Energy Efficiency Recommendations for New Mansoura University for Science & Technology, Egypt

IKI Project: Accelerating 0-emission building sector ambitions in the MENA region (BUILD_ME)

September 2120

Introduction to the BUILD_ME project

Contents

Introduction

Background, Objectives and Methodology

Photo by Scott Graham on Unsplash

Introduction

BUILD_ME Project and the Objectives of Pilot Projects

Methodology

Cost Benefit Analysis

HIGLIGHTS

- Besides classic CAPEX/ OPEX cost, it considers residual values
- Hourly based energy calculation
- Detailed local weather data is considered
- Energy price systematic and PV clearing adapted to local situation (Egypt)

ENERGY CALCULATION

- individual building geometries and windows (incl. orientation)
- Hourly based energy calculation using the international ISO 52016 norm
- Based on the energy demand calculation (useful demand) the HVAC systems are sized
- Five efficiency levels for each HVAC system can be selected individually
- Meteonorm data base delivers detailed local weather input (hourly)

GLOBAL COST

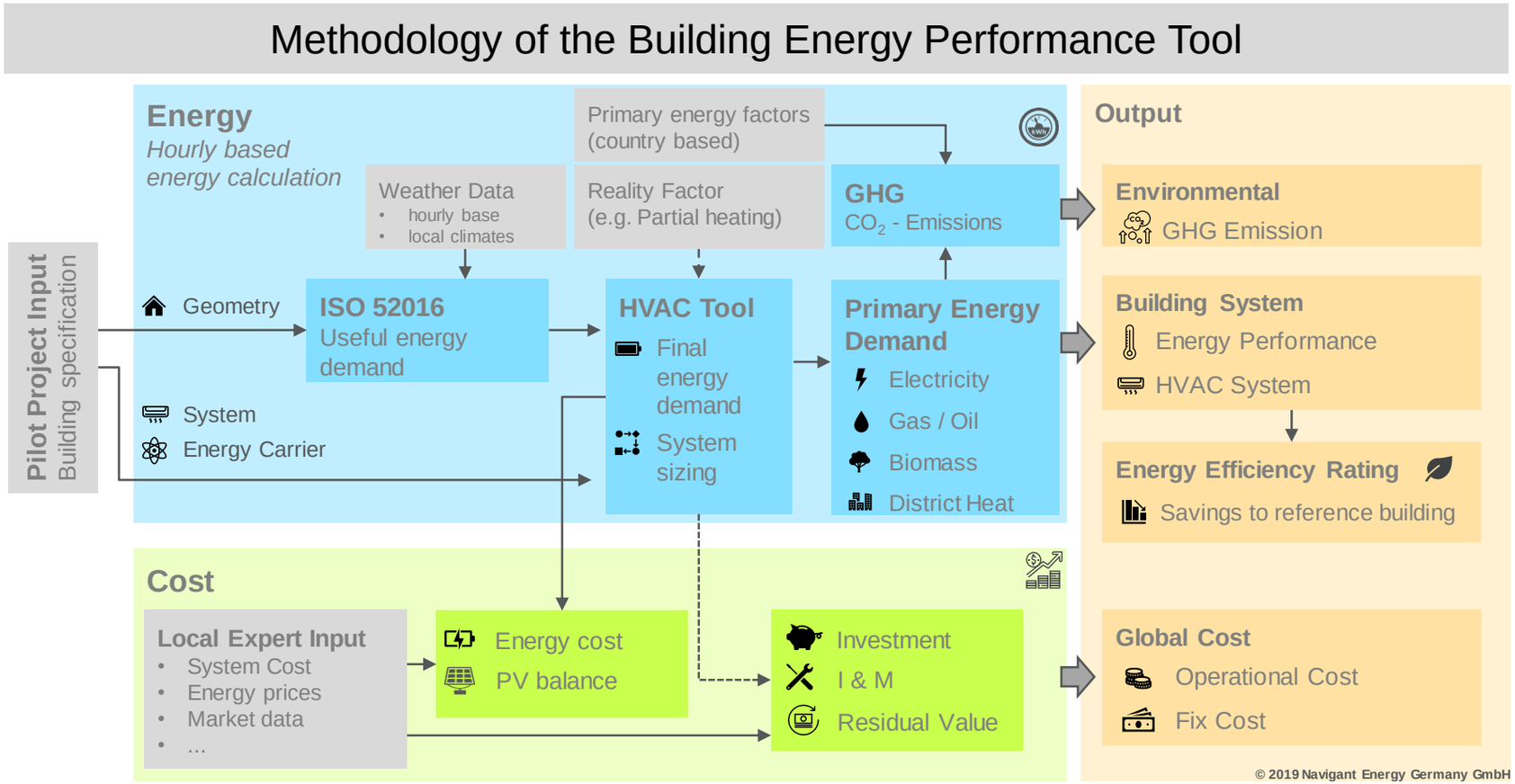
- Calculation of energy cost and investment cost of the systems, based on the HVAC system sized in the energy calculation
- Energy price systematic and PV clearing can be adapted to local situation (here: Jordan)
- Residual values at the end of the calculation period for the systems are considered

Methodology

Cost Benefit Analysis

HIGLIGHTS

- Besides classic CAPEX/ OPEX cost, it considers residual values
- Hourly based energy calculation
- Detailed local weather data is considered
- Energy price systematic and PV clearing adapted to local situation (Egypt)



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Introduction

New Mansoura University

Boundary conditions

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Library Building

Aims

Aims to provide an excellent working environment to encourage
high quality research, teaching and learning. The Central Library is considered
as the main iconic building in the
project

Target Groups

Students of the New Mansoura University

Function

A library with several halls and also a hub for university and academic events.

Size

Gross floor area of around 6,000 sqm spread over four floors.

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Boundary conditions

Site : Context matters

City : New Mansoura City

Location : 200 KM North of Tahrir Sq.

Context

New Mansoura City is a newly developed city on the coast of the Mediterranean sea. It is developed by New Urban Communityy Authority (NUCA), Ministry of Housing, Egypt.

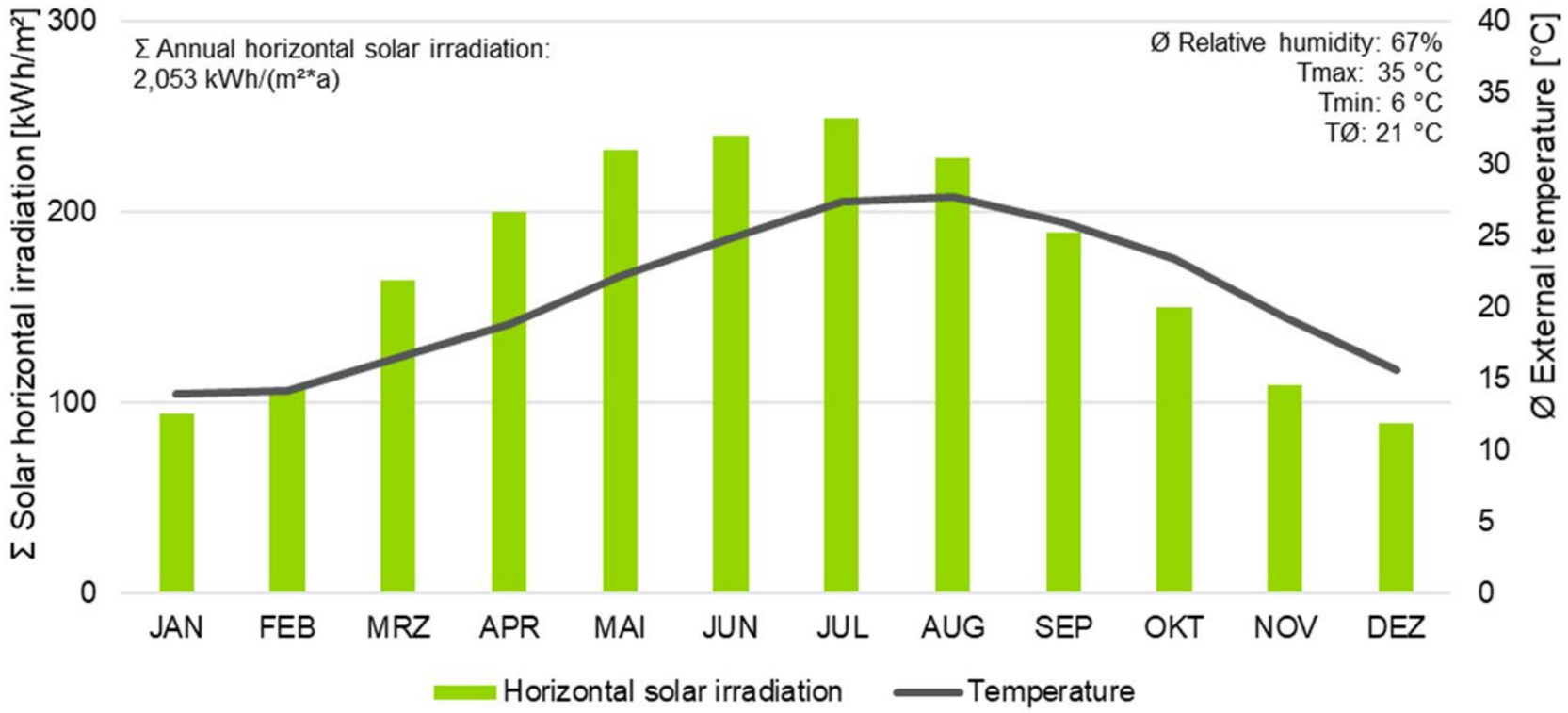
Source: Google Maps

Boundary conditions I Climate Analysis

Temperature and solar radiation, Alexandria (Egypt)

Description

External temperatures in Alexandria range from above zero to 35°C with yearly average temperatures around 21°C. January is the coldest month, August is the hottest one. The minimum temperature level does not fall below 0°C, which means that frost issues do not play a role in terms of construction projects.



Boundary conditions I Climate Analysis

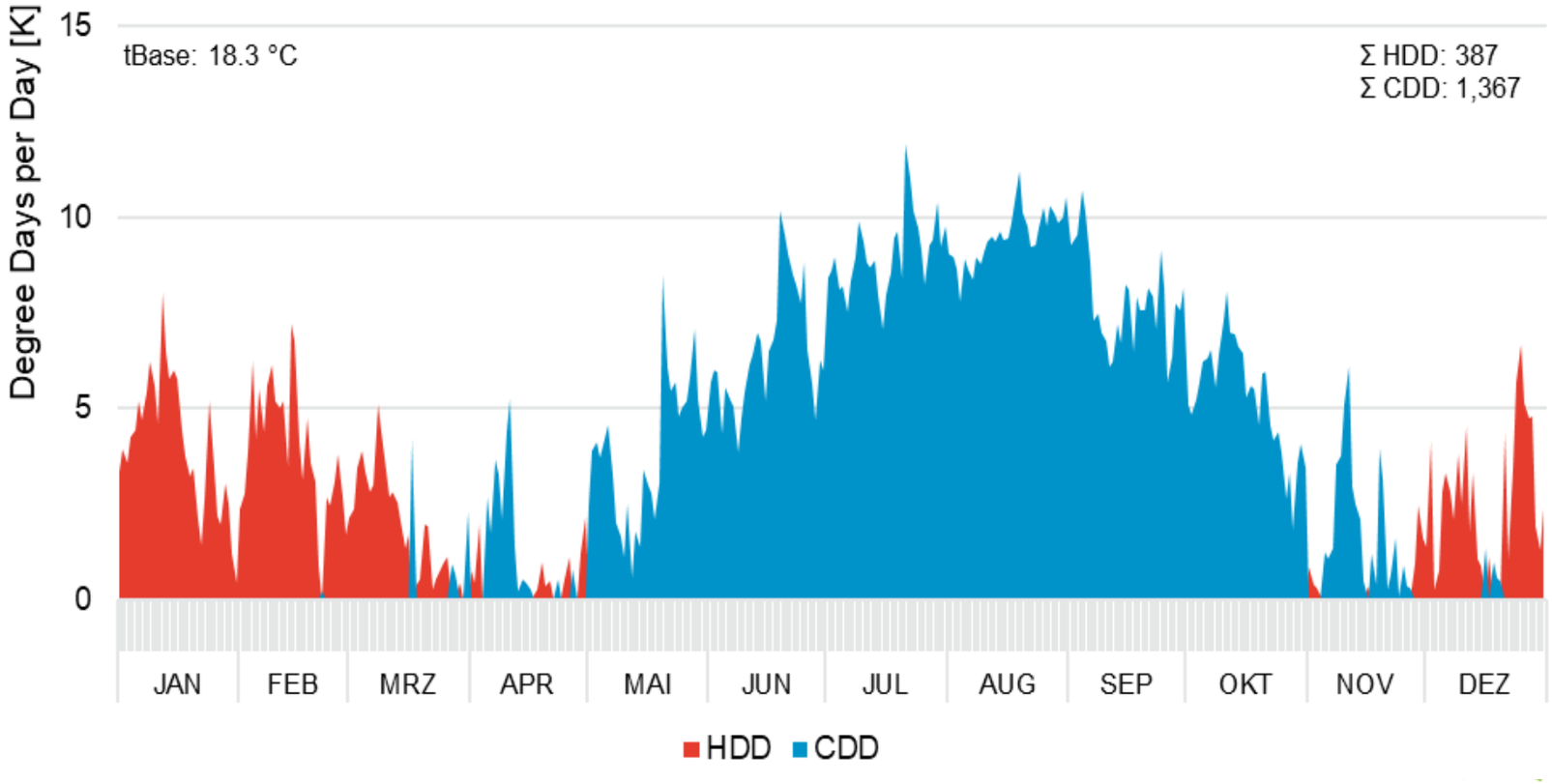
Heating and cooling degree days in Alexandria (Egypt)

Description

High number of >1,300 of CDD cooling degree days and a limited number of 291 of HDD heating degree days.

Challenges and Potentials

The amount of cooling degree days are roughly three times higher compared with the heating degree days. Therefore, a significantly larger amount of the energy demand accumulates for cooling.

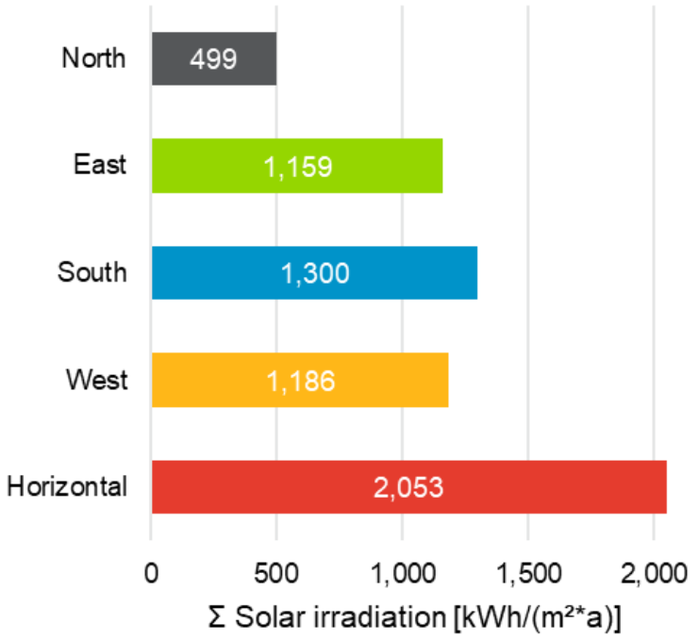


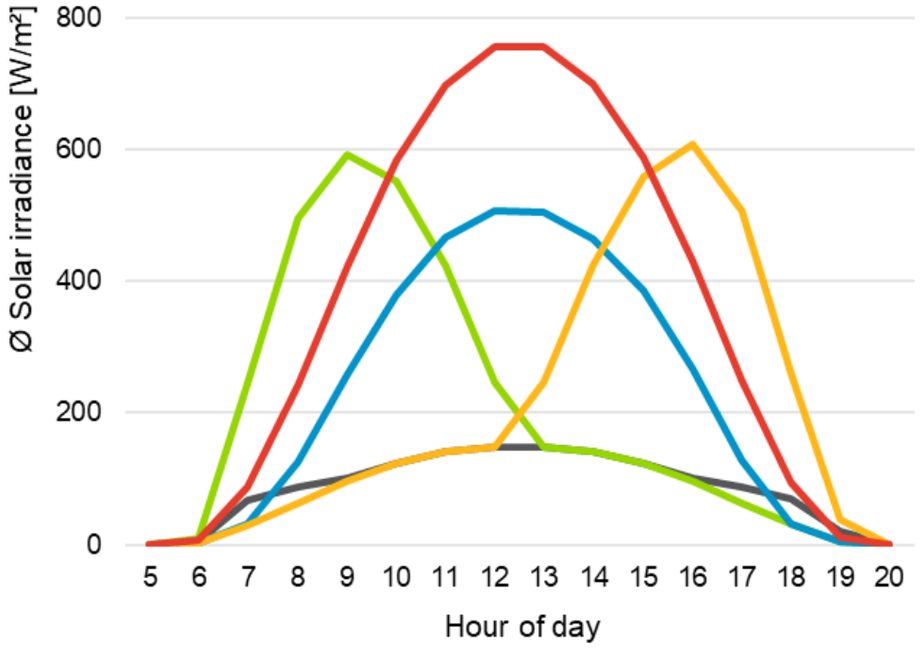
* Calculated according to ASHRAE 2001 methodology

Boundary conditions I Climate

Solar Irradiation in Alexandria (Egypt)

A big potential for renewable energy lies within the solar irradiation in Alexandria. Horizontal irradiation of > 2,000 kWh/(m²*a) and >1000 kWh/(m²*a) for East, South and West orientation bring opportunities for energy generation through solar radiation. Especially the solar energy for cooling purposes appears to be interesting for the area. Meeting the need of the population with a source that is already and infinitely in place.





Boundary conditions I Economic and Emissions Inputs

Cost of Energy and Environmental impact

Status

In Egypt, electricity is main source of power in household consumption. Natural gas is also used for cooking purposes. Energy subsidies will be totally cut in 2023.

Objectives

Energy price increases are assumed in the future and will be calculated in.

Energy prices and CO2 emissions			
Parameter	Unit	Electricity	Natural Gas
Energy price	EG Pound/kWh	Mean 1.0 - 1.45	3.10 per m3
Energy price	EUR/kWh	0.056 – 0.082	0.18 per m3
Price development in the last 5 years	%/year	25%	6%
CO2 emission factor	gCO2/kWh	444	220
Economic parameters			
Interest rate (real)	%/year	9.25	
Calculation period	years	20	

- **Exchange rate: 1 EUR = 17.61 EGP as of 29.05.2020**

Boundary Conditions I Building

Building Data

Status

The library is the design phase and the construction is planned to start in 2021/2022.

Specific Challenge

The building is near to the coast which provides potential of sea breeze but also a high Level of humidity.

Building Key Information	
Data	Input
Latitude	31.47326
Longitude	31.45024
Elevation [m]	6
Number of floors	4
Conditioned floor area [m²]	5,812
Clear room height [m]	3.5 – 5.0
Conditioned volume [m³]	20,342
Year of construction	2020 - 2022

Analysis

Starting Situation - Baseline and Current planning

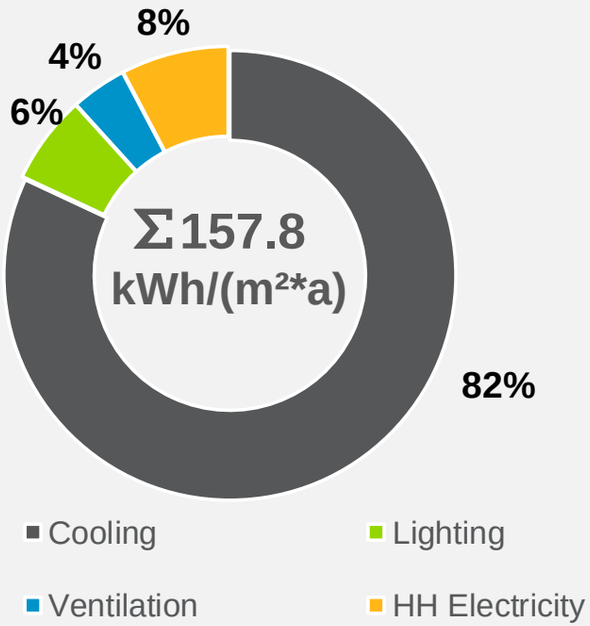
Photo by Jonathan Klok on Unsplashed

Business as Usual

Based on building typology analysis

The key components of the energy concept are illustrated in this table. Representing the boundary conditions of the educational building (BUILD_ME Buildng Typology). The typical educational building doesn´t foresee any heating demand. Regarding the measures: only minor roof insulation is planned and no special attention is given to use renewable energy sources.

Parameters	Baseline
Roof insulation (U-Value)	0.6 W/m²K
Wall insulation (U-Value)	2.1 W/m²K
Floor insulation (U-Value)	1.9 W/m²K
Windows (U-Value; G-Value)	3.0 W/m²K; 0.7
Window fraction	Ø 27%
Shading	Manuel shading
Air tightness	0.25 1/h
Heat supply	-
Cold supply	Central (air vent) - COP 3.5
Hot water	-
Ventilation systems	Mechanical ventilation
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	23°C (/ 20°C)



Energy Cost
11.0 EUR / (m²*a)

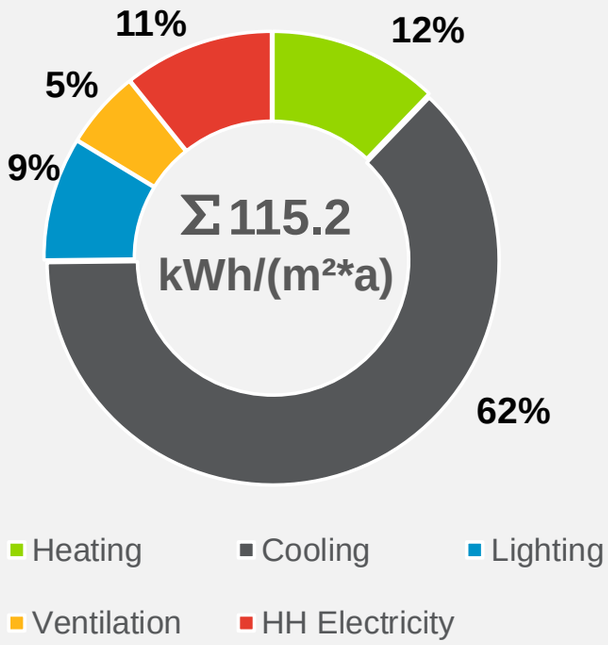
CO2 - Emission
5.6 kg / (m²*a)

Current Situation

Building Characteristics as currently planned

The key components of the energy concept are illustrated in this table, it shows that the building envelope is not in line with the thresholds of the current energy efficiency building code. While no special attention is given to use renewable energy sources.

Parameters	Baseline
Roof insulation (U-Value)	**0.37 W/m²K**
Wall insulation (U-Value)	**2.0 W/m²K**
Floor insulation (U-Value)	**2.4 W/m²K**
Windows (U-Value; G-Value)	**5.7 W/m²K; 0.85**
Window fraction	Ø 27%
Shading	**No**
Air tightness	0.25 1/h
Heat supply	**Reversible VRF - COP 3.2**
Cold supply	**Reversible VRF - EER 3.7**
Hot water	-
Ventilation systems	Mechanical ventilation
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	**24°C** / 20°C



Energy Cost
8.0 EUR / (m²*a)

CO2 - Emission
4.1 kg / (m²*a)

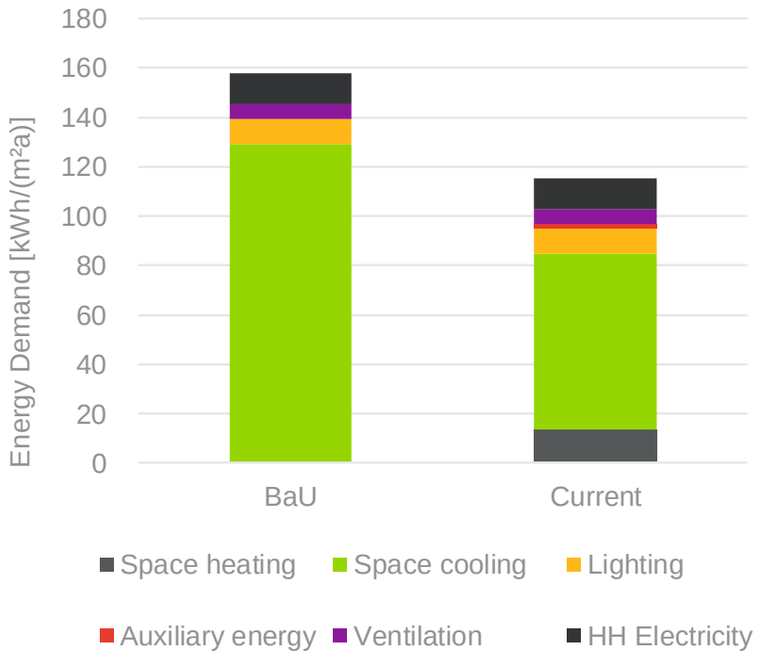
Comparison: BaU and Current Planning

The current planning is already more energy efficient in comparison to the BAU cases.

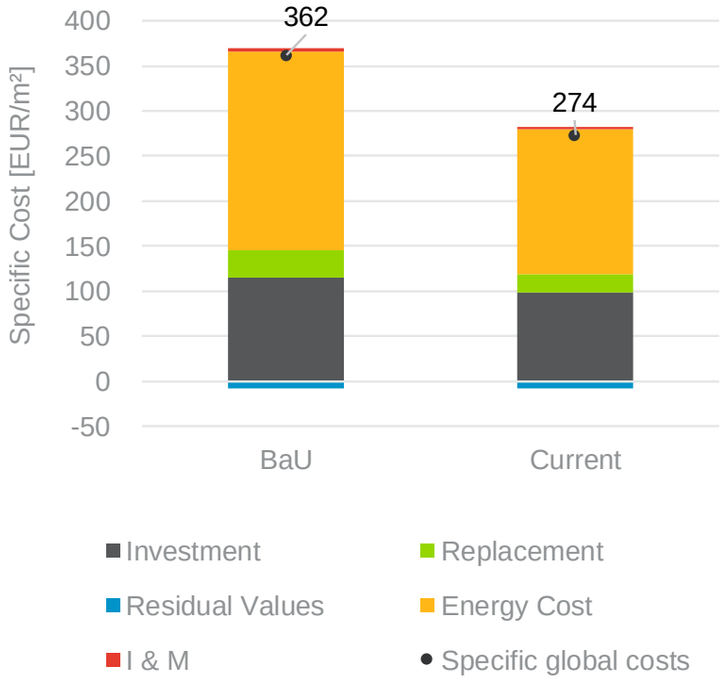
The proposed measures also result in a cost decrease due to the significantly lower energy cost.

However, there is still optimization potential.

Final Energy Demand



Global Cost



Analysis

Investigation of Possible Measures

Photo by Dan Dimmock on Unsplashed
Photo by Jonathan Klok on Unsplash

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Building Envelope | External wall

Results

BaU – No insulation / Brick
U-Value = 2.1 W/m²K

Var 1 - Insulation
U-Value = 0.73 W/m²K

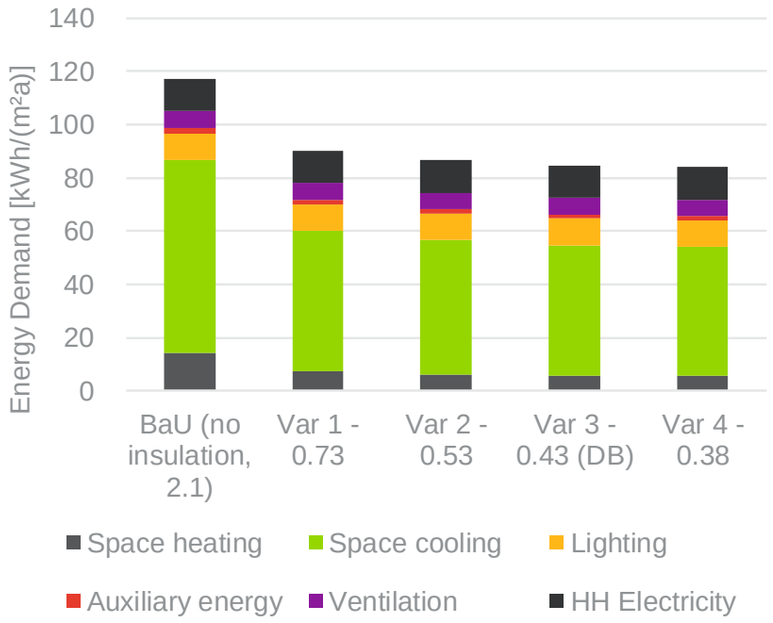
Var 2 - Insulation
U-Value = 0.53 W/m²K

Var 3 – Delta Blocks
U-Value = 0.43 W/m²K

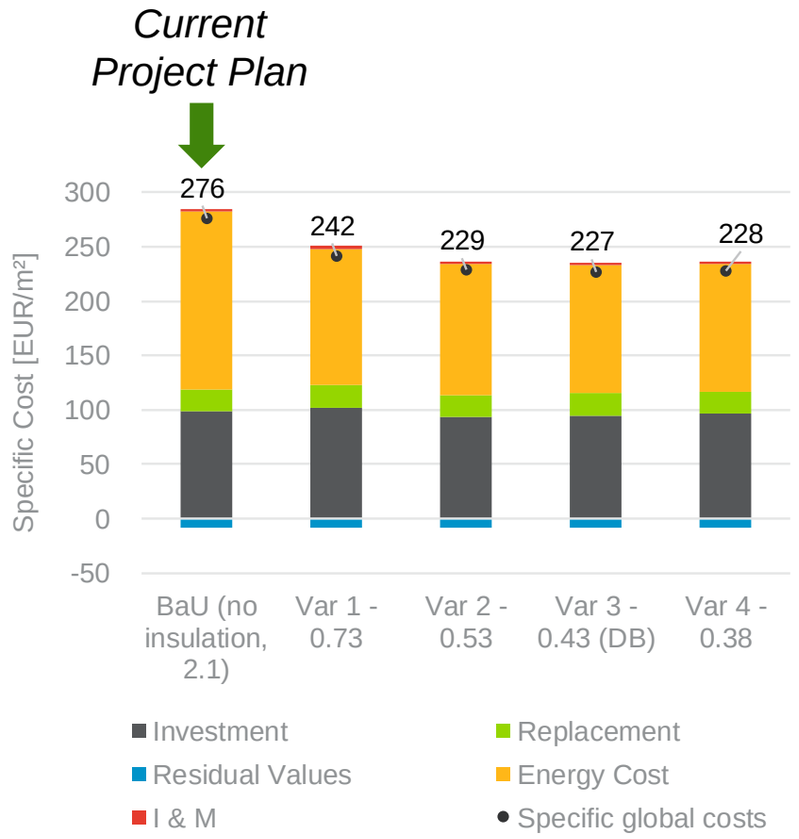
Var 4 - Insulation
U-Value = 0.38 W/m²K

Result: Var 3 with **Delta Blocks** is the most cost effective measure.

Final Energy Demand



Global Cost



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Building Envelope | Roof

Results

BaU

U-Value = 0.6

Current (Var 2)

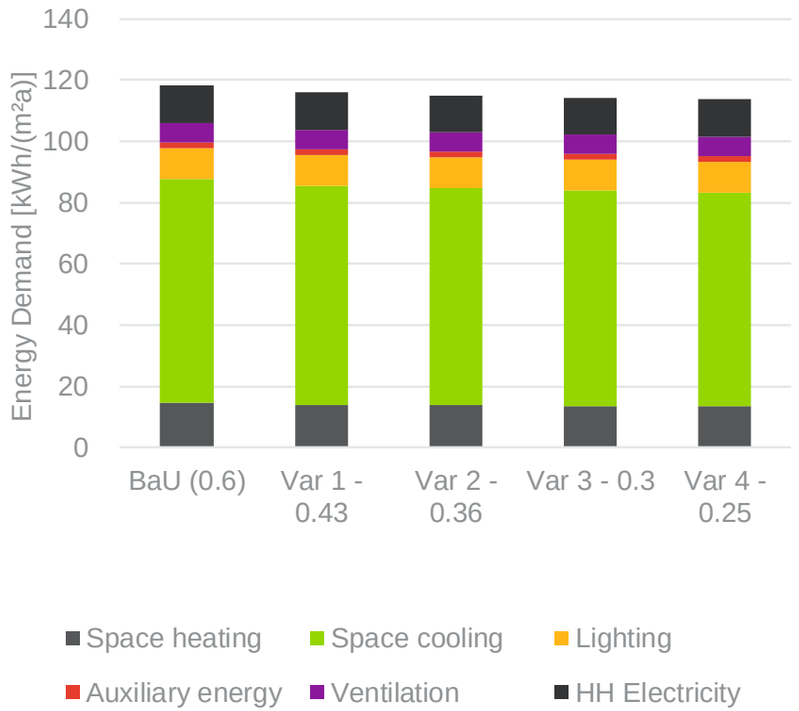
U-Value = 0.36 W/m²K

Var 1 – 4

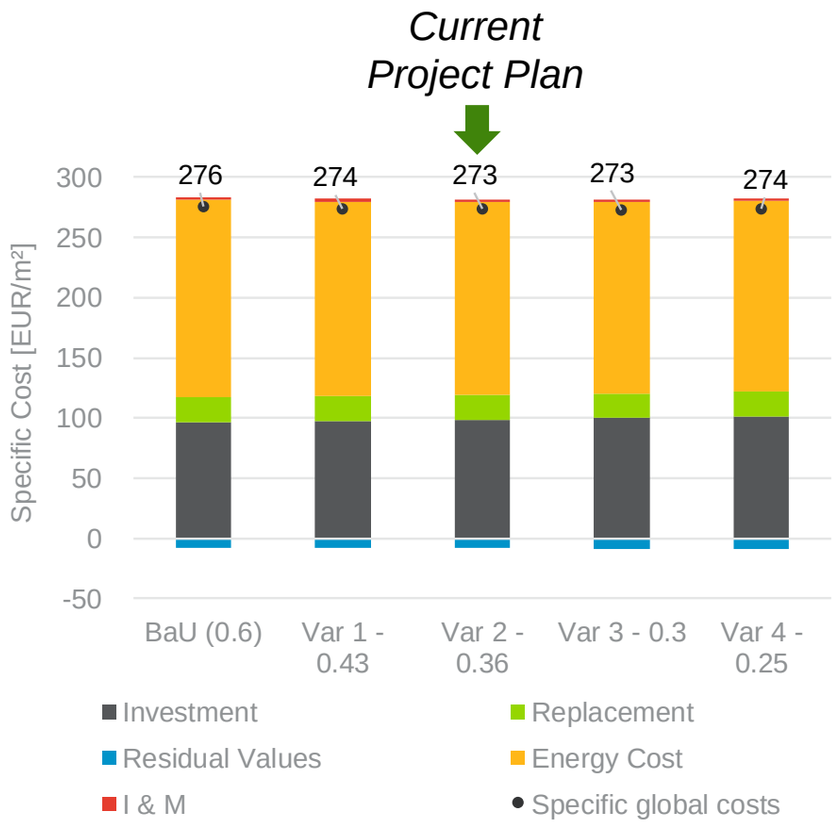
U-Value = 0.43 – 0.25 W/m²K)

Result: Current project plan is already cost effective.

Final Energy Demand



Global Cost



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Building Envelope | Windows

Results

BaU – Single glazing

U value 5.7 W/m²K
G-Value 0.85

Double glazing (Var 1)

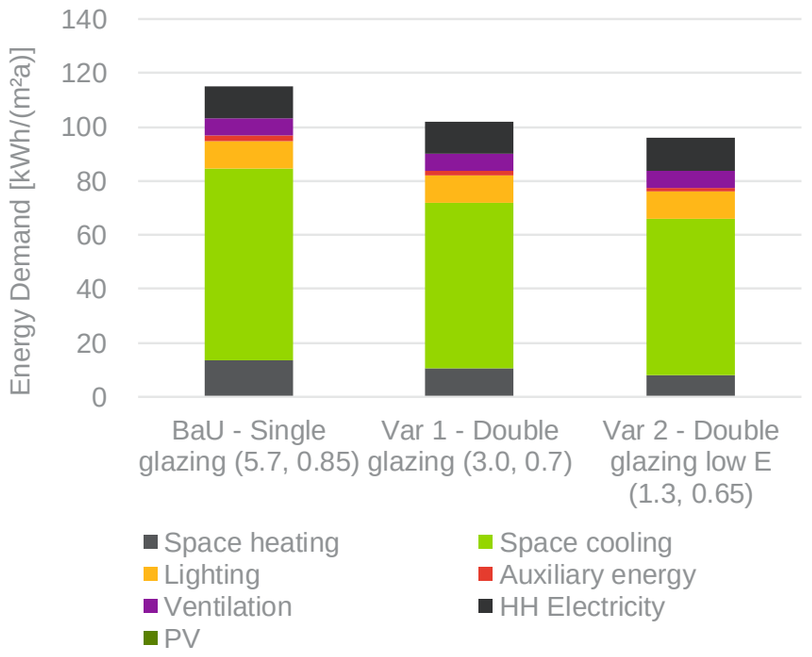
U value 3.0 W/m²K
G-Value 0.7

Double glazing low E (Var 2)

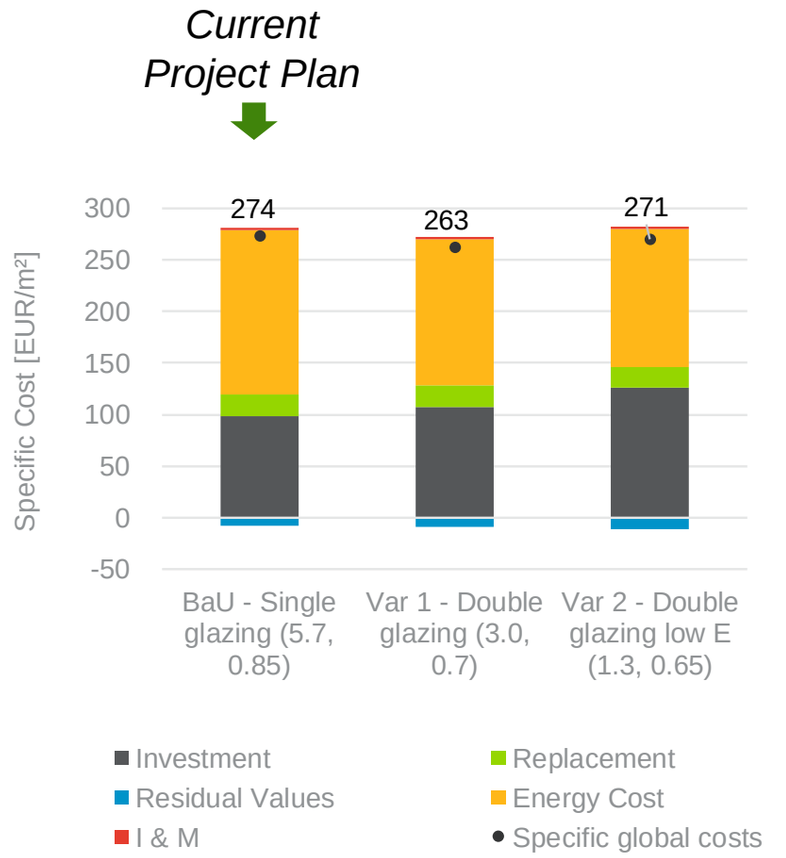
U value 1.3 W/m²K,
G-Value 0.7

Var 2 is the more cost-effective case, with improved but not best window quality.

Final Energy Demand



Global Cost



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Window Fraction

Analysis

Var 1

Window fraction 40 %

Var 2

Window fraction 30 %

Var 3

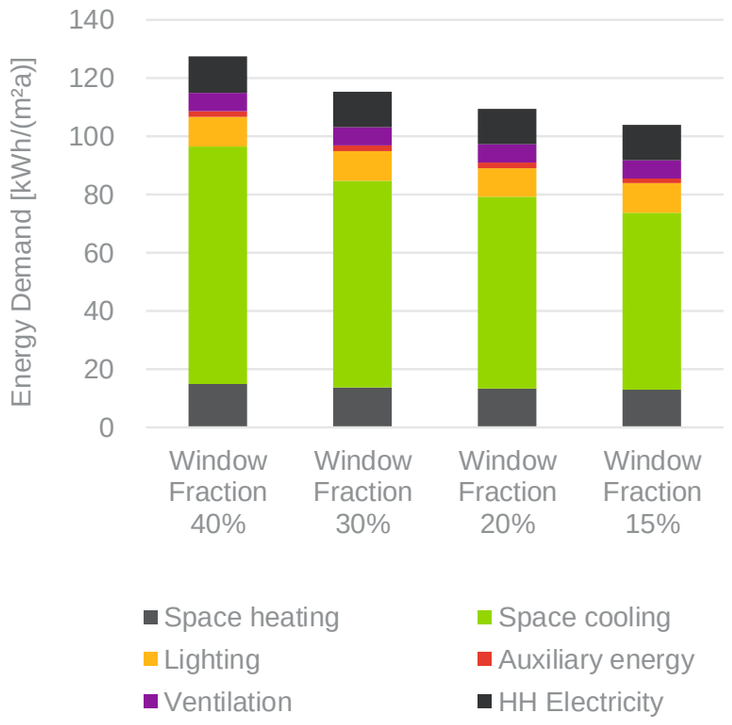
Window fraction 20 %

Var 4

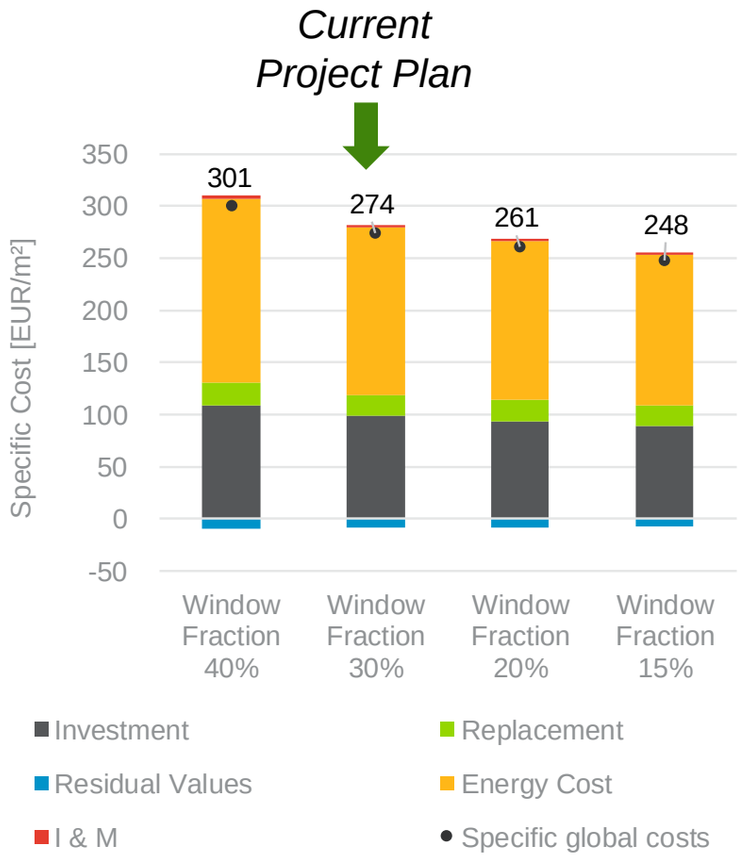
Window fraction 15 %

The Var 4 with the least window fraction has the lowest energy consumption, hence lowest global cost.

Final Energy Demand



Global Cost



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Air Tightness

What is the effect of air tightness?

BaU
0.25

Var 1
0.20

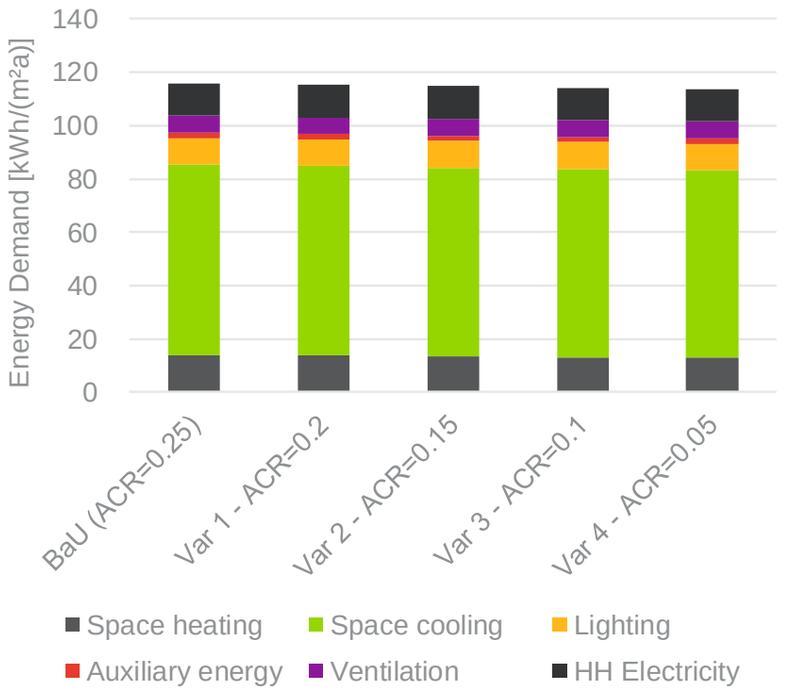
Var 2
0.15

Var 3
0.1

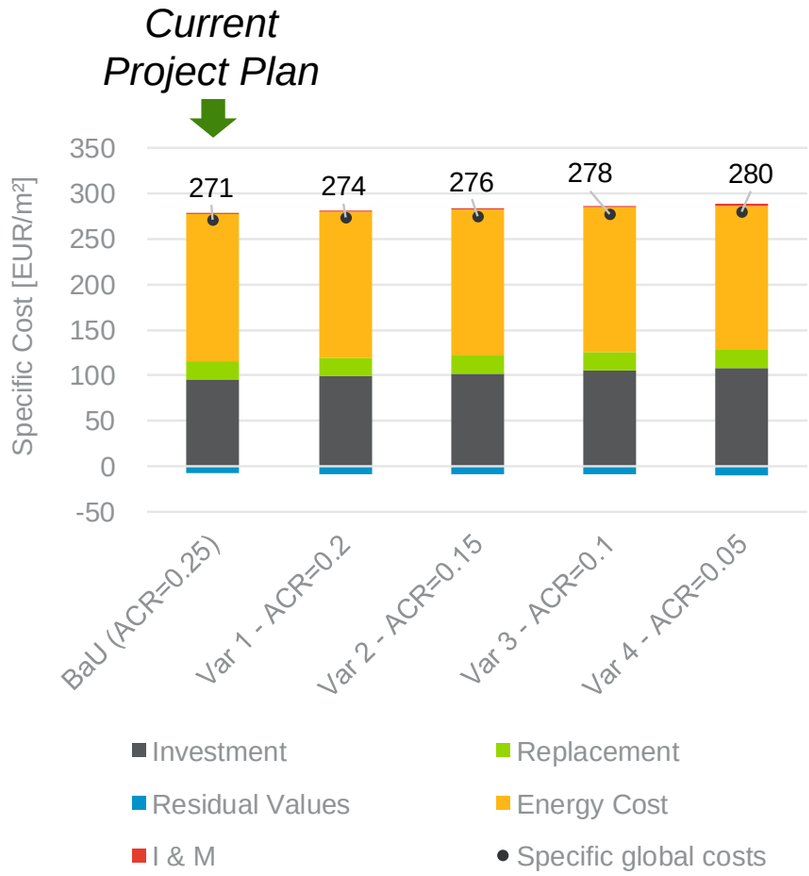
Var 4
0.05

BaU (current) is the most cost effective measure.

Final Energy Demand



Global Cost



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Shading concept

Analysis

BaU

No shading

Var 1

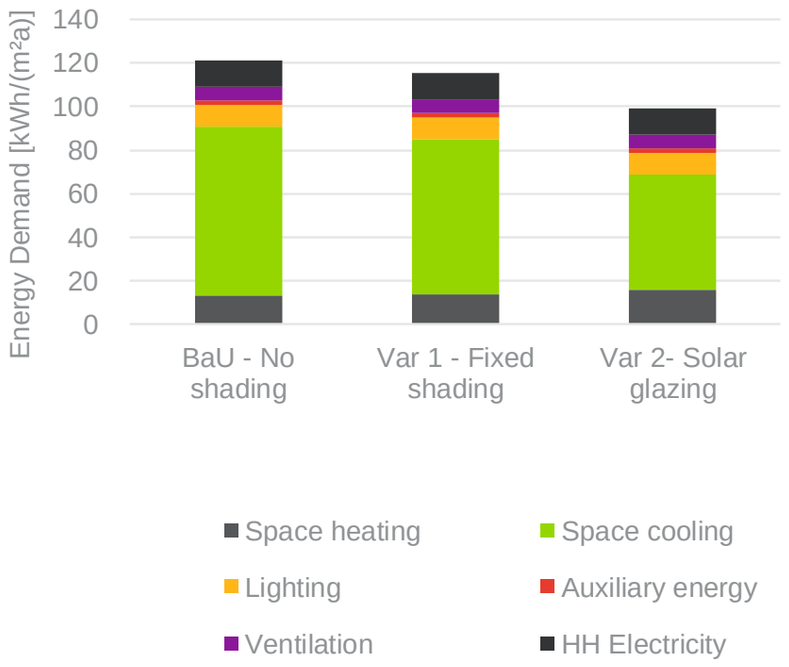
Fixed overhangs

Var 3

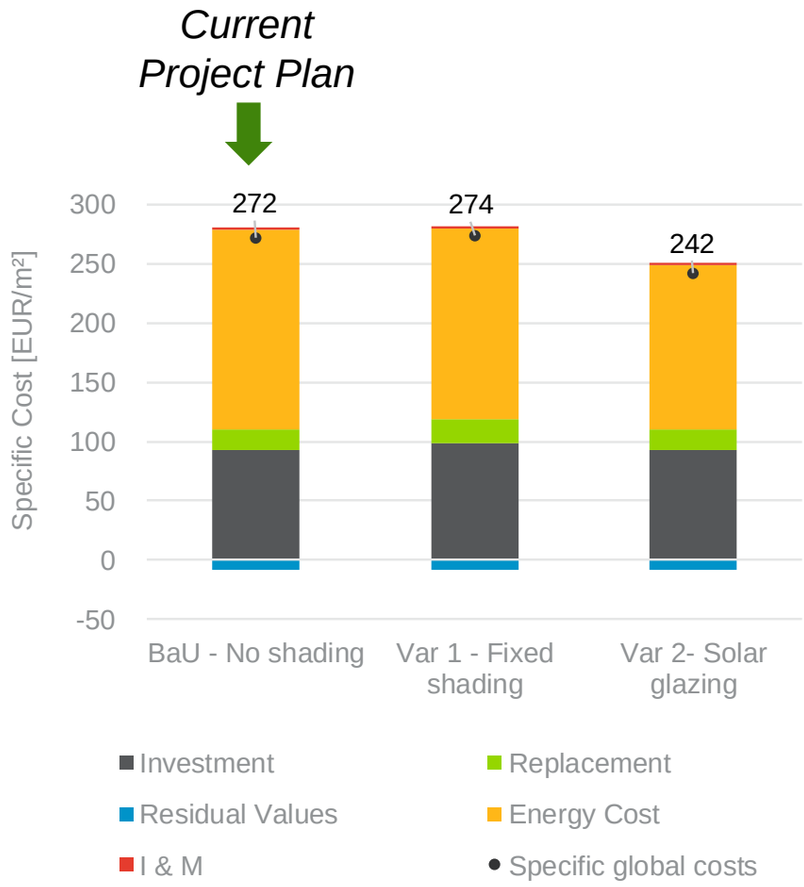
Solar glazing

Var 3 is the most cost effective measure.

Final Energy Demand



Global Cost



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HVAC | Efficiencies

Analysis

BaU

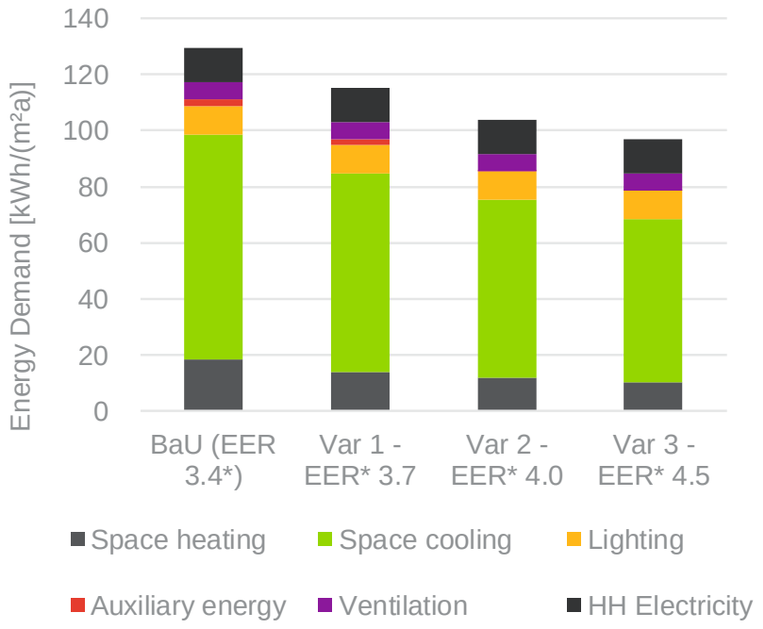
Reversible Split Unit.
Real annual EER: 3.4

Var 1 | 2 | 3

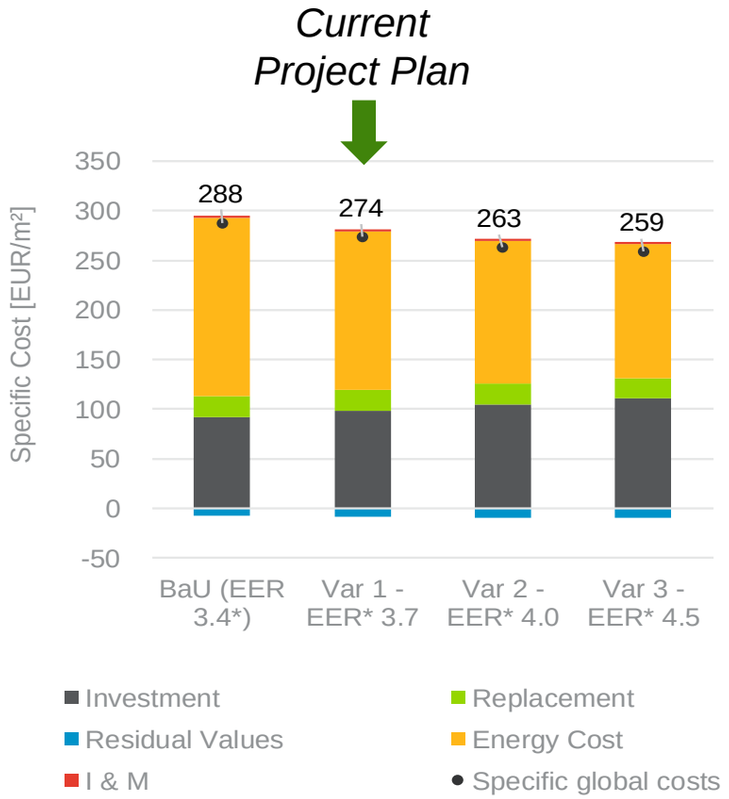
Reversible Split Unit with increased efficiency.
Real annual EER: 3.7 | 4.0 | 4.5

Var 3 (System with best COP) has the highest effect and is very cost-effective.

Final Energy Demand



Global Cost



*EER at standard conditions (35°C/27°C)

HVAC | Type of cooling system

Analysis

BaU

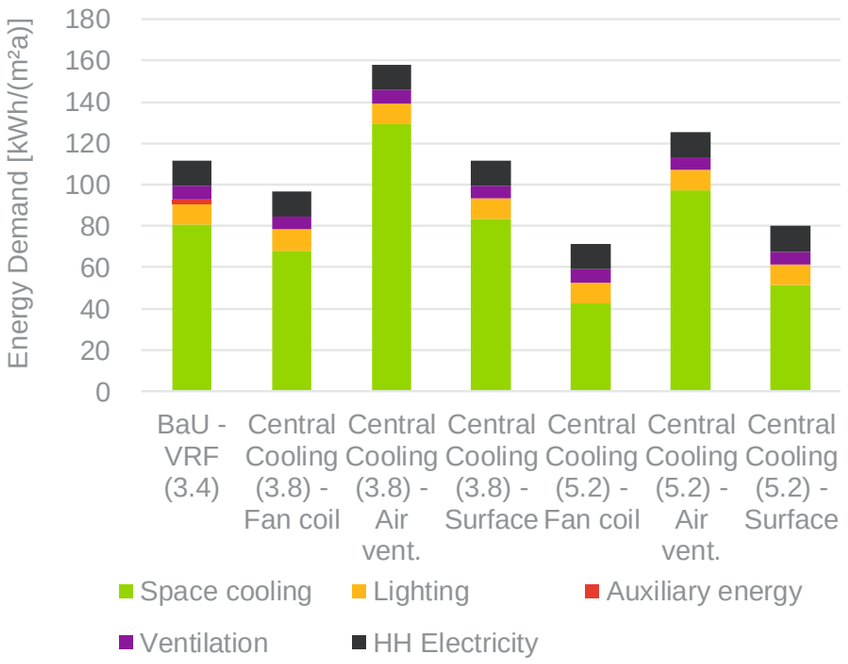
Reversible Split Unit.
Real annual EER: 2.9

Var 1 | 2 | 3

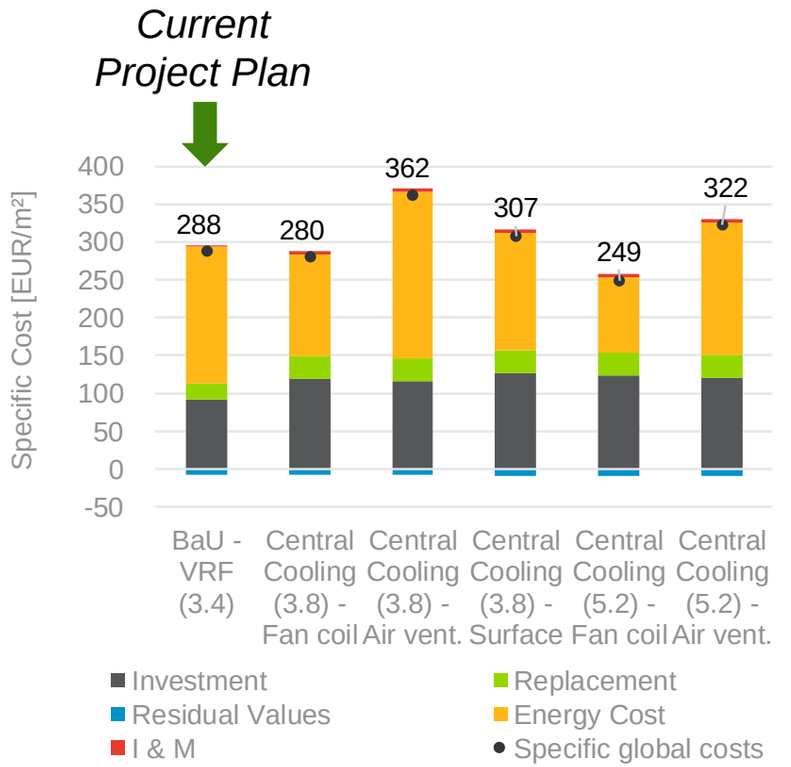
Reversible Split Unit with increased efficiency.
Real annual EER: 2.9 | 3.8 | 4.1

Fan coil distribution systems (current VRF, central fan coil) are efficient and cost-effective.

Final Energy Demand



Global Cost



All EERs at standard conditions (35°C/27°C)

Operational Temperatures

Analysis

BaU

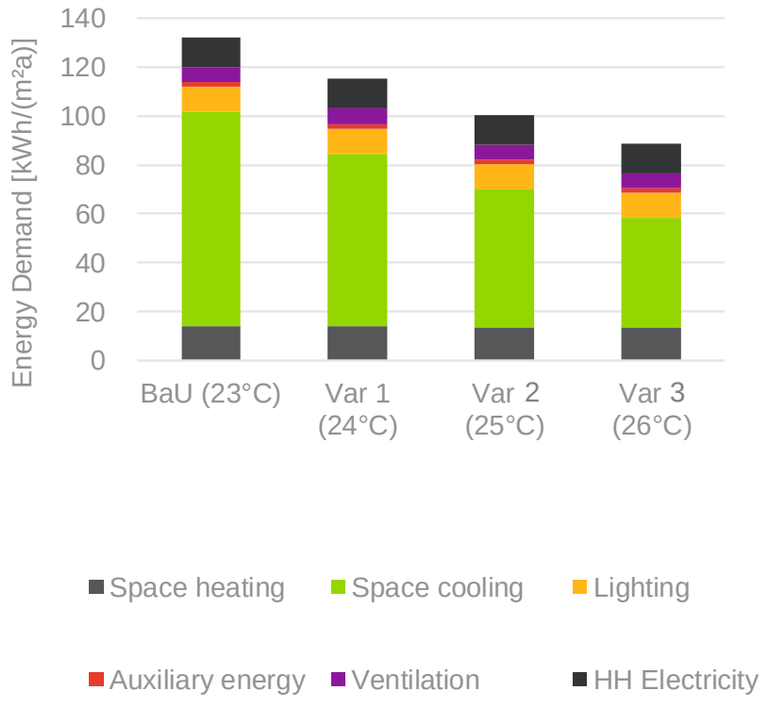
Cooling Temperature: 23°C
Heating Temperature: 23°C

Var 1 - 3

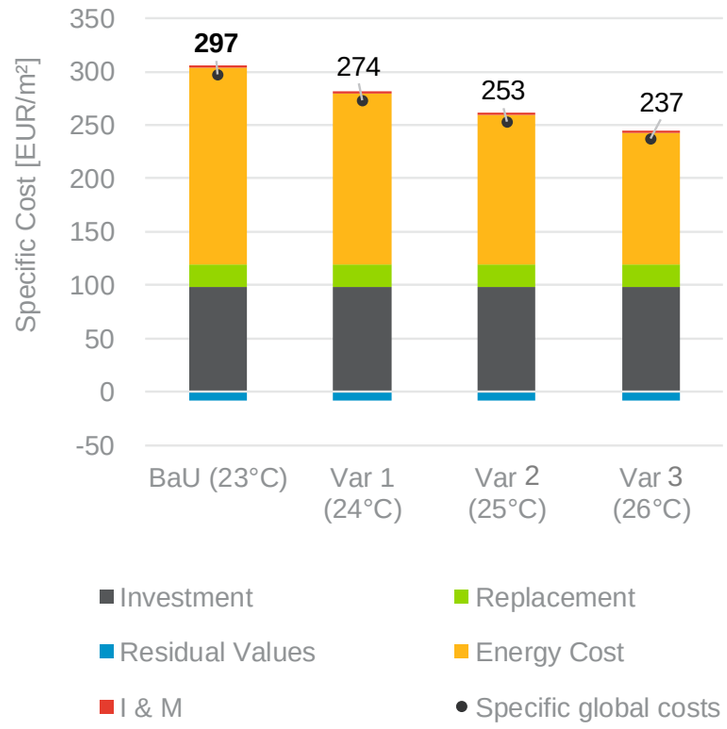
Cooling Temperature adapted (24°C - 26°C)

This measure is very effective and not related to any cost

Final Energy Demand



Global Cost



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Renewables | PV

Analysis

Sizing (net metering as assumption)

BaU / Current

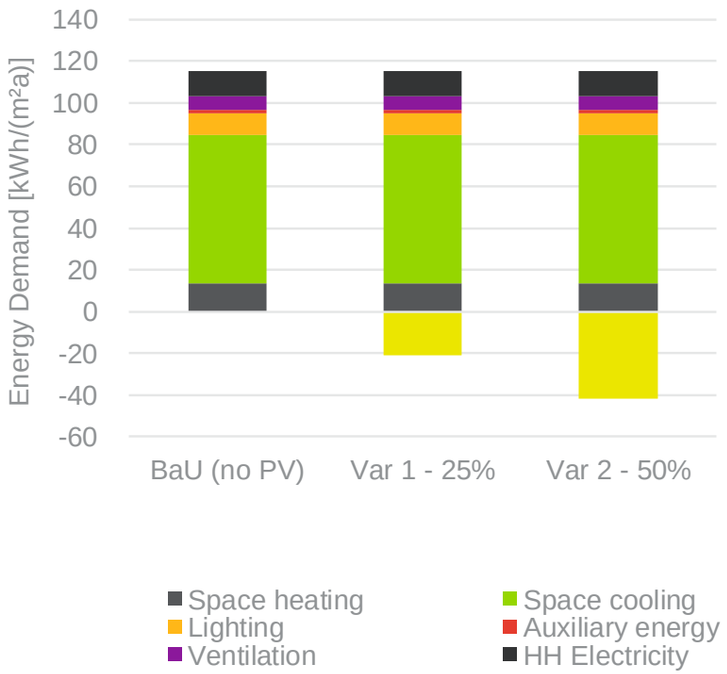
No PV installed.

Var 1 | 2

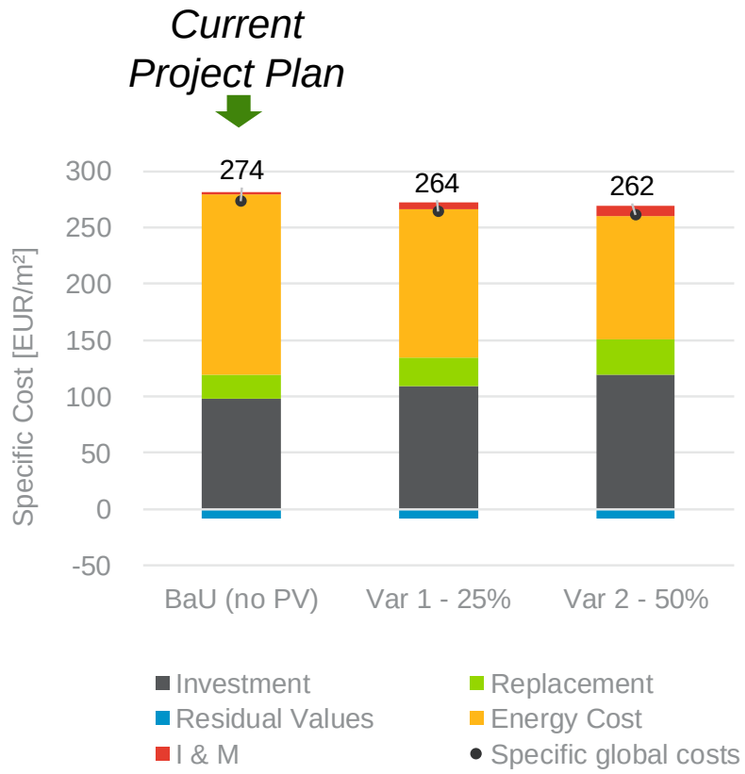
PV 73 | 145 kWp
(Roof area 1,000 m² | 2,000 m²)

Var 2 with **145 kWp** PV is the most cost effective measure (based on the electricity consumption of the Current).

Final Energy Demand



Global Cost



X% = Share of total roof area necessary for PV

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Results & Conclusion

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Overview of recommended measures

Four steps to reduce energy demand significantly

Building envelope

- External wall -> U-Value 0.43 (Delta Block) / alternatively U-Value 0.38 cavity insulation 8 cm
- Roof -> U-Value 0.38 (as planned)
- Windows -> double glazing (U-Value 3.0 W/m²K, G-Value 0.7)
- Shading -> additional solar glazing (G-Value 0.3)

HVAC

- Reversible Split Unit heating / cooling with high efficiency (EER >4)
- Fan coil distribution as cost-effective variant

Renewable (Solar) Energy

- PV 143 kWp (available roof area 2,000 m²)
- Maximum use of available roof area is cost-effective)

Behavior

- Change set temperature from Cooling 23°C/ Heating 23°C to Cooling 26°C/ Heating 20°C

Optimized Solution

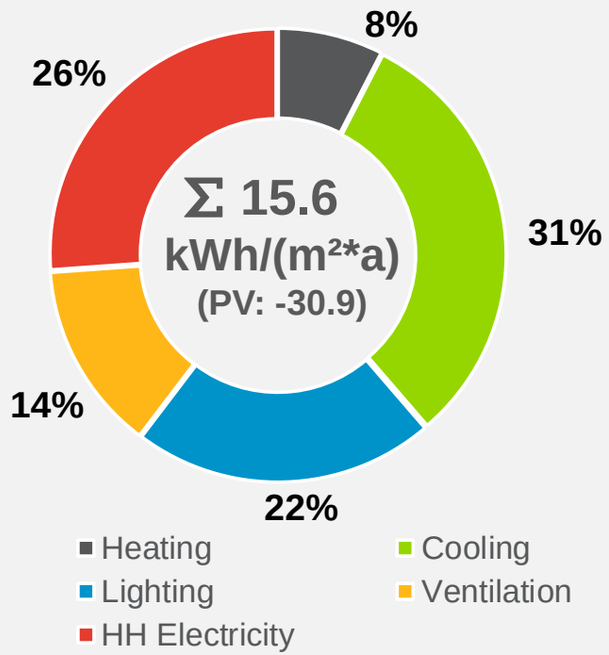
Results

The key components of the energy concept are illustrated in this table, it shows that the building envelope is significantly enhanced to the current building code.

Special attention is given to the use of renewable energy sources in terms of PV (for electricity).

This leads to energy savings and emission reduction.

Parameters	Optimized Building
Roof insulation (U-Value)	0.38 W/m²K
Wall insulation (U-Value)	**0.43 W/m²K**
Floor insulation (U-Value)	2.2 W/m²K
Windows (U-Value; G-Value)	**3.0 W/m²K**; **0.3**
Window fraction	Ø 30%
Shading	**Solar Glazing**
Air tightness	0.25 1/h
Heat supply	Reversible split unit - **COP 3.7**
Cold supply	Reversible split unit - **EER 4.5**
Hot water	-
Ventilation systems	Mech. ventilation (0.3 1/h)
Lighting systems	LED
Renewable energy	**143 kWp (PV)**
Set temperature cooling/heating	**26°C** / 20°C



Energy Cost
1.1 EUR / (m²*a)

CO2 - Emission
0.6 kg / (m²*a)

Comparative overview

BaU vs. Current vs. Optimized

Conclusion

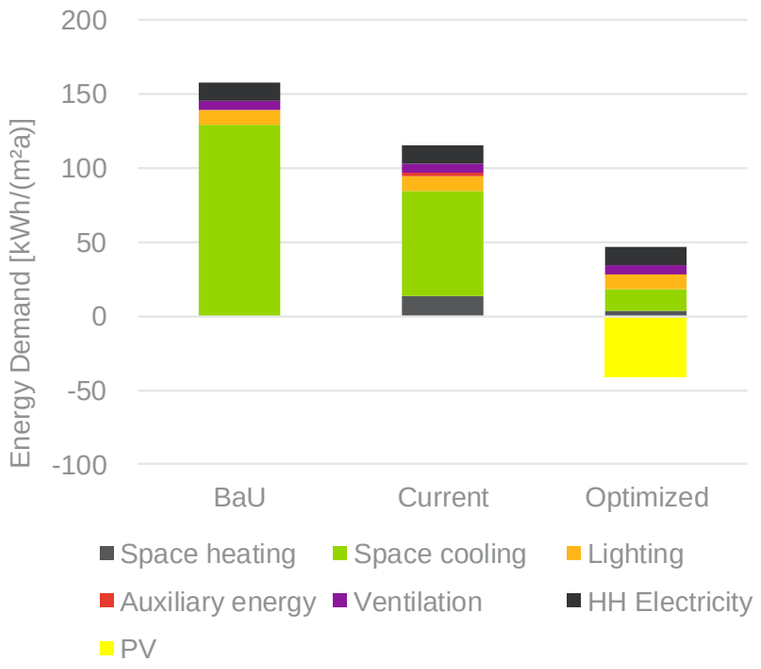
- The suggested measures and the current situation lead to a **significant decrease in energy demand**
- The optimized solution, detected **the most cost effective efficiency measures**

Savings (Current/Optimized related to the BaU)

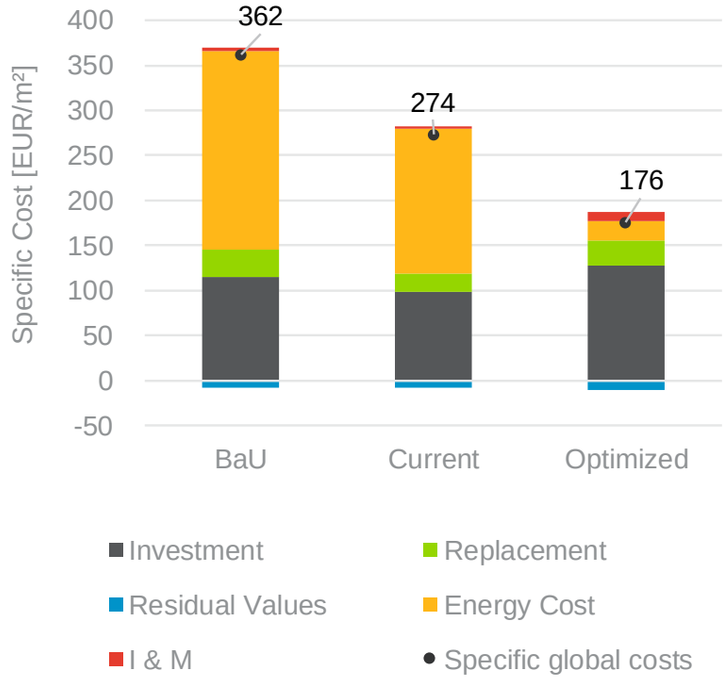
Energy: - 26% / - 90%

Cost: - 24% / -51%

Final Energy Demand



Global Cost



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Optimized vs. current

Payback of single measures and whole package

Parameters	Optimized	Investment (optimized-current) [EUR]	Energy cost savings* [EUR / year]	Payback [years]	Lifetime [year]
Wall insulation (U-Value)	0.43 W/m²K	44,200	-16,000	3	40
Windows (U-Value; G-Value)	3.0 W/m²K; 0.65	50,800	-7,500	7	30
Shading	Solar glazing	67,500	-12,000	6	30
Heat/Cold supply	reversible split unit - COP 5.3	110,000	-18.500	6	15
Renewable energy	143 kWp (PV, maximum)	120,600	-20,900	6	20
Total (current to optimized)**		**393,100 (6.5%)*****	**-74,900 (-36%)**	**6**	

* Remark: The energy cost savings have been calculated conservatively based on the current electricity starting price (appr. 8 Cent/kWh).

** Remark: Investment and savings of single measure savings cannot be summed up due to synergies between the measures (e.g. lower window fraction leads to lower cooling supply costs).

*** Remark: Compared to costs of current case and overall construction costs assumptions of 920 –1000 Euro/m² (6.5 % additional costs).

Key conclusion

Main takeaways for the Mansoura Library Project

Improve further the building envelope

- Use Delta Blocks or increase the insulation thickness of the external wall -> **energy savings up to 25 % are possible**
- Utilize double-glazed Windows with a U-Value around 3.0 W/m²K -> **energy savings over 15 % are possible**

Use Top performer - HVAC

- Use Top performer in the market as the price increase compared to inefficient, cheaper appliances will be recompensated throughout is lifetime

Size renewable (Solar) to demand

- The use of a PV system on the maximum available roof area is cost effective.
- Enable one clearly defined area for PV on the roof (avoid distorted small areas)

Behavior – Buy in User

- Buy in the user to utilize the appropriate set temperature, too low set temperature in the summer could consume too much energy -> 1K equals roughly 10% of energy

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