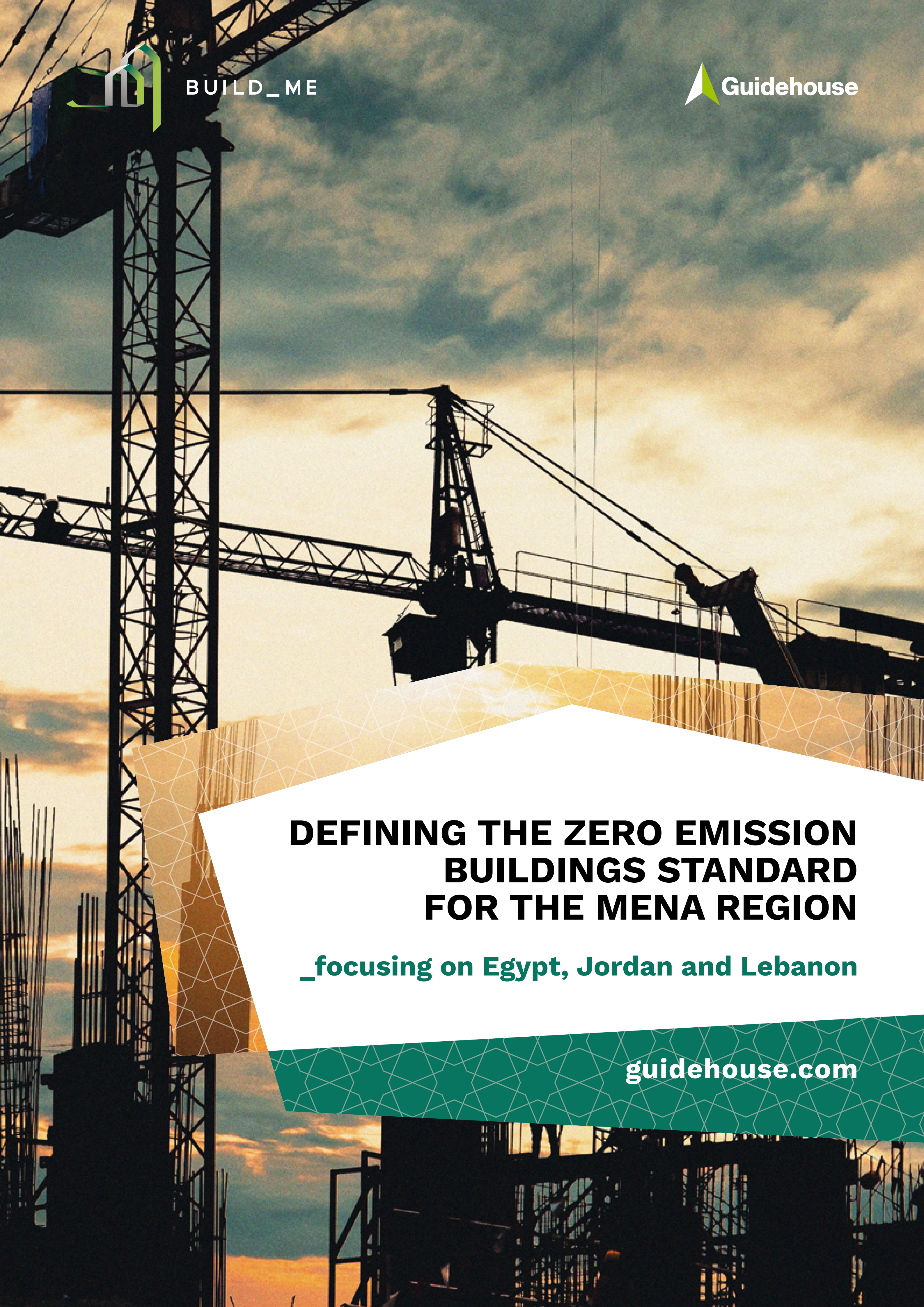

BUILD_ME

Guidehouse

DEFINING THE ZERO EMISSION BUILDINGS STANDARD FOR THE MENA REGION

_focusing on Egypt, Jordan and Lebanon

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EXECUTIVE SUMMARY

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Picture 1 _The MENA-Region

This report introduces a methodology to determine adequate requirements for Zero Emission Buildings (ZEB) in the BUILD_ME countries (Egypt, Jordan and Lebanon), 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 of the BUILD_ME countries (Egypt, Jordan and Lebanon) is presented, where it concluded that all countries are still in the preliminary steps, which are needed to promote adapted ZEB approaches.

Afterwards a deep dive is shown off 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 Egypt, Jordan and Lebanon have been performed. While considering local financial conditions, it was suggested to introduce a so called Zero Emission Ready Building (ZERB), which are on the one hand affordable, but also 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 in very hot regions. For all ZERBs High efficiency air conditioning (AC) systems, efficient shading, and photovoltaics (PV) are recommended. The ZERBs come along with significantly lower global costs (by 15 % to 30 %) than the common practice for new buildings (baselines). ZERBs allow reduction of the final energy demand (electricity) by up to 90 %. The required additional investment costs are typically around 5 % with an expected payback period of 3 years.

It can be assumed that the identified ZERB specifications would be similar for anyhow needed retrofitting, replacements, or refurbishments of components of existing buildings.

Finally, the utilisation of sustainable materials is recommended for ZERBs, such as the consideration of e.g. natural refrigerants or waiver of cement products wherever possible, without significant increase in total costs.

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 decarbonised 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. These findings shall be utilised 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.

Picture 2 _The entrance of the Rockery House, Jordan

© adaa, Sustainable Development Consultants

1.2.1 Approach

The Zero Emission Buildings Standard (ZEBS) for the MENA region 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 countries (Egypt, Jordan and Lebanon) 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 https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=celex%3A32010L0031
2 Directive - EU - 2024/1275 - EN - EUR-Lex (europa.eu)

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 decarbonised 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 of Energy [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.

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**."

3 Pales et al. 2021
4 PCAF September 2022
5 UK Government 2022

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**."

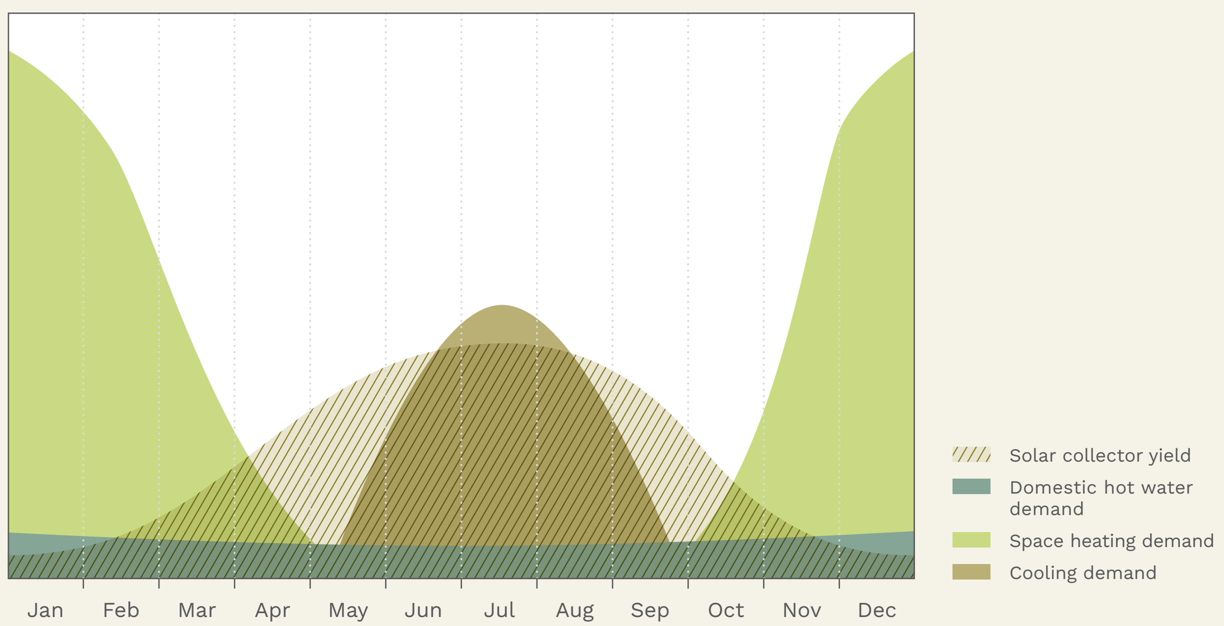
1.3.8 Discussion

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 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 decarbonised 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 comparing these two scenarios of **a)** higher heating demand (illustrated in green), **b)** higher cooling demand (illustrated in brown), **c)** hot water demand (illustrated in dark green) 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.

6 World Green Building Council

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.

Picture 3 _Always keeping the goal in sight

2 DEFINING ZEB FOR EGYPT, JORDAN AND LEBANON

This section presents a framework that defines ZEBs in Egypt, Jordan, and Lebanon. The methodology used in this framework builds 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 MENA region & BUILD_ME target countries

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 characterised 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 Egypt

2.1.1.1 Current discussions

The rising energy consumption and the corresponding greenhouse gas emissions are considered significant global concerns. The building sector accounts for 30 % of global final energy consumption and one third of the total greenhouse gas emissions[8].

According to the Egyptian Ministry of Electricity and Renewable Energy's 2020/2021 annual report, the energy sector accounts for approximately 13.1 % of national GDP. Since 2000, the energy demand has grown 171 %, influenced by factors including population growth, urbanization, and technological advancements. However, increased consumption has failed to fully correlate with improved human well-being and living standards, as energy intensity (amount of energy used per unit of GDP) decreased from 1.3 kilowatt-hours in 2000 to 0.75 kilowatt-hours in 2021[9]. The total energy sold on all efforts distributed over purposes for the financial year 2022/2023 is EGP 169.580 billion, and the investment in renewable energy capacity, presently set at roughly EGP 39.5 billion per year until 2030, requires significant expansion. A focus on macro-level energy savings may neglect necessary micro-level improvements for building energy performance.

The Egyptian Electricity Holding Company's[10] annual report for the FY 2022/2023 revealed that the total quantity of sold electricity has reached 137 terawatt hours, representing an average annual growth rate of 3.1 % from the previous year. The energy consumption has increased significantly over the past decade across three major sectors:

8 IEA, 2023
9 World bank, 2023
10 EEHC, 2023

Building type	Residential / Non-residential		
Standard	BaU scenario		
Building component	**Type**	**Thickness** [mm] including finish layers	**Estimated U-Value** [W/m²K]
Walls	Red brick wall (new and existing)	250 – 320	2.2
	Cement brick wall (new and existing)	250 – 320	2.6
Roofs	Uninsulated concrete roof (new and existing)	365 – 400	1.8
	Insulated concrete roof (good practice new)	480 – 500	0.39
Floor	Uninsulated floor (new and existing)	210 – 220	1.6
	Insulated floor (good practice new)	280	0.87
Windows	Single glazed window (new and existing)	–	▪ u_W = 5.7 W/m²K ▪ g = 0.85
	Double glazed window (good practice new)	–	▪ u_W = 2.9 W/m²K ▪ g = 0.7

Table 2-1 _Building envelope components estimated U-Values

1) the residential sector, which represents 37 % of total final electricity consumption, **2)** the industrial sector, accounting for approximately 27 % of consumption, and **3)** the public and commercial sectors, representing 15 % of consumption. Given these figures from the primary drivers of consumption, buildings present a major opportunity to decrease energy demand and reduce emissions through increased efficiency efforts.

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 Table 1).

Egypt has set ambitious renewable energy targets, aiming for 47 % of electricity generation by 2035. Specific targets include achieving 8.5 gigawatts (GW) of wind power capacity by 2022, 3.5 GW of concentrated solar power (CSP) by 2027 and adding 900 megawatts (MW) of PV solar capacity by the same year[11]. The country has also implemented a landmark investment law to attract foreign investment into its energy sector, offering incentives, prohibiting nationalization, and reducing barriers for international firms. Egypt is actively transitioning towards sustainable energy sources, emphasising cost reductions in renewables, advancing energy storage technologies, and promoting smart grid infrastructure to facilitate this transition.

In response to growing energy consumption and environmental concerns, Egypt has developed a series of efficient building standards and energy codes aimed at improving energy performance and sustainability in the construction sector.

These standards emerged as part of the national strategy to reduce GHG emissions, improve energy efficiency, and harness renewable energy sources, driven by the collaboration between government agencies, industry stakeholders, and international organizations.[12]

These codes include:

- The **Egyptian Code for Improving the Energy Efficiency of Buildings** is overseen by the Ministry of Housing, Utilities, and Urban Communities. It sets standards and guidelines aimed at reducing energy consumption in both new and existing buildings through measures like efficient lighting, insulation, and HVAC systems. The scope includes residential, commercial, and institutional buildings, with stringent requirements for energy performance and building envelope integrity. It also sets obligatory standards aimed at reducing energy consumption across residential, commercial, and institutional buildings. However, enforcement varies, and compliance is often hindered by insufficient monitoring and enforcement mechanisms.

- The **Egyptian Code for Energy Efficiency in Residential Buildings**, managed by the Ministry of Electricity and Renewable Energy, focuses specifically on energy efficiency measures tailored for residential structures. It addresses aspects such as lighting efficiency, appliance standards, and insulation requirements to minimize energy usage and enhance indoor comfort. Despite being legally binding, compliance faces challenges due to limited awareness and capacity among stakeholders.

11 Bissada, 2022

12 Edeisy Mohamed, Carlo Cecere, 2018

- Similarly, the **Egyptian Code for Energy Efficiency in Commercial Buildings**, regulated by the Ministry of Trade and Industry, targets energy efficiency strategies tailored for commercial and public buildings. It emphasizes efficient heating, ventilation, and air conditioning (HVAC) systems, lighting controls, and sustainable building materials to optimize energy performance and reduce operational costs. However, inconsistent application and enforcement impede widespread adherence.

- The **Egyptian Green Building Code**, developed by the Egyptian Green Building Council (EGBC), promotes sustainable building practices across various sectors. It integrates environmentally friendly design principles, renewable energy utilization, water efficiency measures, and waste management strategies into building projects to achieve green building certifications.

These codes enforce strict requirements for electromechanical systems and building envelopes to ensure energy efficiency. However, challenges such as inadequate attention to building envelope tightness, contribute significantly to cooling loads, underscoring the need for greater adherence to these standards to improve overall energy performance and sustainability in Egypt[13]. The Housing and Building National Research Center – HBRC plans to include residential and commercial rules as mandatory sections of the building code[14]. As a result, the HBRC developed a program to implement and support those codes, which included a variety of activities such as compliance training for architects, engineers, and manufacturers, the execution of a number of pilot projects, public outreach activities, and the establishment of an administration in charge of code enforcement[15].

Egypt has made a limited number of initiatives to effectively enforce the **Energy Efficiency Building Codes – EEBCs**, in November 2015, the MoERE and MHUUC signed a Memorandum of Understanding to facilitate the enforcement and implementation of the two codes. The MoU aims to collaborate on information exchange, energy consumption in the building sector, and establishing an institutional structure to implement and enforce the EEBCs[16]. This will involve various ministries and governmental agencies. Egypt's **National Energy Efficiency Action Plan – NEEAP** has proposed the formation of the EEBCs Implementation and Activation Committee. This committee will identify the legal, institutional, technical, and economic constraints of EEBC enforcement and develop an implementation roadmap. The committee will also engage in additional efforts to help the construction and building sectors prepare for compliance with the EEBCs.

NZEB in Papers and Publications

Towards Zero-Energy Buildings in Egypt, there is a need for sustainable housing concepts, the significance of lowering energy usage in residential structures, and the possibility of achieving energy efficiency with Zero Energy Houses[17]. In addition to what (Fatouh et al.,2018) had mentioned, that by applying NZEB strategies, including retrofitting and installing a photovoltaic solar system, the energy consumption of the building can be reduced by 11.925 % and 29.45 %, respectively as his study highlighted that the replacement of glazing and lighting fixtures with energy-efficient alternatives can reduce energy consumption, and the installation of solar panels can further reduce energy consumption and achieve a net zero energy building where he also mentioned that Egypt has a great potential to do so.

Additionally, according to sustainable development strategy, the Egyptian government objective is reducing the energy consumption and greenhouse gas emissions by 14 % and 10 % respectively by 2030[18]. In conclusion, the need for zero energy buildings in Egypt is urgent due to the building sector's major role in energy use and CO_2 emissions and current lack of momentum or discussion around the definition of ZEB in Egypt. Traditional buildings, coupled with rapid urbanization and growing energy needs, contribute significantly to greenhouse gas emissions. Transitioning to zero energy buildings, utilizing Egypt's solar potential, and addressing insulation deficiencies, provides a practical solution. Converting buildings to nZEBs with PV systems, backed by financial feasibility studies introduces and encourages sustainable practices. This would not only cut CO_2 emissions but also reduce dependence on non-renewable energy, ensuring Egypt's long-term sustainability and energy security.

Picture 4 _View of the Nile from the Cairo Tower

13 Sally ElDeeb, 2022
14 HBRC & The Organisation for Energy Planning, PA Consultin, 2006
15 Hanna G. B., 2011
16 NUCA, 2015
17 Abdelmoez,2019
18 Fatouh et al.,2018

2.1.1.2 Examples of high energy performant buildings

PROJECT INFO _Multi-family house in Nasr City[19]

CONSTRUCTION PHASE	New construction
DETAILED BUILDING TYPE	Single Family House (SFH)
NET FLOOR AREA	245 m²
STORIES	1 story
CONSTRUCTION YEAR	2018
Project team	
DEVELOPER(S)/OWNER(S)	KarmBuild
ARCHITECT(S)	KarmBuild

Technical parameters	
BUILDING ENVELOPE	▪ Retaining wall supported platform with embedded foundations, eliminating any excavations respecting the coral limestone formations. 90 % of the walls are exposed load-bearing coral limestone from 60 to 40 cm thick. The rest are 25 cm red brick masonry. ▪ A typical 20 cm thick reinforced concrete slab roof structure. The layers from the inside to the outside are: wood frames, reinforced concrete, foam insulation, light concrete, sand, cement and cladding. ▪ Static (fix) shading systems as part of the building architecture (e.g. Maschrabiyya, porch roofs, pergolas) ▪ Wall U-Value 1.05 W/m²K ▪ Roof U-Value 0.389 W/m²K ▪ Window U-Value 2 W/m²K
HEATING, VENTILATION & AIR CONDITIONING	Free ventilation (windows), a wind catcher tower and a solar chimney tower. Cooling and ventilation improvements in summer due to windcatcher and solar chimney are over 25 % in terms of hours within the comfort range.
LIGHTING	Optimized LED Lights
ON-SITE RENEWABLE ENERGY	The project is powered by an on-site solar station built by KarmBuild's sister company KarmSolar

Results	
TOTAL SPECIFIC FINAL ENERGY DEMAND	49.01 kWh/m²a
PROJECT CONSTRUCTION COST	89,240 EUR

Table 2-2 / Picture 5

19 Somaya Al Badry, Khaled Tarabeih, Hani Sweilam, 2017

PROJECT INFO _Southbound Business Park area of Cairo Festival City (CFC), New Cairo[20]

CONSTRUCTION PHASE	Existing building
DETAILED BUILDING TYPE	Office building
NET FLOOR AREA	20,970 m²
STORIES	4 stories
CONSTRUCTION YEAR	2011
Project team	
DEVELOPER(S)/OWNER(S)	Al-Futtaim Real Estate for Development
ARCHITECT(S)	CallisonRTKL

Technical parameters	

BUILDING ENVELOPE	▪ Walls: 150 mm PU foam insulation with passivehaus-certified facades with mounted granite stone cladding
	▪ Roof: insulated sandwich panel roofing system
	▪ Floor slabs insulated with:
	  ▪ 10 mm cement render coat-plaster
	  ▪ 4 mm waterproof insulation
	  ▪ 250 mm XPS load-bearing insulation
	▪ Air tightness: polyethylene tape in all walls and roof.

HEATING, VENTILATION & AIR CONDITIONING	▪ High efficiency chillers and Variable air volume (VAV) systems to adjust airflow based on demand. ▪ Heat recovery ventilation (HRV) system provides 89 % heat recovery and reduces cooling demand by nearly 45 %
LIGHTING	▪ Optimized LED Lights ▪ Lighting Controls: Occupancy and daylight sensors
ON-SITE RENEWABLE ENERGY	Solar photovoltaics (PV)
Results	
TOTAL SPECIFIC FINAL ENERGY DEMAND	16.2 kWh/m²a
PROJECT CONSTRUCTION COST	1,193,625 EUR

Table 2-3 / Picture 6

20 vincent callebaut architectures, 2014

2.1.2 Jordan

2.1.2.1 Current discussions

Jordan's heavy reliance on imported oil and gas, which make up 94 % of its energy supply, exposes the country to price volatility. In response, the Ministry of Energy and Mineral Resources has developed a revised master strategy for the energy sector covering 2020 to 2030. This strategy sets ambitious goals, targeting a 30 % share of renewable energy in total electricity generation capacity and a 14 % contribution to the overall energy mix by 2030[21].

The Ministry also highlights that residential buildings are the second-largest consumers of energy in Jordan[22], representing 72 % of the country's total building stock. With population growth leading to an annual need for over 44,000 new households – totalling more than 352,000 by 2030 – residential buildings offer a significant opportunity for achieving substantial energy savings.

The building sector plays a pivotal role in Jordan's overall energy consumption and carbon emissions. In particular, the country's residential and commercial buildings account for a significant share of energy use. Residential buildings alone contribute to 22 % of the total energy consumption, with the primary drivers being heating, cooling, and hot water. This demand is further exacerbated by the country's rapid urbanization and the large influx of refugees, which has placed additional pressure on the energy supply system.

Energy consumption in buildings is a key factor in Jordan's greenhouse gas emissions. The building sector is responsible for a substantial portion of the country's CO_2 output, contributing to global climate change. With most of Jordan's energy sourced from imports, the rising demand for energy not only affects the country's energy security, but also has significant economic implications. Jordan's dependence on external energy supplies results in a large share of its GDP being allocated to energy imports, making the country vulnerable to fluctuations in global energy prices. Therefore, addressing energy efficiency in the building sector can directly reduce the nation's carbon footprint and contribute to macroeconomic stability by reducing energy expenditures.

Regulations and codes governing the building sector

Jordan has issued several laws, guidelines and policy instruments that govern the energy efficiency in the building sector and since the mid-1980s. Jordan National Building Council was formed pursuant to the **Jordanian National Building Law No (7) for 1993**. Jordan was one of the first countries in the Middle East to develop a thermal insulation code for buildings. The Royal Scientific Society has developed the **Jordan Green Building Guide**, which sets forth guidelines and best practices for sustainable construction. The guide encourages the use of energy-efficient building designs, materials, and technologies to minimize energy consumption and reduce environmental impact[23].

One of the core concepts emphasized on the importance of thermal performance in buildings, which is measured by the U-Value. The U-Value represents the rate of heat transfer through a building material. Lower U-Values indicate better insulation, leading to reduced heating and cooling demands in buildings. In Jordan, the application of building materials with appropriate U-Values is critical in enhancing energy efficiency, particularly given the country's hot summers and cold winters.

Building component	Residential buildings [W/m²K]	Non-residential buildings [W/m²K]
Roof	0.55	0.55
External wall	0.57	0.57
Ground floor	1.2	1.2
Windows	5.7	3.0

Table 2-4 _U-Values for Jordan EE Building Code related to new buildings

The implementation of Minimum Energy Performance Standards (MEPs) for construction materials and appliances further supports this effort. These standards set mandatory thresholds for energy efficiency, ensuring that all new buildings meet a certain level of performance. Additionally, the Jordan Energy Efficiency Labelling Scheme (JEELS) provides a clear indication of the energy performance of building materials and household appliances, guiding consumers and developers toward more sustainable choices. By promoting energy-efficient products and practices, Jordan is working to align its building sector with global energy efficiency trends and reduce its overall carbon emissions.

ZEB in research papers

Zero Energy Buildings (ZEBs) offer a promising solution to Jordan's energy challenges. ZEBs are designed to produce as much energy as they consume by integrating renewable energy technologies such as solar panels. These buildings not only meet their own energy needs but also contribute surplus energy back to the grid, creating a more resilient and sustainable energy system. Research has demonstrated the effectiveness of ZEBs in reducing energy consumption and lowering greenhouse gas emissions.

21 Renewables readiness assessment: The Hashemite kingdom of Jordan (n.d.-a) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Feb/IRENA_RRA_Jordan_2021.pdf. Accessed 18 September 2024

22 Minister of Energy and Mineral Resources. https://www.memr.gov.jo/En/List/Studies_and_Statistics. Accessed 9 July 2022

23 Analysis and Recommendations for the Improvement of Energy Efficiency Building Codes in Jordan

Bataineh and Abu Qadourah[24/25] conducted studies focusing on the reduction in energy demand in residential buildings located in a warm-dry climate zone (Amman). Passive design measures were employed, and building simulation techniques were used to investigate various design measures. The impact of each measure on the energy demand of residential buildings was assessed both separately and in combination with other measures to identify the optimal solution for reducing energy consumption. The findings revealed a significant potential for energy savings, with annual usage reductions of 53 % for cooling, 71 % for heating, and 78 % for lighting.

Hikmat H et al.[26] outlined a study focused on improving the energy performance of residential buildings in Jordan. A typical house model in Irbid serves as a case study for achieving near net zero energy (nNZEB) design. The research examines the economic and computational potential of various integrated passive and active design strategies, considering factors such as orientation, layout, insulation, windows, shading, and ventilation, including a novel natural convection air-cooled condenser system. Additionally, the study incorporates renewable energy technologies like photovoltaic systems and flat plate solar thermal collectors. Using a combination of computational and analytical approaches, the research employs dynamic modeling to evaluate energy performance under different climatic conditions, while also assessing the economic viability through payback period calculations for the implemented systems.

However, there is a lack of research on the design of ZEBs, and the adoption of ZEBs in Jordan faces several challenges, including the high upfront costs associated with renewable energy technologies and the lack of widespread awareness and technical expertise.

Although there are currently no fully developed programs dedicated to achieving Net Zero Buildings in Jordan, several initiatives and energy efficiency programs serve as foundational references for implementing NetZero practices. These initiatives and policies lay the groundwork for a future in which NetZero Buildings can become a reality[27].

Jordan Green Building Council (Jordan GBC)

The Jordan Green Building Council is a leading non-profit, non-governmental organization committed to promoting sustainable building practices in Jordan. Through internationally recognized training programs, a wealth of expertise, and an extensive regional and international network, the Jordan GBC plays a pivotal role in advancing green building initiatives. Its initiatives, alongside a dedicated volunteer team, actively promote the adoption of green practices and sustainable concepts in the building sector.

Jordan Renewable Energy and Energy Efficiency Fund (JREEEF)

Established to accelerate the Kingdom's investment in renewable energy, JREEEF focuses on key sectors such as residential housing, schools, hospitals, as well as private, public, industrial, and service sectors. The fund aims to foster a transition to sustainable energy practices across Jordan by promoting renewable energy solutions and energy efficiency programs.

Royal Scientific Society (RSS)

As Jordan's largest institution for applied research, consultancy, and technical services, the Royal Scientific Society is a regional leader in the fields of science and technology. Through innovative research and engineering, RSS contributes to Jordan's economic growth and social development. In collaboration with the National Building Council, the RSS introduced the **Jordan Green Building Guide** in 2012, which was the first of its kind in the country. The guide provides comprehensive criteria for green building design and construction and outlines a five-tier certification system, ranging from Certified up to Level A.

In summary, the building sector is a major contributor to Jordan's energy consumption and carbon emissions. By adopting energy efficiency measures, regulating building performance, and promoting the use of ZEBs, Jordan can address its energy challenges while fostering economic stability and environmental sustainability.

Picture 7 _The Roman theater in front of Amman's skyline

24 Abu Qadourah J, Al-Falahat AM, Alrwashdeh SS, Nytsch-Geusen C (2022) Improving the energy performance of the typical multi family buildings in Amman, Jordan. City Territ Archit. https://doi.org/10.1186/s40410-022-00151-8

25 Bataineh K, Alrabee A (2018) Improving the energy efficiency of the residential buildings in Jordan. Buildings 8(7):85. https://doi.org/10.3390/buildings8070085

26 Hikmat H. Ali, Fahmi A. Abu Al-Rub , Bashar Shboul, Hind Al Moumani. Evaluation of Near-net-zero-energy Building Strategies: A Case Study on Residential Buildings in Jordan

27 NetZero Buildings in Jordan, 2020

2.1.2.2 Examples of high energy performant buildings

PROJECT INFO _The Rockery House


© adaa, Sustainable Development Consultants

CONSTRUCTION PHASE	New construction
DETAILED BUILDING TYPE	Single family house
NET FLOOR AREA	825 m²
STORIES	2 stories
CONSTRUCTION YEAR	2020
Project team	
DEVELOPER(S)/OWNER(S)	adaa, Sustainable Development Consultants
ARCHITECT(S)	Hanna Salameh Design

Technical parameters	
BUILDING ENVELOPE	▪ Concrete walls, aktivTHERM for hard to reach thermal bridge areas ▪ Wall U-Value: 0.16 W/m²K ▪ Roof U-Value: 0.21 W/m²K ▪ Window U-Value: 1.43 W/m²K
HEATING, VENTILATION & AIR CONDITIONING	▪ Mechanical ventilation system with heat recovery ▪ Heat Pump (air-water) ▪ For large full height glazing area, mashrabiya and vegetation screen is used, for small windows roller shutters are used
LIGHTING	LED (Light emitting diode lamps)
ON-SITE RENEWABLE ENERGY	None
Results	
TOTAL SPECIFIC FINAL ENERGY DEMAND	N/A
PROJECT CONSTRUCTION COST	N/A

Table 2-5 / Picture 8

PROJECT INFO _Office Business Park CO

CONSTRUCTION PHASE	New construction
DETAILED BUILDING TYPE	Office building
NET FLOOR AREA	26,000 m^2
STORIES	8 stories
CONSTRUCTION YEAR	2021

Project team	
DEVELOPER(S)/OWNER(S)	Business Park CO
ARCHITECT(S)	Engicon – Praxis

Technical parameters	
BUILDING ENVELOPE	▪ The structure of the building is composite reinforced concrete shear walls, with external thermal insulation (50 mm Extruded Polystyrene) faced with mechanically fixed white color local stone. Window to Wall Ratio (WWE) is 35 % ▪ Wall U-Value: 0.81 W/m^2K ▪ Roof U-Value: 0.46 W/m^2K
HEATING, VENTILATION & AIR CONDITIONING	▪ Variable Refrigerant Flow system with COP of 3.20 is used for cooling and heating. Each office space is provided with ducted concealed indoor units and has an individual control room thermostat ▪ Basement Parking Levels: Fresh Air Fan with automatic backdraft damper is used, the middle area is ventilated by jet fans distributed all over the parking floor. Exhaust air is extracted by exhaust fans with fire dampers. The system is automatic. ▪ Variable Refrigerant Flow system for heating and cooling
LIGHTING	LED (Light emitting diode lamps)
ON-SITE RENEWABLE ENERGY	None

Results	
TOTAL SPECIFIC FINAL ENERGY DEMAND	68 kWh/m^2a
PROJECT CONSTRUCTION COST	N/A

Table 2-6 / Picture 9

2.1.3 Lebanon

The need for a climate-friendly energy sector has never been more emphasized at a policy making level. In its updated 2021 Nationally Determined Contribution (NDC), Lebanon committed to a conditional emissions reduction target of 31 % by 2030 compared to business as usual, while also increasing its unconditional emissions reduction target to 20 %. Although this commitment spans multiple sectors, including transport and industry, the building sector is a major contributor to energy demand and consumption. Due to changing habits and population growth, energy needs are continuously rising.

In 2018, the electrical and thermal energy demand for the building sector was approximately 18,860 GWh and 3,476 GWh, respectively, representing a 58 % and 59 % increase compared to 2010. Similarly, the electrical and thermal energy consumption for the building sector in 2018 was around 19,625 GWh and 2,711 GWh, respectively, marking a 57 % and 59 % increase from 2010. Despite a temporary decline in energy consumption due to the economic crisis and the removal of fuel subsidies, it is estimated that energy demand and consumption will continue to rise with population growth.

Consequently, in 2014, the buildings sector accounted for 33.5 % of Lebanon's total final energy consumption (TFEC), a figure projected to reach 40.7 % by 2030.

Nevertheless, the financial crisis that started in 2019 had its impact on the energy sector in the years that follow. This has led to removal of fuel subsidies in August 2021 and increase in the state-run electricity company, Electricite Du Liban (EDL), tariff rate in November 2022. On one side, it reduced energy demand due to a shift in people's behaviour to save on their EDL and diesel generator bills, leading to a decrease in energy demand compared to previous years. For the same reasons, it triggered the installation of solar PV systems for improved energy security, exceeding 1,000 MWp in 2023. There was also a surge in the installation of solar water heaters in recent years to reduce reliance on traditional heaters, whether electrical or oil-based, where rooftop area is available. The total installed area exceeded 1,000,000 sqm by 2023.

2.1.3.1 Current Discussions

Lebanon has yet to establish a zero emission/energy building standard. Nevertheless, various laws, guidelines, and policies have been introduced to enhance energy efficiency in buildings. Notably, the **Lebanese Building Law no. 646 (2004)** includes an optional clause for double wall installation. The **Thermal Standard for Buildings in Lebanon (TSBL 2005 and 2010)** provides recommendations for energy-efficient buildings. The **National Energy Efficiency Action Plans (NEEAP 2011-2015 and 2016-2020)** address energy efficiency measures in all sectors and specifically the building sector, including the development of a building code.

In 2021, the **High-Level Energy Efficiency Guidelines for Building Reconstruction and Upgrades in Lebanon** were developed through a collaboration between Greenfield Cities, LCEC, and the Energy Transition Facility. These guidelines provide Energy Renovation Guideline Sheets for architects and engineers to reduce energy consumption in residential building renovations.

Moreover, green building standards have recently been implemented on several new building projects, focusing on energy, environmental, water, social, and economic aspects. Adoption of LEED and BREEAM standards has been funded through NEEREA mechanism and private sector. The ARZ 2.0 Green Building Rating System (GBRS) was also developed by the Lebanon Green Building Council (LGBC) in collaboration with the United Nations Development Program (UNDP) and funded by the European Union. It aims to evaluate and enhance the environmental performance of buildings in Lebanon, promoting sustainability and higher certification levels to attract eco-conscious tenants and clients.

NZEB in Papers and Publications

The definitions of zero or near-zero energy buildings (NZEBs) have been explored from various perspectives in numerous studies. Osama Omar's work, "Near Zero-Energy Buildings in Lebanon: The Use of Emerging Technologies and Passive Architecture," investigates a new design framework and decision-support tools for NZEBs. Omar proposes that design teams should adhere to four principles to optimize building design based on typology and climate context: reducing energy demand, improving indoor environmental quality (IEQ), integrating renewable energy, and applying specific design measures tailored to the building's typology and climatic conditions. These principles emphasize the emerging relationship between passive architecture techniques, material properties, and intelligent technologies to develop a functional framework for near zero-energy building design. Omar particularly notes the influence of occupants' cultural and social behavior on energy consumption in the Middle East compared to Europe (Omar, 2020).

Similarly, Philippe Homer Saleh's paper, "Towards Nearly Zero Energy Buildings In Lebanon: Bioclimatic Design And Experimental Strategies," investigates optimal wall-construction methods to minimize internal summer overheating in Lebanese apartment buildings. Saleh's research, which combines monitoring, software simulations, and full-scale test cells, concludes that uninsulated double masonry walls outperform various insulated configurations in reducing summer overheating. This challenges conventional recommendations for thermal insulation in hot climates (Saleh, 2018).

Furthermore, Bedros Keushkerian and Caesar Abi Shdid in "Building a sustainable future: Exploring the nexus between climate awareness and thermal insulation choices in new home construction" examine the impact of climate change awareness on Lebanese homeowners' decisions to use thermal insulation in new home constructions. Using a model of a typical single-family home, the thermal loads for insulated and uninsulated homes were analyzed across three Lebanese locations: Beirut (coastal), Chtaura (inland plateau), and Bcharre-Arz (high mountain). The results demonstrated significant energy reductions (23 % to 52 %) with thermal insulation, with varying payback periods. This study also highlighted that while climate awareness significantly influences the decision to insulate, cost considerations remain a crucial factor. Raising awareness about the environmental and economic benefits of thermal insulation could increase its adoption, contributing to energy savings and climate change mitigation (Keushkerian & Abi Shdid, 2022).

Additionally, the comprehensive methodology for optimizing the design of NZEBs is presented by Fatima Harkouss, Farouk Fardoun, and Pascal Henry Biwole in "Multi-objective optimization methodology for net zero energy buildings." This methodology involves building simulation, optimization using the non-dominated sorting genetic algorithm (NSGA-II), multi-criteria decision making (MCDM), and sensitivity analysis. Applied to various climatic zones in Lebanon and France, the study optimizes parameters such as insulation thickness, window glazing, and renewable energy systems. The results demonstrate significant potential for energy savings and cost-effectiveness, highlighting the importance of passive design strategies and appropriate renewable energy systems in achieving NZEB performance across different climates (Harkouss, Fardoun, & Biwole, 2018).

Moreover, Maya Julian and Chafic Salame's analysis in "Energy management, critical analysis and recommendations: Case study Lebanon" discusses Lebanon's energy management situation and offers recommendations for improvement. This research highlights Lebanon's significant potential for energy savings across various sectors despite the current modest energy management efforts. The paper discusses the impact of the refugee crisis on energy consumption, noting that refugees have significantly strained the electricity grid and increased energy demand. Emphasizing the urgent need for a competent national energy management plan to address the rising primary energy consumption, particularly in the transport and residential sectors, the study recommends adopting more efficient household appliances, improving thermal insulation in buildings, and implementing urban cooling solutions to enhance energy efficiency and reduce CO_2 emissions (Julian & Salame, 2022).

Lastly, the feasibility of achieving net zero life cycle primary energy and greenhouse gas (GHG) emissions in apartment buildings is evaluated by André Stephan and Laurent Stephan in "Achieving net zero life cycle primary energy and greenhouse gas emissions apartment buildings in a Mediterranean climate." Using a case study of a building in Sehaileh (coastal), Lebanon, this research employs life cycle cost, energy, and GHG emissions analysis over 50 years. The findings reveal that a combination of improved operational energy efficiency, solar photovoltaic panels, and reduced embodied energy can achieve a net zero life cycle balance. Critical factors include the emissions factor of the electricity grid and the initial embodied energy. This study underscores the importance of comprehensive definitions and policies for net zero buildings to address climate challenges effectively (Stephan & Stephan, 2020).

These studies collectively highlight the importance of tailored approaches to zero and near zero-energy building designs, considering regional climatic conditions, building typologies, and socio-cultural factors that influence energy consumption patterns.

Picture 10 _Corniche Beirut on the Mediterranean coast

2.1.3.2 Examples of high energy performant buildings

PROJECT INFO _Multi family house Ghassan Hajjar

CONSTRUCTION PHASE	New construction
DETAILED BUILDING TYPE	Multi family house
NET FLOOR AREA	5,880 m²
STORIES	4 stories
CONSTRUCTION YEAR	2017
Project team	
DEVELOPER(S)/OWNER(S)	Ghassan Hajjar
ARCHITECT(S)	Samir Sarrouf

Technical parameters	
BUILDING ENVELOPE	▪ Double wall with 5 cm EPS insulation. ▪ Wall U-Value: 0.52 W/m²K ▪ Roof is Concrete slab covered with 10cm EPS insulation and ceramic tiles. ▪ Roof U-Value: 0.35 W/m²K
HEATING, VENTILATION & AIR CONDITIONING	▪ Free ventilation (Windows) ▪ DX split unit for cooling ▪ Gas condensing unit for heating ▪ Solar water heater on the roof
LIGHTING	LED (Light emitting diode lamps)
ON-SITE RENEWABLE ENERGY	Solar water heater

Results	
TOTAL SPECIFIC FINAL ENERGY DEMAND	75.6 kWh/m²a
PROJECT CONSTRUCTION COST	N/A

Table 2-7 / Picture 11

PROJECT INFO _Office Imad Ladkani

CONSTRUCTION PHASE	New construction
DETAILED BUILDING TYPE	Office building
NET FLOOR AREA	1,701 m²
STORIES	4 stories
CONSTRUCTION YEAR	2019

Project team

DEVELOPER(S)/OWNER(S)	Imad Ladkani
ARCHITECT(S)	Avedissian & Partners Architects

Technical parameters

BUILDING ENVELOPE	▪ 30 cm concrete wall incl. thermal insulation ▪ Wall U-Value: 0.26 W/m²K ▪ Roof is a Concrete slab with 5cm extruded polystyrene insulation ▪ Roof U-Value: 0.52 W/m²K
HEATING, VENTILATION & AIR CONDITIONING	▪ Mechanical ventilation system without heat recovery ▪ Centralised Chiller, VRV system for cooling ▪ Air-conditioning system (reversible for heating; air-air heat pump) for heating ▪ Solar water heater on the roof
LIGHTING	LED (Light emitting diode lamps)
ON-SITE RENEWABLE ENERGY	PV

Results

TOTAL SPECIFIC FINAL ENERGY DEMAND	78.88 kWh/m²a
PROJECT CONSTRUCTION COST	1,700,000 EUR

Table 2-8 / Picture 12

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 an overview about the three-step approach:

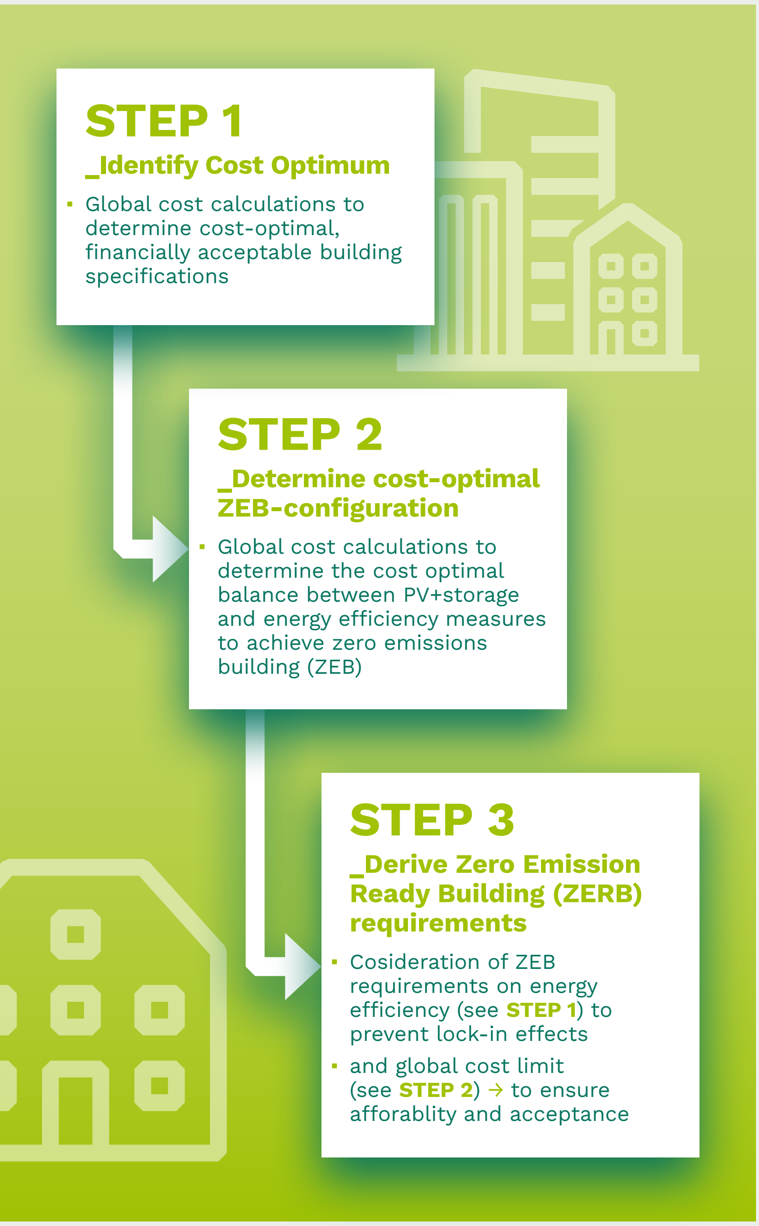


Figure 2-1 _Methodology to identify Zero Emission Building (ZEB) requirements adapted to MENA countries

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[28] (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[29]) 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[30]. 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[31].

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 available, 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 of onsite fossil fuels for heating, domestic hot water and AC.

That required Jordan and Lebanon – with typically fossil fuel heaters – to consider an adapted baseline (baseline-el).

The second assumption is that the cheapest option of renewable electricity supply[32] for buildings in the MENA region will predominantly be PV. Due to the climate conditions, different from northern regions, PV is available all year around in the MENA region. Furthermore, at hot climates highest shares of energy demand are typically required for cooling demand, which aligns well with the PV yields.

28 For global cost calculation the EPBD method is used.

29 30 years, as according to the EPBD for residential building in de EU seem to be too long for the MENA region.

30 https://www.buildings-mena.com/info/building-energy-performance-tool

31 Although only the building related final energy demand is considered, for the cost calculations also the financial benefits of PV for appliances are also considered (sometimes resulting in negative energy costs in the results figures).

32 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.

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 storage-option. As with PV, battery prices have also decreased significantly in recent years. Apart from certain cases where thermal storage options (e.g., ice storage) are indeed cheaper, batteries offer more versatility and flexibility.

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[33] 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[34].

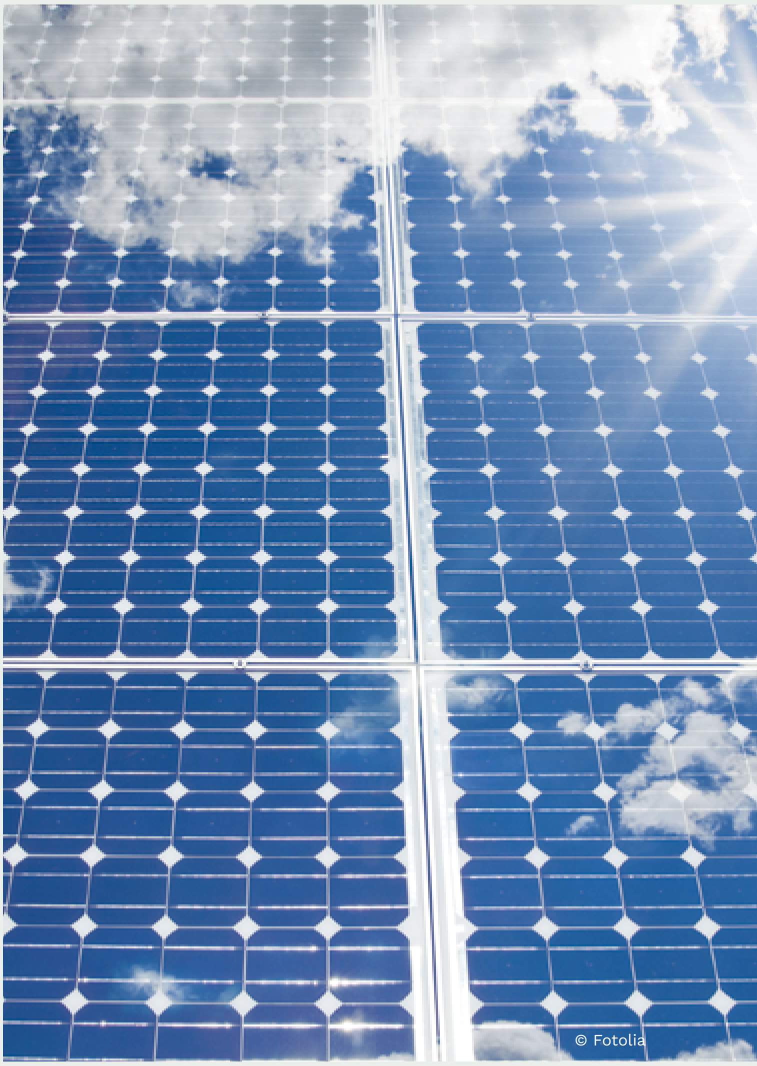
The calculations are performed for typical residential and non-residential buildings.

Due to the beforementioned simplifications (e.g. only considering PV) 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[35] derived. But at least, this approach does consider the real issue of balancing demand and renewable supply.

Under current circumstances in Egypt and Jordan (subsidised prices of non-renewable electricity, net metering tariffs for PV) installation of demand controls and storages (batteries) and in specific cases even onsite (rooftop) PV is financially not attractive.

Therefore, we suggest requiring 'Zero Emission Ready Buildings' (ZERBs). ZERBs only mandate measures that are financially and technically feasible under current local conditions. Specifically, this means that for controls and storage, providing designated space for potential future installation is sufficient. Furthermore, PV requirements should consider, in addition to financial aspects (see **STEP 1**), any potential technical limitations, such as available roof space.[36]

If PV under current circumstances would not be attractive, it would be sufficient to prepare for a future installation (enable roof statics, reserve space for the inverters and empty conduits 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.



Picture 13 _A reliable energy supplier – the sun

33 As it is so far just a theoretical exercise, potential limitations of roof space are not considered for STEP 2.

34 At this step no current net metering subsidies are considered as those would distort the results.

35 Under consideration of county specific constructions and prices

36 The roof space limitation of the PV capacity is determined by the assumption of 5 m²/KWp and the assumption that 50 % of the roof space can be used for PV.

2.3 _Analysis and Results

The following subchapters illustrate the boundary conditions and results of the ZEB analysis for Egypt, Lebanon, and Jordan.

2.3.1 General boundary conditions

The following parameters were considered for all countries to be the same.

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 countries. 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 (Egypt: 13 %, Jordan: 2.4 %, Lebanon: 34 %[37]) but also high corresponding average interest rates (Egypt: 13.7 %, Jordan: 8.2 %, Lebanon: 8.2 %[38]), that would lead to theoretic annual discount rates of:

- Egypt: 0.1 %
- Jordan: 1.7 %
- Lebanon: 1.2 %

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.

37 Due to current crisis the inflation rate in Lebanon is > 100 % since 2022, the average between 2013 and 2019 has been 3.2 %.

38 average between 2013 and 2019

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**	23 °C

Table 2-9 _Lifetimes

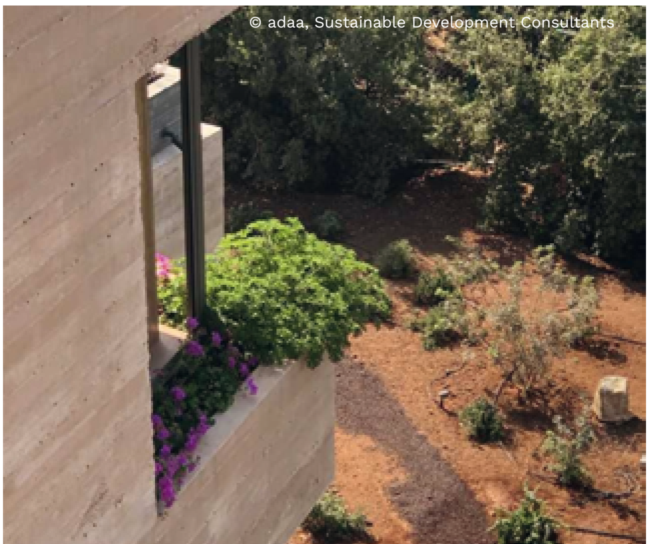
2.3.2 General remarks

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 by definition → electricity) is variable by time and dependant from load profiles. Due to the methodology for the ZEB, we consider the grid-demand interaction by determination of the required renewable capacity and storage needed 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.

Picture 14 _House greening of the Rockery House, Jordan



2.3.3 Egypt

2.3.3.1 Boundary conditions

Climate

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

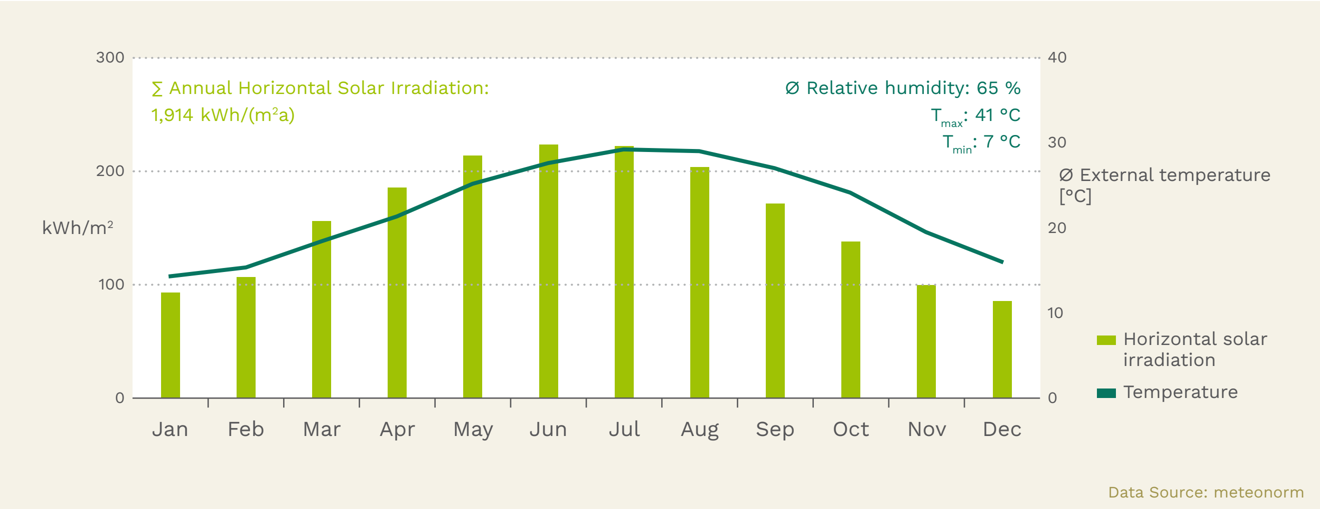


Figure 2-2 _Climate diagram Cairo

The climate in Cairo is primarily hot and reaches an average humidity rate of 65 %. External temperatures range from above 7 to 41 °C with average temperatures around 24 °C.

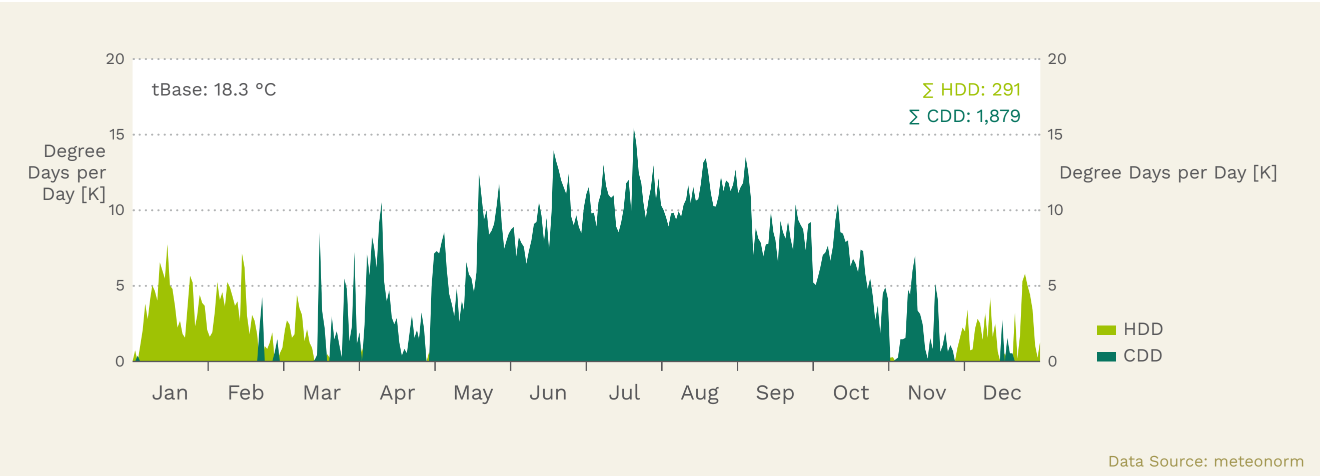


Figure 2-3 _Heating- and cooling degree days Cairo

The number (> 1,800 Kd) of cooling degree days is high, but heating degree days are limited (291 Kd).

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

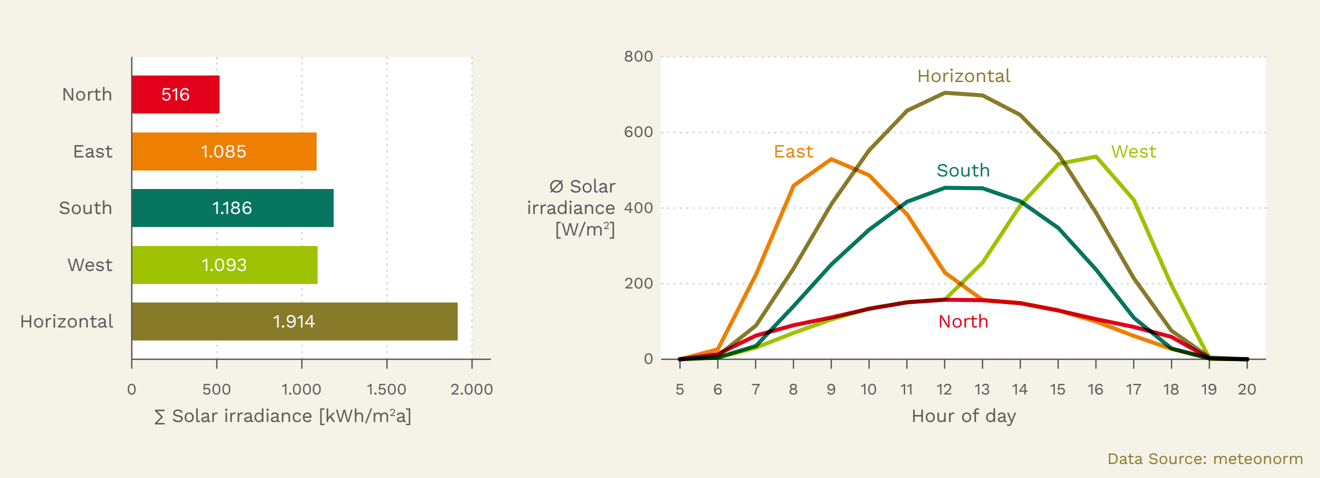


Figure 2-4 _Solar radiation Cairo

There is a high horizontal irradiation of > 1900 kWh/m²a and > 1,000 kWh/m²a for East, South and West orientation.

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

Buildings

Key specifications of the considered reference buildings:

Buildings	Multi Family House	Office Building
Net floor area	2,604 m²	10,531 m²
Roof area	576 m²	2,154 m²
Opaque wall area	1,878 m²	2,292 m²
Window area	470 m²	2,864 m²
Ground floor area	576 m²	2,154 m²
AC-System	Single split units	Central Chiller (central air distribution)
DHW System	Dedicated electric heater	–
Lighting system	LED	LFL
Internal loads (average)	3.5 W/m²	3 W/m²
Ventilation	–	Mechanical
Ventilation rate (including infiltration)	–	0.9 1/h

Table 2-10 _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 table:

Buildings	**Multi Family House**			**Office Building**		
U-Values [W/m²K]	**Wall**	**Roof**	**Floor**	**Wall**	**Roof**	**Floor**
Baseline	2.4	0.76	2.2	2.1	0.6	1.9
Variant ranges	0.11 – 2.1	0.1 – 0.75	0.5 – 0.7	0.15 – 1.1	0.1 – 0.55	0.5 – 0.7
Windows						
Baseline	Single glazing (u_w = 5.7 W/m²K; SHCG = 0.85)			Double glazing Air (u_w = 3.0 W/m²K; SHCG = 0.7)		
Variants	▪ Single glazing (u_w = 5.7 W/m²K; SHCG = 0.85) ▪ Double glazing Air (u_w = 2.9 W/m²K; SHCG = 0.7) ▪ Double glazing Argon (u_w = 1.2 W/m²K; SHCG = 0.7) ▪ Double glazing Solar (u_w = 1.5 W/m²K; SHCG = 0.3) ▪ Triple glazing (u_w = 0.9 W/m²K; SHCG = 0.55) ▪ Triple glazing Solar (u_w = 0.9 W/m²K; SHCG = 0.25)			▪ Double glazing Air (u_w = 3.0 W/m²K; SHCG = 0.7) ▪ Single glazing (u_w = 5.7 W/m²K; SHCG = 0.85) ▪ Double glazing Air (u_w = 2.9 W/m²K; SHCG = 0.7) ▪ Double glazing Argon (u_w = 1.2 W/m²K; SHCG = 0.7) ▪ Double glazing Solar (u_w = 1.5 W/m²K; SHCG = 0.3) ▪ Triple glazing (u_w = 0.9 W/m²K; SHCG = 0.55) ▪ Triple glazing Solar (u_w = 0.9 W/m²K; SHCG = 0.25) ▪ Triple glazing Solar (u_w = 0.8 W/m²K; SHCG = 0.25) ▪ Triple glazing Solar (u_w = 0.7 W/m²K; SHCG = 0.25) ▪ Triple glazing Solar (u_w = 0.6 W/m²K; SHCG = 0.25)		
Shading						
Baseline	Movable Manual Shading			Movable Manual Shading		
Variants	▪ Movable Manual Shading ▪ Fixed Shading			▪ Movable Manual Shading ▪ Fixed Shading		
Ventilation						
Baseline	–			Mechanical without heat recovery		
Variants	–			▪ Mechanical without heat recovery ▪ Mechanical 70 % heat recovery		
Heating and AC Systems						
Baseline	Low standard efficiency			Standard efficiency		
Variants	▪ Low standard efficiency ▪ Standard efficiency ▪ Improved efficiency ▪ High efficiency			▪ Standard efficiency ▪ Improved efficiency ▪ High efficiency		
PV Capacity [kWp]						
Baseline	0			0		
Variants	10 – 300			10 – 700		
Battery Capacity (kWh)						
Baseline	0			0		
Variants	50 – 550			712 – 1140		

Table 2-11 _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		350 €/m²
Office Building		550 €/m²
Insulation (Roof/Wall/Ground Floor)		6 € + 1.35 €/cm
Windows		
Single glazing (u_w = 5.7 W/m²K; SHCG = 0.85)		108 €
Double glazing Air (u_w = 2.9 W/m²K; SHCG = 0.7)		181 €
Double glazing Argon (u_w = 1.2 W/m²K; SHCG = 0.7)		211 €
Double glazing Solar (u_w = 1.5 W/m²K; SHCG = 0.3)		260 €
Triple glazing (u_w = 0.9 W/m²K; SHCG = 0.55)		239 €
Shading		
Fix shading elements		105 €/m²
Manual movable shading		113 €/m²
Automatic movable shading		360 €/m²
Ventilation System (office building)		
Mechanical without heat recovery		28.8 €/$m^2_{floor\ area}$
Mechanical with heat recovery (70 %)		53.8 €/$m^2_{floor\ area}$
AC System (costs derived from equation: $a * x^2 + b * x + c$ with x = design capacity in kW)		
Standard efficiency	Central Chiller Systemy	a = 0 b = 185.90 c = 6,996.0
	Single split units (EER[18] = 3.3)	a = 0 b = 369.13 c = 2.38
Improved efficiency	Central Chiller Systemy	Standard cost + 15 %
	Single split units (EER[18] = 4.5)	Standard cost + 15 %
High efficiency	Central Chiller Systemy	Standard cost + 30 %
	Single split units (EER[18] = 5.6)	Standard cost + 30 %
PV		120€ + 888 €/kWp
Battery		493 €/kWh
Electricity price		**0.03 €/kWh** (6 % annual increase)
PV feed in tariff (net metering[39])		**0.03 €/kWh** (6 % annual increase)

Table 2-12 _Investment costs

39 Bonification up to the total annual electricity demand; 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 multi family 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 efficiency HVAC systems leads to reduction of global costs. The reduced Opex of the variants overweighs the higher Capex. The cost optimum is reached at a final energy demand about 27 kWh/m²a. While the baseline variant results in global costs of about 480 €/m², the global costs of the cost optimum variant are well below 410 €/m², a reduction of more than 15 %. Although a net metering bonification for PV is in place in Egypt, adding PV is not further reducing the global costs due to the low electricity prices.

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 10 kWh/m²a and with that also a significant reduction of CO_2 emissions.

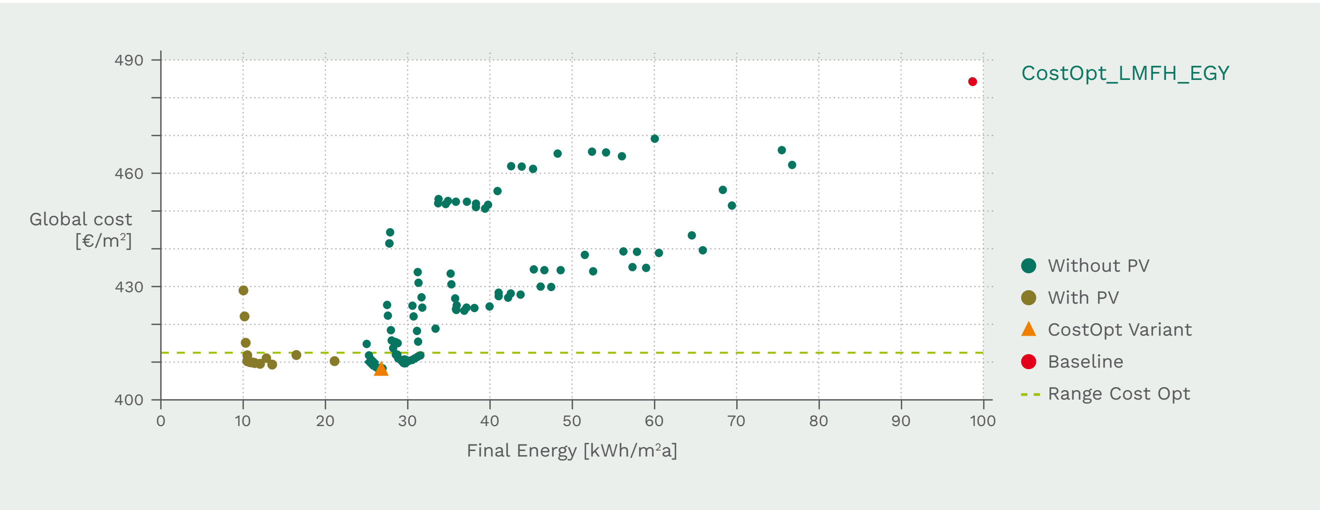


Figure 2-5 _Global cost calculations for identification of the acceptable global cost limit (STEP 1)

The key specifications of the cost-optimal variant

Roof and walls: u = 0.48 W/m²K (→ 6 cm insulation)
Ground floor: u = 0.60 W/m²K (→ 4 cm insulation)
Windows: Double glazed with solar coating (u = 1.5 W/m²K; SHCG = 0.3)
AC: High efficiency split units (EER = 5.6)
Shading: Fixed shading elements
PV: No

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 Egypt. That is the main reason why the global costs of cost optimal configuration necessary to achieve a climate neutral (energy self-sufficient) building although still lower than the baseline, are relatively high.

The cost optimal ZEB is reached by a variant with a highly efficient AC system, a fixed shading and an average u-value of 0.51 W/m²K.

The key specifications of the ZEB variant

Roof and walls:	u = 0.30 W/m²K (→ 10 cm insulation)
Ground floor:	u = 0.60 W/m²K (→ 4 cm insulation)
Windows:	Double glazed with solar coating (u = 1.5 W/m²K; SHCG = 0.3)
AC:	High efficiency split units
Shading:	Fixed shading elements
PV:	20 $W/m^2_{net\ floor\ area}$
Battery capacity:	36 $Wh/m^2_{net\ floor\ area}$

It should be mentioned that the global costs of the ZEB (with almost no energy costs) are in the same range as the global costs of baseline variant.

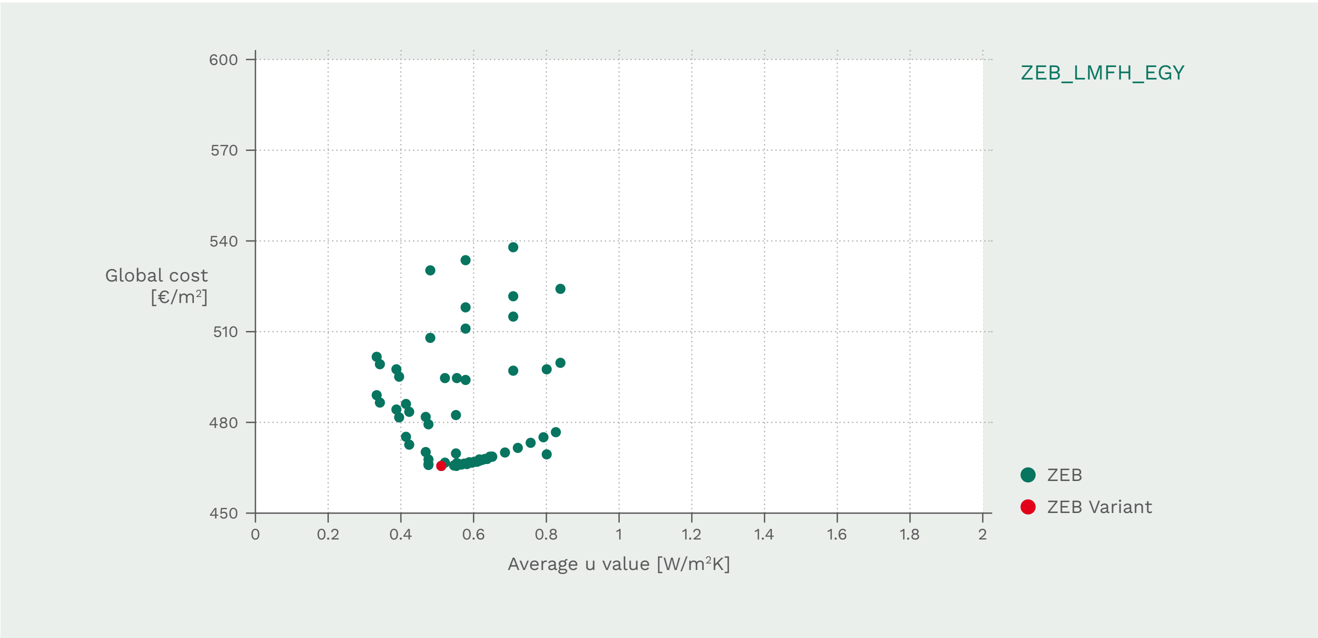


Figure 2-6_Global cost calculations to determine the cost optimal ZEB-specifications (STEP 2)

STEP 3 _Identification of Zero Emission Ready Building (ZERB) requirements

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 less than 1 % higher global costs than the cost optimum but with 15 % lower global costs than the baseline (common practice). The remaining final energy need of 10 kWh/m² is about 10-times smaller than baseline.

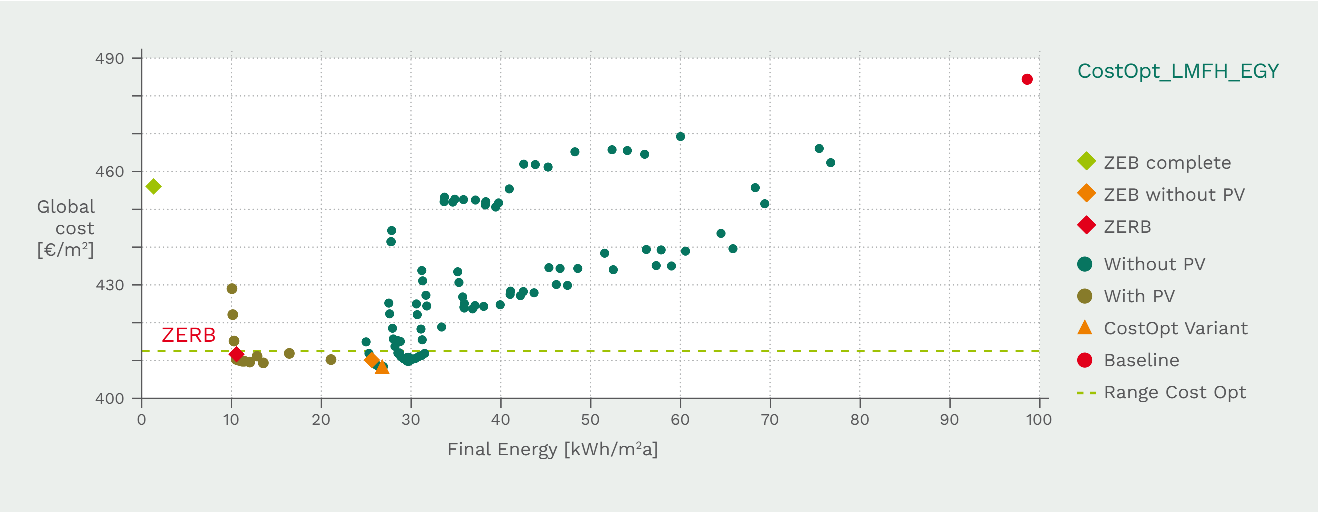


Figure 2-7 _Identification of recommended Zero Emission Ready Building (ZERB)

The key specifications of the ZERB-variant

Roof and walls:	u = 0.30 W/m²K (→ 10 cm insulation)
Ground floor:	u = 0.60 W/m²K (→ 4 cm insulation)
Windows:	Double glazed with solar coating (u = 1.5 W/m²K; SHCG = 0.3)
AC:	High efficiency split units (EER = 5.6)
Shading:	Fixed shading elements
PV:	20 $W/m^2_{\text{net floor area}}$
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:

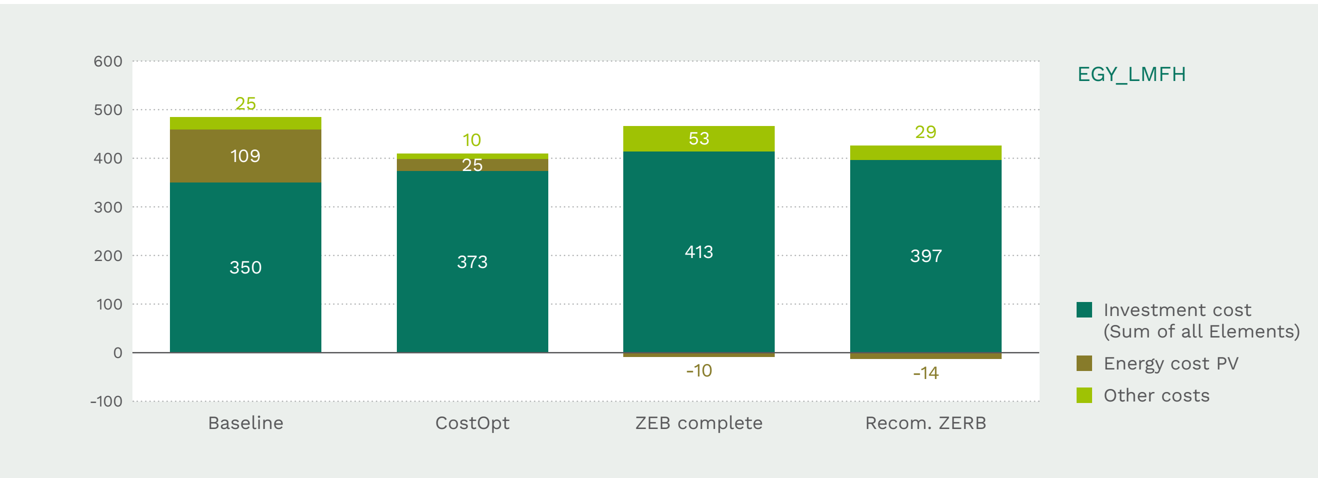


Figure 2-8 _Global cost comparison most relevant variants, including baseline and the recommended ZERB

The required 13.5 % higher initial investment costs of the recommended ZERB compared to Baseline will be paid back by the reduced OPEX in about eight 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

STEP 1 _Identification of Cost Optimum

The cost optimum for an office building is reached at a final energy demand of 19 kWh/m²a. While the baseline variant results in global costs of about 800 €/m², the global cost of the cost optimum variant are only 650 €/m², a reduction of nearly 20 %. Unlike in residential buildings, adding PV in this case reduces the overall costs, making it relevant for the cost-optimal variant. Due to the net metering subsidy, the cost-optimal PV system size is achieved when the electricity produced by the PV system matches the building's total electricity demand.

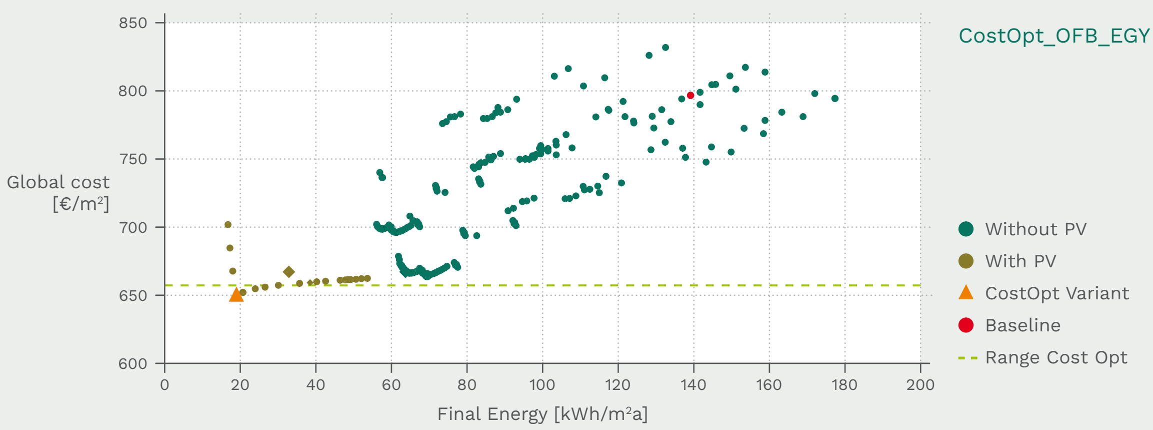


Figure 2-9 _Global cost calculations for identification of the acceptable global cost limit (STEP 1)

The key specifications of the cost-optimal variant

Roof and walls:	u = 0.30 W/m²K (→ 10 cm insulation)
Ground floor:	u = 0.60 W/m²K (→ 4 cm insulation)
Windows:	Double glazed with solar coating (u = 1.5 W/m²K; SHCG = 0.3)
AC:	High efficiency chiller system
Shading:	Fixed shading elements
PV:	57 $W/m^2_{\text{net floor area}}$

STEP 2

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 0.5 W/m²K.

The key specifications of the ZEB variant

Walls:	u = 0.25 W/m²K
Roof:	u = 0.15 W/m²K
Ground floor:	u = 0.60 W/m²K
Windows:	Triple glazed with solar coating (u = 0.9 W/m²K; SHCG = 0.25)
AC:	High efficiency central chiller system
Shading:	Fixed shading elements
PV:	45 $W/m^2_{\text{net floor area}}$
Battery capacity:	85 $Wh/m^2_{\text{net floor area}}$

The required PV size for the ZEB is even a bit 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.

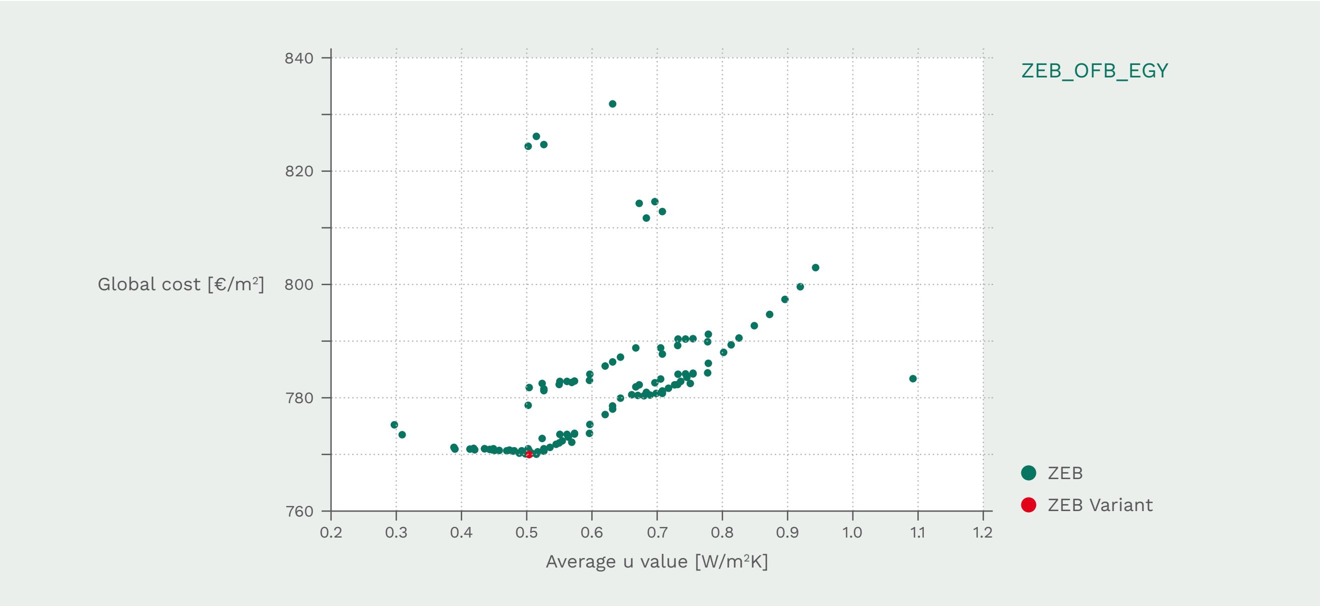


Figure 2-10 _Global cost calculations to determine the cost optimal ZEB-specifications (STEP 2)

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 considering space limitations for PV, the non-residential ZERB in Egypt would require 45 W/m²$_{\text{net floor area}}$ in PV capacity. However, if the PV installation is restricted to the available roof space of the reference office building[40], only 20 W/m$_{\text{net floor area}}$ in PV capacity would be feasible, which would not fully cover the building's electricity demand. The ZERB with consideration of roof space limitation has 2.6 % higher global costs than the cost optimum, but still 16 % lower global costs than the baseline (common practice). The remaining final energy need of 33 kWh/m² is more than 4-times smaller than baseline.

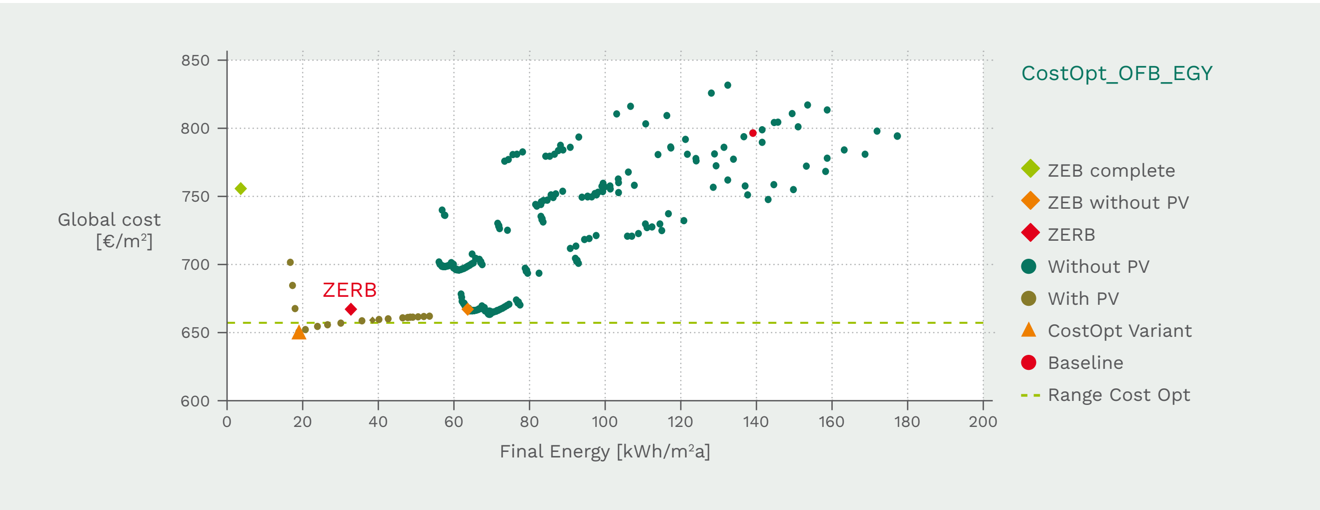


Figure 2-11 _Identification of recommended Zero Emission Ready Building (ZERB)

40 Roof space: 2154 m²; required PV under consideration of roof space limitations 215 kWp.

The key specifications of the ZERB-variant

Walls:	u = 0.25 W/m²K
Roof:	u = 0.15 W/m²K
Ground floor:	u = 0.60 W/m²K
Windows:	Triple glazed with solar coating (u = 0.9 W/m²K; SHCG = 0.25)
AC:	High efficient central chiller system
Shading:	Fixed shading elements
PV:	20 $W/m^2_{net\ floor\ area}$ with consideration of roof space limitation
	≥[41] 45 $W/m^2_{net\ floor\ area}$ 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:

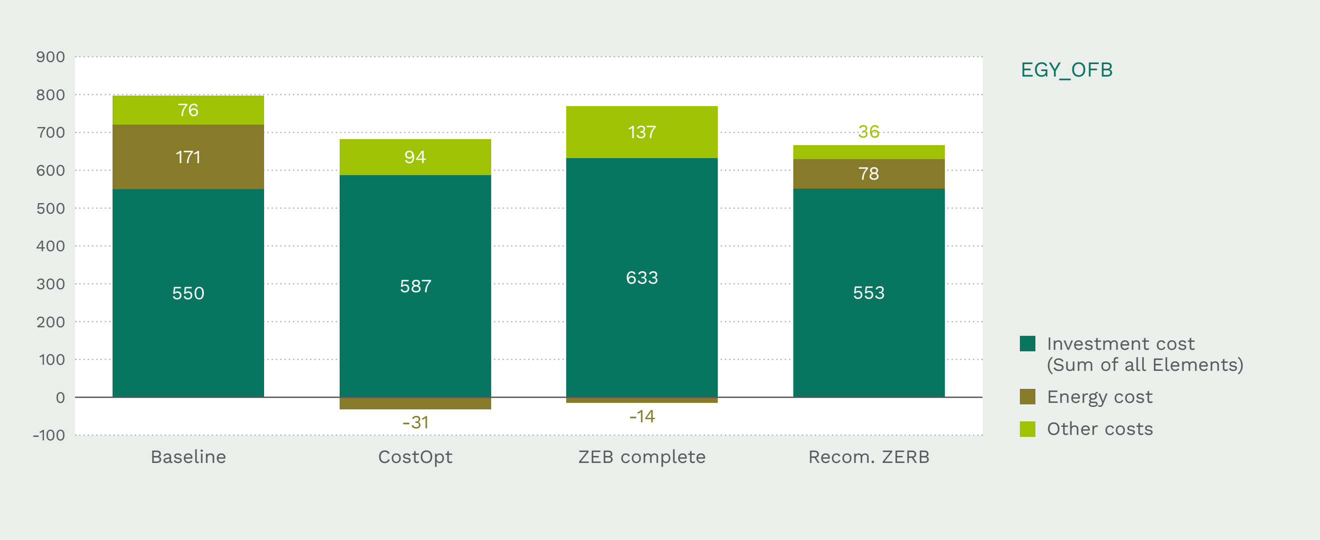


Figure 2-12 _Global cost comparison most relevant variants, including baseline and the recommended ZERB

The introduced energy efficiency measures in the ZERB variant led to a capacity reduction of central chiller system. This impacted the overall Capex positively, as it is only 0.5 % higher than the one for the Baseline. Together with the reduced Opex, the payback of the ZERB measures can be reached in less than one year.

41 Although only 45 W/m² is required to reach ZEB, larger PV capacities would lead to even lower global costs, due to the current net metering subsidy for PV.

2.3.4 Jordan

2.3.4.1 Boundary conditions

Climate

The analysis for Jordan was based on Amman as reference climate, as that is supposed to be the most relevant local climate zone. It is expected that consideration of other local climate zones like valley climate or desert climate will have an impact on the results. Therefore, it is recommended to perform further comparable examinations to the determine the cost optimal requirements also for the other relevant local climates in Jordan.

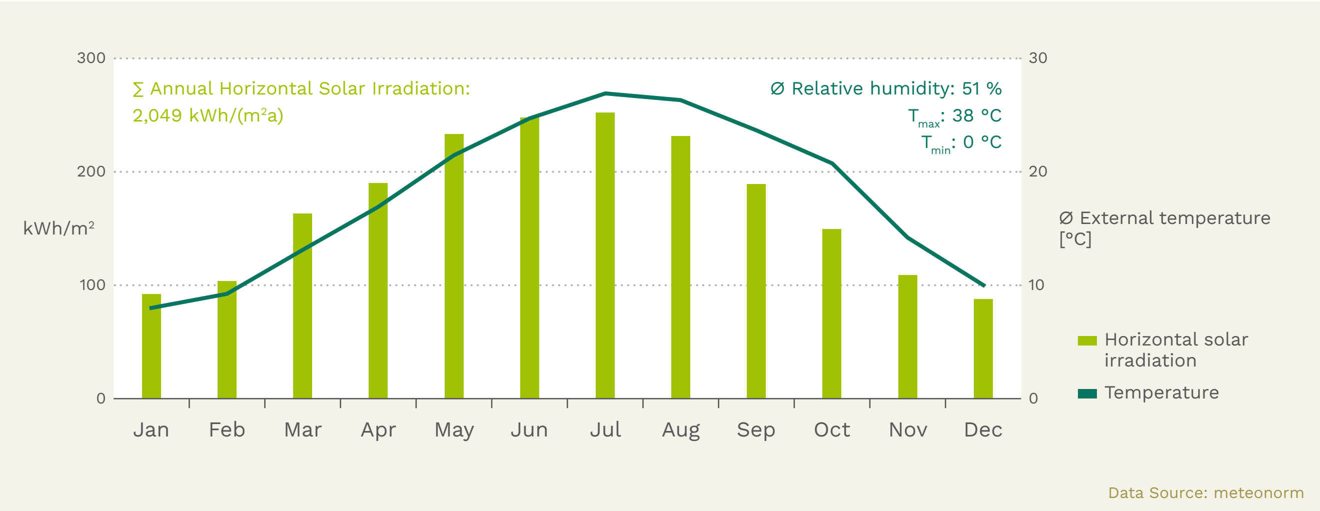


Figure 2-13 _Climate diagram Amman

The climate in Amman is moderate. The annual average temperatures are about 18 °C.

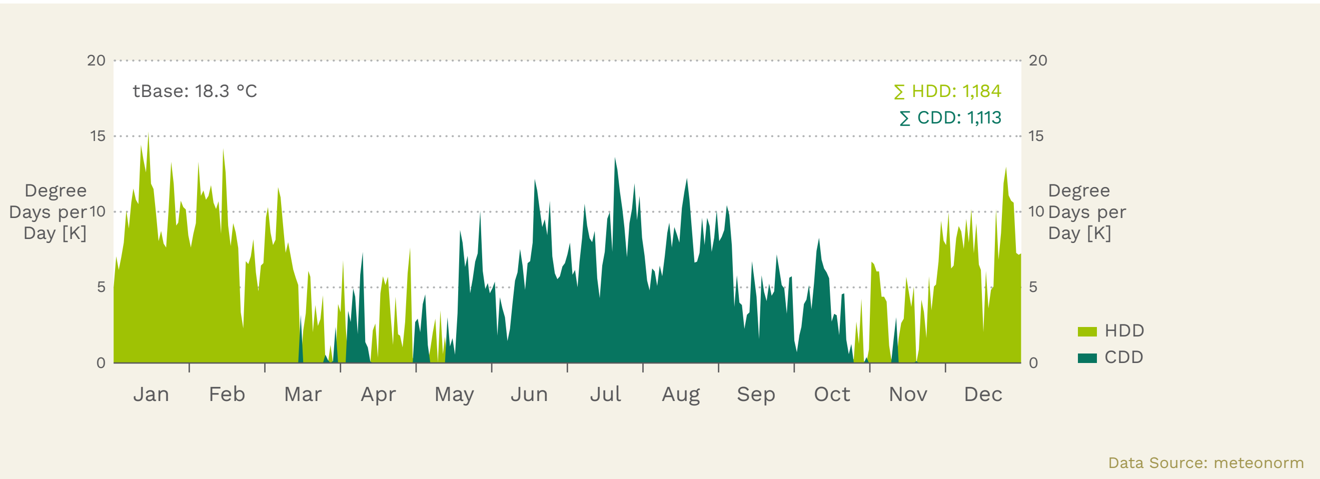


Figure 2-14 _heating- and cooling degree days Amman

A few hours per year undercut the freezing point in Amman.

There are similar heating and cooling degree days of around 1,150 Kd indicate a balanced and moderate need for heating and cooling.

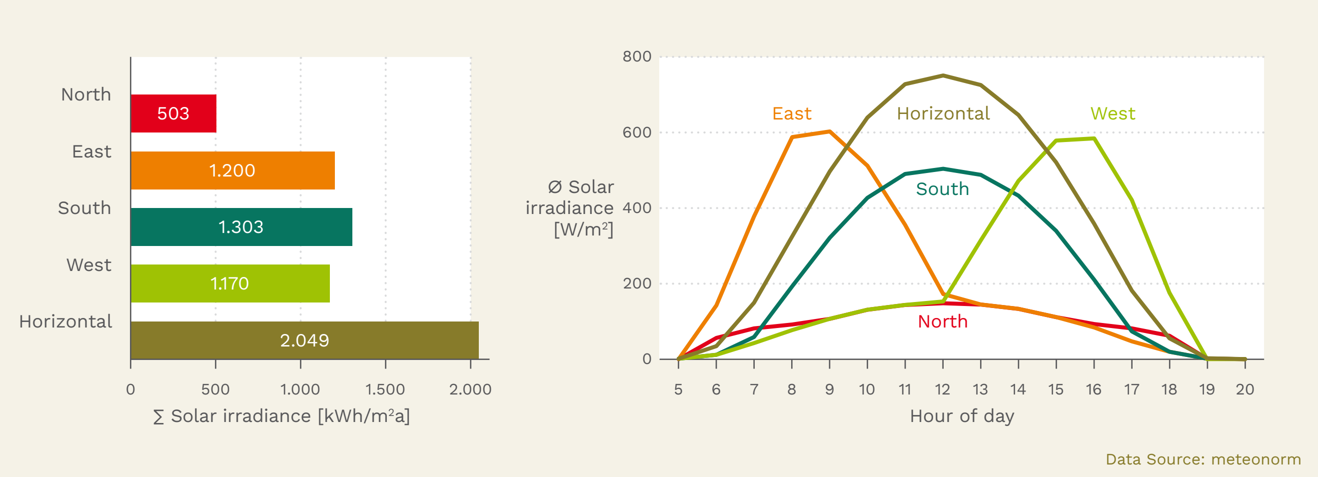


Figure 2-15 _Solar radiation Amman

There is a high horizontal irradiation of > 2,000 kWh/m²a and > 1,100 kWh/m²a for East, South and West orientation. Because of that, buildings in Amman have a big potential to produce energy through solar radiation (e.g. solar water heaters, PVs and solar cooling).

Buildings

Key specifications of the considered reference buildings:

Buildings	Multi Family House	Office Building
Net floor area	2,629 m²	926 m²
Roof area	478 m²	294 m²
Opaque wall area	1,554 m²	907 m²
Window area	389 m²	389 m²
Ground floor area	478 m²	294 m²
Heating- and AC-System	Reversible split units[42]	Reversible split units
DHW System	Dedicated electric heater	–
Ventilation system	–	N/A
Lighting system	LED	LED
Internal loads (average)	3.5 W/m²	3 W/m²

Table 2-13 _Key specifications

42 Standard Baseline of a Jordanian Residential Reference Building uses a portable LPG heater. To be able to reach zero CO_2 -emissions the standard Baseline was adapted to a full electric solution (→ Baseline-el).

Variants

As the common practice (Baseline) for residential heating in Jordan is a portable LPG heater, it was necessary to consider an additional adapted all electric baseline with reversible split units for heating (Baseline el). The configuration of the baselines as well as types and ranges of parameters considered for cost optimality calculation variants are listed in the following tables.

Buildings	Multi Family House			Office Building		
U-Values [W/m²K]	Wall	Roof	Floor	Wall	Roof	Floor
Baseline	0.57	0.55	1.2	0.57	0.55	1.2
Variant ranges	0.15 – 0.5	0.1 – 0.5	0.5 – 0.7	0.26 – 0.36	0.28 – 0.35	0.5 – 0.7
Windows						
Baseline	Single glazing (u_w = 5.7 W/m²K; SHCG = 0.85)			Double glazing Air (u_w = 3.0 W/m²K; SHCG = 0.7)		
Variants	▪ Single glazing (u_w = 5.7 W/m²K; SHCG = 0.85) ▪ Double glazing Air (u_w = 2.9 W/m²K; SHCG = 0.7) ▪ Double glazing Argon (u_w = 1.2 W/m²K; SHCG = 0.7) ▪ Double glazing Solar (u_w = 1.5 W/m²K; SHCG = 0.3)			▪ Double glazing Air (u_w = 3.0 W/m²K; SHCG = 0.7) ▪ Single glazing (u_w = 5.7 W/m²K; SHCG = 0.85) ▪ Double glazing Air (u_w = 2.9 W/m²K; SHCG = 0.7) ▪ Double glazing Argon (u_w = 1.2 W/m²K; SHCG = 0.7) ▪ Double glazing Solar (u_w = 1.5 W/m²K; SHCG = 0.3)		
Shading						
Baseline	Movable Manual Shading			Movable Manual Shading		
Variants	▪ Movable Manual Shading ▪ Fixed Shading			▪ Movable Manual Shading ▪ Fixed Shading		
Heating and AC Systems						
Baseline	Standard efficiency			Standard efficiency		
Variants	▪ Standard efficiency ▪ Improved efficiency ▪ High efficiency			▪ Standard efficiency ▪ Improved efficiency ▪ High efficiency		
PV Capacity [kWp]						
Baseline	0			0		
Variants	30 – 100			10 – 200		
Battery Capacity (kWh)						
Baseline	0			0		
Variants	100 – 151			55 – 114		

Table 2-14 _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		525 €/m^2
Office Building		825 €/m^2
Insulation (Roof/Wall/Ground Floor)		19 € + 4.275 €/cm
Windows		
Single glazing (u_w = 5.7 W/m^2K; SHCG = 0.85)		58 €
Double glazing Air (u_w = 2.9 W/m^2K; SHCG = 0.7)		95 €
Double glazing Argon (u_w = 1.2 W/m^2K; SHCG = 0.7)		152 €
Double glazing Solar (u_w = 1.5 W/m^2K; SHCG = 0.3)		182 €
Shading		
Fix shading elements		115 €/m^2
Manual movable shading		124 €/m^2
Automatic movable shading		368 €/m^2
AC System (costs derived from equation: $a * x^2 + b * x + c$ with x = design capacity in kW)		
Standard efficiency	Reversible split units (EER[35] = 3.3)	a = 0; b = 115.53; c = 105.84
Improved efficiency	Reversible split units (EER[35] = 4.5)	Standard cost + 15 %
High efficiency	Reversible split units (EER[35] = 5.6)	Standard cost + 30 %
PV		120€ + 1,000 €/kWp
Battery		400 €/kWh

Electricity price	**0.15 €/kWh** (3 % annual increase)
PV feed in tariff (net metering[43])	**0.15 €/kWh** (3 % annual increase)

Table 2-15 _Investment costs

43 Bonification up to the total annual electricity demand; beyond: no bonification

2.3.4.2 Results

The following chapter contains the results of global cost calculations to determine the acceptable cost limit (see methodology, **STEP 1**) and to identify the cost-optimal ZEB specifications (see methodology, **STEP 2**) as well as the derived country specific zero-emission-ready building (ZERB) requirements (see methodology, **STEP 3**) for the two beforementioned building types.

New multi family house

STEP 1 _Identification of Cost Optimum

STEP 1

Starting from the baseline variant (upper right corner of figure 16) adding efficiency measures, like improved thermal insulation of roof, walls and floor, double glazed windows with solar coating, High efficiency AC and specifically PV leads to a significant reduction of global costs. The reduced Opex of the variants overweighs the higher Capex. The cost optimum is reached at a final energy demand about 10 kWh/m²a. While the Baseline-el variant results in global costs of more than 640 €/m², the global cost of the cost optimum variant are just about 450 €/m², a reduction of about 30 %.

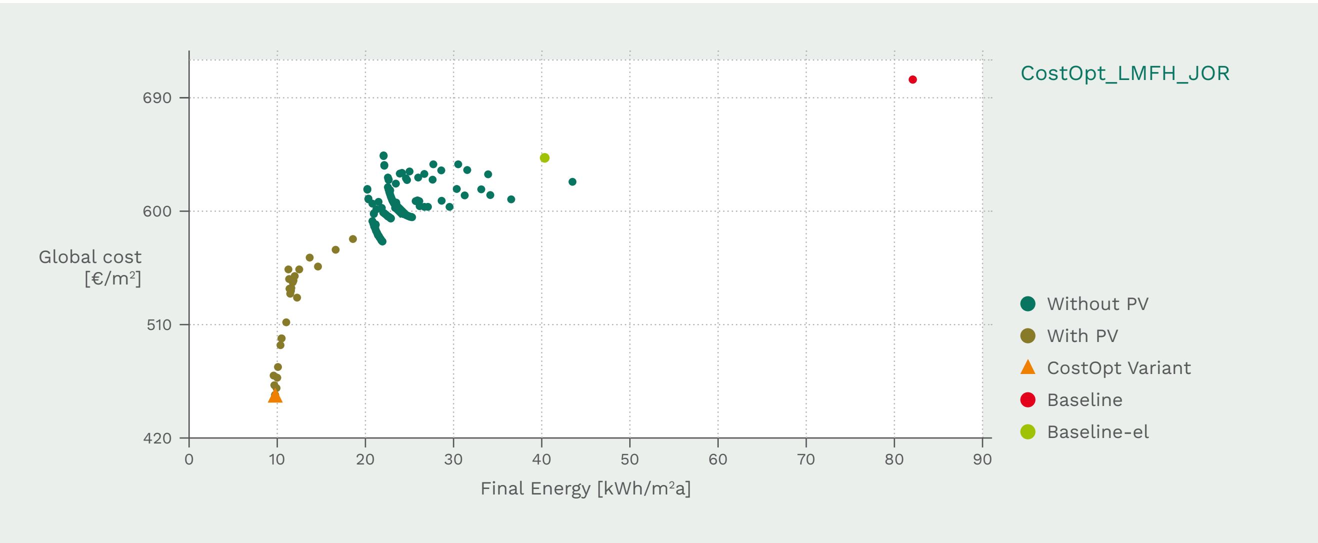


Figure 2-16 _Global cost calculations for identification of the acceptable global cost limit (STEP 1)

The key specifications of the cost-optimal variant

Roof and walls:	u = 0.36 W/m²K
Ground floor:	u = 1.2 W/m²K
Windows:	Double glazed with Argon filling (u = 1.2 W/m²K; SHCG = 0.7)
AC:	High efficiency split units (EER = 5.6)
Shading:	Fixed shading elements
PV:	30 W/m²$_{\text{net floor area}}$
Battery:	No

STEP 2

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. That is the main reason why the global costs of cost optimal configuration, necessary to achieve a climate neutral (energy self-sufficient) building, are high.

The cost optimal ZEB is reached by a variant with a highly efficient AC system, a fixed shading and an average u-value of 0.61 W/m²K.

The key specifications of the ZEB variant

Roof and walls:	u = 0.36 W/m²K
Ground floor:	u = 1.2 W/m²K
Windows:	Double glazed with Argon filling (u = 1.2 W/m²K; SHCG = 0.7)
AC:	High efficiency split units (EER = 5.6)
Shading:	Fixed shading elements
PV:	19 $W/m^2_{net\ floor\ area}$
Battery capacity:	48 $W/m^2_{net\ floor\ area}$

Despite PV and Battery, the ZEB specifications are identical with the cost optimum.

Global costs of the ZEB are significantly less than the global costs of Baseline-el variant[44].

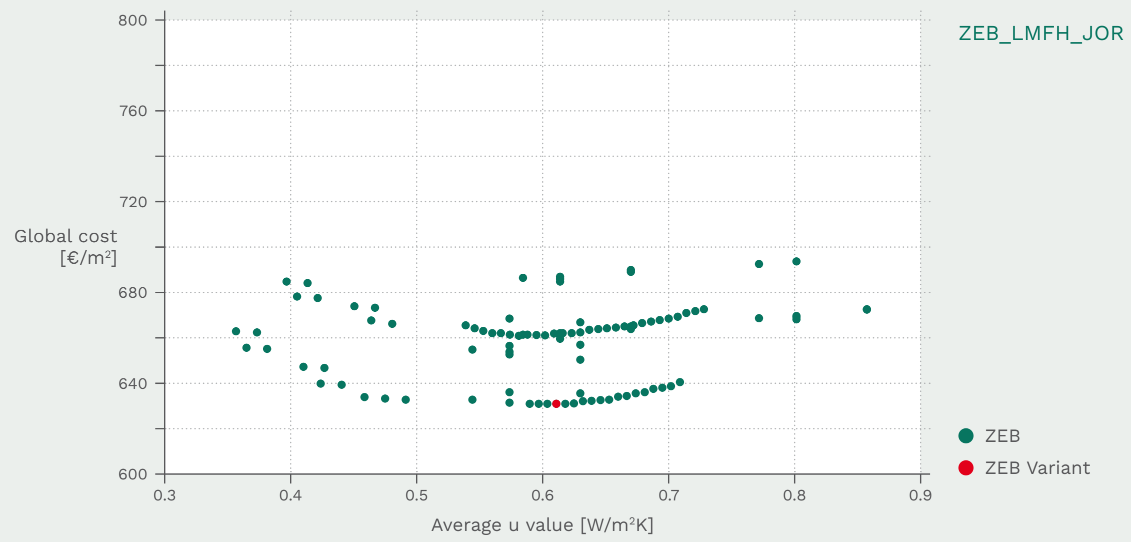


Figure 2-17 _Global cost calculations to determine the cost optimal ZEB-specifications (STEP 2)

STEP 3

STEP 3 _Identification of Zero Emission Ready Building (ZERB) requirements

The recommended ZERB is considering efficiency measures of ZEB but without battery as this is not financially feasible under current circumstances. Without considering space limitations for PV, the residential ZERB for Jordan would require 19 $W/m^2_{net\ floor\ area}$ in PV capacity. However, if the PV installation is restricted to the available roof space of the reference office building[45], only 18 $W/m_{net\ floor\ area}$ in PV capacity would be feasible. The ZERB with consideration of roof space limitation will have 10 % higher global costs than the cost optimum, but still 22 % lower global costs than the Baseline-el. The remaining final energy need of 10 kWh/m² is about 4-times lower than Baseline-el and 8-time lower than the Baseline.

44 ZEB: 631 €/m³; Baseline: 705 €/m²

45 Roof space: 478 m²; required PV under consideration of roof space limitations 47 kWp

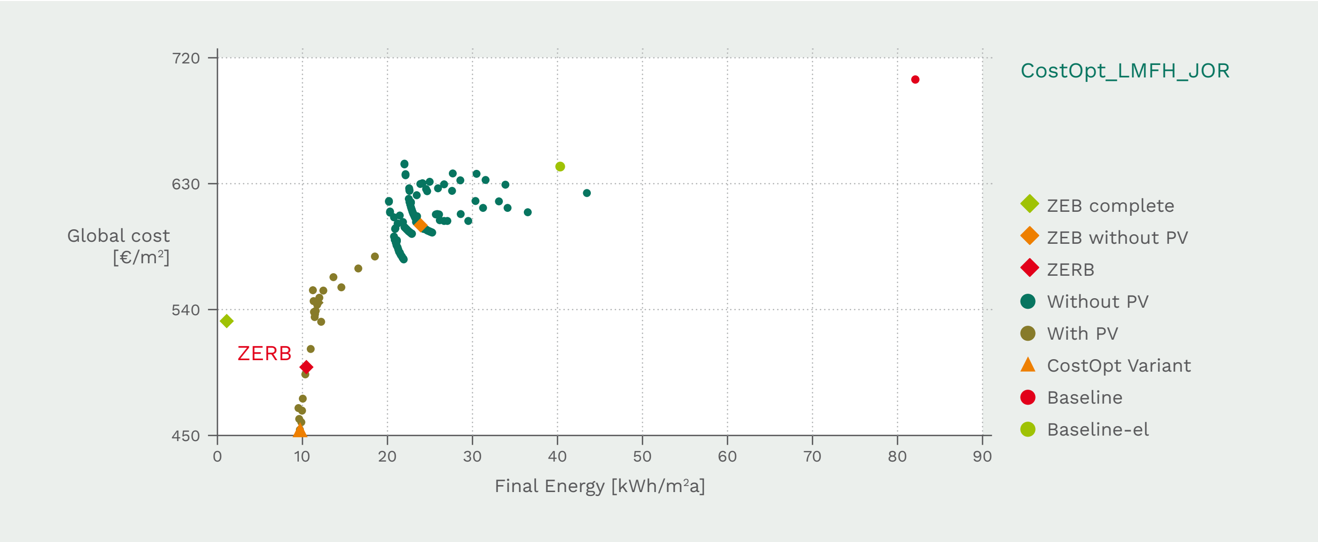


Figure 2-18 _Identification of recommended Zero Emission Ready Building (ZERB)

The key specifications of the ZERB-variant

Roof and walls:	u = 0.36 W/m²K
Ground floor:	u = 1.2 W/m²K
Windows:	Double glazed with Argon filling (u = 1.2 W/m²K; SHCG = 0.7)
AC:	High efficiency split units (EER = 5.6)
Shading:	Fixed shading elements
PV:	18 $W/m^2_{\text{net floor area}}$ with consideration of roof space limitation
	≥[46] 19 $W/m^2_{\text{net floor area}}$ without roof space limitation
Battery:	No, just reservation of sufficient space for later installation

The following figure provides an overview of the most relevant variants and the breakdown of their global costs:

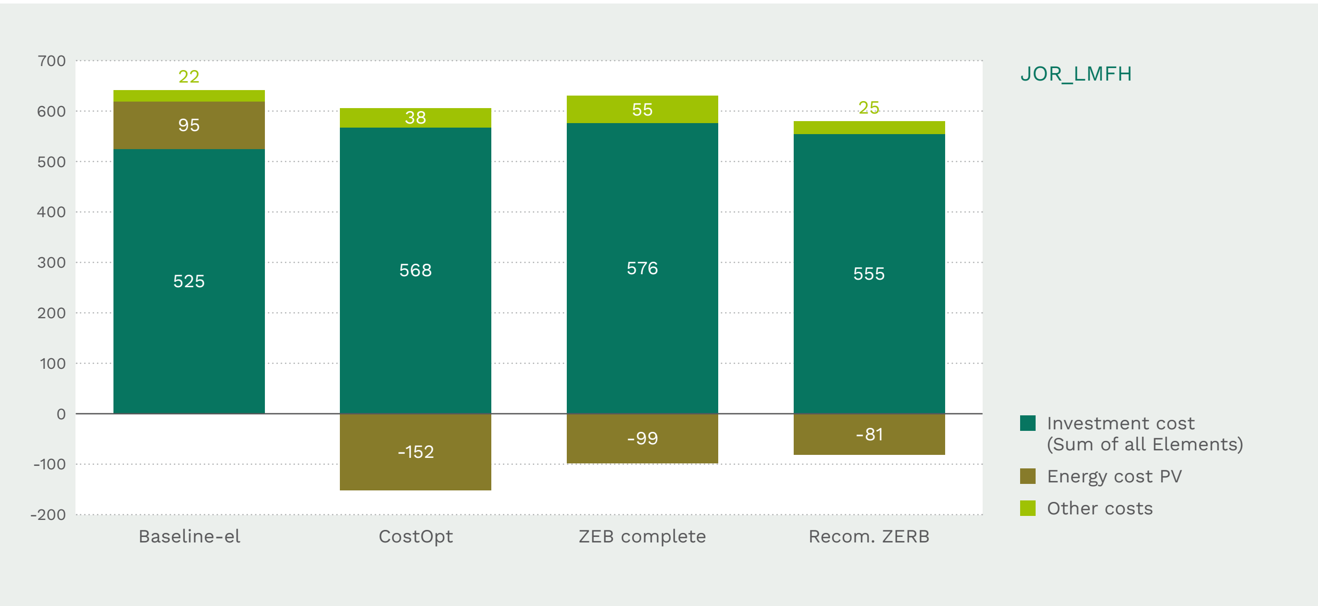


Figure 2-19 _Global cost comparison most relevant variants, including baseline and the recommended ZERB

46 Although only 19 W/m² is required to reach ZEB, larger PV capacities would lead to even lower global costs, due to the current net metering subsidy for PV.

The recommended ZERB requires 6 % higher initial investment costs compared to Baseline-el, but those will be paid back by the reduced Opex in less than four years.

Remark: the negative energy costs of CostOpt, ZEB complete and the 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 12 kWh/m²a. While the baseline variant results in global costs of about 1140 €/m², the global cost of the cost optimum variant are only 805 €/m², a reduction of nearly 30 %. PV is reducing the global costs significantly and therefore, relevant for the cost optimal variant.

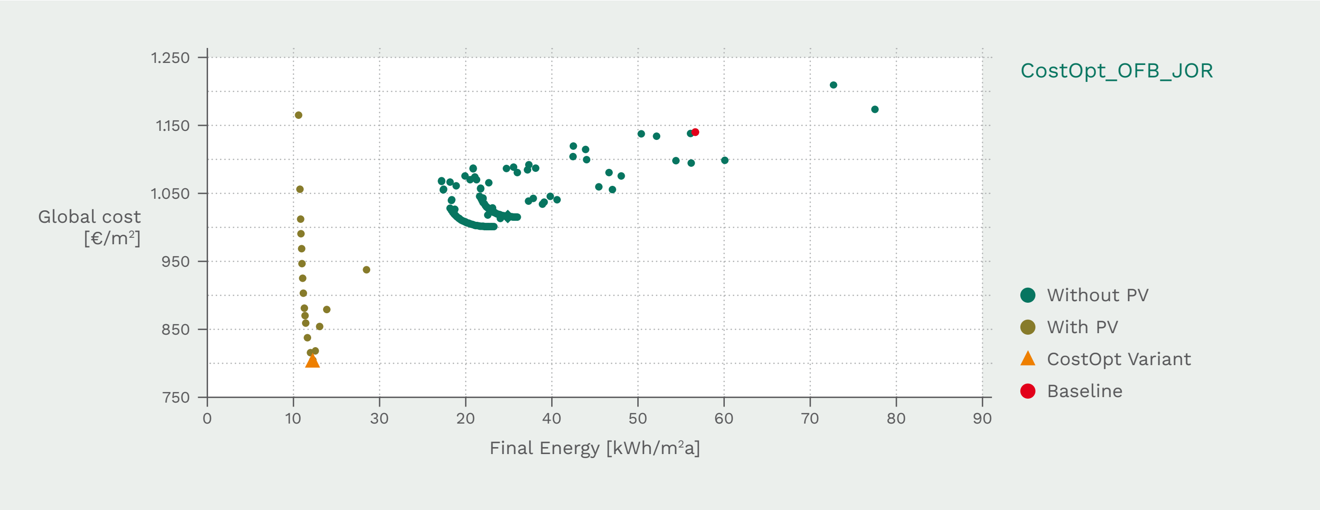


Figure 2-20 _Global cost calculations for identification of the acceptable global cost limit (STEP 1)

The key specifications of the cost-optimal variant

Roof and walls: u = 0.47 W/m²K (in line with current regulations)
Ground floor: u = 1.20 W/m²K
Windows: Double glazed with solar coating (u = 1.5 W/m²K; SHCG = 0.3)
AC: High efficient AC
Shading: Fixed shading elements
PV: 38 $W/m^2_{\text{net floor area}}$

STEP 2 _Determination the cost optimal ZEB-specifications

The cost optimal ZEB is reached by a variant with a high-efficient central chiller system, a fixed shading and an average u-value of 0.71 W/m²K.

The key specifications of the ZEB variant

Roof and walls: u = 0.43 W/m²K
Ground floor: u = 1.20 W/m²K
Windows: Double glazed with Argon filling (u = 1.2 W/m²K; SHCG = 0.7)
AC: High efficiency central chiller system
Shading: Fixed shading elements
PV: 28 $W/m^2_{\text{net floor area}}$
Battery capacity: 70 $Wh/m^2_{\text{net floor area}}$

It should be mentioned that the global costs of the ZEB (with almost no energy costs) are already significantly lower than the global costs of baseline variant[47].

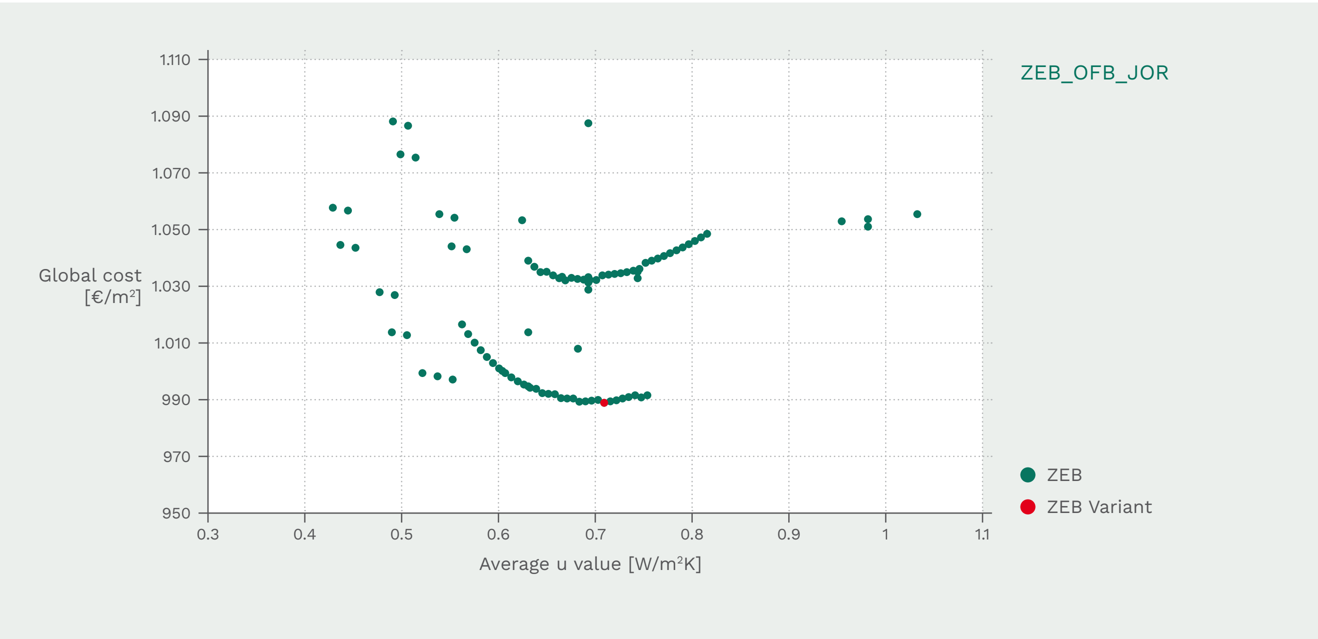


Figure 2-21 _Global cost calculations to determine the cost optimal ZEB-specifications (STEP 2)

STEP 3 _Identification of Zero Emission Ready Building (ZERB) requirements

The recommended ZERB is considering the efficiency measures of ZEB but excludes its battery. In reference to the utilization of PV: the non-residential ZERB in Jordan requires 32 $W/m^2_{\text{net floor area}}$ PV. The ZERB will have 2.8 % higher global costs than the cost optimum, but 27 % lower global costs than the Baseline (common practice). The remaining final energy need of 8.5 kWh/m² is more than 6-times smaller than baseline.

47 ZEB: 989 €/m² (without the consideration of the additional net metering benefit the global costs); Baseline: 1140 €/m²

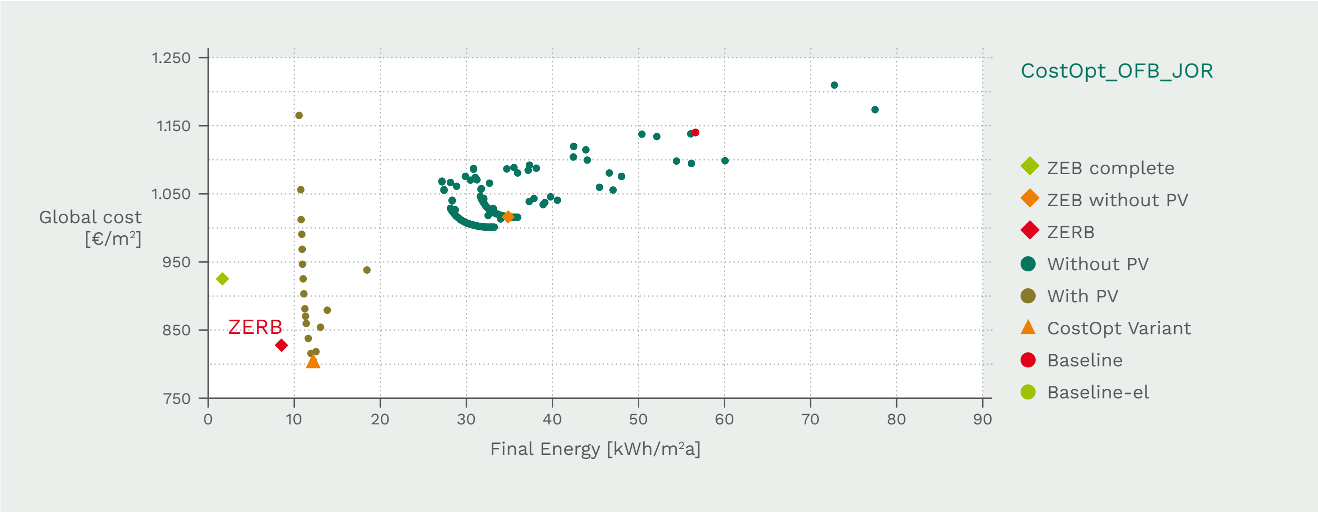


Figure 2-22 _Identification of recommended Zero Emission Ready Building (ZERB)

The key specifications of the ZERB-variant

Roof and walls:	u = 0.43 W/m²K
Ground floor:	u = 1.2 W/m²K
Windows:	Double glazed with Argon filling (u = 1.2 W/m²K; SHCG = 0.7)
AC:	High efficiency central chiller system
Shading:	Fixed shading elements
PV:	≥[48] 28 $W/m^2_{\text{net floor area}}$
	32 $W/m^2_{\text{net floor area}}$ with consideration of 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:

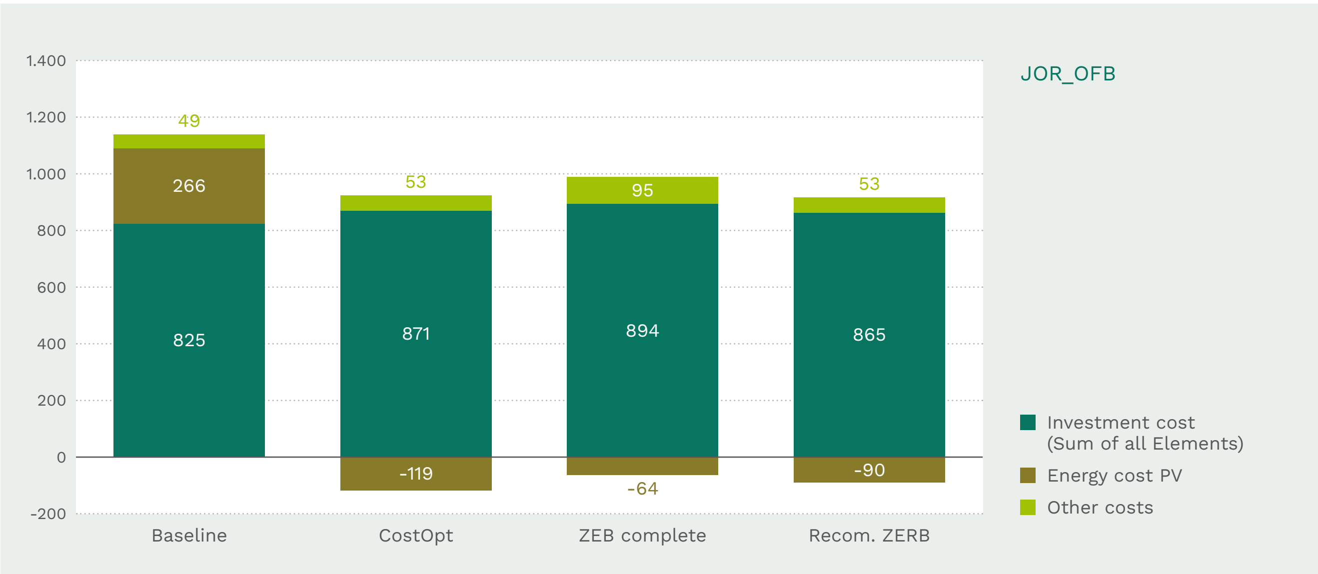


Figure 2-23 _Global cost comparison most relevant variants, including baseline and the recommended ZERB

The Capex of the ZERB is "just" 4.8 % higher than the initial investment costs of the Baseline, this is mainly caused through the much smaller needed AC capacity size.

48 Although only 28 W/m² is required to reach ZEB, larger PV capacities would lead to even lower global costs, due to the current net metering subsidy for PV

2.3.5 Lebanon

2.3.4.1 Boundary conditions

Climate

The analysis for Lebanon was based on Beirut as reference climate, as that is supposed to be the most relevant local climate zone. It is expected that consideration of other local climate zones like mountain climate will have an impact on the results. Therefore, it is recommended to perform further examinations to the determine the cost optimal requirements also for the other relevant local climates.

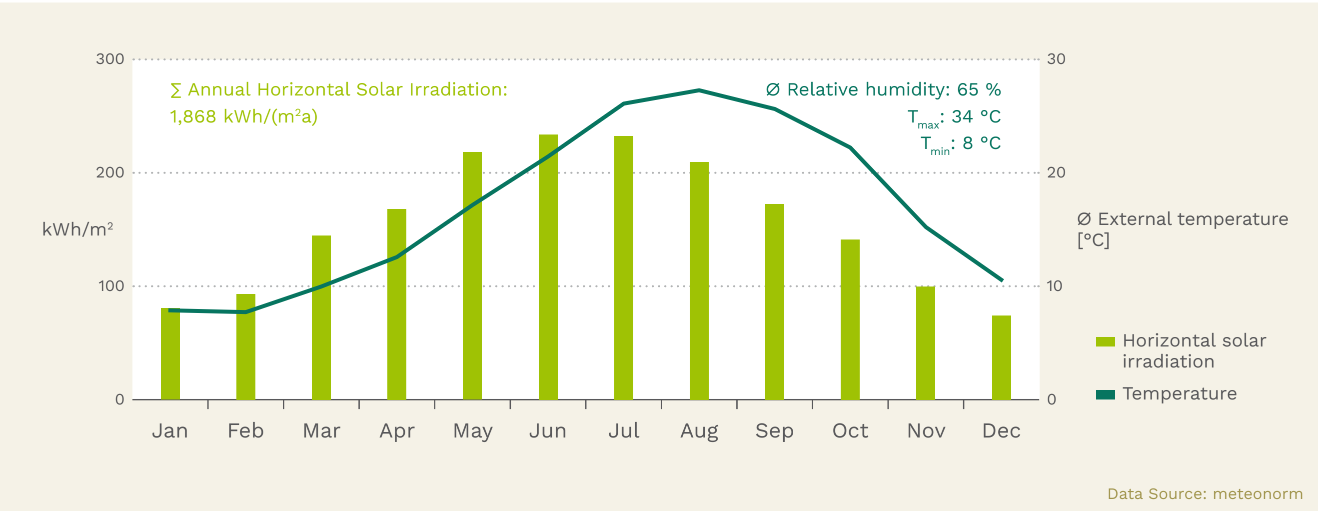


Figure 2-24 _climate diagram Beirut

The climate in Beirut is primarily warm and humid. External temperatures range from 8 °C above 0 °C to 34 °C, with average temperatures around 20 °C.

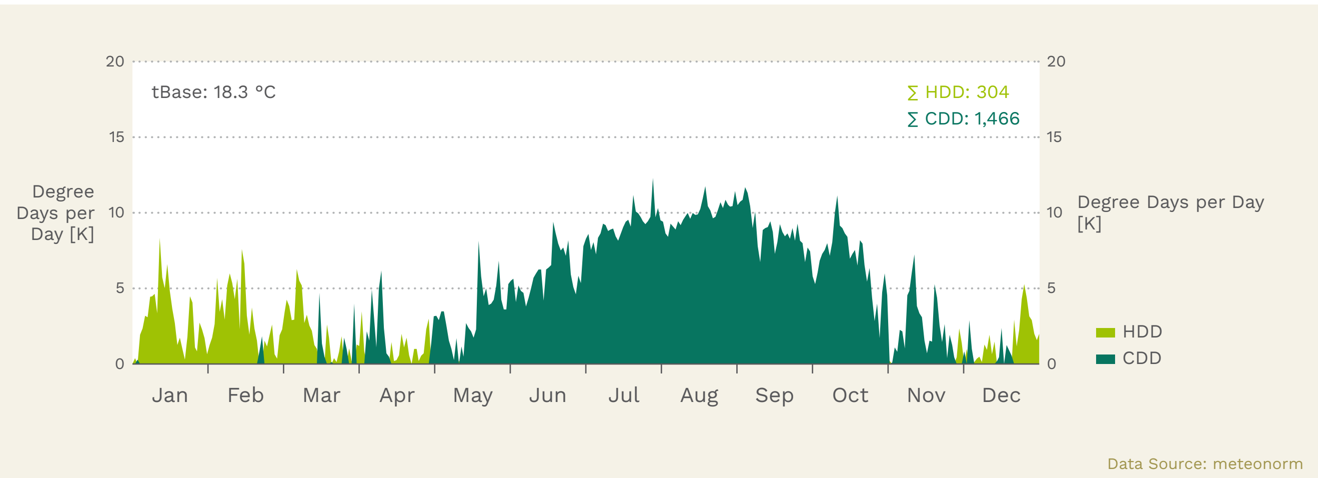


Figure 2-25 _heating- and cooling degree days Beirut

The demand for cooling prevails against heat demand as the high number of > 1,300 CDDs. The cooling degree days are 4 times higher than the HDDs. The monthly average relative humidity is above 65 % but may also reach > 70 % in the summer months.

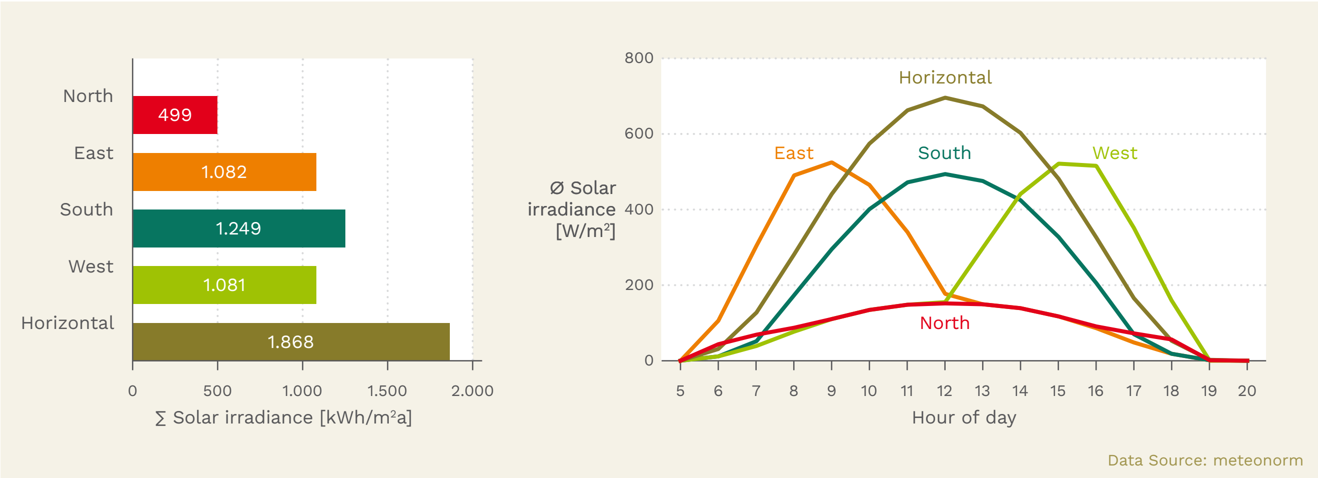


Figure 2-26 _Solar radiation Beirut

Beirut experiences a horizontal irradiation of > 1,800 kWh/m²a and > 1,000 kWh/m²a for each East, South, and West orientations.

The horizontal solar radiation promises a high potential for the utilization of solar energy.

Buildings

Key specification of the considered reference buildings:

Buildings	**Multi Family House** (high rise building)	**Office Building** (high rise building)
Net floor area	7,200 m²	2,079 m²
Roof area	534 m²	210 m²
Opaque wall area	3,011 m²	1,112 m²
Window area	1,841 m²	1,841 m²
Ground floor area	534 m²	210 m²
Heating- and AC-System	Reversible multi-split[49]	Reversible multi-split
DHW System	Electric heater with thermosiphon	–
Ventilation system	–	Mechanical ventilation system without heat recovery
Ventilation rate (including infiltration)	–	0.9 1/h
Lighting system	LED	LED
Internal loads (average)	3 W/m²	3 W/m²

Table 2-16 _Key specifications

49 Standard Baseline of a Lebanon Residential Reference Building uses an oil non-condensing heater. To be able to reach zero CO_2 -Emissions the standard Baseline was adapted to a full electric solution with a reversible multi-split system (Baseline-el).

Variants

As the common practice (baseline) for residential heating in Lebanon is an oil non-condensing heater, it was necessary to consider an additional adapted all electric baseline with a reversible multi-split system for heating (Baseline el). The configuration of the Baselines as well as types and ranges of parameters considered for cost optimality calculations are listed in the following tables.

Buildings	Multi Family House			Office Building		
U-Values [W/m²K]	Wall	Roof	Floor	Wall	Roof	Floor
Baseline	0.6	0.7	22	0.8	0.7	2.4
Variant ranges	0.15 – 0.4	0.1 – 0.5	0.6 – 1.2	0.15 – 0.6	0.1 – 0.56	1.2 – 2.2
Windows						
Baseline	Double glazing Air (u_W = 2.8 W/m²K; SHCG = 0.7)			Double glazing Air (u_W = 2.8 W/m²K; SHCG = 0.7)		
Variants	▪ Double glazing Air (u_W = 2.8 W/m²K; SHCG = 0.7) ▪ Double glazing Argon (u_W = 1.2 W/m²K; SHCG = 0.7) ▪ Double glazing Solar (u_W = 1.5 W/m²K; SHCG = 0.3) ▪ Triple glazing Solar (u_W = 0.9 W/m²K; SHCG = 0.25) ▪ Triple glazing (u_W = 0.9 W/m²K; SHCG = 0.55)			▪ Double glazing Air (u_W = 2.8 W/m²K; SHCG = 0.7) ▪ Double glazing Argon (u_W = 1.2 W/m²K; SHCG = 0.7) ▪ Double glazing Solar (u_W = 1.5 W/m²K; SHCG = 0.3) ▪ Triple glazing Solar (u_W = 0.9 W/m²K; SHCG = 0.25) ▪ Triple glazing (u_W = 0.9 W/m²K; SHCG = 0.55)		
Shading						
Baseline	Movable Manual Shading			Movable Manual Shading		
Variants	▪ Movable Manual Shading ▪ Fixed Shading			▪ Movable Manual Shading ▪ Fixed Shading		
Ventilation						
Baseline	–			Mechanical without heat recovery		
Variants	–			▪ Mechanical without heat recovery ▪ Mechanical 70 % heat recovery		
Heating and AC Systems						
Baseline	Standard efficiency			Standard efficiency		
Variants	▪ Standard efficiency ▪ Improved efficiency ▪ High efficiency			▪ Standard efficiency ▪ Improved efficiency ▪ High efficiency		
PV Capacity [kWp]						
Baseline	0			0		
Variants	10 – 500			10 – 500		
Battery Capacity (kWh)						
Baseline	0			0		
Variants	300 – 866			252 – 561		

Table 2-17 _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		700 €/m²
Office Building		1100 €/m²
Insulation (Roof/Wall/Ground Floor)		14 € + 3.15 €/cm
Windows		
Single glazing (u_w = 5.7 W/m²K; SHCG = 0.85)		127 €
Double glazing Air (u_w = 2.9 W/m²K; SHCG = 0.7)		152 €
Double glazing Argon (u_w = 1.2 W/m²K; SHCG = 0.7)		182 €
Double glazing Solar (u_w = 1.5 W/m²K; SHCG = 0.3)		340 €
Shading		
Fix shading elements		139 €/m²
Manual movable shading		149 €/m²
Automatic movable shading		420 €/m²
AC System (costs derived from equation: $a * x^2 + b * x + c$ with x = design capacity in kW)		
Standard efficiency	VRF/Multi-split (EER[50] = 3.7)	a = 0.13 b = 358.77 c = 745.04
	Single Split (EER[35] = 3.3)	a = 0 b = 179.04 c = 132.81
Improved efficiency	VRF/Multi-split (EER[35] = 4.7)	Standard cost + 15 %
	Single Split (EER[35] = 4.5)	Standard cost + 15 %
High efficiency	VRF/Multi-split (EER[35] = 5.4)	Standard cost + 30 %
	Single Split (EER[35] = 5.6)	Standard cost + 30 %
PV		120€ + 897 €/kWp
Battery		245 €/kWh

Electricity price	**0.60 €/kWh** (3 % annual increase)
PV feed in tariff (net metering[51])	**0.60 €/kWh** (6 % annual increase)

Table 2-18 _Investment costs

50 Part load condition A at 35 °C according to EN 14511-1:2022
51 Bonification up to the total annual electricity demand; beyond: no bonification

2.3.5.2 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 multi family house

STEP 1 _Identification of Cost Optimum

Starting from the baseline and baseline-el variants (upper right corner of the following figure) adding efficiency measures, like improved insulation of roof, walls and floor, triple glazed windows with solar coating, highly efficient AC and specifically also PV a significant reduction of global costs is achieved. The reduced Opex of the variants overweighs the higher Capex. The cost optimum is reached at a final energy demand about only 8 kWh/m²a. While the baseline variants result in global costs of more than 1200 €/m², the global cost of the cost optimum variant are just 600 €/m², less than half.

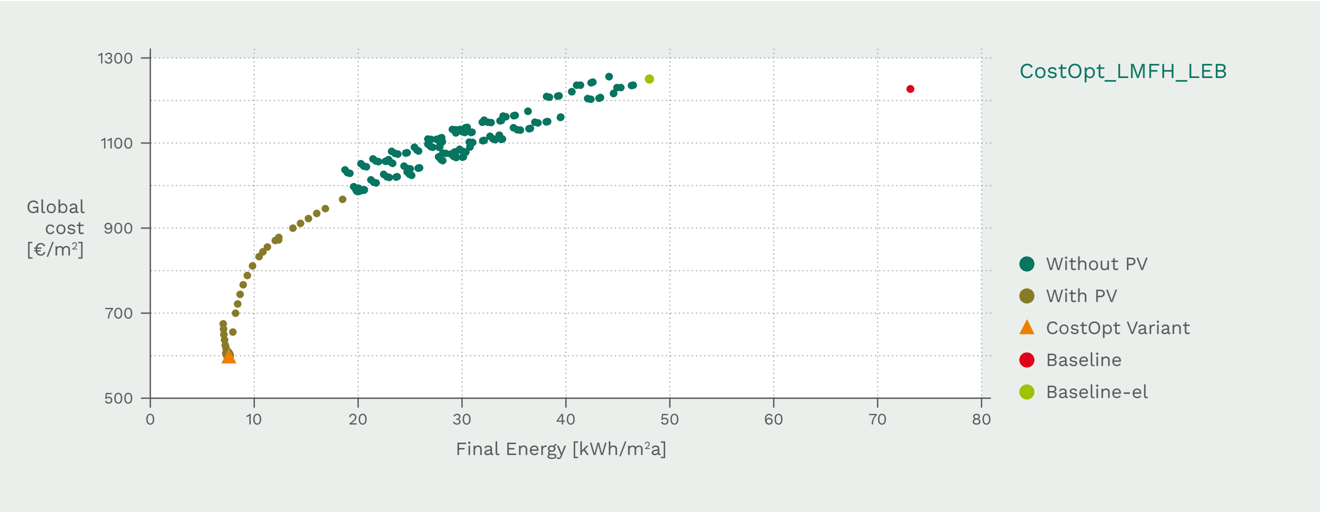


Figure 2-27 _Global cost calculations for identification of the acceptable global cost limit (STEP 1)

The key specifications of the cost-optimal variant

Roof and walls:	u = 0.31 W/m²K
Ground floor:	u = 1.2 W/m²K
Windows:	Triple glazed with solar coating (u = 0.9 W/m²K; SHCG = 0.25)
AC:	High efficient multi-split system
Shading:	Fixed shading elements
PV:	28 $W/m^2_{\text{net floor area}}$
Battery:	No

STEP 2

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.

The cost optimal ZEB is reached by a variant with a High-efficient AC system, a fixed shading and an average u-value of 0.63 W/m²K.

The key specifications of the ZEB variant

Roof and walls: u = 0.40 W/m²K
Ground floor: u = 1.2 W/m²K
Windows: Tripe glazed with solar coating (u = 0.9 W/m²K; SHCG = 0.25)
AC: High efficient multi-split system
Shading: Fixed shading elements
PV: 20 $W/m^2_{net\ floor\ area}$
Battery capacity: 73 $Wh/m^2_{net\ floor\ area}$

The u-values of the ZEB for roof and walls are higher and required PV capacity is lower than the cost optimum.

Global costs of the ZEB (with almost no energy costs) are significantly less than the global costs of baseline variant.

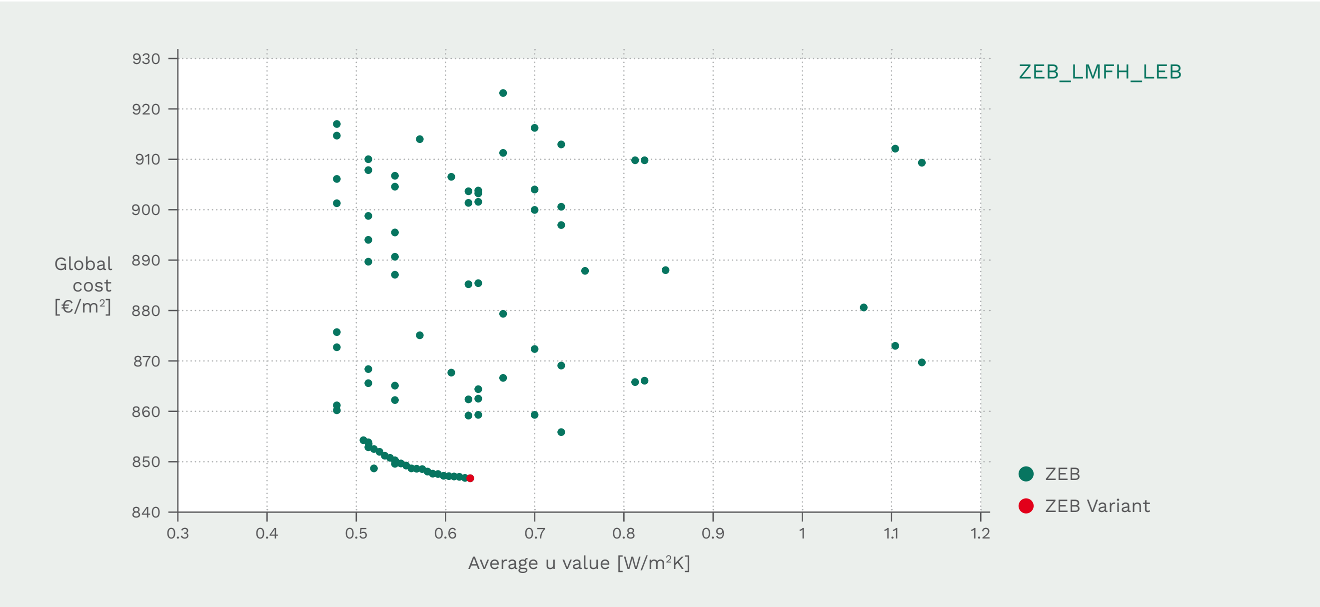


Figure 2-28 _Global cost calculations to determine the cost optimal ZEB-specifications (STEP 2)

STEP 3

STEP 3 _Identification of Zero Emission Ready Building (ZERB) requirements

The recommended ZERB considers the efficiency measures of ZEB, but without battery, which is not cost beneficial under the current circumstances. Residential ZERB for Lebanon should require at least 20 $W/m^2_{net\ floor\ area}$ PV. Restricting the PV to the very limited roof space of the considered high rise building[52], only 7 $W/m^2_{net\ floor\ area}$ PV should be required. The ZERB with consideration of roof space limitation will have 45 % higher global costs than the cost optimum, but still about 30 % lower global costs than the Baselines. The remaining final energy need under consideration of roof space-limitation is 12 kWh/m², which is about 4-times lower than Baseline-el and more than 6-times lower than the Baseline with an oil heating.

52 Roof space: 534 m²; required PV under consideration of roof space limitations 53 kWp

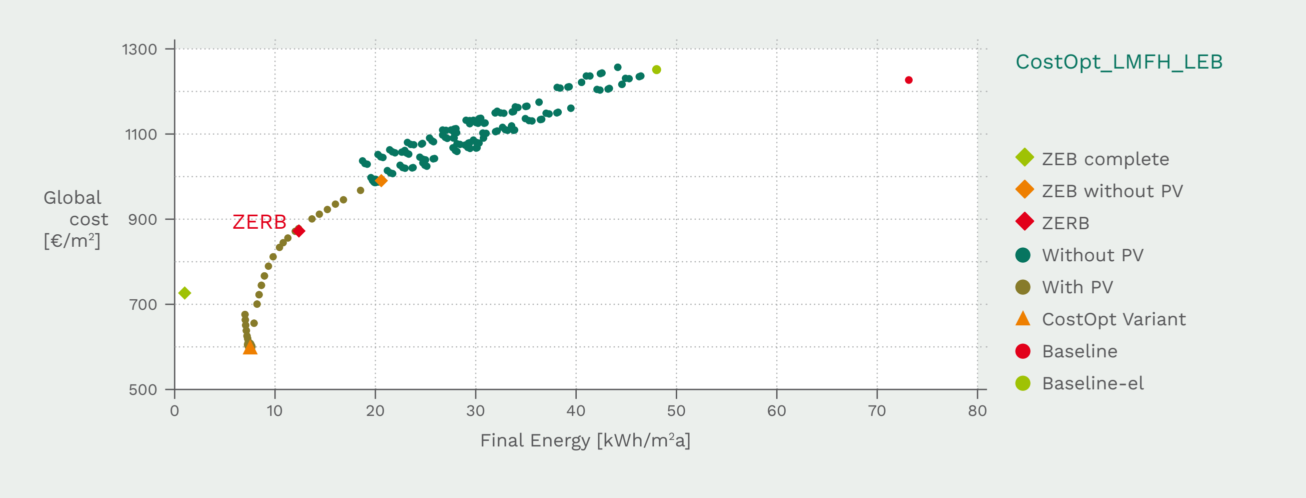


Figure 2-29 _Identification of recommended Zero Emission Ready Building (ZERB)

The key specifications of the ZERB-variant

Roof and walls:	u = 0.4 W/m²K
Ground floor:	u = 1.2 W/m²K
Windows:	Tripe glazed with solar coating (u = 0.9 W/m²K; SHCG = 0.25)
AC:	High efficient multi-split system
Shading:	Fixed shading elements
PV:	7 $W/m^2_{net\ floor\ area}$ with consideration of roof space limitation ≥[53] 20 $W/m^2_{net\ floor\ area}$ 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:

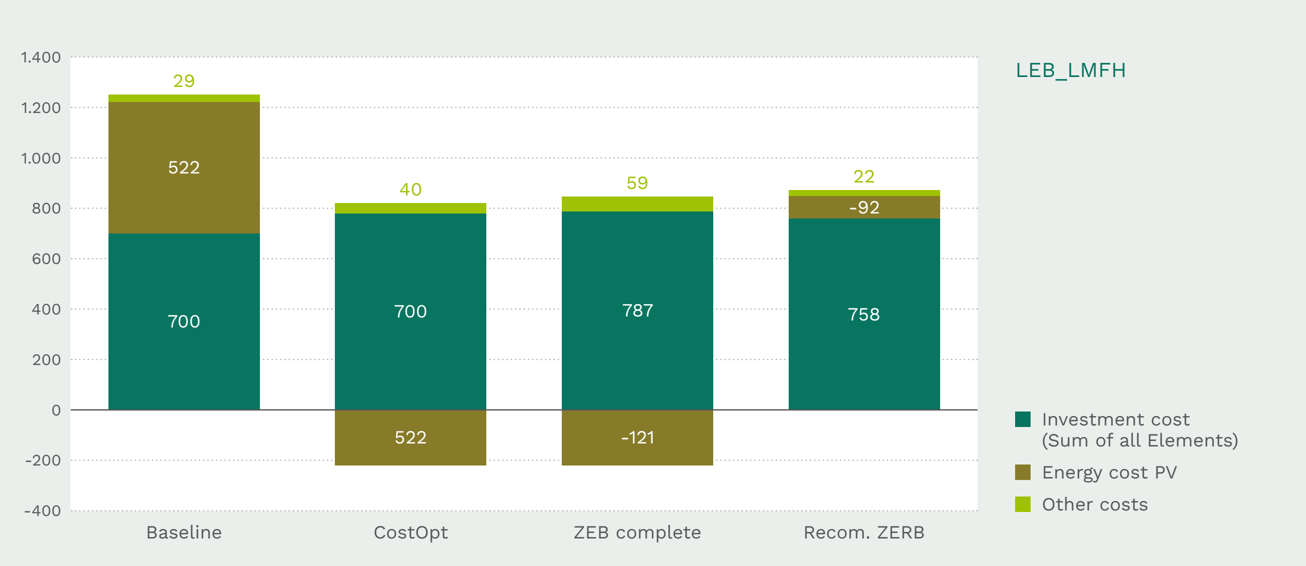


Figure 2-30 _Global cost comparison most relevant variants, including baseline and the recommended ZERB

The recommended ZERB requires 8.3 % higher initial investment costs compared to Baseline-el. But those will be paid back by the reduced OPEX in less than three years.

53 Although only 20 W/m² is required to reach ZEB, larger PV capacities would lead to even lower global costs, due to the current net metering subsidy for PV.

Remark: the negative energy costs of CostOp and ZEB complete, 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 office building

STEP 1 _Identification of Cost Optimum

Starting from the Baseline variant (upper right corner of the following Figure) adding efficiency measures, like improved insulation of roof, walls and floor, triple glazed windows with solar coating, high efficiency AC and specifically PV results in a significant reduction of global costs. The cost optimum is reached at a final energy demand about 14 kWh/m²a. While the Baseline variants results in global costs of nearly 2000 €/m², the global cost of the cost optimum variant less than 1000 €/m², which is only about half.

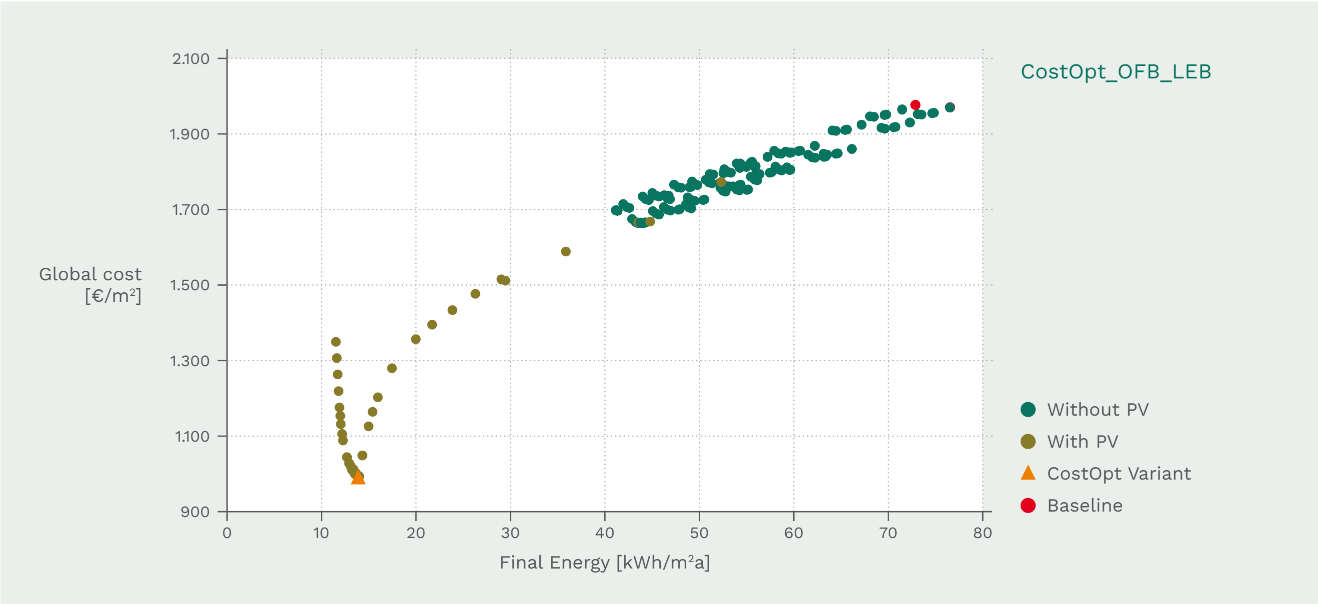


Figure 2-31 _Global cost calculations for identification of the acceptable global cost limit (STEP 1)

The key specifications of the cost-optimal variant

Roof and walls:	u = 0.30 W/m²K
Ground floor:	u = 1.2 W/m²K
Windows:	Triple glazed with solar coating (u = 0.9 W/m²K; SHCG = 0.25)
AC:	High efficient multi-split system
Shading:	Fixed shading elements
PV:	43 $W/m^2_{\text{net floor area}}$
Battery:	No

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.

The cost optimal ZEB is reached by a variant with a high efficient AC system, a fixed shading and an average u-value of 0.68 W/m²K.

The key specifications of the ZEB variant

Roof and walls: u = 0.48 W/m²K
Ground floor: u = 1.2 W/m²K
Windows: Triple glazed with solar coating (u = 0.9 W/m²K; SHCG = 0.25)
AC: High efficient multi-split system
Shading: Fixed shading elements
PV: 36 W/m$^{2}_{\text{net floor area}}$
Battery capacity: 132 Wh/m$^{2}_{\text{net floor area}}$

As is already the case for the Lebanese residential reference building, the u-values for the roof and walls of the ZEB office are higher, and the required PV capacity is lower than the cost-optimum.

Global costs of the ZEB (with almost no energy costs) are significantly less than the global costs of baseline variants.

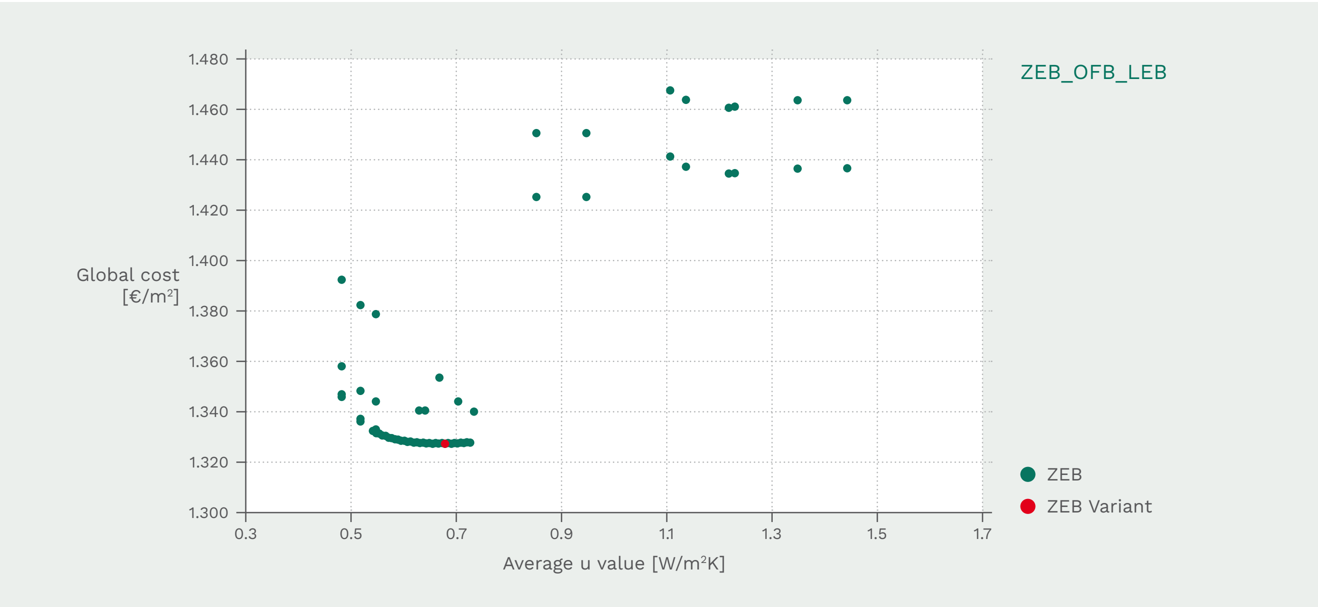


Figure 2-32 _Global cost calculations to determine the cost optimal ZEB-specifications (STEP 2)

STEP 3 _Identification of Zero Emission Ready Building (ZERB) requirements

Residential ZERB for Lebanon should require 36 W/m²net floor area PV. Taking into consideration the limited available roof space for PV[54], the high-rise reference building only requires 10 W/m²net floor area PV. The ZERB with consideration of roof space limitation will have 45 % higher global costs than the cost optimum, but still 30 % lower global costs than the baseline (common practice). The remaining final energy need of 12 kWh/m² is about 4-times lower than baseline.

The key specifications of the ZERB-variant

Roof and walls: u = 0.48 W/m²K
Ground floor: u = 1.2 W/m²K
Windows: Tripe glazed with solar coating (u = 0.9 W/m²K; SHCG = 0.25)
AC: High efficiency multi-split system
Shading: Fixed shading elements
PV: 10 W/m$^{2}_{\text{net floor area}}$ with consideration of roof space limitation
≥[55] 36 W/m$^{2}_{\text{net floor area}}$ without roof space limitation
Battery: No, just reservation of sufficient space for later installation

54 Roof space: 210 m²; required PV under consideration of roof space limitations 21 kWp

55 Although only 36 W/m² is required to reach ZEB, larger PV capacities would lead to even lower global costs, due to the current net metering subsidy for PV

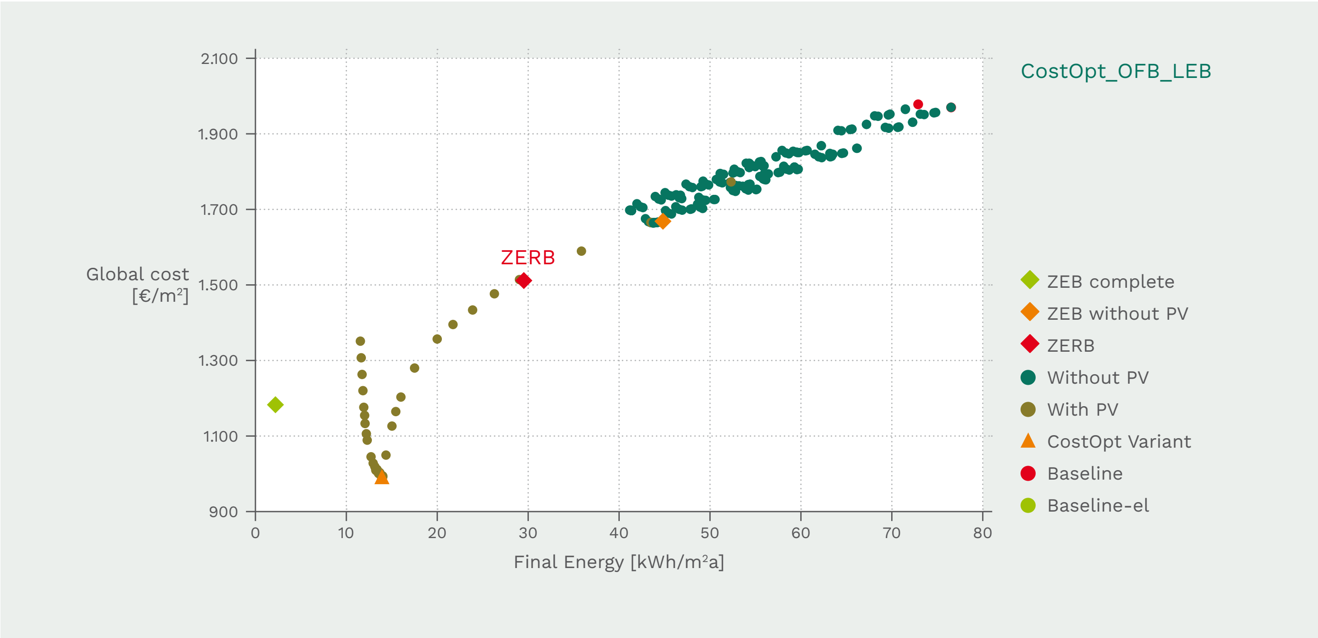


Figure 2-33 _Identification of recommended Zero Emission Ready Building (ZERB)

The following figure provides an overview indicating different components of the global costs of the most relevant variants:

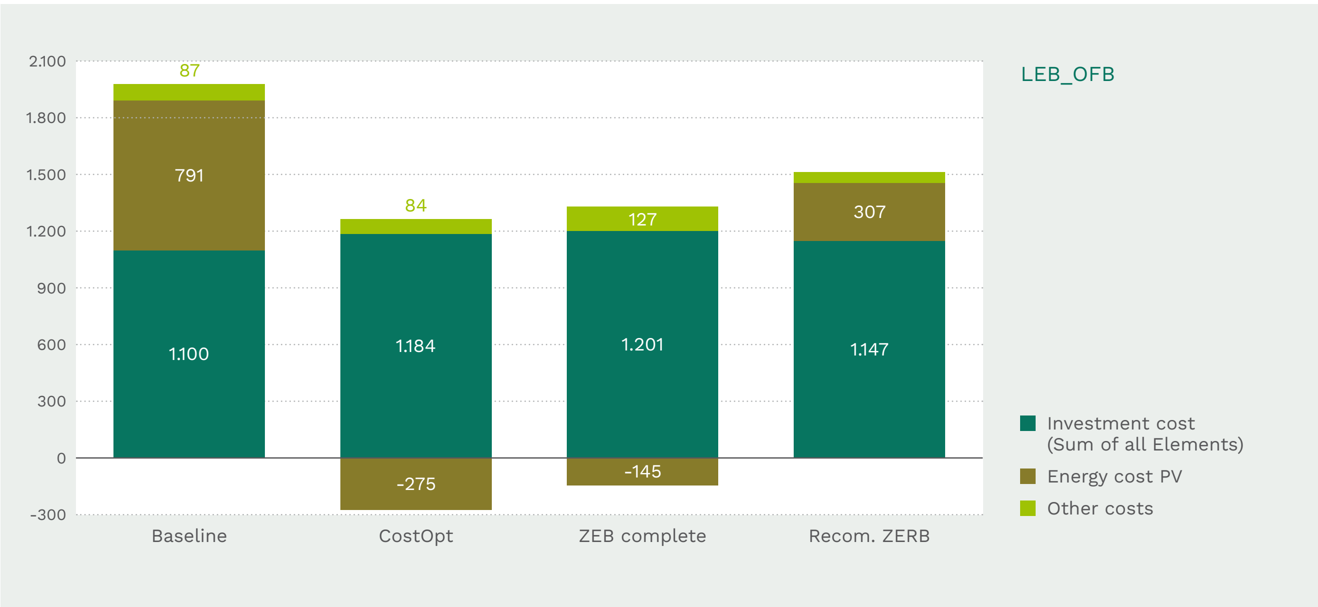


Figure 2-34 _Global cost comparison most relevant variants, including baseline and the recommended ZERB

The recommended ZERB requires 4.3 % higher initial investment costs compared to Baseline But those will be paid back by the reduced OPEX in less than two years.

3 CONCLUSIONS

The recommended Zero Emission Ready Building (ZERB) requirements for all countries and for all building types offer significantly lower global costs (15 % to 30 %) compared to common practices for new buildings (baselines). This approach ensures compatibility with a climate-neutral energy system (transition to ZEB) without creating lock-in effects.

The additional investment costs for ZERB, compared to the baseline, range from negligible to up to 13.5 %, with most cases around 5 %. The payback period, due to reduced energy costs, is typically around 3 years, ranging from less than 1 year to up to 8 years. Implementing ZERB requirements can reduce final energy demand (electricity) by more than 70 %, and up to 90 %, compared to common practices. The recommended ZERBs requirements include thermal insulation of roofs and in Egypt, also for ground floors. For Lebanon and the non-residential building in Egypt, solar-coated triple glazing is recommended, while double glazing is recommended for Jordan. High efficiency AC systems and fixed shading are recommended for all ZERBs.[56] Net-metering subsidies make PV systems financially attractive in all countries, and it is recommended to maximise onsite PV capacities up to the cost optimum, typically when PV yield equals total annual consumption.[57]

Although this study is focused on new buildings, looking into two specific building types per country, and one climate zone per country, the results derive the following general technical measures that are elemental to develop a ZERB, such as:

- Adequate thermal insulation,
- Improved shading,
- Highly efficient AC systems,
- PV systems (especially with net metering subsidies) or at least preparation for subsequent installation should be considered to allow for futureproof cost optimal Zero Emission Buildings.

56 Only at the residential building in Egypt PV lead to little higher global costs
57 Including household electricity and electricity for appliances

Furthermore, this methodology can be used to develop requirements as well for refurbishments. It is assumed that ZERB requirements for refurbishments would be comparable to those applied for new buildings, especially when refurbishment is anyhow necessary (e.g., replacing old windows, malfunctioning AC systems, or cracked roof surfaces). Only in cases of significantly higher costs, such as subsequent wall insulation or replacing a still functional component, would the specific requirements for renovating existing buildings to ZERB levels be less stringent than for new buildings.

While the focus of this study was on mitigating operational emissions, the use of sustainable construction materials should be also considered as a mandatory requirement for ZERBs. This includes using natural refrigerants or avoiding cement products where possible without significantly increasing total global costs. The criterion of "non-significance" can be assumed to be met, if the costs for alternative sustainable materials are less than 1 % of conventional construction costs. An additional cost for sustainable materials of at least € 5 per m² of net floor space can therefore be considered reasonable. m² of net floor space can therefore be considered reasonable.

Picture 15 _Building for the future

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