ENERGY CONSERVATION BUILDING CODE OF PAKISTAN

2023

NATIONAL ENERGY EFFICIENCY AND CONSERVATION AUTHORITY (NEECA)

GOVERNMENT OF PAKISTAN

MINISTRY OF SCIENCE & TECHNOLOGY

2023

Section-1

1. Preface

1.1 Introduction

Pakistan is currently facing a significant energy shortage, which has resulted in frequent blackouts and high energy costs. It is crucial to develop more efficient systems that reduce energy consumption and enhance efficiency. Therefore, it is necessary to strengthen the Energy Provisions in the Energy Provisions-2011, ensuring the safety and economic well-being of communities. The Energy Provisions-2023 have been incorporated into the Pakistan Building Code Energy Provisions-2011 as a crucial component, aimed at providing energy efficiency standards for buildings. These Provisions conform to the relevant standards of organizations such as ASHRAE, ANSI, ARI, ASTM, and others. To ensure their continued relevance, revisions to the Provisions will be made every three years, subject to earlier updates if necessary, and will be open to debate.

1.2 Development

The Government of Pakistan has tasked the National Energy Efficiency & Conservation Authority (NEECA) with the responsibility of acting as the national coordinator for energy conservation measures and policy. NEECA serves as the federal focal authority for initiating, catalyzing, and coordinating the implementation of all energy efficiency and conservation programs in all sectors of the economy. Pursuant to Section 10(p) and (q) of the NEEC Act 2016, NEECA has the power to prescribe and amend energy conservation building codes. The Building Code of Pakistan (Energy Provisions-2011), developed and notified by the Pakistan Engineering Council (PEC), requires revision/update due to changes in allied international standards, technological advancements in building energy-consuming appliances, control systems, insulation technologies, green building concepts, and renewable energy technologies for buildings.

To address this need, NEECA constituted a Task Force to revise the Building Code of Pakistan (Energy Provisions-2011). The implementation and enforcement of this Code is the responsibility of NEECA through concerned authorities.

In accordance with international practices, the revision of building codes typically requires at least one year of study and review of published literature, international guidelines, codes, and standards to formulate a comprehensive document that can be implemented with full strength. However, due to the severe energy crisis in Pakistan, the Federal Government directed NEECA to revise the Building Code of Pakistan (Energy Provisions-2011) within three months. Therefore, NEECA collaborated with the Task Forces to revise the Building Code of Pakistan (Energy Provisions-2011) within the given timeframe and submitted it for implementation and enforcement. However, due to time constraints, in-depth studies could not be conducted, and a comprehensive document was not prepared. Therefore, this Energy Conservation Building Code-2023 will require periodic updates to develop a comprehensive document.

These Provisions focus on high-end domestic and commercial consumers and aim to conserve energy without compromising public safety. Every effort has been made to ensure that these Provisions do not unnecessarily increase costs or restrict the use of new materials and technology. Future development of Energy Provisions-2023 will encompass low-end users and buildings up to 10KW and/or appropriate covered area if deemed necessary.

1.3 Adoption

The Energy Provisions, which are aimed at improving energy efficiency in buildings, will be included as a fundamental element of the Building Code of Pakistan (Energy Provisions-2011). This means that adherence to the Energy Provisions will be mandatory for all new building construction and renovations in Pakistan.

To ensure the implementation and enforcement of these Energy Provisions, the

Government of Pakistan will issue a notification (SRO) which will provide comprehensive legal coverage to the Code. The notification will detail the legal procedures for ensuring that the Energy Provisions are followed in all relevant building construction and renovation projects.

Moreover, the notification will also enable NEECA and relevant stakeholders to make necessary changes to the Code every three to five years to ensure that the Code remains up-to-date and continues to reflect the latest advancements in energy efficiency practices. This periodic review process will ensure that the Energy Provisions remain relevant and effective in achieving the objective of reducing energy consumption and costs while enhancing the safety and economic health of communities in Pakistan.

1.4 Maintenance

To maintain the relevance and effectiveness of the Energy Conservation Building Code 2023, a Standing Committee will be established under the auspices of NEECA. This Committee will be tasked with the responsibility of reviewing the Code periodically and recommending necessary changes to ensure that it continues to meet the evolving needs of the building industry in Pakistan.

To ensure that the proposed changes to the Code are widely accepted and relevant to the industry, the Standing Committee will engage with representatives from different sectors of the industry, engineering professionals, and other relevant stakeholders. This engagement will take place through an open code development process, which will provide stakeholders with the opportunity to express their views and opinions on the proposed changes.

The open code development process will enable the Standing Committee to take into account the perspectives and concerns of all stakeholders, and to make informed decisions based on a thorough understanding of the industry's needs and challenges. The Standing Committee will work diligently to ensure that the proposed changes are practical, cost-effective, and in line with the latest technological advancements in energy efficiency practices. By implementing an open code development process, the Standing Committee will ensure that the Energy Conservation Building Code 2023 remains relevant, effective, and responsive to the needs of the building industry in Pakistan.

1.5 Waiver

The development of the Energy Provisions of the Code has involved a range of individuals and organizations, who have worked diligently to ensure that the Code meets the necessary standards for promoting energy efficiency in buildings. However, despite their best efforts, these individuals and organizations do not accept liability for any consequences resulting from the compliance or non-compliance of the Energy Provisions by practitioners.

It is important to note that the responsibility for ensuring compliance with the Energy Provisions lies solely with the Government of Pakistan. The Government has the power and the authority to enforce the Energy Provisions of the Code and to ensure that they are followed by practitioners. This means that the Government is accountable for any actions or decisions related to the implementation and enforcement of the Energy Provisions.

The disclaimer serves as a reminder that the individuals and organizations involved in developing the Energy Provisions cannot be held responsible for any consequences resulting from the implementation or enforcement of the Code. Instead, it is the Government of Pakistan that bears the responsibility for ensuring that the Energy Provisions are followed in order to promote energy efficiency, safety, and economic health in the building industry.

2. Acknowledgements

The development of the Energy Conservation Building Code 2023 is the culmination of the efforts of many individuals who served on the task force (Technical Committee) responsible for its creation. The task force comprised experts from various sectors of the building industry, including professionals from the engineering and architecture fields, energy efficiency specialists, and representatives from relevant government bodies.

While it may not be possible to acknowledge each individual's contributions to the development of the Code, it is crucial to recognize the members of the Task Force who worked tirelessly to revise the Building Code of Pakistan (Energy Provisions-2011). Their collective efforts and expertise have resulted in the creation of a comprehensive and effective set of provisions that will promote energy efficiency, safety, and economic health in the building industry in Pakistan.

The Task Force's contributions are a testament to their dedication and commitment to the cause of promoting energy efficiency and sustainable building practices in Pakistan. Their hard work and expertise have helped create a document that will serve as a benchmark for the building industry in Pakistan and contribute to the country's efforts to reduce energy consumption and costs while enhancing safety and economic health;

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3. Source Documents

The revision of the Building Code of Pakistan Energy Provisions-2011 involved the use of certain portions of ASHRAE Standard 90.1-2019. The American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) granted NEECA, under the authority of the Government of Pakistan, permission to transcribe and reproduce these portions of their document for the purpose of revising the Energy Provisions.

In accordance with this agreement, NEECA and the Government of Pakistan recognize that ASHRAE retains ownership and copyright of all transcribed and reproduced portions of their document used in the revision of the Building Code of Pakistan Energy Provisions-2011. It is essential to acknowledge the contributions of ASHRAE and to respect their intellectual property rights.

It is important to note that Section-4 Building Envelope, a critical component of the Energy Provisions, was developed with due consideration of the Energy Codes of regional countries and the local environment. Therefore, it does not incorporate any transcribed or reproduced portions from ASHRAE Standard 90.1-2019.

The use of ASHRAE Standard 90.1-2019 in the development of the Energy Provisions is a testament to the collaboration and cooperation between different stakeholders and organizations involved in the promotion of energy efficiency in building design and construction. The recognition of ASHRAE's contributions and their intellectual property rights reinforces the importance of respecting and acknowledging the efforts of all parties involved in the development of the Energy Provisions.

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Section– 1

1. Introduction

1.1 Purpose

The Energy Conservation Building Code of Pakistan (Energy Provisions-2023) has been developed to establish minimum requirements for energy-efficient design and construction of buildings. This Code covers a broad range of factors, including energy-efficient and low-emission construction materials, passive building design, energy appliance monitoring devices, electric vehicle charging points, energy management systems, building insulation, and renewable and geothermal energy. Additionally, the Code includes an implementation and enforcement plan.

Energy has become a defining factor in the progress of nations, and Pakistan is no exception. As such, it is crucial that Pakistan focuses on improving energy efficiency in buildings. The Energy Conservation Building Code of Pakistan was developed to achieve this goal by incorporating international best practices that are appropriate to Pakistan's environment. The Code also recognizes the importance of traditional materials, technologies, and craftsmanship developed indigenously over a long period of time.

By promoting energy-efficient building design and construction, the Energy Conservation Building Code will play a pivotal role in reducing energy consumption, minimizing costs, and enhancing the safety and economic health of communities in Pakistan. Furthermore, the Code recognizes the importance of sustainable energy sources in Pakistan's energy mix, but it also emphasizes the need to use existing energy resources more efficiently. This can be achieved through the adoption of energy-efficient building design and construction practices, which will have a significant impact on reducing the country's energy consumption and dependence on imported energy sources.

Overall, the Energy Conservation Building Code of Pakistan is an important step forward in promoting energy efficiency and sustainable building practices in Pakistan. By incorporating international best practices, as well as traditional materials and technologies, the Code represents a comprehensive and effective set of provisions that will play a critical role in promoting energy efficiency, safety, and economic health in the building industry in Pakistan.

1.2 Title

The document containing the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) is commonly referred to as the "Energy Provisions 2023." This name was chosen to help differentiate this document from previous versions of the building code, and to reflect its focus on promoting energy conservation and efficiency in building design and construction.

By establishing clear and concise terminology for the Energy Conservation Building Code, the term "Energy Provisions 2023" provides a useful shorthand reference for those working in the building industry, policymakers, and other stakeholders who are involved in promoting energy efficiency and sustainability in Pakistan. This will help to ensure that the Code is widely understood and effectively implemented across the country".

1.3 Scope

The Energy Conservation Building Code of Pakistan (Energy Provisions-2023) applies to buildings and building clusters that meet certain criteria. These include a total connected load of 100 kW or greater, a contract demand of 125 kVA or greater, a conditioned area of 500 m2 or greater, or unconditioned buildings with a covered area of 900 m2 or more.

The scope of the Energy Conservation Building Code includes several aspects of building design and construction. These include new buildings and their systems, new portions of existing buildings and their systems (provided that the conditioned area or connected load exceeds the limits mentioned above), new systems and equipment in existing buildings, and an increase in the electricity load beyond the prescribed limits mentioned above. The Code also covers the retrofitting of conventional buildings to convert them into energy-efficient buildings.

The Energy Conservation Building Code's provisions are designed to promote energy efficiency in buildings by setting minimum standards for new buildings, building extensions, and retrofitting projects. These standards apply to buildings that meet the specified criteria for connected load, contract demand, conditioned area, or unconditioned building area. The Code includes guidelines for several systems and equipment related to energy use, including heating, cooling, ventilation, lighting, and appliances.

Overall, the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) represents a comprehensive set of provisions that will play a critical role in promoting energy efficiency, safety, and economic health in the building industry in Pakistan. By establishing clear guidelines for energy-efficient design and construction, the Code will help to reduce energy consumption, minimize costs, and enhance the safety and economic health of communities across the country.

1.4 Applicable Building Systems

The Energy Provisions outlined in the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) cover a range of aspects related to building design and construction. These provisions are designed to promote energy efficiency and sustainability by setting minimum requirements for key areas of building design and construction.

The Energy Provisions apply to building envelopes, which include walls, roofs, windows, and doors. These provisions establish minimum standards for insulation, air sealing, and other features that help to reduce energy loss and improve energy efficiency. In addition to building envelopes, the Energy Provisions also apply to building mechanical systems and equipment. This includes heating, ventilation, and air conditioning (HVAC) systems, which play a critical role in maintaining a comfortable indoor environment while minimizing energy consumption. The Energy Provisions establish minimum standards for HVAC systems, including equipment efficiency, ductwork design, and other factors that affect energy efficiency.

The Energy Provisions also cover service water heating, which is a significant source of energy consumption in many buildings. These provisions establish minimum standards for water heaters, including equipment efficiency and insulation requirements. Lighting is another area covered by the Energy Provisions. These provisions establish minimum requirements for lighting design, including the use of energy-efficient fixtures, lighting controls, and other strategies to reduce energy consumption. Finally, the Energy Provisions apply to electrical power and motors, which are used to operate various systems and equipment within buildings. These provisions establish minimum standards for the efficiency of motors and other electrical equipment, helping to reduce energy consumption and promote sustainability.

Overall, the Energy Provisions outlined in the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) provide a comprehensive set of guidelines for promoting energy efficiency and sustainability in the building industry in Pakistan. By addressing key areas of building design and construction, the Energy Provisions will help to reduce energy consumption, minimize costs, and enhance the safety and economic health of communities across the country.

1.5 Exemptions

The Energy Provisions outlined in the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) include several exemptions designed to ensure that the provisions are applied appropriately and effectively.

One exemption pertains to buildings that do not use either electricity or fossil fuel as sources of energy. Such buildings may use alternative sources of energy such as solar, wind, or hydro power. These buildings are exempted from the Energy Provisions as they are already contributing to energy conservation and sustainability, and therefore do not require additional regulations to be imposed upon them.

Another exemption applies to government-notified historically significant and heritage buildings. Such buildings are often subject to specific regulations and guidelines related to preservation and restoration. These buildings are exempted from the Energy Provisions to ensure that they are not subject to additional regulatory burdens that could impede their preservation.

A third exemption pertains to equipment and portions of building systems that use energy exclusively for manufacturing processes. In these cases, the energy consumption is necessary for production and cannot be easily reduced without compromising the manufacturing process. Therefore, such equipment and portions of building systems are exempted from the Energy Provisions.

Overall, these exemptions are important in ensuring that the Energy Provisions are applied appropriately and effectively. By excluding buildings and systems that do not consume significant amounts of energy, the Energy Provisions can be applied more efficiently to those buildings and systems that are significant sources of energy consumption. This will help to promote energy efficiency and sustainability in the building industry in Pakistan, while minimizing unnecessary regulatory burdens.

1.6 Limitation

The Energy Provisions outlined in the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) are designed to promote energy efficiency and sustainability in the building industry in Pakistan. However, it is important to ensure that these provisions do not conflict with other important codes related to safety, health, or the environment.

In the event of any conflict between the Energy Provisions and any relevant provisions of safety, health, or environmental codes, the latter shall take precedence. This ensures that the safety and well-being of individuals, as well as the protection of the environment, remain the top priority. For example, if there is a conflict between the Energy Provisions and a provision of a safety code that relates to fire safety, the safety code provision would take precedence. Similarly, if there is a conflict between the Energy Provisions and a provision of an environmental code that relates to the disposal of hazardous materials, the environmental code provision would take precedence.

By establishing this principle, the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) helps to ensure that energy efficiency and sustainability goals are pursued in a manner that is consistent with other important goals related to safety, health, and the environment.

Section -2

2. Administration and Enforcement

2.1 Foreword

The Energy Conservation Building Code of Pakistan (Energy Provisions-2023) sets out minimum requirements for energy-efficient design and construction of buildings, as well as for the energy-efficient operation of building systems and equipment. To ensure that these provisions are applied effectively, the code also establishes procedures for administration and enforcement.

The administration and enforcement of the Energy Provisions is the responsibility of the National Energy Efficiency and Conservation Authority (NEECA), which serves as the federal focal authority for initiating, catalyzing, and coordinating the implementation of all energy efficiency and conservation programs in all sectors of the economy. NEECA works closely with other relevant authorities to ensure that the Energy Provisions are enforced consistently and effectively across the country.

To facilitate enforcement, the Energy Provisions include requirements for documentation, inspections, and certifications. Building owners and operators are required to maintain records related to energy consumption, building systems, and equipment, and to make these records available for inspection upon request. Inspections are carried out by relevant authorities to ensure that buildings are in compliance with the Energy Provisions. Penalties may be imposed for non-compliance with the Energy Provisions, in accordance with applicable laws and regulations. NEECA may also suspend or revoke certifications, licenses, or permits if a building owner or operator fails to comply with the Energy Provisions.

Overall, the administration and enforcement procedures established by the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) are designed to ensure that energy efficiency and sustainability goals are pursued effectively and consistently across the building industry in Pakistan.

2.2 Compliance Requirements

The Energy Conservation Building Code of Pakistan (Energy Provisions-2023) establishes minimum requirements for energy-efficient design and construction of buildings. To ensure that these requirements are met, the code requires that plans and specifications for building construction and development be reviewed and approved by the appropriate sanctioning and development authorities/municipalities in accordance with the code's provisions for energy conservation.

Sanctioning and development authorities/municipalities play a critical role in ensuring that buildings are constructed and developed in a safe and sustainable manner. They are responsible for reviewing and approving plans and specifications for building construction and development, and for ensuring that buildings comply with relevant codes and regulations.

Under the Energy Conservation Building Code of Pakistan (Energy Provisions-2023), sanctioning and development authorities/municipalities are required to review and approve plans and specifications for building construction and development in accordance with the code's provisions for energy conservation. This means that they must ensure that the plans and specifications submitted by building owners and operators meet the minimum requirements for energy-efficient design and construction set out in the code.

By requiring that plans and specifications be reviewed and approved in accordance with the code's provisions for energy conservation, the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) helps to ensure that energy efficiency and sustainability goals are pursued consistently and effectively across the building industry in Pakistan. This will help to reduce energy consumption, promote sustainability, and contribute to the overall development of a more sustainable and resilient built environment in Pakistan.

2.3 Mandatory Requirements

The Energy Conservation Building Code of Pakistan (Energy Provisions-2023) sets out minimum requirements for energy-efficient design and construction of buildings, as well as for the energy-efficient operation of building systems and equipment. To ensure that these requirements are met, the code makes compliance mandatory for all buildings mentioned in Section-2.

Section-2 of the code specifies the buildings to which the code applies, including buildings with a total connected load of 100 kW or greater, or a contract demand of 125 kVA or greater, or a conditioned area of 500 m2 or greater, or unconditioned buildings of covered area of 900 m2 or more. The code applies to new buildings and their systems, new portions of existing buildings and their systems if the conditioned area or connected load exceeds the prescribed limits, new systems and new equipment in existing buildings, and increases in electricity load beyond the prescribed limits. The code also applies to the retrofitting of conventional buildings to convert them into energy-efficient buildings.

Given the significant impact that buildings have on energy consumption and greenhouse gas emissions, it is crucial that building owners and operators comply with the Energy Conservation Building Code of Pakistan (Energy Provisions-2023). By making compliance mandatory for all applicable buildings, the code helps to ensure that energy efficiency and sustainability goals are pursued consistently and effectively across the building industry in Pakistan. This will help to reduce energy consumption, promote sustainability, and contribute to the overall development of a more sustainable and resilient built environment in Pakistan.

2.3.1 New Buildings

The Energy Conservation Building Code of Pakistan (Energy Provisions-2023) sets out minimum requirements for energy-efficient design and construction of buildings. To ensure that these requirements are met, the code specifies that all new buildings must comply with the provisions of Sections 4 through 8.

Sections 4 through 8 of the code cover the following areas:

a) **Section 4:** covers the minimum requirements for building envelope design and construction, including insulation, fenestration, and air leakage control.
b) **Section 5:** covers the minimum requirements for mechanical systems and equipment design and installation, including heating, ventilation, and air

conditioning (HVAC) systems.

c) **Section 6:** covers the minimum requirements for service water heating system design and installation.

d) **Section 7:** covers the minimum requirements for lighting system design and installation.

e) **Section 8:** covers the minimum requirements for electrical power and motors design and installation.

By requiring compliance with Sections 4 through 8 for all new buildings, the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) ensures that energy efficiency and sustainability goals are pursued consistently and effectively across the building industry in Pakistan. This will help to reduce energy consumption, promote sustainability, and contribute to the overall development of a more sustainable and resilient built environment in Pakistan.

2.3.2 Alterations To Existing Buildings

The Energy Conservation Building Code of Pakistan (Energy Provisions-2023) sets out minimum requirements for energy-efficient design and construction of buildings. In addition to new buildings, the code also applies to alterations made to existing buildings and building systems.

To ensure that alterations to existing buildings and building systems meet the requirements of the code, the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) specifies that such alterations must comply with Sections 4 through 8 of the code. Sections 4 through 8 cover the minimum requirements for building envelope design and construction, mechanical systems and equipment design and installation, service water heating system design and installation, lighting system design and installation, and electrical power and motors design and installation.

By requiring compliance with Sections 4 through 8 for alterations to existing buildings and building systems, the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) ensures that energy efficiency and sustainability goals are pursued consistently and effectively across the building industry in Pakistan. This will help to reduce energy consumption, promote sustainability, and contribute to the overall development of a more sustainable and resilient built environment in Pakistan.

2.3.2.1 Building Envelope

The building envelope is an important component of a building's energy efficiency, and modifications to it can have a significant impact on a building's overall energy performance. To ensure that alterations to the building envelope meet minimum energy efficiency requirements, the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) specifies that such alterations must comply with the requirements set out in Section 4 of the code.

Section 4 of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) covers the minimum requirements for building envelope design and construction. This includes specifications for insulation, fenestration, and air leakage control. By requiring compliance with these requirements for alterations to the building envelope, the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) ensures that energy efficiency goals are pursued consistently and effectively across the building industry in Pakistan. This will help to reduce energy consumption, promote sustainability, and contribute to the overall development of a more sustainable and resilient built environment in Pakistan.

2.3.2.2 Heating, Ventilation and Air Conditioning

The heating, ventilation, and air conditioning (HVAC) systems in a building are among the largest energy consumers in any building. Therefore, any alterations made to HVAC equipment or systems should adhere to the minimum energy efficiency requirements set out in Section 5 of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023).

Section 5 of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) covers the minimum requirements for HVAC equipment and systems design and installation. This includes specifications for system sizing, equipment efficiency, and air distribution. Any alterations made to HVAC equipment or systems must comply with these requirements applicable to the portions of the building and its systems being altered.

Additionally, if any new equipment or control devices/systems are installed in conjunction with the alteration, they must comply with the specific minimum efficiency requirements provided in the code for that equipment or control device/system. This ensures that any new equipment or systems installed during alterations meet energy efficiency standards and contribute to the overall sustainability of the building.

By requiring compliance with Section 5 of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) for alterations to HVAC equipment or systems, the code ensures that energy efficiency goals are pursued consistently and effectively across the building industry in Pakistan. This will help to reduce energy consumption, promote sustainability, and contribute to the overall development of a more sustainable and resilient built environment in Pakistan.

2.3.2.3 Service Water Heating

Service water heating equipment or systems in a building consume significant amounts of energy. Therefore, any alterations made to the equipment or systems must comply with the minimum energy efficiency requirements set out in Section 6 of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023).

Section 6 of the code covers the minimum requirements for service water heating equipment and systems design and installation. This includes specifications for system sizing, equipment efficiency, and water distribution. Any alterations made to service water heating equipment or systems must comply with these requirements, which apply only to the portion of the building and its system being altered.

Additionally, if any new equipment or control devices/systems are installed in conjunction with the alteration, they must comply with the specific minimum efficiency requirements provided in the code for that equipment or system/control device. This ensures that any new equipment or systems installed during alterations meet energy efficiency standards and contribute to the overall sustainability of the building.

By requiring compliance with Section 6 of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) for alterations to service water heating equipment or systems, the code ensures that energy efficiency goals are pursued consistently and effectively across the building industry in Pakistan. This will help to reduce energy consumption, promote sustainability, and contribute to the overall development of a more sustainable and resilient built environment in Pakistan.

2.3.2.4 Lighting

Section 7 of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) outlines the minimum lighting power density requirements for buildings. Lighting power density refers to the amount of power consumed by lighting systems per unit area of a building. This section of the code sets out specific requirements for the lighting power density of various types of spaces within a building, including offices, corridors, stairways, and parking areas.

If alterations are made to the lighting equipment or systems in a building, they must comply with the lighting power density requirements set out in Section 7 of the code. The requirements apply only to the portion or portions of the building and its system being altered. This ensures that the energy efficiency of the lighting system is maintained or improved during alterations.

In addition, any new equipment or system/control devices installed in conjunction with the alteration must comply with the specific requirements provided in the code for that equipment or system/control device. This ensures that any new equipment or systems installed during alterations meet the energy efficiency standards specified in the code.

By requiring compliance with the lighting power density requirements of Section 7 of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) for alterations to lighting equipment or systems, the code helps to reduce energy consumption and promote sustainability in the building industry in Pakistan. Compliance with these requirements can help to lower energy costs for building owners and occupants and contribute to the development of a more sustainable and resilient built environment in the country.

2.3.2.5 Electric Power System and Motors

The Energy Conservation Building Code of Pakistan (Energy Provisions-2023) specifies the requirements that must be met for alterations to building electric power systems and motors. These requirements are detailed in Section 8 of the code. When alterations are made to a building's electric power systems and motors, compliance with the minimum efficiency requirements outlined in Section 8 of the code is mandatory. The specific requirements outlined in this section apply to the portions of the building and its systems that are being altered.

To ensure that any new equipment or control devices installed during alterations meet the minimum energy efficiency standards specified in the code, they must also comply with the specific requirements applicable to that equipment or control device provided in the code. This helps to promote energy efficiency and reduce energy waste in the building industry.

By adhering to the minimum efficiency standards set out in Section 8 of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023), building owners and professionals can contribute to the development of a more sustainable built environment in Pakistan. Compliance with these requirements can help to reduce energy costs and contribute to the country's efforts to conserve energy and promote sustainability.

Section -3

3. Administrative Requirements

The Energy Conservation Building Code of Pakistan (Energy Provisions-2023) includes administrative requirements that pertain to several aspects of building construction and renovation. These requirements cover areas such as permit requirements, jurisdictional authority, energy standards, interpretation of code provisions, claims of exemption, and rights of appeal.

The authority having jurisdiction (AHJ) is responsible for enforcing the Energy Provisions-2023 and ensuring that all applicable buildings comply with its requirements. The AHJ is also responsible for administering the administrative requirements outlined in the code. One such requirement relates to permit requirements. This involves obtaining the necessary permits for building construction or renovation from the AHJ. The AHJ may also require compliance with specific energy standards and codes, which are outlined in the Energy Provisions-2023.

Interpretation of code provisions is another important administrative requirement specified by the Energy Provisions-2023. The AHJ is responsible for interpreting and enforcing the code provisions, which can include determining whether a building or system is in compliance with the code. In some cases, claims of exemption from the code provisions may be made. The Energy Provisions-2023 specifies that the AHJ is responsible for reviewing and approving any such claims of exemption.

Finally, the Energy Provisions-2023 specifies that building owners have the right to appeal any decisions made by the AHJ related to the enforcement of the code provisions. The AHJ is responsible for ensuring that the appeals process is fair and transparent, and that all appeals are handled promptly and professionally.

3.1 Compliance Documents

The compliance documents are an essential aspect of ensuring that a building meets the requirements of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023). These documents should include all pertinent data and features of the building, its equipment, and systems in a level of detail that enables the authority having jurisdiction to verify compliance. This means that the documents should be clear and comprehensive, leaving no room for ambiguity or uncertainty.

The purpose of requiring such detailed compliance documents is to facilitate effective enforcement of the Energy Provisions-2023. If the documents are incomplete or insufficiently detailed, it would be difficult for the authority having jurisdiction to verify compliance, and this could lead to confusion, disputes, or non-compliance with the code.

Therefore, it is crucial to ensure that compliance documents are carefully prepared and include all relevant information to make the compliance verification process as efficient and effective as possible. By doing so, the building owner or operator can avoid delays, penalties, or other consequences that may result from non-compliance with the Energy Conservation Building Code of Pakistan (Energy Provisions-2023).

3.2 Supplementary Information

The authority having jurisdiction has the right to ask for further information or documentation that may be necessary to verify that the building, equipment, and systems comply with the Energy Conservation Building Code of Pakistan (Energy Provisions-2023). This additional information may include calculations, worksheets, compliance forms, manufacturer's literature, or any other relevant data.

The purpose of these supplementary documents is to provide the authority with sufficient detail to validate the compliance of the building with the Energy Conservation Building Code of Pakistan (Energy Provisions-2023). The authority may use this information to conduct an assessment of the building, equipment, and systems to ensure that they meet the requirements of the Code.

Section-4

4. Building Envelope

4.1 Mandatory Requirements

The criteria set in this section establish the minimum energy conservation and efficiency requirements for the building envelope. Design criteria that results in greater levels of energy efficiency and conservation shall be allowed. The building envelope shall comply with the mandatory provisions of this Section.

The design of buildings, and selection of materials forming their surfaces, shall aim at reducing heat transfer to and from buildings and adhere to the following criteria.

4.1.1 External Walls and Roofs

Overall U values of external walls and roofs shall not exceed limits specified in Table 4.1

Table 4.1. External Walls and Roof

Wall	U: 0.57 W/m*. K (0.100 Btu/h.ft2. °F)
Roof	U: 0.44 W/m2. K (0.078 Btu/h.ft2. °F)

4.1.2 Glass and Framing System

For buildings with external glass area, not exceeding 40% of the external wall area of the building, the overall U values and shading coefficient shall not exceed limits specified in Table 4.2.

Table 4.2. External Glass Area (ñ40%)

Heat Transmission Coefficient (U)	3.5 W/m^2. K (0.44 Btu/h.ft^2. °F)
Shading Coefficient (SC)	0.76

For buildings with external glass area, in excess of 40% of the external wall area of the building, the overall U values and shading coefficient shall not exceed limits specified in Table 4.3.

Table 4.3. External Glass Area (>40%)

Heat Transmission Coefficient (U)	2.5 W/m2.K (0.37 Btu/h.ft2. °F)
Shading Coefficient (SC)	0.35

4.1.3 Window to Wall Ratio

For mechanically ventilated and cooled buildings of all occupancies, other than Hazardous and Storage, the Window to Wall ratio of building (WWRB), will be determined in conjunction with the glazing performance, as indicated by the Solar Heat Gain Coefficient (SHGC) or Shading Coefficient (SC) of the glass used. The relationship can be depicted in Figure 4.4.

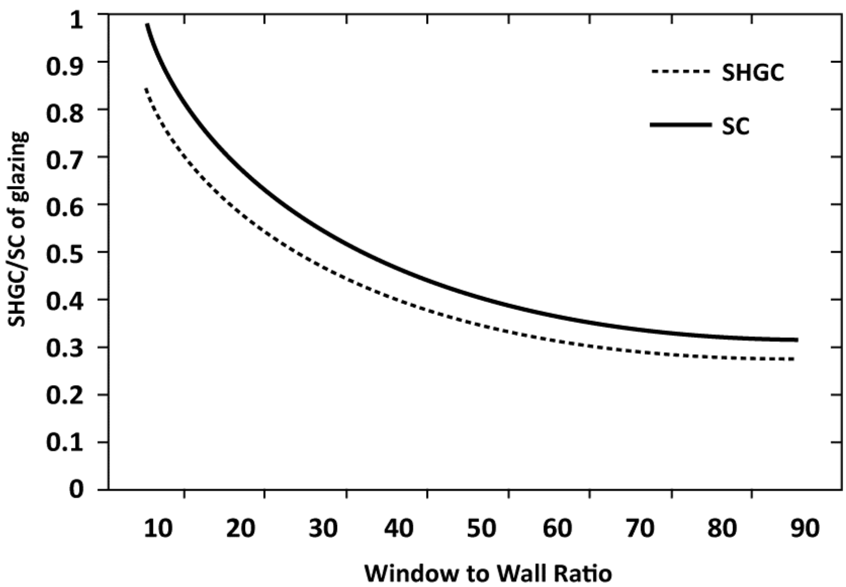

Figure 4.1. Selection of glazing SHGC based on WWR

The relationship can be explained in tabular form as Table 4.5.

Table 4.4. Selection of Glazing SHGC Based on WWR in Tabular Format

WWR	SHGC	SC
10	0.85	0.98
20	0.6	0.69
30	0.5	0.57

40	0.4	0.46
50	0.35	0.4
60	0.33	0.38
70	0.31	0.36
80	0.3	0.34
90	0.27	0.31

In all of the above cases, the Visible Light Transmittance (VLT) of the glazed element shall not be lower than thirty-five (35) percent.

Table 4.5. SHGC and VLT for different WWR

WWR	Maximum SHGC	Minimum VLT
10	0.80	0.80
20	0.70	0.70
30	0.60	0.70
40	0.45	0.60
50	0.44	0.55
60	0.37	0.50
70	0.31	0.45
80	0.27	0.40
90	0.24	0.35

Source: *Prescribed Requirements, IFC Philippine Green Building Code Project, May 2022*

For Air-conditioned buildings with external shading, permitted SGHC limit may be adjusted, but the increase shall not exceed values determined by Eq. 4.1 below:

$$\mathbf{SHGC_{adj} = SHGC + A} \qquad \textbf{(4.1)}$$

Where, $SHGC_{adj}$ is the adjusted solar heat gain coefficient limit for windows with shading, SGHC is the Solar heat gain co efficient from table 4.4. and A is the SHGC correction factor for the external shading as per Table 4.4 or Table 4.5.

For a window with overhang and fin, the value of A can be only used either from overhang or from fin.

4.1.4 Window Openings

Mechanically ventilated and cooled buildings of all occupancies, other than hazardous, retail and storage, shall have the provision of using natural ventilation for cooling and fresh air, in frequently occupied areas, with a fraction > 4% of the floor area being specified as openable windows. Openable balcony doors can be counted in this calculation. Note if the window area defined under Sec 4.1.1.3 is less than openable area, then fifty (50) percent of window area should be openable.

Naturally ventilated buildings of all occupancies, other than hazardous and storage, shall provide for fifty (50) percent of its window area to be openable.

All the openable windows above ground should be designed with safety measures in place such as protection hand rails for child safety.

Windows to any regularly occupied space on exterior walls in naturally ventilated buildings shall be shaded conforming to Sec 4.7.

4.1.5 Shading

For naturally ventilated buildings of all occupancies, horizontal sunshades shall be provided over windows on South, East and West, the depth of which shall be calculated by multiplying the window height with a factor of 0.234 (Figure 4.2). Horizontal louvers can be used instead of sunshades, in which case, depth of louver shall not be less than 0.234 times the gaps between the louvers (Figure 4.3).

Vertical Shading devices shall be provided on the West, depth of which shall be calculated, by multiplying the gaps between the vertical fins, or the window width if the shades border the window width, with a factor of 0.234 (Figure 4.4).

4.1.5.1 Exceptions

a) The above rule shall be relaxed if it can be demonstrated that shading is achieved by existing neighboring structures.

b) The north side of all buildings are exempt from the above rules.

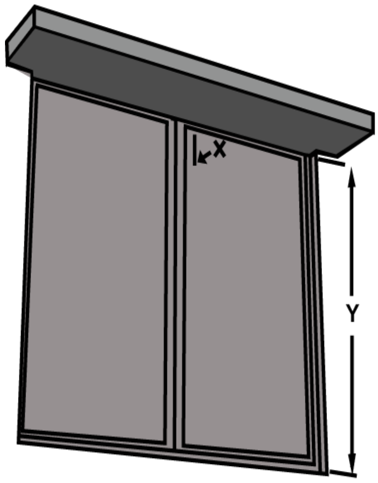

Figure 4.2. Horizontal shade: x ≥ 0.234y

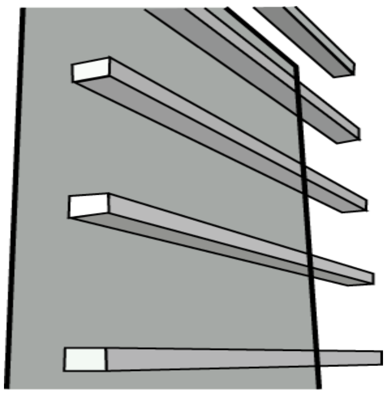

Figure 4.3. Horizontal Louvres: relationship between depth (x) and gap (y): x ≥ 0.234y

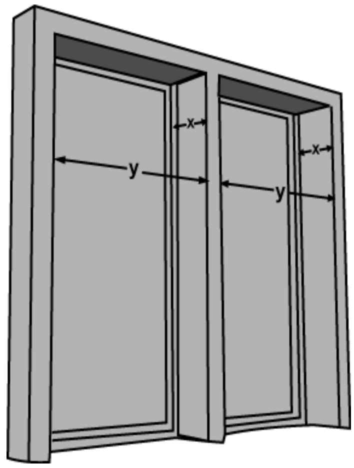

Figure 4.4. Vertical shading or louvres: relationship between depth (x) and gap (y): $x \geq 0.234y$

4.1.6 Roof Insulation and Green Roofing System

Fifty (50) percent of horizontal exposed roof slabs of Buildings of Occupancy B, C, D and E, shall have green roofing system, to manage water run-off from roof tops, to control internal temperatures within the top floors and to reduce the carbon footprint of the building. This shall not include any covered roof surface, e.g., solar panels, solar thermal heaters, machinery for mechanical or electrical systems, water tanks, etc. Stair loft or machine room tops will be exempt from this rule.

a) The roof slab design shall consider structural support of the green roof system, with growing medium of minimum 300 mm.

b) The design will indicate protection from dampness and provide a drainage system

Horizontal roof slabs, which are not covered by green roofing system, will have roof slabs with insulation, so that the time lag and decrement factor is greater than the other floor slabs of the building.

4.1.7 Building Envelope Sealing

Following areas of the building envelope, of all except naturally ventilated buildings or spaces, shall be sealed, caulked, gasketed, or weather-stripped:

a. Joints around fenestration, skylights, and door frames

b. Openings between walls and foundations, and between walls and roof, and wall panels

c. Openings at penetrations of utility services through roofs, walls, and floors

d. Site-built fenestration and doors

e. Building assemblies used as ducts or plenums

f. All other openings in the building envelope

g. Exhaust fans shall be fitted with a sealing device such as a self-closing damper

h. Operable fenestration should be constructed to eliminate air leakages from fenestration frame and shutter frame

4.1.7.1 Air Leakage/ Infiltration

Vestibules/ lounges/ entrances shall be provided to minimize infiltration through revolving/ sliding/ swinging doors. Air leakages for revolving/ sliding/ swinging entrance/ exit doors shall not exceed 5.0 L/s/m^2 (1.0 cfm/ft^2) and for windows, doors air leakage shall not exceed 2.0 L/s/m^2 (0.4 cfm/ft^2).

4.1.8 Skylight

Skylights shall comply with the maximum U-factor and maximum SHGC requirements of Table 4-6. Skylight roof ratio (SRR), defined as the ratio of the total skylight area of the roof, measured to the outside of the frame, to the gross exterior roof area.

Table 4.6. Skylight U-factor (W/m^2. K) and SHGC Requirements

Climate	Maximum U-factor	Maximum SHGC
All climatic zones	4.25	0.35

4.1.9 Building Envelope Color

Light-colored building envelope, especially the roof areas which are the most vulnerable, can reduce heat transfer from the outside to the inside of the building by having surfaces with high Solar Reflectance Index (SRI).

Table 4.7. PPG Color Series for Building Envelope

Sr. No	Metal Surface	SRI
1	Reflective white	86 to 92
2	Basic white	80 to 88
3	Beige / Tan	74 to 80
4	Dark brown	0 to 33
5	Light to medium brown	45 to 56
6	Light to medium grey	39 to 63
7	Dark grey	0 to 41
8	Blue	23 to 30
9	Light to medium blue	35 to 38
10	Red	28 to 36
11	Terracotta red	38 to 40
12	Green	25 to 32
13	Light to medium green	30 to 48

Source: PPG Cool Color Series - www.coolcolorsdatabase.ppg.com as rated by the Cool Roof Rating Council, US.

Building metal roof surfaces shall either be colored white or have a minimum SRI of 70. See Table 5.

Table 5. Solar Reflectance Index Values of Basic Colored Coatings

4.1.10 Roof Insulation

Insulation can help reduce heat gain in a building thus improving thermal comfort, acoustic quality and reducing the load on the air conditioning system. This measure applies to all building occupancies as indicated in Table 4.8. Buildings shall be provided with roof insulation so that the average thermal resistance value (R-Value) of the roof is at least R-8. See Annex 4 (Insulation R-Value).

Table 4.8. R-Value of Common Roof Insulation

Sr No.	Insulation	R-Value / inch (25.4 mm)
1.	Polyisocyanurate	5.6 to 8.0

2.	Polyurethane	5.6 to 6.5
3.	Closed cell spray foam	5.5 to 6.0
4.	Phenolic foam	4.8
5.	Urea formaldehyde foam	4.6
6.	Plastic fiber	4.3
7.	Mineral fiber	4.2 to 4.5
8.	Cementitious foam	3.9
9.	Polystyrene	3.8 to 5.0
10.	Fiberglass	3.7
11.	Rockwool	3.7
12.	Rigid foam	3.6 to 6.7
13.	Cellulose	3.6 to 3.8
14.	Open cell spray foam	3.6
15.	Sheep's wool	3.5
16.	Hemp	3.5
17.	Cotton	3.4
18.	Loose cellulose	3.0 to 3.7
19.	Mineral wool	2.8 to 3.7
20.	Straw	2.4 to 3.0
21.	Vermiculite / Perlite	2.4
22.	Reflective bubble foil	1 to 1.1

Source: U.S. Department of Energy – Insulation Materials

Table 4.9. Insulating values of common building materials

Materials	**R-value (1/C)**		**R-value per Inch (1/K)**	
	Sqft-Hr Deg F/Btu	**Sqm Deg C/W**	**Sqft-Hr Deg F/Btu**	**Sqm Deg C/W**
Metal roof	0.04	0.00704		
Aluminum alloy	0.01	0.00176		
Plastic roof				
Cement tile roof	0.21	0.03698		
Clay tile - 3 Inch [75mm] (1 cell deep)	0.8	0.14088		
Asphalt shingles	0.44	0.07748		
Asphalt			0.12 - 0.34	0.02113-0.05987
Straw thatch			2.04	0.35924
Fiberboard - 1/2 Inch [12.5mm]	1.32	0.23245		

Plywood - 1/2 Inch [12.5mm]	0.62	0.10918		
Plywood - 3/4 Inch [18.75mm]	0.94	0.16553		
Concrete (sand, gravel) 140 lb/cu ft [2246 kg/cu m]			0.05 - 0.11	0.00881-0.01937
Concrete (sand, gravel) 80 lb/cu ft [1283 kg/ cu m]			0.24 - 0.30	0.04226-0.05283
Cement mortar			0.10	0.01761
Stone			0.01	0.00176
Marble/granite, limestone			0.03 - 0.12	0.00528-0.02113
Ceramic tile - 1 Inch [25mm]	0.08	0.01409		
Stone tile - 1 Inch [25mm]	0.05	0.00881		
Air space up to 4 Inches [100mm]	1	0.1761		
Inside surface air film	0.61	0.10742		
Exterior surface air film	0.17	0.02994		
Membrane	0.06-0.12	0.01057-0.02113		
Soil (with 20% moisture content)			0.25 - 1.0	0.04403-0.17610
Sand - 1/2 Inch [12.5mm]	0.1	0.01761		

4.2 Compliance Documentation

The authority having jurisdiction would develop the required documents for implementation.

Section – 5

5. Heating, Ventilating, and Air Conditioning

5.1 General

The Heating, Ventilating, and Air Conditioning (HVAC) chapter of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) provides minimum energy efficiency requirements for HVAC systems in buildings. The chapter covers a range of topics related to HVAC systems, including equipment and system selection, installation, operation, and maintenance. It also includes provisions for ductwork, piping, and insulation, as well as requirements for HVAC controls and monitoring systems. The chapter aims to ensure that HVAC systems are designed, installed, and operated in an energy-efficient manner, while also providing adequate ventilation and maintaining indoor air quality

All heating, ventilating, and air-conditioning systems installed in buildings shall adhere to the mandatory provisions specified in this section of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023). This section sets the minimum requirements for HVAC systems, including equipment and controls, to ensure optimal energy efficiency and conservation. The provisions in this section are designed to reduce the energy consumption of HVAC systems without compromising the indoor environmental quality and thermal comfort of occupants. Adherence to these provisions is necessary to ensure the efficient operation of HVAC systems and to minimize energy waste.

5.2 HVAC

All Heating, ventilating, and air-conditioning systems falling under the subject criteria designed and installed shall comply with the mandatory Provisions of this Chapter.

5.3 HVAC Design

Heating, Ventilating, and Air Conditioning (HVAC) systems are critical components of a building's energy consumption, accounting for approximately 30-40% of the total energy consumed in centrally air-conditioned buildings. Therefore, it is essential to design and install energy-efficient and sustainable HVAC systems that comply with the mandatory provisions of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023). The design consultant plays a critical role in ensuring that the code is followed and all energy-efficient techniques are applied to the HVAC system to minimize energy consumption and reduce the building's carbon footprint. By implementing the code's guidelines, building owners and occupants can benefit from improved indoor air quality, greater thermal comfort, and lower energy bills. Therefore, compliance with the mandatory provisions of this section is necessary to achieve energy efficiency and sustainability in building design and construction.

5.4 Environmental Conditions

5.4.1 Climatic Conditions

Pakistan has diverse weather conditions and different climatic zones, which means that the outdoor design conditions should be tailored to the specific city. To conserve energy, the maximum ambient design criteria for Load Calculations/HVAC system design and Equipment selection purposes in the geographic areas listed in the following table should be the 2.0% exceedance temperature values provided. In case any city is not mentioned in the table, consultation with the Pak met office is necessary. The table 5-1 below shows weather and climate data for different cities in Pakistan. It is crucial to consider these factors while designing and installing HVAC systems to ensure energy efficiency and sustainability. Therefore, design consultants play a critical role in following the Energy Conservation Building Code and applying all energy-efficient techniques to HVAC systems.

Table 5.1. Weather and Climate Data of Major Cities

Station (City)	Lat.	Long.	Elev.	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heating/Cooling Degree Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
Islamabad	33.62N	73.10E	1168	36.2	38.4	105.9	73.1	102.6	73.4	100.4	73.0	82.5	93.8	81.5	92.5	79.7	164.2	88.6	78.9	159.5	88.1	29.0	23.2	20.7	1103	3771
Karachi	24.91N	67.16E	100	50.4	53.4	102.2	72.8	98.9	73.5	96.9	74.3	82.8	92.1	82.	91.1	80.8	160.8	88.0	80.1	156.7	87.6	21.7	19.1	17.3	38	5896
Lahore	31.52N	74.40E	712	37.8	40.8	109.7	74.0	107.4	73.9	104.2	73.9	84.4	94.2	83.5	92.9	82.4	173.7	90.0	81.0	165.1	88.9	17.9	14.3	12.1	780	4741

Hyderabad	Chitral	Multan	Muree	Quetta	Peshawar	Abbottaba
25.38N	35.88N	30.20N	33.91N	30.25N	34.01N	34.18N
68.41E	71.80E	71.42E	73.38E	66.94E	71.58E	73.25E
135	4921	400	6978	5250	1181	4295
50.4	27.1	40.1	28.5	22.7	37.8	30.9
53.1	29.5	42.7	30.3	25.4	40.1	32.8
108.4	99.3	111.3	82.4	99.6	107.2	93.4
75.1	69.3	74.4	62.0	67.6	74.5	68.5
105.8	97.1	108.6	79.7	97.9	104.1	90.9
75.3	69.1	75.5	62.6	67.0	75.8	69.0
103.5	94.9	105.9	77.4	96.1	101.8	88.4
75.7	68.5	76.4	62.8	66.2	76.8	69.4
83.4	75.1	84.4	70.7	72.3	85.1	76.3
96.0	91.8	97.8	74.3	93.4	96.9	84.8
82.6	73.2	83.7	69.7	70.6	83.7	75.3
94.8	90.1	97.2	73.3	91.9	95.6	83.6
80.9	70.5	81.5	69.6	65.9	82.4	74.0
161.4	135.3	166.0	142.2	116.2	176.6	149.1
88.3	85.5	91.3	73.0	85.7	94.0	81.7
80.0	68.3	80.7	68.7	63.7	167.5	73.0
156.6	125.3	161.6	137.4	107.7	91.9	144.0
88.0	83.2	91.3	72.2	84.3	79.6	80.7
36.1	18.5	17.5	11.7	28.3	20.5	4.1
32.8	17.4	15.1	9.0	24.4	16.7	3.2
29.0	14.9	12.1	7.2	22.0	13.2	3.0
103	3273	628	3218	2801	1022	2441
6397	1864	5632	471	2388	4261	1564

Source: *http://ashrae-meteo.info/v2.0/places.php?continent=Asia*

Meaning of acronyms:
DB: Dry bulb temperature, °F *WB: Wet bulb temperature, °F*
MCWB: Mean coincident wet bulb temperature, °F

Long: Longitude, ° *Elev: Elevation, ft*
HR: Humidity ratio, grains of moisture per lb of dry air *WS: Wind speed, mph*
HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day

Lat: Latitude, °
DP: Dew point temperature, °F
MCDB: Mean coincident dry bulb temperature, °F

5.4.2 For all HVAC Systems (Other than 5.4.3)

The cooling load is calculated using the Summer Design Dry Bulb temperature and the Mean Coincident Wet Bulb temperature. These temperatures are used to determine the supply air requirements for the HVAC system. On the other hand, the heating load is designed at the winter Dry Bulb temperature. Essentially, this means that the HVAC system is designed to provide the necessary cooling or heating capacity based on the expected temperature conditions during the summer and winter seasons. This ensures that the HVAC system operates efficiently and effectively, while also meeting the energy efficiency requirements of the Energy Conservation Building Code of Pakistan.

5.4.3 For coastal areas systems

The paragraph is describing an additional calculation that needs to be performed in order to determine the appropriate capacity of the HVAC system for a building. The calculation involves determining the cooling load at both the Design Wet Bulb and coincident Dry Bulb temperatures to determine which set of conditions results in a larger HVAC system capacity.

By performing this calculation, it is possible to determine the cooling capacity of the refrigeration system, while the air-side capacity is determined through a separate calculation described in Section 5.2.2 of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023). This additional calculation helps to ensure that the HVAC system is appropriately sized to meet the cooling needs of the building under various conditions.

5.4.4 For Hotter Climate Zones

For hotter climate zones, this section suggests using air-cooled packaged units, air-cooled condensers, and air-cooled chillers for such zones. It specifies that the selection of these systems should be based on the Summer Design Dry Bulb temperature at 1% exceedance. In other words, the cooling systems should be designed to handle extreme temperatures that may occur with a frequency of 1% or less during summer in hotter climate zones. This requirement is important to ensure that the HVAC system is efficient and can adequately cool the building during the hottest months of the year.

5.4.5 Natural Ventilation

As energy costs and environmental concerns continue to rise, natural ventilation has emerged as a viable option for reducing energy consumption and costs while maintaining a healthy, comfortable and productive indoor environment. Design consultants should consider incorporating natural ventilation strategies into their designs. Guidelines for ventilation rates and indoor air quality are provided by ASHRAE Standard 62.1.

5.5 Indoor Design Condition

1. Table 5.2 contains the minimum indoor conditions to be used for the design of HVAC systems in various facilities.
2. Design conditions for occupancies other than those listed in Table 5-2 shall comply with the recommendations of the ASHRAE Handbooks; ASHRAE STD 55.
3. HVAC systems shall be capable of maintaining dry bulb temperature and relative humidity (if applicable) within the performance range given in Table 5.2

Table 5.2. Inside Design Conditions

Facility	DB	Percent Relative Humidity	Tolerance	
			Air Motion m/s (fps)	DB °C (°F) (% RH)
Offices, schools, theaters	24(75)	50%	0.075-0.25 (0.25-0.82)	±2(±3.6) ±20%
Shops, houses, apartments, trailers, dining halls and stores	24(75)	50%	0.075-0.25 (0.25-0.82)	±2(±3.6) ±20%
Computer rooms, control rooms, communication	22(72)	50%	0.075-0.25 (0.25-0.82)	±2(±3.6) ±20%

facilities, process, interface buildings, analyzer houses				
Unattended equipment rooms (excluding communication rooms)	29(85) (Unless otherwise required by equipment manufacturers)			±2(±3.6) ±10%
Unattended electrical substations	35(95)	-	-	-
Hospitals and clinics (various rooms)	Refer to ASHRAE Applications Handbook & JCIA			
Laboratories	Refer to ASHRAE Applications Handbook			

5.6 HVAC Load, Design Calculations

Design load calculations are the basis of energy efficiency; these shall be done using appropriate software. All energy conservation elements techniques shall be applied to make the project not only energy efficient, sustainable but to provide comfort as required. Design consultant shall prepare an energy consumption model for both Electrical & thermal.

5.7 System Design

1. HVAC system can be designed in many ways. Design consultant shall compare the energy & cost comparison for each system type.
2. HVAC design should be modular where part of the building system can work independently to cope up for after normal working hours needs and part building operation to conserve energy.
3. IAQ & IEQ should also be considered in the design
4. Energy recovery should be considered where feasible.
5. A life cycle cost analysis shall be done to show which system is not only energy efficient but cost effective too during its life cycle

6. Later this should be considered as energy footprint of this project and to be followed in future.

5.7.1 Hydronic Systems

(i) Primary secondary pumping system shall be used to conserve energy.

(ii) HVAC pumping systems that include control valves shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to:

(a) 50% of the design flow rate, or

(b) Less of the design flow rates for proper operation of the chillers or boilers.

(iii) Water cooled air-conditioning or heat pump units with a circulation pump motor greater than or equal to 5 hp (3.7 kW) shall have control devices on each water-cooled air-conditioning or heat pump unit that are interlocked with the compressor to shut off condenser water flow when the compressor is not operating. Pump motors greater than or equal to 5 hp (3.7 kW) shall be controlled by variable speed drives.

5.8 Controls

5.8.1 System Control

All mechanical cooling and heating systems shall be controlled by automated controls preferably through a building management system using DDC system that:

1. Capable of maintaining required in door temperature & Humidity
2. Can start and stop the system under different schedules for different days, usage types & times per week,
3. Is capable of retaining programming and time setting during a loss of power for a period of at least 10 hours, and

4. Includes an accessible manual override that allows temporary operation of the system.

   a) Should be capable of reporting maintenance requirements of the components (Maintenance Management System)
   b) Capable of monitoring, alarms and reporting energy consumption
   c) Capable of communicating with Fire systems installed in the facility.

5.8.1.1 Exceptions to 5.8.1

Residential sector with non-centralized system/s

5.8.2 HVAC Systems Zone Set Points (Temperature Control)

The building project's HVAC systems shall be programmed to allow centralized demand reduction in response to a signal from a centralized contact or software point in accordance with the following:

1. The controls shall be programmed to automatically adjust upward the zone operating cooling set points by a minimum of 3°F (1.7°C).
2. The controls shall be programmed to automatically adjust downward the zone operating heating set points by a minimum of 3°F (1.7°C).
3. The controls shall be programmed to automatically adjust downward the zone operating cooling set points by a minimum of 2°F (1.1°C).
4. The automated DR strategy shall include both ramp-up and ramp-down logic to prevent the building peak demand from exceeding that expected without the DR implementation.

5.8.2.1 Exception

Systems serving areas deemed by the owner to be critical in nature.

5.8.3 Variable-Speed Equipment

1. For HVAC equipment with variable-speed control, the controls shall be programmed to allow automatic adjustment of the maximum speed of the equipment to 90% of design speed during automated DR events.
2. Airflow adjustments shall not decrease the supply airflow rate below the level that would result in outdoor airflow being below the minimum required outdoor airflow rates, or that would cause adverse building pressurization problems.

5.8.4 Fault Detection and Diagnostics (FDD)

A fault detection and diagnostics (FDD) system is preferred to be installed in new buildings to monitor the performance of the building's HVAC system and detect faults in the system. The FDD system shall:

1. Include permanently installed devices to monitor HVAC system operation.
2. Sample the HVAC system performance not more than once per hour.
3. Automatically identify, display, and report system faults.
4. Automatically notify service personnel of identified fault conditions.
5. Automatically provide prioritized recommendations for fault repair based on analysis of collected data; and
6. Be capable of tracking and recording a history of identified faults, from identification through repair completion.
7. Capable of reporting any increase in Energy usage.

5.8.4.1 Exceptions

1. Buildings with gross floor area less than 25,000 ft^2 (2500 m^2).
2. Individual tenant spaces with gross floor area less than 10,000 ft^2 (1000 m^2).
3. Dwelling units and hotel/motel guest rooms.
4. Residential buildings with less than 10,000 ft^2 (1000 m^2) of common area.

5.8.5 Mechanical Ventilation

Each mechanical ventilation system (supply and/or exhaust) shall be equipped with a readily accessible switch or other means for shut off or for volume reduction or shut off when full ventilation is not required. Automatic or gravity dampers that close when the system is not operating shall be provided for outdoor air intake and exhausts. Automatic or manual dampers installed for the purpose of shutting off ventilation systems shall be designed with tight shutoff characteristics to minimize air leakage.

5.8.5.1 Exceptions

Manual dampers for outdoor intakes may be used in the following cases:

a) For single and multi-family residential buildings.

b) Dampers are not required when ventilation air flow is less than 100 ft^3/ min (0.047 m^3/ s).

5.8.6 Non- Residential Kitchen Space

Non-residential kitchen space shall be designed with an exhaust air and make up air balance such that the space is never under a positive pressure with reference to adjacent space.

5.9 Equipment Selection

HVAC Equipment shall meet or exceed the minimum performance at the specified rating conditions when tested in accordance with the specified test procedures. The Equipment shall satisfy all stated requirements unless otherwise stated.

5.9.1 Equipment Selection (Minimum Equipment Efficiencies)

Note: These tables are not yet updated, waiting approval from ASHRAE or ICC.

Table 5.3. Air Conditioners and Condensing Units

Equipment Type	Size Category	Heating	Sub-Category or	Minimum Efficiency [a]	Test Procedure [b]

		Section Type	Rating Condition		
Air Conditioners, Air Cooled	<65,000 Btu/h[c]	All	Split System	12.0 SEER	ARI 210/240
			Single Package	12.0 SEER	
Through-the- Wall, Air Cooled	≤30,000 Btu/h[c]	All	Split System	12.0 SEER	
			Single Package	12.0 SEER	
Small-Duct High-Velocity, Air Cooled	< 65,000 Btu/h[c]	All	Split System	10 SEER	
Air Conditioners, Air Cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (Or none)	Split System and Single Package	10.3 EER	ARI 340/360
		All other	Split System and Single Package	10.1 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (Or none)	Split System and Single Package	9.7 EER	
		All other	Split System and Single Package	9.5 EER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (Or none)	Split System and Single Package	9.5 EER 9.7 IPLV	
		All other	Split System and Single Package	9.3 EER 9.5 IPLV	
	≥ 760,000 Btu/h	Electric Resistance (Or none)	Split System and Single Package	9.2 EER 9.4 IPLV	
		All other	Split System and Single Package	9.0 EER 9.2 IPLV	
Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency [a]	Test Procedure [b]
Air Conditioners, Water and Evaporatively Cooled	< 65,000 Btu/h	All	Split System and Single Package	12.1 EER	ARI 210/240
	≥ 65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or none)	Split System and Single Package	11.5 EER	ARI 340/360
		All other	Split System and Single Package	11.3 EER	
	≥ 135,000 Btu/h and	Electric Resistance (Or none)	Split System and Single Package	11.0 EER	

	<240,000 Btu/h	All other	Split System and Single Package	10.8 EER	
	≥ 240,000 Btu/h	Electric Resistance (Or none)	Split System and Single Package	1 1.0 EER 10.3 IPLV	
		All other	Split System and Single Package	10.8 EER 10.1 IPLV	
Condensing Units, Air Cooled	≥ 135,000 Btu/h			10.1 EER 11.2 IPLV	ARI 365
Condensing Units, Water or Evaporatively Cooled	≥ 135,000 Btu/h			13.1 EER 13.1 IPLV	

a PLVs and part load rating conditions are only applicable to equipment with capacity modulation.

b ASHRAE 90.1-2004 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

c Single-phase, air-cooled air-conditioners < 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

Table 5.4. Electrically Operated Unitary and Applied Heat Pumps Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Sub-Category Or Rating Condition	Minimum Efficiency [a]	Test Procedure [b]
Air Cooled (Cooling Mode)	<65,000 Btu/h[c]	All	Split System Single Package	12.0 SEER	ARI 210/240
				12.0 SEER	
Through the Wall (Air Cooled, Cooling Mode)	<30,000 Btu/h[c]	All	Split System	12.0 SEER	
			Single Package	12.0 SEER	

Small-Duct High-Velocity (Air Cooled, Cooling Mode)	< 65,000 Btu/h[c]	All	Split System	10 SEER	
Air Cooled (Cooling Mode)	>65,000 Btu/h and <135,000 Btu/h	Electric Resistance (Or none)	Split System and Single Package	10.1 EER	ARI 340/360
		All other	Split System and Single Package	9.9EER	
	>135,000 Btu/h and <240,000 Btu/h	Electric Resistance (Or none)	Split System and Single Package	9.3 EER	
		All other	Split System and Single Package	9.1 EER	
	>240,000 Btu/h	Electric Resistance (Or none)	Split System and Single Package	9.0 EER 9.2IPLV	
		All other	Split System and Single Package	8.8 EER 9.0IPLV	
Water-Source (Cooling Mode)	<17,000Btu/h	All	860F Entering Water	11.2 EER	ISO-13256-1
	> 17,000 Btu/h and <65,000 Btu/h	All	860F Entering Water	12.0 EER	ISO-13256-1
	>65,000 Btu/h and < 135,000 Btu/h	All	860F Entering Water	12.0EER	ISO-13256-1
Ground water-Source (Cooling Mode)	<135,000 Btu/h	All	590F Entering Water	16.2 EER	ISO-13256-1
Ground Source (Cooling Mode)	< 135,000 Btu/h	All	770FEntering Water	13.4 EER	ISO-13256-1
Air Cooled (Heating Mode)	<65,000 Btu/hc (Cooling Capacity)	-	Split System	7.4 HSPF	ARI 210/240
			Single Package	7.4 HSPF	
Through the Wall		-	Split System	7.4 HSPF	

(Air Cooled, Heating Mode)	<30,000 Btu/hc (Cooling capacity)		Single Package	7.4 HSPF	
Small-Duct High-Velocity (Air Cooled, Heating Mode)	< 65,000 Btu/hc (Cooling capacity)	-	Split System	6.8 HSPF	ARI 210/240
Air Cooled (Heating Mode)	>65,000 Btu/h and <135,000 Btu/h (Cooling Capacity)	-	47°F db/43°F wb Outdoor air	3.2 COP	ARI 340/360
			17°F db/15°F wb Outdoor air	2.2 COP	
	>135,000 Btu/h (Cooling Capacity)	-	47°F db/43°F wb Outdoor air	3.1 COP	
			17°F db/15°F wb Outdoor air	2.0 COP	
Water-Source (Heating Mode)	<135,000 Btu/h (Cooling Capacity)	-	68°F Entering Water	4.2 COP	ISO-13256-1
Groundwater-Source (Heating Mode)	<135,000 Btu/h (Cooling Capacity)	-	50°F Entering Water	3.6 COP	ISO-13256-1
Ground Source (Heating Mode)	< 135,000 Btu/h (Cooling Capacity)	-	32°F Entering Water	3.1 COP	ISO-13256-1

a. IPLVs and Part load rating conditions are only applicable to equipment with capacity modulation.

b. ASHRAE 90.1-2004 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

c. Single phase, air-cooled heat pumps < 65,000 Btu/h are regulated by NAECA, SEER and HSPF values those set by NAECA.

Table 5.5. Water Chilling Packages Minimum Efficiency Requirements

Equipment Type	Size Category	Minimum Efficiency	Test Procedure
Air Cooled	All Capacities	2.80 COP 3.05 IPLV	ARI550/590
Water Cooled, Electrically Operated, (Reciprocating)	All Capacities	4.20 COP 5.05 IPLV	ARI550/590
Water Cooled, Electrically Operated, (Rotary Screw and Scroll)	<150 tons	4.45 COP 5.20 IPLV	ARI550/590
	≥150 tons and <300 tons	4.90 COP 5.60 IPLV	
	≥300 tons	5.50 COP 6.15 IPLV	
Water Cooled, Electrically Operated, Centrifugal	<15O tons	5.00 COP 5.25 IPLV	ARI550/590
	≥150 tons and <300 tons	5.55 COP 5.90 IPLV	
	≥300 tons	6.10 COP 6.40 IPLV	
Water-Cooled Absorption Single Effect	All Capacities	0.7 COP	
Absorption Double Effect, Indirect-Fired	All Capacities	1.00 COP 1.05 IPLV	
Absorption Double Effect, Direct-Fired	All Capacities	1.00 COP 1.00 IPLV	

Minimum Efficiency: *The chiller equipment requirements do not apply for chillers used in low-temperature applications where the design leaving fluid temperature is* $<40^{0}$*F.*

Test Procedure: *ASHRAE 90.1-2004 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.*

Table 5.6. Electrically Operated Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single -Package Vertical Heat Pumps, Room Air Conditioners, and Room Air Conditioner Heat Pumps-Minimum Efficiency Requirements

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
PTAC (Cooling Mode) New Construction	All Capacities	95°F db Outdoor air	12.5-(0.213 x Cap/I000)[c] EER	ARI 310/380

PTAC (Cooling Mode) Replacements [b]	All Capacities	95°F db Outdoor air	10.9 - (0.213 x Cap/I000)[c] EER	
PTHP (Cooling Mode) New Construction	All Capacities	95°F db Outdoor air	12.3 - (0.213 x Cap/I000)[c] EER	
PTHP (Cooling Mode) Replacements [b]	All Capacities	95°F db Outdoor air	10.8-(0.213 x Cap/ I000)[c] EER	
PTHP (Heating Mode) New Construction	All Capacities		3.2 - (0.026 x Cap/I000)[c] COP	
PTHP (Heating Mode) Replacements [b]	All Capacities		2.9 - (0.026 x Cap/I000)[c] COP	
SPVAC (Cooling Mode)	All Capacities	95°F db/75°F wb Outdoor air	8.6 EER	
SPVHP (Cooling Mode)	All Capacities	95°F db/75°F wb Outdoor air	8.6. EER	ARI 390
SPVHP (Heating Mode)	All Capacities	47°F db/43°F wb Outdoor air	2.7 COP	
Room Air Conditioners, with Louvered Sides	<6000 Btu/h		9.7 SEER	
	≥6000 Btu/h and <8000 Btu/h		9.7 EER	
	≥8000 Btu/h and <14,000 Btu/h		9.8 EER	
	≥14,000 Btu/h and <20,000 Btu/h		9.7 SEER	
	≥20,000 Btu/h		8.5 EER	
Room Air Conditioners, Without Louvered Sides	<8000 Btu/h		9.0 EER	ANSV AHAM RAC-I
	≥8000 Btu/h and <20,000 Btu/h		8.5 EER	
	≥20,000 Btu/h		8.5 EER	
Room Air Conditioner Heat Pumps with Louvered Sides	<20,000 Btu/h		9.0 EER	
	≥20,000 Btu/h		8.5 EER	
Room Air Conditioner Heat Pumps without Louvered Sides	<14,000 Btu/h		8.5 EER	
	≥14,000 Btu/h		8.0 EER	

a ASHRAE 90.1-2004 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

b Replacement units must be factory labeled as follows: “MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS," Replacement efficiencies apply only to units with existing sleeves less than 16 in. high and less than 42 in. wide.

c Cap means the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7000 Btu/h, use 7000 Btu/h in the calculation. If the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculation.

Table 5.7. Warm Air Furnaces and Combination Warm Air Furnaces/Air-Conditioning Units, Warm Air Duct Furnaces and Unit Heaters

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency [a]	Test Procedure [b]
Warm Air Furnace, Gas-Fired	<225,000 Btu/h		78% AFUE or 80%E_t[d]	DOE 10 CFR Part 430 or ANSI Z21.47
	≥225,000 Btu/h	Maximum Capacity [d]	80% E_c[c]	ANSI Z21.47
Warm air Furnace, Oil-Fired	<225,000 Btu/h		78% AFUE or 80%E_t [d]	DOE 10 CFR Part 430 or UL 727
	≥225,000 Btu/h	Maximum Capacity [e]	81%E_t[f]	UL 727
Warm Air Duct Furnaces, Gas-Fired	All Capacities	Maximum Capacity [e]	80%E_c[g]	ANSI Z83.9
Warm Air Unit Heaters, Gas Fired	All Capacities	Maximum Capacity [e]	80%E_c[g]	ANSI Z83.8
Warm Air Unit Heaters, Oil-Fired	All Capacities	Maximum Capacity [e]	80% E_c[g]	UL 731

a *E_t= thermal efficiency. See test procedure for detailed discussion.*

b *ASHRAE 90.1-2004 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.*

c *E_c = combustion efficiency. Units must also include an interrupted or intermittent ignition device (110), have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.*

d *Combination units not covered by NAECA (3-phase power or cooling capacity greater than or equal to 65,000 Btu/h) may comply with either rating.*

e *Minimum and maximum ratings as provided for and allowed by the unit's controls.*

f *E_t thermal efficiency. Units must also include an interrupted or intermittent ignition device (IID), have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space* *g* *E_c = combustion efficiency. See test procedure for detailed discussion.*

Table 5.8. Gas and Oil-Fired Boilers-Minimum Efficiency Requirements

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency [b]	Test Procedure [c]
Boilers, Gas-Fired	<300,000 Btu/h	Hot Water	80% AFUE	DOE 10 CFR Part 430
		Steam	75% AFUE	
	≥300,000 Btu/h and ≤2,500,000 Btu/h	Maximum Capacity [d]	75%E_t [b]	H.I. Htg Boiler Std.
	>2,500,000 Btu/h[a]	Hot Water	80%E_c	
	>2,500,000 Btu/h[a]	Steam	80%E_c	
Boilers, Oil-Fired	<300,000 Btu/h		80% AFUE	DOE 10 CFR Part 430
	≥300,000 Btu/h and ≤2,500,000 Btu/h	Maximum Capacity [d]	78%E_t [b]	DOE 10 CFR Part 430 H.I. Htg Boiler Std.
	>2,500,000 Btu/h[a]	Hot Water	83% E_c	
	>2,500,000 Btu/h[a]	Steam	83%E_c	
Oil-Fired (Residual)	≥300,000 Btu/h and ≤2,500,000 Btu/h	Maximum Capacity [d]	78%E_t [b]	H.I. Htg Boiler Std.
	>2,500,000 Btu/h[a]	Hot Water	83%E_c	
	>2,500,000 Btu/h[a]	Steam	83%E_c	

a. *These requirements apply to boilers with rated input 800,000,000 Btu/h or less that are not packaged boilers, and to all packaged boilers. Minimum efficiency requirements for boilers cover all capacities of packaged boilers.*

b *Et = thermal efficiency. See reference document for detailed information.*

c *ASHRAE 90.1-2004 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.*

d *Minimum and maximum ratings as provided for and allowed by the units' controls.*

Table 5.9. Performance Requirements for Heat Rejection Equipment

Equipment Type	Total System Heat	Subcategory or Rating Condition	Performance Required [a,b]	Test Procedure [c]

	Rejection Capacity at Rated Conditions			
Propeller or Axial Fan Cooling Towers	All	95°F Entering Water 85°F Leaving Water 75°F wb *Outdoor air*	≥38.2 gpm/hp	CTI ATC-105
Centrifugal Fan Cooling Towers	All	95°F Entering Water 85°F Leaving Water 75°F wb *Outdoor air*	≥20.0 gpm/hp	CTI ATC-105
Air-Cooled Condensers	All	125°F Condensing Temperature R-22 Test Fluid 190°F Entering Gas Temperature 15°F Subcooling 95°F Entering db	≥176,000 Btu/h.hp	ARI460

a. For purposes of this table, cooling tower performance is defined as the maximum flow rating of the tower divided by the fan nameplate rated motor power.

b For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan nameplate rated motor power.

c ASHRAE 90.1-2004 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

5.9.2 Insulation Piping and Ductwork

Piping shall be insulated in accordance with table 5.10.

Table 5.10. Minimum Pipe Insulation Thickness [a]

Fluid Design Operation Temp. Range (ºF)	**Insulation Conductivity**		**Nominal Pipe or Tube Size (In.)**				
	Conductivity Btu. in./ (h.ft^2.ºF)	**Mean Rating Temp. ºF**	**<1**	**1 to < 1-1/2**	**1-1/2 to <4**	**4 to < 8**	**≥ 8**
Heating Systems (Steam, Steam Condensate, and Hot Water) [b, c]							
> 350	0.32 - 0.34	250	2.5	3.0	3.0	4.0	4.0

251 – 350	0.29 – 0.32	200	1.5	2.5	3.0	3.0	3.0
201 – 250	0.27 – 0.30	150	1.5	1.5	2.0	2.0	2.0
141 – 200	0.25 – 0.29	125	1.0	1.0	1.0	1.5	1.5
105 – 140	0.22 – 0.28	100	0.5	0.5	1.0	1.0	1.0
Domestic and Service Hot Water Systems							
105+	0.22 – 0.28	100	0.5	0.5	1.0	1.0	1.0
Cooling Systems (Chilled Water, Brine, and Refrigerant) [d]							
40 – 46	0.22 – 0.28	100	0.5	0.5	1.0	1.0	1.0
< 40	0.22 – 0.28	100	0.5	1.0	1.0	1.0	1.5

a *For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows:*

$$T = r \{(1 + t/r)^{K/k} - 1\}$$

Where T = minimum insulation thickness (in.), r = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature (Btu in. [h ft^2, ^{0}F], and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.

b *These thicknesses are based on energy efficiency consideration only. Additional insulation is sometimes required relative to safety issues/surface temperature.*

c *Piping insulation is not required between the control valve and coil on run-outs when the control value is located within 4 ft of the coil and the pipe size is 1 in. or less.*

d *These thicknesses are based on energy efficiency consideration only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.*

Ductwork shall be insulated in accordance with table 5.11.

Table 5.11 provide a general requirement, however depending on hottest & coldest climate zone, these figures should be increased/decreased respectively.

Every effort made to keep the insulation thickness as mentioned while outside wrapping/strapping.

Table 5.11. Minimum Duct Insulation R-Value [a], Combined Heating and Cooling Supply Ducts and Return Ducts

	Duct Locations

	Exterior	Ventilated Attic	Un-vented Attic above Insulated Ceiling	Un-vented Attic with Roof Insulation [a]	Unconditioned Space [b]	Indirectly Conditioned Space [e]	Buried
Supply Ducts							
	R-8	R-8	R-8	R-6	R-6	none	R-6
Return Ducts							
	R-6	R-6	R-6	None	none	none	None

a Insulation R-value, measured in (h. ft^2. ^0F)/Btu, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive conditions. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 75^0F at the installed thickness.

b Includes crawl spaces, both ventilated and non-ventilated.

c Includes return air plenums with or without exposed roofs above.

5.9.3 Cooling Towers/Condenser Water

1. All cooling towers and closed-circuit fluid coolers shall have preferably variable drives controlling the fans.
2. Cooling towers shall have provisions for automatic blow down based on cooling water conductivity or total dissolved solids. Feed tank and pumps shall be provided for chemical treatment.
3. Cooling towers shall be designed in accordance with the requirements of manufacturer of Non- Industrial Cooling Towers & following ASHRAE guidelines.
4. Cooling towers shall be located downwind of any adjacent facility or building. Cooling towers shall also be separated by not less than 15 m (49.5 ft.) from adjacent facilities.
5. Make-up water line for cooling towers shall have an air gap between the termination of the make-up line and the maximum water level of the cooling tower reservoir. This air gap shall be a minimum of two times the diameter of the make-up line.

Condenser water treatment, shall have the following:

a. Condenser water treatment, including scale inhibitors, corrosion inhibitors, dispersants/antifoulants and biocide as a minimum. Condenser water treatment shall comply with the ASHRAE Applications Handbook, Chapter on Water Treatment.
b. Blow down shall be automatic and controlled by a conductivity controller set at the maximum allowable concentration of Total Dissolved Solids

(TDS).

c. Closed chilled or hot water systems shall be treated with a corrosion inhibitor. This corrosion inhibitor shall be a buffered, nitrite-based product, with sodium nitrite residual in the range of 700 to 1200 ppm or molybdate in the range of 250-350 ppm; and with a pH of 7 or higher.

5.10 Design Documents

Design documentation is an important part of the HVAC project that should include Design, installation, commissioning, TAB, O&M and energy monitoring.

5.10.1 Design Documentation Requirements

Design Execution Specifications and Design Drawings shall be prepared for each project. These Specifications shall include all mechanical design requirements for air conditioning and refrigeration (HVAC). Specifications shall be complete and include work description, references to drawings, standards, and description of construction materials.

5.10.2 Drawings

1. HVAC drawings shall be provided with sufficient details to permit the construction of a complete facility.
2. Drawings shall include a list of drafting symbols / abbreviations used, and equipment schedules.
3. All symbols and abbreviations on HVAC drawings shall be consistent with SMACNA & ASHRAE
4. All construction drawings shall be revised to show "as built" conditions.
5. On one of the drawings of each HVAC system, Design Data, including the following items, shall be shown:

    a) Outside air conditions used for load calculations
    b) Indoor design conditions
    c) Total sensible cooling load with a breakdown to its components, i.e.,

external heat gain, heat from lights, people, etc.

d) Total latent cooling load, with breakdown

e) Grand total cooling load

f) Heating load

g) Outside air intake

h) Chilled water (if any) flow rate, temperature rise and pressure drop.

i) Entering and leaving air conditions at cooling coil; and

j) Total pressure drops of air handling system with a breakdown to components, i.e., pressure drop through supply/return ducting, coils, filters, etc.

6. Psychrometric charts shall be shown on one of the HVAC drawings for each HVAC system of 10 tons and larger. This psychrometric chart shall include, as a minimum, the data required by paragraph 5.8.2.5 of this code.

5.10.2.1 Exemption: Residential buildings

1. System curves superimposed with fan curves shall be shown on one of the HVAC drawings, for each HVAC system of 10 tons and larger.
2. As built drawings: The original drawings shall be updated to "as built" conditions when the construction of a project is completed.
3. Vendor drawings shall be specified by the originator of the material requisition and shall conform to the requirements.
4. HVAC sequence of operation shall be shown on one of the HVAC drawings, for each HVAC system of 10 tons and larger which will the basis of controls vendor's design.

5.10.3 Equipment Schedules

Equipment schedules shall be included on one of the HVAC drawings with information necessary for bidding, purchasing, and installation of all HVAC equipment. Schedules shall contain all required data, such as type of equipment, quantity, temperature, medium handled, pressure and pressure drop, design conditions, etc. Area served and location shall be shown on the drawing plans. Each item of equipment schedule shall have the following:

a. Equipment number.
b. Air (water) quantities, from each source.
c. Equipment rpm.
d. Total pressure drops, across each portion of equipment.
e. Unit type.
f. Manufacturer and model number.
g. Motor type, size, rpm, kW (hp), volts/phase/hertz.

In addition, the following specific data shall be given:

a) Filter: type, efficiency, number, size, pressure drop (clean/dirty).
b) Coil: sensible heat, total heat, EAT (DB/WB), LAT (DB/WB)
c) Chillers: capacity, compressor input, EWT, LWT,
d) water flow pressure drops, cond. ambient temp., cond. fans No. and motor size, (or condenser supply, condenser return), refrigerant.
e) Pumps: capacity, total head, type, duty.
f) Fans: type, capacity, static press., wheel diameter, drive, interlocks, accessories.
g) Duct Htr: airflow, capacity, stages, power and control voltages.
h) Air Distr.: size, symbol, duty, air pattern, accessories.
i) Humidifier, type capacity etc
j) Energy recovery type & details

5.11 Commissioning

Commissioning is a quality-focused process for enhancing the delivery of a project for verifying and documenting that the HVAC systems, energy & controls are planned, designed, installed, tested, and include plans for operation and maintenance to meet specified requirements.

5.11.1 Preliminary Commissioning Report

1. The preliminary commissioning report shall include the following:
2. Required performance of commissioned equipment, systems, assemblies, and results of testing and verification
3. Summary of compliance of the HVAC System and its components, assemblies, controls, and systems with required provisions of this code
4. Issues and resolution logs, including itemization of deficiencies found during verification, testing, and commissioning that have not been corrected at the time of report preparation.
5. Deferred tests that cannot be performed at the time of report preparation.
6. Documentation of the training of operating personnel and building occupants on commissioned systems, and a plan for the completion of any deferred trainings not completed at the time of report preparation.
7. A plan for the completion of commissioning and training, including climatic and other conditions required for performance of the deferred tests.

5.11.2 Final Commissioning Report

The construction documents shall require the commissioning provider to provide a final commissioning report to the owner before completion of the contractor's general warranty period.

This report shall be reviewed by respective authority and any discrepancies should be resolved involving design consultant.

5.12 Testing, Adjusting and Balancing (TAB)

Testing, Adjusting and Balancing (TAB) is a critical process used to ensure that heating, ventilation, and air conditioning (HVAC) systems in buildings are operating efficiently and effectively. The TAB process involves a series of tests and adjustments that are performed on HVAC systems to ensure that they are delivering the right amount of air at the right temperature, and in the right locations throughout the building.

The primary goal of TAB is to optimize HVAC system performance to ensure energy efficiency and occupant comfort. The TAB process typically involves the following steps:

A. **Testing:** A series of tests are performed to measure the performance of the HVAC system. This includes measuring air flow rates, temperatures, pressures, and other variables.

B. **Adjusting:** Based on the test results, adjustments are made to the HVAC system to ensure that it is operating efficiently and effectively. This includes adjusting dampers, valves, and other components to optimize air flow rates and temperatures.

C. **Balancing:** Once the adjustments have been made, the HVAC system is balanced to ensure that it is delivering the right amount of air at the right temperature and in the right locations throughout the building. This involves adjusting the airflow distribution system to ensure that the air is being distributed evenly throughout the building.

By performing the TAB process on HVAC systems, building owners and managers can ensure that their systems are operating at peak performance, which can lead to significant energy savings and improved occupant comfort. TAB is often required by building codes and standards, and is typically performed by certified professionals who are trained in HVAC system testing and balancing.

5.12.1 General Requirements

Construction documents shall require that all HVAC systems be balanced in accordance with generally accepted engineering standards. Construction documents shall require that a written testing, commissioning, and balance report be provided to the owner or the designated representative of the building owner for HVAC systems serving zones with a total conditioned area exceeding 5000m^2 ft^2 (50000 ft^2). Test procedure should follow guidelines by NEBB. All building environmental systems and components shall be checked and adjusted to produce the design objectives. It shall include:

a) The balance of air and water distribution adjustment of total system to provide design quantities.
b) Electrical measurement
c) Verification of performance of all equipment and automatic controls, sound and vibration measurement, when required.
d) Energy consumptions as stipulated in the design.

5.12.2 Economizers

5.12.2.1 Air Side Economizer

Each individual cooling fan system that has a design supply capacity over 2,500 cfm (1,200 l/s) and a total mechanical cooling capacity over 75,600 Btu/hr (22.2 kW or 6.3 tons) shall include either:

A. An air economizer capable of modulating outside-air and return-air dampers to supply 100 percent of the design supply air quantity as outside-air; or
B. Heat recovery units are recommended to be installed where appropriate

5.12.2.2 Testing Air Side Economizer

A. Air-side economizers shall be tested in the field to ensure proper operation.

B. Air economizers installed by the HVAC system equipment manufacturer and certified as being factory calibrated and tested per relevant ASHRE/ARI Standard procedures.

5.12.3 Air System Balancing

Air systems shall be balanced in a manner to first minimize throttling losses. Then, for fans with fan system power greater than 1.0 hp (0.75 kW), fan speed shall be adjusted to meet design flow conditions. System should be balanced within 10% of the designed air flow. Any differences should be resolved with consultation with the design consultant.

5.12.3.1 Hydronic System Balancing

Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses; then the pump impeller shall be trimmed (as a last resort), or pump speed shall be adjusted to meet design flow conditions.

The above tests shall be accomplished by:

I. checking installations for conformity to design
II. measurement and establishment of the fluid quantities
III. recording and reporting the results.

A complete system test reports shall be provided on air and water movement system (If Hydronic) as follows:

a) Record data on water side and air side of all air handling units, fans, coils, water chillers, condensers, etc. Data shall include all water and airflow, motor, starter heaters, manufacturer, nameplate data.

b) Balance air distribution system within + 10% of air quantities shown on project drawings and record actual readings taken.

c) Adjust all chilled water balance valves for quantities to within 5% of values shown on project drawings and record actual readings.

d) Check operation of all controls to ensure that all actuators cycle in accordance with the designed action of the controlling device and the sequence of operation.

e) Provide test points and plugs or covers for all openings in duct.

5.12.4 Testing Organization

The Testing and Balancing (TAB) work for HVAC installation shall be accomplished by a Balancing Contractor who has:

A. An organization whose regular activities include testing, adjusting and balancing environmental systems.
B. An organization which utilized only regular employees experienced and trained specifically in the total balancing of environmental systems; and
C. An organization which has satisfactorily balanced at least five systems of comparable type and size.
D. Preferred if NEEB or any other respective approved org

5.12.5 Test Procedures

The Test and Balance Organization shall perform testing, adjustment and balancing of all equipment and systems using general procedure for testing and balancing following:

a) ASHRAE STD 111 (latest edition), Practices for Measurement, Testing, Adjusting and Balancing of Heating, Ventilation, Air Conditioning and Refrigeration Systems

b) ASHRAE Applications Handbook (latest edition), Chapter on "Testing, Adjusting and Balancing";

c) SMACNA (latest edition), "HVAC Systems - Testing, Adjusting and Balancing."

d) NEBB "Testing, Adjusting and Balancing of Environmental Systems."

e) The system balance contractor shall verify installation of mechanical systems and equipment in accordance with design and construction drawings.

5.12.6 Test and Balance Report

The report shall include the detailed information of either:

a) AABC "National Standards for Field Measurement and Instrumentation, (US)

b) NEBB "Procedural Standards for Testing, Balancing and Adjusting of Environmental Systems." (US)

5.13 Operation & Maintenance

HVAC operations and maintenance ("O&M") are the practices that keep the mechanical systems working at peak performance during the life of the building. In order to maintain energy footprint of a system, Operation & Maintenance is vital and should be carried out as stipulated in the design.

1. Design consultant shall prepare & provide an O& M manual for the O&M Staff to follow
2. O&M staff/facility managers must be trained to take over and maintain the system.
3. Use of MMS (Maintenance Management System) is highly recommended
4. A properly executed O&M can not only save the system from premature failure but also maintain its energy footprints.

5.14 Recommended Voluntary Adoption

5.14.1 Alternate Energy

The use of energy recovery system, geothermal energy, solar systems and other renewable energy systems is encouraged for adoption in buildings as an alternative to conventional heating, ventilating and cooling systems.

5.15 Compliance Documentation

The authority having jurisdiction (NEECA) would develop the required documents for its implementation.

Section-6

6. Service Water Heating

6.1 General

All service water heating equipment and systems shall comply with the mandatory Provisions of this Section.

6.2 Mandatory Requirements

6.2.1 Piping Insulation

Piping insulation shall comply with Table 6.

Table 6.1. Minimum Pipe Insulation Thickness [a]

Fluid Design Operating Temp. Range (ºF)	Insulation Conductivity		Nominal Pipe or Tube Size (In.)				
	Conductivity Btu. in./ (h.ft^2.ºF)	Mean Rating Temp. ºF	<1	1 to < 1-1/2	1-1/2 to <4	4 to < 8	≥ 8
Heating Systems (Steam, Steam Condensate, and Hot Water) [b, c]							
> 350	0.32 – 0.34	250	2.5	3.0	3.0	4.0	4.0
251 – 350	0.29 – 0.32	200	1.5	2.5	3.0	3.0	3.0
201 – 250	0.27 – 0.30	150	1.5	1.5	2.0	2.0	2.0
141 – 200	0.25 – 0.29	125	1.0	1.0	1.0	1.5	1.5
105 – 140	0.22 – 0.28	100	0.5	0.5	1.0	1.0	1.0
Domestic and Service Hot Water Systems							
105+	0.22 – 0.28	100	0.5	0.5	1.0	1.0	1.0
Cooling Systems (Chilled Water, Brine, and Refrigerant) [d]							
40 – 46	0.22 – 0.28	100	0.5	0.5	1.0	1.0	1.0
< 40	0.22 – 0.28	100	0.5	1.0	1.0	1.0	1.5

a) For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows:

$$\mathbf{T= r\{1 + t/r)^{K/k} -1\}}$$

where T= minimum insulation thickness (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu·in.[h-ft^2.^{o}F]); and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.

b) These thicknesses are based on energy efficiency considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.

c) Piping insulation is not required between the control valve and coil on run-outs when the control valve is located within 4 ft of the coil and the pipe size is I in. or less.

d) These thicknesses are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.

6.2.2 Equipment Efficiency

Service water heating equipment shall meet or exceed the minimum efficiency requirements presented in Table 6.2.

Table 6.2. Performance Requirements for Water Heating Equipment

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required[a]	Test Procedure[b]
Electric Water Heaters	≤12kW	Resistance ≥20 gal	0.93-0.00132V EF	DOE 10CFR Part 430
	>12kW	Resistance≥ 20 gal	20 + 35 $\sqrt{V}$ SL, Btu/h	ANSI Z21.10.3
	≤24 Amps and	Heat Pump	0.93-0.00 132V EF	DOE 10CFR

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required[a]	Test Procedure[b]
	≤250 Volts			Part 430
Gas Storage Water Heaters	≤75,000 Btu/h	≥20 gal	0.62-0.0019V EF	DOE 10 CFR Part 430
	>75,000 Btu/h	<4000 (Btu/h)/gal	80% E_t (Q/800 + 110 $\sqrt{V}$) SL, Btu/h	ANSI Z21.10.3
Gas Instantaneous Water Heaters	>50,000 Btu/h and <200,000 Btu/h	≥4000 (Btu/h)/gal and <2 gal	0.62-0.0019V EF	DOE 10CFR Part 430
	≥200,000 Btu/h[c]	≥4000 (Btu/h)/gal and <10 gal	80%E_t	ANSI Z21.10.3
	≥200,000 Btu/h	≥4000 (Btu/h)/gal and ≥10 gal	80% E_t (Q/800 + 110 $\sqrt{V}$) SL, Btu/h	
Oil Storage Water Heaters	≤105,000 Btu/h	≥20 gal	0.59-0.0019V EF	DOE 10 CFR Part 430
	>105,000 Btu/h	≥4000 (Btu/h)/gal	78% E_t (Q/800 + 110 $\sqrt{V}$) SL, Btu/h	ANSI Z21.10.3
Oil Instantaneous Water Heaters	≤21 0,000 Btu/h	≥4000 (Btu/h)/gal and <2 gal	0.59-0.00 19V EF	DOE 10CFR Part 430
	>210,000 Btu/h	≥4000 (Btu/h)/gal and <10 gal	80%E_t	ANSI Z21.10.3
	>210,000 Btu/h	≥4000 (Btu/h)/gal and ≥ 10 gal	78% E_t (Q/800 + 110 $\sqrt{V}$) SL, Btu/h	
Hot Water Supply Boilers, Gas and Oil	≥300,000 Btu/h and <12,500,000 Btu/h	≥4000 (Btu/h)/gal and <10 gal	80%E_t	ANSI Z21.10.3
Hot Water		≥4000	80% E_t (Q/800 + 110	

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required[a]	Test Procedure [b]
Supply Boilers, Gas		(Btu/h)/gal and ≥ 1O gal	$\sqrt{V}$) SL, Btu/h	
Hot Water Supply Boilers, Oil		≥4000 (Btu/h)/gal and ≥10 gal	78% E_t (Q/800 + 110 $\sqrt{V}$) SL, Btu/h	
Pool Heaters Oil and Gas	All		78%E_t	ASHRAE 146
Heat Pump Pool Heaters	All		4.0 COP	ASHRAE 146
Unfired Storage Tanks	All		R-12.5	(none)

[a] Energy factor (EF) and thermal efficiency (El) are minimum requirements, while standby loss (SL) is maximum Btu/h based on a 70°F temperature difference between stored water and ambient requirements. In the EF equation, V is the rated volume in gallons. In the SL equation, V is the rated volume in gallons and Q is the nameplate input rate in Btu/h.

[b] ASHRAE 90.1-2004 contains a complete specification, including the year version, of the referenced test procedure.

[c] Instantaneous water heaters with input rates below 200,000 Btu/h must comply with these requirements if the water heater is designed to heat water to temperatures 180°F or higher.

6.2.3 Swimming Pools

6.2.3.1 Pool Covers

Heated pools shall be provided with a vapor retardant pool cover on or at the water surface. Pools are heated to more than 90°F (32°C) shall have a pool cover with a minimum insulation value of R-12 (R-2.1).

Exception to 6.2.3.1

Pools deriving over 60% of their energy from site-recovered energy or solar energy source are exempt.

6.2.3.2 Pool Heaters

Pool heaters shall be equipped with a readily accessible on-off switch to allow shutting off the heater without adjusting the thermostat setting. Pool heaters fired by natural gas shall not have continuously burning lights.

6.3 Volunteer Adoption

Buildings with a centralized system may have heat recovery units. The use of solar/ renewable energy for water heating is also recommended for adoption by the buildings with centralized and non-centralized systems.

Residential facilities of 420 m^2 (4300 sq.ft) or greater plot area, commercial buildings, hotels and hospitals with centralized system may have solar/ renewable energy for water heating at least one fifth of the design capacity.

6.4 Code Updating

Existing specifications referred in the tables 6.2.1 and 6.2.2 will be continually updated as the source code (referred in “Source Document”) will be revised as per formal/official procedure.

6.5 Code Implementation

Labs will be established by the relevant organization as decided by the “Competent Authority” to conduct various “tests” as per adopted code and mentioned in the tables 6.2.1 and 6.2.2. Moreover, the needed human resources for such labs to conduct the “tests” properly will be trained and get certified as prescribed by the adopted code.

6.6 Data collection

Data will be collected from various relevant locations to monitor the “energy conservation”. Such data can be converted to the “Information” to be used by the “competent forum” for the code review/update as per “actual results”.

6.7 Compliance Documentation

The authority having jurisdiction would develop the required documents for implementation.

Section-7

7. Lighting

7.1 General

The Lighting chapter of the Energy Conservation Building Code of Pakistan (Energy Provisions-2023) is an important section of the code that provides guidelines for designing and installing lighting systems in buildings that are energy-efficient and environmentally sustainable. The chapter outlines the minimum requirements for lighting efficiency, controls, and design that are necessary to reduce energy consumption and greenhouse gas emissions associated with lighting. The Energy Provisions-2023 Lighting chapter is based on the latest international standards and best practices in lighting design and technology, and is intended to help building owners, designers, and contractors in Pakistan to improve the energy efficiency of their buildings. By following the guidelines set out in the Lighting chapter of the Energy Provisions-2023, building owners can reduce their energy costs and contribute to a more sustainable future for Pakistan.

7.1.1 Scope

Lighting systems and equipment shall comply with the mandatory provisions of this section. The lighting requirements in this section shall apply to:

a. Interior spaces of buildings
b. Exterior lighting that is powered through the building's electrical service

Exceptions to 7.1.1

(a) Emergency lighting that is automatically off during normal building operation and is powered by battery, generator, or other alternate power source; and,
(b) Self-sustained Lighting i.e. not connected to grid.
(c) Lighting, including exit signs, that is specially designated as required by a health or life safety stature or ordinance.

7.1.2 Lighting Alterations

Any alteration to lighting system in an interior space shall comply with the Lighting Power Allowance (LPA) and the control requirements of relevant sections of this code.

Any alteration to lighting system in an exterior of a building shall comply with the Lighting Power Allowance (LPA) and the control requirements of relevant sections of this code.

Exceptions to 7.1.2

a. Alterations 20% or less of the connected lighting load does not require the compliance with the requirements of 7.1.2 if the alterations do not increase the installed lighting power

b. Alterations in which only lamp plus driver are replaced or light-for-light replacement are only required to comply with LPD requirement of this code.

7.1.3 Installed Lighting Power

The cumulative wattage of all type of lighting installed including lamps, ballasts/driver, transformer and control devices other than those exempted in section 7.1.1.

7.1.4 Luminaire Wattage

The wattage of lighting equipment shall be ascertained based on the following guidelines

i. The wattage of connected lighting equipment shall be manufacturer's labeled maximum wattage.

ii. The wattage of lighting equipment with remote ballast/ driver or similar devices shall be the total input wattage of all components in the system.

iii. The wattage of lighting track and plug-in busway which allows the addition of lighting equipment in the future without any change in the wiring system shall be the lesser of

a. Specified wattage of lighting equipment

b. The wattage limit of permanent current-limiting devices of the system

iv. The wattage of retrofitted luminaire shall be the manufacturer's labeled input power of the new light source plus driver

v. The wattage of all other miscellaneous lighting equipment shall be the specified wattage of the lighting equipment

7.2 Compliance Path

Lighting systems and equipment shall comply with the following section

7.2.1 Requirements for all compliance paths

Lighting systems and equipment shall comply with section 7.1 'General', and section 7.7 'Verification, Testing and commissioning' and one of the following

a. Section 7.3 'Simplified Building Method Compliance Path'

b. Section 7.4 'Mandatory Provisions' and Section 7.5 'Building Area Method Compliance Path'

c. Section 7.4 'Mandatory Provisions' and Section 7.6 'Space-by-Space Method Compliance Path'

7.2.2 Prescriptive Requirements

7.2.2.1 Interior Lighting Power Allowance

Interior Lighting Power Allowance for a building shall be ascertained by one of the following methods;

a. Simplified building Method
b. Building Area Method
c. Space by space Method

Adjustment of LPA between different parts of the building with different calculation criteria of compliance is not permitted.

7.2.2.2 Exterior Lighting Power Allowance

Exterior Lighting power Allowance shall be determined by

a. Simplified Building Method of calculation
b. Exterior Lighting Power

7.3 Simplified Building Method Compliance Path

The simplified building method contains the requirements for interior lighting in sections 7.3.1 and exterior lighting in section 7.3.2. This method shall be applied to the buildings with at least 80% of the floor area contains office buildings, retail buildings or school buildings.

7.3.1 Simplified Building Method of Calculating Interior Lighting

7.3.1.1 Power Allowance

The new buildings as well as alterations in the existing buildings shall comply with the lighting power allowance and control requirements of Tables 7.3.1-1, 7.3.1-2 and 7.3.1-3

7.3.2 Simplified Building Method of Calculating Exterior Lighting

7.3.2.1 Power Allowance

The exterior areas of the building's types mentioned in Section 7.3 shall comply with the lighting power allowance and control requirements of Tables 7.1, 7.2 and 7.3.

Table 7.1. Simplified Building Method for Office Buildings

Interior Space Type	Interior Lighting Power Allowance	Controls [a]
All spaces in office buildings other than parking	0.70 W/ft^2	All lighting shall be automatically controlled to turn off when the building is either unoccupied or

garages, stairwells, and corridors		scheduled to be unoccupied. **(Exception:** Lighting load not exceeding 0.02 W/ft^2 multiplied by the gross lighted area of the building shall be permitted to operate at all times.) Each space shall have a manual control device that allows the occupant to reduce lighting power by a minimum of 50% and to turn the lighting off.
Office spaces less than or equal to 250 ft^2, classrooms, conference rooms, meeting rooms, training rooms, storage rooms and break rooms	0.70 W/ft^2	These spaces shall also be controlled by auto-ON occupant sensors.
Office spaces greater than 250 ft^2 and restrooms	0.70 W/ft^2	These spaces shall also be controlled by occupant sensors.
Stairwells and corridors in office buildings and parking garages	0.70 W/ft^2	These spaces shall also be controlled by occupant sensors that reduce the lighting power by a minimum of 50% when no activity is detected for not longer than 20 minutes and be controlled to turn off when the building is either unoccupied or scheduled to be unoccupied.
Parking garages	0.13 W/ft^2	All lighting shall be automatically controlled to turn off during garage nonoperating hours. Lighting shall also be controlled by occupant sensors. Controls shall reduce the power by a minimum of 50% when no activity is detected for not longer than 20 minutes. No device shall control more than 3600 ft^2.

a. All lights in the space shall be controlled.

Table 7.2. Simplified Building Method for Retails Buildings

Interior Space Type	Interior Lighting Power Allowance	Controls [a]
All spaces in retail buildings other than parking	1.00 W/ft^2	All lighting shall be automatically controlled to turn off when the building is either unoccupied or scheduled to be unoccupied. **(Exception:** Lighting

garages, stairwells, and corridors		load not exceeding 0.02 W/ft^2 multiplied by the gross lighted area of the building shall be permitted to operate at all times.) Each space shall have a manual control device that allows the occupant to reduce lighting power by a minimum of 50% and to turn the lighting off.
Sales area	1.00 W/ft^2	These spaces shall also be controlled • to reduce the general lighting power by a minimum of 75% during nonbusiness hours, • to turn off all lighting other than general lighting during nonbusiness hours, and • by continuous daylight dimming controls [b] in spaces with top lighting.
Stock rooms, dressing/fitting rooms, locker rooms, and restrooms	1.00 W/ft^2	These spaces shall also be controlled by; auto-ON or manual-ON occupant sensors, and continuous daylight dimming controls [b] in spaces with top lighting
Office spaces, conference rooms, meeting rooms, training rooms, storage rooms, break rooms, and utility spaces	1.00 W/ft^2	These spaces shall also be controlled by; Manual-ON occupant sensors, and continuous daylight dimming controls [b] in spaces with top lighting.
Stairwells and corridors in retail buildings and parking garages	1.00 W/ft^2	These spaces shall also be controlled by occupant sensors that reduce the lighting power by a minimum of 50% when no activity is detected for not longer than 20 minutes and be controlled to turn off when the building is either unoccupied or scheduled to be unoccupied.
Parking garages	0.13 W/ft^2	All lighting shall be automatically controlled to turn off during garage nonoperating hours. Lighting shall also be controlled by occupant sensors. Controls shall reduce the power by a minimum of 50% when no activity is detected for not longer than 20 minutes. No device shall control more than 3600 ft^2.

a. All lights in the space shall be controlled.

b. when the combined input power of the general lights completely or partially within the daylight areas is 150W or greater.

Table 7.3. Simplified Building Method for School Buildings

Interior Space Type	Interior Lighting Power Allowance	Controls [a]
All spaces in school buildings other than parking garages, stairwells, and corridors	0.70 W/ft^2	All lighting shall be automatically controlled to turn off when the building is either unoccupied or scheduled to be unoccupied. **(Exception:** Lighting load not exceeding 0.02 W/ft^2 multiplied by the gross lighted area of the building shall be permitted to operate at all times.) Each space shall have a manual control device that allows the occupant to reduce lighting power by a minimum of 50% and to turn the lighting off.
Classrooms, office spaces, conference rooms, meeting rooms, library, storage rooms and break rooms	0.70 W/ft^2	These spaces shall also be controlled by auto-ON occupant sensors.
Gymnasiums and cafeterias	0.70 W/ft^2	These spaces shall also be controlled by occupant sensors.
Restrooms	0.70 W/ft^2	These spaces shall also be controlled by occupant sensors.
Stairwells and corridors in retail buildings and parking garages	0.70 W/ft^2	These spaces shall also be controlled by occupant sensors that reduce the lighting power by a minimum of 50% when no activity is detected for not longer than 20 minutes and be controlled to turn off when the building is either unoccupied or scheduled to be unoccupied.
Parking garages	0.13 W/ft^2	All lighting shall be automatically controlled to turn off during garage nonoperating hours. Lighting shall also be controlled by occupant sensors. Controls shall reduce the power by a minimum of 50% when no activity is detected for not longer than 20 minutes. No device shall control more than 3600 ft^2.

a. All lights in the space shall be controlled.

Table 7.4. Simplified Building Method for Building Exterior

Interior Space Type	Interior Lighting Power Allowance	Controls [a]
Base allowance	200 W	Luminaires shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Facade lighting and special feature areas,	0.10 W/ft^2	Luminaires shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Landscape	0.04 W/ft^2	Luminaires shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Entry doors	14 W/linear foot	Luminaires shall be turned off or the power reduced by a minimum of 75% during nonoperating hours.
Stairs and ramps	0.70 W/ft^2	No additional controls required.
Parking lots and drives	0.05 W/ft^2	Luminaires mounted 25 ft or less above grade shall be controlled to reduce the power by at least 50% when no activity is detected for not longer than 15 minutes.
All other areas not listed	0.20 W/ft^2	Luminaires shall be turned off or the power reduced by a minimum of 75% during nonoperating hours

a. All exterior lighting shall be automatically controlled by either a photocell or an astronomical time switch to shut off the lights when daylight is available.

7.4 Mandatory Provisions

7.4.1 Lighting Control

Building lighting controls shall be installed to meet the provisions of Sections 7.4.1.1, 7.4.1.2, 7.4.1.3 and 7.4.1.4

7.4.1.1 Interior Lighting Controls

For each space in the building, the lighting control functions as tabulated in Table 7.6.1 and mentioned here shall be implemented. The control functions specified as ‘REQ’ are mandatory and shall be implemented.

When using the Space-by-Space method, the space type used for determining control requirements shall be the same space type that is used for determining the LPD allowance.

a. Local Control: There shall be one or more manual lighting control in the space that controls all the lighting in the space. Each control device shall control an area (i) maximum of 2500 ft^2 if space is less than or equal to 10,000 ft^2

b. Automatic Daylight Responsive Control: In any space where the combined input power of all *general* lighting is 150W or greater, the general lighting shall be controlled by photocontrols.

c. The control system shall have the following features

- The calibration adjustment control shall be located no higher than 10 ft above the furnished floor.
- The photocontrol shall reduce the electric lighting power in response to available daylight using continuous diming to 20% or less or even turn off the light in case of abundant daylight.

d. Automatic Full OFF: All lighting, including lighting connected to emergency circuits, shall be automatically shut off after 20 minutes of all occupants leaving the space. A control device meeting this requirement shall control the maximum space of 5000 ft^2.

e. Scheduled shutoff: All lighting in the space, including lighting connected to emergency circuits, shall be automatically shut off during periods when the space is scheduled to be unoccupied using either a time of day operated control device. The control device or system shall provide independent control sequences that (i) control the lighting for an area of maximum 25,000 ft^2 (ii) include only one floor and (iii) shall be programmed to account for weekends and holidays.

Exceptions to 7.4.1.1(d): the following lighting is not required to be on schedule shut off:

i. Lighting in spaces where lighting is required for 24/7 continuous operation

ii. Lighting in spaces where patient care is rendered.

iii. Lighting in spaces where automatic shutoff would endanger the safety or security of the occupants.

iv. Lighting load not exceeding 0.02 w/ft^2 multiplied by the gross lighted area of the building.

7.4.1.2 Parking Garage Lighting Control

Lighting for parking garages shall comply with the following requirements:

a. Parking garage lighting shall have automatic lighting shutoff as per section 7.4.1.1(d)

b. Lighting power of each luminaire shall be automatically reduced by a minimum of 50% where there is no activity detected within a lighting zone for 10 minutes. Lighting zone shall not be more than 3600 ft^2

7.4.1.3 Special Applications

Lighting controls specified in this section are only for equipment and applications mentioned in this section.

1. Lighting used for following applications shall be equipped with a local control independent of the control of general lighting. In addition, such lighting shall be controlled in accordance with the section 7.4.1.1(c) and section 7.4.1.1(d)
    a. Display or accent lighting
    b. Lighting in display cases
2. Guestrooms
    a. All lighting and all switched receptacles in guestrooms and suites in hotels, motels, boarding houses or similar buildings shall be automatically controlled such that power to the lighting and switched receptacles in each enclosed space will be turned off within 10 minutes

after all occupants leave that space.

Exception to 7.4.1.3(2): Enclosed spaces where the lighting and switched receptacles are controlled by card key controls and bathrooms are exempted.

b. Bathrooms shall have separate control device that shall turn off the lighting within 05 minutes after all occupants have left the bathroom

3. Supplemental Task Lighting, including permanently installed undershelf or undercabinet lighting shall be controlled from
    a. A control device integral to the luminaire
    b. A local control independent of the control of general lighting
4. In addition, such lighting shall be controlled in accordance with Section 7.4.1.1(c) and section 7.4.1.1(d).

7.4.1.4 Exterior Lighting Control

Lighting for exterior not exempted in Section 7.1 shall meet the following requirements

a) Lighting shall be controlled by a device that automatically turns off the lights when sufficient daylight is available
b) All building façade and landscape lighting shall be automatically shut off at midnight or business closing, whichever is later.
c) Luminaires serving outdoor parking areas and access roads mounted in the poles shall be controlled to automatically reduce the power of each luminaire to 30% when no activity is detected for 15 minutes.

All time switches shall be capable of retaining programming and the time setting during loss of power for a period of at least 10 hours.

7.4.2 Exterior Building Lighting Power

The total exterior lighting power allowance for all exterior building applications is the sum of the base site allowance

For building exterior lighting applications specified in Table 7.4, the connected lighting power shall not exceed the specified lighting power limits specified for each of these applications.

Table 7.5. Exterior Building Lighting Power

Area Description	Lighting Power Allowance
Parking area and driveways	0.08 W/ft^2
Entry Canopies	0.20 W/ft^2
Landscaping	0.04 W/ft^2
Pedestrian and vehicular entrances and exits	21 W/lin ft of opening
Walkways less than 10 ft wide or greater	0.7 W/linear foot
Automated Teller Machines and night depositories	135 W per location plus 45 W per additional ATM per location
Drive-through windows/ doors	200 W per drive-through

For areas not listed in this table or are not comparable to areas listed in this table, use the comparable interior space type from table 7.5.

Exceptions to 7.4.2:

Lighting used for the following exterior applications is exempted when equipped with an independent control device:

a) Specialized signal, directional, and marker lighting associated with transportation;

b) Lighting used to highlight features of public monuments and registered historic landmark structures or buildings;

c) Lighting that is integral to advertising signage; or

d) Lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation.

e) Temporary lighting.

f) Lighting for industrial production, material handling, and transportation sites, and associated storage areas.

g) Lighting for athletic playing areas.

h) Lighting integral to equipment or instrumentation and installed by its manufacturer.

7.4.3 Dwelling Units

Not less than 75% of permanently installed lighting fixtures shall use lamps with an efficacy of at least 75 lm/W. No other provisions of Section 7 apply to dwelling units.

7.5 Building Area Method Compliance Path

Following method is to be used to determine the interior lighting power allowance by Building Area Method:

a. Determine the appropriate building area type from table 7.5.1 and the corresponding LPD allowance. If the required building area type is not listed in the table, an equivalent area type may be selected.

b. Determine the gross lighted floor area in ft^2 of the building area type

c. Multiply the gross area determined in the last step by LPD

d. The interior lighting power allowance for the building is the sum of the lighting power allowances of all building area types. Trade-offs among building area types are permitted, provided that the total installed interior lighting power does not exceed the interior lighting power allowance.

Table 7.6. Interior Lighting Power Densities Building Area Method

Sr. No	Common Space Type	LPD (W /ft^2)
1	Automotive Facility	0.75
2	Convention Center	0.64
3	Court House	0.79
4	Dining: Bar Lounge/Leisure	0.8
5	Dining: Cafeteria/Fast Food	0.76
6	Dining: Family	0.71
7	Dormitory	0.53
8	Exercise Center	0.72
9	Gymnasium	0.76
10	Healthcare-Clinic	0.81
11	Hospital	0.96
12	Hotel	0.56
13	Library	0.83
14	Manufacturing Facility	0.82
15	Motel	0.56
16	Motion Picture Theater	0.44
17	Multifamily	0.45
18	Museum	0.55
19	Office	0.64

20	Parking Garage	0.18
21	Penitentiary	0.69
22	Performing Arts Theater	0.84
23	Police/Fire Station	0.66
24	Post Office	0.65
25	Religious Building	0.67
26	Retail	0.84
27	School/University	0.72
28	Sports Arena	0.72
29	Town Hall	0.69
30	Transportation	0.5
31	Warehouse	0.45
32	Workshop	0.91

7.6 Space-by-Space Method

Use the following steps to determine the interior lighting power allowance by the Space-by-Space Method:

a. For each space enclosed by partitions that are 80% of the ceiling height or taller, determine the appropriate space type and the corresponding LPD allowance from Table 7.6.1. If a space has more than one functions, where more than one space type is applicable, that space shall be broken up into smaller subspaces, each using its own space type from table 7.6.1. If a subspace is smaller than 20% of the original space and less than 500 ft^2, this space may not be broken out separately. Floor areas of balconies and other projections are to be included in the calculation.

b. In calculating the area of each space and subspace, the limits of the area defined by the centerline of interior walls, the dividing line between the subspaces and the outside surface of exterior walls.

c. Based on the space type selected for each space or subspace, determine the lighting power allowance of each space or subspace by multiplying the calculated area of the space or subspace by the appropriate LPD allowance determined in section 7.6(a)

d. The interior lighting power allowance is the sum of lighting power allowances of all spaces and subspaces. Trade-offs among spaces and subspaces are permitted, provided that the total installed interior lighting power does not exceed the interior lighting power allowance.

Table 7.7. Lighting Power Density Allowances using Space-by-Space Method and Control Method using any method

Common Space Type	LPD Allowance (W/ft^2)	Local Control	Automatic Daylight Control	Automatic Full OFF	Schedule Shut-off
Atrium					
< 20ft in height	0.39	REQ	-	REQ	REQ
≥ 20ft in height and ≤ 40 ft in height	0.48	REQ	-	REQ	REQ
≥ 40 ft in height	0.60	REQ	REQ	REQ	REQ
Audience Seating Area					
Auditorium	0.61	REQ	REQ	REQ	-
Gymnasium	0.23	REQ	REQ	REQ	REQ
Motion Picture Theater	0.27	REQ	-	REQ	-
Penitentiary	0.67	REQ	-	REQ	-
Performing Arts Theater	1.16	REQ	-	REQ	-
Religious Buildings	0.72	REQ	REQ	REQ	REQ
Sports Arena	0.33	REQ	REQ	REQ	-
All other Audience seating areas	0.23	REQ	REQ	REQ	-
Banking Activity Area	0.61	REQ	REQ	REQ	REQ
Classrooms/ lecture theatre halls/ training rooms	0.71	REQ	REQ	REQ	-
Conference/Meeting/Multipurpose	0.97	REQ	REQ	REQ	-
Confinement Cells	0.70	REQ	-	REQ	-
Copy/ Print Room	0.31	REQ	REQ	REQ	-

Corridors					
Facility for visually impaired (not used primarily by the staff)	0.71	REQ	-	REQ	-
Hospital	0.71	REQ	-	REQ	-
All other corridors	0.41	REQ	-	REQ	-
Courtrooms	1.20	REQ	REQ	REQ	REQ
Computer Room	0.94	REQ	REQ	-	REQ
Dining Areas					
Facility for visually impaired (not used primarily by the staff)	1.27	REQ	REQ	-	REQ
Bar Lounge/Leisure	0.86	REQ	REQ	-	REQ
Cafeteria/Fast Food	0.40	REQ	REQ	-	REQ
Family	0.60	REQ	REQ	-	REQ
All other Dining Areas	0.43	REQ	REQ	-	REQ
Electrical / Mechanical Room	0.43	REQ	REQ	-	REQ
Emergency Vehicle Garagre	0.52	REQ	-	-	REQ
Food Preparation Area	1.09	REQ	-	REQ	REQ
Guest Room	0.41	REQ	-	-	REQ
Laboratory					
In a classroom	1.11	REQ	REQ	-	-
All other laboratories	1.33	REQ	REQ	-	-
Laundry/ Washing Area	0.53	REQ	-	-	-
Loading Dock, interior	0.88	REQ	-	-	-
Lobby					
Facility for visually impaired (not used primarily by the staff)	1.69	REQ	-	-	-
Elevator	0.65	REQ	-	REQ	-
Hotel	0.51	REQ	-	REQ	-
Motion Picture Theatre	0.23	REQ	-	-	-
Performing Arts Theater	1.25	REQ	-	-	-
All other Lobbies	0.84	REQ	-	REQ	-
Locker Room	0.52	REQ	-	-	-
Lounge/ Breakroom					
Healthcare Facility	0.42	REQ	REQ	REQ	-
All other lounges/ breakrooms	0.59	REQ	REQ	REQ	-
Office					
Enclosed and ≤ 250 ft^2	0.74	REQ	-	REQ	-
Enclosed and > 250 ft^2	0.66	REQ	REQ	-	-
Open Plan	0.61	REQ	REQ	-	-
Parking Area, Interior	0.15	REQ	-	REQ	-
Pharmacy Area	1.66	REQ	-	-	-
Restroom					
Facility for visually impaired (not	1.26	REQ	-	-	-

used primarily by the staff)					
All other restrooms	0.63	REQ	-	-	-
Sales Area	1.05	REQ	-	-	REQ
Seating Area, General	0.23	REQ	REQ	-	-
Storage Room					
< 50 ft^2	0.51	REQ	-	-	REQ
≥ 50 ft^2	0.38	REQ	-	-	REQ
Vehicular Maintenance Area	0.6	REQ	-	-	REQ
Workshop	1.26	REQ	-	-	REQ
Convention Center – Exhibit Space	0.61	REQ	-	-	REQ
Gymnasium/ Fitness Center					
Exercise Area	0.90	REQ	-	-	REQ
Playing Area	0.85	REQ	-	-	REQ
Healthcare Facility					
Exam/ treatment room	1.40	REQ	-	-	-
Imaging Room	0.94	REQ	-	-	-
Medical Supply room	0.62	REQ	-	-	-
Nursery	0.92	REQ	-	-	-
Nurse's station	1.17	REQ	-	-	-
Operating room	2.26	REQ	-	-	-
Patient Room	0.68	REQ	-	-	-
Physical therapy room	0.91	REQ	-	-	-
Recovery room	1.25	REQ	-	-	-
		REQ	REQ	-	-
Library					
Reading Area	0.96	REQ	REQ	-	-
Stacks	1.18	REQ	REQ	-	-
Manufacturing Facility					
Detailed Manufacturing area	0.80	REQ	-	-	REQ
Equipment room	0.76	REQ	-	-	REQ
Extra high bay area (>50 ft floor-to ceiling height)	1.42	REQ	-	-	REQ
High bay area (25 to 50 ft floor-to0ceiling height)	1.24	REQ	-	-	REQ
Low bay area (<50 ft floor-to ceiling height)	0.86	REQ	-	-	REQ
Post Office – Sorting Area	0.76	REQ	-	-	REQ
Retail Facilities					
Dressing/fitting room	0.51	REQ	-	REQ	-
Mall concourse	0.82	REQ	-	-	REQ
Transportation Facility					
Baggage/carousel area	0.39	REQ	REQ	-	REQ
Airport concourse	0.25	REQ	REQ	-	REQ
Ticket counter	0.51	REQ	REQ	-	REQ

7.7 Verification, Testing and Commissioning

7.7.1 Verification and Testing

Lighting control devices and systems shall be tested according to the guidelines formulated in Section 7.7.1 to verify that control devices are calibrated, adjusted, programmed and in working condition in accordance with manufacturer's recommendations. The following procedures shall be performed for the type of controls.

7.7.1.1 Occupancy Sensors

a) Certify that the Sensor has been located and aimed in accordance with manufacturer's recommendation.
b) For Projects with up to Seven (07) Occupancy Sensors, all sensors shall be tested.
c) For Projects with more than Seven (07) occupancy sensors, testing shall be performed for each unique combination of sensor type used and space geometry

i. For each sensor to be tested, verify the following:

a) Status indicator operates correctly.
b) Controlled lights turn OFF or down to the permitted level within the required time.
c) For auto-ON occupancy sensor, the lights turn ON when someone enters the space.
d) For manual-ON sensors the lights turn ON when manually activated.
e) The lights are not incorrectly turned ON by movement in nearby areas.

7.7.1.2 Automatic Time Switches

The programming of Automatic Time Switches for weekday, weekend and off-day has to be verified.

1. Document for the owner automatic time-switch programing, including weekday, weekend, and holiday schedule.
2. Setting of time and date has to be set properly in the time switch.
3. In case of Battery backup, it has to be properly installed and energized.
4. Schedule for different time settings round the year has been maintained.
5. Simulate occupied conditions verify and document the following:
    a) All lights can be turned ON and OFF by their respective switches.
    b) The switch only operate lighting in the enclosed space in which the switch is located.
    c) Simulate unoccupied conditions. Verify and document the following:
    d) All nonexempt lights turn off
    e) Manual override switch allows only the lights in the enclosed space where the override switch is located to turn on or remain on until the next scheduled shut off occurs.

7.7.1.3 Daylight Controls

1. All control devices (photocontrols) have been properly located and field-calibrated, to set points and threshold light levels.
2. Daylight controlled lights adjust in response to available daylight
3. The locations where calibration adjustments are made is readily accessible to authorized personnel.

7.8 Compliance Documentation

The authority having jurisdiction would develop the required documents for implementation.

SECTION – 8

8. Electrical Power

8.1 General

Designing an electrical power system for a building requires careful consideration of various factors, such as the electrical load requirements, the available power sources, and the safety and regulatory requirements. Here are some general guidelines for designing an electrical power system for a building:

Determine the electrical load requirements: This involves identifying the electrical loads that will be connected to the power system, such as lighting, heating, air conditioning, and appliances. The electrical load requirements will help to determine the size and capacity of the electrical power system.

Select the appropriate power sources: The power sources for the electrical power system can include the utility grid, backup generators, solar panels, and wind turbines. The selection of the power sources will depend on various factors, such as the location of the building, the availability of power sources, and the cost.

Determine the required electrical distribution system: The electrical distribution system will depend on the size and complexity of the building. For small buildings, a simple radial distribution system may be sufficient, while larger buildings may require a more complex distribution system, such as a ring or grid system.

Size and select the electrical equipment: This involves sizing and selecting the electrical equipment, such as transformers, switchgear, circuit breakers, and cables, based on the electrical load requirements and the electrical distribution system.

Ensure compliance with safety and regulatory requirements: The electrical power system design must comply with the International Electrotechnical Commission (IEC) or any other adopted standards. This includes ensuring proper grounding, protection against electrical shock, and protection against overcurrent and short circuits.

Energy efficiency: Energy efficiency should be considered in the design of the electrical power system. This can include the use of energy-efficient lighting and appliances, the optimization of the electrical load requirements, and the incorporation of renewable energy sources.

These are some general guidelines for designing an electrical power system for a building. It's important to work with a qualified electrical engineer or technician to ensure that the design meets the specific requirements of the building and complies with all safety and regulatory requirements.

8.2 Necessary Requirements

8.2.1 Cable Size

Cable sizing is a critical aspect of electrical design for buildings, and it is essential to adhere to standard requirements to ensure compliance with electrical energy building codes. The following points outline the standard requirements for cable sizing in the context of electrical energy building codes.

a. The cable must be sized to carry the expected current without exceeding its maximum allowable temperature. This involves considering various factors, including the expected load, ambient temperature, cable installation conditions, and other factors that may affect the cable's performance. For different type of insulation material, the maximum admissible temperature is given in Fig.

Table 8.1. Maximum operating temperatures for types of insulation (table 52.1 of IEC 60364-5-52)

Type of insulation	Temperature limit °C
Polyvinyl-chloride (PVC)	70 at the conductor

Cross-linked polyethylene (XLPE) and ethylene propylene rubber (EPR)	90 at the conductor
Mineral (PVC covered or bare exposed to touch)	70 at the sheath
Mineral (bare not exposed to touch and not in contact with combustible material)	105 at the sheath

b. The cable should be sized to minimize voltage drop. IEC 60364-5-52 in Annex G states that the voltage drop between the origin of an installation and any load point should not be greater than the values in Table expressed with respect to the value of the nominal voltage of the installation.

Table 8.2. Voltage Drop Limits

Type of installation	Lighting %	Other uses %
A – Low voltage installations supplied directly from a public low voltage distribution system	3	5
B – Low voltage installation supplied from private LV supply [a]	6	8
[a] As far as possible, it is recommended that voltage drop within the final circuits do not exceed those indicated in installation type A. When the main wiring systems of the installations are longer than 100 m, these voltage drops may be increased by 0,005 % per metre of wiring system beyond 100 m, without this supplement being greater than 0,5 %. Voltage drop is determined from the demand by the current-using equipment, applying diversity factors where applicable, or from the values of the design current of the circuits.		

c. The cable should be able to withstand the short circuit current without sustaining damage. This requires consideration of the expected fault current, cable type, insulation, and other factors that may impact the cable's performance in case of a fault. All DISCOS must be bound to define and provide the short circuit MVA rating to the design engineer via some online portal or through an app without any cost.

d. The cable should be able to withstand thermal stresses without exceeding its maximum allowable temperature. This requires consideration of the expected operating conditions, cable type, insulation, and other factors that may impact the cable's performance.

e. The cable should be installed in accordance with applicable electrical energy building codes and standards. This includes requirements for cable routing, support, protection, and termination. In selecting cable sizes for buildings, it is essential to consider de-rating factors that can affect the cables' performance. De-rating factors are factors used to adjust the current-carrying capacity of a cable based on various environmental and installation conditions. These factors are necessary because the current carrying capacity of a cable is dependent on several factors, including its size, insulation type, ambient temperature, and installation conditions. Failure to consider these factors can lead to issues such as overheating of cables, voltage drop, and possible electrical hazards.

The International Electrotechnical Commission (IEC) provides a set of standards and guidelines for cable sizing for building installations. Usually, IEC 60364-5-52 is used for this purpose. This standard considers several de-rating factors to ensure safety and compliance. Some of the de-rating factors commonly used in cable sizing for building installations are ambient temperature, soil thermal resistivity, depth of burial, grouping factor, cable laying method, harmonic current and others. The relevant factors can be found from the standards or cable book.

The current-carrying capacity of three-phase, 4-core or 5-core cables is based on the assumption that only 3 conductors are fully loaded. However, when harmonic currents are circulating, the neutral current can be significant, and even higher than the phase currents. This is due to the fact that the 3rd harmonic currents of the three phases do not cancel each other, and sum up in the neutral conductor. This of course affects the current-carrying capacity of the cable, and a correction factor shall be applied. IEC 60364-5-52 standard defines the factors to cater the effect of harmonic current for cables. These factors can be seen in Figure 4.

Table 8.3. Reduction factors for harmonics currents in four core and five core cables

Third harmonic content of phase current %	Reduction factor	
	Size selection is based on phase current	Size selection is based on neutral current
0 – 15	1,0	–
15 – 33	0,86	–
33 – 45	–	0,86
> 45	–	1,0

8.2.2 Circuit Breaker Sizing

Circuit breakers are an essential component of any electrical system, whether it is a small house or a large building. The circuit breaker is responsible for protecting the electrical system by disconnecting the circuit when it detects an overload, short circuit, or ground fault. Selecting the right size of the circuit breaker is crucial to ensuring the safety and reliability of the electrical system. In this essay, we will discuss the factors to consider when selecting the size of the circuit breaker in a house or building.

a. The first factor to consider is the maximum current that the circuit can carry continuously without overheating. This current rating is determined by the size of the wire used in the circuit and the type of insulation. The circuit breaker's current rating should be equal to or greater than the maximum allowable current for the wire in the circuit as per IEC 60898 standard.
b. The second factor to consider is the type of load that the circuit will be powering. Different types of loads have different characteristics that can affect the circuit breaker's size. For example, motors and other inductive loads require a larger circuit breaker than resistive loads of the same current rating. This is because inductive loads create a surge of current when they start up, which can cause the circuit breaker to trip if it is not sized correctly.

c. The third factor to consider is the ambient temperature of the environment where the circuit breaker will be installed. High temperatures can cause the circuit breaker to trip prematurely, so the current rating of the circuit breaker should be derated for higher temperatures. The amount of derating depends on the type of circuit breaker and the temperature of the environment. As per IEC 60898-1, the ambient temperature for normal operation of circuit breakers is +40°C and the average over a period of 24h does not exceed +35°C.
d. The fourth factor to consider is the type of circuit breaker itself. Different types of circuit breakers have different trip characteristics that can affect their sizing. For example, a thermal-magnetic circuit breaker has a time delay before tripping, while a ground fault circuit interrupter (GFCI) trips much faster. The trip characteristics of the circuit breaker must be considered when selecting its size. IEC 60898-1 standard gives the table for I^2t characteristics of different types of circuit breakers which can be seen in Table 8.4. The proper characteristic of circuit breaker is vary from application to application and as it is depend upon the ampacity of considered network or system.

Table 8.4. Tripping current ranges of overload and short-circuit protective devices for LV circuit breakers

	Type of protective relay	Overload protection	Short-circuit protection		
Domestic breakers IEC 60898	Thermal-magnetic	Ir = In	Low setting type B 3 In ≤ Im ≤ 5 In	Standard setting type C 5 In ≤ Im ≤ 10 In	High setting circuit type D 10 In ≤ Im ≤ 20 In(1)
Modular industrial(2) circuit-breakers	Thermal-magnetic	Ir = In fixed	Low setting type B or Z 3.2 In ≤ fixed ≤ 4.8 In	Standard setting type C 7 In ≤ fixed ≤ 10 In	High setting type D or K 10 In ≤ fixed ≤ 14 In
Industrial(2) circuit-breakers IEC 60947-2	Thermal-magnetic	Ir = In fixed	Fixed: Im = 7 to 10 In		
		Adjustable: 0.7 In ≤ Ir ≤ In	Adjustable: - Low setting : 2 to 5 In - Standard setting: 5 to 10 In		
	Electronic	Long delay 0.4 In ≤ Ir ≤ In	Short-delay, adjustable 1.5 Ir ≤ Im ≤ 10 Ir Instantaneous (I) fixed I = 12 to 15 In		

Finally, it is essential to consider the safety of the electrical system when selecting the size of the circuit breaker. A circuit breaker that is too small can fail to trip when an overload occurs, leading to overheating and potentially a fire. On the other hand, a circuit breaker that is too large can be expensive and lead to nuisance tripping. Normally for circuit breaker sizing, IEC 60898-1 is used.

8.2.2.1 Coordination between circuit breakers

This is achieved through careful selection of the circuit breaker ratings, settings, and trip curves. The goal of coordination is to ensure that the circuit breaker closest to the fault (known as the downstream breaker) trips first, while the upstream breaker remains in operation to provide backup protection. This helps to isolate the fault and minimize damage to the electrical system. The coordination process typically involves the following steps:

a. Determine the maximum fault current that can occur in the electrical system.
b. Select the appropriate rating for each circuit breaker based on the maximum fault current.
c. Set the time-current curves for each circuit breaker to ensure that downstream breakers trip before upstream breakers in the event of a fault.
d. Test the coordination of the circuit breakers to ensure that they operate as expected under fault conditions.

Proper coordination between circuit breakers is essential for protecting electrical equipment and ensuring the safety of personnel working with the electrical system. It's important to consult with a qualified electrical engineer or technician to ensure that circuit breakers are coordinated properly in a given electrical system.

8.2.3 Residual Current Device (RCD)

RCD is a device designed to detect and interrupt any leakage current flowing to the earth, thereby providing protection against electrical shock hazards. When selecting the size of a RCD for a house or building, several factors should be considered, including:

Current rating: The current rating of an RCD should be selected based on the maximum current expected to flow through the circuit. This is determined by the size of the circuit, the number of appliances connected, and the electrical load in the building.

Sensitivity: The sensitivity of an RCD refers to the level of current leakage that the device is capable of detecting. The selection of the sensitivity rating of an RCD should be based on the degree of protection required for the particular application. In residential applications, a sensitivity of 30mA is often used, while commercial and industrial applications may require a higher sensitivity rating.

Voltage rating: The voltage rating of an RCD should be selected based on the voltage of the electrical system in the building. The RCD should be rated to operate at the same voltage as the electrical system it is installed in.

Type of circuit: The type of circuit that the RCD is being installed in will also affect the selection of the device. For example, circuits with high inrush currents, such as motor circuits, may require a different type of RCD than general lighting circuits.

Environmental factors: Environmental factors, such as temperature and humidity, should also be considered when selecting an RCD. The device should be able to operate in the expected environmental conditions without affecting its performance or reliability.

Selectivity criteria for RCDs: The selectivity criteria for RCDs (Residual Current Devices) depend on the type of installation and the level of protection required. Generally, the selectivity criteria require that the RCDs must operate in a sequential and coordinated manner in order to avoid unnecessary tripping and ensure the continuity of the electrical supply.

For example, in a low voltage distribution system, the selectivity criteria require that the RCD nearest to the fault must operate first, without tripping any of the downstream RCDs. If the nearest RCD fails to trip, then the next RCD downstream must operate and trip the circuit. The selectivity criteria for RCDs are specified in various international standards, such as IEC 60364-4-41 and IEC 61008-1.

It should be noted that selectivity criteria are dependent on the type of system and installation, and should be carefully determined by a qualified electrical engineer during the design stage of the electrical system.

Regulatory requirements: The selection of an RCD should also take into account any regulatory requirements or building codes that may apply.

8.2.4 Conserve Electricity

There are many things that can be done to conserve electricity energy in a building. Here are some examples:

a. Use energy-efficient lighting: Replace incandescent light bulbs with LED bulbs, which use less energy and last longer.
b. Install programmable thermostats: Programmable thermostats allow you to set the temperature of your building based on occupancy patterns, reducing energy usage when the building is unoccupied.
c. Upgrade HVAC systems: Upgrade your heating, ventilation, and air conditioning (HVAC) systems to more energy-efficient models, and have them regularly serviced to ensure they are operating at peak efficiency.

d. Use natural light: Make use of natural light by installing skylights or windows, and use reflective surfaces to direct natural light deeper into the building.
e. Install solar panels: Install solar panels on the roof of your building to generate clean energy and reduce your dependence on the grid.
f. Install motion sensors: Install motion sensors in areas of the building that are not frequently used, such as storage rooms, to turn off lights when they are not needed.
g. Use energy-efficient appliances: Replace old, energy-guzzling appliances with newer, more energy-efficient models.
h. Educate building occupants: Educate building occupants on ways to conserve energy, such as turning off lights and electronics when not in use, and encouraging the use of stairs instead of elevators.

These are just a few examples of the many ways that energy can be conserved in a building. By making these changes, building owners and occupants can reduce their energy bills and help to reduce the environmental impact of their building.

8.2.5 Fire hazards due to electricity

Electricity is one of the most essential sources of power in modern buildings, and it is also one of the leading causes of fire accidents. The common fire hazards cause in buildings are as follows.

a. One of the most common causes of electrical fires in buildings is faulty wiring. Wiring that is poorly installed or has become damaged over time can cause electrical arcing, leading to overheating, and eventually, a fire. Additionally, overloaded electrical circuits can also cause fires. Overloading occurs when too many electrical appliances are connected to a single circuit, resulting in excess heat that can cause a fire.
b. Another common cause of electrical fires in buildings is electrical equipment that is left unattended or not adequately maintained. Electrical appliances and equipment

that are left on for extended periods can overheat and ignite nearby combustible materials.

c. Poor maintenance of electrical equipment can also cause fires as the equipment ages and becomes more prone to failure.
d. Furthermore, electrical fires can also be caused by lightning strikes or power surges. Lightning can cause a power surge that can overload electrical circuits and lead to a fire, however such cause is out of scope for low height buildings. Power surges can also occur due to faulty wiring or sudden changes in electrical current, causing equipment to overheat and ignite nearby materials.

There are a number of safety precautions that can be taken to help prevent electrical fires in buildings and reduce the risk of loss if a fire does occur. Here are some examples:

a. **Install smoke detectors:** Smoke detectors are an essential component of any fire safety plan, as they can alert building occupants to the presence of a fire and give them time to evacuate.
b. **Perform regular electrical inspections:** Regular inspections of electrical systems and equipment can help to identify and address potential hazards before they cause a fire.
c. **Keep flammable materials away from electrical equipment:** Flammable materials, such as paper or cloth, should be kept away from electrical equipment to prevent them from catching fire.
d. **Use surge protectors and circuit breakers:** Surge protectors and circuit breakers can help to prevent overloads and short circuits that can lead to electrical fires.
e. **Do not overload electrical circuits:** Overloading electrical circuits by plugging too many devices into an outlet or circuit can cause the wiring to overheat and start a fire.

f. **Use only qualified electricians for electrical work:** Electrical work should only be performed by qualified electricians who are trained and licensed to perform such work.
g. **Have a fire safety plan:** A fire safety plan should be developed and communicated to building occupants, outlining evacuation procedures and the location of fire extinguishers and other firefighting equipment.
h. **Properly maintain electrical equipment:** Electrical equipment should be properly maintained and repaired to prevent electrical faults that can lead to fires.

By taking these precautions, building owners and occupants can help to prevent electrical fires and minimize the risk of loss if a fire does occur. It's important to always follow electrical safety guidelines and be prepared in case of an emergency.

8.2.6 Safety precautions

For ensuring the safe installation and efficient use of electrical energy systems in buildings, the Energy Building Code provides guidelines and requirements. To ensure compliance with these codes, there are several safety precautions that should be taken in the design, installation, and operation of electrical energy systems in the buildings.

Well Trained Technicians and Professionals: Firstly, it is essential to ensure that electrical wiring and equipment are installed by licensed professionals and inspected by certified inspectors. All installations should comply with the code requirements for sizing, grounding, and protection against overcurrent, overvoltage, and overtemperature conditions. These measures are essential to prevent electrical fires, electric shock hazards, and equipment failure.

Preventive measures to reduce electrical arc flash hazards: Secondly, it is recommended that electrical systems in buildings be designed to minimize the risk of electrical arc flash hazards. Electrical arc flash hazards can cause severe injuries or fatalities to maintenance personnel who work on live equipment. Design features such as arc-resistant switchgear, remote racking systems, and the use of Personal Protective Equipment (PPE) can help mitigate the risks of electrical arc flash hazards.

Proper Maintenance of electrical systems: Thirdly, it is critical to maintain electrical equipment and systems in good condition. Regular inspections, testing, and maintenance of electrical equipment can help identify and correct potential problems before they result in electrical hazards. Any equipment that has exceeded its lifespan or shows signs of wear and tear should be replaced immediately.

Well trained personnel for electrical system operation: Fourthly, it is recommended that only trained personnel operate electrical equipment in buildings. The trained personnel should have an adequate understanding of the electrical system, proper handling of equipment, and be knowledgeable about emergency procedures. Proper labeling and signage of electrical equipment should also be installed to ensure that only authorized personnel operate the equipment.

Emergency exit(s) and assembly points: Lastly, emergency and standby power systems should be installed in buildings as required by the Energy Building Code. These systems can provide power in the event of a power outage or emergency, ensuring the safety of occupants and the building itself.

8.2.7 Necessary Distance of a building from the distribution/ transmission lines/ PMT

There are necessary distances that buildings should be located away from distribution, transmission lines, or pole-mounted transformers in every country. Maintaining a safe distance from power lines and transformers can help to reduce the risk of electrical shock, fires, and other hazards, and should be taken into consideration when planning the location of a building.

1. According to IEC 61936-1, the minimum vertical clearance between low voltage lines and the roof of a residential building should be at least 2.5 meters (8.2 feet), while the minimum horizontal clearance should be at least 0.5 meters (1.6 feet) from the edge of the roof.
2. According to IEC 61936-1, the minimum vertical clearance between medium voltage lines and the roof of a residential building should be at least 5 meters (16.4 feet), while the minimum horizontal clearance should be at least 1 meter (3.3 feet) from the edge of the roof.

It is important to note that these clearance distances are minimum requirements, and that local authorities and utility companies may require greater distances to ensure safety and compliance with regulations. Building owners and developers should consult with their local utility company and/or a qualified electrical engineer to determine the specific requirements for building distances from power lines and transformers in their area. In the IEC (International Electrotechnical Commission) standards, the voltage levels for low and medium voltage lines are defined as follows:

a) Low voltage (LV): voltage up to and including 1000 volts AC or 1500 volts DC.
b) Medium voltage (MV): voltage above 1000 volts AC and up to and including 33 kV AC.

8.2.8 Transformers

Transformer efficiency is an important factor in minimizing energy losses in power distribution systems. There are typically requirements for transformer efficiency in building codes as per UK and IEC standards. In the UK, the efficiency standards for distribution transformers are defined by the EU Ecodesign Regulation (EC) No 548/2014. The regulation sets minimum efficiency requirements for transformers placed on the market or put into service in the EU, including the UK.

a. For distribution transformers, the minimum efficiency requirements are:
b. For transformers with rated power between 1 kVA and 40 kVA, the minimum efficiency at 50% load is 93.1%.
c. For transformers with rated power between 40 kVA and 2,500 kVA, the minimum efficiency at 50% load is 97.4%.

For power transformers, the efficiency standards in the UK are defined by the International Electrotechnical Commission (IEC) standard IEC 60076. The standard provides different efficiency classes, including:

a. Class 1: Minimum efficiency of 98.5% at 100% load and 97.5% at 50% load.
b. Class 2: Minimum efficiency of 98.0% at 100% load and 96.5% at 50% load.
c. Class 3: Minimum efficiency of 97.0% at 100% load and 95.5% at 50% load.

All measurement of losses shall be carried out by certified persons by using calibrated digital meters of class 0.5 or better accuracy. All transformers of capacity of 500 kVA and above would be equipped with additional local or remote metering class current transformers (CTs) and potential transformers (PTs) additional to requirements of Utilities so that periodic loss monitoring study may be carried out.

8.2.9 Energy Efficient Motors

Minimum energy efficiency requirements for motors used in energy building code. This is required that all motors with a rated power of 1hp or 0.75 kW or more meet the minimum efficiency levels (IE1/ IE2- should/ voluntary) defined by the International Electrotechnical Commission (IEC).

The terms IE1, IE2, IE3, and IE4 are the energy efficiency classes defined by the International Electrotechnical Commission (IEC) in IEC Standard 60034-30-1 for three-phase asynchronous motors (also known as induction motors).

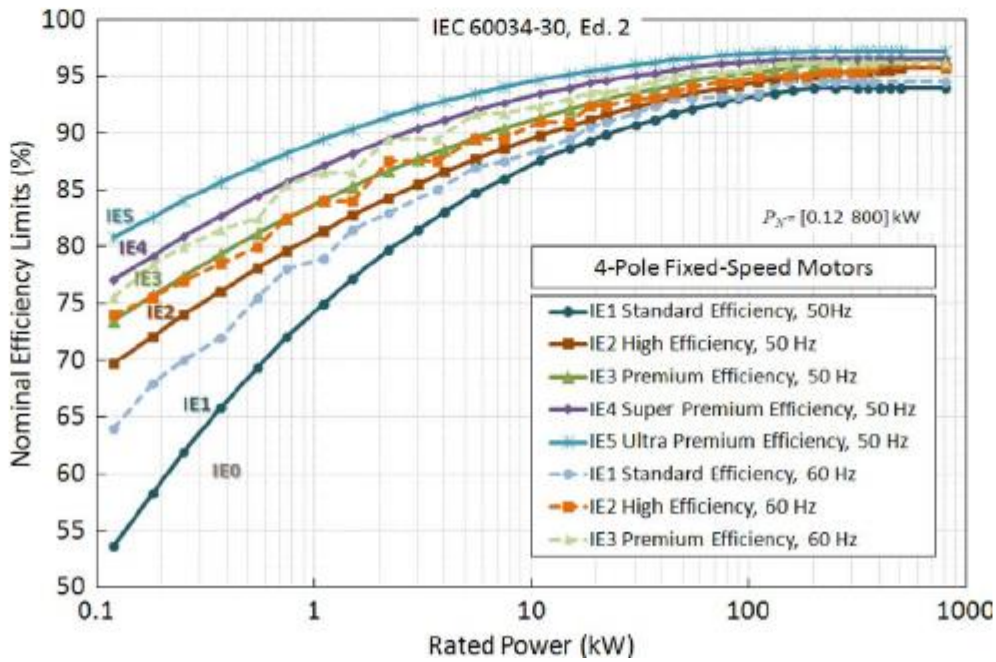

Figure 8.1. Nominal efficiency class limits proposed in the second edition of IEC 60034-30, for four-pole motors (0.12–800-kW power range).

IE1 Standard Efficiency: These are the minimum energy efficiency class motors, also known as Standard Efficiency. They have a lower efficiency and are typically used for general applications where the motor runs for a limited time.

IE2 High Efficiency: These motors have higher energy efficiency compared to IE1 motors and are also known as High Efficiency motors. They are suitable for use in applications where motors operate for longer periods and need to be more energy efficient.

IE3 Premium Efficiency: These motors have even higher energy efficiency compared to IE2 motors and are also known as Premium Efficiency motors. They are suitable for use in applications where motors operate continuously for long periods and require high energy efficiency.

IE4 Super Premium Efficiency: These are the most energy-efficient motors and have the highest efficiency compared to all other classes. They are also known as Super Premium Efficiency motors and are suitable for use in high-demand applications where motors operate continuously for long periods and require very high energy efficiency.

In summary, the energy efficiency class of a motor depends on its design and efficiency level, with higher efficiency motors generally being more expensive but also offering greater energy savings over their lifetime.

Motors shall comply with the following:

a. IEC has defined Minimum Energy Performance Standards (MEPS) for electric motors in IEC Standard 60034-30-1. This standard provides the requirements and test methods for determining the energy efficiency classes for single-speed three-phase cage-induction motors, as well as for determining the efficiency values. The standard also includes a table of Minimum Efficiencies for motors in various power ranges, which serves as a reference for manufacturers and users to ensure that their motors meet the minimum energy efficiency requirements.
b. Motor users should insist on proper rewinding practices for any rewound motors. If the proper rewinding practices cannot be assured, the damaged motor should be replaced with a new, efficient one.
c. Certificates should be obtained and kept on record indicating the motor efficiency. Whenever a motor is rewound, appropriate measures should be taken so that the core characteristics of the motor is not lost due to thermal and mechanical stress during removal of damaged parts. After rewinding, a new efficiency test should be performed and a similar record shall be maintained.

8.2.10 Harmonics and Power Quality

IEEE 519-2014 is a standard developed by the Institute of Electrical and Electronics Engineers (IEEE) that specifies limits for harmonic distortion in electrical power systems. It provides guidelines for limiting the amount of harmonic distortion generated by nonlinear loads in electrical systems. The standard applies to systems with voltage levels greater than 1 kV, and specifies limits on total harmonic distortion (THD) and individual harmonic voltages for both the utility supply and customer loads. It also provides guidance on measurement techniques and corrective measures to be taken in case of non-compliance with the recommended limits.

Table 8.5. Voltage Distortion Limit

Bus voltage V at PCC	Individual harmonic (%)	Total harmonic distortion THD (%)
$V \leq 1.0$ kV	5.0	8.0
1 kV $< V \leq$ 69 kV	3.0	5.0
69 kV $< V \leq$ 161 kV	1.5	2.5
161 kV $< V$	1.0	1.5[a]

[a]High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.

Current Distortion Limits for General Distribution Systems (120 V Through 69000 V)

Maximum Harmonic Current Distortion in Percent of I_L						
Individual Harmonic Order (Odd Harmonics)						
I_{sc}/I_L	<11	11≤h<17	17≤h<23	23≤h<35	35≤h	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0
Even harmonics are limited to 25% of the odd harmonic limits above.						
Current distortions that result in a dc offset, e.g. half-wave converters, are not allowed.						
* All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.						

Where

I_{sc} = maximum short-circuit current at PCC.

I_L = maximum demand load current (fundamental frequency component) at PCC.

TDD = Total demand distortion (RSS), harmonic current distortion in % of maximum demand load current (15 or 30 min demand).

PCC = Point of common coupling.

Overall, the standard aims to ensure the reliable operation of electrical power systems and to prevent excessive harmonic distortion that can cause problems such as equipment malfunction, overheating, and increased energy losses.

8.2.11 Power Factor Correction

Power factor correction is an important aspect of energy efficiency in buildings. A low power factor can result in increased electricity consumption and higher electricity bills, as well as increased wear and tear on electrical equipment. All electricity supplies exceeding rating of 100 A per phase, shall maintain their power factor between 0.90 lag and unity at the point of connection.

IEC 61000-3-2 is an international standard that specifies limits for harmonic current emissions from electrical equipment. The standard also includes requirements for power factor correction, which are designed to reduce the level of harmonic distortion in electrical systems and improve energy efficiency. Under IEC 61000-3-2, the power factor (PF) requirement for electrical equipment is based on the rated power of the equipment, and is defined as follows:

1. For equipment with a rated power of 75 W or less, the PF should not be less than 0.4.
2. For equipment with a rated power of more than 75 W but less than or equal to 600 W, the PF should not be less than 0.5.
3. For equipment with a rated power of more than 600 W, the PF should not be less than 0.9.

It is important to note that these requirements apply to individual pieces of electrical equipment, and not necessarily to the building as a whole. However, improving the power factor of individual pieces of equipment can help to reduce overall harmonic distortion in the building's electrical system and improve energy efficiency.

8.2.12 Earthing System

There are several different types of earthing systems commonly used in electrical installations. Here are the most common types:

1. TT Earthing System: In this system, each item of electrical equipment is connected to the earth through a separate electrode, providing a high degree of safety.
2. TN Earthing System: This system has two variations, TN-S and TN-C-S. In TN-S, the earth and neutral conductors are separated throughout the installation, while in TN-C-S, they are combined up to a point and then separated.
3. IT Earthing System: This system has no direct connection to earth and instead uses an impedance to limit the current in the event of a fault.
4. PNE Earthing System: This system is commonly used in industrial applications and involves the use of a neutral point earthing resistor to limit the earth fault current.

The specific type of earthing system used will depend on a variety of factors, including the local electrical code and the specific needs of the electrical installation. It's important to consult with a qualified electrical engineer or technician to determine the appropriate earthing system for your particular situation. In Pakistan, the most common earthing system used is the TN-S earthing system. This system separates the earth and neutral conductors throughout the installation and provides a low-impedance path to ground for fault currents. However, other earthing systems such as TT and IT are also used in specific situations, particularly in large industrial installations or in areas with high lightning activity. The specific earthing system used in a particular installation will depend on various factors, including the local electrical code, the nature of the installation, and the specific requirements of the equipment being used. It's important to consult with a qualified electrical engineer or technician to determine the appropriate earthing system for your specific situation.

The design criteria for a TN-S earthing system will depend on several factors, including the specific installation requirements and the local electrical code. However, here are some general design criteria that are commonly considered:

a. Earth Electrode: The earth electrode used in the TN-S earthing system should have a low impedance to the earth and be able to carry the fault current for the duration of the fault. The size and material of the earth electrode should be selected based on the soil resistivity, the maximum fault current, and the required duration of the fault.
b. Earth Conductor: The earth conductor should be sized appropriately to carry the fault current without exceeding its temperature rating. The cross-sectional area of the earth conductor should be determined based on the maximum fault current and the duration of the fault.
c. Separation of Neutral and Earth Conductors: In the TN-S system, the neutral conductor and the earth conductor should be separated throughout the installation. The separation distance between the neutral and earth conductors should be maintained to prevent accidental contact between the two conductors.

d. Equipotential Bonding: All metallic parts of the installation should be connected to the earth conductor using equipotential bonding conductors. This will help to ensure that all metallic parts in the installation are at the same potential, reducing the risk of electric shock.
e. Testing and Maintenance: The TN-S earthing system should be tested and maintained regularly to ensure that it is functioning correctly. Regular testing can help to identify any faults or deficiencies in the system, which can then be corrected to maintain the safety and reliability of the electrical installation.

These are some general design criteria for a TN-S earthing system. It's important to consult with a qualified electrical engineer or technician to determine the specific design criteria for your particular installation, as they can vary depending on the specific requirements of the system.

8.2.13 Earthing Resistance Value

The earthing resistance of a building is an important parameter that affects the performance and safety of electrical systems. In general, a lower earthing resistance is better, as it helps to reduce the risk of electrical shock and can improve the performance of sensitive electronic equipment.

The exact earthing resistance requirements for a building can vary depending on a number of factors, including the size of the building, the electrical load, and the local electrical codes and standards. However, in general, a typical target value for earthing resistance is less than 5 ohms.

It is important to note that achieving a low earthing resistance can be challenging in some environments, such as rocky or dry soils. In these cases, additional measures may be needed to ensure safe and reliable earthing, such as using special conductive materials or installing additional earthing electrodes. A qualified electrical engineer or contractor should be consulted to determine the most appropriate earthing design for a specific building or site.

8.2.14 Metering and Recording

Buildings having approved demand equal or greater than 3-phase 5kW shall have the electrical distribution system with their energy metering as under;

a. Voltmeter and current meter
b. Peak/ off-peak time
c. Maximum Demand Indicator (kVA) meter
d. kW meter
e. kWh meter
f. Power Factor meter
g. Net-metering option (in case of solar and wind generation)

8.2.15 Power Distribution Systems Losses

The power cabling shall be adequately sized as to maintain the distribution losses less than the total power usage. Record of design calculation for the losses should be maintained. The maximum permissible distribution system losses are defined for low voltage (up to 1000V) and medium voltage (above 415V and up to 33kV) systems. This is recommended that distribution system losses should be limited to 5% for low voltage systems and 3% for medium voltage systems. Distribution system losses occur due to the resistance of the conductors used to transmit electrical power from the source to the load. The higher the resistance, the more power is lost as heat, resulting in lower efficiency and higher operating costs. In this context, the 5% and 3% limits mean that the total losses in the distribution system should not exceed 5% and 3% of the total power generated, respectively. For example, if a power plant generates 100 units of electricity, the total losses in the distribution system should not exceed 5 units (or 5%) for a low voltage system and 3 units (or 3%) for a medium voltage system.

8.2.16 Availability of Back-up Power Sources

The availability of power sources in building codes refers to the requirement that buildings must have a reliable and consistent supply of electrical power to meet the needs of their occupants. This includes provisions for backup power in case of emergencies or power outages, as well as requirements for the quality and stability of the electrical supply.

The necessary minimum number of power sources required for a given building or occupancy type can vary depending on several factors, including the size and type of the building, the electrical demand, and the criticality of the loads. A minimum of two power sources for certain critical loads, such as emergency lighting, fire pumps, and life safety systems are required. the electrical infrastructure be installed and maintained in accordance with applicable codes and standards to ensure the safety and reliability of the system.

The selection of multiple power sources and their grid synchronization must be as per the standards.

8.2.17 Renewable Power Sources

Renewable energy sources are a way to promote sustainability and reduce carbon emissions. Some common examples of renewable energy sources are solar panels, wind turbines, geothermal systems, and hydropower. The minimum encouraging requirements for renewable energy sources is the maximum sanctioned load of the system for new construction or renovations. However, the maximum allowable renewable sources could be as per the local net-metering policy. The use of renewable energy sources in building codes can help promote the growth of the renewable energy industry, reduce dependence on fossil fuels, and contribute to the fight against climate change.

8.3 Compliance Documentation and Enforcement

a. The authority having jurisdiction would develop the required documents for implementation.

b. All the design and safety compliance must be passed from the electrical consultant or electrical power system engineers (Professional Engineer) with certain minimum industrial exposure.
c. All the results must be verified after the site verification and testing from the local firms.
d. All the designs must be submitted to the local building control authority.
e. The completion certificate could be issued after the site verification and testing from the local firms.
f. Building codes can be enforced through education and outreach efforts to promote awareness and understanding of the code among contractors, builders, and the public.

SECTION – 9

9. Monitoring Devices

9.1 General

The building should have provision for quantifying energy input & output of different sources such as electricity, fuel, and water. The quantification is to be based on adequate measurements through instruments of acceptable accuracy and credible information from energy suppliers. The monitored data of at least previous 3 years is required to be archived in electronic or paper form. Calibration of the monitoring instruments and cross-verification of the recorded data is essential to ensure accuracy of monitoring data.

9.2 Monitoring of Electricity Consumption

Following parameters are mandatory to be monitored at least monthly. The monitoring is to be done by installing permanently fixed meter (instrument).

1. Total electricity **kWh** consumption by the building
2. Average Power Factor of the building

Additional meters can be installed based on physical sections (e.g., story), type of load, and time of utilization in order to perform analysis of electricity consumption.

Multi-story buildings are required to quantify total electricity consumption (kWh), and average power factor of each story at least on monthly basis through permanently fixed meter(s) / instrument(s).

Electrical wiring of the building should enable easy and quick monitoring – through permanent or portable meter(s) / instrument(s) – of electricity consumption by type of load e.g., HVAC Load, Fan Load, Lighting Load, Water Heating Load, Motors Load, Plug Load, etc.

Followings are required to have permanently installed dedicated energy metering:

1. Each charging point for electric vehicle
2. Swimming pool plant (pump sets, water filtration, etc.)
3. Continuous & Emergency Duty infrastructure such as Information Technology (IT) & Security systems, emergency lighting, firefighting, etc.
4. Electricity consumed and supplied by UPS of capacity 2000 VA or higher
5. Each elevator
6. Each Escalator

9.3 Monitoring of Electricity Supply from Various Sources

A building having multiple sources of electricity supply should be able to quantify electricity supplied from each source.

Electricity **kWh** supplied from each off-grid solar electricity system should be monitored preferably on daily (at least on weekly) basis.

9.4 Net Metering

In case of Net Metering (import / export meter), monitoring of electricity import and export is to be done on daily basis.

9.5 Monitoring of Generator Set

Electricity supplied and fuel consumed by each generator set (genset) should be monitored in order to determine efficiency of individual genset.

Date and time of start and stop, and reason for operation of each genset should be recorded. The electricity **kWh** supplied by the genset should be preferably measured by meter(s) / instrument(s). In case the genset has provision to measure only the electrical power **kW**, then average power supplied is to be estimated by recording values of instantaneous power at appropriate intervals (the maximum interval can be of 30 minutes).

Fuel (oil / gas) consumed by individual genset during each operation is to be recorded in order to calculate the consumed energy. Calorific values of fuel can be determined through laboratory test or credible information from supplier of the fuel. In case, instrumentation is available to measure only flow rate or mass rate of the fuel, then average fuel consumed is to be estimated by recording values of instantaneous rate at appropriate intervals (the maximum interval can be of 30 minutes).

For gensets of 500 kVA and higher capacity, following additional parameters are to be monitored.

a. Exhaust gas temperature & pressure on hourly basis.
b. Electricity consumption by auxiliary load of the genset.

9.6 Monitoring of Natural Gas Consumption

Total gas consumption by the building is mandatory to be monitored at least monthly. The monitoring is to be done by installing permanently fixed meter (instrument). Calorific values of fuel can be determined through laboratory test or credible information from supplier of the fuel.

1. Additional meters can be installed based on physical sections (e.g. story), and type of load in order to perform analysis of gas consumption.
2. Multi-story buildings are required to quantify total gas consumption of each story at least on monthly basis through permanently fixed meter(s) / instrument(s).
3. Gas piping network of the building should enable easy and quick monitoring – through permanent or portable meter(s) / instrument(s) – of gas consumption by type of load e.g., Water Heaters, Space Heaters, Boilers / Chillers, Stoves, etc.
4. Similarly, quantity of LPG cylinders consumed by the building should be recorded on monthly basis.

9.7 Monitoring of Boilers

Steam supplied and fuel consumed by each boiler should be monitored in order to determine efficiency of individual boiler. Following parameters are to be monitored:

a. Date and time of start and stop of each boiler
b. Temperature of steam
c. Pressure of steam
d. Quantity of steam supplied by the boiler should be preferably measured by meter(s) / instrument(s). In case the boiler has provision to measure only flow rate or mass rate of steam, then average steam supplied is to be estimated by recording values of instantaneous flow at appropriate intervals (the maximum interval can be of 1 hour).
e. Quantity, Temperature, and Pressure of feed water
f. Fuel (oil / gas) consumed by individual boiler during each operation is to be recorded in order to calculate the consumed energy. Calorific values of fuel can be determined through laboratory test or credible information from supplier of the fuel. In case, instrumentation is available to measure only flow rate or mass rate of the fuel, then average fuel consumed is to be estimated by recording values of instantaneous rate at appropriate intervals (the maximum interval can be of 1 hour).
g. Flue gas temperature & pressure on hourly basis.
h. Electricity consumption by auxiliary system of the boilers.

9.8 Monitoring of Water Consumption

1. Total water consumption by the building is mandatory to be monitored at least monthly. The monitoring is to be done by installing permanently fixed meter (instrument).
2. Additional meters can be installed based on physical sections (e.g. story), and type of load in order to perform analysis of water consumption.
3. Multi-story buildings are required to quantify total water consumption of each story at least on monthly basis through permanently fixed meter(s) / instrument(s).

4. Water piping network of the building should enable easy and quick monitoring – through permanent or portable meter(s) / instrument(s) – to perform consumption analysis.
5. Swimming pools are required to have permanently installed dedicated meters to determine consumption of water.

9.9 Monitoring of Water Supply from Various Sources

A building having multiple sources of water supply should be able to quantify water supplied from each source.

9.10 Monitoring of Underground Water Extraction Pump set

Water supplied and electricity consumed by each underground (sub-soil) water extraction pump set should be monitored in order to determine efficiency of individual pump set.

Section-10

10. Geothermal Energy

10.1 General Introduction

Geothermal energy is an underutilized resource in Pakistan. Despite having significant potential, it has not been widely adopted for energy production or buildings construction. The purpose of this report is to explore the possible usage of geothermal technology in buildings construction for the purpose of energy efficiency with reference to Pakistan. The report provides an overview of geothermal technology, its components, advantages and disadvantages, and its applications in buildings construction. It also highlights the geothermal potential in Pakistan, geothermal projects in the country, and the challenges and opportunities for geothermal technology in Pakistan. Furthermore, the report discusses the relationship between geothermal technology and energy efficiency in buildings.

The purpose of this report is to explore the potential usage of geothermal technology in buildings construction for the purpose of energy efficiency in Pakistan. The report will provide an overview of the existing literature on geothermal technology in buildings construction and its benefits in terms of energy efficiency. The report will also discuss the scope of geothermal technology, applicable building systems, exemptions, and limitations.

10.2 Scope

This report focuses on the possible usage of geothermal technology in buildings construction for the purpose of energy efficiency in Pakistan. The report provides an overview of geothermal technology, its benefits in terms of energy efficiency, and the potential areas for geothermal development in Pakistan. The report also highlights some successful case studies of geothermal technology in buildings construction in Pakistan and other countries.

10.2.1 Applicable Building Systems

Geothermal technology can be applied to various building systems, including heating, ventilation, and air conditioning (HVAC) systems, domestic hot water systems, and swimming pool heating systems. The report will discuss the application of geothermal technology in these building systems and their benefits in terms of energy efficiency.

10.2.2 Exemptions

This report does not cover the technical details of geothermal technology and its installation process. The report focuses on the benefits of geothermal technology in buildings construction for the purpose of energy efficiency in Pakistan.

10.2.3 Limitations

This report is limited to the available literature on geothermal technology in buildings construction for the purpose of energy efficiency in Pakistan. The report may not cover all the potential areas of geothermal development in Pakistan, and the information provided may not be up-to-date. The report is not intended to be a comprehensive guide on geothermal technology in buildings construction, and readers are encouraged to seek additional information from relevant sources.

10.3 Methodology

The report is based on a comprehensive review of existing literature and reports on geothermal technology, energy efficiency in buildings, and the geothermal potential in Pakistan. Primary data was also collected through interviews with experts in the field of geothermal energy in Pakistan. The report follows a structured approach to present the findings and recommendations. The report is intended for policymakers, developers, architects, and other stakeholders who are interested in promoting energy efficiency in buildings through the adoption of geothermal technology.Geothermal technology is a renewable energy technology that harnesses the heat energy from the Earth's core. This technology is based on the principle that the Earth's core is a massive heat source that produces an almost limitless supply of energy. Geothermal technology involves the use of geothermal heat pumps and ground-source heat exchangers to transfer the heat energy from the Earth's core to buildings and homes.

10.4 Types of Geothermal Systems

10.4.1 Ground Source Heat Pump (GSHP) Systems

A Ground Source Heat Pump (GSHP) system uses the earth's constant temperature to heat and cool buildings. The system consists of three main components: a ground loop, a heat pump unit, and a duct or radiant system.

The ground loop is made up of pipes that are buried underground, either vertically or horizontally, and contain a fluid, such as water or antifreeze. The fluid absorbs heat from the earth in winter and rejects heat to the earth in summer.

The heat pump unit is typically located inside the building and has two heat exchangers: one for the ground loop and another for the building's heating and cooling system. The unit uses electricity to compress the fluid from the ground loop, which raises the temperature, and then circulates it through the building's heating and cooling system.

In heating mode, the heat pump extracts heat from the fluid in the ground loop and uses it to warm the air or water used for space heating. In cooling mode, the heat pump extracts heat from the building and transfers it to the ground loop. The fluid in the ground loop absorbs the heat, and it is then released into the cooler earth.

Overall, a GSHP system is an efficient and sustainable way to provide heating and cooling to buildings while reducing energy consumption and costs.

10.4.2 Direct Use Systems

Direct use geothermal systems, are a type of geothermal technology that uses hot water from underground reservoirs to provide heat directly to homes, buildings, and other structures.

In a direct use system, a well is drilled into the underground reservoir and the hot water or steam is brought to the surface and distributed through a network of pipes. The heated water can be used for space heating, domestic hot water, and even industrial processes.

Direct use systems are often used in areas where there is a high concentration of geothermal resources, such as geothermal hot spots or volcanic regions. These systems can provide a reliable and renewable source of energy for heating, reducing dependence on fossil fuels and improving energy security.

Direct use geothermal systems have been used for centuries, with the first documented use of geothermal energy for heating and bathing in China dating back to 3rd century BC. Today, direct use systems are used around the world, with the largest installations found in the United States, Iceland, and Turkey.

Geothermal power systems are renewable and emit very little greenhouse gases, making them an attractive alternative to fossil fuel power plants. However, they require a reliable source of hot water or steam, which is limited to specific locations. Currently, the largest geothermal power plants are located in the United States, the Philippines, and Indonesia.

10.4.3 Components of a Geothermal System

The basic components of geothermal technology include a heat pump, a ground-source heat exchanger, and a distribution system. The heat pump extracts the heat energy from the ground-source heat exchanger and transfers it to the distribution system, which circulates the heat throughout the building. The ground-source heat exchanger consists of a loop of pipes that are buried underground and filled with a heat transfer fluid. The fluid absorbs the heat energy from the ground and transfers it to the heat pump, which then transfers it to the distribution system.

10.4.4 Heat Source

The heat source is the underground reservoir of hot water and steam that is used to generate heat or electricity. This can be accessed through drilling one or more wells into the reservoir.

10.4.4.1 Heat Exchanger

The heat exchanger is a device that transfers heat between the heat source and the heat pump or power plant. In a closed-loop system, the heat exchanger consists of a series of pipes buried underground that circulate a fluid to transfer heat to and from the ground. In an open-loop system, the heat exchanger is a direct exchange of heat between the hot water from the underground reservoir and the fluid used in the heating or power generation process.

10.4.4.2 Heat Pump or Power Plant

The heat pump or power plant is the device that extracts heat from the heat exchanger and uses it to provide heating, cooling or generate electricity. In a heating or cooling application, a heat pump is used to transfer heat to or from the underground reservoir to the building or HVAC system. In a power generation application, a steam turbine or binary cycle system is used to convert the heat into electricity.

10.4.4.3 Distribution System:

The distribution system delivers the heated or cooled air or water to the building or end-use system. This can be a network of pipes or ducts, or a combination of both.

10.4.4.4 Control System

The control system regulates the operation of the heat pump or power plant and the distribution system to ensure optimal performance and efficiency.

The specific components and configuration of a geothermal system will vary depending on the application, location, and available resources. For example, a residential heating system may consist of a single heat pump and a closed-loop heat exchanger, while a large-scale power plant may require multiple wells and a more complex heat exchanger and distribution system.

10.4.4.5 Advantages of Geothermal Technology:

Geothermal technology has several advantages over conventional heating and cooling systems. Firstly, it is a renewable and sustainable source of energy that is not dependent on fossil fuels. Secondly, it has lower operating costs than traditional heating and cooling systems, as it requires less energy to operate. Thirdly, it has a longer lifespan than conventional systems, with some systems lasting up to 50 years. Finally, geothermal technology can provide both heating and cooling to buildings, which eliminates the need for separate heating and cooling systems.

10.4.4.6 Disadvantages of Geothermal Technology:

Despite its advantages, geothermal technology also has some limitations and challenges. One of the major limitations is that it requires significant upfront costs for installation and drilling. Moreover, the availability of suitable geothermal resources and access to drilling sites can be limited, which can increase the installation costs. Furthermore, the maintenance of geothermal systems can be complex and require specialized skills and equipment.

To recapitulate, geothermal technology is a promising and sustainable source of energy that has significant potential for use in buildings construction. It offers several advantages over conventional heating and cooling systems, such as low operating costs, long lifespan, and energy efficiency. However, its widespread adoption in Pakistan faces several challenges, including high upfront costs and limited access to suitable geothermal resources. Therefore, further research and development are required to make geothermal technology more accessible and affordable for buildings construction in Pakistan.

10.5 Geothermal Technology in Buildings Construction

10.5.1 Introduction

Geothermal technology is becoming an increasingly popular option for energy-efficient buildings construction. By tapping into the heat energy stored in the earth, geothermal systems can provide heating, cooling, and hot water at significantly lower operating costs compared to traditional HVAC systems. However, successful implementation of geothermal technology in buildings requires careful planning and design considerations to ensure optimal performance and efficiency.

10.5.2 Design Considerations for Geothermal Systems

10.5.2.1 Site Selection

The first step in designing a geothermal system is selecting the most suitable site. The site should have access to a geothermal resource, such as a hot water reservoir, and sufficient space for drilling and installation of the necessary components. Factors such as soil type, groundwater level, and seismic activity should also be considered to ensure the stability and durability of the system.

10.5.2.2 Building Design

The design of the building also plays a crucial role in the success of a geothermal system. The building should be well-insulated to minimize heat loss or gain, reducing the heating and cooling load required from the system. Orientation and shading of windows and walls can also affect the energy efficiency of the building. Designers should also consider the integration of the geothermal system with the building's other systems, such as ventilation and air conditioning.

Moreover, Geothermal technology can be used in various types of buildings, including residential, commercial, and industrial buildings. It is a versatile technology that can be used for both heating and cooling purposes, and it can be adapted to different building sizes and designs.

a. In **residential** buildings, geothermal technology can be used to provide space heating, space cooling, and hot water. Geothermal heat pumps can be installed in new or existing homes, and they are often used in conjunction with radiant floor heating systems for maximum efficiency and comfort.

b. In **commercial** buildings, geothermal technology can be used for a wide range of applications, including space heating and cooling, hot water production, and process heating and cooling. Large-scale geothermal systems can be used to heat and cool buildings such as schools, hospitals, and office buildings, while smaller systems can be used in retail stores and restaurants.

c. In **industrial** buildings, geothermal technology can be used for process heating and cooling, as well as space heating and cooling. Industrial applications of geothermal technology include food processing, greenhouse heating, and mining operations.

Overall, geothermal technology can be used in a wide range of building types and applications, and it offers numerous advantages over traditional heating and cooling systems, including higher energy efficiency, lower operating costs, and reduced environmental impact.

10.5.2.3 System Sizing

The size of the geothermal system should be carefully calculated to meet the specific heating and cooling needs of the building. Oversized or undersized systems can result in inefficiencies and higher operating costs. Factors such as the building's size, insulation, and orientation, as well as the local climate, should be taken into account when sizing the system.

10.5.2.4 Piping Design & Fluids to be used:

10.5.2.4.1 Piping Design

1. The type of pipes used in geothermal technology depends on several factors, such as the temperature and pressure of the geothermal fluid, the specific application of the geothermal system, and the geological conditions of the site.
2. The amount of pipe required for a geothermal system depends on several factors, such as the size of the building, the heat load, and the type of geothermal system being installed. However, as a general rule of thumb, a typical horizontal loop system requires between 400 to 600 feet of pipe per ton of heating and cooling capacity.
3. For a vertical loop system, the amount of pipe required will depend on the depth of the borehole and the geological conditions at the site. Typically, vertical loop systems require between 150 to 200 feet of pipe per ton of heating and cooling capacity.
4. In general, two types of pipes are commonly used in geothermal systems**: high-density polyethylene (HDPE)** pipes and **cross-linked polyethylene (PEX)** pipes. Both of these materials are highly resistant to corrosion and have good thermal properties, making them suitable for use in geothermal systems.
    - **a.** HDPE pipes are commonly used in vertical borehole systems, where they are inserted into the borehole and connected to a horizontal pipe loop at the bottom of the hole. These pipes are highly durable and can withstand high temperatures and pressures, making them suitable for use in deep boreholes.
    - **b.** PEX pipes, on the other hand, are typically used in horizontal pipe loops or in shallow trench systems. They are more flexible than HDPE pipes, which allows them to be easily installed in a variety of configurations. PEX pipes are also less expensive than HDPE pipes, which can make them a more cost-effective option for some applications.

In addition to HDPE and PEX pipes, other materials such as copper, steel, and polypropylene may also be used in geothermal systems, depending on the specific requirements of the project. It is important to select the appropriate pipe material and size for the geothermal system to ensure optimal performance and longevity.

The piping design of a geothermal system is critical to its overall performance and efficiency. In a closed-loop system, the piping must be buried underground and designed to minimize heat loss or gain. The pipe material must be resistant to corrosion and able to withstand the high temperatures and pressures involved in the system. In an open-loop system, the piping design must allow for the flow of hot water from the geothermal source to the heat exchanger and back to the source without contamination or loss of heat.

10.5.2.4.2 Fluid details

Geothermal technology uses different types of fluids, depending on the specific application and the temperature range of the geothermal resource. The fluid used in geothermal systems is typically water-based, but it may also contain various additives or chemicals to improve performance or prevent corrosion.

a. For low-temperature geothermal systems, such as those used for space heating and cooling, water or water-based solutions such as propylene glycol are commonly used as the heat transfer fluid. These solutions are circulated through the ground loop to absorb or release heat from the ground, depending on the heating or cooling needs of the building.

b. For high-temperature geothermal systems, such as those used for power generation, a binary fluid system is often used. This system consists of two fluids, one of which is typically a low-boiling-point organic fluid such as isobutane or pentane, which is vaporized by the heat from the geothermal resource. The vapor then drives a turbine to generate electricity. The second fluid in the system is typically water, which is used to cool and condense the vapor back into a liquid.

In some cases, geothermal fluids may also contain dissolved minerals, such as calcium, magnesium, and silica. These minerals can cause scaling or fouling of the heat transfer surfaces in the geothermal system, which can reduce the system's efficiency and lifespan. In these cases, water treatment or other measures may be needed to mitigate the effects of mineral scaling and fouling.

The design considerations for geothermal systems in buildings construction are critical to the success of the system in terms of performance and efficiency. By carefully selecting the site, designing the building for energy efficiency, sizing the system appropriately, and designing the piping system for optimal performance, designers and builders can ensure that geothermal technology provides a cost-effective and sustainable solution for heating, cooling, and hot water in buildings.

10.5.2.5 Applications of Geothermal Technology in Buildings Construction

10.5.2.5.1 Heating and Cooling

One of the primary applications of geothermal technology in buildings construction is heating and cooling. Geothermal heat pumps (GHPs) are used to extract heat from the ground and transfer it to the building's interior during the winter months. In the summer, the process is reversed, and the heat is extracted from the building's interior and transferred to the ground. This technology provides efficient heating and cooling solutions for buildings, reducing the need for fossil fuel-based systems and lowering energy costs.

10.5.2.5.2 Hot Water

Geothermal technology can also be used to provide hot water for buildings. A geothermal heat pump can extract heat from the ground and transfer it to a hot water tank, providing a constant supply of hot water for the building's needs. This eliminates the need for a separate hot water system and reduces energy costs.

10.5.2.5.3 Snow and Ice Melting

Geothermal technology can also be used for snow and ice melting in outdoor areas, such as driveways and walkways. Piping is installed under the surface, and hot water is circulated through the pipes to melt snow and ice. This solution is more efficient and environmentally friendly than traditional methods of snow and ice removal, such as salt and chemicals.

10.5.2.5.4 Indoor Pool Heating

Geothermal technology can also be used to heat indoor swimming pools. The same geothermal heat pump used for heating and cooling can be used to extract heat from the ground and transfer it to the pool. This solution is more energy-efficient than traditional pool heating systems, reducing energy costs and carbon emissions.

10.5.2.5.5 Benefits of Geothermal Technology in Buildings Construction

The benefits of geothermal technology in buildings construction are numerous. They include:

1. **Energy efficiency:** Geothermal technology is highly energy-efficient, reducing the building's energy consumption and lowering energy costs.
2. **Cost-effective:** Although geothermal technology requires a higher upfront cost, it provides significant savings in the long run, making it a cost-effective solution.
3. **Environmental sustainability:** Geothermal technology is a renewable energy source, reducing the building's carbon footprint and environmental impact.
4. **Durability:** Geothermal systems are designed to last for several decades, making them a reliable and durable solution for buildings.

10.5.3 Case Studies

> The Discovery Elementary School in Arlington, Virginia, uses a geothermal system to heat and cool the building, reducing its energy consumption by 50%.[1] Most notable are the financial benefits: a school of similar size to Discovery Elementary has approximately $120,000 in annual energy costs. Discovery's energy innovations are projected to reduce that cost to $72,000 a year.[2]

Geothermal technology has a wide range of applications in buildings construction, including heating and cooling, hot water, snow and ice melting, and indoor pool heating. The benefits of geothermal technology include energy efficiency, cost-effectiveness, environmental sustainability, and durability. Several successful case studies demonstrate the effectiveness of geothermal technology in buildings construction.

10.6 Geothermal Technology in Pakistan

10.6.1 Introduction

Pakistan is a developing country with a growing population and an increasing demand for energy. In recent years, the country has been facing severe energy shortages, which have resulted in power outages, load shedding, and an overall negative impact on economic growth. The government of Pakistan is actively seeking to find alternative

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[1] U.S. Department of Energy. (n.d.). Discovery Elementary School. Retrieved from https://www.energy.gov/eere/buildings/discovery-elementary-school

[2] https://greenschoolsnationalnetwork.org/net-zero-discovery-elementary-school-in-arlington-va-raises-the-bar-for-energy-efficiency/

sources of energy to mitigate the energy crisis. One of the most promising sources of renewable energy in Pakistan is geothermal energy.

10.6.2 Geothermal Potential in Pakistan

Pakistan is located in a region that has significant geothermal potential. The country is situated on the western edge of the Indo-Gangetic Plain and the northern edge of the Indian Ocean. This location places Pakistan in an ideal position to tap into the geothermal resources of the region.

Pakistan has several potential areas for geothermal development including (but not limited to): [3]

10.6.3 Himalayan Arc

The Northern Himalayan Region is a part of the Global Geothermal Belt and is characterized by the Main Karakoram Thrust (MKT), which extends from Myanmar in the east to the Alps in the west. This region in Pakistan is known for its high-temperature geothermal activity, which includes hot springs, geysers, and fumaroles. It is located in the Plate Marginal Zone, which is situated along the striking junction (suture zone) of Eurasia, encompassing the Northern Areas of Pakistan and some parts of Kashmir. The primary heat sources in this region are active secondary faults and volcanic activity in the shallow part of the Earth's crust. The deeper part of the Earth's crust near the subduction zone is situated beneath the sub-Himalaya and lesser Himalaya regions, while the shallow part of the crust is affected by secondary faults such as the Main Boundary Thrust (MBT), Main Central Thrust (MCT), Salt Range Frontal Thrust, among others. The active movement of these associated faults is the primary source of heat in the region. Mughal proposed the possibility that young intrusions of granite and grano-diorite, which have not yet surfaced,

[3] https://publications.mygeoenergynow.org/grc/1033590.pdf

are still cooling. However, there is no evidence of recent volcanic activity, except for the Kamila Amphibolite in the Swat area and Panjal Volcanism of Permo-Carboniferous Ages.

10.6.4 Indus Basin

The Indus Basin is the major sedimentary basin of Pakistan. The hot sedimentary aquifers are associated with hydrocarbons and also developed as a result of development of secondary faults in the Indus Basin where dozens of geothermal springs have been identified. The Indus Basin has been further subdivided into Upper, Middle & Lower Indus Basin.

10.6.5 Baluchistan Basin

The Baluchistan Basin is situated in a subduction zone where the oceanic slab of the Arabian plate has been pushed beneath the Eurasian plate. The basin primarily consists of thick Tertiary and Quaternary clastic sediments, along with some carbonate rocks from the Cretaceous, Palaeocene, and Eocene Ages in the northern region of the basin. Despite its potential, there has been limited exploration to assess the hydrocarbon reserves in this basin. The vast offshore area, as well as the Coastal Belt, show significant promise for the discovery of hydrocarbons. In the Makran Coastal area, there are various mud volcanoes, as well as geothermal springs and fumaroles that flow with hydrothermal fluids in some locations. Unfortunately, there has been no attempt to survey the mud volcanoes or geothermal sites in the Baluchistan Basin, including the Makran Coastal Areas.

10.6.6 Pishin Basin

The Pishin sedimentary Basin is located in the northeastern part of Baluchistan Province and extends into Afghanistan, where it is known as the Katawaz Basin. The Basin is bounded by two significant faults, namely the Chaman Transform Fault in the northwest and the Zhob Valley Thrust in the east. There are other faults in the basin, including thrust faults and high-angle reverse faults. The presence of thermally mature hydrocarbons has been confirmed in the Pishin Basin, with numerous oil and gas seeps observed in the area.

In the north of Killa Saifullah Town, a series of mud volcanoes can be found. Geothermal springs are located in the Killa Saifullah and Zhob Districts within the Pishin Basin, where hot geothermal fluids flow in some locations.

10.6.7 Chagai Volcanic Arc

The Chagai Volcanic Arc, located in the Chagai District of Baluchistan, is associated with active magmatic activity and multiple dormant volcanoes. The Koh-i-Sultan dormant volcano is a significant source of geothermal water in the area. There are various geothermal springs in the Cheken Dik area, located to the north of Nokhundi town, and fumaroles observed in the northwest of the Baluchistan Basin. The heat sources in the area mainly come from volcanic influence in the shallow part of the Earth's crust. Geothermal water temperatures from the Koh-i-Sultan dormant volcano have been recorded between 120 to 150°C.It is important to note that the geothermal potential of these areas has not been fully explored, and further geological surveys and exploration are needed to assess the feasibility of geothermal energy development in Pakistan.

10.7 Challenges and Opportunities for Geothermal Technology in Pakistan

10.7.1 Challenges

a. **Lack of Awareness and Technical Expertise**: One of the main challenges for geothermal technology in Pakistan is the lack of awareness and technical expertise. Most people are not aware of the potential of geothermal energy and how it can be harnessed to provide clean and sustainable energy. Furthermore, there is a shortage of technical expertise in this field, which makes it difficult to develop and implement geothermal projects.

b. **High Initial Investment**: Geothermal technology requires a high initial investment, which can be a significant challenge in a developing country like Pakistan. The cost of drilling and installing geothermal systems can be prohibitive, and it may be difficult to secure financing for such projects.

c. **Geological and Environmental Constraints**: Geothermal energy is highly dependent on geological and environmental factors, such as the availability of suitable geothermal reservoirs and environmental regulations. In Pakistan, there may be limitations on where geothermal projects can be developed due to geological and environmental constraints.

10.7.2 Opportunities

a. **Large Potential Resource**: Pakistan has a large potential resource for geothermal energy, with several areas identified as having high geothermal potential. This provides an opportunity to develop geothermal projects and reduce the country's dependence on fossil fuels.

b. **Energy Security:** Developing geothermal projects can help Pakistan achieve energy security by diversifying its energy mix and reducing its reliance on imported energy sources.

c. **Job Creation:** The development of geothermal projects can create new job opportunities, both in the construction and operation of geothermal facilities, as well as in related industries such as manufacturing and maintenance. This can have a positive impact on local economies and communities.

d. **Environmental Benefits:** Geothermal energy is a clean and renewable energy source that does not produce greenhouse gas emissions or air pollution. Developing geothermal projects can help Pakistan reduce its carbon footprint and contribute to global efforts to combat climate change.

10.8 Energy Efficiency

10.8.1 Introduction

Energy efficiency has become a crucial aspect of sustainable development in Pakistan due to the increasing demand for energy resources and the country's energy crisis. The building sector accounts for a significant portion of the country's energy consumption, making it an ideal area for the application of geothermal technology. This section will discuss the concept of energy efficiency in buildings, the role of geothermal technology in promoting energy efficiency, and relevant case studies in Pakistan.

10.8.2 Energy Efficiency in Buildings

Energy efficiency in buildings refers to the utilization of technology and design strategies that reduce energy consumption while maintaining the same level of comfort and functionality. Buildings with high energy efficiency are designed to reduce energy losses through proper insulation, efficient Heating, Ventilation, and Air Conditioning (HVAC) systems, and use of natural light. In Pakistan, the building sector accounts for about 30% of the country's total energy consumption, which makes it an ideal area for promoting energy efficiency measures.

10.8.3 Geothermal Technology and Energy Efficiency

Geothermal technology is an excellent solution to promote energy efficiency in buildings. It provides heating and cooling through a sustainable and cost-effective source of energy, which reduces the dependency on fossil fuels. The use of geothermal systems in buildings can significantly reduce energy consumption and greenhouse gas emissions. Moreover, geothermal systems have a longer lifespan than traditional HVAC systems, which reduces maintenance costs and increases the durability of the building.

The amount of pipe required for a geothermal system depends on several factors, such as the size of the building, the heat load, and the type of geothermal system being installed. However, as a general rule of thumb, a typical horizontal loop system requires between 400 to 600 feet of pipe per ton of heating and cooling capacity.

For a vertical loop system, the amount of pipe required will depend on the depth of the borehole and the geological conditions at the site. Typically, vertical loop systems require between 150 to 200 feet of pipe per ton of heating and cooling capacity.

It is important to note that these estimates are only rough guidelines, and the actual amount of pipe required will vary depending on the specific details of the project. A qualified geothermal installer or engineer can help determine the appropriate amount of pipe required for a given project.

The amount of energy that geothermal technology can provide to a residential house in Pakistan will depend on several factors, including the size of the house, the specific geothermal system being used, and the geological conditions at the site.

In general, geothermal heat pump systems can provide up to 70% savings on heating and cooling energy consumption compared to traditional HVAC systems, which can result in significant cost savings over time.

In Pakistan, the use of geothermal technology is limited due to the lack of knowledge, expertise, and infrastructure. However, there is potential for the use of geothermal systems in areas such as the Baluchistan province, which has hot springs and geothermal resources that could be utilized for heating and cooling applications.

Overall, the amount of energy that geothermal technology can provide to a residential house in Pakistan will depend on a range of factors, and it is important to consult with a qualified geothermal installer or engineer to determine the appropriate system and size for a given project.

10.8.4 Case Studies

There are several case studies in Pakistan that demonstrate the application of geothermal technology in promoting energy efficiency in buildings. One such example is the installation of geothermal HVAC systems in the National University of Sciences and Technology (NUST) campus in Islamabad. The project was completed in 2011, and the installation of the geothermal system has reduced the energy consumption of the campus by 55%[4].

Also, the GeoAirCon, also known as Geothermal Pakistan, installed the geothermal system which has a capacity of 20 tons, and will cater more than 100 students at Lawa, Namal University hostels, with a remarkably low power requirement of less than 2.4 kW[5].

10.9 Administration and Enforcement

10.9.1 Administration and Enforcement

To encourage the usage of geothermal technology in building construction for the purpose of energy efficiency, it is important to establish an effective administration and enforcement framework. This framework should aim to ensure that all building projects comply with the relevant standards and guidelines.

10.9.2 Compliance Requirements

To ensure compliance with the relevant standards and guidelines, the following mandatory requirements should be in place:

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[4] Pakistan Council of Renewable Energy Technologies (PCRET). (2011). Geothermal energy in Pakistan: current status and future prospects. Islamabad, Pakistan: Ministry of Science and Technology. Link: http://www.pcret.gov.pk/reports/Geothermal%20Energy%20in%20Pakistan%20-%20Current%20Status%20and%20Future%20Prospects.pdf

[5] https://www.linkedin.com/posts/geoaircon_sustainability-geothermal-sustainablepakistan-activity-7005242464550727680-BWLR?utm_source=share&utm_medium=member_desktop

10.9.3 Mandatory Requirements

All new buildings and building alterations must meet the minimum requirements for energy efficiency as outlined in the relevant building codes and regulations.

10.9.4 New Buildings

For new buildings, the usage of geothermal technology for heating, cooling, and hot water should be considered as a mandatory requirement. The design and installation of the geothermal system should be carried out by licensed professionals with expertise in geothermal technology.

10.9.5 Alterations to Existing Buildings

For alterations to existing buildings, the following areas should be considered for the usage of geothermal technology:

a. **Building Envelope**

   The building envelope should be evaluated for opportunities to improve energy efficiency. This may include the installation of insulation, weatherstripping, and the replacement of windows and doors with more energy-efficient options.

b. **Heating, Ventilation and Air Conditioning**

   The heating, ventilation, and air conditioning (HVAC) systems should be evaluated for opportunities to improve energy efficiency. This may include the installation of geothermal heat pumps for heating and cooling.

c. **Service Water Heating**

The service water heating system should be evaluated for opportunities to improve energy efficiency. This may include the installation of geothermal heat pumps for hot water.

d. Lighting

The lighting system should be evaluated for opportunities to improve energy efficiency. This may include the installation of energy-efficient lighting fixtures and controls.

e. Electric Power System and Motors

The electric power system and motors should be evaluated for opportunities to improve energy efficiency. This may include the installation of energy-efficient motors and the use of renewable energy sources such as solar panels.

10.9.6 Administrative Requirements

The administrative requirements for compliance should include the establishment of a geothermal technology certification program for professionals and contractors involved in the design and installation of geothermal systems. This program should ensure that all professionals and contractors are adequately trained in the design and installation of geothermal systems.

10.9.7 Compliance Documents

Compliance documents should include plans, drawings, specifications, and other relevant documentation that demonstrate compliance with the relevant building codes and regulations. These documents should be submitted to the relevant authorities for review and approval.

10.9.8 Supplementary Information

Supplementary information should be provided to building owners and occupants to promote the benefits of geothermal technology and encourage its usage. This may include information on energy savings, environmental benefits, and available incentives and financing options. Collaboration with international organizations and countries that have extensive experience in geothermal technology can also help promote its usage in Pakistan.

10.10 Conclusion

10.10.1 Summary of Findings

Geothermal technology has significant potential for promoting energy efficiency in buildings in Pakistan. The country has a vast potential for geothermal resources, and several projects have been implemented to utilize this energy source. The application of geothermal systems in buildings can significantly reduce energy consumption and greenhouse gas emissions while providing a sustainable and cost-effective source of energy.

10.10.2 Implications and Recommendations

The government of Pakistan needs to promote the use of geothermal technology in buildings through policies and incentives. This will encourage developers and building owners to invest in geothermal systems and promote sustainable development in the country. Moreover, awareness campaigns and training programs should be conducted to educate the public about the benefits of geothermal technology and its potential for promoting energy efficiency in buildings.

10.10.3 Future Directions

In the future, there is a need to conduct further research on the potential of geothermal resources in Pakistan and develop innovative designs for geothermal systems to make them more efficient and cost-effective. Furthermore, collaborations with international organizations and countries that have extensive experience in geothermal technology can help Pakistan in achieving sustainable development through the promotion of energy efficiency in buildings.

NEECA

Section-11

11. Renewable Energy

11.1 Introduction

Solar PV Quality is a big concern in Pakistan and non-standard and low-quality equipment are being dumped in Pakistan. There is a need to impose standards at import, design and installation of solar systems. Because of no standardization, the customers do not look satisfied from performance of solar system deployments.

The installation of photovoltaic (PV) equipment is governed by a number of industry codes and standards. Electrical contractors need to be aware of the codes and standards to ensure a safe and functional PV installation. This document will briefly discuss the *International Electrotechnical Commission (IEC) Standards, National Electrical Code (NEC)* requirements as well as *The Institute of Electrical and Electronics Engineers Inc. (IEEE)* interconnection standards.

11.2 International Standards and Best Practices

11.2.1 International Electrotechnical Commission (IEC) Standards

IEC standards are available and are widely being practiced in Pakistan in electrical sector and the same should be implemented for design, installation, commissioning and performance of solar systems in Pakistan. PV is an international business in terms of supply of materials, manufacturing of products and deployment of products. If each country or region had its own set of standards it would be confusing, time consuming and expensive to participate in these markets. Imagine if a module manufacturer would have to pass different qualification test sequences or even measure their products in different ways for each national market. The result would be chaos and much higher product costs. Also imagine if a material supplier or cell manufacturer would have to meet a different specification in each market and have to provide different product specifications for each different market. One set of worldwide standards helps make PV cost effective. It also allows developers of new technologies or new materials to know what specifications and tests they are going to have to qualify before they can commercialize those products. The International Electrotechnical Commission (IEC) is the leading global organization that develops and publishes consensus-based International Standards for electric and electronic products, systems and services, collectively known as electrotechnology. The following is a list of the IEC standards on PV modules (and devices) published by TC82. The list includes details on which edition is now current and what year that edition was published.

a. IEC 61215-1:2021 - Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements
b. IEC 61730-1:2016 Ed 1- Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction
c. IEC 61730-2:2016 Ed 1 - Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing
d. IEC 61701:2020 Photovoltaic (PV) modules - Salt mist corrosion testing
e. IEC 61726:2013 Photovoltaic (PV) modules - Ammonia corrosion testing

IEC-60068-2-68 Environmental testing - Part 2-68: Tests - Test L: Dust and sand

11.2.2 National Electrical Code

Even though PV arrays produce low-voltage direct current (DC) power, PV systems can be hazardous if not installed correctly and are therefore addressed in the *NEC*. In almost all applications, the low-voltage DC power produced by the PV array is converted to standard alternating current (AC) voltages to serve building loads and may also be interconnected with the utility grid through the building's service entrance.

NEC Sections Applicable to PV Systems

1. Article 110: Requirements for Electrical Installations
2. Chapter 2: Wiring and Protection Most of the chapter—especially

3. Article 250: Grounding
4. Chapter 3: Wiring Methods and Materials Most of the chapter—especially
5. Article 300: Wiring Methods
6. Article 310: Conductors for General Wiring
7. Article 480: Storage Batteries
8. Article 690: Solar Photovoltaic Systems

   A. Chapter 6 addresses special equipment and includes Article 690: "Solar Photovoltaic Systems." Article 690 covers the wiring of the PV arrays as well as the installation of inverters and controllers. The method for determining the minimum conductor sizes and overcurrent device ratings throughout the PV system based on the characteristics of the PV panels, inverters and other equipment is provided Part II. Part III states the requirements for the location, rating and installation of disconnect switches throughout the PV system. Parts IV and V address PV-system wiring methods and grounding. Interconnection with the building's distribution system and ultimately the utility grid is covered in Part VII. Part VIII addresses the installation of storage batteries and chargers.

   B. Article 705- "Interconnected Electric Power Production Sources"-applies to PV systems that are interconnected to other power sources such as the serving electric utility's system or on-site generator.

11.3 Interconnection standards

Connecting the facility's PV system to the serving utility's system provides a number of potential advantages to both the facility's owner and utility. A grid-connected PV system allows power to flow to and from the building depending on the building load at any instant relative to the amount of power being produced by the PV system. Excess power can be sold to the utility at a predetermined rate or exchanged for utility power when the facility has a power deficit such as at night. PV system output usually tracks utility demand. Its peak output occurs midday when the utility experiences its peak demand and the cost of utility power production is highest. A grid-connected PV system can also eliminate the owner's need to install expensive battery banks or backup generators that have ongoing operating and maintenance costs, which will make the PV system a less attractive investment.

A major barrier to grid-connected PV has been the lack of standards for interconnecting the facility's PV system with the utility's system. Different utilities, even with adjacent service areas, often have different policies and requirements for connecting on-site distributed generation to their systems. Two standards have been developed by the IEEE aimed at standardizing the requirements for interconnecting PV systems with the serving utility's system:

1. 1547-2003: Standard for Interconnecting Distributed Resources with Electric Power Systems
2. 929-2000: Recommended Practice for Utility Interface of Residential and Intermediate Photovoltaic (PV) Systems

IEEE Standard 1547 establishes recommended practices for interconnecting distributed generation technologies with the electric grid. The goal of these recommended practices is to promote the use of alternative energy sources and make connecting to the utility grid economical for the building owner.

11.3.1 IEEE Standard 929

IEEE Standard 929 specifically addresses the interconnection of photovoltaic systems generating 10 kilowatts or less to the utility grid but can be applied to PV systems of any size. Many utilities require that small- to medium-sized PV systems comply with the same interconnection requirements that apply to very large rotating generators such as those found in industrial cogeneration. These requirements are not practical for PV systems and can be a roadblock to PV installation. IEEE Standard 929 simplifies the PV system interconnection with the utility grid with the objective of safety for linemen, safeguarding the utility's equipment and protecting the utility customer. The use of PV inverters that comply with IEEE Standard 929 reduces the cost of meeting interconnection requirements and helps remove another barrier to widespread PV use.

There is a need to put standardization at three levels.

> ***First*** *level is the import and local assembling of Solar PV components.*
>
> ***Second*** *level is the design of solar systems. In case of building and housing sector there are Architects duly licensed by PCATP and PEC for design of buildings in Pakistan and building is designed by approved and Licensed Engineers but in case of solar designing there is no such authority for license to designers for solar systems.*
>
> ***Third*** *level is the installation, commissioning and Performance Monitoring. In this case also there is no authority providing certification to installers for certified installations of solar systems. There is no concept of certified installers in Pakistan.*

The solar industry in Pakistan is currently in its early stages of growth, with over 2000 companies operating in the country. However, there is a lack of quality assurance and standardization in Pakistan when it comes to importing, designing, installing, and monitoring the performance of solar systems. Currently, there is no recognition or certification for qualified solar designers, engineers, technicians, and installers in the field of solar energy in Pakistan. To ensure quality standards, it is important to implement the International Electro technical Commission (IEC) standards and NEC Codes in Pakistan.

11.4 IEC Standards for Solar Components

11.4.1 Solar PV modules standards

IEC standards for Solar PV crystalline modules are IEC 61215 and IEC 61730. IEC standard IEC 61215 is Design and Qualification standard and IEC 61730 is safety standard. International Accredited Labs like TUV and UL certifies the solar PV modules as per IEC standards and import of solar panels should be banned which are not certified from International accredited Laboratories as per IEC standard 61215 and 61730. The latest version is IEC 61215-2:2016 and it is intended to apply to all terrestrial flat plate module materials such as crystalline silicon module types as well as thin-film modules. The objective of this test sequence is to determine the electrical and thermal characteristics of the module and to show, as far as possible within reasonable constraints of cost and time, that the module is capable of withstanding prolonged exposure in general open-air climates. The actual lifetime expectancy of modules so qualified will depend on their design, their environment and the conditions under which they are operated. There are about 18 to 20 tests and all are outdoor tests because solar panels have to stay in outdoor environments and they are tested in outdoor environments and if all tests are passed, then you can say that solar panels will give 25 years limited performance which means that in first 10 years 90% and next 15 years 80%.

11.4.2 Solar Inverters Standards

IEC standard IEC 62109 is safety of Power Converters for use in Photovoltaic Power Systems. Part-1 is General requirements and part-2 relates to Photovoltaic requirements. IEC 62109-1:2010 applies to the power conversion equipment (PCE) for use in photovoltaic systems where a uniform technical level with respect to safety is necessary. It defines the minimum requirements for the design and manufacture of PCE for protection against electric shock, energy, fire, mechanical and other hazards. Provides general requirements applicable to all types of PV PCE. IEC 62109-2:2011 covers the particular safety requirements relevant to DC. to AC inverter products as well as products that have or perform inverter functions in addition to other functions, where the inverter is intended for use in photovoltaic power systems. Inverters covered by this standard may be grid-interactive, stand-alone, or multiple mode inverters, may be supplied by single or multiple photovoltaic modules grouped in various array configurations, and may be intended for use in conjunction with batteries or other forms of energy storage. This standard must be used jointly with IEC 62109-1.

IEC 62109 is the standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources. These requirements cover inverters, converters, charge controllers, and interconnection system equipment (ISE) intended for use in stand-alone or grid-connected power systems.

11.4.3 Solar Charge Controllers Standard

IEC 62509 is a standard for Battery charge controller for photovoltaic systems and it relates to Performance and monitoring of charge controllers. IEC 62509:2010 establishes minimum requirements for the functioning and performance of battery charge controllers (BCC) used with lead acid batteries in terrestrial photovoltaic systems. The main aims are to ensure BCC reliability and to maximize the life of the battery.

11.4.4 Solar Battery Standards

IEC 60896 is a standard for Valve Regulated Stationary lead acid batteries and part -21 relates to method of test of stationary lead acid batteries and Part-22 relates to Type Requirements. IEC 60896-21-2004 applies to all stationary lead-acid cells and mono-block batteries of the valve regulated type for float charge applications, (i.e., permanently connected to a load and to a DC power supply), in a static location (i.e., not generally intended to be moved from place to place) and incorporated into stationary equipment or installed in battery rooms for use in telecom, uninterruptible power supply (UPS), utility switching, emergency power or similar applications. The objective of this part of IEC 60896 is to specify the methods of test for all types and construction of valve regulated stationary lead acid cells and mono-block batteries used in standby power applications. IEC 60896-22-2004 applies to all stationary lead-acid cells and mono-block batteries of the valve regulated type for float charge applications, (i.e., permanently connected to a load and to a DC power supply), in a static location (i.e., not generally intended to be moved from place to place) and incorporated into stationary equipment or installed in battery rooms for use in telecom, uninterruptible power supply (UPS), utility switching, emergency power or similar applications. The objective of this part of IEC 60896 is to assist the specifier in the understanding of the purpose of each test contained within IEC 60896-21 and provide guidance on a suitable requirement that will result in the battery meeting the needs of a particular industry application and operational condition. This standard is used in conjunction with the common test methods described in IEC 60896-21 and is associated with all types and construction of valve regulated stationary lead-acid cells and mono-blocks used in standby power applications.

IEC 61427:2015 is a standard for secondary cell and batteries for renewable energy storage General requirements and method of test and part-1 relates to photovoltaic off-grid applications and Part-2 relates to On-Grid Applications.

11.4.5 Solar Cable Standard

EN 50618:2014 is the standard for cables for photovoltaic applications. There is a new European Standard EN 50618 published in 2014 for Solar DC Cable, which specifies cables for use in Photovoltaic (PV) systems, and in particular those for installation at Direct Current (DC) side with a nominal DC voltage of up to 1.5kV between conductors as well as between conductor and earth. EN 50618 requires cables to be low smoke zero halogen and be flexible tin-coated copper conductors with a single core and cross-linked insulation and sheath. Cables are required to be tested at a voltage of 11kV AC 50Hz.

11.4.6 Solar PV Performance Standard

IEC 61724 is a standard for Photovoltaic Performance Monitoring. This standard recommends procedures for the monitoring of energy-related photovoltaic (PV) system characteristics, and for the exchange and analysis of monitored data. The purpose is the assessment of the overall performance of PV systems.

11.5 Reasons for Implementation of Codes for Solar PV Installation

The installation of rooftop solar PV systems raises issues related to building, fire, and electrical codes. Because rooftop solar is a relatively new technology and often added to a building after it is constructed, some code provisions may need to be modified to ensure that solar PV systems can be accommodated while achieving the goals of the codes. Some primary code issues that impact rooftop PV installations include:

a) Restrictive or ambiguous language written into the codes;
b) Lag time between the release of updated model codes and new PV industry best practices and the widespread adoption of the codes and best practices;
c) Variation across jurisdictions in which code editions and amendments are adopted; and
d) Inconsistent, inefficient, or improper enforcement of codes.

Building, fire, and electrical codes should be adopted across the nation. The federal government should issue the codes while provincial government through its local government should implement at the municipality level. It can provide a level of consistency and uniformity to the industry that reduces costs and achieve safe and sustainable systems.

Authorities having jurisdiction (AHJs) may have different, and in some cases overlapping, powers and responsibilities over the solar installation process. For example, AHJs responsible for implementing building and fire codes may include state fire marshals, county building and health departments, and local development authorities and fire departments.

Code enforcement is essential to ensuring that rules are followed and properly implemented. Even well designed and unambiguous codes can fail to achieve their purpose if building inspectors, permitting staff, fire marshals, and other personnel lack the training and other support to correctly and consistently apply code standards. In many cases, regardless of whether code adoption is a state-level function or a local jurisdiction-level function, code enforcement is performed by local jurisdictions.

Although local authority leverages local expertise and provides local governments with flexibility, variation across jurisdictions can add complexity and additional permitting and other compliance costs for solar installers, as well as inconsistencies in PV inspections.

These issues are of particular concern to solar installers who work in multiple jurisdictions, as well as state-level program administrators tasked with overseeing statewide solar implementation programs. State-level policymakers and solar program administrators can help address these issues by providing local jurisdictions guidance and other support resources to foster greater consistency in code adoption and enforcement as it pertains to PV installation.

11.6 Building Codes

Building codes set minimum standards for structures and buildings to protect public health, safety, and welfare. Building code requirements related to installation, materials, wind resistance, and fire classification can help ensure the safe installation and operation of PV systems. AHJs typically require a PV system to pass a permitting and inspection process prior to commissioning. Inconsistency across AHJs in building code adoption and amendments can create challenges for solar installers and contractors. The permitting and inspection process can be lengthy, costly, and uncertain in some jurisdictions.

Model building codes assist AHJs in creating uniformity in their building codes. Often, AHJs will adopt amendments or modifications to model building codes to meet local preferences or circumstances. Building codes in most states and local jurisdictions in the country are based on various editions of the International Code Council's model building and residential codes. The International Residential Code, which applies to detached one- and two-family dwellings and townhouses three stories or less, and the International Building Code, which applies to buildings and structures not covered by the International Residential Code, have been widely adopted.

Still, there is significant variation across jurisdictions in how quickly updated editions of the model codes are adopted.

The current versions of the International Residential Code and the International Building Code require rack-mounted rooftop PV systems to be installed according to the manufacturer's instructions, the National Electrical Code, and Underwriters Laboratories product safety standards [such as UL 1703 (PV modules) and UL 1741 (Inverters)], which are design requirements and testing specifications for PV-related equipment safety (see Equipment Standards below).5

The International Residential Code also requires that:

a. The roof be structurally capable of supporting the load of the modules and racking;
b. The modules and racking be non-combustible; and
c. Roof or wall penetrations (such as to attach the racking to the roof) be flashed and sealed to prevent water, rodents, or insects from entry.

The International Building Code also:

a. Requires that rooftop solar systems have the same fire classification as the roof assembly;6 and
b. Establishes criteria for calculating the minimum design loads for rooftop solar PV systems, including guidance on wind load engineering calculations.7

These model codes are updated every three years to integrate emerging industry best practices, although states vary in how quickly or even if they adopt updated codes. In addition to timely review and adoption of updated versions of model codes, officials can create innovative policies that go above and beyond the solar-related provisions in the model codes, to further encourage and streamline solar installations. Importantly, ambiguous or overly restrictive provisions in building codes can create unintended barriers for solar installations without providing additional benefits. The increasing popularity of rooftop PV installations and the pace at which solar technologies evolve mean that officials may need to evaluate building code provisions specific to rooftop solar periodically.

In 2010, Oregon enacted the first statewide solar code in the nation.8 The Oregon Solar Installation Specialty Code has been included in the Oregon Structural Specialty Code and is applied in conjunction with Oregon's Electrical Specialty Code. Together, Oregon's solar installation code and electrical code standardize requirements for the installation, repair, or maintenance of residential and commercial PV systems. The code includes:

A prescriptive pathway to expedite permitting for installations that meet requirements relating to:

1. Building type, roof structure, and material requirements;
2. Loading requirements (not to exceed 4.5 pounds per square foot);
3. Height restrictions (not to exceed 18 inches above the roof); and
4. Positive attachment to the roof structure (rather than ballasted systems);

Minimum structural requirements for the installation of PV components and support systems; and Guidance for how AHJs should process building permits applications and determines fees, including a flat fee for prescriptive pathway applications.

The Building Code Division within the Oregon Department of Consumer and Business Services created a *checklist* for installers to easily determine eligibility for the prescriptive pathway. By expansively covering topics related to PV installation, Oregon's solar installation code and structural code reduce uncertainty and inconsistency in the review and enforcement of technical installation requirements and the procedural permitting processes. The stability and standardization afforded by such an approach can foster solar market growth and development.

11.6.1 Solar Ready Buildings

Local governments can encourage homebuilders and developers to design and erect buildings that make it easy to add a rooftop solar PV system in the future. A "solar ready" building can offer substantial cost savings compared to retrofitting a building for a PV system. The 2015 IRC includes "Solar-Ready Provisions" in an optional Appendix U that AHJs can elect to adopt.11

Incorporating a few key design considerations in new or significantly modified buildings goes a long way in reducing costs associated with installing a PV system. Elements in building codes that can facilitate future rooftop PV installations include requirements to:

1. Minimize rooftop equipment, or group it on a building's north side,12 to leave ample contiguous space for a future rooftop PV system;
2. Designate a section of the roof as a "Solar-Ready Zone" or "Solar-Ready Roof" that is reserved for a future solar PV system;
3. Orient the building in a north-south manner to the extent possible and avoid placing the building or landscaping in a manner that results in significant rooftop shading;
4. Plan for and document the interconnection pathways to clearly delineate the routing of conduit for a future rooftop PV system to the electrical service panel; and,

Include detailed roof specifications in building plans so solar installers can confirm the roof can structurally support a PV system without additional (and often expensive) engineering studies.

AHJs can take many policy approaches to encourage developers to make solar-ready buildings, such as rebates or other cash incentives, streamlined permitting, "green building" certification, or acknowledgement for solar-ready buildings. Solar-ready building features can also be required for certain types of new housing or commercial property development.

Some local jurisdictions have gone even further by *requiring* PV installation on some buildings.

11.7 Permitting and Inspection

Most local governments require a building permit prior to the installation of a PV system to ensure the system meets engineering and safety standards. After installation of a PV system is completed and prior to it being energized, a system inspection is often required to ensure code compliance. Rooftop system inspections are often performed at the local government level by building inspectors. It is worth noting that permitting and inspection have limitations. The permitting and inspection process usually does not consider whether the system is designed and installed to maximize performance. A system located in the shade may not produce any energy, but still pass code inspection, for example

Although solar permitting and inspection help ensure a minimum level of safety, lengthy or overly complicated permitting processes can impede solar deployment. Permitting fees that exceed the administrative cost of processing a solar permit can unfairly penalize new PV systems.

A streamlined permitting process can be established for small rooftop PV systems or those meeting a standard set of design criteria. Establishing standard design criteria allows installers to know in advance that a PV system will be approved if it is designed to code, thereby reducing the uncertainty, time, and costs associated with additional engineering studies or redoing an incomplete or incorrect permit application. Standard design criteria can also help AHJs that do not have extensive experience with solar to understand whether a system meets basic minimum code requirements.

Often, a good place for AHJs to start is by explicitly identifying their current solar permitting and inspection process in detail, including each step of the process, who reviews various elements of the permit application, and which departments are involved. By making this internal process explicit, officials can identify where administrative efficiency can be improved and prepare staff for when a permit application is submitted. It may prove fruitful to implement improvements, such as online permitting, not only for PV systems but globally across all areas of the AHJ’s permitting authority. Generally, AHJs should adhere to the following guidelines:

Provide clear, publicly available, easily accessible information about solar permitting and inspection processes and make these materials available online;

- Standardize and consider reducing application fees, particularly for more uniform system applications, such as rooftop PV systems; and

Reduce the time period between permit application and approval, and project completion and inspection, and/or establish a standard processing window to increase process certainty for contractors

The Interstate Renewable Energy Council (IREC) has published an overview of permitting and inspection best practices. IREC recommends policymakers consider the following best practices when adopting residential solar permitting rules:

1. Post requirements online
2. Implement an expedited permit process
3. Enable online permit processing
4. Require fast turnaround time
5. Implement reasonable permitting fees
6. Do not require community-specific licenses
7. Offer a narrow inspection appointment window
8. Eliminate excessive inspections
9. Train permitting staff in solar

11.8 Fire Codes

Rooftop PV systems present special considerations for fire- fighters and first responders. Potential system hazards include tripping, structural collapse due to extra weight from the system, fire spread (depending on the materials used), inhalation exposure to toxic materials, electrical shock, and other hazards if battery energy storage systems are also present. Fire codes are designed to minimize the risk of fire, protect public health and safety, and safeguard firefighters and other emergency responders.

In addition to the International Fire Code (IFC), the National Fire Protection Association (NFPA) produces the NFPA 1 Fire Code. Both codes have been adopted by AHJs in the United States. Ideally, fire codes should strike a careful balance of ensuring firefighters can effectively and safely do their jobs while at the same time allowing consumers to maximize their solar PV potential. Various versions of the IFC have been adopted or are in use by AHJs in 42 states and the District of Columbia (see Figure 1, page 13). Both the Clean Energy States Alliance and the International Association of Fire Fighters in conjunction with the Interstate Renewable Energy Council, among others, offer online PV fire training resources for first responders.

Recent versions of the IFC include sections specific to PV systems and their electrical components, as well as more generic requirements that apply to these systems. The 2015 IFC requires that PV systems obtain a permit and be installed according to the International Building Code or International Residential Code and the National Electrical Code (NFPA 70). Provisions within the National Electrical Code are particularly critical to first responder safety and are provided in greater detail in the following section.

11.8.1 Pathways, Spacing, and Setbacks

Fire codes can address the location of rooftop PV systems, in order to minimize tripping and electrocution hazards and to provide first responders access to roof space. Firefighters can require access to the roof during a fire, especially for the purpose of vertical ventilation (i.e., making a hole in the roof in order to allow heated gas and smoke to escape from the building). The IFC provides an exception to roof ridge clearance requirements where an alternative ventilation method approved by the fire chief is provided or where the fire chief determines that vertical ventilation techniques would not be required

11.9 Electrical Codes

The National Electrical Code (NEC) provides comprehensive electrical safety design, installation, and inspection requirements for electrical conductors, equipment, and raceways related to a solar PV system. The NEC, also called the NFPA 70, is developed by the National Fire Protection Association (NFPA) and updated every three years. The NEC 2014 has been adopted by 35 states as of October 2016. In some states, however, local jurisdictions have primary or complete authority over electrical code adoption.

The NEC devotes two of its articles to addressing solar PV systems: Article 690 (Solar Electric Systems) and Article 705 (Interconnected Electrical Power Production Sources). These articles are key to the safe installation and operation of PV systems. The NEC requires that “qualified” individuals install solar panels, but it does not define the criteria for vetting installers, resulting in differing state and local government interpretation (see Licensing and Certification, page 21). Revisions in the past several code cycles have contained important updates designed to protect firefighters, contractors, installers, and homeowners. For example, in 2011, the NEC was amended to expand labeling requirements for all PV systems. Rapid shut down and disconnection device provisions have been a major topic of discussion in the 2014 and 2017 NEC updates

11.9.1 Signage and Labeling

Signage and labeling requirements are important safety elements because they alert firefighters to electrocution hazards from PV system equipment. Even when all the circuit breakers have been shut off and a rooftop disconnect has been used, electricity can flow from the panels through DC wiring, creating an electrocution risk. Identification, signage and labeling requirements are specified in detail in the NEC. The IFC requires that systems comply with the National Electrical Code. Electrical components connected to a PV system must meet requirements that detail where, when, and how labels are applied. The main service panel should be clearly labeled to alert firefighters to the presence of a PV system. Systems should have a dedicated, clearly labeled breaker for the inverter, in addition to DC (direct current) conduit runs and other electrical wiring and components.

11.9.2 Rapid Shutdown and Disconnect Devices

When responding to a fire, firefighters reduce electrical shock risk by opening an AC (alternating current) service disconnect, thereby shutting off power flowing from the grid to the building. With a rooftop PV system, mitigating the risk of electrical shock becomes substantially more challenging since opening an AC service disconnect does not address the DC flowing from the PV modules to the inverter. Moreover, a DC disconnect device, while stopping the flow of current, would generally not provide voltage isolation, as lethal voltages can still occur on PV system output circuits for five minutes after disconnect due to energy stored in DC capacitors. Thus, a DC disconnect device can provide a false sense of security to firefighters since the shock hazard would not have been completely mitigated in the panels and DC wiring, while adding a substantial additional expense to the cost of a PV system. Consequently, the solar industry has been working to help develop codes and standards related to rapid shutdown to address the electrical shock hazard to emergency responders.

An important addition to the NEC 2014 essentially requires rooftop PV systems to have the ability to very quickly reduce voltage to non-lethal levels in the event of an emergency. This rapid shutdown provision represents a substantial safety improvement for firefighters and first responders by mitigating the risk of electrical shock when responding to emergency situations. The NEC 2014 also requires that when a rooftop DC disconnect device is used, it contains warning labels indicating the presence of a shock hazard even when in the open (i.e., “off”) position.

While some stakeholders initially sought to add rapid shutdown provisions at the level of individual PV modules during the drafting of the NEC 2014, that provision was modified following collaborative stakeholder input. The NEC 2014 as adopted includes a provision requiring array-level-only rapid shutdown capabilities, which can be achieved through a variety of system designs and technologies. This modification stemmed from concerns the solar industry expressed related to the availability of equipment compliant with the proposed requirement. Some technologies such as DC optimizers and micro inverters comply with the NEC 2014 rapid shutdown requirements, whereas systems with conventional string inverters need additional equipment to comply.

Some states elected not to adopt the rapid shutdown requirements when adopting updated electrical codes. Moreover, some AHJ inspectors in states adopting the 2014 NEC rapid shut down provisions have not consistently enforced the provisions. Similarly, some AHJs responded to changes to the NEC 2011 regarding arc-fault requirements which are designed to protect against arcing faults (a high-power discharge that could start an electrical fire) in PV system components and wiring through use of a protective device, by waiving or delaying enforcement of the provision to allow time for devices to comply with the applicable product safety standard.

The NEC 2017 was issued by NFPA in August 2016. As of January 1, 2017, it has been adopted by Massachusetts, with 23 other states in the process of adopting it. It includes compromise provisions on rapid shutdown requirements including a delayed effective date of January 1, 2019, to allow for the industry to develop product safety standards. The NEC 2017 will also allow three different compliance options for rapid shutdown. Other changes to the NEC 2017 are aimed at reducing confusion among PV installers and inspectors, improving overall safety, eliminating superfluous warning signage requirements, cutting provisions on center-fed panel boards that resulted in unnecessary expenses (as implemented by some AHJs), and substantially improving accuracy in calculations that allow for better sizing of system components.

These examples underscore how code requirements can push technological innovation to improve safety. Ongoing discussions regarding provisions such as rapid shutdown requirements, however, also demonstrate that implementing code provisions can be challenging and costly. Collaborative and transparent code adoption processes can help alert officials to both industry and first responder concerns and creates a forum where both innovation and compromise are possible.

11.10 Planning and Zoning for Solar

Zoning regulations can significantly impact where and how solar development can occur in a community. Critical components of zoning regulations related to rooftop PV systems include height restrictions and setbacks, applicability of these restrictions to PV systems, and whether additional permits or zoning variances are needed to install a PV system. Zoning ordinances and building codes often require that structures meet specific minimum setbacks from property lines or that rooftop equipment (such as PV panels) be set back from the edge of the roof. Similarly, building height regulations restrict the height of development for specific types of buildings and structures. Some of these ordinances may unnecessarily apply to PV installations and impose unintended burdens on solar development goals.

11.11 Important Considerations for Solar Designers

The codes are created to ensure the safety, reliability, and efficiency of renewable energy systems, which include solar photovoltaic (PV) systems, and energy storage systems domestic, commercial & industrial buildings in both public and private sectors.

While designing the Solar PV system requires the following equipment:

i. Solar Power Generation system consisting of required number of PV Modules.

ii. Efficient On-Grid/Hybrid Inverters

iii. Mounting structures

iv. Cables and hardware

v. Miscellaneous Item

   a. Junction box and distribution boxes
   b. Earthing kit
   c. Lightning arrestors
   d. PVC pipes and accessories
   e. Control room and civil pedestals

11.11.1 Energy Audit of building

Ensure energy audit of building and calculate its electrical load and propose best solution for the replacement of conventional electrical appliances with energy efficient to reduce the load and cost of solar system.

11.11.2 Space Availability

Ensuring space availability on roof of the building or ground with protection fence for solar system.

11.11.3 Spacing

1. 4 feet minimum clear space shall be kept on all sides of solar PV plant for accessibility purpose for installation, operation and maintenance etc.
2. The height of the last panel in the structure from the ground multiply a factor of 2 and that shall be kept minimum distance between two rows.
3. The lowest point of solar panel in structure should be kept at least 1 foot above roof or ground level.

11.11.4 PV Module Efficiency

The term efficiency is thrown around a lot but a slightly more efficient panel **doesn't always** equate to a better-quality panel. Many people consider efficiency to be the most important criteria when selecting a solar panel, but what matters most is the manufacturing quality which is related to real world performance, reliability, manufacturers service, and warranty conditions.

1. Comply the latest and best efficient PV Module for design more than 20 % module efficiency.
2. Latest Cell types N-type IBC & N type IBC half cut, P or N type HJT half cut, N-type Topcon half cut must be given priority due to higher efficiency, low LID (Light induced degradations)

3. The PV module(s) Mono crystalline /poly crystalline silicon solar cells are less efficient nowadays and most of the manufactures are shifted towards production of new cell types of higher efficiencies.

Efficiency of panels using different cell types

1) Polycrystalline - 15 to 18%
2) Monocrystalline - 16.5 to 19%
3) Polycrystalline PERC - 17 to 19.5%
4) Monocrystalline PERC - 17.5 to 20%
5) Monocrystalline N-type - 19 to 20.5%
6) Monocrystalline N-type TOPcon - 20 to 22.4%
7) Monocrystalline N-type HJT - 20.5 to 22.6%
8) Monocrystalline N-type IBC - 20.8 to 22.8%

11.11.5 Faster Payback

In environmental terms, increased efficiency generally means a solar panel will pay back the embodied energy (energy used to extract the raw materials and manufacture the solar panel) in less time. Based on detailed lifecycle analysis, most silicon-based solar panels already repay the embodied energy within two years, depending on the location. However, as panel efficiency has increased beyond 20%, payback time has reduced to less than 1.5 years in many locations. Increased efficiency also means a solar system will generate more electricity over the average 20+ year life of a solar panel and repay the upfront cost sooner, meaning the return on investment (ROI) will be improved further.

Solar panel efficiency generally gives a good indication of performance, especially as many high-efficiency panels use higher-grade N-type silicon cells with improved temperature coefficient and lower power degradation over time.

11.11.6 Area Vs Efficiency

Efficiency does make a big difference in the amount of roof area required**.** Higher efficiency panels generate more energy per square meter and thus require less overall area. This is perfect for rooftops with limited space and can also allow larger capacity systems to be fitted to any roof.

11.11.7 Real-World Efficiency

In real-world use, solar panel operating efficiency is dependent on many external factors. Depending on the local environmental conditions these various factors can reduce panel efficiency and overall system performance. The main factors which affect solar panel efficiency are listed below:

1. Solar Irradiance (W/m2)
2. Shading
3. Panel orientation
4. Temperature
5. Location (latitude)
6. Time of year
7. Dust and dirt

11.11.8 Temperature coefficient comparison

The power temperature coefficient is measured in % per °C - Lower is more efficient

1. Polycrystalline cells - 0.39 to 0.43 % /°C
2. Monocrystalline cells - 0.35 to 0.40 % /°C
3. Monocrystalline IBC cells - 0.28 to 0.31 % /°C
4. Monocrystalline HJT cells - 0.25 to 0.27 % /°C

Power loss between panels using different PV cell types. N-type heterojunction (HJT) and IBC cells show far lower power loss at elevated temperatures compared with common poly and monocrystalline PERC cells.

11.11.9 Cost Vs Efficiency

All manufacturers produce a range of panels with different efficiency ratings depending on the silicon type used and whether they incorporate PERC, multi busbar or other cell technologies. Very efficient panels above 21% featuring N-type cells are generally much **more expensive**, so if cost is a major limitation, it would be better suited to locations with limited mounting space, otherwise, you can pay a premium for the same power capacity which could be achieved by using 1 or 2 additional panels. However, high-efficiency panels using N-type cells will almost always outperform and outlast panels using P-type cells due to the lower rate of light-induced degradation or LID, so the extra cost is usually worth it in the long term.

11.11.10 Panel Size Vs Efficiency

Panel efficiency is calculated by the power rating divided by the total panel area, so just having a larger size panel does not always equate to higher efficiency. However, larger panels using larger size cells increases the cell surface area which does boost overall efficiency.

11.11.11 Ingress Protection PV Junction Box:

The junction box must comply IP 65 or high for dust and water proof.

11.11.12 Limited performance guarantees:

Panel power, in standard conditions, should not be less than 90% of nominal power for first 10-years of operation and at least 80% for the 20 years of operation with 12-year product warranty and 25- year linear power warranty.

11.11.13 Orientation & Facing

1. South facing for solar arrays or module is suitable for getting maximum solar irradiance in our region.

2. Solar Array or module must have an appropriate tilt angle for getting maximum benefits of energy yield.
3. The degree of tilt shall be close to latitude degree of that specific area for flat roof or ground.
4. The degree of tilt shall be close to pitch angle in case of pitched roofs.

11.11.13.1 Accessibility

Ensure easy accessibility for installation & O & M purpose like stairs, ladders etc

11.11.14 Panel Mounting Structure

1. The PV solar panel mounting metallic structure should be fixed mount L2 or L3 or above structure where required with 12 Gauge thickness, mounted on concrete base above ground level. The tilt angle should set to year-round compromise (Equal to latitude).
2. The entire mechanical structure should be hot dipped galvanized and powder coated for longer life of the structure. Structure should be hot dip galvanized up to min 80 microns.
3. The Surface azimuth angle of PV Module 180^{o} and the Tilt angle (slope) of PV Module should be according to the site location.
4. The mounting structure must be engineered for wind resistance min for 150 km per hour and safety as per geographical location of site.
5. Module should be fixed with the frame through SS bolts. The bolts should be tightened at the required angle.
6. The Nuts, Bolts & Washers for modules & Mounting structures must be stainless steel material with appropriate gauge.
7. Shading shall be avoided all over the year (around) from 30 minutes after the sunrise to 30 minutes before sunset.
8. To allow regular cleaning of the solar modules, they should be easily accessible for personnel.

11.11.15 Power and Control Cables

Power Cables of adequate rating as per IEC standard shall be required for interconnection of:

a) Modules/panels within array
b) Array & Hybrid Inverter
c) Charge Controller & Battery
d) Distribution Box & Loads

1) The cable shall be A grade, heavy duty, stranded flexible copper conductor, PVC type A insulated, galvanized steel wire/strip armored, flame retardant low smoke (FRLS) extruded PVC type ST-1 outer sheathed. The cables shall, in general conform to IS-1554 P+I & other relevant standards.

2) External cables should be specifically adapted to outdoor exposure (see IEC 60811). Especially the outer insulation must be sunlight (UV)-resistant, weatherproof and designed for underground installation. Preferably rubber-coated and PE-coated cables shall be used.

3) The temperature resistance of all interconnecting wires and cables should be > 75° C. The minimum acceptable cross-section of the wire in each of the following sub-circuits is as in ISO:

4) Notwithstanding the ISO /IEC requirements, all wires must be sized accordingly to keep line voltage losses to less than 3% between PV generator and battery, less than 1% between battery and charge regulator, and less than 3% between battery and load, all of them at the maximum current conditions.

5) All wiring shall be color-coded.

6) All wires must be in UV-resistant conduits or be firmly fastened to the building and/or support structure. Cable binders, clamps and other fixing material must also be UV-resistant, preferably made of polyethylene.

7) All connections should be properly terminated, soldered and/or sealed using MC4 connectors for outdoor and indoor elements.

11.11.16 Shading Effects

1. Avoidance of shading that occurs from the trees, building structure that obstruct sunlight.
2. Design must consider an appropriate distance between different rows of solar arrays that must be taken into account for avoiding shading and free working space.

11.11.17 Load bearing capacity of roof

Load bearing capacity of roof i.e., dead and live load must be taken into account while designing solar system on the roof of either new or old buildings.

11.11.18 Safety Considerations

1. Solar PV systems should be installed in a way that minimizes the risk of fire or electrical shock.
2. This includes proper grounding and the installation of disconnect switches for both side ie generating and load end.
3. Surge arrestors and lighting arrestors for protection.

11.11.19 Verification

Solar system Design and installation of work must be verified by the Energy Authorities of the jurisdictions.

11.11.20 Installers/Contractors Enlistments

Solar contractor/installers must have valid licensed by the Energy authorities for ensuring their technical capabilities.

11.11.21 Solar PV modules Standards & Certification

Solar PV modules must comply with the International Electrotechnical Commission (IEC) certifications and standards for safety, reliability, performance and sustainability purpose. These standards are as under:

IEC 61215: This standard covers the design qualification and type approval of crystalline silicon terrestrial photovoltaic (PV) modules. It specifies the requirements for the design, materials, construction, and performance of PV modules that are intended for long-term operation in general open-air climates.

IEC 61730: This standard covers the safety qualification of PV modules. It specifies the requirements for the design, construction, and testing of PV modules to ensure that they can withstand mechanical, electrical, and environmental stresses, and do not pose a hazard to people or property.

IEC 61853: This standard covers the performance testing and energy rating of PV modules. It specifies the procedures for measuring the electrical performance of PV modules under standardized conditions, and for calculating their energy output in different climates and operating conditions.

IEC 61853: This standard provides requirements for the performance testing and energy rating of PV modules. It specifies the measurement procedures for electrical performance and calculation methods for energy output under different operating conditions and climates.

11.11.22 Inverters

The DC power produced is fed to inverter for conversion into AC. In a grid interactive system AC power should be fed to the grid at three phase bus. Inverter should comply with IEC 61683/IS 61683 for efficiency and measurements and should comply IEC 60068-2 (1, 2, 14, 30) / Equivalent BIS Standard for environmental testing. Inverter should supervise the grid condition continuously and in the event of grid failure (or) under voltage (or) over voltage, Solar System should be disconnected to share with National Grid circuit

Breaker / Auto switch provided in the inverter. Two types of inverters i.e., Grid Tie and Hybrid Inverters has been recommended based on the site design. The inverters has been mentioned below: -

11.11.22.1 Grid-Tied Inverters

Important Features/Protections required in the Grid-Tie Inverter are-

1. The grid-connected inverters shall comply with UL 1741 standard.
2. Power generated from the solar system during the day time is utilized fully by powering the all building loads and feeding excess power to the grid as long as grid is available. In cases, where solar power is not sufficient due to more demand or cloud cover etc. the building loads should be served by drawing power from the grid. The inverter should always give preference to the Solar Power and will use Grid power only when the Solar Power is insufficient to meet the load requirement.
3. The output of the inverter must synchronize automatically its AC output to the exact AC voltage and frequency of the grid.
4. Inverter equipped with array ground fault detection option.
5. Grid voltage should also be continuously monitored and in the event of voltage going below a pre-set value and above a pre-set value, the solar system should be disconnected from the grid within the set time. Both over voltage and under voltage relays should have adjustable voltage (50% to 130%) and time settings (0 to 5 seconds).
6. Metal Oxide Varistors (MOVs) should also be provided on DC and AC side of the inverter.
7. The inverter control unit should be so designed so as to operate the PV system near its maximum Power Point (MPP), the operating point where the combined values of the current and voltage of the solar modules result in a maximum power output.
8. The inverter should be a pure sine way inverter for a grid interactive PV system.

9. The degree of protection of the outdoor inverter panel should be at least IP-67.
10. Inverters must mention as per following.
    a) Continuous output power rating (1.1 times for 60seconds)
    b) Nominal AC output voltage and frequency
    c) Accuracy of AC voltage control ±1%
    d) Accuracy of frequency control ±0.5%
    e) Grid Frequency Control range +/- 3 Hz
    f) Maximum Input DC Voltage range
    g) MPPT Range DC
    h) Ambient temperature -10 deg C to 55 deg C
    i) Humidity 95 % non- condensing
    j) Protection of Enclosure IP-67
    k) Grid Voltage tolerance -20 % and + 15 %
    l) Power factor control 0.95 inductive to 0.95 capacitive
    m) No-load losses < 1% of rated power
    n) Inverter efficiency (minimum) plus 97%
    o) Liquid crystal display should at least be provided on the inverters front panel or on separate data logging/display device to display following
        i. DC Input Voltage
        ii. DC Input current
        iii. AC Power output(kW)
        iv. Current time and date
        v. Time active
        vi. Time disabled
        vii. Time Idle
        viii. Temperatures (C)

11.11.22.2 Converter status

Following should also be displayed like Protective function limits, over voltage, AC under voltage, over frequency, under frequency, ground fault, PV starting voltage, PV stopping voltage, over voltage delay, under voltage delay over frequency, ground fault delay, PV starting delay, PV stopping delay.)

1. Nuts & bolts and the inverter enclosure should have to be adequately protected taking into consideration the atmosphere and weather prevailing in the area.
2. All doors, covers, panels and cable exits should be gasketed or otherwise designed to limit the entry of dust and moisture. All doors should be equipped with locks.

11.11.22.3 Operation Mode

1. Night or sleep mode: where the Inverter is almost completely turned off, with just the timer and control system still in operation, losses shall be less than 2 W per 5 kW.
2. Standby mode: where the control system continuously monitors the output of the solar generator until pre-set value is exceeded (typically 10 W).
3. Operational of MPP tracking mode: the control system continuously adjusts the voltage of the generator to optimize the power available. The power conditioner should automatically re-enter standby mode input power reduces below the standby mode threshold. Front panel should provide display of status of the inverter.

11.11.22.4 Grid Tied Hybrid Inverter

Hybrid inverter(s) (system with provision for net-metering and battery back-up, should convert DC power produced by SPV modules in to AC power and adjust the voltage & frequency levels to suit the local grid conditions. Pure Sine wave output. Ground Fault Protection. Residual Current Detection (RCD) protection. Monitoring software for real-time status display and fault control. The unit should be able to operate in a high ambient temperature environment. Efficiency must be 96% or above at full load. The inverter must conform to the latest edition of IEC 61727, IEC 61000-6-1, IEC 610006-2, IEC 62109 and IEC 62116 standards

11.11.22.5 Other important Protections required in the Inverter

1. The grid-connected hybrid inverters shall comply with UL 1741 standard.
2. Power generated from the solar system during the daytime should be utilized fully by powering the critical building loads and feeding excess power to the grid as long as grid is available. In cases, where solar power is not sufficient due to more demand or cloud cover etc. the building loads should be served by drawing power from the grid. The inverter should always give preference to the Solar Power and will use Grid/DG power only when the Solar Power is insufficient to meet the load requirement.
3. The output of the hybrid inverter must synchronize automatically its AC output to the exact AC voltage and frequency of the grid.
4. Inverter equipped with array ground fault detection option.
5. The On-Grid Inverter may be of Hybrid type has an ability to synchronize with battery bank as backup system.
6. On-grid hybrid Inverters should have anti-islanded features built in and should continuously monitor the condition of the grid and in the event of grid failure; the inverter automatically switches to off-grid supply within 20-50 milliseconds and synchronize with battery bank and fulfil shortcoming from battery bank as PV-Battery hybrid system. The solar system should be resynchronized with the grid within two minutes after the restoration of grid or DG set.
7. Grid voltage should also be continuously monitored and in the event of voltage going below a pre-set value and above a pre-set value, the solar system should be disconnected from the grid within the set time. Both over voltage and under voltage relays should have adjustable voltage (50% to 130%) and time settings (0 to 5 seconds).

8. The inverter control unit should be so designed so as to operate the PV system near its maximum Power Point (MPP), the operating point where the combined values of the current and voltage of the solar modules result in a maximum power output.
9. The inverter should be a true sine wave for a grid interactive PV system.
10. The degree of protection of the outdoor inverter panel should be at least IP-67.
11. Typical technical features of the suggested inverters must mention as per following sequence.
    a) Continuous output power rating (1.1 times for 60seconds)
    b) Nominal AC output voltage and frequency
    c) Accuracy of AC voltage control ±1%
    d) Accuracy of frequency control ±0.5%
    e) Grid Frequency Control range +/- 3 Hz
    f) Maximum Input DC Voltage range
    g) MPPT Range DC
    h) Battery Input voltages + 48 VDC or Plus
    i) Ambient temperature -10 deg C to 55 deg C
    j) Humidity 95 % non- condensing
    k) Protection of Enclosure IP-55 (minimum)
    l) Grid Voltage tolerance -20 % and + 15 %
    m) Power factor control 0.95 inductive to 0.95 capacitive
    n) No-load losses < 1% of rated power
    o) Inverter efficiency (minimum) plus 97%
    p) Protective function limits display indicating over voltage, AC under voltage, over frequency, under frequency, ground fault, PV starting voltage, PV stopping voltage, over voltage delay, under voltage delay over frequency, ground fault delay, PV starting delay, PV stopping delay.)

11.11.23 Synchronizing Equipment

Solar PV systems should be provided with synchronizing equipment having three inputs for comparison i.e., grid supply vs. solar output, DG output vs solar output so as to connect the Solar PV systems in synchronism with grid or DG. In case of grid failure, solar PV system should be disconnected from the grid and out of synchronization for a period DG supply is not restored. PV system should be synchronized with the DG supply after DG is started.

11.11.24 Protections And Control

1. PV system software and control system should be equipped with islanding protection as described above. In addition to disconnection from the grid (islanding protection i.e., on no supply), under and over voltage conditions, PV systems should be provided with adequate rating fuses, fuses on inverter input side (DC) as well as output side (AC) side for overload and short circuit protection and disconnecting switches to isolate the DC and AC system for maintenances are needed. Fuses of adequate rating should also be provided in each solar array module to protect them against short circuit.
2. A manual disconnect switch and change over switch beside automatic disconnection to grid should also be provided at utility end to isolate the grid connection by the utility personal to carry out any maintenance. This switch should be locked by the utility personal.

11.11.25 Integration Of PV Power with Grid

The output power from Solar PV system would be fed to the Hybrid inverter which feed some portion to battery bank for backup in case of grid failure and major portion converts DC produced by SPV array to AC and feeds it into the main electricity grid after synchronization. In case of grid failure, or low or high voltage, solar PV system shall be out of synchronization and shall be disconnected from the grid and feed power to the load as PV-Battery backup hybrid system. Once the DG set comes into service.

PV system shall again be synchronized with DG supply and load requirement would be met to the extent of availability of power.

11.12 Harmonics standard

As per the standard of IEEE 519, the permissible individual harmonics level shall be less than 3% (for both voltage and current harmonics) and Total Harmonics Distortion (THD) for both voltage and current harmonics of the system shall be less than 5%.

11.12.1 Energy storage certification for solar power systems

Batteries are the heart of any Off-Grid solar power system. Due to the intermittent nature of electricity generation, batteries become responsible for making the overall solar power system as continuous as possible. The following certification standards lists certain critical information for solar batteries such as the general requirements, testing requirements, recommended practices for installation and maintenance to name a few.

1. IEC 61427-1 (Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 1: Photovoltaic off-grid application)
2. IEC 61427-2 (Secondary cells and batteries for Renewable Energy Storage - General Requirements and methods of test - Part 2: On-grid application)
3. IEEE Std. 937 (Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic (PV) Systems)
4. IEEE Std. 1013 (Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems)
5. IEEE Std. 1361 (IEEE Guide for Selection, Charging, Test, and Evaluation of Lead-Acid Batteries Used in Stand-Alone Photovoltaic (PV) Systems)

6. IEC 63056:2020 (Product safety of secondary lithium cells and batteries used in electrical energy storage systems (Figure 2) with a maximum DC voltage of 1 500 V (nominal).
7. IEC 62899: Quality assessment - Failure modes and mechanical testing - Flexible and/or bendable primary or secondary cells.

For lithium-ion batteries the following may be complied in design:

1) Charge/Discharge Efficiency
2) Self-Discharge
3) The battery bank should provide backup to a critical load of building.
4) The battery must ensure safe and reliable operation in the whole range of ambient temperatures from -10° C to + 50° C.
5) The maximum permissible self-discharge rate is 5 percent of rated capacity per month at 25 C.
6) Cycle life of the batteries must be greater than 6000 when discharged down to depth of discharge (DOD) of 80% percent discharge rate.
7) The battery shall have a certificate of compliances, issued by a recognized laboratory.
8) The performance guarantee shall cover at least 3 to 5 years.

11.12.1.1 Battery Box

The battery bank should be housed in a vented compartment that prevents users from coming in contact with batteries terminals. This compartment should be strong enough to accommodate the weight of the batteries. A mechanism to prevent opening and entry of the batteries should be provided. The entire enclosure must be constructed to last at least twenty years without maintenance and should be protected against corrosion. The battery Bank enclosure should have a clean and neat appearance.

11.13 Miscellaneous Items

11.13.1 Earthing Material

Earthing is essential for the protection of the equipment & manpower. Two main grounding must be used for power equipment protection are:

1. DC Earthing.
2. AC Earthing.

DC and AC earthing should be provided separately where required as per standard. In case of equipment earth all the non-current carrying metal parts are bonded together and connected to earth to prevent shock to the man power & also the protection of the equipment in case of any accidental contact.

To prevent the damage due to lightning the terminal of the lightning protection must be earthed separately. The provision for lightning & surge protection of the solar PV power source is required to be made as per standard.

In case the solar PV Array could not installed close to the equipment to be powered & a separate earth has been provided for solar PV Panel. Earth resistance shall not be more than 3 ohms. It shall be ensured that all the earths are bonded together to make them at the same potential.

The Earthing conductor rating shall be rated for the maximum short circuit current. & shall be 1.56 times the short circuit current. The area of cross-section shall not be less than 2.5 sq. mm in any case. The array structure of the PV modules shall be grounded properly using adequate numbers of earthing pits. All metal casing/ shielding of the plant shall be thoroughly grounded to ensure safety of the power plant.

11.13.2 Wiring PVC/GI Channel Ducts

A product of good quality standard material with suitable size to be provided / used.

11.13.2.1 Flexible PVC Pipe

The flexible PVC pipe should be of good quality material with suitable size should be used.

11.13.2.2 Combiner Box

Combiner Box should be manufactured through GI material with 100% copper strip in it for termination of PV Arrays must be IP65 for outdoor installation.

11.13.2.3 Junctions Boxes or Combiners

Dust, water and vermin proof junction boxes of adequate rating and adequate terminal facility made of fire-resistant Plastic (FRP) shall be provided for wiring.

Each solar shall be provided with fuses/ Circuit breakers of adequate rating to protect the solar arrays from accidental short circuit.

11.13.3 Civil Works

The following civil works should be carried out.

Site grading, levelling, drilling exploratory bore holes and consolidation of the area pertaining to the installation of SPV modules.

1. Embedment of structures suitable for mounting PV modules.
2. Lying of earthing equipment /structures and connecting to the main ground as per the statutory requirements.
3. Construction of control room
4. Cutting of cable trenches etc. wherever necessary

11.13.4 Other Features

1. The PV Module(s) should be warranted for max period of 10-20 years from the date of supply, inverter with five years and the battery should be warranted for a period of 3 to 5 years from the date of installation. The warranty card to be

supplied with the system must contain the details of the system. The manufacturers can also provide additional information about the system and conditions of warranty as necessary.

2. Adequate space should be provided behind the PV module/array for allowing unobstructed airflow for passive cooling.
3. Cable of appropriate size should be utilized to keep electrical losses to a bare minimum.
4. The control electronics should not be installed directly with the battery. All wiring should be in proper conduit of capping casing. Wire should not be hanging loose.

It is important to note that UL standards are voluntary, but many jurisdictions and regulatory bodies require compliance with UL standards as a condition of approval or certification. Compliance with UL standards can provide assurance to customers, regulators, and insurance providers that renewable energy products are safe and reliable.

Section-12

12. Energy Management System

12.1 General

The Energy Management System (EnMS) in line with the International Standard for Energy Management Systems ISO 50001:2018 requirements, sets out an energy management framework for establishing policies, processes, procedures and specific energy-tasks to meet an organization's energy objectives. It requires an organization to define its desired energy performance, and work towards achieving its stated objective(s).

The aim of this Chapter is to enable organizations to establish the systems and processes necessary to continually improve energy performance, including energy efficiency, energy use and energy consumption.

This Chapter applies to the activities under the control of the organization. This Chapter does not apply to product use by end-users outside of the scope and boundaries of the EnMS, nor does it apply to product design outside of facilities, equipment, systems or energy-using processes. This Chapter does apply to the design and procurement of facilities, equipment, systems or energy-using processes within the scope and boundaries of the EnMS.

Development and implementation of an EnMS includes an energy policy, objectives, energy targets and action plans related to its energy efficiency, energy use, and energy consumption while meeting applicable legal requirements and other requirements. An EnMS enables an organization to set and achieve objectives and energy targets, to take actions as needed to improve its energy performance and to demonstrate the conformity of its system to the requirements of this Chapter.

12.2 Energy Performance Approach

This Chapter provides requirements for a systematic, data-driven and facts-based process, focused on continually improving energy performance. Energy performance is a key element integrated within the concepts introduced in this Chapter in order to ensure effective and measurable results over time. Energy performance is a concept which is related to energy efficiency, energy use and energy consumption. Energy performance indicators (EnPIs) and energy baselines (EnBs) are two interrelated elements addressed in this Chapter to enable organizations to demonstrate energy performance improvement.

12.3 Plan-Do-Check-Act (PDCA) Cycle

The EnMS described in this Chapter is based on the Plan-Do-Check-Act (PDCA) continual improvement framework, as illustrated in Figure 1. The PDCA approach can be outlined as follows:

a. Plan: understand the context of the organization, establish an energy policy and an energy management team, consider actions to address risks and opportunities, conduct an energy review, identify significant energy uses (SEUs) and establish energy performance indicators (EnPIs), energy baseline(s) (EnBs), objectives and energy targets, and action plans necessary to deliver results that will improve energy performance in accordance with the organization's energy policy.
b. Do: implement the action plans, operational and maintenance controls, and communication, ensure competence and consider energy performance in design and procurement.
c. Check: monitor, measure, analyze, evaluate, audit and conduct management review(s) of energy performance and the EnMS.
d. Act: take actions to address nonconformities and continually improve energy performance and the EnMS.

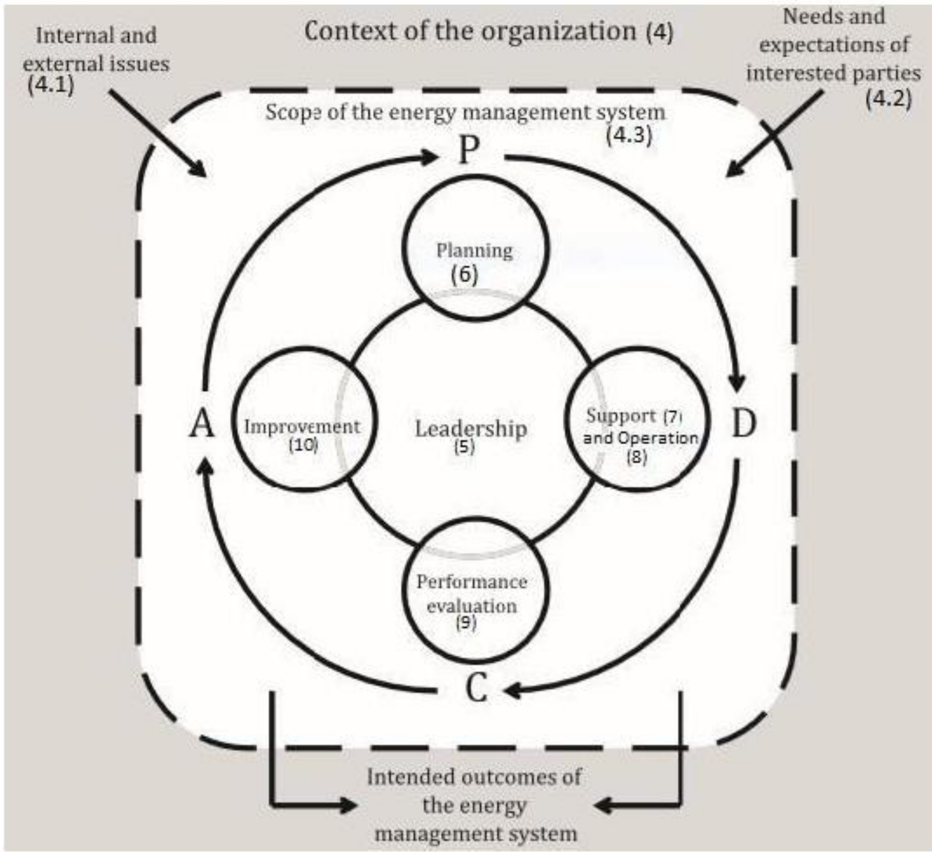

Figure 12.1. Plan-Do-Check-Act (PDCA) Cycle

In this Chapter, the following verbal forms are used:

i. "shall" indicates a requirement;
ii. "should" indicates a recommendation;
iii. "can" indicates a possibility or a capability;
iv. "may" indicates a permission.

12.4 Benefits of EnMS

Effective implementation of this Chapter provides a systematic approach to improvement of energy performance that can transform the way organizations manage energy. By integrating energy management into business practice, organizations can establish a process for continual improvement of energy performance. By improving energy performance and associated energy costs, organizations can be more competitive. In addition, implementation can lead organizations to meet overall climate change mitigation goals by reducing their energy-related greenhouse gas emissions.

Following are specific benefits of implementing an EnMS which is based on ISO 50001:2018:

a. Framework to Manage Energy

An effective EnMS that is aligned with an organization's business strategy, will allow visibility of how energy is being used and areas where performance can be improved. It provides the structured policies, processes, procedures and action plans to implement energy saving opportunities. Continual improvement in energy management is therefore achieved.

b. Cost Reduction

Any energy reductions identified through an EnMS will, in turn, offer demonstrable savings on energy bills, which will reduce the overhead of a business and in some cases substantially. There are many examples of an organization undertaking the ISO 50001 process achieving first year energy cost savings which are equal to or greater than the initial costs of implementing the Standard.

c. Reducing Energy

Cost reduction as identified in b) above and reducing energy, go hand in hand. By establishing, implementing, maintaining and continually improving an EnMS, an organization will be able to not only deal with the initial energy saving opportunities but to identify and manage where, when and how energy is being consumed and identify energy efficiency improvements and reductions.

d. Carbon Reduction

Many businesses report their output of carbon dioxide (CO2) or "carbon footprint". Whilst CO2 reduction cannot really be cited as a primary reason for achieving the ISO 50001 Standard, any reductions in energy will have a direct correlation with an organization's overall carbon footprint.

e. Organizational Engagement

The "top down" approach within ISO 50001 ensures that key senior stakeholders within the organization understand, as appropriate, its EnMS and are therefore motivated to achieve its objectives. ISO 50001 can be also be used to drive engagement on energy management; providing other members of an organization with a structured approach to managing energy use.

f. Benchmarking

ISO 50001 requires an organization to establish a baseline to act as an indicator of energy performance. By identifying a baseline, energy efficiency can be tracked over time.

g. Regulatory Compliance

ISO 50001 requires an organization to identify and have access to applicable "legal and other requirements" in relation to its energy efficiency, energy use, energy consumption and its EnMS.

h. Reputation

Achieving ISO 50001 certification can offer significant reputational benefits by demonstrating to an organization's stakeholders that it is fully committed to managing its energy consumption and seeking ways to increase its energy efficiency. When an organization gains certification, it can display the Certifying body logos on appropriate materials. This can not only publicize an organization's credentials (and perhaps provide a competitive edge) but can provide a short-hand info graphic that energy “governance” is being achieved.

I. Commerciality

It is an ever-increasing trend, that when seeking to supply goods and services to the business sector (Particularly the Public Sector) accredited systems such as ISO 50001 are required, in order to meet pre contract procurement award criteria.

12.5 Scope

This Chapter specifies requirements for establishing, implementing, maintaining and improving an energy management system (EnMS). The intended outcome is to enable an organization to follow a systematic approach in achieving continual improvement of energy performance and the EnMS.

This Chapter is applicable to any organization having ownership of buildings and building clusters that have a total connected load of 100 kW or greater, or a contract demand of125 kVA or greater, or a conditioned area of 900 m^2 or greater, or unconditioned buildings of covered area of 1,200 m^2 or more (as described in Section 2.1, 2.2 and 2.3 of Building Code of Pakistan (Energy Provisions – 2011). These Provisions focus on high-end domestic and commercial consumers, and are designed to conserve energy without compromising public safety.

12.6 Terms And Definitions

For the purposes of this Chapter, the following terms and definitions apply:

Audit: Systematic, independent and documented *process* for obtaining audit evidence and evaluating it objectively to determine the extent to which the audit criteria are fulfilled

Continual Improvement: A recurring process which results in the enhancement of energy performance and the Energy Management System

Correction: An action to eliminate a detected Non-conformity

Corrective Action: An action to eliminate the cause of a detected Non-conformity

Documented information: Information required to be controlled and maintained by an organization and the medium on which it is contained

Energy: Electricity, Fuels, Steam, Heat, Compressed Air and other similar Electricity, Fuels, Steam, Heat, Compressed Air and other similar media

Energy Baseline EnB: Quantitative references providing a basis for the comparison of Energy Performance

Energy Consumption: Quantity of energy applied

Energy Efficiency: Ratio or other quantitative relationship between an output of performance, service, goods or energy and an input of energy

Energy Management System EnMS: Set of interrelated or interacting elements to establish an Energy Policy and Energy Objectives, and processes and procedures to achieve those objectives

Energy Management Team: Person(s) responsible for the effective implementation of the Energy Management System activities and for delivering energy performance improvements

Energy Objective: A specified outcome or achievement set to meet organization's Energy Policy related to improved Energy Performance

Energy Performance: Measurable results related to Energy Efficiency, Energy Use and Energy Consumption

Energy Performance Indicator EnPI: A quantitative value or measure of Energy Performance, as defined by the organization

Energy Policy: A statement by organization of its overall intentions and direction related to its Energy Performance, as formally expressed by Top Management

Energy Review: A determination of organization's Energy Performance based on data and other information, leading to identification of opportunities for improvement

Energy Services: Activities and their results related to the provision and/or use of energy

Energy Target: A detailed and quantifiable energy performance requirement, applicable to organization, that arises from the Energy Objective and that needs to be set and met to achieve this objective

Energy Use: Manner or kind of application of energy

Interested Party (preferred term), Stakeholder (admitted term): A person or organization that can affect, be affected by, or perceive itself to be affected by a decision or activity

Internal Audit: A systematic, independent and documented process for obtaining evidence and evaluating it objectively to determine the extent to which requirements are fulfilled

Non-conformity: non-fulfilment of a requirement

Objective: Results to be achieved.

Organization: Person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its objectives.

Note: The concept of organization includes, but is not limited to, sole-trader, company, corporation, firm, enterprise, authority, partnership, charity or institution, or part or combination thereof, whether incorporated or not, public or private.

Preventive Action: Action to eliminate the cause of a potential Non-conformity

Procedure: A specified way to carry out an activity or a process

Risk: Effect of uncertainty

Record: A document stating results achieved or providing evidence of activities performed

Scope: The extent of activities, facilities and decisions that organization addresses through its EnMS, which can include several Boundaries

Significant Energy Use SEU: Energy use accounting for substantial energy consumption and/or offering considerable potential for energy performance improvement

Top Management: The person or group of people who direct and control organization at the highest level

NOTE: Definition of terms not included here can be found in ISO 50001:2018 Standard and at ISO and IEC terminological databases for use in standardization at the following addresses:

a. ISO Online browsing platform: available at https: //www .iso .org/obp
b. IEC Electropedia: available at https: //www .electropedia .org/

12.7 Context Of the Organization

12.7.1 Understanding the Organization and its Context

The ‘context’ of the organization (sometimes called its business environment) refers to the combination of internal and external factors and conditions that can have an effect on an organization's approach to its energy performance. The organization shall determine external and internal issues that are relevant to its purpose and which affect its ability to achieve the intended outcome(s) of its EnMS and to improve its energy performance.

External issues shall include:

a. Issues relating to interested parties such as existing national or sector objectives, requirements or standards
b. Restrictions or limitations on energy supply, security and reliability
c. Energy costs or the availability of types of energy
d. Effects of climate change
e. Effect on greenhouse gas (GHG) emissions

Internal issues shall include:

a. Core business objectives and strategy
b. Asset management plans
c. Financial resource (labor, financial, etc.) constraints affecting the organization
d. Energy management maturity and culture
e. Sustainability considerations
f. Contingency plans for interruptions in energy supply
g. Maturity of existing technology
h. Operational risks and liability considerations

12.7.2 Understanding the Needs and Expectations of Interested Parties

The organization shall determine:

a) The interested parties that are relevant to energy performance and the EnMS

b) The relevant requirements of these interested parties

c) Which of the identified needs and expectations the organization addresses through its EnMS.

The organization shall:

a. Ensure that it has access to the applicable legal requirements and other requirements related to its
b. energy efficiency, energy use and energy consumption
c. Determine how these requirements apply to its energy efficiency, energy use and energy consumption
d. Ensure that these requirements are taken into account
e. Review at defined intervals its legal requirements and other requirements.

12.7.3 Scope of the Energy Management System

The scope of the EnMS is already defined in 12.6. The organization shall consider:

a) The external and internal issues referred to in 12.7.1

b) The requirements referred to in 12.7.2.

The organization shall ensure that it has the authority to control its energy efficiency, energy use and energy consumption within the scope and boundaries. The organization shall not exclude an energy type within the scope and boundaries.

The EnMS scope and boundaries shall be maintained as documented information.

12.7.4 Energy Management System

The organization shall establish, implement, maintain and continually improve an EnMS, including the processes needed and their interactions, and continually improve energy performance, in accordance with the requirements of this Chapter.

The processes needed can differ from one organization to another due to:

a. the size of organization and its type of activities, processes, products and services
b. the complexity of processes and their interactions
c. the competence of personnel.

12.8 Leadership

12.8.1 Leadership and Commitment

Top management shall demonstrate leadership, commitment with respect to continual improvement of energy performance and take accountability for the effectiveness of the EnMS, by:

a) Ensuring that the EnMS scope and boundaries are established
b) Ensuring that the energy policy, objectives and energy targets are established and are compatible with the strategic direction of the organization
c) Ensuring the integration of the EnMS requirements into the organization's business processes
d) Ensuring that action plans are approved and implemented
e) Ensuring that the resources needed for the EnMS are available
f) Communicating the importance of effective energy management and of conforming to the EnMS requirements
g) Ensuring that the EnMS achieves its intended outcome(s)
h) Promoting continual improvement of energy performance and the EnMS
i) Ensuring the formation of an energy management team
j) Directing and supporting persons to contribute to the effectiveness of the EnMS and to energy performance improvement
k) Supporting other relevant management roles to demonstrate their leadership as it applies to their areas of responsibility
l) Ensuring that the EnPI(s) appropriately represent(s) energy performance

m) Ensuring that processes are established and implemented to identify and address changes affecting the EnMS and energy performance within the scope and boundary of the EnMS.

12.8.2 Energy Policy

Top management shall establish an energy policy that:

a) It is appropriate to the purpose of the organization
b) Provides a framework for setting and reviewing objectives and energy targets
c) Includes a commitment to ensure the availability of information and necessary resources to achieve objectives and energy targets
d) Includes a commitment to satisfy applicable legal requirements and other requirements
e) related to energy efficiency, energy use and energy consumption
f) Includes a commitment to continual improvement of energy performance and the EnMS
g) Supports the procurement of energy efficient products and services that impact energy
h) performance
i) Supports design activities that consider energy performance improvement.

The energy policy shall:

a. be available as documented information
b. be communicated within the organization
c. be available to interested parties, as appropriate
d. be periodically reviewed and updated as necessary.

12.8.3 Organization Roles, Responsibilities and Authorities

Top management shall ensure that the responsibilities and authorities for relevant roles are assigned and communicated within the organization. Top management shall assign the responsibility and authority to the energy management team for:

a) Ensuring that the EnMS is established, implemented, maintained and continually improved
b) Ensuring that the EnMS conforms to the requirements of this Chapter
c) Implementing action plans to continually improve energy performance
d) Reporting on the performance of the EnMS and improvement of energy performance to top management at determined intervals
e) Establishing criteria and methods needed to ensure that the operation and control of the EnMS are effective.

12.9 Planning

12.9.1 Actions to Address Risks and Opportunities

When planning for the EnMS, the organization shall consider the issues referred to in 12.7.1 and the requirements referred to in 12.7.2 and review the organization's activities and processes that can affect energy performance. Planning shall be consistent with the energy policy and shall lead to actions that result in continual improvement in energy performance. The organization shall determine the risks and opportunities that need to be addressed to:

i. Give assurance that the EnMS can achieve its intended outcome(s), including energy performance improvement
ii. Prevent or reduce undesired effects
iii. Achieve continual improvement of the EnMS and energy performance.

A concept diagram illustrating the Energy Planning Process is shown in Figure 12.2.

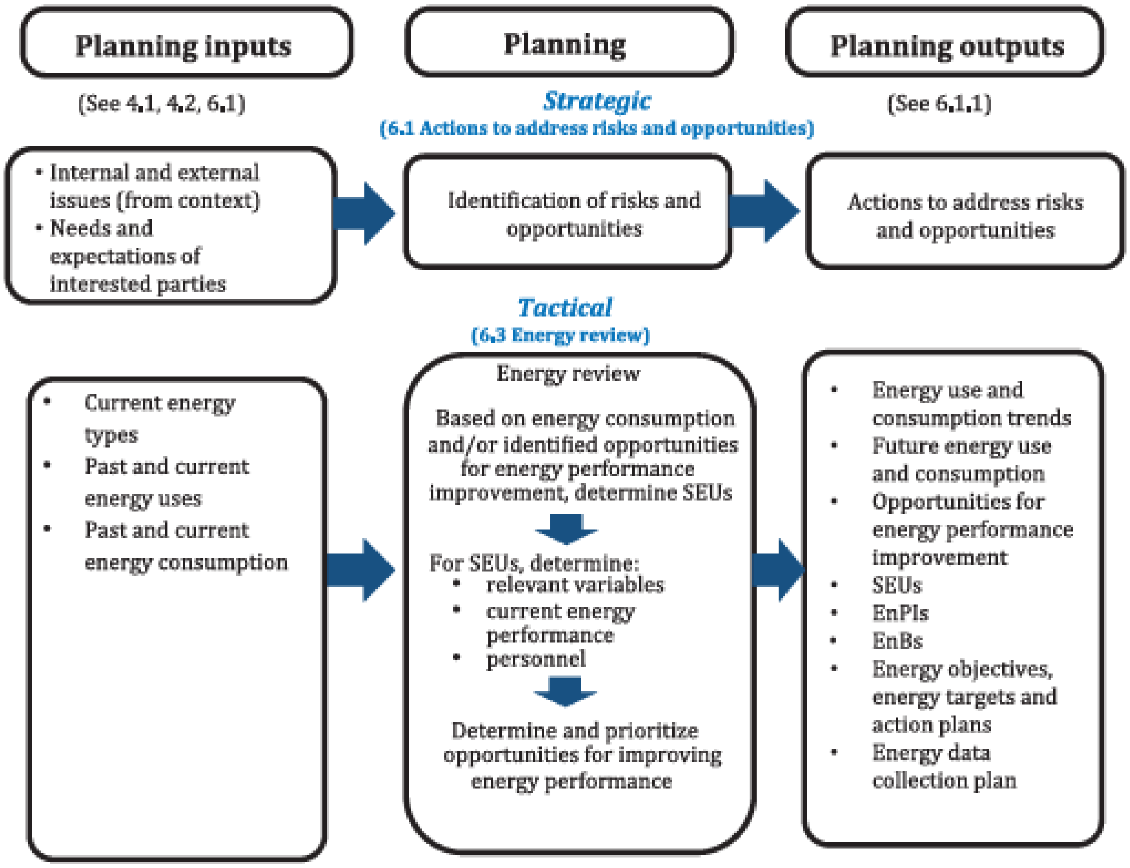

Figure 12.2. Energy Planning

The organization shall plan:

a) Actions to address these risks and opportunities

b) How to:

i. Integrate and implement the actions into its EnMS and energy performance processes

ii. Evaluate the effectiveness of these actions.

12.9.2 Objectives, Energy Targets and Planning To Achieve Them

The organization shall establish objectives at relevant functions and levels. The organization shall establish energy targets.

The objectives and energy targets shall:

i. Be consistent with the energy policy
ii. Be measurable (if practicable)
iii. Take into account applicable requirements
iv. Consider Significant Energy Uses SEUs
v. Take into account opportunities to improve energy performance
vi. Be monitored
vii. Be communicated
viii. Be updated as appropriate.

The organization shall retain documented information on the objectives and energy targets.

When planning how to achieve its objectives and energy targets, the organization shall establish and maintain action plans that include:

a. What will be done?
b. What resources will be required?
c. Who will be responsible?
d. When it will be completed?
e. How the results will be evaluated, including the method(s) used to verify energy performance Improvement?

The organization shall consider how the actions to achieve its objectives and energy targets can be integrated into the organization’s business processes. The organization shall retain documented information on action plans.

12.10 Energy Review

The organization shall develop and conduct an energy review. To develop the energy review, the organization shall:

a) Analyze energy use and consumption based on measurement and other data:

1) Identify current types of energy

2) Evaluate past and current energy use(s) and consumption

b) Based on the analysis, identify SEUs

c) For each SEU:

1) Determine relevant variables

2) Determine current energy performance

3) Identify the person(s) doing work under its control that influence or affect the SEUs

d) Determine and prioritize opportunities for improving energy performance

e) Estimate future energy use(s) and energy consumption.

The energy review shall be updated at defined intervals, as well as in response to major changes in facilities, equipment, systems or energy-using processes. The organization shall maintain as documented information, the methods and criteria used to develop the energy review, and shall retain documented information of its results.

12.10.1 Energy Performance Indicators EnPIs

The organization shall determine EnPIs that:

a) Are appropriate for measuring and monitoring its energy performance

b) Enable the organization to demonstrate energy performance improvement.

The method for determining and updating the EnPI(s) shall be maintained as documented information. Where the organization has data indicating that relevant variables significantly affect energy performance, the organization shall consider such data to establish appropriate EnPI(s). EnPI value(s) shall be reviewed and compared to their respective Energy Baselines EnB(s), as appropriate. The organization shall retain documented information of EnPI value(s).

12.10.2 Energy Baseline EnB

The organization shall establish (an) EnB(s) using the information from the energy review(s), taking into account a suitable period of time. Where the organization has data indicating that relevant variables significantly affect energy performance, the organization shall carry out normalization of the EnPI value(s) and corresponding EnB(s).

NOTE Depending on the nature of the activities, normalization can be a simple adjustment, or a more complex procedure. EnB(s) shall be revised in the case of one or more of the following:

a) EnPI(s) no longer reflect the organization’s energy performance

b) There have been major changes to the static factors

c) According to a pre-determined method.

The organization shall retain information of EnB(s), relevant variable data and modifications to EnB(s) as documented information.

12.10.3 Planning For Collection of Energy Data

The organization shall ensure that key characteristics of its operations affecting energy performance are identified, measured, monitored and analyzed at planned intervals. The organization shall define and implement an energy data collection plan appropriate to its size, its complexity, its resources and its measurement and monitoring equipment. The plan shall specify the data necessary to monitor the key characteristics and state how and at what frequency the data shall be collected and retained.

Data to be collected (or acquired by measurement as applicable) and retained documented information shall include:

a) The relevant variables for SEUs

b) Energy consumption related to SEUs and to the organization

c) Operational criteria related to SEUs

d) Static factors, if applicable

e) Data specified in action plans.

The energy data collection plan shall be reviewed at defined intervals and updated as appropriate. The organization shall ensure that the equipment used for measurement of key characteristics provides data which are accurate and repeatable. The organization shall retain documented information on measurement, monitoring and other means of establishing accuracy and repeatability.

12.11 Support

12.11.1 Resources

The organization shall determine and provide the resources needed for the establishment, implementation, maintenance and continual improvement of energy performance and the EnMS.

12.11.2 Competence

The organization shall:

a) Determine the necessary competence of person(s) doing work under its control that affects its energy performance and EnMS

b) Ensure that these persons are competent on the basis of appropriate education, training, skills or experience

c) Where applicable, take actions to acquire the necessary competence, and evaluate the effectiveness of the actions taken

d) Retain appropriate documented information (see 7.5) as evidence of competence.

NOTE Applicable actions can include, for example, the provision of training to, the mentoring of, or the reassignment of currently employed persons; or the hiring or contracting of competent persons.

12.11.3 Awareness

Persons doing work under the organization's control shall be aware of:

a. The energy policy
b. Their contribution to the effectiveness of the EnMS, including achievement of objectives and energy targets and the benefits of improved energy performance
c. The impact of their activities or behavior with respect to energy performance
d. The implications of not conforming to the EnMS requirements.

12.11.4 Communication

The organization shall determine the internal and external communications relevant to the EnMS, including:

a) On what it will communicate?

b) When to communicate?

c) With whom to communicate?

d) How to communicate?

e) Who communicates?

When establishing its communication process (es), the organization shall ensure that information communicated is consistent with information generated within the EnMS and is dependable. The organization shall establish and implement a process by which any person(s) doing work under the organization's control can make comments or suggest improvements to the EnMS and to energy performance. The organization shall consider retaining documented information of the suggested improvements.

12.11.5 Documented Information

12.11.5.1 General

The organization's EnMS shall include:

a) Documented information required by this Chapter

b) Documented information determined by the organization as being necessary for the effectiveness of the EnMS and to demonstrate energy performance improvement.

NOTE: The extent of documented information for an EnMS can differ from one organization to another due to:

a. The size of organization and its type of activities, processes, products and services
b. The complexity of processes and their interactions
c. The competence of persons.

12.11.5.2 Creating and updating

When creating and updating documented information, the organization shall ensure appropriate:

a) Identification and description (e.g. a title, date, author or reference number)

b) Format (e.g. language, software version, graphics) and media (e.g. paper, electronic)

c) Review and approval for suitability and adequacy.

12.11.5.3 Control of Documented Information

Documented information required by the EnMS and by this Chapter shall be controlled to ensure:

a. It is available and suitable for use, where and when it is needed

b. It is adequately protected (e.g. from loss of confidentiality, improper use, loss of integrity).

For the control of documented information, the organization shall address the following activities, as applicable:

a. Distribution, access, retrieval and use

b. Storage and preservation, including preservation of legibility

c. Control of changes (e.g. version control)

d. Retention and disposition.

Documented information of external origin determined by the organization to be necessary for the planning and operation of the EnMS shall be identified, as appropriate, and controlled.

NOTE: Access can imply a decision regarding the permission to view the documented information only, or the permission and authority to view and change the documented information.

12.12 Operation

12.12.1 Operational Planning and Control

The organization shall plan, implement and control the processes, related to its SEUs, needed to meet requirements and to implement the actions determined in 6.2, by:

a) Establishing criteria for the processes, including the effective operation and maintenance of facilities, equipment, systems and energy-using processes, where their absence can lead to a significant deviation from intended energy performance

NOTE: Significant deviation criteria are determined by the organization.

b) Communicating the criteria to relevant person(s) doing work under the control of the organization

c) Implementing control of the processes in accordance with the criteria, including operating and maintaining facilities, equipment, systems and energy-using processes in accordance with established criteria

d) Keeping documented information to the extent necessary to have confidence that the processes have been carried out as planned.

The organization shall control planned changes and review the consequences of unintended changes, taking actions to mitigate any adverse effects, as necessary. The organization shall ensure that outsourced SEUs or processes related to its SEUs are controlled.

12.12.2 Design

The organization shall consider energy performance improvement opportunities and operational control in the design of new, modified and renovated facilities, equipment, systems and energy-using processes that can have a significant impact on its energy performance over the planned or expected operating lifetime. Where applicable, the results of the energy performance consideration shall be incorporated into specification, design and procurement activities.

The organization shall retain documented information of the design activities related to energy performance.

12.12.3 Procurement

The organization shall establish and implement criteria for evaluating energy performance over the planned or expected operating lifetime, when procuring energy using products, equipment and services which are expected to have a significant impact on the organization's energy performance. When procuring energy using products, equipment and services that have, or can have, an impact on SEUs, the organization shall inform suppliers that energy performance is one of the evaluation criteria for procurement.

Where applicable, the organization shall define and communicate specifications for:

a) Ensuring the energy performance of procured equipment and services

b) The purchase of energy.

12.13 Performance Evaluation

12.13.1 Monitoring, Measurement, Analysis and Evaluation of Energy Performance and the EnMS

12.13.1.1 General

The organization shall determine for energy performance and the EnMS:

a) What needs to be monitored and measured, including at a minimum the following key characteristics:

1) The effectiveness of the action plans in achieving objectives and energy targets

2) EnPI(s)

3) Operation of SEUs

4) Actual versus expected energy consumption

b) The methods for monitoring, measurement, analysis and evaluation, as applicable, to ensure valid results

c) When the monitoring and measurement shall be performed?

d) When the results from monitoring and measurement shall be analyzed and evaluated?

The organization shall evaluate its energy performance and the effectiveness of the EnMS. Improvement in energy performance shall be evaluated by comparing EnPI value(s) against the corresponding EnB(s). The organization shall investigate and respond to significant deviations in energy performance. The organization shall retain documented information on the results of the investigation and response. The organization shall retain appropriate documented information on the results from monitoring and measurement.

12.13.1.2 Evaluation of Compliance with Legal Requirements and Other Requirements

At planned intervals, the organization shall evaluate compliance with legal and other requirements related to its energy efficiency, energy use, energy consumption and the EnMS. The organization shall retain documented information on the results of the evaluation of compliance and any actions taken.

12.13.2 Internal Audit

The organization shall conduct internal audits of the EnMS at planned intervals to provide information on whether the EnMS:

a) Improves energy performance

b) Conforms to:

i. The organization’s own requirements for its EnMS

ii. The energy policy, objectives and energy targets established by the organization

iii. The requirements of this Chapter

c) Is effectively implemented and maintained.

12.13.2.1 The organization shall:

a) Plan, establish, implement and maintain (an) audit program (s) including the frequency, methods, responsibilities, planning requirements and reporting, which shall take into consideration the importance of the processes concerned and the results of previous audits
b) Define the audit criteria and scope for each audit
c) Select auditors and conduct audits to ensure objectivity and the impartiality of the audit process
d) Ensure that the results of the audits are reported to relevant management
e) Take appropriate actions in accordance with 10.1 and 10.2
f) Retain documented information as evidence of the implementation of the audit program(s) and the audit results.

12.13.3 Management Review

Top management shall review the organization's EnMS, at planned intervals, to ensure its continuing suitability, adequacy, effectiveness and alignment with the strategic direction of the organization.

The management review shall include consideration of:

a) The status of actions from previous management reviews
b) Changes in external and internal issues and associated risks and opportunities that are relevant to the EnMS
c) Information on the EnMS performance, including trends in:
    1) Nonconformities and corrective actions
    2) Monitoring and measurement results
    3) Audit results

4) Results of the evaluation of compliance with legal requirements and other requirements

d) Opportunities for continual improvement, including those for competence

e) Energy policy.

The energy performance inputs to management review shall include:

a. The extent to which objectives and energy targets have been met
b. Energy performance and energy performance improvement based on monitoring and measurement results including the EnPI(s)
c. Status of the action plans.

The outputs of the management review shall include decisions related to continual improvement opportunities and any need for changes to the EnMS, including:

1. Opportunities to improve energy performance
2. The energy policy
3. The EnPI(s) or EnB(s)
4. Objectives, energy targets, action plans or other elements of the EnMS and actions to be taken if they are not achieved
5. Opportunities to improve integrati999on with business processes
6. The allocation of resources
7. The improvement of competence, awareness and communication.

The organization shall retain documented information as evidence of the results of management reviews.

12.14 improvement

12.14.1 Nonconformity and Corrective Action

When a nonconformity is identified, the organization shall:

a) React to the nonconformity and, as applicable:

1) Take action to control and correct it

2) Deal with the consequences

b) Evaluate the need for action to eliminate the cause(s) of the nonconformity, in order that it does not recur or occur elsewhere, by:

1) Reviewing the nonconformity

2) Determining the causes of the nonconformity

3) Determining if similar nonconformities exist, or can potentially occur

c) Implement any action needed

d) Review the effectiveness of any corrective action taken

e) Make changes to the EnMS, if necessary.

Corrective actions shall be appropriate to the effects of the encountered nonconformities. The organization shall retain documented information of:

a. The nature of the nonconformities and subsequent actions taken

b. The results of any corrective action.

12.14.2 Continual Improvement

The organization shall continually improve the suitability, adequacy and effectiveness of the EnMS. The organization shall demonstrate continual energy performance improvement. Figure 12.3 shows relationship between Energy Performance and EnMS.

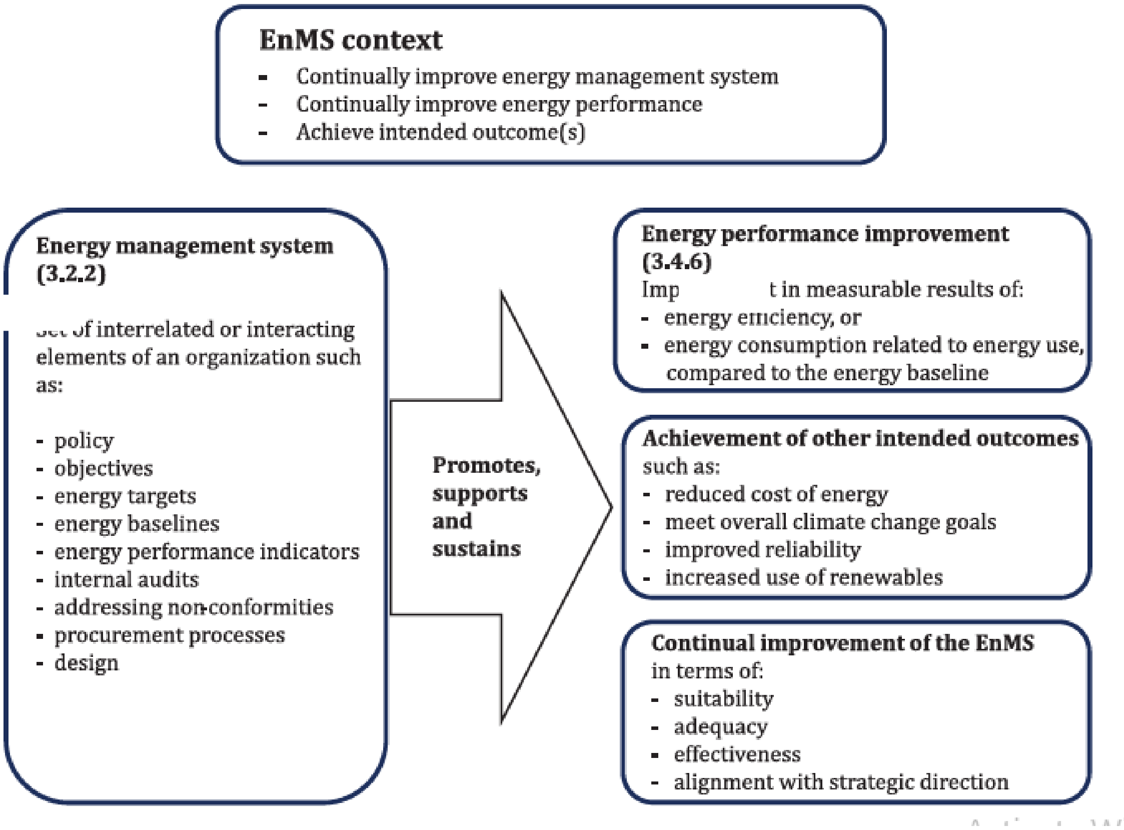

Figure 12.3. Relationship between Energy Performance and EnMS

12.15 Reference Documents

ISO 50001:2018 Energy management systems — Requirements with guidance for use

Section-13

13. Parking Provisions for Electric Vehicle Charging Infrastructure

All new or reconstructed parking structures or lots / plazas shall be required to install Electric Vehicle Charging Infrastructure according to Table 12.1 when one of the following conditions is met:

1. The development includes a new off-street parking facility with more than 10 spaces; or
2. The parking capacity of an existing building, site, or parking facility with 20 or more spaces is increased by 30 percent or more (expressed as [number of additional spaces]/ [number of existing spaces] x 100).
3. Site design must provide electrical, associated ventilation, accessible parking, and wiring connection to transformer to support the additional potential future electric vehicle charging stations.

Fuel station layout shall be designed with the provision of parking spaces designated for Electric Vehicles including Canopy on Chargers (in case of open space). The allocated spaces shall have safety precautions e.g., barricaded parking space and safety barrier for charger protection etc.

Table 13.1. EV Charging Requirements for new and reconstructed parking structures

Land Use Type	Percentage of Parking Spaces
High-rise Residential	5-10%
Retail, Restaurants	2%

Land Use Type	Percentage of Parking Spaces
Office, medical	3%
Industrial	1%
Institutional, municipal	3%
Recreational/entertainment/cultural	1%
Other	3%

These requirements may be revised upward or downward as part of an application for a conditional use permit or planned unit development based on verifiable information pertaining to parking.

13.1 General station requirements

Size. A standard size parking space shall be used for an electric vehicle charging station where such a station is required or planned.

13.1.1 Equipment Standards and Protection.

1. **Clearance**. Charging station equipment mounted on pedestals, light posts, bollards or other devices shall be a minimum of 12 inches clear from the face of curb.
2. **Charging Station Equipment**. Charging station outlets and connector devices shall be according to the OEMs specifications. It shall be mounted, and located as not to impede pedestrian movement or create trip hazards on footpaths.
3. **Charging Station Equipment Protection**. When the electric vehicle parking space is perpendicular or at an angle to curb face and charging equipment, adequate equipment protection, such as wheel stops or concrete-filled steel bollards shall be used.

13.1.2 Signage

Electric vehicle charging stations, other than in residential use, shall have posted signage allowing only charging electric vehicles to park in such spaces. For the purposes of this subsection, “charging” means that an electric vehicle is parked at an electric vehicle charging station and is connected to the charging station equipment. Signage for parking of electric vehicles shall include:

i. Information on the charging station to identify voltage and amperagelevels and any time of use, fees, or safety information.

ii. Restrictions shall be included on the signage, if removal provisions are tobe enforced by the property owner.

iii. As appropriate, directional signs to effectively guide motorists to thecharging station space(s).

13.1.3 Lighting

Site lighting shall be provided where EVCS is installed unless charging is for daytime purposes only.

13.2 Accessible Facilities

Where electric vehicle charging points are provided in the parking lots or parking garages, accessible electric vehicle charging points shall be provided according to the ratios shown in Table 12.2. The first column indicates the number of parking bays / spaces provided on-site and the second column indicates the number of accessible charging points that are to be provided for the corresponding number(s) of parking bays / spaces.

Table 13.2. Minimum Number of Accessible Electric Vehicle (EV) Charging Points in new / renovated parking lots / plazas

Number of Parking Bays /	Minimum accessible EV

Spaces	charging points
5–50	1
51–100	2
101–150	3

Accessible electric vehicle charging points should be located in close proximity to the building or facility entrance and shall be connected to a barrier-free accessible route of travel. It is not necessary to designate the accessible electric vehicle charging points exclusively for the use of disabled persons.

13.3 Charging and Parking

EVCS parking spaces are to be included in the calculation for both the number of minimum and maximum parking spaces required, as provided by the Energy Conservation Building Code 2023.

EVCS parking spaces, where provided for public use, are reserved for parking and charging electric vehicles only, except as otherwise provided by the Energy Conservation Building Code 2023.

Decommissioning: Unless otherwise directed by National Energy Efficiency and Conservation Authority (NEECA). Within ninety (90) days of cessation of use of the EVCS, the property owner or operator shall restore the site to its original condition. Should the property owner or operator fail to complete said removal within ninety (90) days, NEECA shall conduct the removal and disposal of improvements at the property owner or operator's sole cost and expense.

Note: For further details regarding EV Charging Infrastructure requirements, please refer to Electric Vehicle Charging Infrastructure Regulations 2023.

SECTION-14

14. Implementation and enforcement methodology for Energy Building codes

14.1 General Introduction

Building codes regarding energy efficiency vary widely around the world, and their implementation and enforcement can differ significantly depending on the region, country, or even the local jurisdiction. However, some common approaches and methodologies are used to ensure that these codes are enforced effectively.

14.1.1 Building energy codes and standards development

Governments organizations develop building energy codes and standards that set the minimum requirements for energy-efficient building design and construction. The codes and standards usually cover aspects such as building envelope design, HVAC systems, lighting, electrical power, refrigeration, lights, fans, renewable energy and etc. Building codes regarding energy efficiency are implemented and enforced through a combination of regulation, education, and compliance methods. The key is to ensure that all stakeholders on Federal and provincial levels understand the requirements and benefits of energy-efficient building design and construction and work together to achieve compliance.

14.1.2 Adoption of energy codes and standards

Once developed, building energy codes and standards are adopted by the government or industry organizations and become legally binding for new buildings or major renovations. Adoption can vary by country, region, or state, and compliance is usually mandatory.

14.1.3 Compliance and enforcement

Governments or industry organizations are responsible for ensuring that building owners, builders, and designers comply with the energy codes and standards. Compliance can be achieved through several methods, including building permits, inspections, and performance testing. Enforcement may also include penalties, fines, or legal action for non-compliance.

The compliance and enforcement shall be the responsibility of several departments and organizations at the national and state levels.

14.1.4 National Energy Efficiency and Conservation Authority (NEECA)

NEECA shall be responsible for promoting energy efficiency in various sectors, including buildings. NEECA shall also be responsible for developing energy efficiency codes and standards, providing technical assistance and capacity building, monitoring compliance with the codes and standards. NEECA shall responsible for formulating and updating of policies and programs related to energy conservation and efficiency.

14.1.5 Housing /Building Authorities in jurisdiction

The Ministry of Housing/Building authorities in the jurisdiction shall comply the energy conservation building codes in building designs for the promotion of energy conservation and energy efficiency in the country.

14.2 Provincial Designated Agencies (PDAs)

Provincial Designated Agencies (PDAs) are government agencies responsible for implementing and enforcing energy building codes in their respective jurisdictions. They shall be responsible for issuing permits/NOC’s and conducting inspections to ensure that the building design and construction comply with the energy building codes. They shall ensure the Energy Conservation Building Code (ECBC) by conducting inspections, checking compliance, and issuing notices for non-compliance.

The Energy Conservation Building Code Implementation Cell (ECBC-IC) inside the designated agencies shall be responsible for promoting and implementing the ECBC by providing technical support and training to building professionals to ensure that they understand the requirements of the code and can comply with them with support of NEECA.

The Energy Conservation Building Code Compliance Monitoring Cell (ECBC-CMC) inside the designated agencies shall be responsible for monitoring compliance with the ECBC. The ECBC-CMC conducts compliance audits, issues notices for non-compliance, and takes legal action against violators.

14.3 Methodology for Promotion of Energy Conservation and Efficiency

14.3.1 Building Energy Efficiency Certification

NEECA and other designated agencies may promote and offer voluntary certification program for buildings that meet or exceed the minimum energy performance requirements. Builders and developers to showcase the energy efficiency of their buildings to potential buyers or tenants.

14.3.2 Third-Party Audits

Third-party audits may be conducted by private agencies to assess the energy performance of buildings and ensure compliance with energy building codes. Private sector organizations, such as energy service companies (ESCOs), offer energy audit services to building owners and provide recommendations for improving energy efficiency.

14.3.3 Green Building Certification

NEECA and other designated agencies may promote Green Building Certification program. These certifications provide guidelines for building design and construction that minimize environmental impact and promote energy efficiency. Private developers and building owners can choose to adopt these rating systems voluntarily.

14.3.4 Education and outreach

NEECA and other designated agencies may conduct awareness campaigns and outreach programs to promote energy conservation and energy efficiency in buildings. Conduct trainings and capacity-building programs for stakeholders to promote the adoption of energy-efficient building practices training and education on building energy codes and standards to builders, designers, and other stakeholders. Outreach can include workshops, webinars, conferences, and publications, to help ensure that everyone understands the requirements and can comply with them.

14.3.5 Industry associations

Industry associations may conduct awareness campaigns, seminars, and workshops for their members to promote energy-efficient building practices. These associations also provide guidance and support to their members to ensure compliance with energy building codes.

14.3.6 Non-Governmental organizations (NGOs)

NGOs may conduct awareness campaigns and outreach programs to promote energy-efficient building practices. These NGOs also provide technical support and guidance to stakeholders to ensure compliance with energy building codes.

14.3.7 Building Energy Efficiency Certification (BEEC)

BEEC certification programs provide training and education to building professionals to promote awareness and understanding of energy building codes. BEEC certification also helps to promote the adoption of energy-efficient building practices by showcasing the energy efficiency of certified buildings to potential buyers or tenants.

14.3.8 Continuous Improvement

Building energy codes and standards shall be updated regularly to reflect technological advancements and changes in building practices. This continuous improvement ensures that the energy efficiency requirements remain relevant and effective.

14.3.9 Star Rating

Energy-efficient practices in residential and commercial buildings may be adopted. The rating system is voluntary and provides a star rating based on the energy efficiency of the building design and systems. The rating will support builders and developers to showcase the energy efficiency of their buildings to potential buyers or tenants.

14.3.10 Green Building Rating Systems

Green building rating systems for promote sustainable building practices and provide guidelines for building design and construction that minimize environmental impact and promote energy efficiency may be adopted. Builders and developers may choose to adopt these rating systems voluntarily, but many government buildings and projects require them to achieve a specific rating.

Enforcement of the green building rating and start rating systems shall be carried out through a combination of voluntary compliance and regulatory mechanisms. Voluntary compliance is encouraged through incentives such as tax benefits, grants, and subsidies for green buildings.

14.4 Benefits Through Green Rating Systems

There are several benefits of green rating systems, some of which are:

14.4.1 Environmental Benefits

Green rating systems encourage the adoption of sustainable building practices that help to reduce the impact of buildings on the environment. This includes reducing energy and water consumption, reducing greenhouse gas emissions, and promoting the use of renewable energy sources.

14.4.2 Health Benefits

The Green buildings provide a healthier indoor environment by improving air quality, reducing exposure to toxins and pollutants, and promoting natural light and ventilation. This leads to better occupant health and well-being.

14.4.3 Economic Benefits

The Green buildings can help to reduce operational costs by lowering energy and water consumption. Additionally, green building projects may be eligible for tax benefits, grants, and subsidies, which can help to offset the higher initial costs of building green.

14.4.4 Social Benefits

The Green buildings are designed to be more comfortable and convenient for occupants, leading to increased satisfaction and productivity. Additionally, green building projects create jobs and promote the use of local and sustainable materials.

14.4.5 Recognition and Marketability

The Green building rating systems provide a framework for recognizing and promoting sustainable building practices. Buildings that achieve high ratings can be marketed as environmentally responsible and may have a competitive advantage in the real estate market.

14.4.6 Tax Benefits

The developers may get tax benefits to green building developers in the form of accelerated depreciation, tax holidays, and exemptions on certain taxes such as excise duty, customs duty, and service tax.

14.4.7 Subsidies and Grants

The government provides financial incentives to green building developers in the form of subsidies and grants for the installation of energy-efficient and renewable energy systems.

14.4.8 Fast-Track Approvals

Governments may offer fast-track approvals for green building projects, in order to encourage developers to adopt sustainable building practices.

14.4.9 Lower Interest Rates

Some banks and financial institutions may offer lower interest rates on loans for green building projects, as a way to promote sustainable development.

14.4.10 Certification Fee Waivers

Certification bodies may offer fee waivers or discounts for certification of green building projects, as a way to encourage developers to pursue green building certification.

14.5 Penalties & Legal Actions on Non-Compliance of Energy Building Codes

The penalties shall be imposed and legal action may be taken against the building owners for violating and non-compliance of energy conservation building codes that will be decided by the designated Authorities as per rules and policies.

14.6 Recommendations

In view of above, the implementation and enforcement of energy building codes requires a well-defined administrative structure. Here's a possible administrative structure that can ensure the implementation and enforcement of energy building codes:

14.7 National-level administrative body

The NEECA under the Ministry of Science & Technology is the national-level administrative body responsible for promoting energy efficiency & responsible for promoting energy efficiency in various sectors, including buildings. The NEECA is responsible for developing energy efficiency codes and standards, providing technical assistance, upgradation and capacity building, and monitoring compliance with the codes and standards through the following agencies/departments/organization.

1. Development Authorities i.e., local government, city/town development authorities, municipal development authorities are responsible for issuance of building permits, conducting inspections, and ensuring compliance with energy building codes relates to infra structure building projects or retrofitting with certain delegation of powers.
2. Electrical Inspectorate in the jurisdiction with delegation of powers for issuance of NOCs, for compliance with energy building codes relates to Electrical power.
3. Renewable Energy organization in the jurisdiction with delegation of power is responsible for issuance of NOCs for compliance with energy building codes relates to Renewable Energy projects.
4. Online integrated system may be proposed to be developed among the stakeholders for efficient and transparent monitoring, implementation and enforcement of these codes.

Provincial-level administrative body: Each province can have a designated administrative body responsible for enforcing energy building codes within the province. This administrative body can be created by the Provincial government and can be responsible for implementation and enforcement on provincial level through the following agencies/departments/organizations

1. Development Authorities i.e., local government, city/town development authorities, municipal development authorities can be responsible for issuance of building permits, conducting inspections, and ensuring compliance with energy building codes relates to infra structure building projects or retrofitting with certain delegation of powers.

2. Electrical Inspectorate in the jurisdiction with delegation of powers can be responsible for issuance of NOCs, for compliance with energy building codes relates to Electrical power works.
3. Renewable Energy organization in the jurisdiction with delegation of power can be responsible for issuance of NOCs for compliance with energy building codes relates to Renewable Energy projects.
4. Online integrated system can be proposed to be developed for interaction among the stakeholders for efficient and transparent monitoring, implementation and enforcement of these codes

Technical committees: Technical committees can be established at the national, provincial, and local levels to provide technical guidance and support in the implementation of energy building codes. These committees can consist of experts from the construction industry, academia, and government.

Training and capacity building: To ensure effective implementation and enforcement of energy building codes, it is essential to train and build the capacity of building professionals, code officials, and other stakeholders. The national and provincial-level administrative bodies can be responsible for providing training and capacity building programs.

Monitoring and evaluation: Regular monitoring and evaluation of the implementation and enforcement of energy building codes can help identify gaps and improve the overall process. The national and provincial-level administrative bodies can be responsible for conducting monitoring and evaluation activities.

Public awareness and participation: Public awareness and participation are crucial for the successful implementation and enforcement of energy building codes. The national and provincial-level administrative bodies can conduct awareness campaigns and engage with the public to promote energy efficiency in buildings.

In conclusion, the implementation and enforcement of energy building codes requires a well-defined administrative structure that involves national, state, and local-level bodies, technical committees, training and capacity building programs, monitoring and evaluation activities, and public awareness and participation. Such a structure can help achieve energy efficiency goals and promote sustainable development in the building sector.

SECTION-15

15. Retrofitting Techniques for Energy Conservation

15.1 Purpose

The purpose of this code is to provide minimum functional requirements for making the existing building structures energy-efficient through different Retrofitting Techniques.

15.2 Scope

The code shall apply to independent housing units only.

15.3 Applicable Building System

The provisions of this code shall apply to:

a) Building envelopes
b) Building mechanical systems and equipment, including heating, ventilation and air conditioning (HVAC) and general appliances.
c) Water System (WS)
d) Lighting

15.3.1 Exemptions

The code shall NOT apply to the following:

i. Buildings that are older than 30 years.
ii. Government notified historically significant and heritage buildings.
iii. Low-Cost buildings i.e., Village Constructions.

15.4 Safety, Health and Environmental Considerations

The safety, health or environmental codes shall take precedence where this code is in conflict with safety, health, or environmental codes.

15.5 Administration and Enforcement

The chapter on Administration and Enforcement of retrofitting of existing buildings to convert them into energy-efficient buildings focuses on the steps and procedures required to ensure the successful implementation of retrofitting projects.

The chapter emphasizes the need for proper administration and enforcement measures to ensure that retrofitting projects are completed effectively and efficiently. It provides guidelines on the regulatory framework, codes and standards, financial incentives, and procurement procedures that can be used to support the retrofitting process.

The chapter also highlights the importance of effective communication and stakeholder engagement in the retrofitting process. It recommends the establishment of a dedicated project team that can oversee the project and ensure compliance with all relevant regulations and standards.

Overall, the chapter provides useful insights and guidance on the administrative and enforcement aspects of retrofitting existing buildings to make them energy-efficient. By following these guidelines, building owners and managers can ensure that their retrofitting projects are successful and contribute to a more sustainable future.

15.6 Compliance Requirements

Review and approval of plans and specifications by respective sanctioning and development authorities/municipalities to get the certification tag.

15.7 Mandatory Requirements

Compliance with the requirements of the Energy Efficiency and Conservation Building Code of Punjab – 2017 shall be mandatory for all applicable buildings.

15.8 Building Envelope

The techniques to upgrade building envelop shall aim at reducing heat transfer to and from the building.

15.8.1 External Walls and Roof

External walls should have a minimum R Value of 15. Roof should have a minimum R Value of 30.

A. Spray polyurethane foam (SPF) is a spray-applied material that is widely used to insulate buildings and seal cracks and gaps, making the building more energy-efficient and comfortable.

More details are listed in Section 4, where structures are categorized according to their type, size and orientation.

15.8.2 Glass and Shading Devices

The glazing shall be used very carefully, maintain a balance between natural light, ventilation and heat gain. The windows must be properly shaded and insulated to minimize the heat exchange.

More details are listed in Section 4, where Glazing size and shading is discussed w.r.t orientation and classification of the structure.

15.9 Air Leakage/Infiltration

The building envelope shall be durably sealed, caulked, gasketed or weather-stripped to minimize air leakages wherever the tendency exists.

(Details to be Added)

15.10 Building mechanical systems and equipment, including heating, ventilation and air conditioning (HVAC) and general appliances.

A. Building mechanical system i.e., air conditioner, fridge, washing machines, fans etc. must be energy efficient (DC Inverters).

B. Power Intensive machinery like Air Conditioner should be switched off during peak hours. (Excellent Building Envelope can make it possible.)

C. Temperature to be maintained as follows:

   i. Summer: not less than 26^0 C
   ii. Winter: not more than 20^0 C

15.11 Recommended Voluntary Adoption

Natural Ventilation Natural ventilation shall comply with the design guidelines as per ASHRAE.

Alternate Energy The use of energy recovery system, geothermal energy, solar systems and other renewable energy systems is encouraged for adoption in buildings as an alternative to conventional heating, ventilating and cooling systems.

(Details to be Added)

15.12 Water System (WS)

A. Water heating should be done through Solar Heaters or other renewable energy sources.
B. Piping Insulation should comply with Energy Efficiency & Conservation Building Code of Punjab – 2017 (EE&CBC Punjab – 2017).
C. If Conventional water Heating Devices has to be used then they must comply with Energy Efficiency & Conservation Building Code of Punjab – 2017 (EE&CBC Punjab – 2017).

(Details to be Added)

15.13 Lighting

Interior and exterior Lighting scheme should comply with NECCA lighting code.

15.13.1 Retro-Fitting Techniques for Energy Efficiency

Recommendations to Achieve Energy Efficiency in Existing Structures.

Existing structures has to be categorized with respect to their scale.

15.13.1.1 For Row Houses (Only open at front or back or both, 5 Marla and under Houses Generally)

The side walls are attached to adjacent houses hence we can ignore them (as they are not exposed to Solar Radiation at all). Front and back walls need to be addressed in such houses.

i. We can apply Poly Urethane sprays or other Insulation sprays/ materials at front and back walls to increase their R, value ideally in the range of 15-20.
ii. Similarly, roofs have to be insulated as well and we should aim to achieve 30-40 R values.

The windows are only at front and back as well so we can treat them according to their orientation.

i. If the house is open to east and west sides (East at front and back towards west or vice versa) then windows must have some vertical shading devices either some natural shading device like tress or some screen pattern (Jali) to save them from direct Exposure of Solar Radiation.
ii. If the house is in South to North direction, then a horizontal shade of 21-24 inches is enough to block the direct sunlight. In such scenario we don't need vertical Shading devices.

iii. Apart from shading, windows should either be covered with Bubble Wraps or changed with Double Glazed windows (not recommended though as budget must be low for this category) to maintain interior temperatures.

15.13.1.2 Semi Detached Houses

Houses which have 3 sides open (5 Marla to 1 Kanal)

In this category we have to deal with 3 open sides. All 3 sides have to be Insulated (15-20 R Value). Similarly roofs also need to be insulated (30-40 R Value).

Window shades has to follow the same as discussed above, Horizontal shading devices on the South side and vertical shading devices towards the East and West Side. (In this category we can bound landlords to use some expensive materials i.e Double Glazed windows can be made mandatory, to achieve higher efficiency.)

15.13.1.3 Detached Houses

These houses are open from all sides, hence building envelope should be well insulated from all four sides. On all four sides, the envelop should have a 15-20 R value. The roof should have a R value of 40. The windows on all four sides should be properly shaded. Vertical or horizontal shading devices for windows should be used w.r.t orientation as discussed above. Windows must be double glazed. Double Heights, if any, should be equipped with clerestory windows to allow the hot air to escape and hence enhancing the ventilation.

This category must be capable of producing their own energy through renewable means i.e., 10 Kw Solar Energy system.

Section-16

16. Passive Design

16.1 Introduction to Passive Design

Adopting passive design measures is an economical approach to enhancing energy efficiency in both residential and commercial buildings. Almost half of energy consumption is utilized for cooling purposes in hot and humid climates. As a result, the measures outlined in this chapter should be given priority and employed to the fullest extent possible. To optimize passive cooling strategies, adopting passive design measures, which are primarily architectural, makes sense. Passive design measures aim to reduce heat gain within buildings and improve environmental cooling through natural methods such as landscaping, vegetation, and shading.

Since buildings are primarily designed to provide comfortable internal environments for occupants, passive design measures must take the building's surrounding environment into account. The essential passive design measures are discussed below.

16.1.1 Site Planning and Orientation

When designing a new building on open land, it is crucial to consider site planning and orientation. In equatorial regions, the primary goal of proper orientation is to avoid exposing building openings to intense solar radiation as the sun moves from east to west. As a general guideline, the building layout should be oriented in such a way that the main long axis, with more openings or glazing, faces north to south, while the narrow ends of the building face the east-west direction (as shown in Figure 15.1 and Figure 15.2). The objective is to minimize the exposure of building openings to the east-west direction of the movement of sun as much as possible.

The orientation of buildings can also have an impact on the immediate microclimate of open spaces by providing shade and shadow to the surrounding areas. This can be beneficial to the adjacent indoor spaces, helping to regulate their temperature and provide a more comfortable environment.

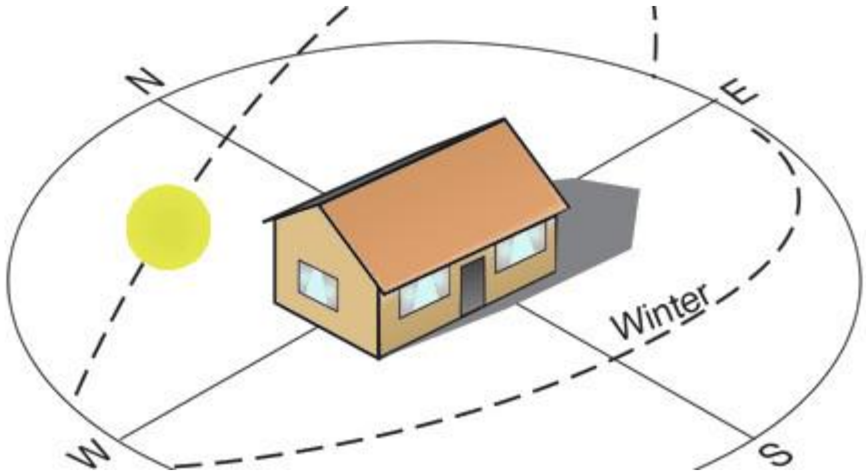

Figure 16.1. Longer Axis of Building Should Face North and South as Much as Possible

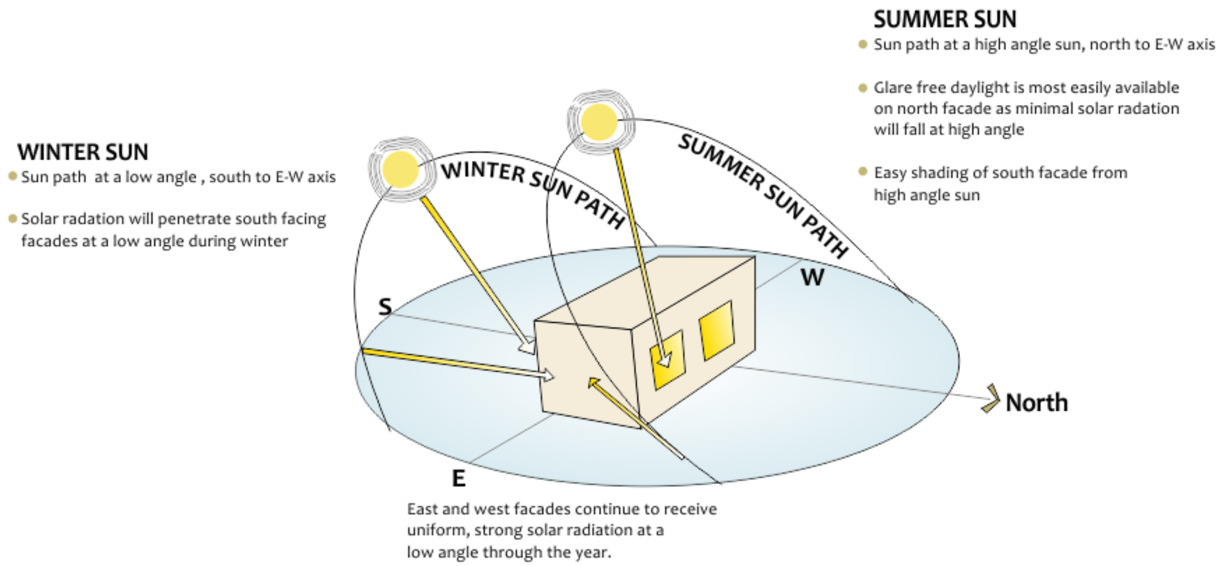

Figure 16.2. Longer Axis of Building Should Face North and South as Much as Possible

16.1.2 Daylighting

Before considering efficient electrical lighting, it is essential to incorporate daylight harvesting in a building to fulfill the lighting requirements during the daytime, where possible. A well-designed daylight harvesting system can benefit the building occupants by providing a comfortable working environment and improving energy efficiency. On the other hand, a poorly designed system can cause discomfort due to glare, excessive heat gain, increased thermal discomfort, and high energy consumption in buildings.

The daylight factor (DF) is a straightforward way to describe daylight distribution, penetration, and intensity. It is expressed as a percentage and represents the ratio of the internal space illuminance ($E_{internal}$) at a point in a room to the instantaneous external illuminance ($E_{external}$) on a horizontal surface (as shown in equation 1).

$$E(internal)$$

$$DF = \frac{\qquad}{E(external)} \; x \; 100 \qquad \text{----------------- (1)}$$

Where:

DF = daylight factor (%)

E(internal) = horizontal illumination of reference point indoor (Lux)

E(external) = horizontal illumination of unobstructed point outdoor in an overcast sky condition (Lux)

As a general guideline, the brightness levels and distribution within a building can be broadly categorized based on the daylight factors described in Table 15.1. A recommended range of daylight factor is 1.0-3.5. Incorporating daylighting into a design of building can lead to energy savings by reducing the need for artificial electrical lighting, which in turn reduces lighting energy emissions that need to be removed by the air-conditioning and mechanical ventilation (ACMV) system.

Table 16.1. Daylight Factors and Impact (Source: MS1525:2019)

Daylight Factor	Lighting	Glare	Thermal Comfort	Appearance and Energy Implication
> 6.0	Intolerable	Intolerable	Uncomfortable	The room appears strongly daylit. Artificial lighting is rarely needed during the day, but thermal problems due to solar heat gains and glare may occur.
3.5–6.0	Tolerable	Uncomfortable	Tolerable	
1.0–3.5	Acceptable	Acceptable	Acceptable	The room appears moderately daylit. It is generally a good balance between lighting and thermal aspects. Supplementary artificial lighting may be needed in dark areas due to the effect of layout or furniture arrangement.

< 1.0	Perceptible	Imperceptible	Acceptable	The room looks gloomy; artificial lighting is needed most of the time.

16.1.3 Façade Design and Building Envelope

The design of a building's façade is a crucial element in implementing passive design measures. It offers architects the opportunity to incorporate innovative ideas to minimize solar heat gains in the building. The façade is the external envelope of a building that not only defines its form and aesthetics but can also optimize daylighting and thermal comfort by reducing solar heat gains with the help of architectural treatments and appropriate materials.

To prevent heat from entering the building through conduction and solar radiation, the building envelope should be designed to act as a barrier. A well-designed envelope can significantly reduce the cooling load and, as a result, the energy consumption of the building. A design criterion called Overall Thermal Transfer Value (OTTV) is one way to measure the performance of a building envelope. This criterion is particularly useful for non-air-conditioned and partially air-conditioned buildings. Its objective is to optimize the design of the building envelope to minimize external heat gain, which in turn reduces the cooling load of the ACMV system.

A maximum value of 50 W/m2 is recommended for the OTTV of a building envelope. However, stakeholders should deliberate on this value and the Department of Energy (DOE) should ultimately decide whether to adopt a higher energy efficiency goal, as there may be cost implications for such a decision. For the purpose of this report, the maximum OTTV value for a commercial building is set at 50 W/m2. The OTTV is calculated based on all external walls of the building. Achieving an OTTV not exceeding 50 W/m2 confirms that the building envelope design incorporates measures to minimize external heat gain, which in turn reduces the cooling load of the ACMV system. Such efforts will also result in a decrease in the required capacity of the ACMV equipment.

The shading design of the main façade are shown follows:

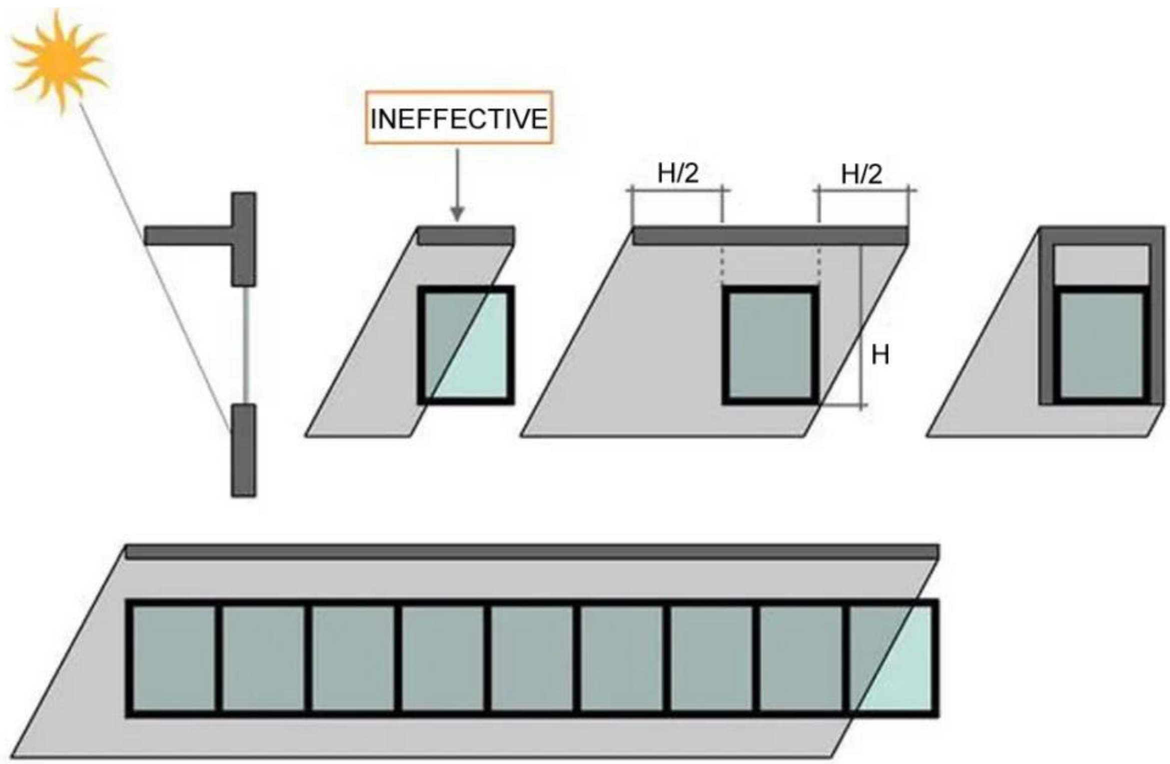

Figure 16.3. Façade Design with External Shading

1. The building envelope design should aim to achieve an OTTV of 50 W/m2 or less for external walls and 25 W/m2 or less for the roof.

16.1.3.1 Fenestration design and glazing selection

i. When possible, choose a building form and fenestration design that minimize glazing while still meeting the building's aesthetic requirements.
ii. Selecting the right glazing properties can help to lower the OTTV value, reduce cooling loads, and increase energy efficiency.
iii. A suitable selection guide is to choose glazing with a low solar heat gain coefficient (SHGC) to decrease the amount of solar heat gain in the

building, and high visible light transmission (VLT) to maximize daylight harvesting.

iv. It is recommended to choose a balanced selection because glazing with a low SHGC may result in an unsatisfactory VLT, such as glazing with a VLT of less than 10%, which can make the building appear dim. For instance, high-performance low-e double glazing can achieve a low SHGC of less than 0.15 with a VLT of 25% or higher.

v. As a general rule, the ratio of light to solar gain (VLT to SHGC), also known as LSG, can be used as a guide. A higher LSG ratio is preferable for commercial buildings that utilize daylight harvesting.

- Single glazing without low-e properties usually has LSG values between 0.5 to 1.0.
- Single glazing with low-e properties typically has LSG values between 1.05 to 1.3.
- High-performance double glazing with low-e properties generally has LSG values ranging from 1.5 to 2.0.

16.1.3.2 Building materials

In a tropical climate, using appropriate building materials with insulating properties can substantially decrease energy consumption. During the day, outdoor air temperature is usually high, whereas air-conditioned spaces are maintained at temperatures of 23°C to 27°C. As a result, heat is transferred from the outside to the inside of the building via conduction. However, during the night and early morning, the outdoor air temperature is likely to be lower than the indoor air temperature, causing heat flow to reverse compared to daytime conditions.

Table 15.2 illustrates the varying energy-saving potential of wall materials with different coefficients of heat transfer (U-values). The estimated values presented in the table are based on an energy simulation study outlined in BSEEP 2021. The study's model was constructed using a square building without external shades, with a service core located in the building's center. The high, medium, and low night-time baseloads are associated with night baseloads of 50%, 35%, and 10% of the daytime peak load, respectively. The data in Table 3.2 highlights that lower U-values correspond to lower simplified energy indices, which can be used as a straightforward method to estimate energy savings resulting from selecting wall materials with improved U-values in hot and humid climates.

Table 16.2. Comparison of Estimated Energy (Electricity) Reduction of Various Wall Materials under Three Baseload Scenarios

Case	Description	ASHRAE U-value (W/m²K)	Wall Simplified Energy Index (kWh/y per m² of wall area)		
			High nighttime baseload	Medium night-time baseload	Low night time baseload
1	Concrete wall, 100 mm	3.40	55	32	28
2	Brick wall, 115 mm	2.82	52	30	25
3	Brick wall, 220 mm	2.16	50	27	22
4	Double brick wall with 50 mm cavity, 300 mm	1.42	48	25	20
5	Autoclave lightweight concrete, 100 mm	1.25	47	24	18
6	Autoclave lightweight concrete, 150 mm	0.94	45	22	17
7	Autoclave lightweight concrete, 200 mm	0.75	45	22	16

Source: Extracted from Public Works Department Malaysia (2021).

16.1.3.3 Core location

A. Placing the service core (which includes lift core, services, etc.) strategically in a building can serve as a buffer zone, mitigating the effects of solar radiation in air-conditioned spaces. Ideally, the core should face east or west. However, in some cases, other architectural considerations may limit the available options. In such cases, the designer should choose the next best alternative.

B. The main goal of positioning the core is to optimize the effectiveness of the façade design in reducing solar heat gains.

C. By comparing Figures 15.5 and 15.6, it can be observed that a square building with a central core has a better view and larger glazing area, while a square building with a side core facing west has a smaller view and less glazing. However, in terms of solar heat gains, OTTV, and building energy performance (BEI value), the square building with a central core facing west has better performance (Figure 15.5).

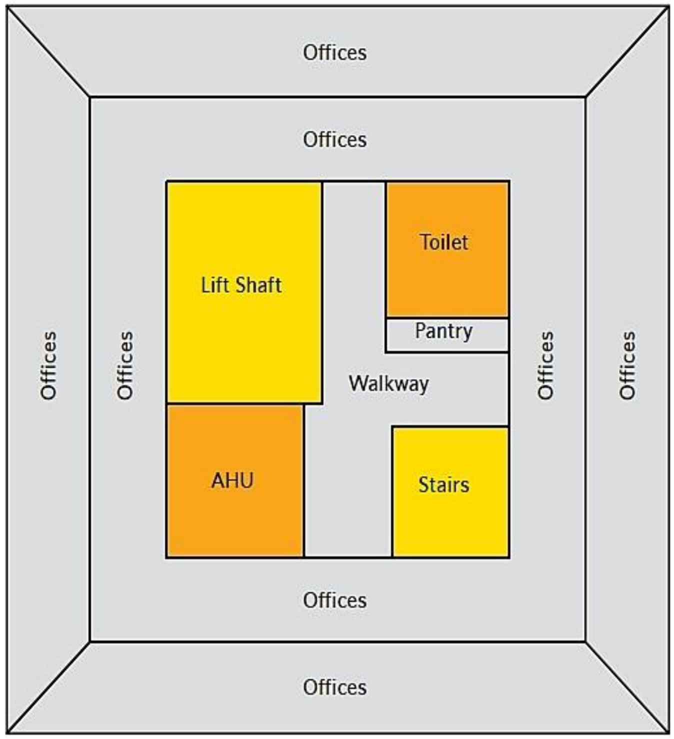

Figure 16.4. Square Building Centre Core

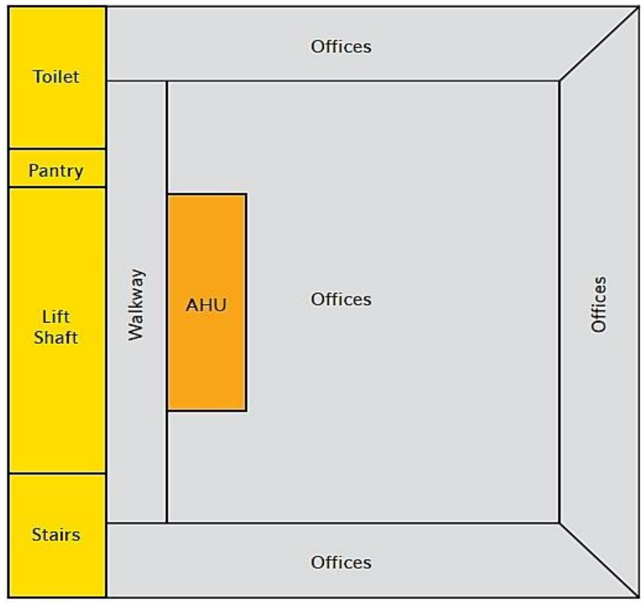

Figure 16.5. Square Building Core West

Source: Public Works Department Malaysia (2021).

16.1.4 Natural Ventilation

Ventilation, or the movement of air, serves three essential functions:

i. It supplies the required fresh air to occupants of a building.

ii. It helps maintain the thermal comfort of building occupants.

iii. It reduces the temperature of the interior space when outdoor air is cooler.

ASHRAE Standard 62.1 - Ventilation for Acceptable Indoor Air Quality - outlines the necessary ventilation requirements. From an energy efficiency perspective, properly conditioning ventilation air can be costly, especially in hot and humid regions. It requires cleaning, drying, cooling, and distributing outdoor air to the breathing zone, all of which are expensive processes. Despite this, it is essential to introduce outdoor air to air-conditioned spaces for health reasons. During specific periods, such as mornings and evenings, natural ventilation can effectively cool offices and other areas with fresh air. During these times, air flushing of building spaces can be considered. However, security, ambient exterior noise levels, outdoor air quality, outdoor air temperatures, humidity, weather conditions, and other factors should also be taken into account.

Given the current COVID-19 pandemic situation, ASHRAE's Position Document on Infectious Aerosols recommends increasing ventilation and filtration in air-conditioned spaces provided by ACMV systems. These measures can help lower the concentration of COVID-19 in the air and, as a result, reduce the risk of transmission.

Natural ventilation employs natural forces such as wind and buoyancy to provide adequate fresh air and air changes to ventilate enclosed or semi-enclosed spaces. In the design of common areas such as lobbies, corridors, staircases, toilets, semi-enclosed parking lots, and canteen areas, natural ventilation without mechanical means should be considered to promote energy efficiency.

There are two methods for implementing natural ventilation:

16.1.4.1 Cross ventilation (wind-driven)

Figure 15.6 illustrates cross ventilation, which involves the flow of air across a building space through windows, driven by wind.

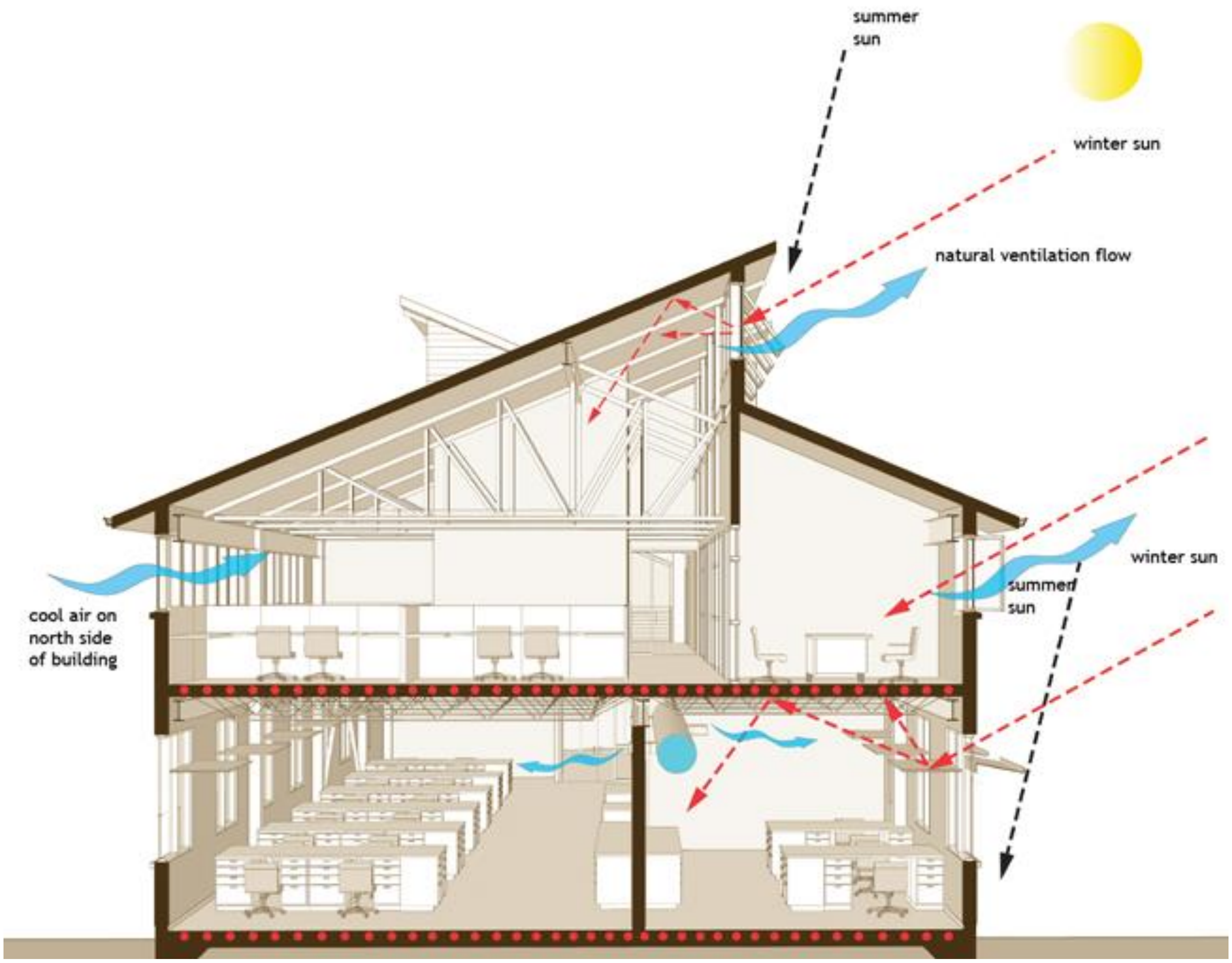

Figure 16.6. Building Section Showing Cross Ventilation

16.1.4.2 Stack ventilation (buoyancy driven)

Figure 15.7 depicts stack ventilation, which is buoyancy-driven and is typically utilized in high-rise buildings through void spaces or atriums.

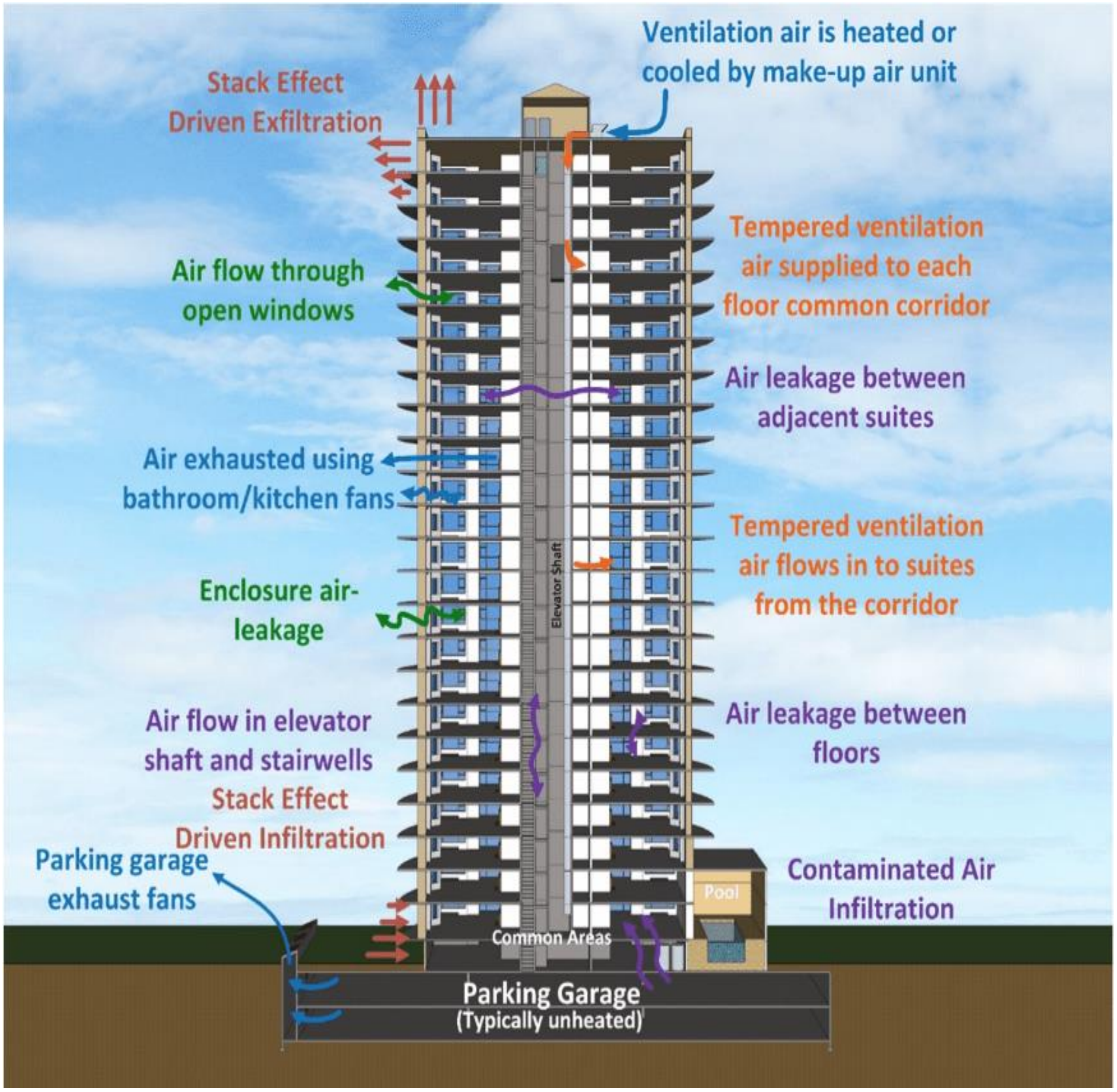

Figure 16.7. High-rise Building Section Showing Stack Ventilation

Overview of components of airflow and ventilation in a multi-unit building (Source: RDH Building Science)

16.1.5 Strategic Landscaping

This approach is well-suited for highly urbanized areas, where the surrounding buildings are densely packed with little greenery. Strategic landscaping within a building development can help mitigate heat gain. The aim of strategic landscaping is to create a cooler microclimate around the building and reduce the urban heat island effect. Highly urbanized and densely built-up areas tend to be considerably warmer than rural and less populated regions.

Figures 15.8 and 15.9 showcase some approaches that can be implemented to establish a cooler microclimate around a building:

i. Utilize as much available space around a building for landscaping (see Figure 15.9)

ii. Integrate an aquascape or water feature (see Figures 15.8 and 15.9)

The selection of appropriate plant species and the use of high-reflectance materials in hardscape areas can help minimize the solar absorption of hard surfaces, thereby mitigating the urban heat island effect. Materials with a high solar reflectance index should be chosen. For instance, trees and shrubs near building facades that face east and west can offer external shading, reducing solar heat gain inside the building (refer to Figure 15.9).

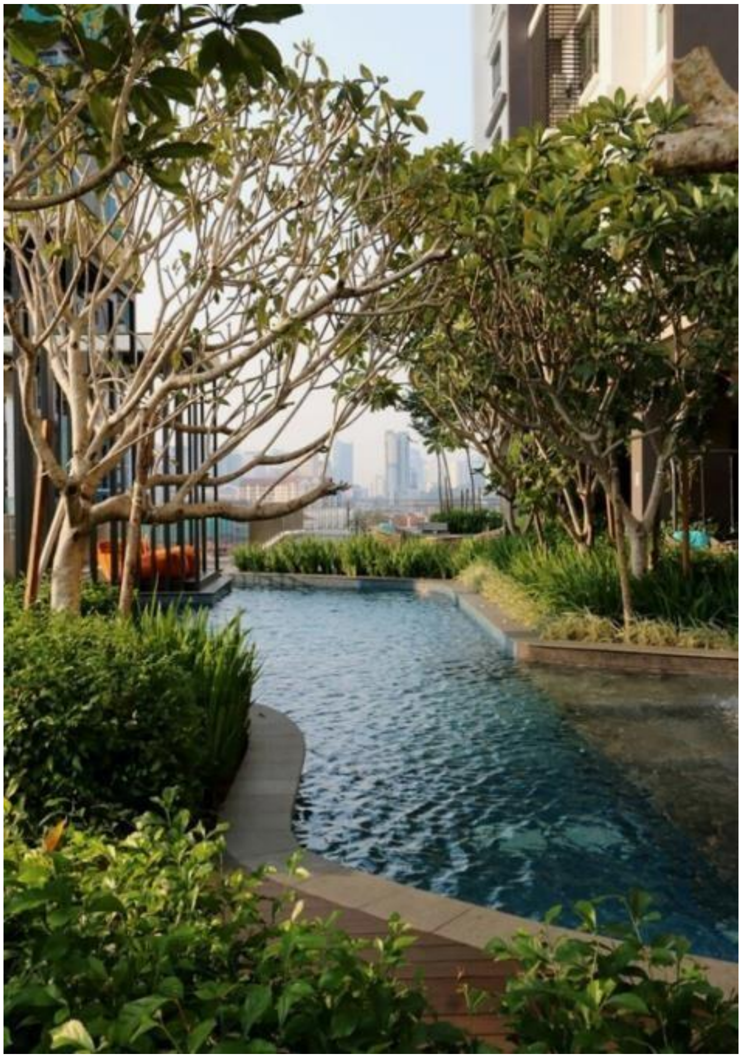

Figure 16.8. Water feature and shrubs placed in close proximity to western-facing building facades

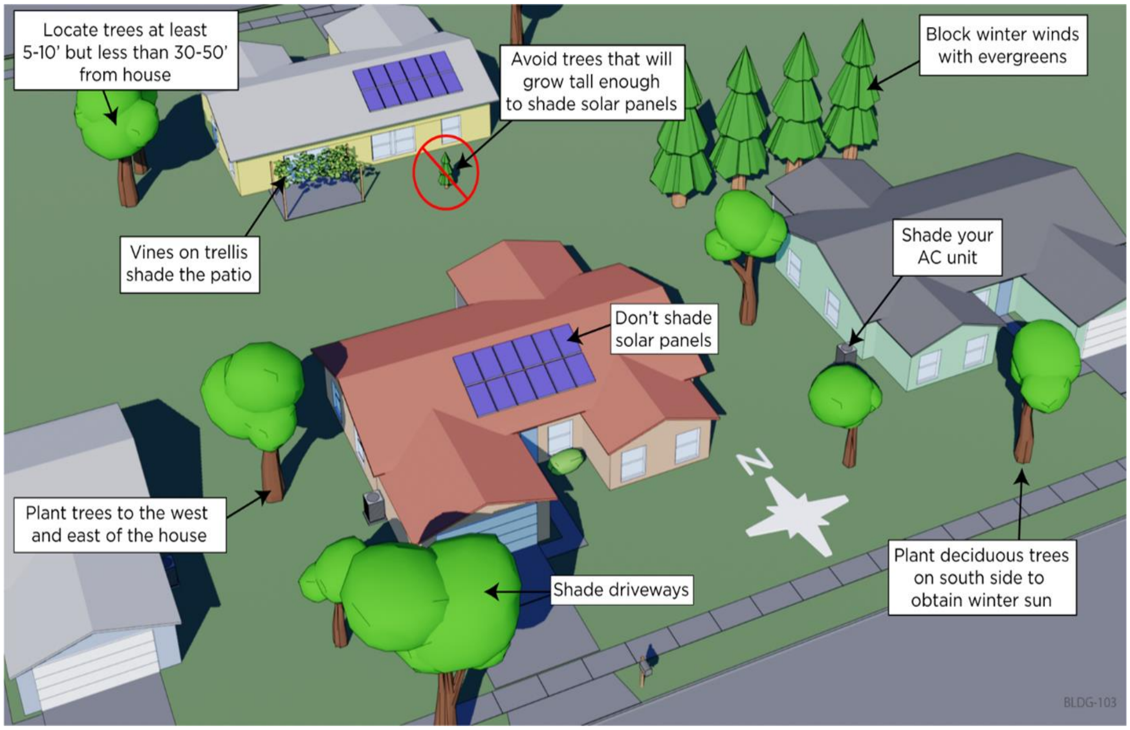

Figure 16.9. strategic landscaping designed to establish a cooler microclimate

(Source: Building America Solution Centre)

16.1.5.1 Develop and implement a landscaping plan to minimize heat gain in residential buildings

1. Develop a site map indicating the current vegetation and the location of existing or planned buildings (refer to the Success tab for an example).
2. Design a landscaping plan that maximizes shading and evaporative effects, minimizes heat gain from hardscaping, and preserves solar access in the wintertime.
3. Ensure proper grading for drainage around the house and for water retention on the grounds.
4. Strategically plant or maintain landscaping around the home to provide shade for walls, windows, roof, skylights, hardscaping, and pavement.

5. Consider installing architectural structures such as pergolas and trellises to support strategic plantings.
6. Integrate water features where appropriate.
7. Use light-colored and permeable hardscaping and pavement materials.

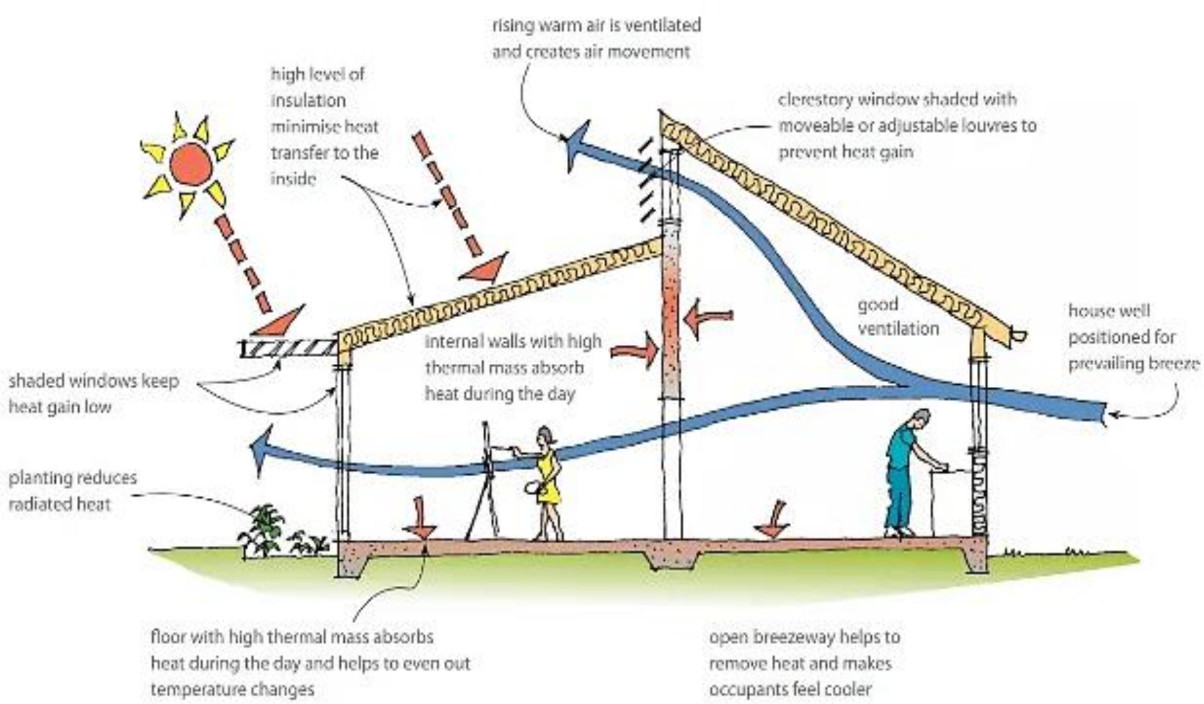

Figure 16.10. Overall Passive design strategies ***(Source: Archimonarch)***

16.2 Roof top Gardening

Roof top gardening is a passive design strategy that involves using the rooftop of a building for vegetation. This approach can decrease the building's heat gain, offer insulation, and decrease stormwater runoff. The following is a brief overview of the code for rooftop gardening in passive building design:

16.2.1 Building Assessment

The initial step is to evaluate the building's structural capability to support the garden's additional weight, as well as the roof's suitability for planting.

Garden Design: The garden design should consider the local climate, the amount of sunlight and shade the rooftop receives, and the type of vegetation that will be planted.

Watering System: A watering system must be designed to ensure that the plants receive adequate moisture while also managing excess water runoff.

Soil and Drainage: The soil selection should be based on the type of vegetation and the local climate. The drainage system should be planned to prevent waterlogging.

Maintenance Plan: A maintenance plan should be developed to ensure the garden is well-cared for, including regular watering, pruning, and fertilization.

Safety Measures: Appropriate safety measures should be taken to prevent accidents, such as installing guardrails and warning signs.

The rooftop gardening code for passive building design may vary depending on the local jurisdiction's specific requirements and regulations, as well as the type of building and vegetation used. It is critical to consult with experts in building design and horticulture to ensure that the project is safe and effective.

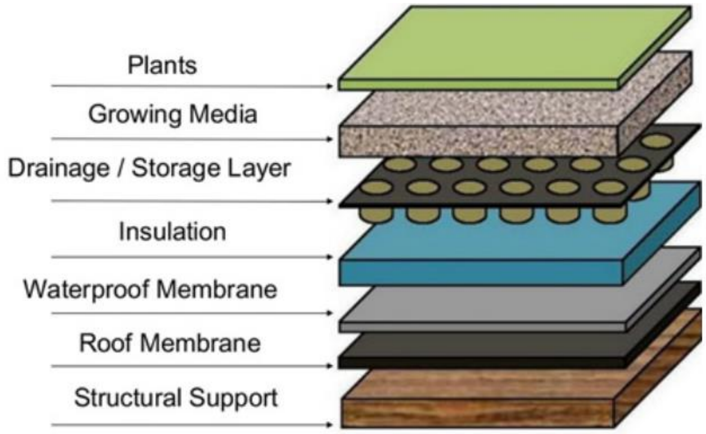

Figure 16.11. Green Roof Concepts as a Passive Cooling Approach ***(Source: EDP Science)***

16.3 Vertical Gardening

Vertical gardening is a passive design strategy that involves using the vertical surfaces of a building to cultivate vegetation. This approach can reduce the heat gain of the building, provide insulation, and decrease stormwater runoff. The following is a brief explanation of the code for vertical gardening for passive building design:

Building assessment: The first step is to assess the building's structural capacity to support the additional weight of the garden and the suitability of the vertical surfaces for planting.

Garden design: The garden design should consider the local climate, the amount of sunlight and shade the walls receive, and the type of vegetation to be planted. The design should also take into account factors such as irrigation, fertilization, and pruning.

Plant selection: The plant selection should consider factors such as the ability to withstand the local climate and the amount of maintenance required.

Soil and drainage: The soil should be chosen based on the vegetation type and the local climate. The drainage system should be designed to prevent waterlogging.

Maintenance plan: A maintenance plan should be developed to ensure that the garden is well-maintained, including regular watering, pruning, and fertilization.

Safety measures: Safety measures should be taken to prevent accidents, such as installing guardrails and warning signs.

The code for vertical gardening for passive building design may vary depending on the specific requirements and regulations of the local jurisdiction and the type of building and vegetation being used. It is crucial to consult with building design and horticulture experts to ensure that the project is safe and effective.

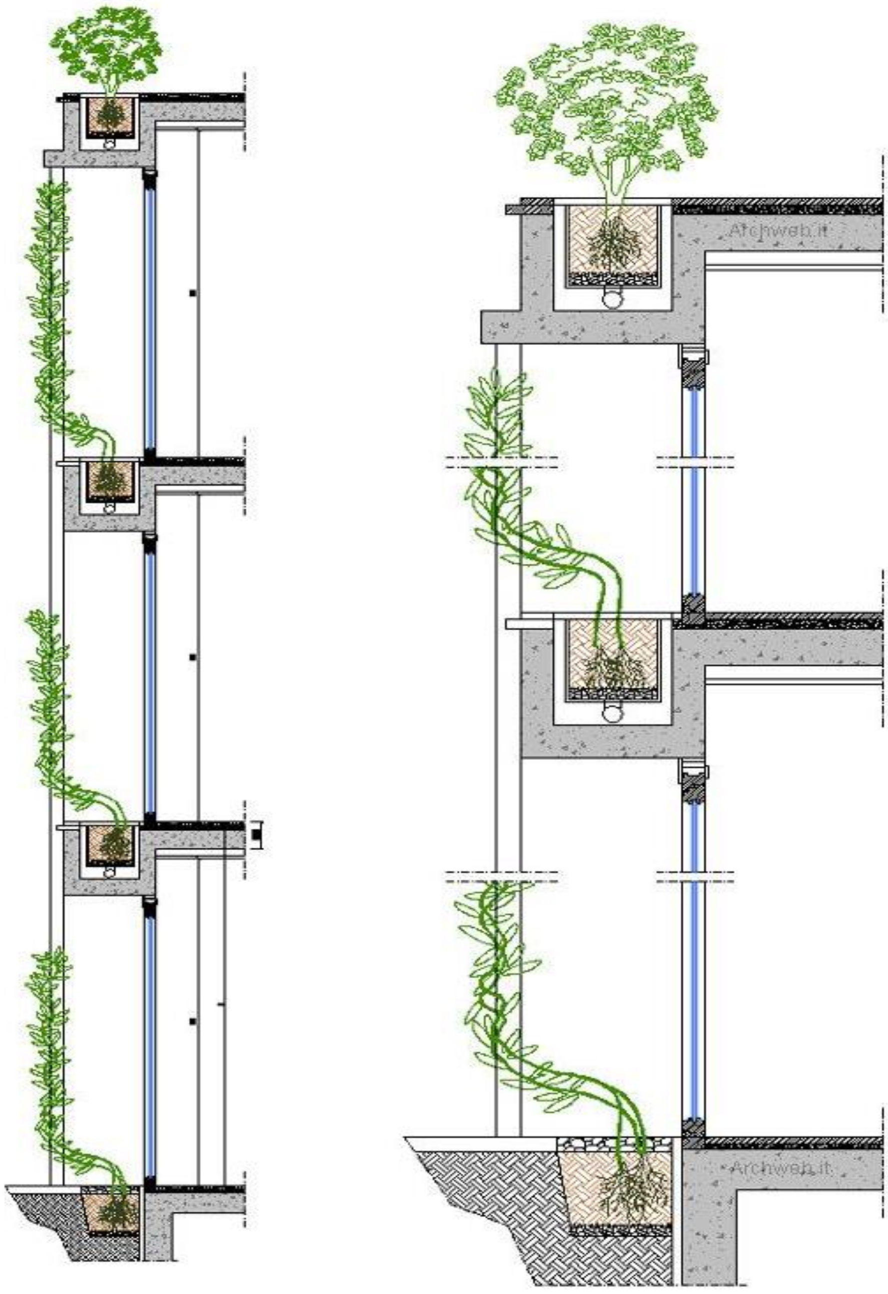

Figure 16.12. Vertical Gardening Concepts as a Passive Cooling Approach ***(Source: EDP Science)***

Section-17

17. Building Insulation

17.1 General Introduction

The building insulation chapter of the Energy Conservation Building Code (ECBC) provides guidelines for the insulation of building envelopes to improve energy efficiency and reduce heat gain/loss. The chapter outlines the minimum thermal insulation requirements for walls, roofs, floors, and windows, as well as the methods for determining the R-value (a measure of thermal resistance) of insulation materials. The chapter also covers the installation, testing, and maintenance of insulation systems. Additionally, it provides recommendations for the use of natural insulation materials and the reduction of thermal bridges (areas of the building envelope that allow for significant heat transfer). The ultimate goal of the chapter is to promote the use of insulation to reduce the energy consumption and associated carbon emissions of buildings.

The construction of a building requires careful consideration of its building envelope, which plays a crucial role in maintaining energy efficiency and ensuring occupant comfort. Apart from factors such as air and vapor permeability, insulation levels, resistance to unplanned air leakage, color, and thermal mass, there are several other factors that must be taken into account. Furthermore, the materials used in construction can impact resource efficiency and environmental sustainability. The construction of the building shell can also impact thermal comfort, as poorly insulated components can impact the radiant temperature of a space, even with the presence of heating and cooling systems. Additionally, the building envelope can contribute to acoustic comfort by reducing external noise from sources such as traffic.

17.2 Heat Transfer Through the Building Envelope

The process of heat transfer through building envelopes is a complex and dynamic phenomenon, which is influenced by a variety of factors including solar gain, outdoor temperature, and indoor temperature. The performance of building envelopes is determined by four critical characteristics: thermal resistance (measured in terms of U-factor or R-value), air and vapor permeability, heat storage capacity (also known as thermal mass), and the condition and finish of the exterior surface.

17.3 U-factor

The U-factor measures heat flow at a steady-state. In one hour, a temperature difference of 1°F between indoor and outdoor air moves a specific amount of heat through a 1 ft2 surface area, measured in British thermal units (Btu). Heat can move from warmer to cooler regions in either direction. The majority of building materials and insulation have a uniform effect on the flow of heat in both directions. Nonetheless, specific building components, such as radiant barriers, can lower the amount of heat entering the structure, with little impact on the heat leaving the building.

For an adequate duration, the temperature continuity on both sides of a building element is assumed, allowing the heat leaving one side to be equal to the heat entering the other. Although U-factor is an oversimplified measure, it can provide an estimate of the average heat flow rates over time, making it a useful tool for illustrating building thermal performance. R-values and U-factors are fundamental terms in the field of building energy efficiency, as they are simple to comprehend and utilize. However, since temperatures fluctuate continuously in the real world, steady-state heat flow models may not always be entirely accurate.

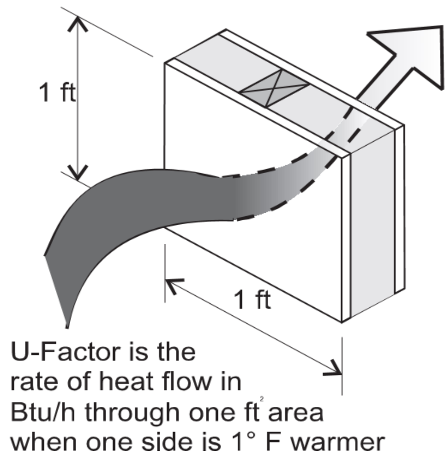

Figure 17.1. Conceptual Representation of U-factor

If metal framing is used in construction, a thermal bridge can significantly diminish the insulation effectiveness of the assembly. The U-factor considers all elements of the building assembly, which includes the conductance of the air layer present on both the inner and outer surfaces. The conductance of the air film gauges how fast heat travels between the construction assembly surface and its surrounding surroundings. Several factors, such as the roughness and orientation of the surface, as well as the wind speed across it, can affect the conductance of the air layer.

While the U-factor can adequately describe heat transfer for light frame walls, it may not be as effective for heavy concrete and masonry walls, particularly under dynamic temperatures. The U-factor becomes less accurate in predicting heat flow through walls because concrete and masonry have different thermal properties.

17.4 Concept of R-Value

The R-values are also utilized to indicate constant-state heat flow, although they are expressed differently. Material R-values are proportionate to the thermal resistance of the material, signifying its ability to impede the flow of heat. A lower R-value indicates poorer thermal resistance, while a higher R-value indicates better insulation.

Despite being commonly used in the construction industry, R-values alone cannot provide a comprehensive representation of an overall performance of assembly. For wall or roof assemblies, the R-value only reflects the thermal resistance of the insulation material and does not account for air leakage. Elements such as metal framing, steel beams, and metal window casements that penetrate the insulation can substantially diminish the efficiency of assembly.

Wood stud walls provide a suitable illustration, having insulated cavities and solid wood framing components within a single layer. Wood framing exhibits a lower R-value, allowing heat to conduct more easily compared to insulated regions. Therefore, when computing U-factors for walls, roofs, or floors, framing elements must be taken into account.

17.5 Thermal Mass

Construction assemblies that possess higher thermal mass usually demonstrate superior thermal performance. Compared to lighter counterparts, heavy walls, roofs, and floors have greater thermal mass. Thermal mass can moderate and slow down the process of heat transfer, as demonstrated in Figure-16.2. The duration between the peak outdoor temperature and interior heat transfer can vary between 4 to 12 hours, depending on factors such as thickness, heat capacity, and other properties of the assembly. Delaying heat transfer can be as beneficial as reducing it, particularly for buildings that are not heated or cooled at night when outside air temperature decreases. In regions with humid climates, the diurnal temperature range on hot days is usually minor, so this effect is less significant than in arid areas, where the temperature swing can exceed 30°F.

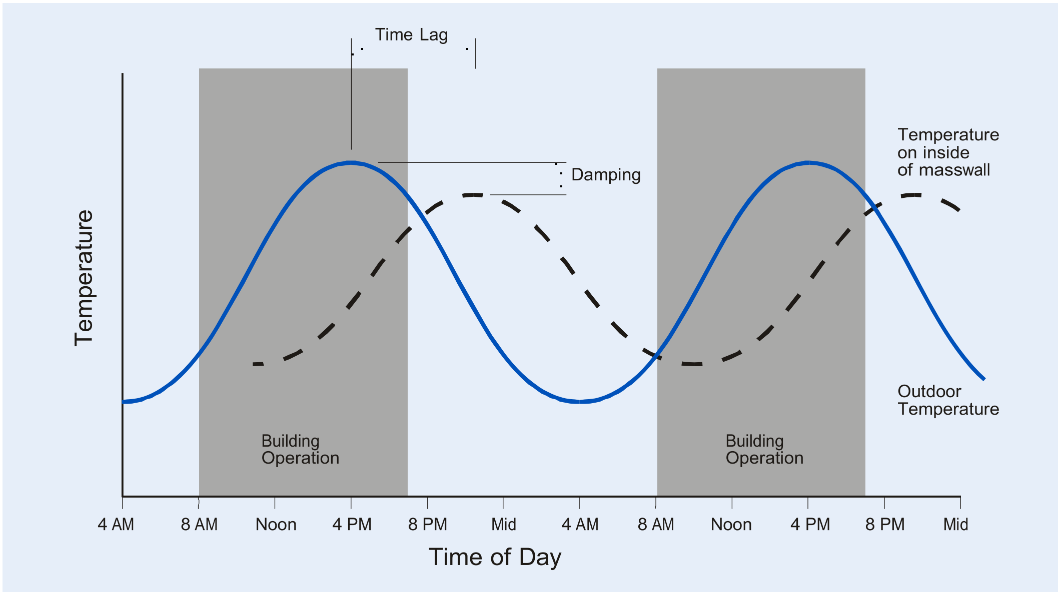

Figure 17.2. Temperature Swing

Providing interior air access to thermal mass can result in additional advantages. Enabling the cooling system to cool the thermal mass at night lowers the morning cooling load. During the daytime, the thermal mass inside a building heat up and emits heat at night when exposed to sunlight. This principle is of utmost importance in passive solar design for regions with cold and humid, cool and humid, or cool and dry climates. Figure 16.3 showcases a number of mass walls that are commonly employed in building construction.

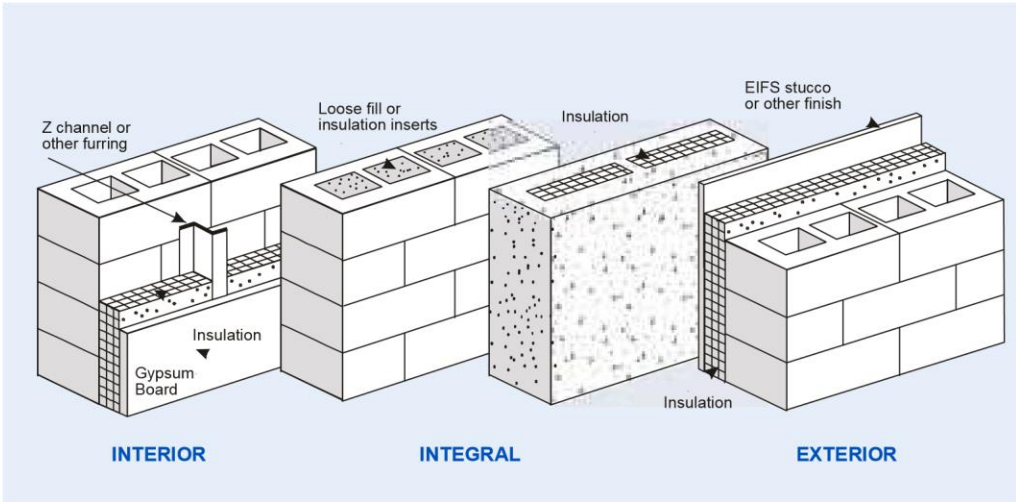

Figure 17.3. Construction of Mass Walls of Buildings

17.6 Heat Capacity

Heat capacity (HC) is a parameter that indicates the amount of heat required to elevate the temperature of a building material by 1°F, expressed in Btu/ft²·°F. It serves as a measure of thermal mass, accounting for the heat capacity of each layer in a wall. HC can be approximated by multiplying the weight of a ft2 of wall, roof, or floor by 0.2. For instance, a wall weighing 100 lb./ft² has an HC of approximately 20 Btu/ft²·°F. Energy efficiency standards such as ASHRAE/IESNA Standard 90.1-2019 utilize HC as a factor in the overall performance evaluation of building envelope components. Mass wall construction represents a distinct category of construction that must adhere to specific thermal performance standards. While concrete is not an optimal insulating material, incorporating air bubbles through aerated concrete can enhance its insulation capability. Lightweight concrete can be created using low-density aggregates such as perlite or vermiculite. Additionally, moisture transport characteristics should be considered.

17.7 Cool Roof Systems

The exterior surface significantly affects heat transfer, especially for roofs. Cool roofs have desirable surface characteristics, including high solar reflectance and high or normal emittance, which are two critical factors. High solar reflectance indicates that the roof surface reflects solar radiation rather than absorbing it, keeping the surface temperature low, reducing heat gain, and minimizing the need for air conditioning. Additionally, high or normal emittance is crucial as it enables a surface to release heat by radiating it back to the sky, thereby reducing cooling loads and extending the lifespan of roofing materials. In contrast, surfaces with low emittance, such as galvanized metal and other metallic finishes, struggle to release their heat by radiating it back to the sky. The advantages of cool roofs go beyond energy efficiency and can also alleviate the heat island effect in buildings, which is particularly important in densely populated urban areas.

17.7.1 Radiant Barrier in Buildings

When constructing a building, various factors must be taken into account, including the use of radiant barriers. In numerous building assemblies, a large cavity is present between the ceiling and roof, much like an attic. Radiant barriers are not typically utilized in walls but can be beneficial in reducing heat transfer from a warmer surface to a cooler one within cavities where radiation is the primary mode of heat transfer. A radiant barrier incorporates a metallic surface within the cavity that emits low levels of light. As a result, radiant barriers are often installed in attics.

17.7.2 Applicable Codes

Several states have established building insulation standards to guarantee energy efficiency in buildings. In this section, we refer to these standards as Standard 90.1, although they may differ from one state to another. Table 16-1 outlines the minimum R-values for prescriptive criteria, while Table 16-2 lists the maximum U-factors for component performance criteria. Exceeding the recommendations in Standard 90.1 may be more cost-effective for most buildings than merely meeting them. For a comprehensive list of recommendations, please refer to the guidelines below.

The presented table outlines the minimum R-value range for building components necessary to satisfy the prescriptive building envelope criteria specified in Standard 90.1.

The table is arranged into columns for each of the seven climate zones, each with representative cities, and rows for various construction classifications. The label "ci" denotes that the insulation should be installed continuously, without any breaks from framing members. Table 16.1 displays the same criteria as in the previous table but shows maximum U-factors instead of minimum R-values.

Table 17.1. Minimum Range of R-values of Building Components from ASHRAE/IESNA Standard 90.1-2019

The presented table outlines the minimum R-value range for building components necessary to satisfy the prescriptive building envelope criteria specified in Standard 90.1. The table is arranged into columns for each of the seven climate zones, each with representative cities, and rows for various construction classifications. The label "ci" denotes that the insulation should be installed continuously, without any breaks from framing members. Table 16.1 displays the same criteria as in the previous table but shows maximum U-factors instead of minimum R-values.

Building Components	Climate Region						
	Hot and Dry	Hot and Humid	Temperate and Humid	Temperate Mixed	Cool and Humid	Cool and Dry	Cold and Humid
Roofs							
Insulation Entirely above Deck	R-15 ci	R-15 ci	R-15 ci	R-15 ci	R-15 ci	R-15 ci	R-15 ci
Attic and Other	R-30	R-30	R-30	R-30	R-30	R-30	R-38
Walls, Above Grade							
Mass	NR	NR	R-5.7 ci	R-5.7 ci	R-7.6 ci	R-7.6 ci	R-9.5 ci
Steel Framed	R-13	R-13	R-13	R-13	R-13+3.8 ci	R-13+3.8 ci	R-13+3.8 ci
Wood Framed and Other	R-13	R-13	R-13	R-13	R-13	R-13	R-13
Wall, Below Grade							
Below Grade Wall	NR	NR	NR	NR	NR	NR	NR
Floors							
Mass	R-4.2 ci	R-4.2 ci	R-6.3 ci	R-6.3 ci	R-8.3 ci	R-8.3 ci	R-8.3 ci
Steel Joist	R-19	R-19	R-19	R-19	R-19	R-19	R-30
Wood Framed and Other	R-19	R-19	R-19	R-19	R-30	R-30	R-30
Slab-On-Grade Floors							
Unheated	NR	NR	NR	NR	NR	NR	NR

Heated	R-7.5@12 in.	R-7.5@12 in.	R-7.5@12 in.	R-7.5@24 in.	R-10@36 in.	R-10@36 in.	R-10@36 in

Table 17.2. Maximum Range U-factors for Building Components from ASHRAE/IESNA Standard 90.1-2019

The maximum range of U-factors for building components, as specified by Standard 90.1, is outlined in the subsequent table. The delineates the criteria for each of the seven climate zones (with representative cities) in the columns, while the rows depict the criteria for different construction types. If insulation is required to be installed continuously, Table-16.2 illustrates the same criteria expressed as minimum R-values.

Building Components	**Climate Region**						
	Hot and Dry	**Hot and Humid**	**Temperate and Humid**	**Temperate Mixed**	**Cool and Humid**	**Cool and Dry**	**Cold and Humid**
Roofs							
Insulation Entirely above Deck	0.063	0.063	0.063	0.063	0.063	0.063	0.063
Attic and Other	0.034	0.034	0.034	0.034	0.034	0.034	0.027
Walls, Above Grade							
Mass	NR	NR	0.151	0.151	0.123	0.123	0.104
Steel Framed	0.124	0.124	0.124	0.124	0.084	0.084	0.084
Wood Framed and Other	0.089	0.089	0.089	0.089	0.089	0.089	0.089
Wall, Below Grade							
Below Grade Wall	NR	NR	NR	NR	NR	NR	NR
Floors							
Mass	0.137	0.137	0.107	0.107	0.087	0.087	0.087
Steel Joist	0.052	0.052	0.052	0.052	0.052	0.052	0.038
Wood Framed and Other	0.051	0.051	0.051	0.051	0.033	0.033	0.033
Slab-On-Grade Floors							
Unheated	NR	NR	NR	NR	NR	NR	NR
Heated	1.020	1.020	1.020	0.950	0.840	0.840	0.840

The insulation levels recommended for buildings that are cost-effective go beyond the minimum requirements of Standard 90.1, which are presented in Table 16.1 and Table 16.2. Table 16.3 and Table 16.4 display the recommended insulation levels that are considered to be more effective in terms of cost.

Table 17.3. Recommended Minimum Range of R-value for Building Components

The table below exhibits the minimum R-value range required for different components of the building envelope. The designates each column to represent a climate zone (including representative cities), with various construction categories depicted in the rows. The term "CI" denotes the need for continuous installation without any obstructions by framing members. The recommendations in Table-16.3 are also provided in terms of maximum U-factors.

Building Components	**Climate Region**						
	Hot and Dry	**Hot and Humid**	**Temperate and Humid**	**Temperate Mixed**	**Cool and Humid**	**Cool and Dry**	**Cold and Humid**
Roofs							
Insulation Entirely above Deck	R-20 ci	R-20 ci	R-20 ci	R-20 ci	R-20 ci	R-20 ci	R-20 ci
Attic and Other	R-38	R-38	R-38	R-38	R-38	R-38	R-60
Walls, Above Grade							
Mass	R-7.6 ci	R-7.6 ci	R-9.5 ci	R-11.4 ci	R-13.3 ci	R-13.3 ci	R-15.2 ci
Steel Framed	R-13+3.8 ci	R-13+3.8 ci	R-13+7.5 ci	R-13+7.5 ci	R-13+7.5 ci	R-13+7.5 ci R-13+7.5 ci	R-13+3.8 ci
Wood Framed and Other	R-13	R-13	R-13	R-13	R-13+7.5 ci	R-13+7.5 ci R-13+7.5 ci	R-13
Wall, Below Grade							
Below Grade Wall	NR	NR	NR	R-7.5 ci	R-7.5 ci	R-7.5 ci	R-7.5 ci
Floors							
Mass	R-8.3 ci	R-8.3 ci	R-8.3 ci	R-10.4 ci	R-12.5 ci	R-12.5 ci	R-14.6 ci
Steel Joist	R-30	R-30	R-30	R-30	R-30	R-30	R-38
Wood Framed and Other	R-30	R-30	R-30	R-30	R-30	R-30	R-30

Slab-On-Grade Floors							
Unheated	NR	NR	NR	NR	R-10@24 in.	R-10@24 in.	R-15@24 in.
Heated	R-7.5@12 in.	R-7.5@12 in.	R-10@36 in.	R-10@36 in.	R-10	R-10	R-15

Table 17.4. Recommended Range of Maximum U-factors for Buildings Components

The subsequent table displays the recommended maximum ranges of U-factors for building envelope components. The columns present an overview of the each of the seven climate zones and corresponding representative cities. The rows showcase different construction types. To ensure continuous insulation, insulation should not be interrupted by framing members, which is denoted by the abbreviation CI. Table-16.4 also presents the same recommendations, but in the form of minimum R-values.

Building Components	**Climate Region**						
	Hot and Dry	**Hot and Humid**	**Temperate and Humid**	**Temperate Mixed**	**Cool and Humid**	**Cool and Dry**	**Cold and Humid**
Roofs							
Insulation Entirely above Deck	0.048	0.048	0.048	0.048	0.048	0.048	0.048
Attic and Other	0.027	0.027	0.027	0.027	0.027	0.027	0.017
Walls, Above Grade							
Mass	0.123	0.123	0.104	0.090	0.080	0.080	0.071
Steel Framed	0.084	0.084	0.064	0.064	0.064	0.064	0.064
Wood Framed and Other	0.089	0.089	0.089	0.089	0.051	0.051	0.051
Wall, Below Grade							
Below Grade Wall	C-1.140	C-1.140	C-1.140	C-0.119	C-0.119	C-0.119	C-0.119
Floors							
Mass	0.087	0.087	0.087	0.074	0.064	0.064	0.057
Steel Joist	0.038	0.038	0.038	0.038	0.038	0.038	0.032
Wood Framed and Other	0.033	0.033	0.033	0.033	0.033	0.033	0.033

Slab-On-Grade Floors							
Unheated	F-0.730	F-0.730	F-0.730	F-0.730	F-0.540	F-0.540	F-0.520
Heated	F-1.020	F-1.020	F-0.840	F-0.840	F-0.550	F-0.550	F-0.440

Various calculation methods can be utilized to determine the thermal performance of construction assemblies, depending on their complexity and type. There are several ways to perform calculations.

1. The most straightforward way to determine the U-factor is through the series calculation method, which can only be used for constructions made of homogeneous materials.
2. For wood-framed assemblies, the parallel path calculation method is an extension of the series calculation method.
3. Effective R-value (Isothermal Planes): This method is appropriate for construction assemblies that use highly conductive materials in combination with insulated or hollow cavities, such as metal-framed walls/roofs and concrete masonry, as with the series and parallel path calculation methods.
4. Various calculation methods are available to determine a building's thermal performance. Depending on the construction's type and complexity, the appropriate method will be chosen. The Series Calculation Method is used for homogeneous materials, the Parallel Path Calculation Method is used for wood-framed assemblies, and the Effective R-value (Isothermal Planes) method is used for constructions containing conductive materials and insulated or hollow cavities.
5. Advanced mathematics and computer modeling can be used to accurately predict the U-factor of complex construction assemblies using two-dimensional calculation methods. For all construction types except slabs-on-grade, testing remains the most accurate method of determining the U-factor. Nonetheless, because testing can be time-consuming and expensive, calculation methods are frequently more cost-effective.

Table 16.5 Provides recommendations on the appropriate calculation method to use for different types of building assemblies

Table 17.5. Suitable Methods for Calculating U-factors for Assemblies of Opaque Building

Building Components	Series Calculation Method	Parallel Path Calculation Method	Effective R Value (Isothermal Planes)	Two-Dimensional Calculation Method	Testing
Roofs					
Insulation Entirely above Deck	✓			✓	✓
Attic (Wood Joists)		✓		✓	✓
Attic (Steel Joists)			✓	✓	✓
Other Systems				✓	✓
Walls, Above Grade					
Mass			✓	✓	✓
Wood Frame		✓		✓	✓
Steel Frame			✓	✓	✓
Other Frames				✓	✓
Wall, Below Grade					
Mass Walls			✓	✓	✓
Other Components				✓	✓
Floors					
Mass Flooring	✓		✓	✓	✓
Steel Joist			✓	✓	✓
Wood Framed		✓	✓	✓	✓
Other Frames				✓	✓

17.7.3 Computer Aided Program for Calculating U-factors for Assemblies of Opaque Building

Different design tools and computer programs can be used to implement the above-mentioned calculation methods. The following tools and programs are among them:

A. A two-dimensional heat transfer analysis can be performed using Therm-program, which is designed for analyzing window frames. Download the program from the following link http://windows.lbl.gov/software/therm/therm_getacopy.htm.
B. Various construction assemblies can be calculated using general-purpose energy simulation programs such as DOE-2 and EnergyPlus. A temperature gradient in constructions is modeled by EnergyPlus, while a simpler response factor method is used by DOE-2 to model heat transfer. An energy-modeling program suitable for architects is Energy-10, available from SBIC. In spite of its limitations, it is able to quickly analyze simple buildings relative to one another.

17.7.4 Pre-calculated Values for Buildings

For common building constructions, U-factor values have been calculated and published in various sources. The ASHRAE/IESNA Standard 90.1-2019, Appendix A, contains published measurements for walls, roofs, floors, slabs, and below-grade walls in both inch-pound and metric (SI) units. The EnvStd 4.0 computer program is also available at http://www.eley.com.

17.8 Indoor Air Quality and Moisture

In order to prevent moisture from infiltrating construction cavities, it is essential to have an exterior weather barrier with a drainage plane. A proper drainage and drying system must also be incorporated into the wall, roof, and foundation systems to prevent water entry. Damp or wet cavities, attics, and plenums can cause mold and poor indoor air quality (IAQ). In addition to damaging the structure and negatively impacting insulation performance, moisture can also increase energy and operating costs. Mold growth in wall systems, attics, and foundation spaces, such as crawl spaces or utility trenches, can often cause IAQ complaints.

Moisture can also migrate into construction cavities due to the movement of water vapor from the warm and humid side of an assembly to the cold and dry side. When it cools and reaches dew point conditions, vapor can condense into water molecules, causing damage and mold growth. Moisture migration can also be caused by air leaks. In non-humid climates, a vapor barrier should be installed on the hot, moist side of framed walls, floors, and roofs, and on the exterior side in humid climates. Materials such as asphalt-impregnated paper or metal foil are commonly used as vapor barriers in insulation products. During construction, it is crucial to install vapor barriers continuously, securely attach them to framing members, and avoid damaging them. Areas with high humidity, such as locker rooms and food preparation areas, require special attention.

Proper ventilation, in addition to the installation of vapor retarders, is critical for drying spaces where moisture can accumulate. Attics and crawl spaces must be ventilated, and vaulted ceilings must be ventilated with a minimum of one inch of airspace above insulation. Even wall cavities may need to be ventilated in extreme climates. Ventilated gravel should be used as an infiltration barrier under slabs with soil gas contaminants such as radon or methane.

17.8.1 Air Infiltration

Effective infiltration control is essential for achieving energy-efficient buildings. Air leaks allow outside air to enter conditioned and semi-heated spaces, adding to the sensible heat and, in humid conditions, the latent heat load. Removing latent heat through air conditioning systems can be costly. In several states, the installation of air barriers in walls and roofs is mandatory to prevent air leakage. These barriers should not only be durable and easy to maintain but should also be able to withstand both positive and negative pressures and transfer loads. The substrate must be permanent or sandwiched between gypsum sheathing and rigid insulation. It is essential to ensure that the air barrier is continuous throughout all envelope parts, including foundations, roof, and all control, construction, and expansion joints.

17.8.2 Insulation Protection

To ensure the effectiveness of insulation, it is crucial to protect it from various sources of damage such as sunlight, moisture, landscaping equipment, and wind. To protect rigid insulation installed along the perimeter of the slab from damage caused by gardening or landscaping equipment, it should be covered. In addition, a waterproof membrane or exterior finish is required to protect rigid insulation used on walls and roofs. Typically, a drainage plane is necessary for exterior insulation finish systems (EFIS) to allow wind-driven rain to escape behind the insulation.

In cold climates, it is best to avoid installing mechanical equipment in attics as it generates heat, leading to uneven snow melting and ice dams. However, in moderate climates, access to equipment in attic spaces can be achieved without compressing or damaging the insulation, by using walking boards, access panels, and other techniques.

Fiberglass insulation in exposed areas, such as return air plenums, must be encapsulated to prevent fibers from becoming airborne. To maintain a continuous vapor barrier, all seams should be sealed with tape or mastic. To serve this purpose, insulation must be stapled in place, not simply left hanging.

17.8.3 Environmental Considerations and Efficiency of Material

One of the most effective ways to promote material efficiency in buildings is by reusing all or part of an existing building envelope. This reduces solid waste generation during construction and decreases the environmental impact associated with producing and transporting materials for a new building envelope. However, if the existing building structure cannot be upgraded to meet high-performance standards, reusing the building envelope may not be feasible.

To make a building envelope more material efficient, panelized, pre-cut, and engineered construction products can be used, and standard dimensions can be incorporated in the design to reduce on-site waste. Planning for future adaptability and selecting durable materials and systems can also contribute to material efficiency.

In addition, there are building envelopes and insulation materials that are recyclable, contain recycled materials, or are environmentally friendly. These products use materials that do not introduce toxins into the building or natural environment, and they may be produced in an eco-friendly manner. Table 16.6 presents some simple strategies for improving the resource efficiency of building envelopes and insulation.

Table 17.6. Approaches to Building envelope for Improved Resource Efficiency

Building Components	**Strategies**	**Environmental Benefits & Considerations**
Foundation and Concrete Work	To improve the sustainability of concrete materials, it is recommended to specify fly ash as a replacement rather than an addition. It is common to specify a replacement range of 10% to 25%, although higher percentages can be used depending on the specific application.	Concrete mixes now incorporate fly ash instead of energy-intensive Portland cement, which used to be disposed of in landfills. By including fly ash, concrete becomes more workable and more durable.
	Consider using autoclaved and/or aerated concrete in appropriate concrete applications.	Aerated concrete is a lightweight alternative to standard concrete with improved insulating properties.
	One should not dispose of concrete waste on surfaces intended to be porous.	This helps maintain the integrity of the site and allows for proper infiltration.
	Consider using steel forms instead of wood forms.	When steel reaches the end of its service life, it can be recycled and its content can be reused, despite the high energy consumption during its production.
	If wood forms must be used, it is recommended to reuse the wood for framing and sheathing.	It reduces resource consumption and waste generation by using reclaimed wood in framing and sheathing.
	To promote sustainability and reduce environmental impact, consider utilizing form releases that are derived from bio-based sources and have low or non-toxic properties.	Low and non-toxic form releases, which can be accomplished with bio-based products, have the additional benefits of promoting worker safety, as well as preventing soil contamination and reducing the risk to human health. To prevent damage, water-based products should be kept from freezing during storage.
	Consider using expansion joint fillers made with recycled materials.	It is feasible to use recycled materials, like waste cellulose obtained from recycled

		newspapers, as materials with relatively low strength.
	Rebar supports with recycled content can be utilized, and it is recommended to use products approved by the Department of Transportation (DOT) that have 100% recycled content. Some options include engineered fiberglass and plastic materials.	Rebar supports used in concrete formwork have minimal structural demands, making them suitable for incorporating recycled waste plastic.
	When using insulated concrete forms (ICFs), opt for versions that utilize foam ingredients that are safe for the ozone. It is important to note that not all ICFs are the same, and the actual R-values in the field can vary greatly, so it is best to rely on data from completed projects. ICFs possess inherent insulation that is integrated into the structure and cannot be removed after the concrete has cured.	Energy-efficient ICFs that incorporate ozone-friendly foam components can lower the demand for Portland cement and aid in global warming reduction. It is suggested that completed projects be used as a reference to determine the R-values of ICFs, which can differ considerably in the field.
	Implement sill sealers at the foundation to reduce infiltration.	Using sill sealers at the foundation can help reduce air infiltration and improve energy efficiency.
	Implement sub-slab ventilation in regions that may have radon or other soil gas emissions.	Enhances the quality of indoor air.
Masonry Walls	To prevent the obstruction of weep holes, utilize a mortar dropping control product, which is available with 100% recycled polyethylene.	Using a mortar dropping control product prevents the obstruction of weep holes and enables the movement of air and moisture from behind masonry veneer facades, thereby enhancing the durability of the building. The product is made available with 100% recycled polyethylene.
	To maximize resource efficiency, it is recommended to use concrete masonry units (CMUs) with a high percentage of recycled content. CMUs with up to 10% recycled content are commonly available.	The use of recycled materials in concrete masonry units (CMUs) results in decreased resource consumption and uncompromised product performance. These products are known for their high strength, durability, and fire resistance. Typically, CMUs with

		10% recycled content can be found.
	"Utilize concrete masonry units (CMUs) that include fly ash."	The use of fly ash in CMUs can contribute to sustainability. Instead of energy-intensive Portland cement, concrete mixes now include fly ash. Previously considered industrial waste and deposited in landfills, fly ash is now being utilized. This component enhances both workability and strength.
	Consider using lightweight concrete masonry units (CMUs).	Using lightweight CMUs can reduce the environmental impacts related to transportation.
	Lower the watermark line on CMUs below window framing to eliminate the need for additional finishing details.	This approach reduces the need for maintenance throughout the building's lifespan.
	Instead of painting, order colored CMUs to eliminate the need for painting.	To reduce the consumption of paint production resources and avoid the use of VOC-emitting paints that are typically used for finishing CMUs, consider using
Steel Framing	Building systems should prioritize using the highest possible proportion of recycled content. Most structural steel framing contains a minimum of 90% recycled content, while steel can contain as little as 25% recycled material. In addition, many load-bearing stud systems can incorporate up to 60% recycled material.	The recycling of materials reduces energy consumption in production and mitigates the waste and pollution associated with mining for virgin materials. This is especially true for steel, which can contain a significant amount of recycled content. Due to its weight, steel is transported more efficiently than dimensional lumber. However, steel has good thermal conductivity and requires proper insulation to prevent thermal bridging and heat loss. In addition, steel is highly recyclable, which helps to reduce job site waste.
	Consider utilizing fireproofing that includes recycled expanded polystyrene (EPS) foam and recycled newsprint.	Conventionally, fireproofing materials contained harmful materials such as fiberglass and

		asbestos. It is better to use more environmentally friendly options that utilize recycled materials effectively, such as fireproofing products made with recycled EPS foam and newsprint.
Wood Framing	To ensure seismic requirements are met, use advanced or intermediate framing systems whenever possible. Examples of such systems include two-stud corners with drywall clips, 24-inch on-center framing, and ladder partitions.	To increase insulation and reduce cold spots, consider using advanced framing systems, such as 24-inch on center framing, insulated headers, two-stud corners with drywall clips, and ladder partitions. These systems can improve both energy and material efficiency. Additionally, it is crucial to consider seismic requirements for the building site.
	To improve floor and roof joists, consider replacing dimensional lumber with engineered wood products like laminated strand lumber, parallel strand lumber, or laminated veneer lumber.	The resource efficiency of floor and roof joists can be enhanced by using engineered wood products, which have a lighter weight and lower resource requirements than dimensional lumber.
	The Forest Stewardship Council (FSC) and Scientific Certification Systems (SCS) are two organizations that provide certification for wood products. Numerous certified engineered and dimensional wood products are available.	Using wood certified by organizations such as FSC or SCS helps prevent the degradation of forests and wildlife habitats.
Siding	Consider using fiber cement siding, which is often factory-primed, but it is recommended to back prime it for added durability. It is important to properly paint the siding to ensure its longevity.	Fiber cement siding is a sustainable alternative to virgin wood siding that can withstand the test of time. When choosing fiber cement siding, opt for factory-primed options and consider back priming. Proper painting is crucial to ensure the longevity of the siding.
Roofing	Consider using metal roofing as a roofing material.	Using metal roofing has the advantage of containing recycled content, being durable, and being recyclable at the end of its service life.

	For low-slope roofs, a green or vegetated roof system can be utilized. This system contains a lightweight soil that absorbs and reduces rooftop runoff. A drainage system for this type of roof usually consists of three layers: soil, soil, and vegetation. It is recommended to use native plants and grasses when constructing this green roof system.	Green roofs can mitigate rainwater runoff, reduce peak load on the sewer system, and offer additional environmental benefits, such as decreasing building heat gain, preventing urban heat islands, and absorbing carbon dioxide. Moreover, they promote energy conservation by insulating rooftops during winter. It is recommended to use plants and grasses native to the area in green roof systems. However, structural steel roofs require high embodied energy, which can offset some of the environmental advantages of green roofs.
Moisture and Water Proofing	Proper detailing can help minimize the use of sealants and repellents, while selecting non-toxic options is crucial. It is also essential to avoid any products containing harmful substances, such as methylene chloride, chlorinated hydrocarbons, aromatic and aliphatic solvents, styrene butadiene, or bactericides and fungicides like phenol mercury acetate, phenol phenates, or phenol formaldehyde.	Proper detailing techniques and low-toxicity materials can prevent air quality problems in buildings and enhance their durability.
	Waterproofing a building involves more than just caulking. Proper flashing is crucial to prevent water from entering the building.	Proper flashing not only enhances the durability of the building shell, but it also helps prevent the growth of mold and mildew. This, in turn, reduces the associated health risks.
	When selecting a vapor retarder, it is recommended to choose a film made of up to 100% LDPE (plastic).	The use of plastic waste that would otherwise be sent to landfills can lower the number of resources needed to manufacture virgin products.
Insulation	Fiberglass insulation with up to 30% verified recycled content (SCS) should be used. Formaldehyde-free fiberglass is also an option, although it may come at a higher cost.	Glass collected from curbsides by recycling programs can be used in this product. Moreover, formaldehyde-free alternatives contribute to better indoor air quality and safer working conditions.

	Insulating your home with 100% recycled newsprint cellulose insulation is recommended.	By using paper waste that would otherwise end up in landfills, it is possible to reduce waste generation and promote sustainability.
	When using rigid insulation with polyisocyanurate foam, it's important to select an option that is ozone-friendly.	By taking action to reduce greenhouse gas emissions and other harmful environmental impacts, we can help prevent the further degradation of the Earth's atmosphere and mitigate the effects of global warming.
Exterior Doors and Windows	Consider using doors made from reclaimed lumber.	Using reclaimed lumber helps alleviate the demand for timber and reduces the degradation of forest habitats.

Source: *Adapted from Green Spec: The Environmental Building News Product Directory and Guideline Specifications*

17.9 Recommendation for Wall Insulation

R-13 is the minimum recommended cavity insulation for wood-framed walls, irrespective of climate. Furthermore, in climates with cool and humid conditions, cold and humid conditions, and cool and dry conditions, R-7.5 insulating sheathing should be installed. Please refer to the table below for the equivalent U-factor recommendations.

All climates recommend R-13 cavity insulation for metal-framed walls.

a. For hot and humid climates and hot and dry climates, continuous insulating sheathing of R-3.8 is recommended. In other climates, continuous insulating sheathing of R-7.5 is recommended.

b. For hot and dry as well as hot and humid climates, it is recommended to use continuous R-7.6 insulation for mass walls. In temperate and humid climates, it is advisable to upgrade to R-9.5, whereas in cool and humid climates, R-13.3 insulation is recommended.

c. For cold and humid climates, the recommended insulation level is R-15.2. Depending on the local climate, higher insulation levels may be necessary.

Wood-framed walls have better overall thermal performance than metal-framed walls, despite the fact that R-13 is recommended for both types of walls.

17.9.1 Description

It is important to consider the construction of exterior walls in terms of comfort, operating costs, and acoustic separation, as well as the size of the heating and cooling systems required. The construction type, whether wood-framed, steel-framed, or mass construction, is typically determined by factors such as the size and height of the building, budget constraints, fire separation requirements, and durability requirements.

Each climate region and class are presented separately, with recommended insulation levels based on a life-cycle cost analysis. In colder climates, more insulation is needed, while in temperate climates, less insulation may be required.

17.9.2 Applicability

It is recommended that all exterior walls in heated or cooled spaces adhere to these recommendations. During the schematic design phase of the project, any design decisions that may affect wall thickness should be taken into consideration.

17.9.3 Integrated Design Implications

Properly insulated and sealed walls can effectively reduce moisture intrusion caused by wind-driven rain, cold drafts, and thermal loads in buildings. This can result in lower HVAC equipment requirements and cost savings.

17.9.4 Cost Effectiveness

The cost of insulating the cavity of wood- and steel-framed walls is relatively low, but the value of this insulation is also low due to the thermal compromise of the system caused by metal studs. The most cost-effective way to install continuous insulation is outside of the framing, as required by building codes. When continuous insulation is added between the studs, the R-value of the insulation between the studs is significantly improved since the temperature gradient between the studs is reduced.

In contrast, mass walls are more difficult and expensive to insulate. Despite seismic safety requirements, most hollow cells in mass walls must be grouted and reinforced to prevent thermal bridges across the concrete webs. The most effective way to insulate mass walls is to use an Exterior Insulation Finish System (EIFS) for 1-inch-thick walls. There is a cost of PKR 2300/ft2 for 2-inch insulation. Due to the benefit of thermal mass, this method is preferred when the budget allows. The interior of the wall can be finished with gypsum board, as well as steel or wood furring, batt insulation, and gypsum board in the cavities between the furring strips.

17.9.5 Benefits

Insulating walls and minimizing air infiltration yield several significant benefits for high-performance buildings, including:

a. Reducing energy consumption
b. Allowing for natural ventilation during more hours of the day
c. Improving indoor air quality by minimizing mold and mildew growth
d. Reducing initial costs by enabling the purchase of smaller HVAC equipment
e. Providing improved acoustic separation from outdoor noise

f. Enhancing occupant comfort by maintaining interior surface temperature closer to room temperature, reducing drafts and promoting more uniform indoor temperatures. **Design Tools**

In the Overview section, this chapter discusses the techniques and processes for calculating U-factors. For mass walls, it is recommended to analyze insulation options using energy simulation programs, as this type of construction typically involves time delays and dynamic effects.

17.9.6 Design Details

In cold climates, it is recommended to install a continuous vapor barrier on the inside surface of framed walls. However, in hot and humid climates and air-conditioned buildings, vapor barriers should be installed on the exterior of the buildings. When using paper or foil vapor barriers provided with batt insulation, they should be stapled to the face of the studs instead of the inside to provide a more secure and continuous vapor barrier while reducing insulation compression.

The air barrier should be continuous and durable, with details on how it is connected to the foundation, windows, doors, different wall systems, roof, and utility penetrations. Wood framing with a stud spacing of 24 inches should be used for wood framing in hot and dry climates, cool and humid climates, and cool and dry climates, with 2x6 framing preferred. Minimum wood framing and rigid insulation over headers over doors and windows should be used at corners, intersections, and openings.

When installing EIFS systems on mass walls, a durable and weather-resistant exterior finish and a drainage plane are recommended.

To minimize thermal bridges and infiltration, electrical and mechanical equipment should be minimized for exterior walls. The back of exterior wall outlet boxes should be sealed both to the gypsum wallboard and around wires if insulation is used in stud cavities. Outlets are commonly located on the interior walls and wings of buildings.

The Forest Stewardship Council recommends using wood-framed walls harvested using environmentally friendly forest practices and framing members certified by the organization. When using steel to manufacture metal-framed walls, ensure that it contains 30% recycled material.

It is important to seal the top and bottom of the drywall to ensure a continuous air barrier.

17.9.7 Operation and Maintenance Issues

Regular maintenance of exterior and interior wall finishes is essential. In addition to preserving light colors, interior finishes should be maintained to ensure that electric lighting and daylighting systems function effectively. To prevent water from entering construction cavities, exterior surfaces should be waterproof or water-resistant. Otherwise, mold can grow, structural damage can occur, and the performance of thermal insulation can be reduced. Mold can negatively impact indoor air quality, so it should be avoided. Wall systems must allow moisture entering from wind-driven rain to escape back out to prevent damage.

17.10 Roof Insulation

17.10.1 Recommendations for Roof insulation

To ensure adequate insulation, it is recommended to install R-20 insulation completely above the structural deck. The thickness of the insulation will vary depending on the type of insulation used. In all climates except cold and humid, R-38 insulation should be installed in attics and other constructions, while R-60 insulation should be installed in cold and humid climates.

17.10.2 Description

The construction of roof assemblies can impact the size of heating and cooling systems in addition to comfort, operating costs, and acoustic separation. The size, height, fire separation requirements, durability, and other factors typically determine the construction class of a building (wood-framed, steel-framed, or mass). Based on a lifecycle cost analysis, different insulation levels are recommended for each climate region and class. Insulation is generally more critical in colder climates, while it is less critical in more temperate climates. Roofs and other components of the building envelope require a review of the concepts of thermal heat transfer discussed in the Overview section of this chapter.

17.10.3 Applicability

Buildings with heated or cooled spaces are required to comply with this guideline for roof insulation. Insulation levels can be determined during the design development or contract document phase, in conjunction with the construction class. Properly insulated roofs and roof cavities can significantly reduce drafts and thermal loads in buildings. HVAC ducts located in ceiling cavities can cause a significant increase in thermal load if they leak. However, if ducts are located in sealed and insulated ceiling cavities, these losses can be greatly reduced. Using smaller HVAC equipment can help reduce these loads and associated costs.

17.10.4 Cost Effectiveness

Different types of construction can impact the cost of roof insulation. During construction, attics and roof cavities of wood- and steel-framed roof assemblies are easily accessible and relatively inexpensive to insulate. However, the cost of rigid insulation and the construction details required make rigid insulation more expensive when installed over structural decks. Insulation of roofs and ceilings can provide several advantages for high-performance buildings, including reducing energy use, increasing natural ventilation, and reducing the initial costs of HVAC equipment. Properly insulated spaces can also have interior surface temperatures closer to room temperature, reducing drafts and improving comfort.

17.10.5 Benefits

High-performance schools can significantly benefit from roof and ceiling insulation, which can lead to reduced energy usage, improved natural ventilation, and potential cost savings from smaller HVAC equipment. Insulated spaces can provide a more comfortable learning environment by maintaining interior surfaces closer to room temperature, resulting in more uniform temperatures and fewer drafts.

17.10.6 Design Details

When insulating the ceiling of a sloped roofed attic, it is important to have full depth insulation all the way to the edge. Raised heel trusses may be required for this type of construction. A constant temperature should be maintained across the roof in addition to providing a continuous and effective thermal barrier. If insulation is thinner near the edge, snow can melt and refreeze as an ice dam, causing water leakage and structural damage if it melts and refreezes.

1. Attics should not be used to house heat-producing equipment such as furnaces, water heaters, or air handlers, as they can cause uneven roof temperatures and lead to ice dams.
2. Insulation should not be installed in exposed applications or in return air plenums unless it is enclosed or sealed to prevent contact with moving air. Leaving it exposed is always a bad idea. In addition, ensure that insulation is dry before enclosing walls or other cavities to prevent moisture buildup.
3. Insulation should not be installed over suspended ceilings as it can be easily disturbed by maintenance workers and does not act as an effective barrier to infiltration. Building codes may require ventilation to the exterior if insulation is located at the ceiling. Type IC light fixtures should be used to light insulated gypsum board ceilings.
4. Consider using recycled insulation materials, such as cellulose made from recycled paper, in attics and other areas where loose-fill insulation is used. The fire retardant used in cellulose insulation should not contain VOCs and should be non-polluting.

17.10.7 Operation and Maintenance Issues

Regular maintenance of the roof membrane is crucial to prevent moisture from seeping in. Moisture can cause mildew to grow on ceilings and roofs, resulting in significant indoor air quality problems. Materials used for insulation do not require maintenance. The roof drainage system must also be maintained regularly, especially for low-pitched roofs.

17.11 Cool Roofs

17.11.1 Recommendation for Cool Roof

To achieve high reflectance and emissivity, it is advisable to install a non-metallic finish on the light-colored roof surface of a building with air conditioning. Roofing materials with an initial reflectance greater than 0.7 and an emittance greater than 0.8 are recommended for asphalt roofs with a cap sheet and modified bitumen roofs. The same considerations should be taken into account when selecting single-ply roofing materials.

17.11.2 Description

Roof surfaces absorb a lot of heat from solar radiation, but using materials with high reflectance and emittance can significantly reduce this load. Materials with high reflectance prevent sunlight from being absorbed, while those with high emittance emit radiation into the sky. Cool roofs, which are typically white in color and smooth in texture, are a popular option for reducing heat gain. Single-ply roofs and liquid-applied roofs are two types of cool roof products available. White PVC, CPE, CPSE, and TPO are among the most effective single-ply roofing products. Asphalt cap sheets, modified bitumen, and other substrates can be coated with liquid-applied products, such as white elastomeric, polyurethane, and acrylic coatings. Additionally, cool roofs are now available in a variety of colors.

1. White PVC (polyvinyl chloride)
2. White CPE (chlorinated polyethylene)
3. White CPSE (chlorosulfonated polyethylene, e.g.Hypalon)
4. White TPO (thermoplastic polyolefin).
5. Liquid-applied products may be used to coat asphalt cap sheets, modified bitumen, and other substrates. Products include:
6. White elastomeric coatings
7. White polyurethane coatings
8. White acrylic coatings

9. White paint (on metal or concrete)
10. Cool roofs are becoming available in different colors.

Table 16.7 lists several common roofing products and their reflectance and emittance values.

Table 17.7. Solar reflectance and emittance values for various roofing materials.

Description	Material	Reflectance	Emittance
Reflective Coatings	Elastomeric coating over asphalt shingle	0.71	0.91
	Aged elastomeric on plywood	0.73	0.86
	Elastomeric coating on shingle	0.65	0.89
	Aluminum pigmented roof coating	0.30 - 0.55	0.42 - 0.67
	Lo-mit on asphalt shingle	0.54	0.42
White Metal Roofing	Siliconized white	0.59	0.85
Single-Ply Roof Membrane	Black EPDM	0.06	0.86
	Grey EPDM	0.23	0.87
	White EPDM	0.69	0.87
	White T-EPDM	0.81	0.92
Paint	White	0.85	0.96
	Aluminum paint	0.80	0.40
Asphalt Shingles	Black	0.03 - 0.05	0.91
	Dark brown	0.08 - 0.10	0.91
	Medium brown	0.12	0.91
	Light brown	0.19 - 0.20	0.91
	Green	0.16 - 0.19	0.91
	Grey	0.08 - 0.12	0.91
	Light grey	0.18 - 0.22	0.91
	White	0.21 - 0.31	0.91
Note: Products with shading have a reflectivity greater than 0.70 and emittance greater than 0.80.			

The advantages of cool roofs may be somewhat limited in regions that are cool and humid or cold and humid. However, cool roofs can be employed in all areas of buildings and climates. As part of the schematic design process, cool roofs should be considered to maximize the benefits of downsizing equipment.

17.11.3 Integrated Design Implications

Cool roofs can significantly reduce cooling loads, which can lead to downsizing of air conditioning equipment or even replacement of air conditioning with natural ventilation in some cases. When designing the roof, all roofing systems, including skylights, roof penetrations, and rooftop equipment mounts, must be considered. It is important to protect roof membranes from excessive wear and damage caused by equipment access.

17.11.4 Cost Effectiveness

The cost of coating an asphalt cap sheet or modified bitumen roof typically ranges from PKR 300 to PKR 600 per square foot. In contrast, conventional single-ply roof membranes with high reflectance (all of which have high emittance) are not significantly more expensive.

17.11.5 Benefits

Cool roofs are highly cost-effective, particularly in hot and dry climates, as they can reduce both demand and energy costs. By reducing the effects of solar radiation, which is a major cause of roof deterioration, including ultraviolet light, cool roofs can significantly extend the life of the roof membrane. Additionally, cool roofs can mitigate the heat island effect and contribute to lowering the overall temperature of a community.

17.11.6 Design Tools

Assessing the effectiveness of cool roofs can be quite challenging, as many factors contribute to their performance. One reason is that cool roofs reflect sunlight, which requires a model that considers the location and intensity of the sun. If the roof absorbs the sun's energy instead of reflecting it, the surface temperature of the roof increases, exacerbating the temperature differences. Moreover, when the roof surface temperature is hot, it radiates heat to the cool night sky, providing an important benefit that relies on knowing the temperature of the roof surface and the night sky. To accurately evaluate the benefits of cool roofs, energy simulation programs are necessary, given the intricate heat transfer involved. It is crucial to customize these programs according to the building's intended use to ensure that the energy savings are accurately reflected.

17.11.7 Design Details

To maintain the efficacy of a cool roof, it is important to prevent the accumulation of dirt on its surface. A slope of at least 0.25 inches/foot is recommended for roof surfaces to minimize dirt buildup. It is also crucial to choose liquid-applied coatings that are compatible with the underlying substrate when using them. To meet the ASTM Standard 6083-2021 for durability and elongation, a minimum thickness of 20 mils is required for liquid-applied cool roof coatings.

17.11.8 Operation and Maintenance Issues

To ensure the continued effectiveness of cool roofs, it is recommended to clean them annually using high-pressure water sprays, although it is important to check whether this will void the warranty. Additionally, it may be necessary to refinish liquid-applied coatings every five years or so.

Section-18

18. Appendix A - Definitions, Abbreviations, and Acronyms

18.1 General

Certain terms, abbreviations, and acronyms are defined in this section for the purposes of this standard. These definitions are applicable to all sections of this code. Terms that are not defined shall have their ordinarily accepted meanings within the context in which they are used. Ordinarily accepted meanings shall be based upon American standard English language usage as documented in an unabridged dictionary accepted by the adopting authority.

18.2 Definitions

Addition: an extension or increase in floor area or height of a building outside of the existing building envelope.

Alteration: any replacement, change, rearrangement, or addition to a building or its systems and equipment; any modification in construction or building equipment; maintenance, repair or change in the building usage shall not constitute an alteration.

Area: see roof and wall, conditioned floor, day lighted, facade, fenestration and lighted floor.

Authority having jurisdiction: the agency or agent responsible for enforcing this Code.

Automatic: self-acting, operating by its own mechanism when actuated by some non-manual influence, such as a change in current strength, pressure, temperature or mechanical configuration.

Automatic control device: a device capable of automatically turning loads off and on without manual intervention.

Balancing, air system: adjusting airflow rates through air distribution system devices, such as fans and diffusers, by manually adjusting the position of dampers, splitters vanes, extractors, etc., or by using automatic control devices, such as constant air volume or variable air volume boxes.

Balancing, hydronic system: adjusting water flow rates through hydronic distribution system devices, such as pumps and coils, by manually adjusting the position valves or by using automatic control devices, such as automatic flow control valves.

Ballast: a device used in conjunction with an electric-discharge lamp to cause the lamp to start and operate under proper circuit conditions of voltage, current, waveform, electrode heat, etc.

Boiler: a self-contained low-pressure appliance for supplying steam or hot water.

Boiler, packaged: a boiler that is shipped complete with heating equipment, mechanical draft equipment, and automatic controls; usually shipped in one or more sections. A packaged boiler includes factory-built boilers manufactured as a unit or system, is disassembled for shipment, and reassembled at the site.

Building: a structure wholly or partially enclosed within exterior walls, or within exterior and party walls, and a roof, affording shelter to persons, animals, or property.

Building, existing: a building or portion thereof that was previously occupied or approved for occupancy by the authority having jurisdiction.

Building complex: a group of buildings in a contiguous area under single ownership.

Building entrance: any doorway, set of doors, turnstiles, or other form of portal that is ordinarily used to gain access to the building by its users and occupants.

Building envelope: the exterior plus the semi-exterior portions of a building. For the purposes of determining building envelope requirements, the classifications are defined as follows:

a. Building envelope, exterior: the elements of a building that separate conditioned spaces from the exterior.
b. Building envelope, semi-exterior: the elements of a building that separate conditioned space from unconditioned space or that encloses semi-heated spaces through which thermal energy may be transferred to or from the exterior, or to or from unconditioned spaces, or to or from conditioned spaces.

Building exit: any doorway, set of doors, or other form of portal that is ordinarily used only for emergency egress or convenience exit.

Building grounds lighting: lighting provided through a building's electrical service for parking lot, site, roadway, pedestrian pathway, loading dock, and security applications.

Building material: any element of the building envelope through which heat flows and that heat is included in the component U-factor calculations other than air films and insulation.

Circuit breaker: a device designed to open and close a circuit by non-automatic means and to open the circuit automatically at a predetermined over-current without damage to itself when properly applied within its rating.

Class of construction: for the building envelope, a subcategory of roof, wall, floor, slab-on-grade floor, opaque door, vertical fenestration, or skylight.

Coefficient Of Performance (COP) – cooling: the ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigerating system or some specific portion of that system under designated operating conditions.

Coefficient Of Performance (COP) – heating: the ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system, including the compressor and, if applicable, auxiliary heat, under designated operating conditions.

Commercial building: all buildings except for multi-family buildings of three stories or fewer above grade and single-family buildings.

Construction documents: drawings and specifications used to construct a building, building systems, or portions thereof.

Control: to regulate the operation of equipment.

Control device: a specialized device used to regulate the operation of equipment.

Cool roof: a property of a surface that describes its ability to reflect and reject heat. Cool roof surfaces have both a light color (high solar reflectance) and a high emittance (can reject heat back to the environment).

Vertical fenestration: all fenestration other than skylights. Trombe wall assemblies, where glazing installed within 12 inch (30 mm) of a mass wall, are considered walls, not fenestration.

Dead band: the range of values within which a sensed variable can vary without initiating a change in the controlled process.

Demand: the highest amount of power (average Btu/h over an interval) recorded for a building or facility in a selected time frame.

Design capacity: output capacity of a system or piece of equipment at design conditions.

Design conditions: specified environmental conditions, such as temperature and light intensity, required to be produced and maintained by a system and under which the system must operate.

Distribution system: conveying means, such as ducts, pipes, and wires, to bring substances or energy from a source to the point of use. The distribution system includes such auxiliary equipment as fans, pumps, and transformers.

Door: all operable opening areas (which are not fenestration) in the building envelope, including swinging and roll-up doors, fire doors, and access hatches. Doors that are more than one-half glass are considered fenestration. For the purposes of determining building envelope requirements, the classifications are defined as follows:

(a) non-swinging: roll-up sliding, and all other doors that are not swinging doors.

(b) swinging: all operable opaque panels with hinges on one side and opaque revolving doors.

Door area: total area of the door measured using the rough opening and including the door slab and the frame.

Dwelling unit: a single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, coking, and sanitation

Economizer, air: a duct and damper arrangement and automatic control system that together allow a cooling system to supply outdoor air to reduce or eliminate the need for mechanical cooling during mild or cold weather.

Economizer, water: a system by which the supply air of a cooling system is cooled indirectly with water that is itself cooled by heat or mass transfer to the environment without the use of mechanical cooling

Efficacy: the lumens produced by a lamp/ballast system divided by the total watts of input power (including the ballast), expressed in lumens per watt.

Efficiency: performance at specified rating conditions.

Emittance: the ratio of the radiant heat flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions.

Enclosed building: a building that is totally enclosed by walls, floors, roofs and openable devices such as doors and operable windows.

Energy: the capacity for doing work. It takes a number of forms that may be transformed from one into another such as thermal (heat), mechanical (work), electrical, and chemical. Customary measurement units are: kilojoules (kJ) or British thermal units (Btu) in this document.

Energy Efficiency Ratio (EER): the ratio of net cooling capacity in Btu/h to total rate of electric input in watts under designated operating conditions.

Energy Factor (EF): a measure of water heater overall efficiency.

Equipment: devices for comfort conditioning, electric power, lighting, transportation, or service water heating including, but not limited to furnaces, boilers, air conditioners, heat pumps, chillers, water heaters, lamps, luminaires, ballasts, elevators, escalators or other devices or installations.

Existing equipment: equipment previously installed in an existing building.

Facade area: area of the facade, including overhanging soffits, cornices, and protruding columns, measured in elevation in a vertical plane, parallel to the plane of the face of the building. Non-horizontal roof surfaces shall be included in the calculations of vertical facade area by measuring the area in a plane parallel to the surface.

Fan system power: the sum of the nominal power demand (nameplate horse power) of motors of all fans that are required to operate at design conditions to supply air from the heating or cooling source to the conditioned space(s) and return it to the source of exhaust it to the outdoors.

Fenestration: all areas (including the frames) in the building envelope that let in light including windows, plastic panels, clerestories, skylights, glass doors that are more than one half glass and glass block walls.

a. Skylight: a fenestration surface having a slope of less than 60 degrees from the horizontal plane. Other fenestration, even if mounted on the roof of a building, is considered vertical fenestration.

b. Vertical fenestration: all fenestration other than skylights. Trombe wall assemblies, where glazing is installed within 12 in. of a mass wall, are considered walls, not fenestration.

Fenestration area: total area of the fenestration measured using the rough opening and including the glazing, sash, and frame. For doors where the glazed vision area is less than 50% of the door area, the fenestration area is the glazed vision area. For all other doors, the fenestration area is the door area.

Floor area gross: the sum of the floor areas of the spaces within the building including basements, mezzanine and intermediate-floored tiers and penthouses with headroom height of 7.5 ft or greater. It is measured from the exterior faces of exterior walls or from the centerline of walls separating buildings, but excluding covered walkways, open roofed over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs and similar features.

a) Gross building envelope floor area: the gross floor area of the building envelope, but excluding slab-on-grade floors.

b) gross conditioned floor area: the gross floor area of conditioned spaces.

c) Gross lighted floor area: the gross floor area of lighted spaces.

d) Gross semi-heated floor area: the gross floor area of semi-heated spaces.

Flue damper: a device in the flue outlet or in the inlet of or upstream of the draft control device of an individual, automatically operated, fossil fuel-fired appliance that is designed to automatically open the flue outlet during appliance operation and to automatically close the flue outlet when then appliance is in standby condition.

Fossil fuel: fuel derived from a hydrocarbon deposit such as petroleum, coal, or natural gas derived from living matter of a previous geologic time.

Fuel: a material that may be used to produce heat or generate power by combustion.

Grade: the finished ground level adjoining a building at all exterior walls.

Guest room: any room or rooms used or intended to be used by a guest for sleeping purposes.

Heat capacity: the amount of heat necessary to raise the temperature of a given mass 1°F. Numerically, the heat capacity per unit area of surface (Btu/ft^2-°F) is the sum of the products of the mass per unit area of each individual material in the roof, wall or floor surface multiplied by its individual specific heat.

Heating Seasonal Performance Factor (HSPF): the total heating output of a heat pump during its normal annual usage period for heating (in Btu) divided by the total electric energy input during the same period.

Historic: a building or space that has been specifically designed as historically significant.

HVAC system: the equipment, distribution systems, and terminals that provide, either collectively or individually, the processes of heating, ventilating or air conditioning to a building or portion of a building.

Infiltration: the uncontrolled inward air leakage through cracks and crevices in any building element and around windows and doors of a building caused by pressure differences across these elements due to factors such as wind, inside and outside temperature differences (stack effect), and imbalance between supply and exhaust air systems.

Installed interior lighting power: the power in watts of all permanently installed general, task, and furniture lighting systems and luminaries.

Integrated part-load value (IPLV): a single number figure of merit based on part-load EER, COP, or KW/ton expressing part-load efficiency for air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment.

Kilovolt-ampere (kVA): where the term “kilovolt-ampere” (kVA) is used in this code, it is the product of the line current (amperes) times the nominal system voltage (kilovolts) times 1.732 for three-phase currents. For single-phase applications, kVA is the product of the line current (amperes) times the nominal system voltage (kilovolts).

Kilowatt (kW): the basic unit of electric power, equal to 1000 W.

Labeled: equipment or materials to which a symbol or other identifying mark has been attached by the manufacturer indicating compliance with specified standard or performance in a specified manner.

Lamp: a generic term for man-made light source often called bulb or tube. Generally, followings types are used.

(a) Compact fluorescent lamp.
(b) Fluorescent lamp.
(c) General service lamp.
(d) high-intensity discharge (HID) lamp.
(e) Incandescent lamp.
(f) Reflector lamp.

Lighted floor area, gross: the gross floor area of lighted spaces.

Lighting, decorative: lighting that is purely ornamental and installed for aesthetic effect. Decorative lighting shall not include general lighting.

Lighting, emergency: lighting that provides illumination only when there is a general lighting failure.

Lighting, general: lighting that provides a substantially uniform level of illumination throughout an area. General lighting shall not include decorative lighting or lighting that provides a dissimilar level of illumination to serve a specialized application or feature within such area.

Lighting Efficacy (LE): the quotient of the total lumens emitted from a lamp or lamp/ballast combination divided by the watts of input power, expressed in lumens per watt.

Lighting system: a group of luminaires circuited or controlled to perform a specific function.

Lighting power allowance:

a. Interior lighting power allowance: the maximum lighting power in watts allowed for the interior of a building

b. Exterior lighting power allowance: the maximum lighting power in watts allowed for the exterior of a building

Lighting Power Density (LPD): the maximum lighting power per unit of area of a building classification of space function.

Low-rise residential: single-family houses, multi-family structures of three stories or fewer above grade, manufactured houses (mobile homes), and manufactured houses (modular).

Luminaire: a complete lighting unit consisting of a lamp or lamps together with the housing designed to distribute the light, position and protect the lamps, and connect the lamps to the power supply.

Manual (non-automatic): requiring personal intervention for control. Non-automatic does not necessarily imply a manual controller, only that personal intervention is necessary.

Manufacturer: the company engaged in the original production and assembly of products or equipment or a company that purchases such products and equipment manufactured in accordance with company specifications.

Mean temperature: one-half the sum of the minimum daily temperature and maximum daily temperature.

Mechanical cooling: reducing the temperature of a gas or liquid by using vapor compression, absorption, desiccant dehumidification combined with evaporative cooling, or another energy-driven thermodynamic cycle. Indirect or direct evaporative cooling alone is not considered mechanical cooling.

Metering: instruments that measure electric voltage, current, power, etc.

Multifamily high-rise: multifamily structures of four or more stories above grade.

Multifamily low-rise: multifamily structures of three or less stories above grade.

Multiplication factor (M): indicates the relative reduction in annual solar cooling load from overhangs and/or side fins with given projection factors, relative to the respective horizontal and vertical fenestration dimensions.

Non-automatic: see manual.

Occupant sensor: a device that detects the presence or absence of people within an area and causes lighting, equipment or appliances to be regulated accordingly.

Opaque: all areas in the building envelope, except fenestration and building service openings such as vents and grilles.

Orientation: the direction an envelope element faces, i.e., the direction of a vector perpendicular to and pointing away from the surface outside of the element. For vertical fenestration, the two categories are north-oriented and all other.

Outdoor (outside) air: air that is outside the building envelope or is taken from outside the building that has not been previously circulated through the building.

Overcurrent: any current in excess of the rated current of the equipment of the ampacity of the conductor. It may result from overload, short circuit or ground fault.

Packaged Terminal Air Conditioner (PTAC): a factory-selected wall sleeve and separate un-encased combination of heating and cooling components, assemblies or sections. It may include heating capability by hot water, steam or electricity and is intended for mounting through the wall to service a single room or zone.

Party wall: a firewall on an interior lot line used or adapted for joint service between two buildings.

Permanently installed: equipment that is fixed in place and is not portable or movable.

Plenum: a compartment or chamber to which one or more ducts are connected, that forms a part of the air distribution system and that is not used for occupancy or storage. A plenum often is formed in part or in total by portions of the building.

Pool: any structure, basin, or tank containing an artificial body of water for swimming, diving or recreational bathing. The terms include, but not limited to swimming pool, whirlpool, spa, hot tub.

Process load: the load on a building resulting from the consumption or release of process energy.

Projection factor: the ratio of the horizontal depth of the external shading projection divided by the sum of the height of the fenestration and the distance from the top of the fenestration to the bottom of the farthest point of the external shading projection, in consistent units.

Projection factor, side-fin: the ratio of the horizontal depth of the external shading projection divided by the distance from the window jamb to the farthest point of the external shading projection, in consistent units.

Rated R-value of insulation: the thermal resistance of the insulation alone as specified by the manufacturer in units of $h \cdot ft^2 \, {}^oF/Btu$ at a mean temperature of 75°F. Rated R-value refers to the thermal resistance of the added insulation in framing cavities or insulated sheathing only and does not include the thermal resistance of other building materials or air films. (See thermal resistance.)

Readily accessible: capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. In public facilities, accessibility may be limited to certified personnel through locking covers or by placing equipment in locked rooms.

Recirculating system: a domestic or service hot water distribution system that includes a close circulation circuit designed to maintain usage temperatures in hot water pipes near terminal devices (e.g., lavatory faucets, shower heads) in order to reduce the time required to obtain hot water when the terminal device valve is opened. The motive force for circulation is either natural (due to water density variations with temperature) or mechanical (recirculation pump).

Reflectance: the ratio of the light reflected by a surface to the light incident upon it.

Resistance, electric: the property of an electric circuit or of any object used as part of an electric circuit that determines for a given circuit the rate at which electric energy is converted into heat or radiant energy and that has a value such that the product of the resistance and the square of the current gives the rate of conversion of energy.

Reset: automatic adjustment of the controller set point to a higher or lower value.

Residential: spaces in buildings used primarily for living and sleeping. Residential spaces include, but are not limited to, dwelling units, hotel/motel guest rooms, dormitories, nursing homes, patient rooms in hospitals, lodging houses, fraternity/sorority houses, hostels, prisons and fire stations.

Roof: the upper portion of the building envelope, including opaque areas and fenestration, that is horizontal or tilted at an angle of less than 60° from horizontal.

Roof area, gross: the area of the roof measured from the exterior faces of walls or from the centerline of party walls.

Service: the equipment for delivering energy from the supply or distribution system to the premises served.

Service water heating: heating water for domestic or commercial purposes other than space heating and process requirements.

Set point: point at which the desired temperature (°F) of the heated or cooled space is set.

Shading Coefficient (SC): the ratio of solar heat gain at normal incidence through glazing to that occurring through 1/8 in thick clear, double-strength glass. Shading coefficient, as used herein, does not include interior, exterior or integral shading devices.

Simulation program: a computer program that is capable of simulating the energy performance of building systems.

Single-zone system: an HVAC system serving a single HVAC zone.

Site-recovered energy: waste energy recovered at the building site that is used to offset consumption of purchased fuel or electrical energy supplies.

Slab-on-grade floor: that portion of a slab floor of the building envelope that is in contact with ground and that is either above grade or is less than or equal to 24 in below the final elevation of the nearest exterior grade.

Solar energy source: source of thermal, chemical, or electrical energy derived from direct conversion of incident solar radiation at the building site.

Solar Heat Gain Coefficient (SHGC): the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convicted into the space.

Space: an enclosed space within a building. The classifications of spaces are as follows for the purpose of determining building envelope requirements.

a. **Conditioned space:** a cooled space, heated space, or directly conditioned space.
b. **Semi-heated space:** an enclosed space within a building that is heated by a heating system whose output capacity is greater or equal to 3.4 Btu/h-ft^2 of floor area but is not a conditioned space.
c. **Unconditioned space:** an enclosed space within a building that is not conditioned space or a semi-heated space. Crawlspaces, attics, and parking garages with natural or mechanical ventilation are not considered enclosed spaces.

Story: portion of a building that is between one finished floor level and the next higher finished floor level or the roof, provided, however, that a basement or cellar shall not be considered a story.

System: a combination of equipment and auxiliary devices (e.g., controls, accessories, interconnecting means, and terminal elements) by which energy is transformed so it performs a specific function such as HVAC, service water heating or lighting.

System, existing: a system or systems previously installed in an existing building.

Terminal: a device by which energy form a system is finally delivered, e.g., registers, diffusers, lighting fixtures, faucets, etc.

Thermal block: a collection of one or more HVAC zones grouped together for simulation purposes. Spaces need not be contiguous to be combined within a single thermal block.

U-factor (Thermal Transmittance): heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side. Units of U are Btu/h-ft^2-°F or Watts /(m^2.^{o}C).

Thermostat: an automatic control device used to maintain temperature at a fixed or adjustable set point.

Tinted (as applied to fenestration): Bronze, green, or grey coloring that is integral with the glazing material. Tinting does not include surface applied films such as reflective coatings, applied either in the field or during the manufacturing process.

Transformer: a piece of electrical equipment used to convert electric power from one voltage to another voltage.

a. **Dry-type transformer:** a transformer in which the core and coils are in a gaseous or dry compound.
b. **liquid-immersed transformer:** a transformer in which the core and coils are immersed in an insulating liquid.

Variable Air Volume (VAV) system: HVAC system that controls the dry-bulb temperature within a space by varying the volumetric flow of heated or cooled supply air to the space.

Vent damper: a device intended for installation in the venting system or an individual, automatically operated, fossil fuel-fired appliance in the outlet or downstream of the appliance draft control device, which is designed to automatically open the venting system when the appliance is in operation and to automatically close off the venting system when the appliance is in standby or shutdown condition.

Ventilation: the process of supplying or removing air by natural or mechanical means to or from any space. Such air is not required to have been conditioned.

Wall: that portion of the building envelope, including opaque area and fenestration, that is vertical or tilted at an angle of 60° from horizontal or greater. This includes above- and below-grade walls, between floor spandrels, peripheral edges of floors, and foundation walls. For the purpose of determining building envelope requirements, the classifications are defined as follows:

a. above-grade wall: a wall that is not below grade wall.
b. below-grade wall: that portion of a wall in the building envelope that is entirely below the finish grade and in contact with the ground.

Wall area, gross: the overall area off a wall including openings such as windows and doors, measured horizontally from outside surface to outside service and measured vertically from the top of the floor to the top of the roof. The gross wall area includes the area between the ceiling and the floor for multi-story buildings.

Water heater: vessel in which water is heated and is withdrawn for use external to the system.

Zone, HVAC: A space or group of spaces within a building with heating and cooling requirements that are sufficiently similar so that desired conditions (e.g., temperature) can be maintained throughout using a single sensor (e.g., thermostat or temperature sensor).

18.3 Abbreviations and Acronyms

AFUE	Annual fuel utilization efficiency
ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc.
ASTM	American Society for Testing and Materials
Btu	British thermal unit
Btu/h	British thermal units per hour
Btu/ft^2-°F	British thermal units per square foot per degree Fahrenheit
Btu/h- ft^2	British thermal units per hour per square foot
Btu/h- ft^2-°F	British thermal units per hour per lineal foot per degree Fahrenheit
^{o}C	Celsius
cfm	cubic feet per minute
cm	centimeter
COP	coefficient of performance
EER	energy efficiency ratio
EF	energy factor
^{o}F	Fahrenheit
ft	foot
h	hour
HC	heat capacity
h-ft^2-°F/Btu	hour per square foot per degree Fahrenheit per British thermal unit
h-m^2-°C/W	hour per square meter per degree Celsius per Watt

hp	horsepower (746 W)
HSPF	heating seasonal performance factor
HVAC	heating, ventilating, and air conditioning
I-P	inch-pound
in.	inch
IPLV	integrated part-load value
J	joule;
kJ	kilojoule
kVA	kilovolt-ampere
kW	kilowatt;(power)
kWh	kilowatt-hour; (energy)
LE	lighting efficacy
lin ft	linear foot
lin m	linear meter
lm	lumen
LPD	lighting power density
m	meter
mm	millimeter
NAECA	National Appliance Energy Conservation Act
PF	power factor
PTAC	packaged terminal air conditioner
R	R-value (thermal resistance)
SC	shading coefficient
SHGC	solar heat gain coefficient
SL	standby loss
VAV	variable air volume
VLT	visible light transmission
W	watt

W/ft^2	watts per square feet
W/m^2	watts per square meter
W/m^{2}K	watts per square meter per degree kelvin
W/m-K	watts per lineal meter per degree kelvin
Wh	watthour