simple Payback (Yr)	Life cycle of measure (yr.)	IRR (%)
ECM 01 Wall insulation 50mm	30,070	2,246	132,941	59.3	30	-5%
ECM 02 Roof Insulation 50mm	34,773	2,598	183,529	70.7	30	-6%
ECM 03 High Performance Glazing	36,151	2,701	62,353	23.0	30	1%
ECM 04 Reduced LPD 30 %	81,124	6,060	35,294	5.4	10	16%
ECM 05 Reduced LPD 40 %	1,13,587	8,486	52,941	6.2	10	15%
ECM 06 Efficient Chiller: COP -3.3	3,20,873	23,971	84,706	3.5	15	27%
ECM 07 AHU's with EC Motors	1,45,702	10,885	65,882	6.0	15	15%
ECM 08 Reduced Fan Speed	2,18,174	16,299	90,588	5.6	15	17%
ECM 09 VFD on Pumps	53,991	4,033	2,353	0.6	15	176%
ECM 10 Solar SHW	14,785	1,105	17,647	16.2	15	4%
Package 01 Combined ECMs	**7,72,655**	**57,722**	**278,824**	**4.8**	**20**	**19%**

Recommendations:

- Reduce LPD by 30% from current designed value
- Replacing existing chillers with COP of 3.3
- Replace all AHUs fan motor by Electronically Commutated (EC) motors
- Reduce the fan power of FCU (0.4 - 0.5 W/CFM)
- Install VFD on primary and secondary Pumps

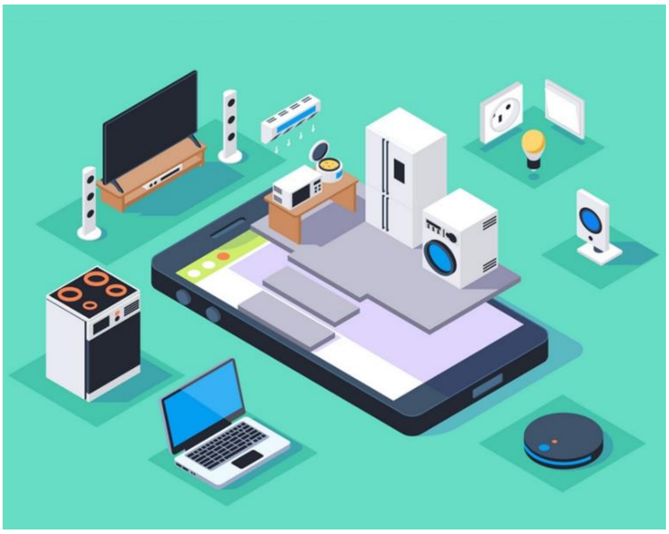
Total investment required – USD 278,824

Simple Payback – 4.8 years

Case Study-4: Use of Smart Controls and IoT Devices

Smart appliances are the devices that can be connected with hub or directly to Internet using home Wi-Fi. These devices can push information and also receive commands from other devises or the users. Some of these devices can be controlled by utility or the aggregators.

Smart blinds	Smart Thermostats	Smart IAQ Devices
Smart AC	Smart Washing Machine	Smart Refrigerator
Smart Geysers	Smart Lighting	Energy Monitoring Systems



Below is the example of installed smart devices in a building and its characteristics.

Smart blinds

Particular	Details
User interface	• Touch: Manufacturer app • Voice: Alexa or google assistant
Connectivity	Bluetooth, WiFi
Display	Smart phone or tablet
Features	• Voice or app or remote based control • Battery powered, optional solar PV system for charging • Sun tracking and manual scheduling options are available • Can be linked with smart AC, smart hub, smart IAQ devices.

Smart Thermostats

Particular	Details
User interface	• Touch: Manufacturer app • Voice: Alexa or google assistant or Apple Home or Nest
Connect over	• WiFi
Display	• In build or Smart phone or tablet
Features	• Voice or app-based control • User can monitor, control and schedule (set temperature) thermostat from anywhere • Smart thermostat learns from user preference and keep track of weather conditions to minimize the energy consumption of HVAC system.

Smart IAQ Devices

Particular	Details
User interface	• Touch: Manufacturer app • Voice: Alexa or google assistant
Connect over	Bluetooth, WiFi
Display	Smart phone or tablet
Features	• Voice or app based control • Monitors the Air Quality, temperature and humidity at anytime and can be accessed from anywhere. • Controls appliances such as air purifier, AC, fan, dehumidifier to Control or maintain air qualify parameters at user preference or set point

Smart AC

Particular	Details
User interface	• Touch: Manufacturer app • Voice: Alexa or google assistant • IR remote control
Connect over	Wifi, infrared
Display	Smart phone or tablet
Features	• Voice or app-based control and scheduling • Easily monitors and controls the Air Conditioner at anytime and from anywhere. • Can control smart blinds and detect air leakage • 20% - 25% energy savings over conventional AC

Smart Washing Machine

Particular	Details
User interface	• Touch: Manufacturer app • Voice: Alexa or google assistant • Dashboard on machine
Connect over	Wifi, infrared
Display	Smart phone or tablet
Features	• Smart Sensors for low voltage usage and smart detergent dosage. • Multiple wash and dry options/program based on cloth type and how dirty cloths are. • Smart selection of wash/dry program reduces wash time and energy consumption. • Wash program can be updated over the air same as any mobile apps.

Smart Refrigerator

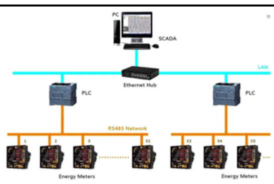
Particular	Details
User interface	Touch: Manufacturer app Voice: Alexa or google assistant
Connect over	Wifi
Display	In Build Display or smart phone or tablet
Features	• User can see inside refrigerator without opening door using cameras • can provide recipe ideas, • Order groceries • look up the weather. • Bluetooth speakers also let user stream music • Can control other smart appliances such as geysers, AC etc.

Smart Geysers

Particular	Details
User interface	Touch: Manufacturer app Voice: Alexa or google assistant
Connect over	Wifi
Display	In Build Display or smart phone or tablet
Features	• User can set temperature and schedule the geyser using app or touch panel • User can monitor and control geyser from any where • Can monitor user preference of temperature and keeps water ready at preferred temperature and preferred time

Smart Lighting

Particular	Details
User interface	Touch: Manufacturer app Voice: Alexa or google assistant or IFTTT or NEST or Apple Home
Connectivity	Wifi, Bluetooth, ZigBee
Display	Smart phone or tablet
Features	• Option of multi level dimming is available. • User can monitor and control light from anywhere using smart phone • User can change light color based on requirement



Energy Monitoring Systems

- Energy monitoring systems (EMS) are used to monitor the real time power consumption. Using the smartphone app, live alerts regarding usage of each appliance can be obtained.
- EMS allows to track energy consumption of appliances and track monthly energy statistics.
- Based on the feedback and analysis of the present and past energy consumption trends insights for energy saving may be identified.

Case Study-5: Use of Smart Controls

The REFIT (Personalised Retrofit Decision Support Tools for UK Homes Using Smart Home Technology) project is an interdisciplinary research project that aims to highlight how smart homes are able to provide useful information about retrofit, energy efficiency and on-site renewable technology options for UK homes. Moreover, the aim of the project is to reduce energy related costs with help of user engagement and expert-related advice. The project involved 20 households in U.K. and a 2-year period to assess both baselines and energy savings.

Monitored variables and technology information

After the identification of the case study, there was the installation of monitoring sensors to identify the baseline, with the aim to provide a benchmark to assess energy savings. During this time the occupants followed their usual routines and the sensor networks captured energy, performance and occupant behavior data.

After a 1-year period detailed models were created for each household based on data collected by sensors. Each household was equipped with 9 Individual appliance monitors (that represented the maximum numbers of IAM that did not lead to information loss), shown in Figure 24. The household aggregate was acquired by a CurrenCost transmitter, and the data were acquired every 8 seconds and collected via the EnvIR aggregator, connected to the communication gateway.

Appliance	House Number																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21	Total
Television	x	x	x	x	x	x	x	x	x	x		2 ×	2 ×								21
Wi-Fi		×							×		×							×			4
Fridge-Freezer		×	×	×	×				×	×	×	×		×	2 ×	×	×			×	14
Fridge	×			×			×	×			×						×	×	×		7
Freezer	2 ×		×	×		×	2 ×	×		2 ×						×	×	×	×		13
Microwave		×	×	×	×	×			×	×	×	×	×	×		×	×	×	×		16
Cooker Hood		×																			1
Kettle		×	×	×	×	×	×	×	×		×	×	×	×		×		×	×	×	16
Toaster		×	×		×	×	×	×				×		×							8
Misc Kitchen										2 ×								×		×	4
Washing Machine	×	×	×	2 ×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	×	20
Washer Dryer									×								×				2
Tumble Dryer	×		×		×		×	×					×	×		×			×	×	10
Dishwasher	×	×	×		×	×	×		×	×	×		×	×	×		×		×	×	15
Computer	×			×	×	2 ×		×			×		×	×	×	×	×				13
Router											×										1
Elec Heater	×								×						2 ×						4
Lamp																		×			1
Misc															×	×				2 ×	4

Figure: Monitored appliances for each house

Moreover, using specific algorithm such as decision-tree algorithm, REFIT propose a load disaggregation per appliance that helps the occupant understand the impact of a specific appliance on the total energy consumption.

Another major aspect is related to temperature sensors to provide feedback to users to reduce heating consumption. In particular, in the REFIT project, 3 different kind of smart sensors were used: thermostat, motion and contact sensors, to identify potential energy savings deriving from a more conscious heating system use.

In terms of costs REFIT expected cost package is £199, with expected saving up to £150 per year. Apart from a monetary aspect, the system provides an interactive interface, shown in below figure that can control different deferrable appliances, influencing both electrical and thermal loads. Moreover, this kind of system could help the occupant to schedule the appliances to take full advantage of time-of-use tariff price and demand response programs.

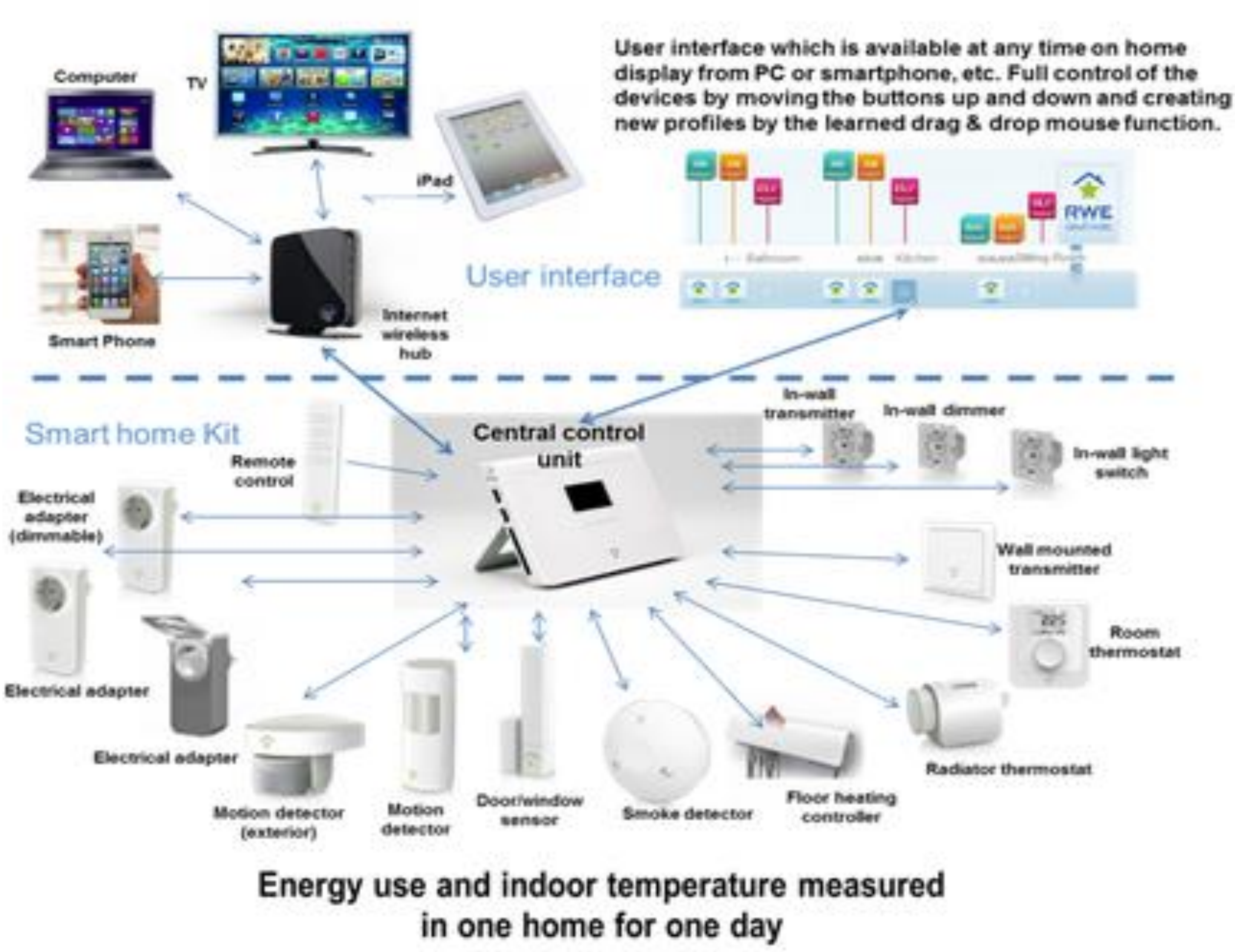


Figure: REFIT Interface

The project also considered the interaction with the occupant providing feedback regarding possible retrofit options to further reduce energy consumption and the interaction among expert and occupant provided a reduction of 20% of heating energy consumption. Finally, REFIT also provides report based on data previously acquired, to compare consumption with previous years or with other “representative” buildings. Moreover, the previous disaggregation algorithm is able to identify the contribution of an activity (related to the use of a certain appliances) to the total loads. This kind of information has proven to be useful to increase user’s consciousness and reduce energy consumption.

Annexure-2: Survey Questionnaire for Data Collection for Benchmarking

Range of Energy Use Intensity for Commercial Buildings in Mauritius

S.N.	Questions
1	**Please Select the Building Typology** ☐ Wholesale and retail trade ☐ Storage ☐ Information and Communication ☐ Financial and insurance activities ☐ Professional, scientific and technical activities ☐ Education ☐ Human health and social work activities ☐ Arts, entertainment and recreation
2	**Name of the building**
3	**Number of floors in the building (***Including Ground floor)*
4	**Gross Floor Area of the Building (sqm)** *The total floor area contained within the building measured to the external face of the external walls*
5	**Total Built-up Area excluding Unconditioned Basement (sqm)** *The carpet area plus the area that is covered by the inner walls and the balcony*
6	**Total Conditioned Area, i.e. area which has Provision to HVAC Systems (sqm)**
7	**Planned Operational Hours for a Year**
8	**Actual Operational Hours in a Year**
9	**Annual Energy Consumption of Building (from electricity) in kWh/year**

Annexure-3: Energy Audit Checklist for Walkthrough Energy Audit

1. Basic Information about Building		
1.1 General Information		
Particulars	**Units**	**User Input**
Name of the building	-	
Address of the building	-	
Contact Person and Designation	-	
Telephone No.	-	
Email ID	-	
Building Year of construction		
Year when last major renovation done (if applicable)	#	
Any Expansions planned in the next 3 years?	-	
If yes, please provide brief information	-	
Whether building is owned		
Whether building is leased		
If yes, when is the lease up for renewal (date/year)?		
How long does the lease contract last (years)?		
1.2 Building Data		
Particulars	**Units**	**User Input**
Building Typology	-	
Building Orientation		
Building longer façade orientation		
Total No. of Floors	#	
Gross Floor area	m^2	
Conditioned floor area	m^2	
Total Built-up area	m^2	
Total Carpet area	m^2	
Percentage of Floor area that is cooled	%	
Operating hours per day	Hours/day	
Operating days per week	Days/week	
Operating days per year	Days/year	
Number of daily shifts carried in the building	#	
Total Number of Occupants	#	
Total occupancy per shift	#	
Building roof type	-	
Type of glazing on building façade	-	
Building window to wall ratio (WWR)	-	
1.3 Building Construction Properties		
Roof construction details		
Floor construction details		
Wall construction details		
Whether insulation used in wall or roof?		
Fenestration glazing type		
Fenestration frame type		
1.4 Energy Meter Related Information		
Particulars	**Units**	**User Input**
The organization receives monthly bills based on energy meter readings	-	
Meters are read regularly by on-site staff	-	

1. Basic Information about Building		
Bills are compared to monthly meter readings on a regular basis	-	
Is building having separate meters for different feeders/floors/occupants?	-	
A Building Automation System is in place and used to track utility data regularly	-	
Is the building sub-metered?	-	
Does the building have automated 15-minute interval or SMART meters	-	
1.5 Annual Utility Consumption		
1.5.1 Electricity Consumption		
Particulars	**Units**	**User Input**
Name of Electric Utility Company	-	
Name of Gas Utility Company	-	
Type of Power connection	-	
Total Connected Load	kW	
Total Contract Demand	kVA	
Building Maximum Demand	kW or kVA	
Building Annual Electricity consumption	kWh/year	
Percentage of electricity sourced from grid	%	
Has the building installed any Renewable Energy (RE) source for electricity generation?	-	
If yes, please specify the source of RE generation	-	
If yes, what is the installed capacity of RE source in the building?	kW	
Building Annual Electricity generation from the RE source	kWh/year	
Building Annual Electricity consumption from Renewable Energy *(Please provide the RE details for past 2 years)*	kWh/year	
Percentage of electricity sourced from RE source	%	
Rating of Diesel Generator (DG) sets installed in the building	kVA	
Make of DG sets	-	
Total No. of DG sets installed in the building	#	
Mode of operation of DG sets	-	
Monthly operating hours of DG sets	Hours	
Annual operating hours of DG sets	Hours	
Building Annual Electricity Consumption from DG sets *(Please provide the electricity consumption and cost details for past 2 years)*	kWh/year	
Percentage of electricity sourced from DG	%	
Building Electricity Tariff/ Rate	MUR/kWh	
Building Annual Electricity Bill *(Please provide the electricity bills past 2 years)*	MUR	
1.5.2 Fuel Consumption (e.g. Natural gas (NG), Diesel, Furnace Oil (FO), Other)		
Particulars	**Units**	**User Input**
Type of fuel		
If type of fuel used is not from the above said list, please specify the name of 'other' fuel		

1. Basic Information about Building		
Purpose of Use		
Annual Fuel Consumption *(Please provide the fuel consumption and cost details for past 2 years)*	cubic meter for Natural Gas and Diesel kg for Steam	
1.6 Transformer details		
Particulars	**Units**	**User Input**
Type of transformer		
Type of transformer winding		
Mention the no-load and full-load losses		
Year of installation of transformers		
Please specify the failure rate of transformers		
Make of Transformers		
Whether the metering is done on the transformers?		
If yes, please specify no. of meters and make of meters		
Total Rating of transformers	kVA	
Average loading of each of the transformer	%	
Voltage Ratio	%	
Transformer efficiency	%	
1.7 Energy Audit information		
Particulars	**Units**	**User Input**
Has an Energy Audit been carried out in the last 5 years?	-	
If yes, please provide the following details: (i) Auditing agency responsible for conducting the audit (ii) Copy of report. (iii) List of recommended energy conservation measures (ECM) along with their energy saving and GHG emissions reduction potential and investment proposed	-	
Does the building have implemented ECM measures?	-	
If yes, please specify the following:		
(i) What are the ECM measures?		
(ii) What is the annual energy savings (kWh)?		
(iii) What is the annual cost savings (US $)?		
(iv) What is the GHG emissions reduction (tCO2/kWh)?		
(v) What is the investment cost made? (US $)		
If no, what is the reason for not implementing the ECM?	-	

2. Basic Information about Lighting

2.1 Lighting Equipment Inventory Checklist

Particulars	Units	User Input
Do you have inventory data for lighting installed in the building?	-	Please select from drop down
If yes, please specify the following information		
Is your facility using the most energy efficient lighting options?	-	Please select from drop down
Are there areas that have excessive or unneeded lighting?	-	Please select from drop down
Are you making effective use of available lighting, such as natural sunlight?	-	Please select from drop down
Have you installed lighting management equipment such as dimmers, timers and sensors?	-	
Type of Luminaires in the building		
Type of Ballast in the building		
Type of Lighting Control		
Total No. of fixtures/ luminaires	#	
Total Wattage/ Lighting Connected Load	kW	
Daily Operating hours of indoor lights	hours/day	
Daily Operating hours of outdoor lights	hours/day	
Total Daily Electricity Consumption from Lighting	kWh/day	
Annual Lighting Electricity Consumption	kWh/year	
Building Average Lighting Power Density (LPD)	W/ m^2	
Type of Lighting Control (whether it is manual, timer, occupancy sensor, dimming, photocell or others)		
Installation location of luminaire		

3. Heating, Ventilation, and Air Conditioning (HVAC) System Equipment Inventory Checklist		
3.1 General Information		
Particulars	**Units**	**User Input**
Do you have inventory data for HVAC system installed in the building?		
If yes, please specify the following information		
Is HVAC system operating efficiently?		
Is there a regular maintenance and update schedule for these systems?		
Are filters replaced regularly?		
Is the building properly ventilated?		
Type of Cooling distribution equipment system installed in the building		
Type of Cooling source		
Type of compressor		
Type of condenser		
Type of Heating source		
Type of heating fuel		
If other, please specify the heating fuel	-	
3.2 Chiller details		
Particulars	**Units**	**User Input**
Type of Chiller		
Total no. of Chillers installed in the building	#	
Rating/ Capacity of Chillers	BTU	
Make of Chillers	-	
Please specify the Type of Refrigerant used		
Cooling Seasonal Performance Factor (CSPF) of chillers	kW/BTU	
Is it VFD control?		
What fuel type does the system use?		
Is the system air cooled or water cooled?		
How is the system controlled?		
3.3 Pumping System details		
Particulars	**Units**	**User Input**
Type of Pump		
Purpose of Use		
Total no. of pumps installed in the building		
Rating/ Capacity of Pumps	kW	
Make of Pumps		
Pump Efficiency	%	
Is it VFD control?		
If no, what type of control system is installed?		
3.4 Cooling Tower (CT) details		
Particulars	**Units**	**User Input**
Make of Cooling Tower		
Purpose of Use		
Heat rejection type in CT		
Total no. of cooling towers installed in the building	#	
Heat rejection capacity of cooling tower	BTU	
Type of fan		
Please specify the Type of Fan drive used		
Is VFD installed on fan?		

3. Heating, Ventilation, and Air Conditioning (HVAC) System Equipment Inventory Checklist		
If no, what type of control system is installed?		
Type of fluid cooler		
3.5 Air Handling Unit (AHU) details		
Particulars	**Units**	**User Input**
Make of AHUs installed in the building	-	
Purpose of Use	-	
Heat rejection capacity (TR)	BTU	
Total no. of AHUs installed in the building	#	
CFM rating of AHUs	CFM	
Type of AHU		
If the type of AHU is more than one list down here.	-	
Type of heating source	-	
Type of cooling source		
Type of control		

4. Hot Water Heating System		
Particulars	**Units**	**User Input**
Do you have inventory data for hot water system installed in the building?	-	
If yes, please specify the following information		
What is the source	-	
Type of water heating system installed in the building	-	
If electricity, please specify the following:		
Total no. of electric based water heating system installed in the building?	#	
What is the rating/total connected load of water heating system?	kW	
What is the monthly energy consumption of water heating system?	kWh/month	
Daily operating hours	hours/ day	
If solar, please specify the following:		
Total no. of solar water heating system installed in the building?	#	
What is the installed capacity solar water heating system?	kW	
What is the monthly energy consumption of water heating system?	kWh/month	
Daily operating hours	hours/ day	
Please specify, what is the monthly quantity of gas/ other fuel used for water heating?	m^3	
What is the total building's hot water requirement?	m^3	
Please specify the Make of hot water heating system installed in the building	-	
What is the tank capacity?	m^3	
What is the efficiency rating?	%	
How old is the water heating system?	years	
Does the tank have an external insulation jacket?		
What is the average hot water temperature?	°C	
Is there any recirculation pump installed along with the system?		
If yes, please specify the type of control		
What is the average recirculation time?	Minutes	

5. Other Equipment Inventory Checklist		
5.1 Service Equipment		
Particulars	**Units**	**User Input**
No. of lifts/ escalators/travelator used in the building	#	
Year of installation	year	
Type of lifts/ escalators/travelator used in the building	-	
Total Connected Load for each of the lifts/ escalators	kW	
Monthly Electricity consumption	kWh/month	
Frequency of use	#	
Standby Power of lifts/ escalators/travelator used in the building	W or kW	
5.2 Office/ IT Equipment		
Type of Office/ IT Equipment		
Make and Model of Office/IT equipment	-	
Size of monitor	-	
Total Connected Load of Office/IT Equipment	kW	
Operating hours of Office/IT equipment	hours	
Annual Energy Consumption of Office/IT Equipment	kWh/year	
5.3 Laundry Equipment		
Particulars	**Units**	**User Input**
Type of equipment	-	
If the type of equipment is more than one for the above question, list down here	-	
Total quantity of the selected equipment	#	
Capacity	kg or m^3 or kW	
Total Connected Load of Laundry Equipment	kW	
Annual Operating hours	hours/ year	
Annual Energy Consumption of laundry equipment (kWh)	kWh/year	
5.4 Other Equipment		
Particulars	**Units**	**User Input**
Type of equipment	-	
If the type of equipment is more than one for the above question, list down here	-	
Please specify the name and use of the particular equipment from the above said selected type	-	
Total quantity of the selected equipment	#	
Total Connected Load	kW	
Annual Operating hours	hours/ year	
Annual Energy Consumption	kWh/year	

Annexure-4: Energy Planning Ledger and Assessment Checklist

Energy planning ledger

Building Statistics		
Description	**Unit**	**Value**
Carpet Area	m^2	
Built-up Area	m^2	
Air-Conditioned Area	m^2	
Number of Floors	Nos.	
Building Age	Years	
Inventory Details	-	
Energy Source of past 12 months		
Electricity Consumption	kWh	
Natural Gas	m^3	
Oil	liters or kg	
Other	-	
Energy Cost of past 12 months		
Electricity	MUR per kWh	
Natural Gas	MUR per m^3	
Oil	MUR per liters or MUR per kg	
Other	-	
With the information one can determine the following:		
Daily/ Annual Use of Energy	kWh/ day or kWh/ year	
Monthly/ Annual Cost of Energy	MUR/ month or MUR/ year	
Percentage Areas of Energy Use	Lighting: HVAC: Hot water use: Other:	
Predominant Type of Lighting		
Operating Hours		
Other Relevant Information		

Energy assessment checklist

Key Questions	Checklist
Energy Management	
Are the figures on energy consumption and its driving force known and available?	☐
Have tasks, responsibilities and authority been determined for all staff involved in energy management (e.g. energy aspects, energy consumption, objectives, corrective measures)?	☐
Has the organization identified the primary energy aspects based on the energy consumption, and are they kept up to date?	☐
Have the energy consumption and consumption patterns been examined, including idle consumption during nights and weekends and consumption patterns?	☐
Are sufficient financial resources made available for managing and improving the energy aspects (consumption and efficiency)?	☐
Is the energy policy known and adhered to by all relevant employees?	☐
When purchasing goods and services, are the consequences on energy consumption taken into consideration?	☐
Are the primary energy consumers (energy aspects) regularly measured, registered, analysed and reported?	☐
Is there sufficient necessary knowledge and information regarding energy efficiency, and have the employees who can influence the energy efficiency been instructed and/or trained?	☐
Are energy performance and energy management regularly discussed internally on the operational and management levels?	☐
Is the evaluation of the energy management system performed by management at least once a year?	☐
Building Envelope	
Ensure space temperature is not significantly greater than the highest requirement.	☐
Whether windows and doors are closed during cooling/heating?	☐
Whether building insulation is up to standard?	☐
Are there any high-performance windows to reduce heat gain/losses?	☐
Is there any innovative use of passive technology for space, especially when combined with improved insulation, and window design?	☐
Lighting	
Identify the different lamps that are in use, and their wattage. If you can't see the rating by inspecting the lamps, then ask whoever is responsible for maintaining them?	☐
Is the lighting performing its task?	☐
Are the luminaires clean and lamps in working order?	☐
Are the luminaire effective at casting light into the occupied space, or do they waste light?	☐
Has light output deteriorated with age, suggesting lamps need to be replaced?	☐
How are the lights controlled/switched?	☐
Do operating hours match occupancy hours?	☐
Are they on when daylight levels would be adequate for requirements?	☐
Are lighting levels adequate or excessive for requirements?	☐
What do you hear most often regarding lighting in this building from the occupants?	☐
Do fluorescent lamps have electro-magnetic or high frequency controls?	☐
Office Equipment	
What proportion of PCs and monitors automatically switch to standby if left idle, and what is the time delay?	☐
What other office equipment is used, and does it switch to standby?	☐

Key Questions	Checklist
HVAC System	
Document the load on the system – meter cooling or heating input	☐
Evaluate the space requirements – schedules, occupancy, temperatures, and humidity, exhaust and ventilation	☐
Carefully consider any effect energy management opportunities might have on the environmental quality of the conditioned space	☐
Ensure that supply temperature and humidity are not significantly greater than required.	☐
Monitor overall HVAC performance (energy input to conditioned space).	☐
If HVAC is operating at minimum possible temperature, humidity, fresh air % and/or airflow.	☐
Is scheduling of systems and temperatures are matching occupancy and O/A conditions?	☐
Whether controls are operating properly and calibrated regularly?	☐
Are there any variable speed drives where operating hours are varying in the building?	☐
Are there any local air treatment units (e.g. electronic air cleaners, high-efficiency filters) to reduce the need for general exhaust?	☐
Ensure that duct and pipe insulation is up to standard.	☐
Ensure that they are maintaining seals, air ducts, breeching, and access doors to ensure airtightness.	☐
Regularly check mechanical maintenance parts (fans, bearings, alignment, etc.)	☐
Refrigeration System	
Document the cooling load and temperature requirements	☐
Use conservative practices at the point of end-use to minimize the cooling load.	☐
Ensure that cooling towers are effectively maintained to obtain the lowest water temperature possible.	☐
Ensure that all heat exchange surfaces are regularly cleaned and maintained.	☐
Ensure the free circulation of air around condensing units and cooling towers by lowering condensing temperatures.	☐
Investigate floating head pressure or liquid pressure boost to reduced condensing temperature and pressure on a seasonal basis.	☐
Fan and Pump Systems	
Determine the requirement for air/water flow, possibly as a profile over time.	☐
Determine the range of pressures that the fan/pump will need to overcome.	☐
Determine if the need for flow is fixed or variable.	☐
Determine the duration of the need for flow (hours per day).	☐
General Process Equipment	
Are auxiliary equipment, motors and conveyors switched off when the production lines are shut down?	☐
Are motors for pumps, agitators, circulation etc. system-demand controlled and equipped with a variable speed drive (e.g. frequency converter)?	☐
Are there many displays and computers on standby?	☐
Are there heaters, heating elements, fan heaters, shrinkage oven etc., which are in operation without demand?	☐
Are the processing plants (furnaces, tubs, silos, tanks etc.) properly insulated?	☐
Are the processing plants kept on service temperature for no reason even though there is no production?	☐

Annexure-5: Water Saving Measures

To reduce water wastage and enhance water use efficiency in commercial buildings, a range of effective strategies may be employed. These measures not only reduce operational costs associated with water consumption but also contribute significantly to environmental sustainability. These measures help in lowering water bills as well as contribute to environmental sustainability. Some of the key measures are provided below:

1. Efficient Plumbing Fixtures

- **Low-Flow Fixtures:** Install low-flow faucets and showerheads to significantly reduce water consumption without compromising functionality. For example, low-flow faucets typically use less than 6 liters per minute (lpm), compared to standard faucets that may use up to 10 lpm.
- **Dual-Flush Toilets:** Use dual flush two toilets which offer separate flush options, a low-volume flush for liquid waste and a high-volume flush for solid waste, thereby optimizing water usage per flush.
- **Water-Efficient Urinals:** Use waterless urinals or low-flow urinals that use significantly less water per flush compared to conventional urinals.
- **Automatic Faucets:** Utilize sensor-operated faucets which prevent water wastage by turning off automatically when not in use, thus reducing unnecessary water flow.

2. Rainwater Harvesting

- **Rainwater Collection System:** Install a rainwater harvesting system allows commercial buildings to collect rainwater from rooftops and store it in tanks or cisterns. This harvested water may be used for non-potable purposes such as landscape irrigation, cooling systems, or even flushing toilets, reducing the need for potable water. The rainwater can be filtered and treated to meet specific quality standards, depending on its intended use, making it a valuable alternative water source.
- **Stormwater Management:** Design rainwater harvesting systems with provisions to divert excess water to stormwater infrastructure, thereby preventing waterlogging and structural damage.

3. Wastewater Treatment and Reuse

- **On-Site Wastewater Treatment Systems:** For large commercial facilities, implement on-site wastewater treatment plants (WWTPs) capable of treating sewage and greywater for reuse in irrigation, cooling, and toilet flushing. Advanced systems such as Membrane Bioreactors (MBRs) provide high-quality treatment suitable for diverse reuse applications.

4. Efficient Irrigation and Cooling Systems

- **Drip Irrigation Systems:** Install drip irrigation systems in landscaping to deliver water directly to plant roots, thereby minimizing evaporation and surface runoff.
- **Smart Irrigation Controllers:** Utilize automated irrigation controllers that adjust watering schedules based on real-time data such as weather forecasts and soil moisture levels, ensuring water is applied only when necessary.
- **Cooling Tower Optimization:** Optimize the use of water in cooling towers by regular maintenance and monitoring to ensure water-efficient operation. This includes chemical balancing, periodic cleaning, and the use of appropriate treatment systems to control scale and corrosion. Using recycled or treated water in cooling towers helps to reduce the demand for portable water.

5. Smart Water Metering and Monitoring

- **Water Meters and Sensors:** Install smart water meters and leak detection sensors to enable continuous monitoring of water usage and facilitate the early detection of inefficiencies or leaks.
- **Data Analytics:** Use water consumption data to identify patterns, inefficiencies, and areas for improvement. This can help building managers optimize water use across different systems and reduce overall consumption.

6. Regular Maintenance and Occupant Engagement

- **Regular inspection:** Conduct regular inspections of plumbing infrastructure to detect and promptly repair leaks or defects. Even minor leaks can result in significant cumulative water losses if left unaddressed.
- **Water Conservation Awareness**: Promote water-saving practices among building occupants and staff through training and awareness campaigns. Encourage behaviours such as shutting off taps when not in use, promptly reporting leaks, and utilizing water-efficient appliances and fixtures.

By adopting these measures, commercial buildings can significantly improve water use efficiency, reduce waste, and support broader sustainability objectives. In addition to lowering water utility expenses, these practices contribute to environmental stewardship and enhance the overall performance of the building.

Energy Efficiency Management Office,
Level 4, The Celicourt Tower,
6, Sir Celicourt Antelme Street,
Port -Louis, 11302