DEFINING THE ZERO EMISSION BUILDINGS STANDARD FOR TUNISIA

PROJECT:

BUILD_ME

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Executive Summary

This report introduces a methodology to determine adequate requirements for Zero Emission Buildings (ZEB) in Tunisia, which are compatible to a cost optimal climate neutral energy system.

The report starts with illustrations of several international and European definitions related to zero energy buildings that consider to some extent different boundary conditions and / or targets.

Then a high-level description of the current built environment and the status of energy efficient buildings in Tunisia is presented, which shows off several instruments available to decarbonize the building sector. Though the ZEB approach is still new in the Tunisian context.

Afterwards a deep dive is illustrated on the methodology that has been utilized to determine the adapted standard of ZEB. The methodology is based on an evaluation of comparable international standards and considers the specific local conditions of countries in the Middle East and North Africa (MENA) region. With this novel methodology, calculations for typical new reference buildings in Tunisia have been performed. While considering local financial conditions, it was suggested to introduce a so called Zero Emission Ready Building (ZERB), which is on the one hand affordable, but also helps prevent possible lock-in-effects of low efficiency measures.

The identified ZERBs require thermal insulation of roofs and external walls as well as thermal insulation of the ground floor. For all ZERBs high-efficient air conditioning (AC) systems, efficient shading, and photovoltaics (PV) are recommended. The ZERBs come along with significantly lower global costs (by 8% to 13%) than the common practice for new buildings (baselines). ZERBs allow reduction of the final energy demand (electricity) by up to 87%. The required additional investment costs are typically around 35% to 45% with an expected payback period of less than 3 years.

1. INTRODUCTION

1.1 Background

Driven by the global efforts to mitigate and adapt to climate change, there has also been a growing emphasis on improving the sustainability of buildings in recent years, with a particular focus on reducing energy consumption and greenhouse gas (GHG) emissions. For example, the European Union has introduced the Energy Performance of Buildings Directive (EPBD) in 2010[1], which has set the goal for all new buildings being nearly zero energy (nZEB) by 2021. To ensure the EU's legally binding target (European Climate Law) of climate-neutral by 2050 the EPBD and the Energy Efficiency Directive (EED) have been revised in 2023/2024[2], aiming to achieve a fully decarbonized building stock in Europe by 2050.

The importance of achieving zero emission status in buildings cannot be overstated. Buildings are responsible for about 40% of the share of global energy consumption and more than 30% of carbon emissions; as such, they play a crucial role in the combat against climate change. Zero emission buildings, furthermore, improve energy security and create more comfortable and healthy indoor environments for occupants along with a multitude of other macroeconomic benefits.

1.2 Objective of this report

This report discusses the definition of a Zero Emission Buildings standard for selected countries in the MENA region, with a focus on Tunisia. These findings shall be utilized to initiate discussions on further development of national building regulations and strategies.

The standard shall ensure futureproof compatibility to climate neutral energy systems. It shall prevent lock-in effects, which may be created by too low ambitious building requirements. By considering local boundary conditions concerning climate, current economic situation, local markets, and common practices the standard is aiming for maximum practical acceptance and relevance.

[1] https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=celex%3A32010L0031

[2] Directive - EU - 2024/1275 - EN - EUR-Lex (europa.eu)

1.2.1 APPROACH

The Zero Emission Buildings Standard (ZEBS) for the MENA region, with a focus on Tunisia, developed in this study builds on existing international zero energy/emission building standards. Therefore, firstly an overview about existing definitions of zero energy/emission building standards is provided and evaluated.

Furthermore, the specific situation in the BUILD_ME target country Tunisia is examined to identify the common construction practices, existing building regulations, and the status of best practice regarding efficient buildings or –in some cases– existing zero emission buildings.

Based on the previous steps, economic and energetic calculations are performed to finally determine a technically and financially acceptable Zero Emission Building Standard.

1.3 Overview of existing definitions for zero energy/emission building standards

This subchapter reviews a selection of definitions commonly used in the context of zero-energy/emissions buildings.

1.3.1 NEARLY ZERO-ENERGY BUILDINGS (EPBD 2010/31)

Due to the meanwhile outdated regulation, "'nearly zero-energy building' means a building that has a ***very high energy performance... 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." While the regulation did not further specify the expressions "nearly zero" or "high energy performance" and furthermore required the member states to set the minimum requirements on energy performance of buildings to be at least cost optimal under consideration of capital expenditures (Capex) and operating expenses (Opex) over a calculation period of 30 years (20 years for non-residential buildings). The combination of those two requirements lead to the fact that ***from 2021 onwards nearly zero energy buildings were defined to be at least cost optimal***.

1.3.2 ZERO-EMISSION BUILDINGS (EPBD 2024/1275)

According to the revised EPBD, "A zero-emission building shall ***not cause any on-site carbon emissions from fossil fuels***. A zero-emission building shall, where economically and technically feasible, ***offer the capacity to react to external signals and adapt its energy use, generation or storage***." Moreover, the regulation requires, "Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set with a view to at ***least achieving cost-optimal levels*** and, ***where relevant, more stringent reference values*** such as nearly zero-energy building requirements and zero-emission buildings requirements."

Regarding solar energy installation the regulation states that, "Member States shall ensure the ***deployment of suitable solar energy installations***, if technically suitable and economically and functionally feasible…" Starting from 2026, for new public and non-residential buildings this solar energy obligation covers all new buildings and adjacent covered car parks and existing non-residential buildings.

1.3.3 ZERO CARBON READY BUILDINGS (INTERNATIONAL ENERGY AGENCY [IEA][3])

A 'zero-carbon-ready building' is highly energy efficient and uses either renewable energy directly or from an **energy supply that will be fully decarbonized by 2050** such as electricity or district heating. This means that ***a zero-carbon ready building will become a zero-carbon building by 2050***, without any further changes to the building or its equipment. [IEA]

1.3.4 NET-ZERO BUILDINGS (PARTNERSHIP FOR CARBON ACCOUNTING FINANCIALS [PCAF][4])

"A new or renovated net-zero building is ***highly energy efficient***, does not cause any on-site GHG emissions from fossil fuels, and ***reduces embodied carbon*** to a significant extent. It uses renewable energy, ***preferably generated on-site***, if technically feasible, and/or off-site to **fully cover** its remaining, very low energy use".

1.3.5 NET-ZERO ENERGY BUILDINGS (DEPARTMENT OFENERGY [DOE])

According to the United States (U.S.) Department of Energy (DOE)'s Building Technologies Programme, a net zero energy building (NZEB) is a building that has significantly reduced energy needs through efficiency gains and can meet the remaining energy needs with renewable sources and technologies; in other words, NZEB is a building that produces enough renewable energy to cover its own annual energy needs.

[3] Pales et al. 2021

[4] PCAF September 2022

1.3.6 NET-ZERO CARBON BUILDINGS (UNITED KINGDOM [UK] GOVERNMENT[5])

For all buildings in operation, "The amount of ***carbon emissions associated with the building's operational energy on an annual basis is zero or negative***. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset."

For new buildings and major renovations, "The ***amount of carbon emissions associated with a building's product and construction*** stages up to practical completion ***is zero or negative, through the use of offsets or the net export of on-site renewable energy***."

1.3.7 NET-ZERO CARBON BUILDINGS (WORLD GREEN BUILDING COUNCIL [WGBC][6])

The definition related to net-zero carbon buildings by World Green Building Council (WGBC) is, "***If 100% of energy demand is met by on-site renewable energy***, it can be called a net zero energy building. In reality, it may not be possible in all building types and locations. ***If renewable energy from off-site is imported to meet the balance***, it can be called ***net zero operational carbon***. In new building developments, maximum embodied carbon reductions should seek to achieve, for example by choosing to renovate existing buildings or through building material selection. If the ***remaining residual emissions from embodied carbon and any remaining fossil-fuel use within the building during the operational stage*** are compensated for, for example through the use of offsets, the building asset is ***net zero whole life carbon***."

1.3.8 DISCUSSION

There is a risk not to meet the climate goals (Paris Agreement) with too vague or ambitionless targets formulated for the building sector. Therefore, the above mentioned "net-zero" or "near-zero" definitions could lead to lock in effects and might increase the cost of decarbonization. The same issue of potential non-climate goal-compliance might occur when the buildings requirements are only determined by private perspective cost optimum calculations. Although cost optimum method can ensure that the ambitious level of the building requirements is affordable and acceptable (at least unless the political/legal framework allows for a fair distribution of additional efforts and benefits of

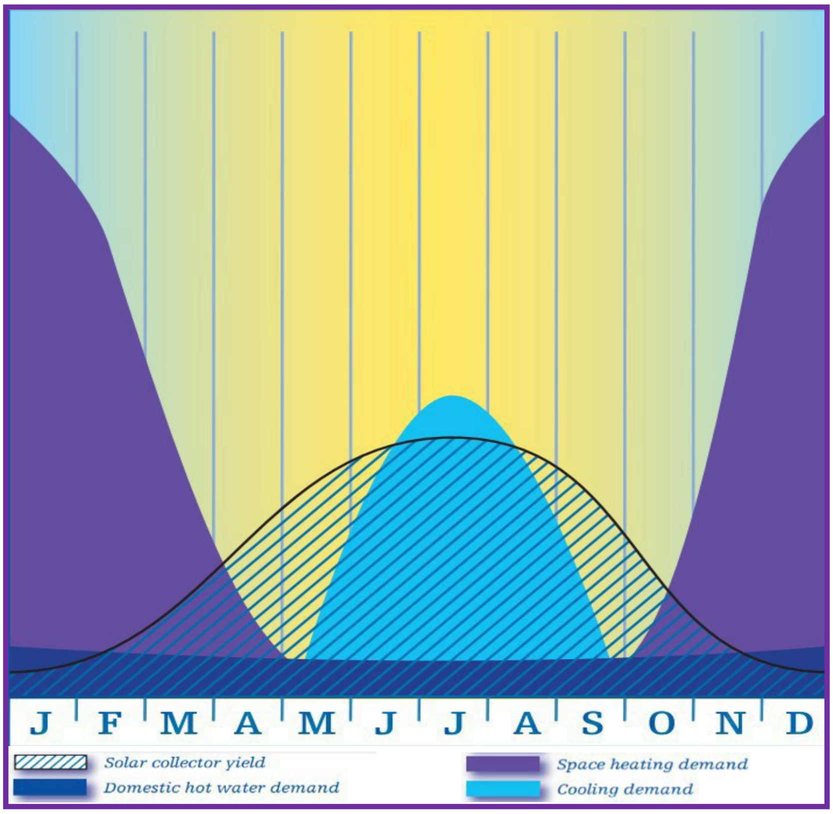
[5] UK Government 2022

[6] World Green Building Council

improved energy efficiency, which is a necessary precondition). Achieving zero-emission buildings, such as those defined by the EPBD or the IEA, involves balancing renewable energy supply (preferably on-site) with demand. This balance is crucial for aligning with a fully decarbonized energy system. The challenge of achieving zero-emissions varies by region:

1. Where there is a **higher heating demand**, countries with significant heating needs face greater challenges in achieving zero-emission buildings.
2. Where there is a **higher cooling demand**, countries with higher cooling needs, such as those in the MENA region, might achieve zero-emission buildings easier due to the high potential for electricity generation from PV and its matching with the demand.

The graphic below illustrates this concept by comparting these two scenarios of a) higher heating demand (illustrated in purple), b) higher cooling demand (illustrated in blue), c) hot water demand (illustrated in dark blue) and their potential matching with the solar energy production (striped area).



Source: European Solar Thermal Industry Federation [7]
Figure 1-1 _Solar cooling & heating system: demand & supply

[7] European Solar Thermal Industry Federation (ESTIF) 2007

Additionally, the availability of renewable energy sources like water, wind and solar differ across countries and regions, making it harder for some countries to generate the necessary clean energy to bring down the operational emissions to zero.

As a full alignment with overall climate strategies and future energy systems is very complex, simplifications are required to determine specific ZEB requirements which result to low (in optimal case lowest possible) costs for the climate neutral transition of the whole energy system.

Most zero-emissions buildings focus solely on operational emissions, neglecting the emissions generated throughout the building's entire life cycle, including construction and demolition phases. While reducing operational emissions is crucial, it is equally important to consider the environmental and climate impact across the entire lifecycle of a building – from materials production, design and manufacturing, to construction, usage, and recycling. This holistic approach is particularly vital for rapidly developing countries that may lack regulations or incentives for sustainable building practices.

Buildings with features like green roofs or rainwater harvesting systems enhance the sustainability of the built environment. These aspects are typically addressed by sustainable certification schemes such as LEED, BREEAM, or Estidama, as well as in the 'net zero whole life carbon' buildings (WCBC) and Net-zero carbon buildings (UK Government).

Although considering the carbon footprint across the lifetime of a building is essential, its determination is complex and requires significant effort to meet related requirements, especially if these requirements are not merely qualitative, such as, "preferred use of renewable materials, where applicable."

The goal of achieving climate neutral buildings requires an all-encompassing definition, robust certification schemes and regulations, while this is particularly important for developing regions to ensure technical and financial feasibility.

2. DEFINING ZEB IN MENA FOCUSING ON TUNISIA

This section presents a framework that defines ZEBs in Tunisia. The methodology used in this framework build on currently established ZEB standards for countries in the hot and warm climates of Europe. Furthermore, it builds on the analysis of the common practice and current trends in the MENA region. Additionally, it is tailored to the climate, building standards, and construction practices relevant to the country-specific context. This approach is instrumental to create a common understanding of a ZEB definition for all relevant local stakeholders. Although, the focus of the study is put on the mitigation of operational carbon dioxide (CO_2) emissions, sustainable construction with a low carbon and ecological footprint as well as the use of sustainable (natural) refrigerants should be also considered.

2.1 Current situation in the MENA region & BUILD_ME target country: Tunisia

The MENA region is facing significant challenges related to climate change, energy security, and air pollution. As such, the importance of ZEBs in this region cannot be overstated. ZEBs offer an opportunity to reduce energy consumption and greenhouse gas emissions in the building sector, which is one of the largest consumers of energy in the MENA region. Moreover, ZEBs can improve energy security and reduce dependence on fossil fuels, which are often imported and subject to price volatility.

Despite the measures taken by the governments to promote the energy efficiency in the building sector, there is still significant room for improvement. Building codes and regulations need to be updated and enforced, and awareness and education about sustainable building practices need to be increased among building professionals and the public.

While construction in the MENA region can typically be characterized as dominated by conventional practices, the region is well adapted to the use of renewable energy sources, a good starting point for the adoption of ZEBs, which are not yet widely apparent. Barriers to a more widespread uptake of the ZEB concept in the MENA region include:

- Higher initial costs,
- Alternative government priorities for the building sector,
- Social and awareness barriers,
- Not sufficient support for R&D.

2.1.1 TUNISIA

The rising energy consumption and corresponding greenhouse gas emissions are pressing global challenges. Globally, buildings account for around 30% of final energy consumption and nearly one-third of total greenhouse gas emissions[8].

In Tunisia, the energy sector is a major pillar of the economy, although it faces multifaceted challenges. According to the National Energy Balance and recent annual reports, Tunisia's energy sector has been grappling with a steadily growing energy deficit, which rose from about 2 Mtoe in 2010 to nearly 6.1 Mtoe (million tonnes of oil equivalent) in 2022—a 200% increase, with the deficit relative to demand rising from 20% to 55% between 2010 and 2023. Contributing factors include declining domestic hydrocarbon production and rising energy demand driven by population growth, urbanization, and evolving consumption patterns.

The energy sector also significantly impacts Tunisia's economy and trade. Structural challenges—such as an increasing reliance on energy imports, ballooning energy subsidies (which surged from 3,327 MTD in 2021 to 7,600 MTD in 2022, a 128.4% rise), and a worsening energy trade balance deficit that jumped from 2,505 MTD in 2016 to 8,972 MTD in 2023—exacerbate fiscal pressures. Yet, the increase in final energy consumption has not consistently translated into improved living standards, as energy intensity remains a critical concern. Although final energy consumption grew from 7,219 ktoe in 2010 to 8,166 ktoe in 2023 (an increase of 13.2%), the building sector still presents a significant opportunity. Residential and tertiary sectors, which have experienced annual consumption increases of nearly 1.9%, now offer a prime area for enhanced efficiency measures that could reduce emissions and lower energy demand.

By addressing both macro-level energy imbalances and micro-level improvements in building performance, Tunisia can work toward reducing its carbon intensity—a key objective under its

[8] Bissada, 2022

updated Nationally Determined Contribution, which aims to cut carbon intensity by 45% by 2030 compared to 2010 levels.

The previously mentioned values are depending on the local market, regarding building envelope components that are used in the Business as Usual (BaU) scenario; with their specific U-values. (see Appendix)

Building Component	Residential Buildings [W/m²K]	Non-residential buildings [W/m²K]
Roof	0.75	0.75
External wall	1.1	1.1
Ground Floor	2.2	2.2
Windows	5.7	5.7

Values

Tunisia has set ambitious GHG emissions cutting targets. The country is now committed to reducing its carbon intensity by 45% by 2030, compared to an initial target of 41%, using 2010 as the reference year.

Tunisia has also set ambitious renewable energy targets as part of its National Energy Strategy to 2035. The strategy envisions increasing the share of renewable energy in the electricity mix to 35% by 2030 and 50% by 2035. Initiatives are underway to expand solar photovoltaic and wind power capacities, alongside investments in smart grid infrastructure and energy storage solutions to enhance grid reliability and facilitate a sustainable energy transition.

In response to rising energy consumption and environmental concerns, Tunisia has developed several building energy efficiency standards and codes designed to improve the performance of new and existing constructions. The Tunisian Thermal Regulation for new buildings sets minimum performance requirements for building envelope components to enhance indoor comfort and reduce energy use. Complementary measures include mandatory energy audits for high-consuming existing buildings, on-plan energy audits for high-consuming new building projects, as well as minimum energy performance standards (MEPS) and energy labelling for household appliances [9]. These regulatory frameworks are supported by initiatives such as the PROMOISOL programme for roof insulation, the PROSOL Thermal and PROSOL ELEC programs for solar energy integration, and the voluntary écoBAT label, which collectively aim to drive the market toward higher energy performance. Ongoing efforts by the Ministry of Industry, Mines and Energy, along with the National Agency for Energy Management (ANME), include training programs, pilot projects, and the establishment of dedicated committees to strengthen code enforcement and support industry compliance.

[9] MIME (2023b).

Recognizing the significant potential of the building sector to curb energy consumption and reduce greenhouse gas emissions, Tunisia is increasingly embracing the concept of Net Zero Energy Buildings (NZEB). Emerging studies indicate that retrofitting existing buildings—by upgrading insulation, replacing inefficient glazing and lighting fixtures, and integrating on-site renewable energy systems such as photovoltaic installations—can markedly reduce energy use. Such measures are vital for meeting Tunisia's Nationally Determined Contribution, which targets a 45% reduction in carbon intensity by 2030 relative to 2010 levels[10]. However, despite promising pilot projects and supportive policies, further efforts in awareness, capacity building, and financial incentives are needed to mainstream NZEB practices across both new constructions and retrofits.

Recent studies have demonstrated that the potential for transforming the building stock in Tunisia into net-zero energy buildings (NZEBs) is promising when both passive and active strategies are integrated. For example, design optimization approaches using genetic algorithms have revealed that retrofitting typical residential buildings with advanced insulation (with an optimum wall insulation thickness of approximately 10 cm) and improved glazing systems can reduce annual energy consumption by up to 50% compared to conventional practices[11].

Complementing these passive measures, the incorporation of renewable energy systems—particularly rooftop photovoltaic (PV) installations—has been shown to further offset the remaining energy demand. In one techno-economic analysis, a rooftop PV system integrated with building energy management strategies resulted in substantial reductions in both CO_2 emissions and utility costs, making NZEBs economically viable in regions with high solar irradiance such as Tunisia[12].

[10] République Tunisienne (2021).

[11] Daouas, 2011

[12] Ihm, P., and Krarti, M. (October 17, 2013). "Design Optimization of Energy Efficient Office Buildings in Tunisia.

2.1.2 EXAMPLES OF HIGH ENERGY PERFORMANT BUILDINGS IN TUNISIA

PROJECT INFO: HQ building of ENDA tamweel

CONSTRUCTION PHASE	New construction
DETAILED BUILDING TYPE	Office Building
NET FLOOR AREA	2917 m^2
STORIES	5 Stories
CONSTRUCTION YEAR	2011

PROJECT TEAM	
DEVELOPER(S)/OWNER(S)	Enda Inter-Arabe
ARCHITECT(S)	TASMIM Architecture et Aménagement

TECHNICAL PARAMETERS	
BUILDING ENVELOPE	• External walls U-value: 0.29 W/(m^2·K). • Roof U-value: 1.13 W/(m^2·K). • Bay windows Overall U-Value window: 3.1 W/(m^2·K). • Basement floor: U-Value: 2.192 W/(m^2·K). • Shading devices: Fixed horizontal and vertical metal-based shading
HEATING, VENTILATION & AIRCONDITIONING	• Free ventilation (through operable windows). • Space cooling and heating: VRF reversible air-to-air heat pumps with fan coil units. Efficiency: EER 4.2
LIGHTING	• LFL and CFL with presence sensors
ON-SITE RENEWABLE ENERGY	• None

RESULTS	
TOTAL SPECIFICFINAL ENERGY DEMAND	82 kWh/m^2·year
PROJECT CONSTURCTION COST	N/A

Table 2-2 / Figure 2-2

PROJECT INFO: Energy renovation of Taieb Al-Mhiri House

CONSTRUCTION PHASE	Refurbishment
DETAILED BUILDING TYPE	Single Family House (SFH)
NET FLOOR AREA	211 m^2
STORIES	2 Stories
CONSTRUCTION YEAR	1990

PROJECT TEAM

DEVELOPER(S)/OWNER(S)	Municipality of Sfax
ARCHITECT(S)	Mr. Mohamed Sadok Bouallègue

TECHNICAL PARAMETERS

BUILDING ENVELOPE	• External walls U-value: 0.497 W/(m^2·K). • Roof U-value: 0.654 W/(m^2·K). • Windows Overall U-Value window: 2.56 W/(m^2·K). • Basement floor: U-Value: 2.192 W/(m^2·K). • Shading devices: Fixed vertical shading
HEATING, VENTILATION & AIRCONDITIONING	• Free ventilation (through operable windows). • Space cooling and heating: Wall-mounted single-split air conditioning system with an energy efficiency ratio (EER) of 3.40 and a coefficient of performance (COP) of 3.82. • Solar water heater on the roof
LIGHTING	• Lighting system: 5 W LED lamps with a luminous efficiency of 80 lum/W.
ON-SITE RENEWABLE ENERGY	• 2 kWp low-voltage grid-connected PV system.

RESULTS

TOTAL SPECIFIC FINAL ENERGY DEMAND	30.4 kWh/m^2·year
PROJECT CONSTURCTION COST	N/A

Table 2-3 / Figure 2-3

2.2 Methodology

The aim of the methodology is to identify Zero Emission Building (ZEB) requirements adapted to MENA countries, which are financially and technically acceptable as well as futureproof and in line with climate neutral energy systems. As the usage type of a building has a relevant impact, specific requirements for residential and non-residential buildings should be determined. The following figure provides and overview about the three-step approach:

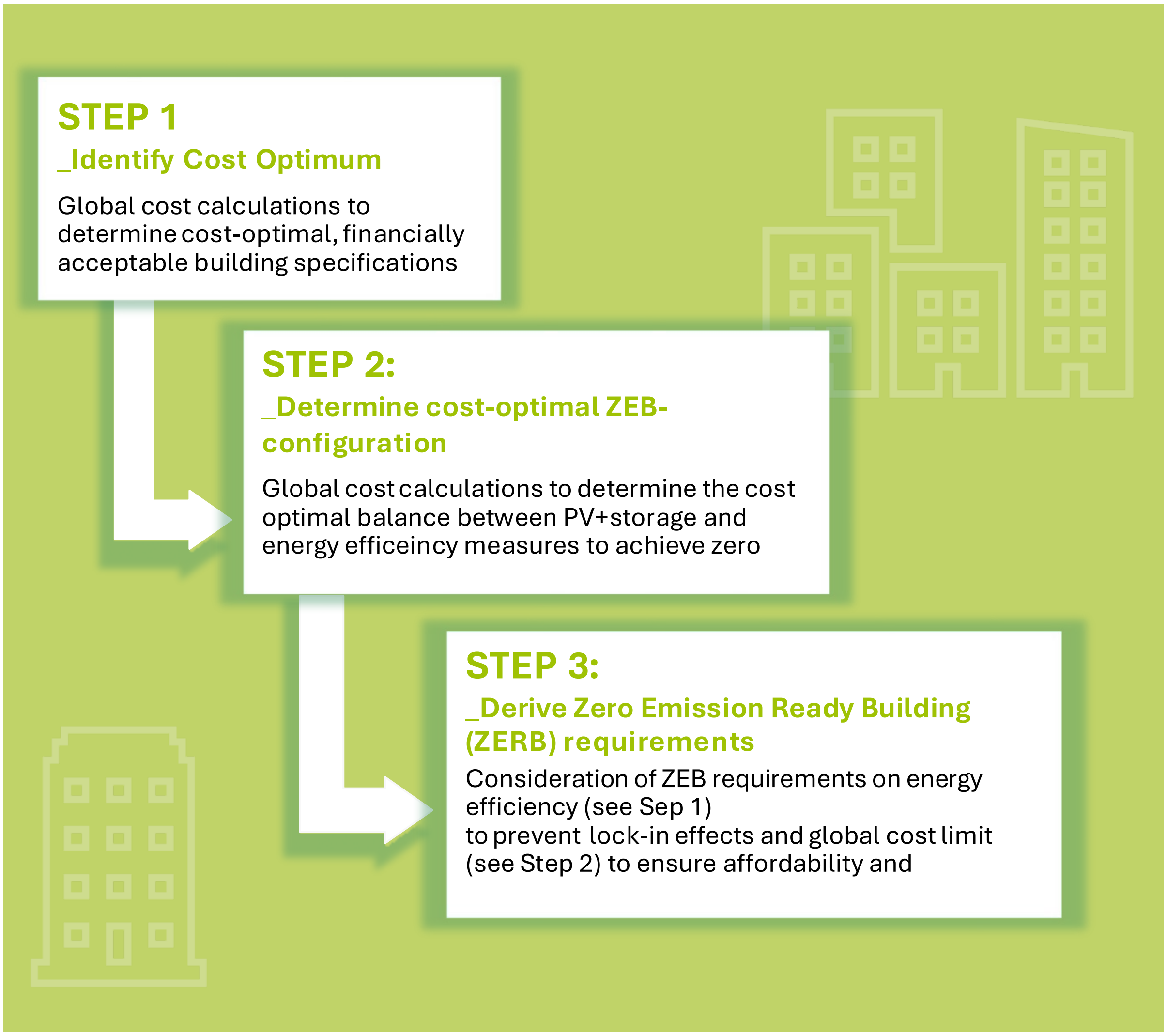


Figure 2-4 _Methodology to identify Zero Emission Building (ZEB) requirements adapted to MENA countries.

The starting point for the determination of ZEB requirements of the MENA countries is the identification of cost optimal building specifications. For that purpose, a calculation of global cost[13]

[13] For global cost calculation the EPBD method is used

(capital value) should be performed. For determining the capital value, in addition to the investment costs, the energy, maintenance and repair costs as well as the costs for replacement measures and residual values after the end of the period under review (20 years [14]) are taken into account. The calculation is based on real costs and prices for the reference year 2024. The related energy calculations are performed with the Building Energy Performance (BEP) tool[15]. The BEP model utilizes a calculation engine based on the ISO 52016, calculating the annual energy demands with an hourly resolution based on local reference climate data. This step shall provide arguments for the financial acceptance of highly efficient buildings. The most relevant KPI (Key Performance Indicator) for energy is the final energy demand. As ZEBs, by definition, should not use fossil fuels, all reference buildings are considered as "all electric" buildings. To determine the cost optimality (CostOpt), firstly, the cost-optimum without PV is identified. Based on the variant different sizes of PV are considered, to determine the cost optimal PV size. For PV only the directly usable onsite produced electricity is accounted to reduce the final energy demand (no net metering considered to reduce the final energy demand). Although in all countries a net metering bonification is in place[16].

In a second step, the requirements for alignment with a climate neutral energy system is determined. As country specific energy system projections are not available, and even if, a consideration of those would be too complex, a simplified approach needs to be chosen.

The baseline of the simplified approach is the assumption of completely electrified buildings without the utilization onsite fossil fuels for heating, domestic hot water and AC.
That required for Tunisia with typically fossil heaters- to consider an adapted baseline (baseline-el).

The second assumption is that the cheapest option of renewable electricity supply[17] for buildings in the MENA region will predominantly be PV. As of the climate conditions, different from northern regions, PV is available all year around in the MENA region. Furthermore, at hot climate highest shares of energy demand are typically required for cooling demand, which matches good with the PV yields.

To fully match PV supply with the building related demand (HVAC + lighting and DHW) controls and storages are required. That leads to the third simplification assumption: Batteries are considered as

[14] 30 years, as according to the EPBD for residential building in de EU seem to be too long for the MENA region.

[15] https://www.buildings-mena.com/info/building-energy-performance-tool

[16] Although only building-related final energy demand is considered, the cost calculations also include the financial benefits of PV for appliances (sometimes resulting in negative energy costs).

[17] Other renewable energy sources, e.g. solar thermal, biomass or renewable district heating are surely also valid alternative options for a renewable supply of Zero Emission Buildings.

storage-option. As in case of PV also battery prices have decreased significantly within the last years. Other than in some cases surely cheaper option of thermal storages (e.g. ice storages), batteries are more universal and flexible.

Based on these three assumptions, the cost optimal configuration necessary to achieve a climate neutral (energy self-sufficient) ZEB building is determined. Parameters for the different options to achieve climate neutrality are energy efficiency (specifically different u-values) and different theoretical[18] required sizes of PV and batteries. Therefore, this method determines the cost-optimal balance between measures to reduce the electricity consumption and efforts for fully renewable energy supply[19].

The calculations are performed for typical residential and non-residential buildings, specifically office buildings.

Due to the beforementioned simplifications (e.g. only considering PV) and the uncertainties of the price development of PV and Batteries, this approach can only be an approximate for the cost-optimal balance and the efficiency requirements[20] derived. But at least, does this approach consider the real issue of balancing demand and renewable supply.

Under current circumstances in Tunisia—where electricity prices for buildings are subsidized, net metering applies to PV systems for residential and non-residential buildings connected to the low-voltage grid, and net billing applies to PV systems for non-residential buildings connected to the medium-voltage grid—the installation of energy storage-based solutions (batteries) for demand management, particularly with PV under net metering regulation, and in some cases even onsite (rooftop) PV under net billing regulation, is not financially attractive. Therefore, we suggested to require the so-called “Zero Emission Ready Buildings” (ZERB). ZERBs only require measures, which are financially and technically acceptable under the current local circumstances. Specifically, that means regarding controls and storages a provision of specific space for a potential later installation is sufficient. Furthermore, requirements for PV should take into consideration besides the financial aspects (see Step 1) also potential technical limitations as the available roof space[21].

[18] As it is so far just a theoretical exercise, potential limitations of roof space are not considered for Step 2.

[19] At this step no current net metering subsidies are considered as those would distort the results

[20] Under consideration of county specific constructions and prices

[21] The roof space limitation of the PV capacity is determined by the assumption of 5 m^2/KWp and the assumption that 50 % of the roof space can be used for PV

If PV under current circumstances would not be attractive, it would be sufficient to prepare for a later installation (enable roof statics, reserve space for the inverters and empty tubes from roof to potential inverter locations). In that case only the determined efficiency requirements need to be fulfilled, as lower requirements would lead to lock-in effects.

2.3 Analysis and Results

The following subchapters illustrate the boundary conditions and results of the ZEB analysis for Tunisia.

2.3.1 GENERAL BOUNDARY CONDITIONS

The following parameters were considered.

The specified investment prices are in Euro (year 2024) for comparison reasons, but also to eliminate the effect of the partly high inflation rates in the country. If prices would be specified in local currency that would require a more accurate time definition of prices and lead to higher risk of misinterpretation.

Discount rate:

The discount rate (DR) considers the effect of real price development on future investments and earnings. It is depending on the inflation rate (IFR) and the interest rate (ITR). It is determined by the following equation:

DR = (1+ITR)/(1+IFR)-1

With high average annual inflation rates over the past 10 years (5.7%[22]) but also high corresponding average interest rates (10% [23]), that would lead to theoretic annual discount rates of 4%.

As conservative assumption (considering the existing barriers and the lack of general understanding on benefits of energy efficiency and carbon reduction measures) a uniform ***discount rate*** of ***4 %*** is considered.

Lifetimes:	
Building envelope components (roof/walls/floor/windows)	**30 a**
HVAC/movable shading elements/ PV	**20 a**
Batteries	**10 a**
Internal temperature setpoints (no night set back considered):	
▪ **Heating:**	**20 °C**
▪ **Cooling:**	**26 °C**

Table 2-4 _Lifetimes and internal temperature setpoints

2.3.2 GENERAL REMARKS

Although the focus of this study is on CO_2-mitigation, results-figures indicate "final energy". This -on the first sight not obvious parameter- was chosen as the emission factor of final energy (for ZEB in this study = electricity) is variable by time and dependent from load profiles. Due the methodology for the ZEB, we consider the grid-demand interaction by determination of the required renewable capacity and storage need to reduce the energy demand to zero, which consequently results in zero CO_2-emissions.

For the global cost calculation of the cost-optimal zero emission (= zero final energy demand) variants (see methodology, Step 2) the average u-value of the building shell was selected as parameter for the x-axis. Alternatively, it would have been also possible to use the related necessary PV and battery sizes to reduce the final energy demand to zero.

The reason why there are variants with different global cost for one average u-value is because the variants also consider other efficiency measures like improvement of shading and AC system efficiency.

[22] https://www.focus-economics.com/country-indicator/tunisia/inflation/

[23] average between 2013 and 2019

2.3.3 TUNISIA

2.3.3.1 Boundary conditions

Climate

The analysis for Tunisia were based on Tunis as the reference climate, as it is supposed to be the most relevant city in Tunisia in terms of construction activity and population.

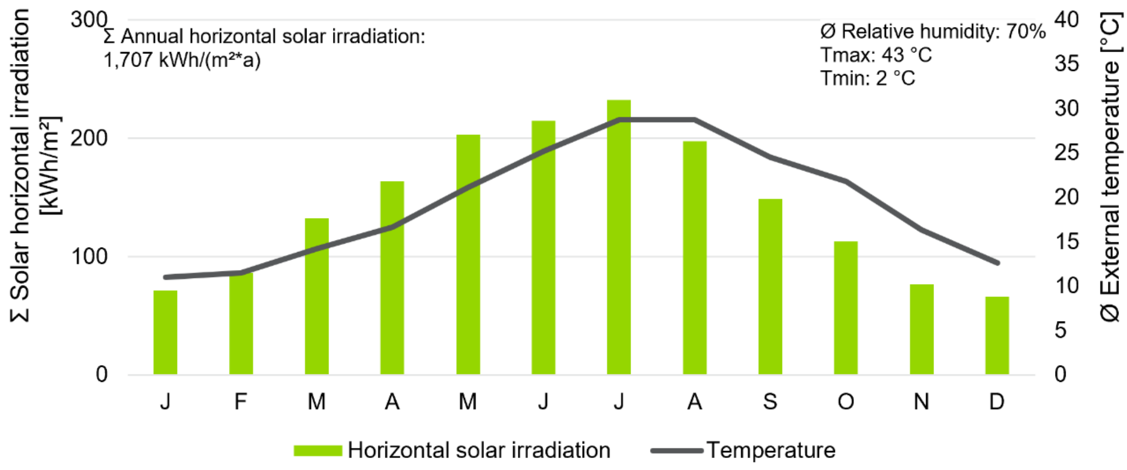


Figure 2-5 _Climate diagram of Tunis (data source: Meteonorm)

The climate in Tunis is primarily hot and reaches an average humidity rate of 70%. External temperatures range from above 2°C to 43°C with average temperatures around 20°C.

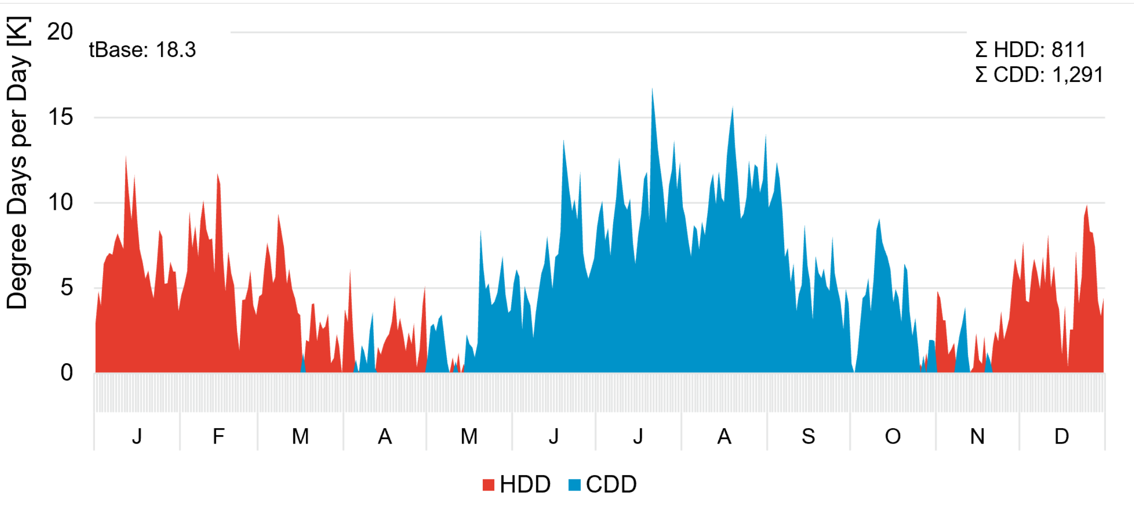


Figure 2-6 _Heating- and cooling degree days of Tunis (data source: Meteonorm)

The number (>1,291 Kd) of cooling degree days is high, but heating degree days is much less at (811Kd).

The amount of cooling degree days is higher than the heating degree days. Therefore, major share of the energy demand accumulates for cooling.

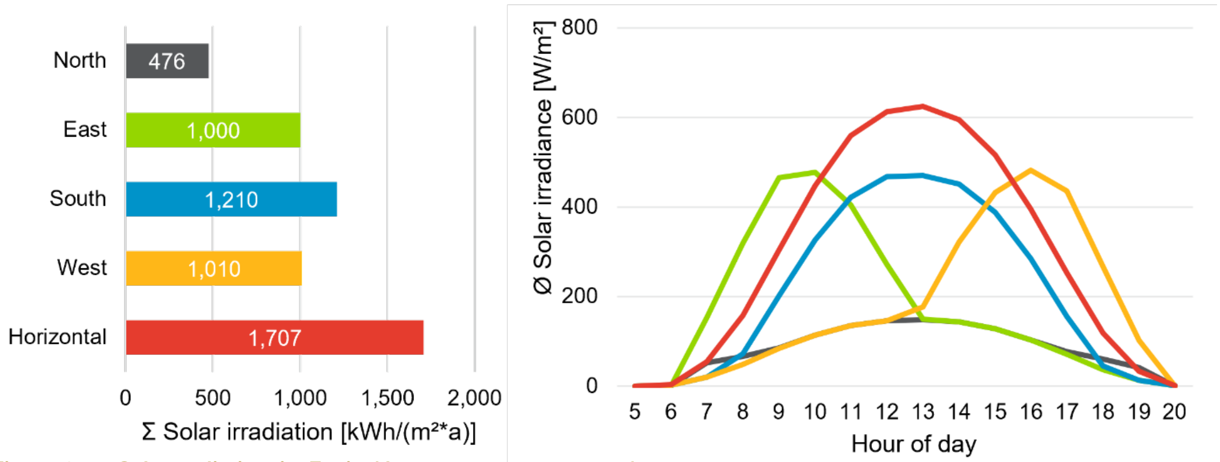


Figure 2-7 _Solar radiation in Tunis (data source: meteonorm)

There is a high horizontal irradiation of > 1,700 $kWh/(m^2*a)$ and >=1,000 $kWh/(m^2*a)$ for East, South and West orientation.

Because of that, Tunis has big potentials for energy generation through solar radiation, solar water heaters, PVs and solar cooling.

Buildings	Multi Family House	Office Building
Net floor area	1,440	1,824
Roof area	240	190
Opaque wall area	1,653	974.79
Window area	223.68	133.37
Ground floor area	240	190
AC – System	Single-split units	Central - fan coil distribution
DHW System	Dedicated gas heater	—
Lighting System	Compact fluorescent lamps (CFL)	Linear fluorescent lamps (LFL)
Internal Loads (average)	3.5 W/m^2	3 W/m^2
Ventilation	—	—
Ventilation Rate (including infiltration)	—	—

Table 2-5 _Key specifications

Variants

The configuration of the baseline variant as well as types and ranges of parameters considered for cost optimality calculations are listed in the following tables.

Building	Multi Family House			Office Building		
U-Values [W/m²K]	Wall	Roof	Floor	Wall	Roof	Floor
Baseline	1.1	0.75	2.2	1.1	0.75	2.2
Variant ranges	0.1 - 0.8	0.1 – 0.65	0.1 - 2	0.1 - 0.8	0.1 – 0.65	0.1 – 1.5
Windows						
Baseline	Single glazing (u_w = 5.7 W/m²K; SHCG = 0.85)			Single glazing (uw = 5.7 W/m2K; SHCG = 0.85)		
Variants	▪ Single glazing (uw = 5.7 W/m2K; SHCG = 0.85) ▪ Double glazing Air (u_w = 3 W/m2K; SHCG = 0.7) ▪ Double glazing Argon (u_w = 2.6 W/m2K; SHCG = 0.7) ▪ Double glazing lowE (u_w = 1.5 W/m2K; SHCG = 0.7) ▪ Double glazing solar (u_w = 1.5 W/m2K; SHCG = 0.3) ▪ Double glazing lowE Argon (u_w = 1.1 W/m2K; SHCG = 0.7)			▪ Single glazing (uw = 5.7 W/m2K; SHCG = 0.85) ▪ Double glazing Air (u_w = 3 W/m2K; SHCG = 0.7) ▪ Double glazing Argon (u_w = 2.6 W/m2K; SHCG = 0.7) ▪ Double glazing lowE (u_w = 1.5 W/m2K; SHCG = 0.7) ▪ Double glazing solar (u_w = 1.5 W/m2K; SHCG = 0.3) ▪ Double glazing lowE Argon (u_w = 1.1 W/m2K; SHCG = 0.7)		
Shading						
Baseline	—			Movable Manual Shading		
Variants	▪ Movable Manual Shading ▪ Fixed Shading ▪ Automatic Shading			▪ Movable Manual Shading ▪ Fixed Shading ▪ Automatic Shading		
Ventilation						
Baseline	—			Mechanical without heat recovery		
Variants	—			▪ Mechanical without heat recovery ▪ Mechanical 70 % heat recovery ▪ Mechanical 90 % heat recovery		
Heating and AC Systems						
Baseline	Low standard efficiency			Low standard efficiency		
Variants	▪ Low standard efficiency ▪ Improved efficiency ▪ High efficiency			▪ Low standard efficiency ▪ Improved efficiency ▪ High efficiency		
PV Capacity (kWp)						
Baseline	0			0		
Variants	0 – 150			0 – 200		
Battery Capacity (kWh)						
Baseline	0			0		
Variants	70 – 175			70 – 150		

Table 2-6 _Baseline configuration and considered parameter variations of the Multi Family House and the Office Building.

Investment costs

Annual price increase (for replacement costs)	1.5 %
Standard construction costs	
Multi Family House	850 €/m^2
Office Building	1160 €/m^2
Insulation (Roof/Wall/Ground Floor)	6 € +1.25 €/cm | 16 € + 2.75 €/cm | 19 € + 3 €/cm
Windows	
Single glazing (uw = 5.7 W/m2K; SHCG = 0.85)	142 €
Double glazing Air (uw = 3 W/m2K; SHCG = 0.7)	187 €
Double glazing Argon (uw = 2.6 W/m2K; SHCG = 0.7)	199 €
Double glazing lowE (uw = 1.5 W/m2K; SHCG = 0.7)	236 €
Double glazing solar (uw = 1.5 W/m2K; SHCG = 0.3)	275 €
Double glazing lowE Argon (uw = 1.1 W/m2K; SHCG = 0.7)	248 €
Shading	
Fix shading elements	157 €
Manual movable shading	236 €
Automatic movable shading	346 €
Ventilation System (office building)	
Mechanical without heat recovery	0.72 €/m^{2}floor area
Mechanical with heat recovery (70 %)	2.01 €/m^{2}floor area
Mechanical with heat recovery (90 %)	2.66 €/m^{2}floor area
AC System (costs derived from equation: $a * x^2 + b * x + c$ with x = design capacity in kW)	
Standard efficiency – Central Chiller System	a = 0 b = 471.20 c = 6,322.10
Standard efficiency – Single split units (EER= 3.3)	a = 0 b = 213.20 c = 18.25
High efficiency – Central Chiller System	Standard Cost + 30%
High efficiency – Single split units (EER = 5.6)	Standard Cost + 30%
PV	110 € + 943 €/kWp
Battery	700 €/kWh
Electricity price	**0.11 €/kWh** (3 % annual increase)
PV feed in tariff [24]	**0.04 €/kWh**

Table 2-7 _Investment Costs

[24] Bonification up to 30% of the total annual surplus electricty; beyond: no bonification

2.3.3.2 Results

The following chapter contains the results of the energy- and global cost calculations to determine the cost optimal configuration (see methodology, Step 1), to identify the cost-optimal ZEB specifications (see methodology, Step 2) and derive country specific zero-emission-ready building (ZERB) requirements (see methodology, Step 3) for the two beforementioned reference building types.

New multifamily house

Step 1: Identification of Cost Optimum

Starting from the baseline variant (upper right corner of following figure) adding efficiency measures, like improved thermal insulation of roof, walls and floor, double glazed windows with solar coating and high-efficient HVAC systems leads to reduction of global costs. The reduced Opex of the variants overweighs the higher Capex. The cost optimum without PV is reached at a final energy demand about 22.5 kWh/m^{2}a. While the baseline variant results in global costs of about 990 €/m^2, the global costs of the cost optimum variant are well below 885 €/m^2, a reduction of more than 11 %. With a net metering bonification for PV in place in Tunisia, adding PV is further reducing the global costs to approximately 857 €/m^2, which means a reduction of more than 13% from global costs of the baseline variant, which makes this variant our cost optimum variant.

Under the assumption of an acceptable global cost increase allowance of just 1 % (see “Range Cost Opt” in the following figure), PV can be considered as a recommended option as it contributes to a significant reduction in final energy down to 13.8 kWh/m^{2}a and with that also a significant reduction of CO_2 emissions.

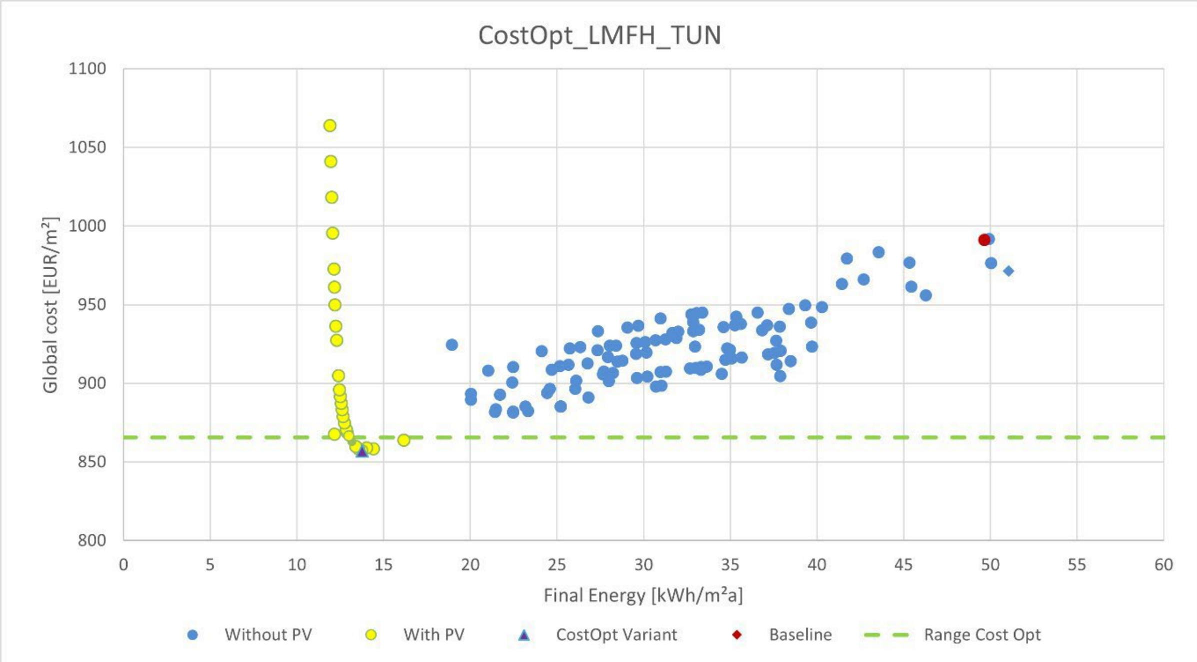


Figure 2-8 _Global cost calculations for identification of the acceptable global cost limit (Step 1)

The key specifications of the cost-optimal variant (see Appendix):

Roof and walls:	u=0.30 W/m^{2}K (=> 8 cm insulation)
Ground floor:	u=0.60 W/m^{2}K (=> 4 cm insulation)
Windows:	Double glazed with solar coating (u=1.5 W/m^{2}K; SHCG=0.3)
AC:	High efficiency split units (EER=5.6)
Shading:	Fixed shading elements
PV:	20 W/m$^2_{\text{net floor area}}$

Step 2: Determination the cost optimal ZEB-specifications

As of the current net metering regulation, an additional consideration of a battery is currently financially not feasible in Tunisia. That is the main reason why the global costs of cost optimal configuration necessary to achieve a climate neutral (energy self-sufficient) building comparingly are high, although still lower than the baseline.

The cost optimal ZEB is reached by a variant with a highly efficient AC system, a fixed shading and an average u-value of 0.3 W/m^{2}K.

The key specifications of the ZEB variant:

Roof and walls:	u=0.10 W/m^{2}K (=> 30 cm insulation)
Ground floor:	u=0.45 W/m^{2}K (=> 6 cm insulation)
Windows:	double glazed with solar coating (u=1.5 W/m^{2}K; SHCG=0.3)
AC:	high efficiency split units
Shading:	Fixed shading elements
PV:	25 W/m$^2_{\text{net floor area}}$
Battery capacity:	57 Wh/m$^2_{\text{net floor area}}$

It should be mentioned that the global costs of the ZEB (with almost no energy costs) is only 5% less than the global costs of the baseline variant.

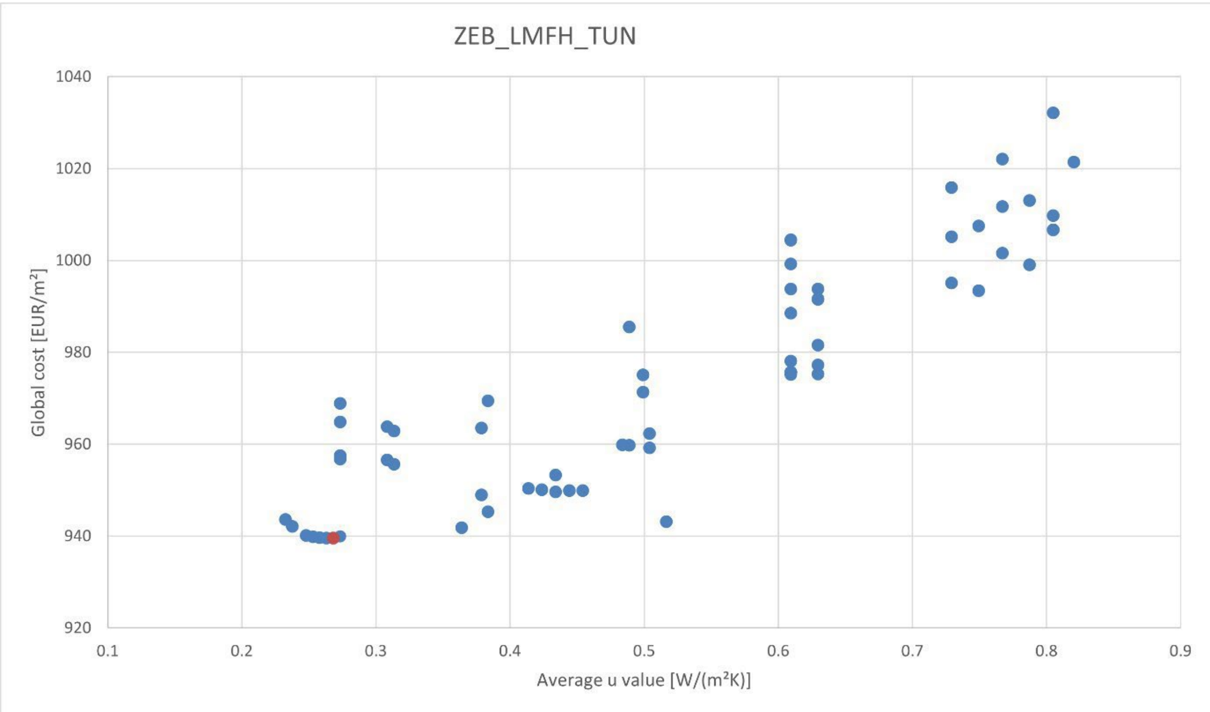


Figure 2-9 _Global cost calculations to determine the cost optimal ZEB-specifications (Step 2).

Step 3: Identification of Zero Emission Ready Building (ZERB) requirements

STEP 3

Based on the identified cost-optimal ZEB requirements the recommended ZERB is considering efficiency measures and PV of ZEB but without battery. With that, it comes along with only 1.2 % higher global costs than the cost optimum but with 13 % lower global costs than the baseline (common practice). The remaining final energy need of 12 kWh/m^2 is about 4-times smaller than baseline.

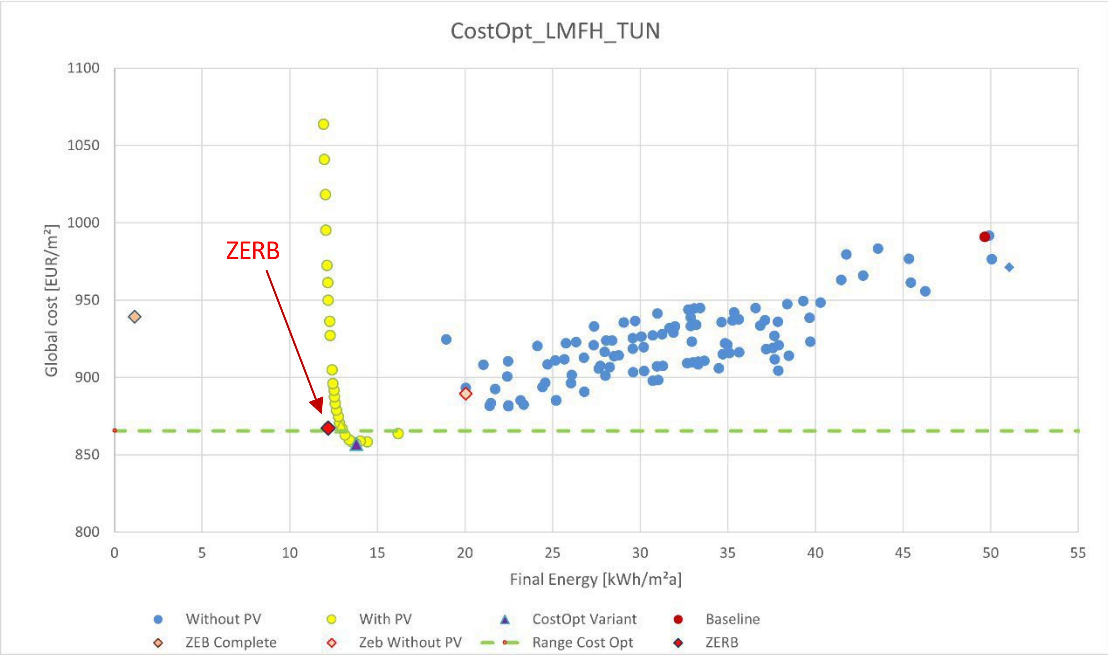


Figure 2-10 _Identification of recommended Zero Emission Ready Building (ZERB)

The key specifications of the ZERB-variant (see Appendix):

Roof and walls:	u=0.10 W/m^{2}K (=> 30 cm insulation)
Ground floor:	u=0.45 W/m^{2}K (=> 6 cm insulation)
Windows:	double glazed with solar coating (u=1.5 W/m^{2}K; SHCG=0.3)
AC:	high efficiency split units (EER=5.6)
Shading:	Fixed shading elements
PV:	17 W/m$^2_{\text{net floor area}}$
Battery:	no, just reservation of sufficient space for later installation

The following figure provides the split of different components of the global costs for the most relevant variants:

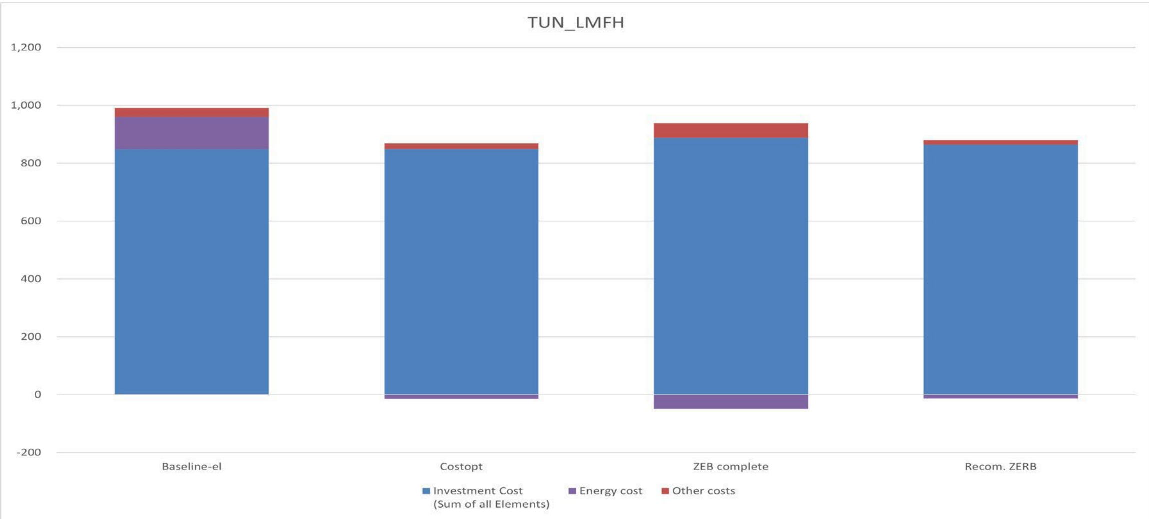


Figure 2-11 _Global cost comparison most relevant variants, including baseline and the recommended ZERB

The required 34 % higher initial investment costs of the recommended ZERB compared to Baseline will be paid back by the reduced OPEX in less than three years.

Remark: the negative energy costs of ZEB complete and recommended ZERB result from the consideration of the current net metering subsidy. PV surplus electricity can cover parts of household electricity, which is considered as reduction to the building related energy costs.

New Non-Residential Building

Step 1: Identification of Cost Optimum

The cost optimum for an office building is reached at a final energy demand of 4.25 kWh/m^{2}a. While the baseline variant results in global costs of about 1285 €/m^2, the global costs of the cost optimum variant are only 1134 €/m^2, a reduction of nearly 11 %. Adding PV is reducing the global costs and therefore, relevant for the cost optimal variant. Because of the net metering subsidy, the cost optimal size of PV is reached when the produced PV equals the total electricity demand of the building.

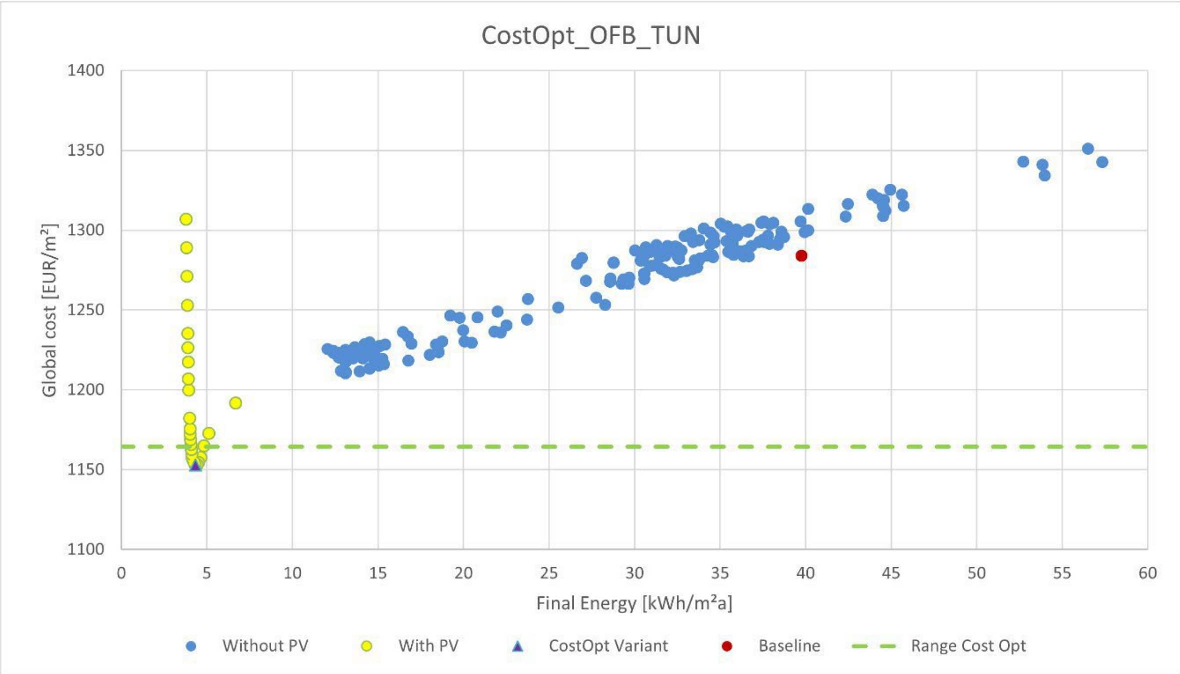


Figure 2-11 _Global cost calculations for identification of the acceptable global cost limit (Step 1)

The key specifications of the cost-optimal variant (see Appendix):

Walls:	u=0.15 W/m^{2}K (=> 20 cm insulation)
Roof:	u=0.30 W/m^{2}K (=> 7 cm insulation)
Ground floor:	u=0.50 W/m^{2}K (=> 6 cm insulation)
Windows:	Double glazed with solar coating (u=1.5 W/m^{2}K; SHCG=0.3)
AC:	High efficiency chiller system
PV:	33 W/m$^2_{\text{net floor area}}$

Step 2: Determination the cost optimal ZEB-specifications

The cost optimal ZEB is reached by a variant with a highly efficient central chiller system, a fixed shading and an average u-value of 0.4 W/m^{2}K.

The key specifications of the ZEB variant:

Walls:	u=0.25 W/m^{2}K (=> 11 cm insulation)
Roof:	u=0.15 W/m^{2}K (=> 20 cm insulation)
Ground floor:	u=0.50 W/m^{2}K (=> 6 cm insulation)
Windows:	Double glazed (u=1.5 W/m^{2}K; SHCG=0.7)
AC:	High efficiency central chiller system

Shading: Fixed shading elements

PV: $17\ W/m^2_{\text{net floor area}}$

Battery capacity: $40\ Wh/m^2_{\text{net floor area}}$

The required PV size for the ZEB is even lower than the PV size of the cost optimum.

Furthermore, it should be mentioned that the global costs of the ZEB (with almost no energy costs) are lower than the global costs of baseline variant.

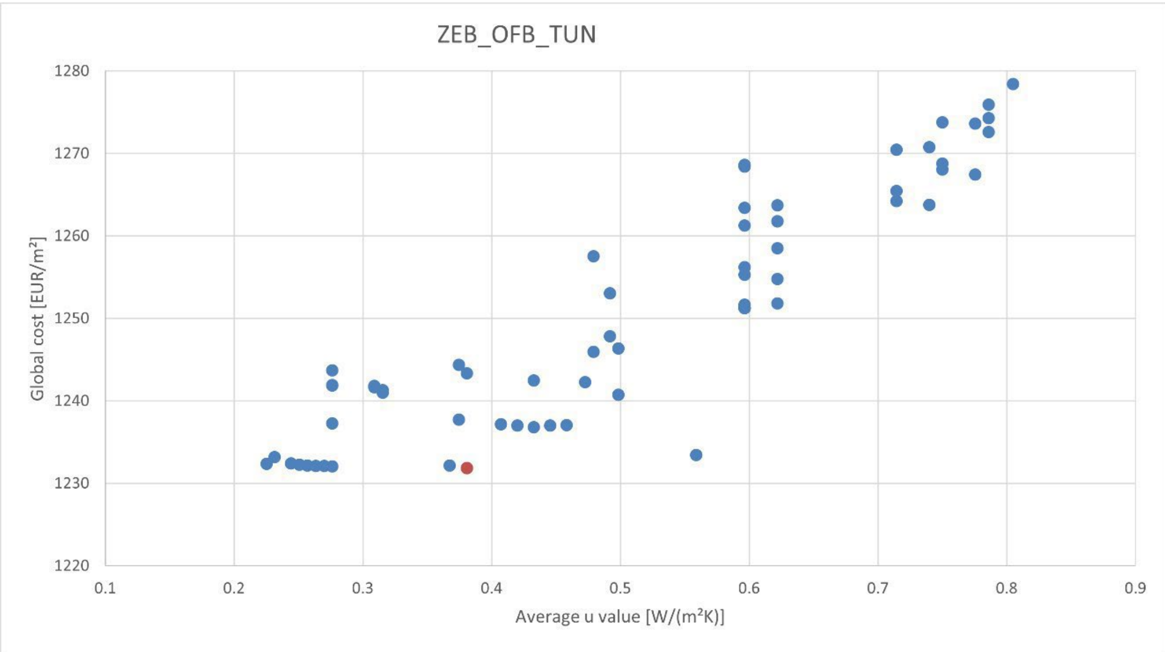


Figure 2-12 _Global costs calculations to determine the cost optimal ZEB-specifications (Step 2).

Step 3: Identification of Zero Emission Ready Building (ZERB) requirements

The recommended ZERB takes into account the efficiency measures of ZEB package, but without the utilization of a battery. Without consideration of space limitation for PV, the non-residential ZERB in Tunisia should require $17\ W/m^2_{\text{net floor area}}$ PV. Under consideration to limit the PV to the available roof space of the reference office building[25], only $10\ W/m^2_{\text{net floor area}}$ PV should be required, although that would not fully

[25] Roof space: 190 m^2; required PV under consideration of roof space limitations 19 kWp.

cover the electricity demand. The ZERB with consideration of roof space limitation has 3.7% higher global costs than the cost optimum, but still 8 % lower global costs than the baseline (common practice). The remaining final energy need of 5 kWh/m^2 is about 8-times smaller than baseline.

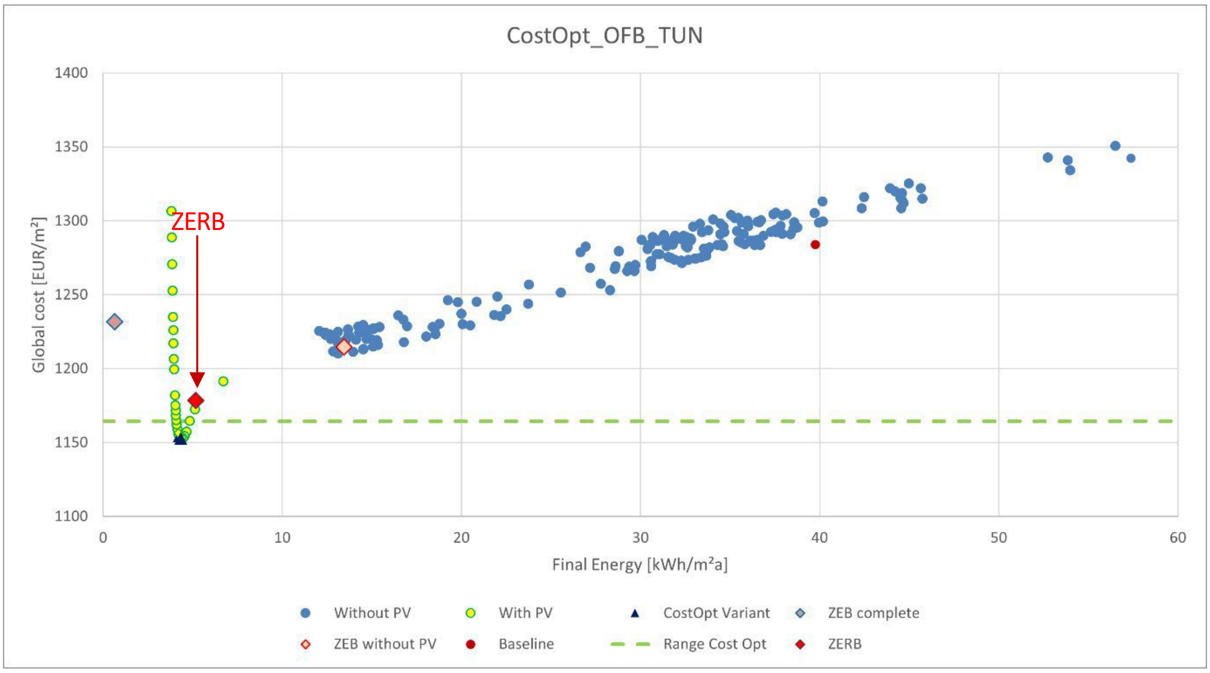


Figure 2-13 _Identification of recommended Zero Emission Ready Building (ZERB)

The key specifications of the ZERB-variant (see Appendix):

Walls:	u=0.25 W/m^{2}K (=> 11 cm insulation)
Roof:	u=0.15 W/m^{2}K (=> 20 cm insulation)
Ground floor:	u=0.50 W/m^{2}K (=> 6 cm insulation)
Windows:	Double glazed with (u=1.5 W/m^{2}K; SHCG=0.7)
AC:	High-efficient central chiller system
Shading:	Fixed shading elements
PV:	10 W/m$^2_{\text{net floor area}}$ with consideration of roof space limitation ≥ 17 W/m$^2_{\text{net floor area}}$ without roof space limitation
Battery:	no, just reservation of sufficient space for later installation

The following figure provides a split indicating different components of the global costs of the most relevant variants:

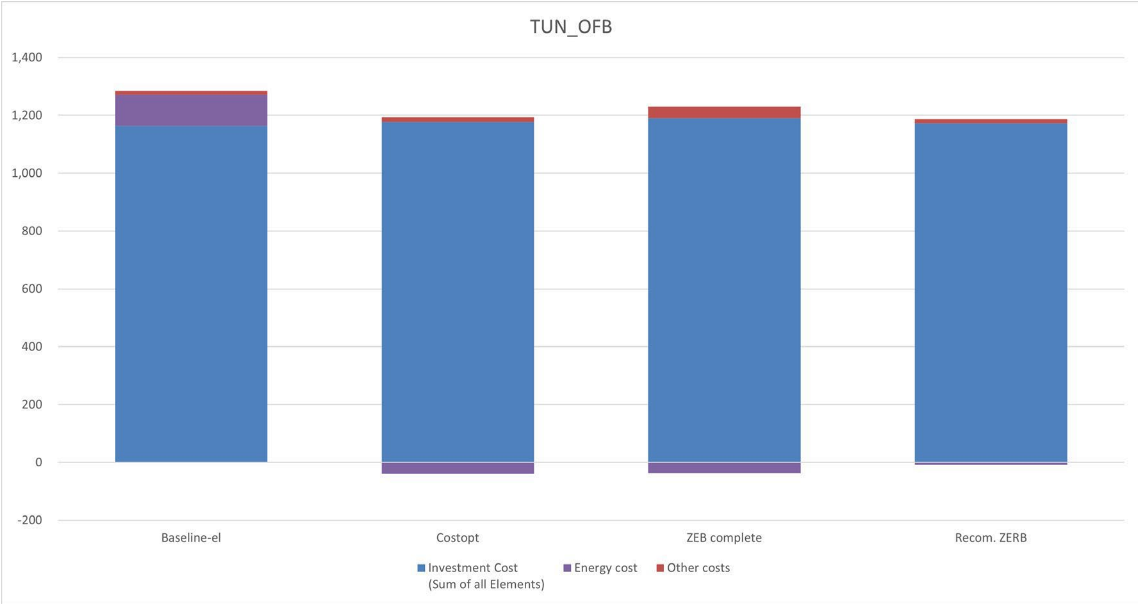


Figure 2-14 _Global cost comparison most relevant variants, including baseline and the recommended ZERB

Together with the reduced Opex, the payback of the ZERB measures which costs 45% more than investment for baseline, can be reached in less than two years.

3. CONCLUSIONS

This study has shown off a robust and context-specific framework for defining Zero Emission Buildings (ZEB) in Tunisia, harmonizing international best practices with local market realities and construction practices. The framework—embodied in the Zero Emission Ready Building (ZERB) concept—demonstrates that substantial energy demand reductions, up to 87% for final electricity consumption, can be achieved by integrating tailored efficiency measures that are both technically viable and financially attractive within the Tunisian context.

Central to this approach is the strategic enhancement of the building envelope. Our analysis underscores that advanced thermal insulation for roofs, external walls, and ground floors is critical, particularly in very hot regions where cooling loads are significant. While high-performance glazing solutions such as triple-glazed windows offer superior thermal performance, they have been deliberately excluded from the ZERB specifications because they are not commonly available or cost-effective in Tunisia. Instead, the framework relies on more conventional, locally prevalent window types that align better with market practices and support the cost-optimal transition.

Furthermore, the study examined the design variants for office buildings. Despite international recommendations that advocate for comprehensive ventilation systems in new office constructions, our findings indicate that the ZERB standard for office buildings in Tunisia does not include such advanced ventilation systems. Our simulations have confirmed that, based on common practice and cost-optimum evaluations, the achieved energy performance targets for office buildings are met without incorporating these additional ventilation measures. This adaptation reflects a realistic approach that respects the existing market and technical capabilities while still delivering the desired performance improvements.

Additionally, a key distinction emerged in the treatment of window technologies. While the cost-optimum scenario for conventional buildings often incorporates double-glazed windows with solar coatings to enhance energy efficiency, our simulations—accounting for the benefits of net metering—demonstrated that both the ZEB and the ZERB models perform satisfactorily with double-glazed windows without the solar coating. This deviation is not only reflective of the local market availability but also reinforces the notion that the pursuit of advanced glazing features must be balanced against cost and practicality.

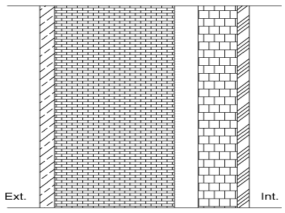
Overall, this framework provides a comprehensive and pragmatic pathway toward achieving climate-neutral energy systems in Tunisia. By emphasizing measures that are technically effective, economically feasible, and aligned with local practices—such as excluding triple glazed windows, adapting ventilation strategies in office buildings and opting for non-solar coated double glazing— the proposed ZERB standard offers a realistic model for scaling up energy efficiency across new constructions and retrofits alike. These insights not only support Tunisia’s ambitious renewable energy and emissions reduction targets but also serve as a valuable reference for updating national building codes and fostering a resilient, low-carbon built environment in the region.

4. APPENDIX

This annex presents the building envelope qualities discussed in the report and shows off how the specific U-Values can be reached in Tunisia.

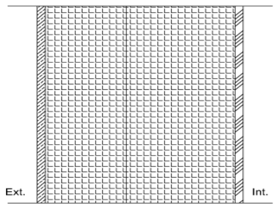
Tunisia - External Wall for Large Multi Family House

BaU



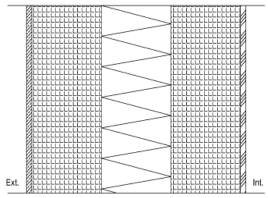
Layer	Thickness (mm)	U-Value ($W/m^2 \cdot K$)
Cement Mortar	25	1.1
12-Hole brick	200	
Air gap	40	
8-Hole brick	65	
Bastard mortar	20	

Cost Optimum



Layer	Thickness (mm)	U-Value ($W/m^2 \cdot K$)
Cement mortar	15	0.3
Thermostone	150	
Thermostone	200	
Bastard mortar	15	

ZERB



Layer	Thickness (mm)	U-Value ($W/m^2 \cdot K$)
Cement mortar	15	0.1
Thermostone	200	
Glass wool	200	
Thermostone	200	
Bastard mortar	15	

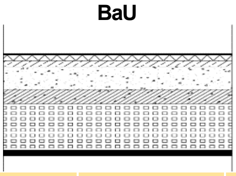
BUILD_ME Building Component Database

Guidehouse

BUILD_ME

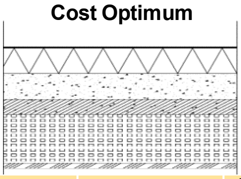
Tunisia - Roof for Large Multi Family House

BaU



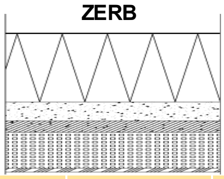
Layer	Thickness (mm)	U-Value ($W/m^2 \cdot K$)
Waterproofing membrane	5	0.75
EPS Polystyrene	20	
Cement mortar	20	
Cellular concrete	80	
Armoured concrete	50	
Hollow body	160	
Plaster coating	20	

Cost Optimum



Layer	Thickness (mm)	U-Value ($W/m^2 \cdot K$)
Waterproofing membrane	5	0.3
Rock wool	100	
Cellular concrete	100	
Armoured concrete	60	
Hollow body	190	
Bastard mortar	20	

ZERB



Layer	Thickness (mm)	U-Value ($W/m^2 \cdot K$)
Waterproofing membrane	5	0.1
Glass wool	360	
Cellular concrete	100	
Armoured concrete	60	
Hollow body	190	
Bastard mortar	20	

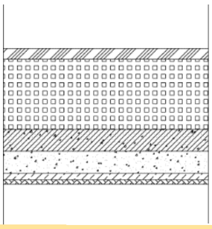
BUILD_ME Building Component Database

Guidehouse

BUILD_ME

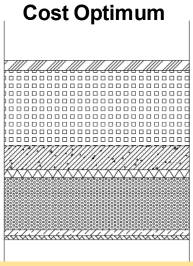
Tunisia - Floor for Large Multi Family House

BaU



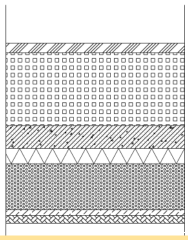
Layer	Thickness (mm)	U-Value (W/m²·K)
Cement mortar	25	2.2
Hollow body	160	
Armoured concrete	50	
Solid concrete	50	
Fixing Mortar	15	
Floor Tiles	10	

Cost Optimum



Layer	Thickness (mm)	U-Value (W/m²·K)
Cement mortar	25	0.6
Hollow body	190	
Armoured concrete	60	
XPS polystyrene	20	
Cellular concrete	130	
Fixing mortar	15	
Floor tiles	10	

ZERB



Layer	Thickness (mm)	U-Value (W/m²·K)
Cement mortar	25	0.45
Hollow body	190	
Armoured concrete	60	
XPS polystyrene	40	
Cellular concrete	120	
Fixing mortar	15	
Floor tiles	20	

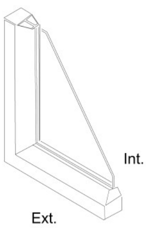
BUILD_ME BuildingComponent Database

Guidehouse

BUILD_ME

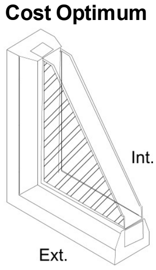
Tunisia - Windows for Large Multi Family House

BaU



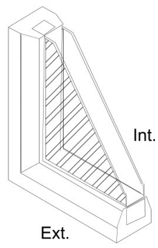
Layer	Thickness (mm)	U-Value (W/m²·K)	G-Value
Single Glass	4	5.7	0.85

Cost Optimum



Layer	Thickness (mm)	U-Value (W/m²·K)	G-Value
Single Glass	4	1.5	0.3
Solar coating	-		
Low E	-		
Air Gap	12		
Single Glass	4		

ZERB



Layer	Thickness (mm)	U-Value (W/m²·K)	G-Value
Single Glass	4	1.5	0.3
Solar coating	-		
Low E	-		
Air Gap	12		
Single Glass	4		

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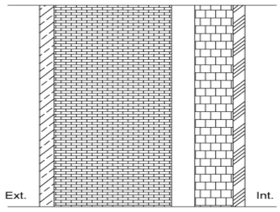
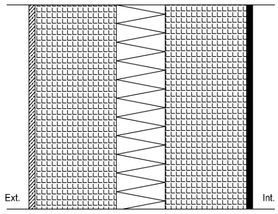
Tunisia - External Wall for Office Building

BaU



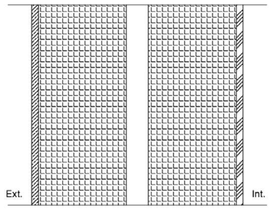
Layer	Thickness (mm)	U-Value (W/m²·K)
Cement Mortar	25	1.1
12-Hole brick	200	
Air gap	40	
8-Hole brick	65	
Bastard mortar	20	

Cost Optimum



Layer	Thickness (mm)	U-Value (W/m²·K)
Cement mortar	15	0.15
Thermostone	200	
Rock wool	120	
Thermostone	200	
Plastercoating	15	

ZERB



Layer	Thickness (mm)	U-Value (W/m²·K)
Cement mortar	15	0.25
Thermostone	200	
Air gap	50	
Thermostone	200	
Bastard mortar	15	

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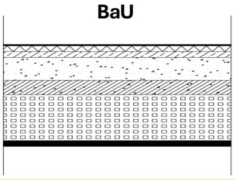
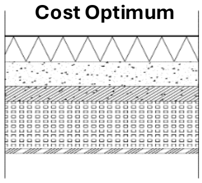
Tunisia - Roof for Office Building

BaU



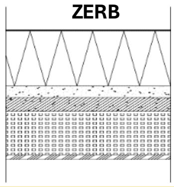
Layer	Thickness (mm)	U-Value (W/m²·K)
Waterproofing membrane	5	0.75
EPS Polystyrene	20	
Cement mortar	20	
Cellular concrete	80	
Armoured concrete	50	
Hollow body	160	
Plaster coating	20	

Cost Optimum



Layer	Thickness(mm)	U-Value (W/m²·K)
Waterproofing membrane	5	0.3
Rock wool	100	
Cellular concrete	100	
Armoured concrete	60	
Hollow body	190	
Bastard mortar	20	

ZERB



Layer	Thickness(mm)	U-Value (W/m²·K)
Waterproofing membrane	5	0.15
Glass wool	240	
Cellular concrete	50	
Armoured concrete	60	
Hollow body	190	
Bastard mortar	20	

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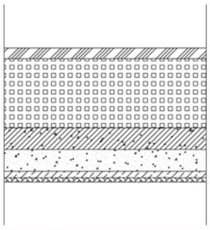
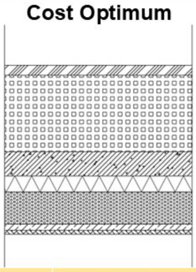
Tunisia - Floor for Office Building

BaU



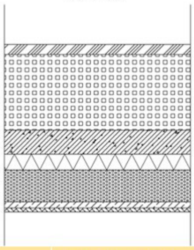
Layer	Thickness (mm)	U-Value (W/m²·K)
Cement mortar	25	2.2
Hollow body	160	
Armoured concrete	50	
Solid concrete	50	
Fixing Mortar	15	
Floor Tiles	10	

Cost Optimum



Layer	Thickness (mm)	U-Value (W/m²·K)
Cement mortar	25	0.5
Hollow body	190	
Armoured concrete	60	
XPS polystyrene	40	
Cellular concrete	80	
Fixing mortar	15	
Floor tiles	10	

ZERB



Layer	Thickness (mm)	U-Value (W/m²·K)
Cement mortar	25	0.5
Hollow body	190	
Armoured concrete	60	
XPS polystyrene	40	
Cellular concrete	80	
Fixing mortar	15	
Floor tiles	10	

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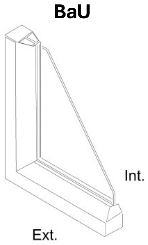
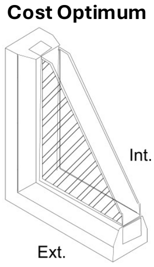
Tunisia - Windows for Office Building

BaU



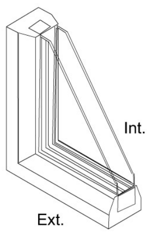
Layer	Thickness (mm)	U-Value ($W/m^2{\cdot}K$)	G-Value
Single Glass	4	5.7	0.85

Cost Optimum



Layer	Thickness (mm)	U-Value ($W/m^2{\cdot}K$)	G-Value
Single Glass	4	1.5	0.3
Solar coating	-		
Low E	-		
Air Gap	12		
Single Glass	4		

ZERB



Layer	Thickness (mm)	U-Value ($W/m^2{\cdot}K$)	G-Value
Single Glass	4	1.5	0.7
Low E	12		
Air Gap	4		

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Costs for Tunisia – EE measures

ZERB Variant

	LMFH (€/m²)	OFB (€/m²)
External Wall	81 €	56 €
Roof	115 €	82 €
Floor	97 €	55 €
Window	275 €	236 €

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