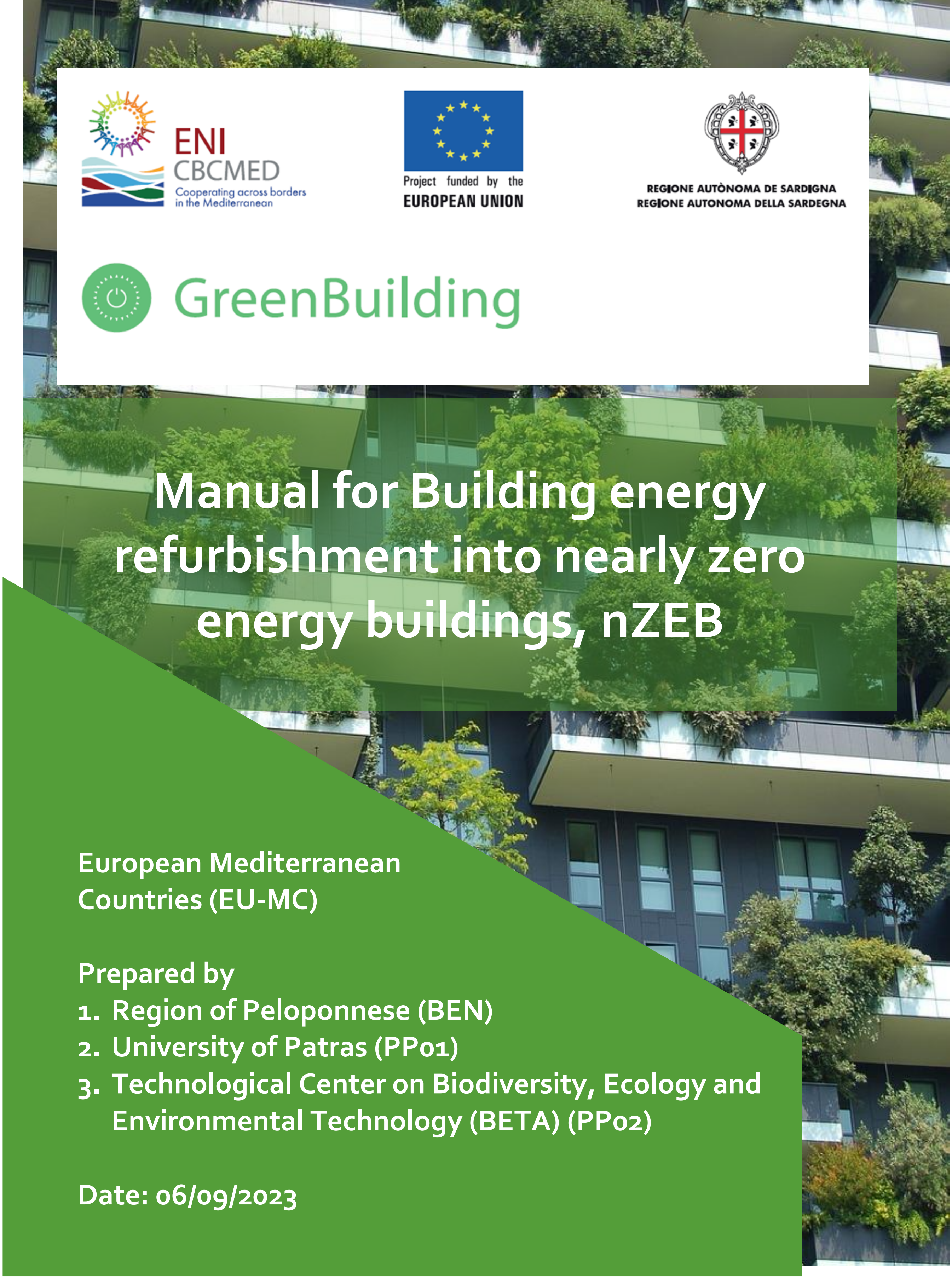

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GreenBuilding

Manual for Building energy refurbishment into nearly zero energy buildings, nZEB

European Mediterranean
Countries (EU-MC)

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EXECUTIVE SUMMARY

The preparation of this manual for Building energy refurbishment to arrive at nearly zero energy buildings, nZEB is done in fulfillment of a required Output 5.4 of the GreenBuilding project of the ENI CBC Med Programme. The goal of this manual is presented along with the definition of nearly zero energy for public building in the MED regions illustrating the benefits in energy consumption. These benefits include:

- Reducing environmental impact (e.g. greenhouse gas and carbon emissions) and increasing resiliency.
- Lower operational costs in particular the energy costs.
- Promoting healthier and more comfortable spaces for occupants and efficiency.
- Implementing this manual will be carried when intending to refurbish public offices and buildings to achieve nearly zero energy consumption annually. Involving a team to engage with occupants and a leader will be required. Climate will be one of the parameters affecting the demand of energy, thanks for the air conditioning heat gains for an existing building where orientation cannot be manipulated. The energy audit of the building prior to undertaking the measures to convert to nZEB, would be very helpful in setting
- Control the demand of HVAC & lighting where it is needed within the building. Minimize and turn off the systems by the use of sensors when no one is present and offer the heating / cooling and ventilating when they are occupied. (Steps 9 and 10)
- Train, engage and involve staff and visitors to understand the various steps by offering workshops and training sessions. (Step 5)
- Minimize the energy consumption for maintaining the required conditions inside the building such as free cooling, passive solar heating and day lighting. (Steps 9, and 10)
- Maximize the efficiency of existing equipment of HVAC and lighting that are mostly used. (Steps 6, 8, 9, and 10)
- Avoid energy consumption when missing the control of conflicting parameters (Steps 4, 6, 10 and 11)

These steps for owned public building may face barriers such the initial investment and availability of the will to consider turning the building to nearly zero energy over its life time. If these barriers are removed, this specific public building will join the world wide pool of nearly zero buildings. The support of the regulations and codes will require implementing the measures incompliance with the standards, with strict mandates on buildings that are tightening each year. The nearly net- zero energy buildings are the future, especially when moving into Net - Zero energy buildings.

GreenBuilding Consortium
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ABBREVIATIONS

A/E	Architectural/engineering
AEDG	Advanced Energy Design Guide
AFF	Above finished floor
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
AHU	Air-handling unit
BAS	Building automation system
BOD	Basis of Design
Btu	British thermal unit cfm cubic feet per minute
c.i.	Continuous insulation
CO_2	Carbon dioxide
COP	Coefficient of performance, dimensionless
CRI	Color Rendering Index
Cx	Commissioning
CxP	Commissioning provider
CZ	Climate zone
DCV	Demand-controlled ventilation
DX	Direct expansion
ECM	Electronically commutated motor
EER	Energy efficiency ratio, Btu/W·h
EF	Energy factor
ET	Thermal efficiency, dimensionless
EUI	Energy use intensity
F	Slab edge heat loss coefficient per foot of perimeter, Btu/h·ft·°F
Fc	Foot-candle
FC	Filled cavity
GSHP	Ground-source heat pump
HVAC	Heating, ventilating, and air-conditioning
IEER	Integrated energy efficiency ratio, Btu/W·h
In.	Inch = 2.54 cms
in. w.c.	Inches of water column
IPLV	Integrated part-load value, dimensionless
KW	Kilowatt
KWh	Kilowatt-hour
LED	Light-emitting diode
LLLC	Luminaire-level lighting control
LPD	Lighting power density, W/m^2
LPW	Lumens per watt
Ls	Liner system
M&V	Measurement and verification
N/A	Not applicable
NPLV	Nonstandard part load value
OPR	Owner’s Project Requirements
PPL	Plug and process load
Ppm	Parts per million

PV	Photovoltaic
QA	Quality assurance
R	Thermal resistance, h·mt2·°k/w
REC	Renewable energy certificate
Rh	Relative humidity
SAT	Supply air temperature
SEER	Seasonal energy efficiency ratio, Btu/W·h
SHGC	Solar heat gain coefficient, dimensionless
SWH	Service water heating
U	Thermal transmittance, Btu/h·ft^2·°F
VAV	Variable air volume
VRF	Variable refrigerant flow
VSD	Variable-speed drive
VT	Visible transmittance, dimensionless
W	Watt
WH	Service water heating
WWR	Window-to-wall ratio ZE zero energy

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Chapter 1: INTRODUCTION

1.1 Goal of the Manual

Buildings and among them public ones are responsible for 40% of total energy consumption and for 30-35% greenhouse gas emissions. In the last two decades, concerns have increased over the non-renewable energy sources and their impacts on environment and their responsibility in contributing to the climate change as illustrated by the increase of continuing global rise in temperature.

Targeting public buildings was considered one of the low hanging fruits strategies for reducing energy consumption to the lowest figures possible, and to enable the investment in renewable energy sources in the buildings sector. Directives, standards and regulations mushroomed in the recent years, and setting dates for coping with these directives, whether for existing or new building design, and sometimes are with ambitious dates, required the support of all stake holders of the built environment, including the financial institutions and investors, property advisors, architects, engineers, construction professionals, and occupants and developers, to assist in raising the bar on building performance.

It is evident that there are difficulties with the prevailing efficiencies and availability of the renewable sources to balance the current demand of energy. This prompted the policy makers, regulators and institutions to set the dates to reach nearly zero energy, and to start to promote the notion of passive buildings, zero carbon emissions, low energy buildings, and net zero energy, NZEB. Requirements for rating the buildings, and in many countries, worked in bringing the green building case viable, and demonstrations for pilot projects continued to promote an increase in the number of nearly zero energy buildings.

This manual aims to provide the authorities of public buildings in the MED region with a tool facilitating the process of turning their buildings to nearly zero energy and in the hope that this will make it more possible to move into net zero energy buildings and sooner than expected. It focuses on the existing public building, offering simple steps and in the order of their required investment values and budgets.

1.2 What is a Nearly Zero Energy, nZEB, Public Building & Targets?

According to the "Directive 2010/31 EU of the European Parliament and of the Council of 19 May 2010" the definition of '*nearly zero-energy building'* means *a building that has a very high energy performance*, as determined in accordance with Annex I. *The nearly zero or very low amount of* *energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;*

Governments established various changing dates to require converting public building to become nearly zero buildings on one hand, and to devise standards and codes to be implemented on the design of new buildings.

Conflicting interests among stakeholders troubled the development of codes and compliance with national and international standards. Certain public buildings are rented, utilities and private generation of electricity, performance contractors, lending schemes, other no none energy related considerations, optimization of human comfort, are all hindering the process of converting the building to become near zero energy.

The definition of nearly zero energy building, nZEB, will be referred to a highly energy efficient building with specific Energy Utilization Index, EUI and will be covered by a significant portion of its energy by renewable energy sources produced on site or off site.

Lack of energy benchmarks in certain countries will not be helpful in evaluating the reduction of energy consumption upon following the recommended steps. Several factors will affect the outcome such as the existing building envelope, systems incorporated and funding of the renewable energy systems and integrating them with the energy technologies, lighting and HVAC systems (2).

1.3 Importance and benefits of nZEB

The aim is to identify the improvement of energy consumption based on various measures and following certain metrics. Less consumption of energy is featuring the nearly net zero energy building.

Moving into nZEB requires a specific transition phase from the unresponsive and highly energy demanding elements to buildings becoming highly efficient one.

Chapter 2: HOW TO MOVE TO nZEB

2.1 Planning for nZEB

The impact of climate change and energy prices are encouraging stakeholders to target the energy use in building aiming at decreasing its energy consumption. By incorporating energy efficient strategies in retrofits, further dependence on renewable energy derived from non-fuel energy produced on-site and off-site will be also reduced.

Many conventional energy sources result in emissions of carbon dioxide, and sulfur dioxide gases, that nZEB will cater to reduce them and use emissions-free energy instead.

To move to nearly zero energy public building, the following tasks can be summarized:

- Assess the building by simply finding how much energy this building is consuming compared to a typical public building consumption.
- Set the goals for performance and how to reach them.
- Implement retrofitting measures and consider timing and realities of the ownership resources and markets.
- Involve the owner of this public building, occupants and community.

The process will consider maximizing efficiency opportunities that will be carried before developing renewable energy plans. This will minimize the cost of the needed renewable energy.

When reaching minimum building load, efficient equipment and systems will include energy efficient lighting, electric lighting controls, high performance HVAC system. The remaining energy needs can then be met using renewable energy technologies such as Photo Voltaic "PV" and solar water heating. Since the public is existing in densely populated area, wind turbine will not be attractive. It is also important to consider the interruptions to the public building operation.

If feasible, the effective use of biomass, wood pellets, and agriculture waste can be used for space heating and service water heating.

The introduction of the steps will consider efficiently first, and leverage improvements over time in conjunction with capital upgrades and other building lifecycles events (e.g. equipment replacements). Note that energy retrofits have a payback, while many other common building improvements have no direct payback, (e.g. new lobby refurbishment, fresh coat of paint, etc.).

2.2 Performance of nZEB

Following the strategies of nZEB, the energy efficiency stands to be the most effective strategy.

These measures include reduction of demand side loads such as moving into a high-performance envelope, introducing air barrier systems, efficient utilization of day lighting, sun control and shading devices, optimal glazing, passive solar heating, natural ventilation, and consideration of water conservation.

The investment will impact the climate crisis by:

- Providing infrastructure to reduce the impacts on the environment and on the communities.
- It will support the clean energy technologies and reduce the greenhouse gases.
- It will remove the current environmentally damaging energy resources.

Chapter 3: ESTABLISH nZEB PROCESS

3.1 Establish nZEB Process

According to annex 1 of the "Directive 2010/31 EU of the European Parliament and of the Council of 19 May 2010", the energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs.

Also, the energy performance of a building shall be expressed in a transparent manner and shall include an energy performance indicator and a numeric indicator of primary energy use, based on primary energy factors per energy carrier, which may be based on national or regional annual weighted averages or a specific value for onsite production.

Projected for the year 2020 and tailored to the Mediterranean region, the energy performance standards for nearly zero-energy buildings (NZEB) encompass the following specific value ranges (COMMISSION RECOMMENDATION (EU) 2016/1318 of 29 July 2016) on guidelines for the promotion of nearly zero-energy buildings and best practices to ensure that, by 2020, all new buildings are nearly zero-energy buildings).

- Offices: 20-30 kWh/(m^2.y) of net primary energy, typically with 80-90 kWh/(m2.y) of primary energy use, 60 kWh/(m2.y) of which is typically supplied by on-site renewable sources.
- New single-family houses: 0-15 kWh/m^2.y) of net primary energy, typically with 50-65 kWh/(m^2.y) of primary energy use, 50 kWh/(m^2.y) of which is typically supplied by on-site renewable sources.

3.2 Set the goal

Nearly net zero energy building aims at approaching a balance between generation of energy and its consumption, by reducing losses and improving the efficiency of existing systems.

To generate the same amount of energy with fewer natural resources and getting the same service with less energy.

This process will include:

a. Turning the building to become energy efficient upon reducing the energy consumption due to its imposing envelope conditions.
   Façade includes walls, windows and slabs of roof, ceilings and floors. This may require investing in windows and doors and insulating the walls and roof.
b. Eliminating the use of fossil fuels utilized by existing inefficient systems and equipment (HVAC & lighting, etc.)
c. Provide renewable energy on site and whenever possible.

3.3 Hire the project team

There should be a team to look into the various steps for reaching the nearly net zero energy building. The responsibility of the team will be to perform the energy audit, review the utility bills, examine the building envelope, determine which systems to replace and decide on the investment that the public building can afford and make it available.

It is important that the team members should understand the whole building benefits, have the knowledge on the lowest possible energy use that could be provided by efficiency using available technologies and best practices, and have the passion and vision for taking the building to nearly net zero energy with minimum energy consumption and maximum CO2 emissions.

3.4 EUI target (Performance & emissions).

A nearly net zero building has the following characteristics.

- Should have the aim to avoid future misunderstandings and failures.
- Feasible technically and financially

- Flexible if adapting it in various locations, type of construction and climates.
- Accept current voluntary and updated standards of energy conservation.
- Comparative different technologies should be considered
- Gain the support of all stakeholders and stimulate their current understanding of net zero.
- Can be monitored and verified
- Able to compare its EUI with other prevailing values in the region.

Chapter 4: REFURBISHMENT STEPS - PUBLIC BUILDINGS

4.1 Step No. 1: Walk-Through Energy Audit

Perform a Walkthrough Energy Audit to reveal what Systems to be Upgraded & Identify Target

The aim of the walk-through energy audit is to identify the energy saving opportunities in the building. It will assess and identify the envelope and the existing energy systems of the building. Information about the building & climate zone, activity and energy consumption are briefly collected. No instruments or equipment are needed.

The walk-through audit will provide information on:

- Year of construction and date of occupying the building, Owned or leased.
- Working and overtime hours' schedule,
- Area of the building, foot print, site and number of floors, Number of offices, guard room if separate, Basement area and use, meeting rooms and assembly halls.
- Envelope including roof and orientation description, fenestration, doors and windows
- Heating (Boiler, burner, installation, insulation, radiator, etc.) and cooling and ventilation systems (unitary, central A/Cs, fans and types), Electrical devices and office equipment (Photocopiers and printers, refrigerators, microwave)
- Insulation status of the envelope, ducts, and piping,
- Daily/ weekly number of occupants and visitors,

- Type of energy and fuel: natural gas, LPG, Diesel fuel and others.
- Total energy consumption of the last three years and their average cost,
    - Electricity (purchased) Utilities and Neighborhood
    - Electricity (produced as self-generation)
- Renewable energy resources on site
- Lighting and lighting fixtures, and interior & exterior lighting
- Central computer and data systems if existing
- Domestic Hot water: piping, storage tank, heaters, Heating water, solar, instantaneous heaters and use
- Energy meters, timers, sensors if existing
- Heat exchangers if existing
- Decorative water fountains if existing,
- Water pumps if existing,
- Building automation system

A typical scenario of an energy audit report will provide information on the exterior lighting, interior lighting, heating, cooling, and ventilation of fans, pumps and miscellaneous plug loads.

As a result, recommendations for energy saving opportunities, reduction of energy waste, etc. through improvement of energy management and/or no- or low-cost measures that can be easily identified to be implemented by the facility using human and/or limited financial own resources. This will lead to step 2.

4.2 Step No. 2: Thermal Mass & Insulation

Minimize the Heat Gains and Heat Losses by Insulating the Opaque Walls & Roof

Results of the step (1) Walkthrough energy audit will enable listing the existing equipment and their schedule of operation.

The location of the existing public building in a certain climate zone, elevation above sea level, wind patterns, and building’s orientation will dictate certain limitations and opportunities to improve the load of equipment.

Identifying the Climate zone will direct the attention to look for the performance and energy consumption of heating, cooling or both and to identify which load is more dominant.

The impact of the orientation of the building would be studied if it were undergoing the design stage. But still the orientation may impact the harnessing renewable energy generation mechanisms (search for the south façade in our territories).

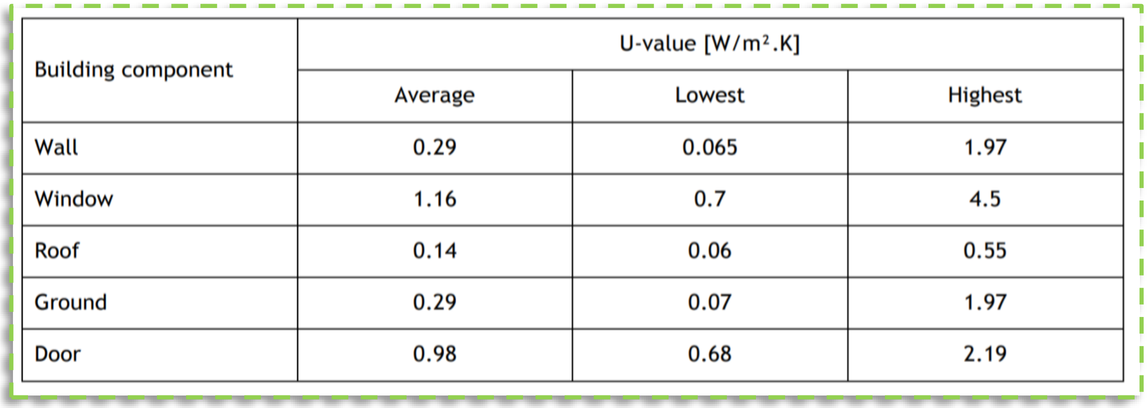
The thermal mass is a property of a material that allows it to store and release thermal energy. Thermal massive materials have high densities and high specific capacities. The rate of heat flow through the material is moderate and enable matching a desired time delay for storing and releasing energy within the daily cycle.

The process will focus on re-skinning the building of the exterior façade with insulation, which is a quick and effective method.

External mass where the insulation is located outside the insulation of the envelope and directly exposed to the exterior. This mass reduces the total thermal loads over the time when the impact of intermittent exterior conditions, such as air temperature and sun.

The effectiveness of insulation is rated in R-values (seeking the highest value) and dependent on the thickness, density, and the type of insulation.

Recommended U values of exterior walls can vary between one building and another:



Building component	U-value [W/m².K]		
	Average	Lowest	Highest
Wall	0.29	0.065	1.97
Window	1.16	0.7	4.5
Roof	0.14	0.06	0.55
Ground	0.29	0.07	1.97
Door	0.98	0.68	2.19

4.2.1 Roof Insulation

- Consider the consequences if the specified installation method in association with the roofing method.
- Avoid mechanical attached insulation layers to minimize thermal bridges losses.
- Avoid penetration to roofing system air barrier to minimize condensation issues.
- Select insulation type taking into account the energy efficiency improvements and impact of increasing Volatile Organic compounds inside the envelope and adhering to the requirements of building codes:

- Fiberglass
- Wool
- Foam boards or blocks
- Cellulose
- Polystyrene
- Polyisocyanurate
- Polyurethane

These types can be of rigid boards, semi-rigid boards, spray in place, loose fill and Batts (fiber glass or mineral wool). Board insulation should be installed in at least two layers staggering the joints.

- Coordinate the installation of PV panels and their fixation elements with the roof load and avoid penetrating the insulation layers.

4.2.2 Wall and slabs Insulation

A. Concrete and Masonry
   - Continuous exterior insulation is preferred over interior insulation and should meet the U factor recommendations for relevant climate zones.

B. Steel Framed
   - Continuous insulation on the exterior of framed steel walls is recommended to minimize the thermal bridges
   - Continuous insulation should provide the total wall assembly as long as it will meet the required U factor recommendations.

C. Below grade walls
   - Continuous exterior insulation of the below grade walls and portion of the ground floor (closed-cell foam insulation) will maintain continuity of the air barrier layers.

D. Mass floors
   - Continuous insulation beneath the floor slab is recommended.
   - Consider extending to the column in the basement with proper means of protecting the insulation in the parking.

4.3 Step No. 3: Air Leakage, Glazing, Thermal Bridge and Tightness

Replace Windows by Low Emissivity Coated Double Pane Glass, Minimize Infiltration & Mitigate Thermal Bridges.

The objective is to ensure air-tight enclosures by selecting glass window and frames that minimize infiltration and heat transfer and maintaining continuous air barrier system and continuous insulation strategies.

An important step is to close leaks, and to reduce humidity and air infiltration.

4.3.1 Air Leakage

Air leakage through the envelope should be controlled to a determined recommended maximum rate of 4.57 m^3/ hr/ m^2 of total envelope surface area at 75 Pa depending upon the climate where the building is located. These rates are based on the air leakage testing procedures.

Factors affecting the amount of air infiltration are caused by pressure differences from wind, stack effect, and existing building equipment and are controlled by the air barrier that should be continuous over all surfaces of the building envelope.

As part of the continuous barrier, fenestration and doors should be checked for their air leakage rates. The window assembly should be checked when tied to the wall and air barrier by using combination of flashing, self-adhering membranes and low-expansion foam insulation and sealants.

4.3.2 Thermal Bridge Controls

Continuous insulation is usually compromised by thermal bridging through the building envelope.

Highly conductive elements like concrete, steel and Aluminum Bridge, through the thermal barrier when connecting the internal and external surfaces of the building. The studs, fasteners, assembly penetrations, assembly interfaces or at transitions such as wall to roof, floor to wall, corners, and window openings are responsible for thermal bridging.

Pipe penetrations, hangers, parapets, etc. create impacts on the heat of coefficient of conductance.

- Mitigate thermal bridges to the maximum extent possible, by adding more insulation inboard and outboard of the bridging component
- Integrate the conductive elements with non-conductive ones.
- Use the least conductive element when it is a must to use the bridge.
- Use fewer and larger bridges.
- Treat the same for roof drain fittings and vent, and curbs if existing on roof by using insulation
- Insulate roof parapets.
- Insulate and use non-conductive attachments such as shelf angle clips, canopies, and shades. (Vertical or Horizontal)
- Lower penetrations in walls and if using ducts should be insulated

4.3.3 Window Glazed System

The system should help in reducing the peak cooling load resulting in crashing the mechanical equipment load first cost.

Climate specificities will define the ideal window choice. In cold climates, the combination of high insulation together with enhanced entry of free heat from the sun (high solar heat gains) allows to save heating energy and minimize cold surfaces perceptions near the window. On the other hand, warm climates have to manage sun heat influx together with reasonable insulation level in order to minimize indoor temperature with high cooling loads and only efficient ventilation.

Modern coated glasses combined with efficient window frames allow to find a compromise between these two aspects.

Operable fenestration will reduce the need for Air Conditioning and ventilation equipment when resorting to natural ventilation.

Replacing the windows should take in consideration the gains on one hand for daylight, natural ventilation and views and on the other hand, the impact of heat gains during summer and heat loss in winter.

Glass, though it consumes large amounts of carbon during manufacturing, has a high degree of recyclability.

- Window transitions in walls should align the insulated glazing units.

- The exterior insulation should extend to window frame at all sides, requiring coordination between the replaced widow and the structural opening.
- Replace window glazing system by considering the U factor, solar heat gain coefficient, SHGC and visible transmittance for each climate, orientation and façade.
- When considering renovation, and if possible, work on reducing the glass to wall area ratio to 30%.
- Consider choosing the right specification of the window glazing relevant to the climate by selecting the appropriate U factor for fixed window, operable window, the SHGC for operable and fixed windows and correct minimum ratio of visible transmittance and solar heat gain coefficient, SHGC and for swinging doors.
- Coordinate the selection of glass with the climate and shades.

The Recommendation of the dimensional heat loss to be less

1.7 W per m^2 building envelope in a one floor building,
4.7 W per m^2 building envelope in two floors building, and
5.7 W per m^2 building envelope in a building of three or more floors.

The area of windows and doors and the dimensioning heat loss through these is not included in the calculation.

For buildings with high rooms that are comparable with buildings of two or three floors or above, the corresponding dimensioning heat loss is 4.7 and 5.7 W respectively per m^2 building envelope.

4.4 Step No. 4: Shading & daylight

Install shades on windows (certain facades) without compromising solar daylight radiation penetration in winter.

The objective of this step is to optimize each façade based on exposure to direct solar radiation.

Immediate reaction towards putting window shading is concern of blocking out a lot of the heat gain. Uncontrolled solar heat gain is a major component of the total energy consumption in cooling and in warmer climates.

Existing building and windows may not allow proper configuration of the placement of windows compared to new design.

- Prioritize the reduction of direct solar on glass

The most effective control of solar heat gain and radiation should be on the outside of the building as aiming at blocking penetration before allowing it to reach inside.

Horizontal surfaces (skylight), West and East facing façades receive the most of solar radiation.

Horizontal shades and over hung on the width of the windows are more effective as they will provide maximum shading and without compromising the heat gains in other seasons when requiring heat gain.

Shades include overhangs, shade structures, screens, double skins, exterior blinds and landscaping are typical tools to use.

Several shapes of the over hung may offer additional space for external lighting, green plantations. Compact size of shades on certain exposure will be effective in cold climate and cost offering effective day lighting, while elongated shapes will have an increase in daylight requiring careful decision for optimizing the size and location. The target is narrowed to minimize surfaces receiving direct solar radiation, especially in cooling season.

Method of connecting shades to the envelope:

- Cantilevered shades should minimize the penetration of steel support to the envelope. Ground supported canopies will be recommended as it will save lot on the sealing and insulations strategies.
- Use the least amount of penetrating materials that meets structural requirements and the use of thermally broken penetrating structural connections.
- Use thermally broken structural penetrations and high strength bolts and place nonconductive plates placed between the interior and exterior structural membranes if located in the wall insulation plane.
- If not, then the building insulation should be wrapped around the entirety of the projecting canopy,
- Insulate the penetrating cantilevering the structural membrane inboard and outboard of the wall envelope. Insulation should be extended of 2 meters on interior and exterior members using sprayed polyurethane foam.

Lighting systems can account for almost of 25-30% of the building's total energy consumption. Assessment of how natural day lighting including skylights that reduce the load will be carried.

Passive architecture would call for using as much as natural light during the day while balancing thermal energy losses, the orientation of the existing frames and how they absorb and reflect, will make the building able to passively take the advantage of the natural resources and connection with the exterior.

4.5 Step No. 5: Occupants Engagement and Behavior

Engage Staff, Occupants and Visitors with the process of nearly net zero energy.

The occupants can publicize that the building is turned into nearly net zero energy, internally and externally. This will improve the occupant morale and the building public image.

Occupants should be engaged in the transition. The behavior of the occupants is critical in a nearly net zero energy building, since plug loads are usually the largest component of energy use.

Staff who will be responsible for operating the building, and visitors will be educated and setting up dashboards that will be attracting them to understand the impact of nearly net zero building.

Every watt of energy saved through controls, occupant behavior changes. The occupant will help to eliminate energy waste.

Occupants are part of the equation: keep the building cooler/ warmer due to a few complaints? Are occupants plugging in equipment they do not really need, do occupants understand how their behavior is driving building energy use?

The building caretaker will be publicizing the energy budget and how to cope with the rising of energy cost and by bringing down the operational expenses.

All involved will realize that moving to nearly net zero energy will not be happening in few months. All should be prepared to get engaged timely with detailed plan, using indicators to show how the process will contribute to the energy and CO2 emission reductions.

Surveys and interviews of staff and occupants will continue to keep them involved with the process of transforming the building into o nearly net one.

It will be important to secure and information campaign focused on tasks associated with nearly net zero building which needs to be directed all levels of those involved in the process of change over this public building and at the general public.

4.6 Step No. 6: Electric Lighting

Optimize The Energy Consumption of Interior and Exterior Lighting and Improve Their Controls.

4.6.1 Electric Lighting

The objective of this step is to optimize the energy impact of appropriate lighting strategies, by daylight integration and responding to occupant appropriate light levels.

Lighting systems can account for almost 25% of the building's total energy consumption

Assessment of how natural day lighting including skylights that reduce the load will be carried. Through automatic controls, electric lighting will correspond to daylight. A decrease in the morning and decrease in the afternoon and before concluding the working hours.

* Light Emitting Diode, LED, the solid-state semiconductor device can produce a wide range of saturated colored light and can be manipulated with color mixing continuous dimming systems will offer this strategy aiming at achieving energy savings. In addition, electric lighting needs of occupants should be offered with little waste and not to create but vibrant environment.to produce white light.

* Efficacy of LED lamp can be of 125 Lumens per watt, LPW as a minimum and have over 50,000 hours' life with over 80% CRI and dimmable.

* These lighting controls are invisible to occupants hence the feedback is important. Utilization of Luminaire Level Lighting Control will be ideal to allow sequence of operations based on specific behavior and preferences resulting in energy savings.

Interior Lighting

* Surfaces must have light colored finishes to allow providing the right light levels at the low lighting power density, LPD (w/m2), and the ceiling reflectance must be 80-90% with walls of at least 50% and floor of at least 20%.

* Task lighting should not be needed during daylight hours and should be provided only where needed. These lighting should be connected to vacancy sensors, and to continually check that are turned off during day-light hours.

* LED Color: To reveal correctly the color characteristics of objects and people, LED Color Rendering Index (CRI) should be measured to identify the Correlated Color Temperature (CCT)

whether the lamp is relatively warmth or coldness, and identify the distribution of wavelength across the visible light spectrum (Spectral Power Distribution, SPD).

* Allow for open office LPD of 6.7 W/m2 and for private office of 8.8 W/m2

Open Layout Offices:

- Dimming electric lighting should be responsive to daylight (offices located on the north and south of the building) and partitions between workstations should be taller than one meter, otherwise provide translucent partition.
- Target lighting to have 10 Lux resulting in 20 when combining daylight, either by local switches, time controller or remote wireless.

Private offices:

- Offices may have window blinds and best located at east and west sides.
- Target lighting to have 10 Lux resulting in 20 when combining daylight, either by local switches, time controller or remote wireless. Supplemental task lighting may be required during non-daylight hours
- Wireless controlled luminaires may save wiring of controls

Other Offices and Areas

- Conference Rooms of 10 LUX controlled by switches, occupancy sensor or multi scene dimming controllers and 7.8 W/m2
- Corridors of 4 LUX, luminaire lighting the walls uniformly
- Lobbies of 6 LUX, and 3.5 w/m2
- Storage areas of 6 LUX, and 3.5 w/m2
- Rest rooms of 4.8 w/m2
- Twenty-Four hours: limit total lighting power to 10% of Light Power Density, LPD

<u>Exterior Lighting</u>

- Decide on the lighting zones for parking and grounds by not attempting to decrease the number of poles with height if 6 m. integrated with 15 min. occupancy sensor and eliminating trespass and light pollution.
- Avoid using flood light
- Identify back, up light and glare, BUG rating
- Limit lighting power for LED parking lots to 4 W/m2 in neighborhood district and 5 W/m2 for commercial district locations and with dimming driver
- Parking lighting should not be significantly brighter than the lighting of adjacent street.
- Limit aboveground and underground parking garages lighting power to 1.3 W/m2 and 6 W/m2 for elevator lobbies and stairwells.

- Limit pathways, walkways, plaza areas to 1.0 W/m2 for commercial district, and 0.5 W/m^2 for neighborhood areas.

Installation of Hybrid lighting systems:

- The inbuilt double glazed light collector receives sunlight over a large surface area and distributes light into the reflective system placed below it.
- This is built from highly reflective surfaces assembled in an aluminum fixing system which guides the intercepted light to diffuser further below.
- The high performance diffuser then spreads the daylight evenly without any glare or heat into the sitting place.
- The system's daylight sensor continuously monitors the ambient sunlight.
- The electric lamps are divided into three groups each representing a step for switch on/off. If the daylight on sitting area is less than desired light intensity, called the set point, the controller switches on the required number of steps in electric lighting to achieve the set point, compensating the reduction of daylight.

4.7 Step No. 7: Electric Lighting

Optimize the circulation of outdoor air during mild weather.

4.7.1 Natural Ventilation

The objective of this step is to optimize the quality of natural ventilation to reduce the heating/ cooling load in mild weather.

Natural ventilation has become an increasingly attractive method for reducing energy use and cost and for providing acceptable indoor environmental quality and maintaining a healthy, comfortable, and productive indoor climate rather than the more prevailing approach of using mechanical ventilation. In certain climates, it can be used as an alternative to air-conditioning plants, saving 10%–30% of total energy consumption.

It relies on pressure differences that is caused by wind or buoyancy effects, to move the outdoor air through the building. The amount of ventilation will depend critically on the size and placement of openings in the building. Louvers, grills, or open plans are techniques to complete the airflow circuit through a building.

Code requirements regarding smoke and fire transfer are challenges to have a proper system.

Outdoor air is required in the building to change odors, to provide oxygen for respiration, and to increase thermal comfort. Excess outdoor air with low quality may pose additional energy load for treatment.

Natural ventilation methodology varies based on building type and local climate. The amount of ventilation depends critically on the internal spaces, and the size and placement of openings in the building.

- Plant trees to mitigate cold winter winds
- Each room should have two separate supply and exhaust openings. Locate exhaust high above inlet to maximize stack effect.
- Window openings should be operable by the occupants.
- Provide ridge vents at the highest point in the roof that offers a good outlet for both buoyancy and wind-induced ventilation. This ridge opening should be free of obstructions to allow air to freely flow out of the building.
- Allow for adequate internal airflow interior doors should be kept open to encourage whole-building ventilation. If privacy is required, ventilation can be provided through high louvers.
- Consider vented skylights.
- Provide attic ventilation if exits
- Provide stairwell ventilation system in parallel to smoke ventilation requirements.
- Consider the use of fan-assisted cooling strategies by the use of ceiling and whole-building fans.
- Coordinate natural ventilation philosophy with the existing HVAC system.
- Provide wind towers supporting an evaporative system, and summer ventilation control methods.
- Observe all codes and standards regarding transport of smoke and fire when deciding on the applicability of natural ventilation.

4.8 Step No. 8: Electric Lighting

Implement a Plug Load Management Policy.

4.8.1 Plug Load

The objective of this step is to develop plug load management policy to be implemented.

Plug loads (excluding HVAC and lighting) can get high as much as 50 % of the building's energy use. This will be a significant portion of energy in such low-energy building, with the indirect impact of increasing the consumption of energy for cooling and ventilating the building to cope with the heat generated by the use of equipment and appliances inside the building. Plug load management policy requires engagement of the staff.

- Plug load thorough inventory should be performed with identifying working hours and occupied periods. Include all electronic loads at all offices and meeting rooms and other areas. This inventory will include desktop computers, laptops, monitor, phones, time clock, personal devices, task lighting, device chargers, TV screens, copiers, printers, printing stations, WIFI routers & modems., appliances such as microwave ovens, refrigerators, coffee machines, water coolers, vending machines (if existing) , telecommunication servers, routers, Uninterruptable power supply supplies, fire alarms, security and digital cameras, and elevators. Include future plan of including electric chargers for cars. In addition, the management of the building should define the programs needed to reduce these plug load.
- Choose low power demand equipment and appliances.
    - Use only energy-efficient appliances and replace old ones.
    - Select equipment that require low energy usage.
    - Use of multifunction devices to provide printing and scanning.
- Offer controlling mechanisms for various appliances and equipment to minimize waste energy by shutting down when such equipment is not in use.
    - Two folds will result: reduce the energy consumption and reduce the heat generating the appliance and equipment when in use.
    - Receptacles with one out uncontrolled should be controlled by an automatic shutoff device.
    - Connect computers with automatic sleep mode if connected to the non- controlled section.
    - IT equipment should be powered when needed
    - Consider automation by BMS.
    - Integrate the plug load controls with the lighting controls system (occupancy sensors, motion sensors with 10 min. after an occupant has left the room and sending the same to the lighting controls system)
    - Occupancy controls in addition to plug controls will strip power and time enabled power.
    - Controls should turn off devices at specific, programmed times when the building is unoccupied, and by providing manual over ride.
    - Use time switches for central equipment if not used during unoccupied periods. (Water coolers and coffee machines).
    - Provide plug load consumption monitors.

4.9 Step No. 9: Heating & Cooling Loads Systems and Equipment

Optimize the Energy Consumption and Sizing of the Heating/ Cooling/ Ventilation Equipment and Systems.

In recent years, the prevalence of air-conditioning systems has surged in European countries, creating challenges during peak demand periods, such as increased electricity costs and energy imbalances. Addressing this issue requires prioritizing strategies that boost building thermal efficiency in summer, including measures to prevent overheating like shading, enhanced building thermal capacity, and the promotion of passive cooling techniques that enhance indoor climates and microenvironments (Directive 2010/31 EU of the European Parliament and of the Council of 19 May 2010)

The objective of this step is to optimize the energy consumption of the HVAC equipment and their efficiency, and to ensure that such equipment can cover the required load estimates.

In accordance with Directive 2010/31 EU of the European Parliament and of the Council of 19 May 2010 for heating systems:

1. Member States shall lay down the necessary measures to establish a regular inspection of the accessible parts of systems used for heating buildings, such as the heat generator, control system and circulation pump(s), with boilers of an effective rated output for space heating purposes of more than 20 kW. That inspection shall include an assessment of the boiler efficiency and the boiler sizing compared with the heating requirements of the building. The assessment of the boiler sizing does not have to be repeated as long as no changes were made to the heating system or as regards the heating requirements of the building in the meantime.
2. Member States may set different inspection frequencies depending on the type and effective rated output of the heating system whilst taking into account the costs of the inspection of the heating system and the estimated energy cost savings that may result from the inspection.
3. Heating systems with boilers of an effective rated output of more than 100 kW shall be inspected at least every two years.

Based on the energy audit results (Step #1), it will become possible to verify if the existing equipment will meet rightly the estimated load of the building:

- Right size the equipment to meet all applicable load factors, and limit the usage of excessive unwarranted safety factors on load estimates.
- Consider diversity assumptions, like uncertainty factors to be applied to the actual parameters and redundancy factors to reflect the needs to upsize the components to accommodate operation during a planned or unplanned breakdown.

Typical improvement to reduce the load of HVAC systems:

i. Replace of belt driven AHU fan with direct driven: Electronically commutated brushless direct driven fans where in the losses at every stage from wire to air has been reduced considerably making the unit 15-20% more efficient than the belt drives, these fans are having inbuilt speed control mechanism which further eliminates the need of VFD too,
ii. Replace existing chillers by chillers (if existing) having more Coefficient of Performance, COP. Certain chillers may have COP on the range of 5.5 to 5.8
iii. Opt for indirect evaporative cooling system that has 20-30% less power consumption when delivering similar loads.
iv. Active refrigerant agent for chillers: Active refrigerant agent is an intermetallic compound technology which, when introduced in the refrigerant oil of a refrigeration system, forms a permanent bond to metal surfaces. This action removes oil fouling, changes the thermal nature of the metal and lowered the boiling point of the refrigerant gas, resulting in a more efficient operating system with substantial energy cost savings.
v. Waste heat recovery from chillers and generators in hot water: If cooling systems have vapor compression technology, wasted heat is estimate around 30-40% of total energy involved. Add recovery systems and depending on the refrigerant type and its temperature a substantial amount can be recovered typically like 10-15% of the condenser load.
vi. Demand Controlled Ventilation: in buildings ensures that the ventilation suits the actual requirements. It contributes to savings on the electricity bill while at the same time providing the necessary air change. However, with demand-controlled ventilation, there is still a minimum air change requirement in all rooms that must guard against increased concentrations of CO_2, and other VOC pollutants in the indoor climate. Its use can lead to significant energy saving on energy consumption for ventilation of around 40 %.
vii. Air Quality: The minimum quantity of outdoor air should ensure having optimum improvement in the air quality. Heat recovery units will assist in saving the energy. There are also stricter requirements for the permissible amount of CO_2.
viii. Use economizer on AHUs (if existing) and free cooling in certain weather conditions.
ix. Check the step # 7 for providing natural ventilation.
x. Minimize pumps and fans energy consumption when opting for replacement by selecting efficient equipment and select the proper strainers and filters.
xi. Verify duct sizing and insulation. Carry blow testing.
xii. Use electronic commutated motors, ECM that control electronically the voltage and current.

xiii. Consider proper plans for periodic maintenance.

Proposed actions by the European Commission on heating and cooling systems (COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS – An EU Strategy on Heating and Cooling, 2016)

- District Heating and Cooling:
    - District heating integrates renewable electricity (via heat pumps), geothermal and solar thermal energy, waste heat, and municipal waste.
    - Offers flexibility to the energy system by efficiently storing thermal energy (e.g., in hot water tanks or underground).
- Cogeneration of Heat and Power (CHP):
    - CHP results in substantial energy and CO_2 savings compared to separate heat and power generation.
    - Combining CHP with thermal storage increases its efficiency.
    - Many CHP technologies can utilize renewable energy (e.g., geothermal, biogas), alternative fuels (e.g., hydrogen), and waste heat.
    - Tri-generation 17 should be exploited, using heat production for cooling in summer.
- Smart Buildings:
    - Smart buildings connected to a smart grid allow remote or automatic control of heating, cooling, water heating, appliances, and lighting based on factors like time, date, humidity, outdoor temperature, and occupancy.
    - Automatic energy demand management enables consumer participation in demand response by adjusting consumption timing in response to electricity prices.

4.10 Step No. 10: Service Hot Water

Optimize the Performance of Service Hot Water, SHW Equipment.

The objective of this step is to optimize the distribution of low water consumption fixtures, including hand-washing and break room, showers (if existing) and kitchenette sinks.

To optimize the performance of the service hot water, an inventory of service water end -use applications will be taken along the establishment of the frequency of use and fixtures, enabling setting the efficiency strategies in two paths: improve the efficiency of generation of hot water and minimize the energy losses in delivering the hot water to various demand points.

Two factors are considered: water storage capacity and type of fuel available.

Several types of these systems may include: Gas fired storage water heater, gas fired instantaneous water heater, electric-resistance storage water heater, electric-resistance instantaneous water heaters for small systems, and heat pump electric water heaters.

Newly installed heat meters and heat cost allocators should be remotely readable to ensure cost-effective, and frequent provision of, consumption information. (DIRECTIVE (EU) 2023/1791 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 September 2023της 13ης Σεπτεμβρίου 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast))

This step will require the following strategies:

a. Reduce overall water consumption by specifying low-flow hand washing and break room & kitchenette sinks.
b. Water heating system should be sized to meet anticipated peak hot-water load, taking in to consideration life cycle cost
c. The best recommendation will be to use small local water heaters.

Minimizing system losses:

- Reduce hot water consumption by providing water-efficient fixtures, with aerated proximity faucets and low flow rates.
- Eliminate heat loss from pumped circulating loops (if exists)
- Low-volume of hot water demand will not justify having a centralized hot water plant.
- Insulate the hot water piping.

Renewable Hot water service source:

- When fixtures are distributed in the building, it will become not practical to install renewable hot water source system as the recirculation of hot water cost exceeds the cost of generating hot water by other non-renewable source.

4.11 Step No. 11: Renewable Energy Systems

Maximize the Generation of Renewable Energy and Connect with the Grid Through Net Metering.

The objective of this step is to optimize generating energy by minimizing the reliance on nonrenewable resources.

It is the final step in the process of producing a nearly net zero energy building.

Various choices exist for fulfilling the energy requirements of an eco-efficient building through renewable energy sources, including on-site solutions like solar thermal, solar photovoltaics, heat pumps, and biomass; renewable energy supplied by community or citizen energy groups; and district heating and cooling systems utilizing renewable sources or residual heat (proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the energy performance of buildings (recast) COM/2021/802 final).

There are two different nearly net zero building typologies:

1. Renewable-oriented buildings:
   - When using more energy but also generate more energy.
   - Relying on active strategies such s HVAC systems, thermal storage, and demand response.
2. Efficiency-oriented buildings:
   - Use and generate less energy
   - Relying on passive strategies like effective insulation, built-in shading, and day lighting.

Usage of renewable sources be one or combination of:

- Solar Power using Photovoltaic, PV: The direct conversion of light into electric power using semiconducting materials such as silicon. Each solar panel contains numerous photovoltaic cells which work together to produce electricity, when sunlight shines on the panel, and creates an electrical charge in response to an electrical field in the cell, producing electricity. Several considerations will be considered for the selection of PV system:

  - The type, efficiency and quality
  - Where to locate- check orientation and tilt of panel.
  - Number and quality of inverters, location and number of panels.
  - Type and quality of energy storage, if any.
  - Type of wire and conduit
  - Point of connection to building power switch board and transformer
  - Roof accessibility & shade
  - If parking lot will be covered by the panels or not.
  - Shut down during lightning strikes
  - Battery storage and its impact on the cost of the system and its payback period.
  - Double sided solar PV system: Bifacial solar panels having glass coating on both sides with low annual degradation, will produce more than the one sided by 20%
  - Building integrate PV: Two or more panes of heat treated, safety glass which provides the same thermal and sound insulation and natural light can replace the curtain walls if exist.

- Wind Power: it is affected by the sun unevenly heating the atmosphere, irregularities in the earth surface and the planet rotation. The resulting wind turns propeller blades around a rotor, which spin a generator, creating electricity.
- Solar thermal: sunlight will be collected using flat glass or mirror to concentrate it, will raise the temperature of the water running in tubes.
- To less extent, consider the Biomass energy when storing chemical energy from the sun, produced by the plants through photosynthesis. It can be burned directly to produce heat or can be converted into renewable liquid and gas fuels.

Connection with the Grid:

Buildings will continue to be connected to the electric grid having electricity production from traditional energy sources. It is the attempt to generate renewable energy on site quantities to offset the demand crashing the energy demand of the building to a minimum.

Full connectedness to the grid will be demonstrated as follows:

- Integrating a building with the grid to produce building energy will be reliable when the climate conditions allow (solar PV at the minimum)
- Excess electricity during such periods is fed back in to the grid employing net metering which turns back electricity meter when sending power to grid. It is conditional to have a responsive and interactive utility grid
- If excess is not available, energy will be provided by the provider.

The current technology and cost limitations associated with energy storage, the grid connection is usually necessary to enable the nearly net zero energy building

Utilities and providers are dictating the method of reverse billing for the energy exported from the building into the grid and this may impact the feasibility of generating the energy on site.

This will save on the storage of generated energy on a large scale. Load flexibility under which demand can be shifted to accommodate fluctuations in the solar supply.

4.12 Step No. 12: Ground Source Heat Pumps

If Feasible, Explore the Installation of Ground Source Heat Pumps, GSHP.

The objective of this step is to optimize the energy consumption with respect to cooling & heating generation by the use of Ground Source Heat Pumps, GSHP subject to rules and regulations where the building is located.

- Ground source heat pumps are considered to be part of the push to reach nearly net zero energy buildings, a switch from gas central heating systems to clean, low carbon options for heating offices,
- Closed loop GSHP eliminates the need of a boiler and cooling tower, their maintenance and chemical treatment required, and is much smaller unit in size and noise. Hence it is safer and more reliable.
- GHSP system consists of an exterior ground coupled heat exchanger, either in a vertical borehole, in a horizontal trench or submerged in a surface water feature; a piping system connecting the ground heat exchanger to the GSHP heat pump unit; and the thermal distribution to individual thermal zones.
- Heat is transferred to the building to warm radiators and other heating coils in winter and heat is absorbed by the unit in summer to offer cooling via a reversible heat pump system. Variable speed compressors and fans will help in improving the energy consumption.
- Upfront cost is high but more efficient than electricity heating by 300-400% and creates 70% fewer carbon dioxide emissions compared to conventional fuel boiler system.
- If renewable energy source will energize the GSHP, entire carbon emissions will be reduced to zero.

4.13 Recommended tools

AZEB | Affordable Zero Energy Buildings

The European Horizon 2020 project AZEB (Affordable Zero Energy Buildings) has created and nearly finalized the solution to make n-ZEBs affordable. The AZEB project has created the AZEB methodology for developing cost effective NZEB. Also, AZEB Learn has been launched to help professional clients, investors, project managers and other building professionals to apply the AZEB methodology and achieve affordable nearly Zero Energy Buildings step-by-step. Finally, AZEB trainer manuals have been created and AZEB train-the-trainer courses are being developed to facilitate educators in applying AZEB material in their own educational programs.

Energy in Time

Capacity Building on Energy Performance Contracting in European Markets in Transition
PREPARED by
EnPC-INTRANS

Energy IN TIME is a Large-scale integrating project within the 7th Framework Programme FP7-NMP, Sub-programme EeB.NMP.2013-4, which brings together a total of 13 partners from 8 different European countries. Energy IN TIME (EiT) project goes beyond existing building control techniques, developing an integrated control & operation approach, that will combine state of the art modelling techniques with the development of an innovative simulation-based control technique with the overarching objective of automating the generation of optimal operational plans tailored to the actual building and users' requirements.

A2PBEER

A2PBEER aimed to demonstrate that is feasible to reach current Nearly Zero Energy Buildings requirements in the existing public buildings through affordable and adaptable new technologies, through the development, demonstration and evaluation of:

- Different KITs of technological solutions
- Systemic and innovative retrofitting methodology for Public Buildings and NZEB district, and
- Demonstrated in 3 real District and 3 virtual demo-sites through evaluation of energy performance by monitoring or thermal simulations before and after being retrofitted.

NewTREND

New integrated methodology and Tools for Retrofit design towards a next generation of ENergy efficient and sustainable buildings and Districts.

Deep Renovation - New approaches to transform the renovation market!

Chapter 5: SUMMARY OF KEY nZEB FEATURES

Low hanging fruits will show the followings:

- Windows, orientation and placement
- Building color
- Window sizes
- Shading
- Daylight
- Passive solar
- Active solar
- PV

On -site Supply Options:

- Use renewable energy sources available within the building's footprint and directly connected to the building's electrical or hot/chilled water distribution system. Example Photovoltaic, solar hot water and wind located on the building
- Use renewable energy sources available at the building site and directly connected to the building's electrical or hot/chilled water distribution system. Example Photovoltaic, solar hot water, low impact hydroelectric, and wind located on parking lots, adjacent open space but not physically mounted on the building
- Use renewable energy of off-site. Example: Bio mass, wood pellets, ethanol, or biodiesel that can be imported from off-site, or collected from waste streams from on-site processes that can be used on-site to generate electricity.
- Use renewable energy by purchasing. Example: Utility-based wind, photovoltaic and emission credits.

REFERENCES AND RESOURCES

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- ⇒ Defining Nearly Zero Energy Buildings in the UAE- 2017
- ⇒ Detailed energy efficiency strategies for converting an existing office building to NZEB; a case study in the Pacific Northwest; Volume 13. Pages 1089-1104
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