Guidehouse

Energy Efficiency Recommendations for FRAMES - Multi-Family House (MFH), Lebanon

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

BUILD_ME

June 2021

Introduction to the BUILD_ME project

Contents

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Background, Objectives and Methodology

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 (Jordan)

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

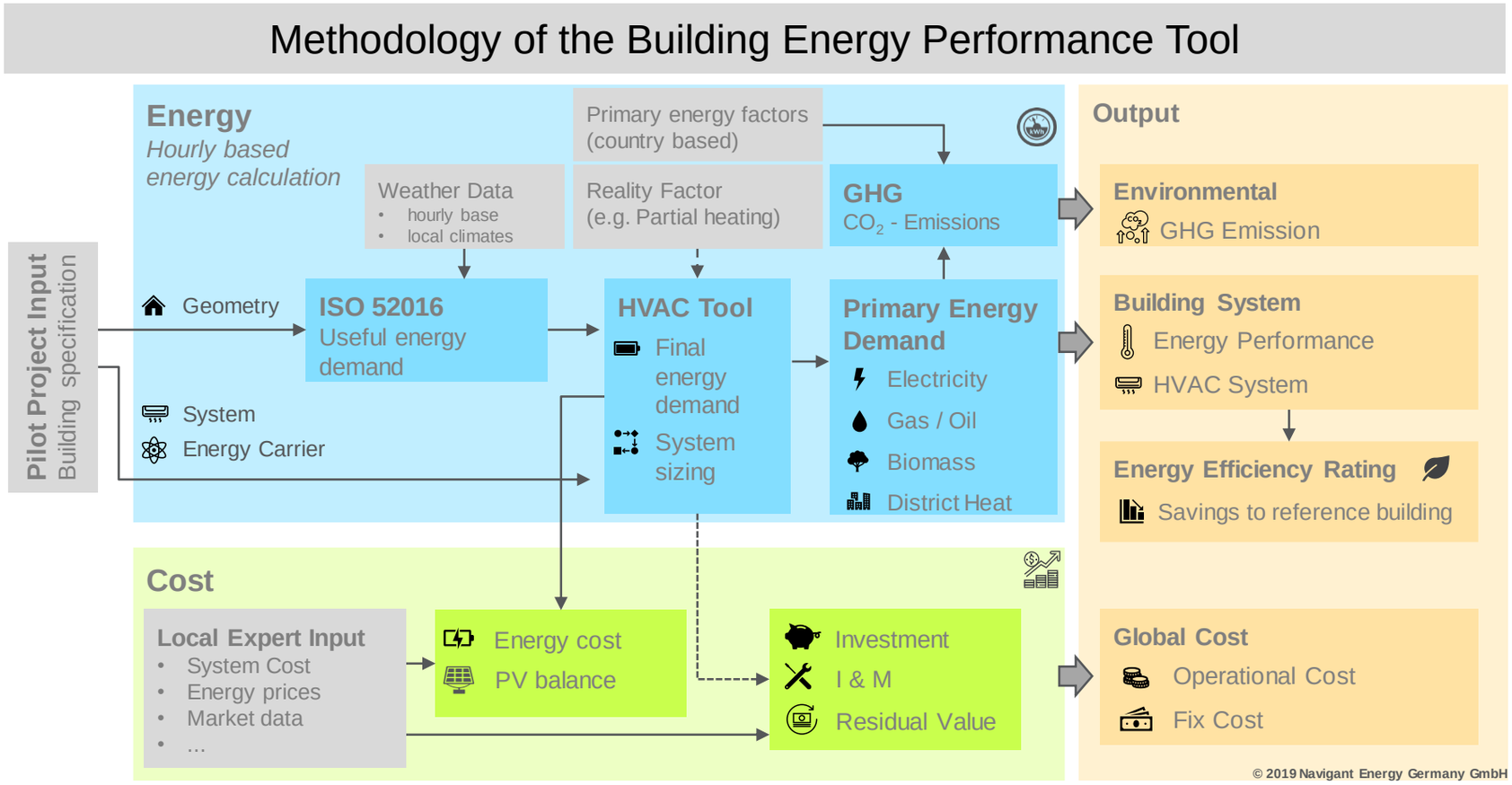
- Calculation of energy cost and investment cost of the systems, based on the HVAC system sized in the energy calculation
- Energy price systematic and PV clearing can be adapted to local situation (here: Jordan)
- Residual values at the end of the calculation period for the systems are considered

Methodology

Cost Benefit Analysis

HIGHLIGHTS

- 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 (Jordan)



Introduction

FRAMES - Multi-Family House (MFH), Boundary conditions

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FRAMES - Multi-Family House (MFH)

Aims

Creating multiapartment building with a design suggests energy efficient measures such as double walls and double-glazing windows.

Target Groups

Residential units for middle-class groups.

Function

Multiapartment buildings with several amenities and facilities.
.

Size

The project consists of three blocks with a total GFA of more than 4000 Sqm. This reports focuses on one building block.

Boundary Conditions I Building

Building Data

Status

Under construction

Specific Challenge

The project is located close to the coast. This provides potential of sea breeze but also a high Level of humidity.

Building Key Information	
Data	Input
Latitude	33.890704
Longitude	35.520156
Elevation [m]	73
Utilization	MFH
Number of floors	3
Number of apartment	12
Conditioned floor area [m²]	1,008
Clear room height [m]	2.80
Conditioned volume [m³]	2,800
Number of inhabitants [#]	4 per Unit
Year of construction	2020/2021

Boundary conditions

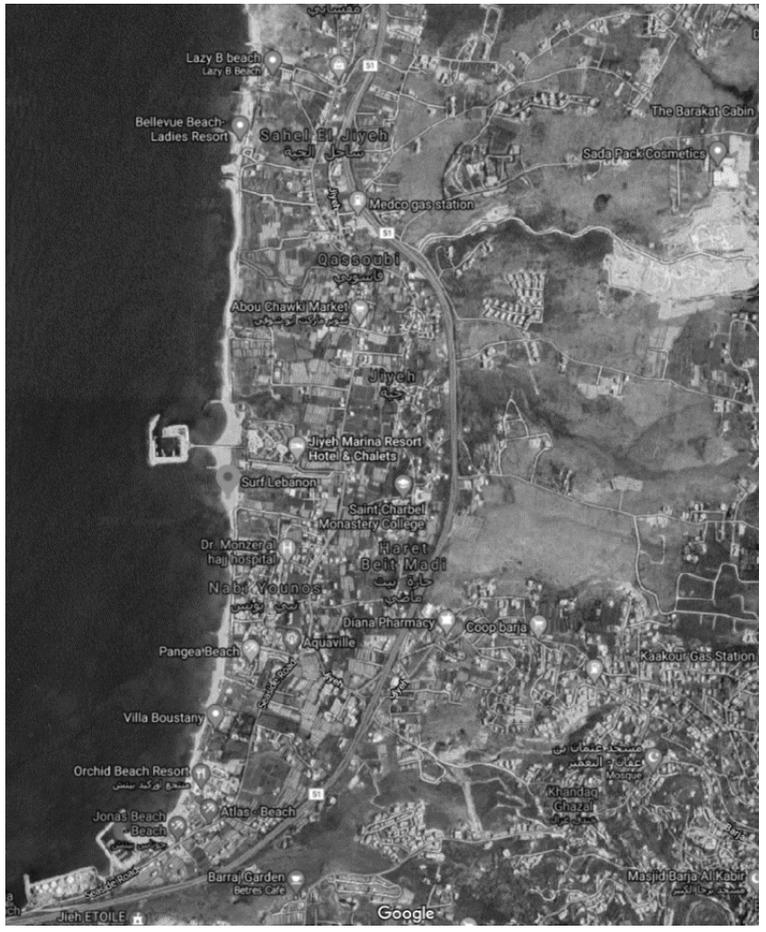
Site : Context matters

City : Jieh

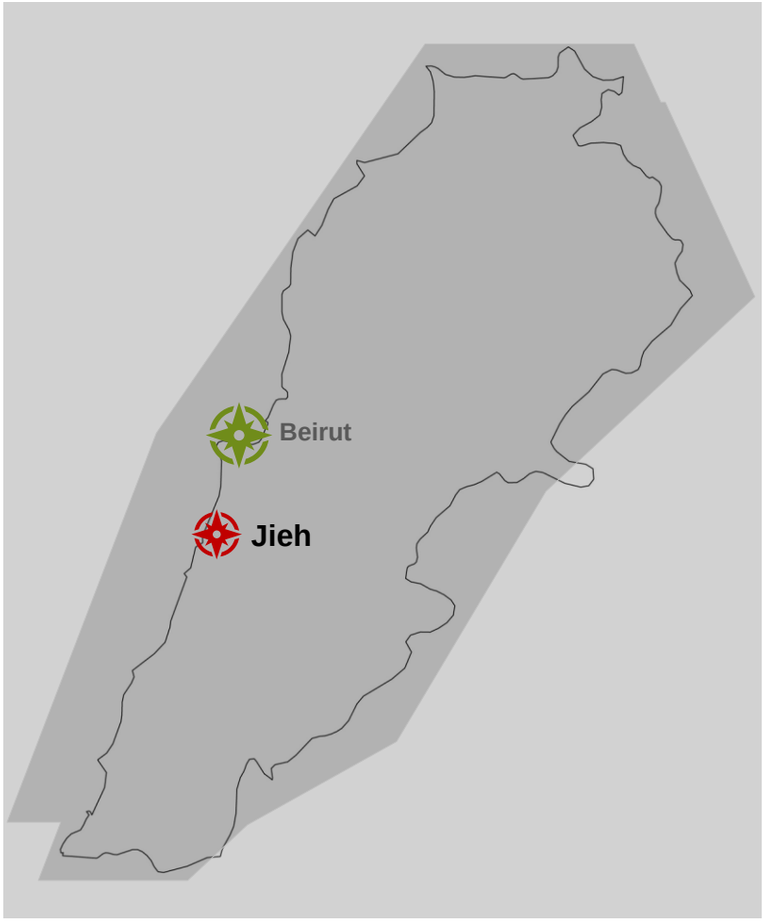
Location : 30 km south of Beirut

Context

The project located in the town of Jieh in the Chouf district.



Source: Google Maps

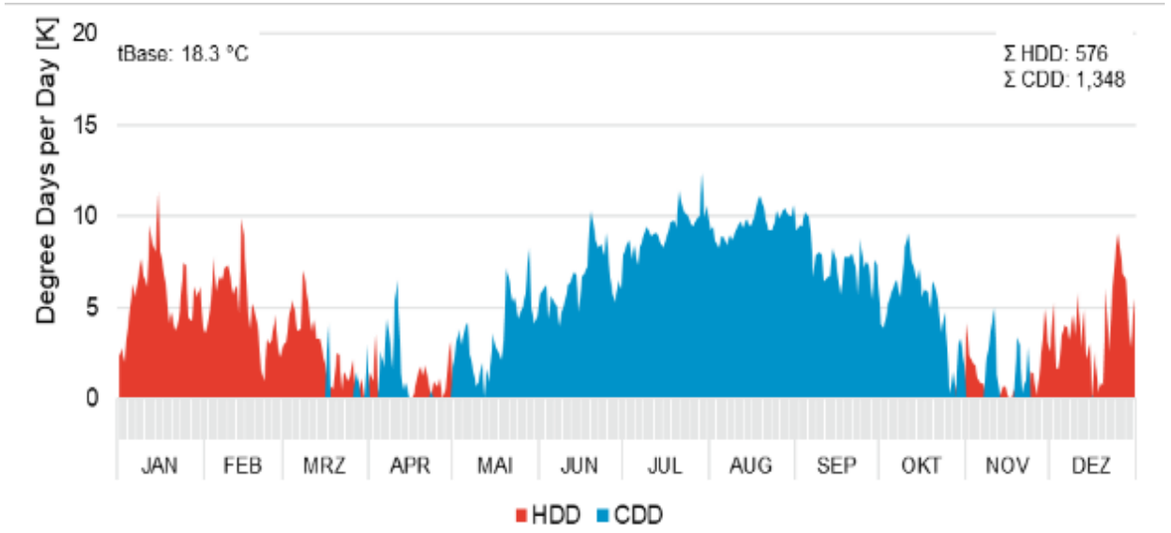


Boundary conditions I Climate Analysis

External temperatures and Relative Humidity *

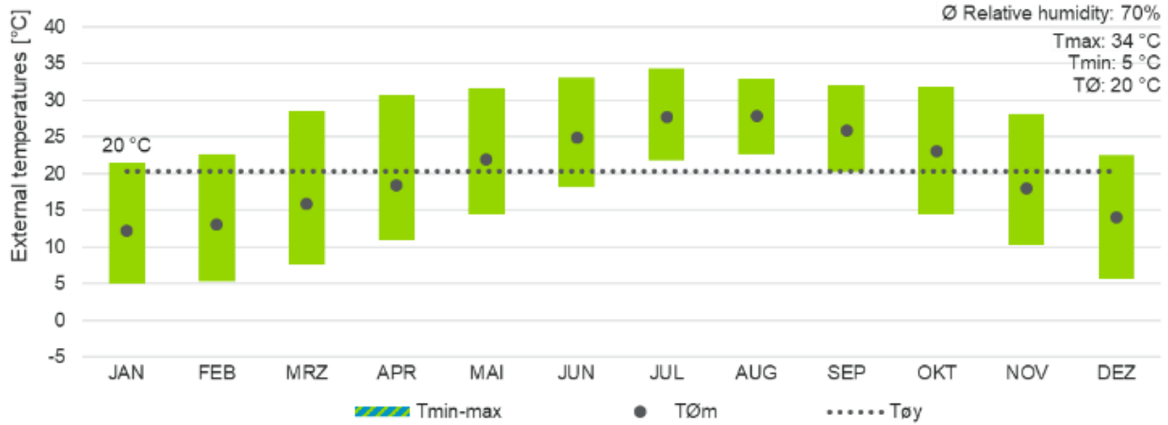
Description

The climate at the project site primarily warm and humid. External temperatures range from 5°C above 0°C to 34°C, with average temperatures around 20°C



Challenges and Potentials

The demand for cooling prevails against heat demand as the high number of >1,300 CDDs. The cooling degree days are 2 times higher than the HDDs. The monthly average relative humidity is above 65% but may also reach >70% in the summer months.



* HDD: heating degree days; CDD: cooling degree days; according to ASHREA methodology

Boundary conditions I Climate

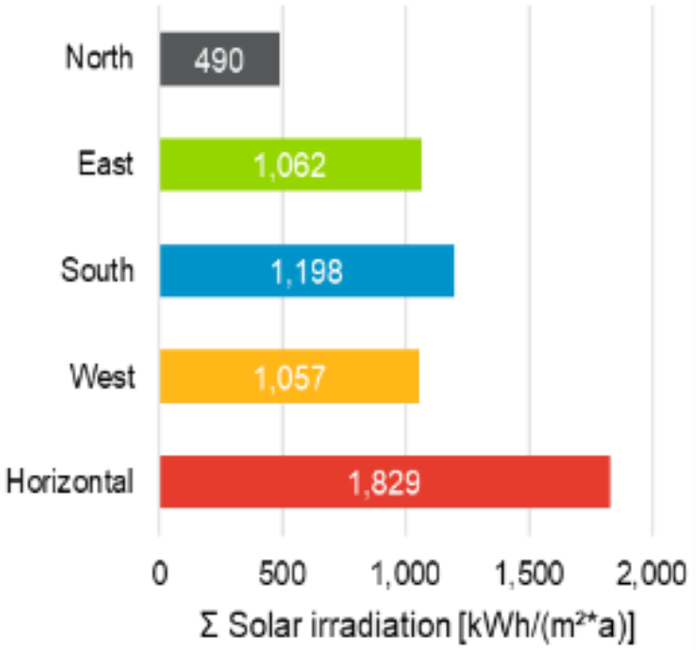
Solar Irradiation in Beirut (Lebanon)

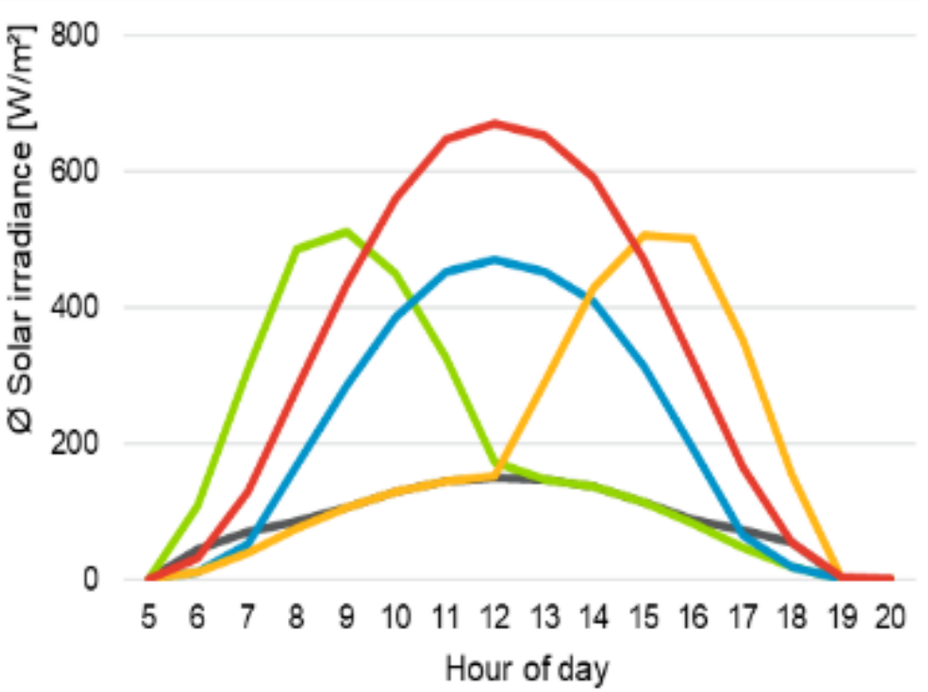
Description

The site experiences a horizontal irradiation of >1,800 kWh/(m²*a) and >1,000 kWh/(m²*a) for each East, South, and West orientations.

Challenges and Potentials

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





Boundary conditions I Economic and Emissions Inputs

Cost of Energy and Environmental impact

Energy price increases are assumed in the future and have been considered in the calculation as follows:

- Electricity price 0.125 - 0.133 Eur/kWh (depending on consumption of dwelling, incl. 9h generator)
- Price development of electricity = 10%/a,
- Interest rate = 5%.

Energy prices and CO2 emissions		
Parameter	Unit	Electricity
Energy price (EDL)	LBP/kWh I EUR/kWh*	200 I 0.175
Energy price (Gen Set)	LBP/kWh I EUR/kWh*	510 I 0.3
Price development	%/year	3
CO2 emission factor	gCO2/kWh	806
Economic parameters		
Interest rate (real)	%/year	5
Calculation period	years	20

- **Exchange rate: 1 EUR = 1,700 LBP**

Analysis

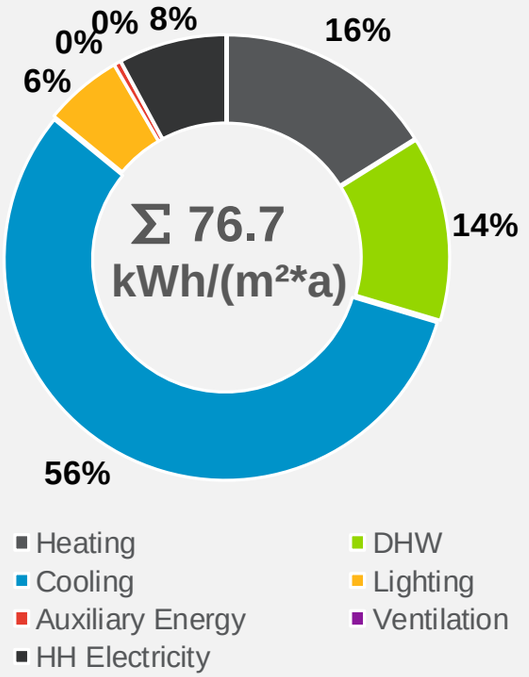
Starting Situation - Baseline and Current planning

Business as Usual

Building Characteristics as planned

The key components of the energy concept are illustrated in this table, it shows that the building envelope is in line with the thresholds of BUILD_ME Building Typology. While no special attention is given to use renewable energy sources.

Parameters	Baseline
Roof insulation (U-Value)	0.6 W/m²K
Wall insulation (U-Value)	0.9 W/m²K
Floor insulation (U-Value)	1.2 W/m²K
Windows (U-Value; G-Value)	2.0 W/m²K; 0.60
Window fraction	Ø 24%
Shading	no shading
Air infiltration through leakages	0.40 1/h
Heat supply	reversible unit - COP 3
Cold supply	reversible unit - COP 3
Hot water	electrical instantaneous
Ventilation system	No
Lighting system	LED
Renewable energy	No
Set temperature cooling/heating	22°C / 21°C



Energy Cost
10.1 EUR / (m²*a)

CO2 - Emission
43.7 kg / (m²*a)

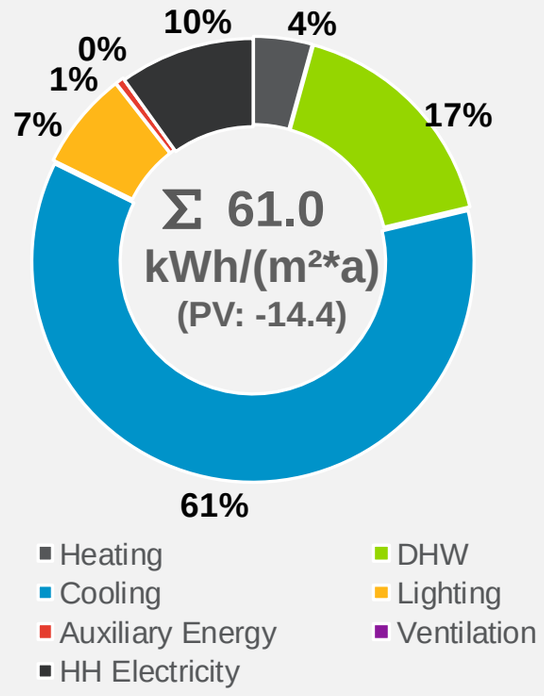
Current situation, FRAMES - Multi-Family House (MFH)

Results

The key components of the energy concept are illustrated in this table, it shows that the building envelope is enhanced to the baseline of the BUILD_ME building typology and shading and renewable energy (PV) has been added.

This leads to energy savings and emission reduction.

Parameters	Current
Roof insulation (U-Value)	**0.48 W/m²K**
Wall insulation (U-Value)	**0.48 W/m²K**
Floor insulation (U-Value)	**1.78 W/m²K**
Windows (U-Value; G-Value)	**2.9 W/m²K; 0.70**
Window fraction	Ø 24%
Shading	**manual shading**
Air infiltration through leakages	0.40 1/h
Heat supply	reversible unit - COP 3
Cold supply	reversible unit - COP 3
Hot water	electrical instantaneous
Ventilation system	No
Lighting system	LED
Renewable energy	**PV, 8.8 kWp**
Set temperature cooling/heating	22°C / 21°C



Energy Cost
6.6 EUR / (m²*a)

CO2 - Emission
31.7 kg / (m²*a)

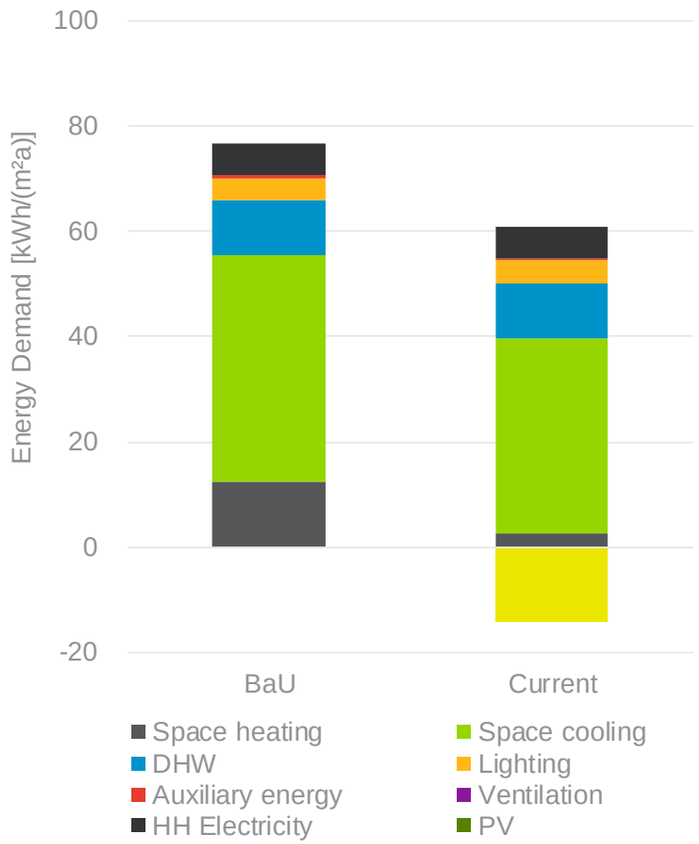
Current situation (project developer)

Results VS. BaU

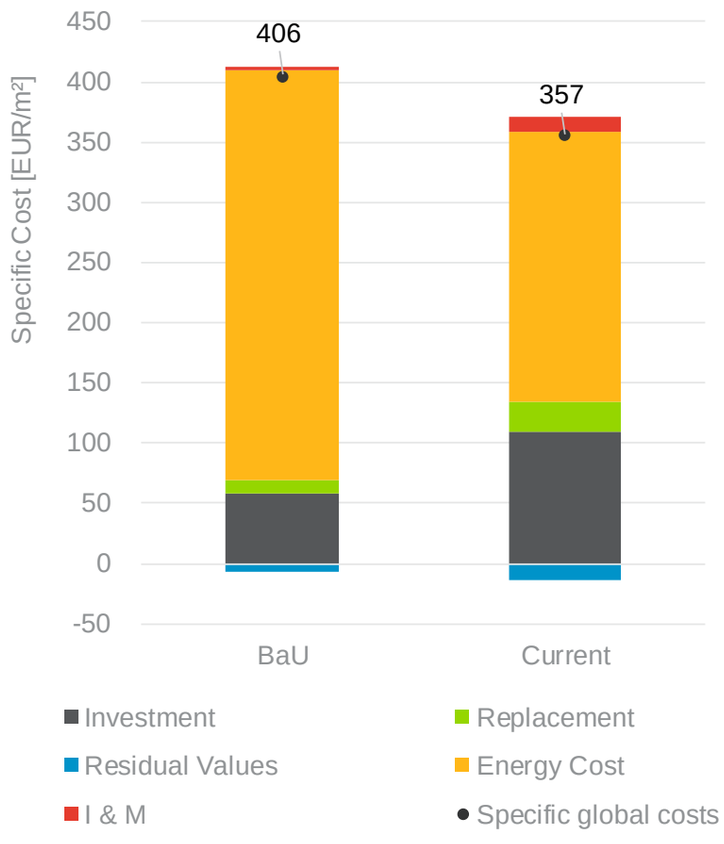
The proposed design is significantly more energy efficient in comparison to the BAU cases.

The proposed measures are already very reasonable in terms of energy and cost efficiency. But the analyzed measures will show even higher improvement potentials.

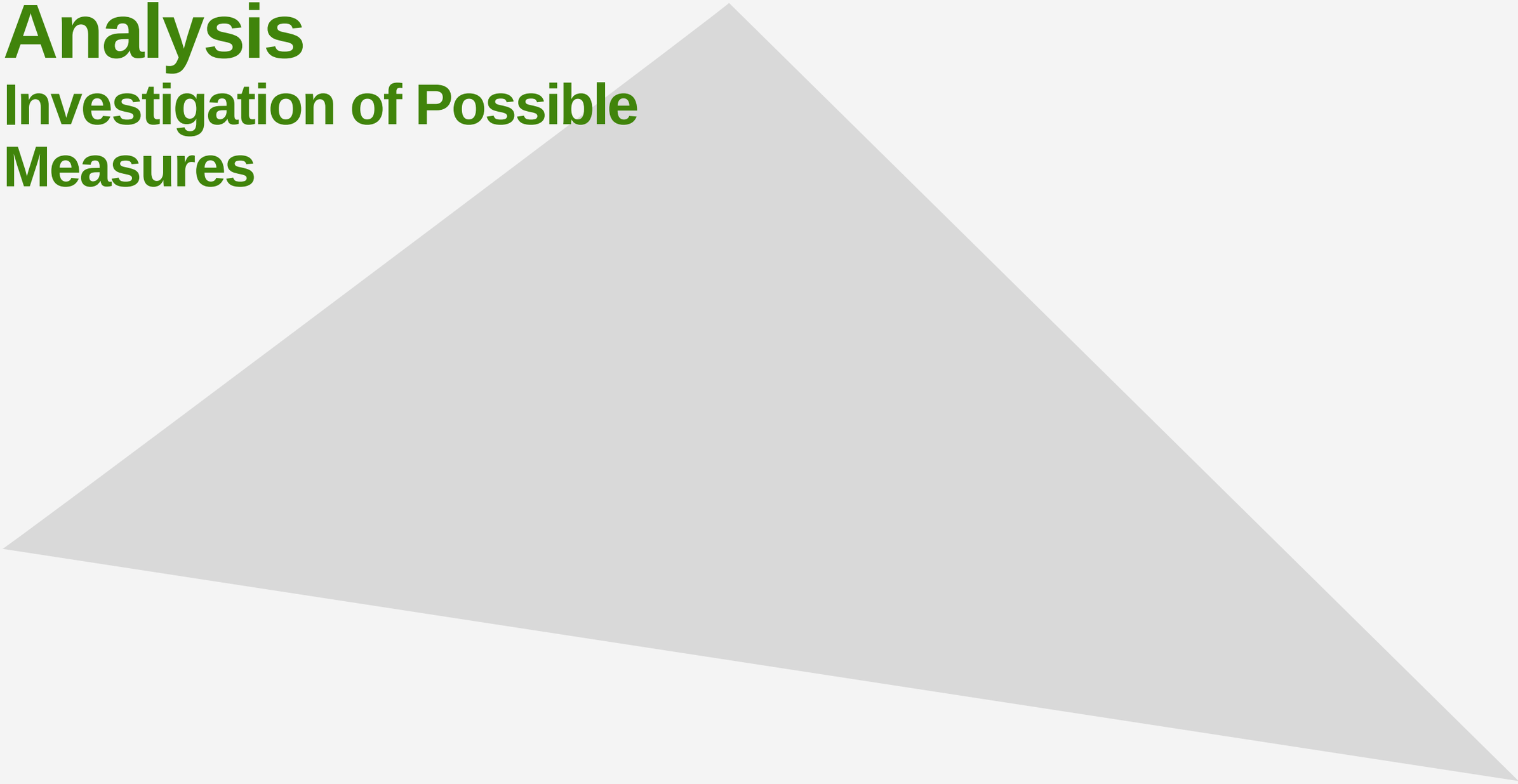
Final Energy Demand



Global Cost



Analysis
Investigation of Possible Measures



Overview of Analyzed Measures

Scope of Measures

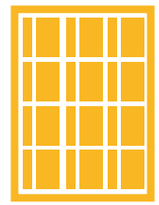
Envelope

- Roof insulation and color
- External wall insulation
- Windows (U, g, window fraction)
- Shading
- Air tightness

Systems

- Cooling
- Ventilation systems
- Operational temperatures

Renewable



- PV
- Solar Thermal

Qualitive assesment of facade concept

Pros and cons of facade design

Pro:

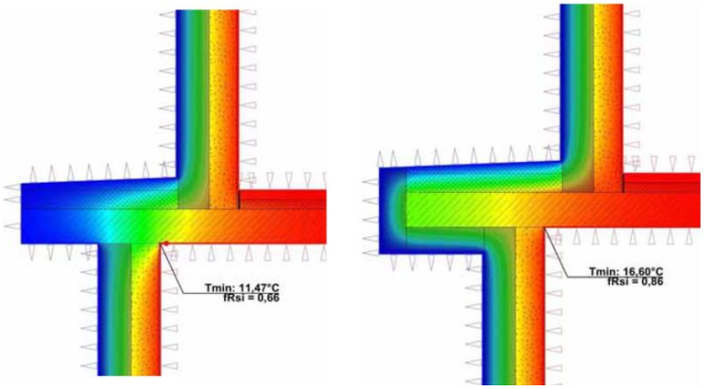
South oriented facade – overhangs

- Reducing the solar gains in summer

Con:

The displaced cubes in the facade,

Increases (the negative effect of) heat bridges



S: Zebau

Building Envelope I External wall

Thermal insulation

Var 1

U-Value = 2.2 W/m²K
(single wall, no insulation)

BaU

U-Value = 0.9 W/m²K
(double wall, no insulation)

Var 2

U-Value = 0.7 W/m²K
(double wall, 3 cm insulation)

Current

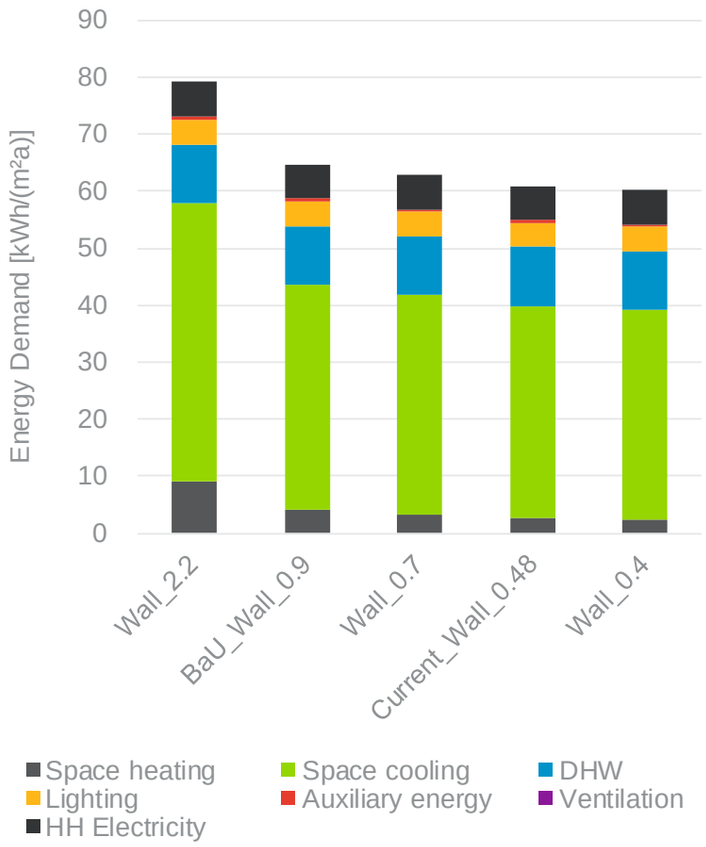
U-Value = 0.48 W/m²K
(double wall, 5 cm insulation)

Var 3

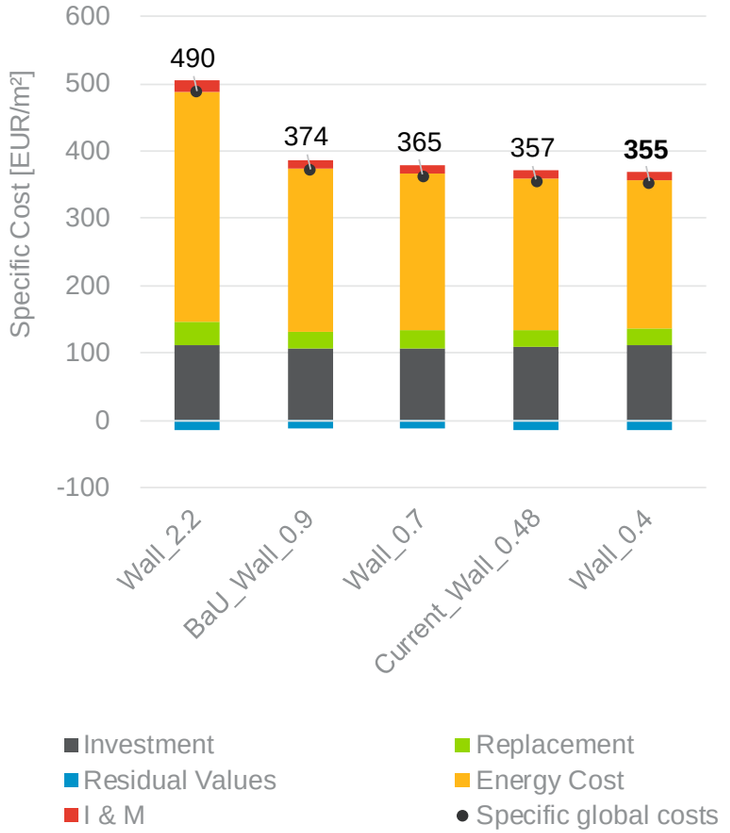
U-Value = 0.4 W/m²K
(double wall, 8 cm insulation)

Result: Var 3 is the most cost effective measure.

Final Energy Demand



Global Cost



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Building Envelope I Roof

Thermal insulation

Var 1

U-Value = 3.2 W/m²K (no insulation)

Var 2

U-Value = 2.0 W/m²K (no insulation)

Var 3

U-Value = 0.95 W/m²K (3 cm insulation)

BaU

U-Value = 0.6 W/m²K (5 cm insulation)

Current

U-Value = 0.48 W/m²K (8 cm insulation)

Var 4

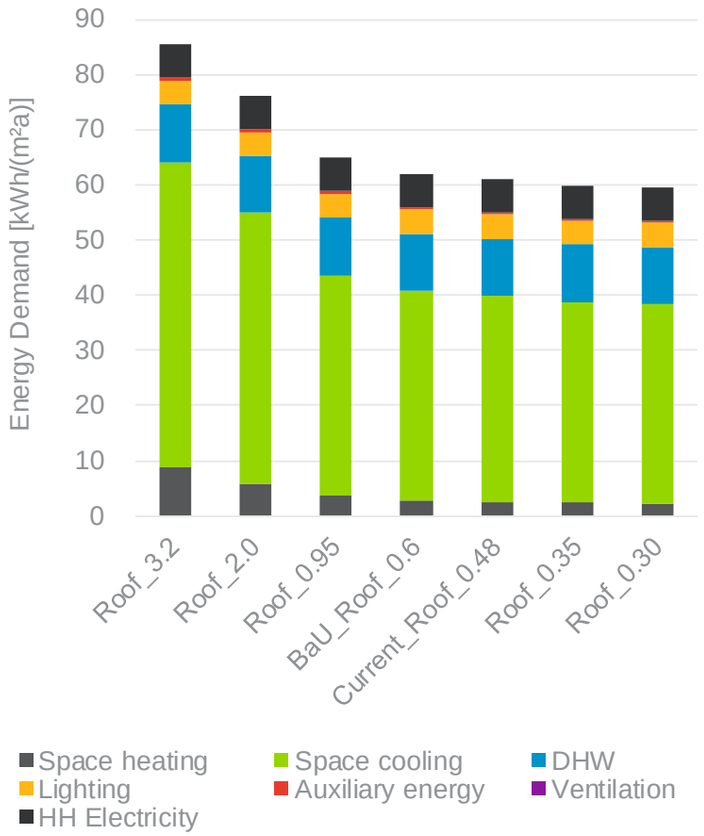
U-Value = 0.35 W/m²K (10 cm insulation)

Var 5

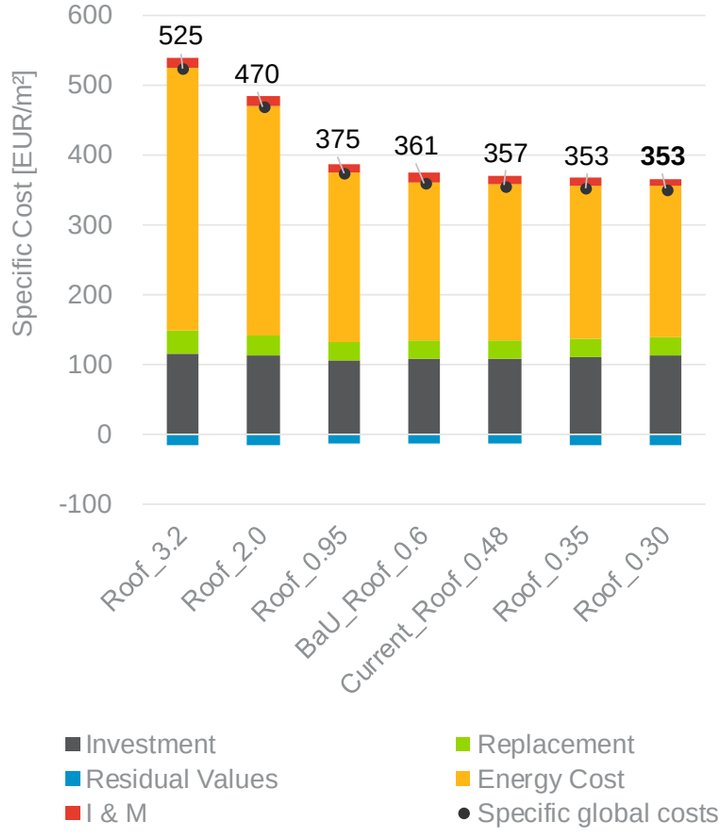
U-Value = 0.30 W/m²K (12 cm insulation)

Result: Var 5 is the most cost effective measure.

Final Energy Demand



Global Cost



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Building Envelope I Roof

Appropriate Color - Absorption factor

BaU / Current

Dark color (0.9)

Var 1

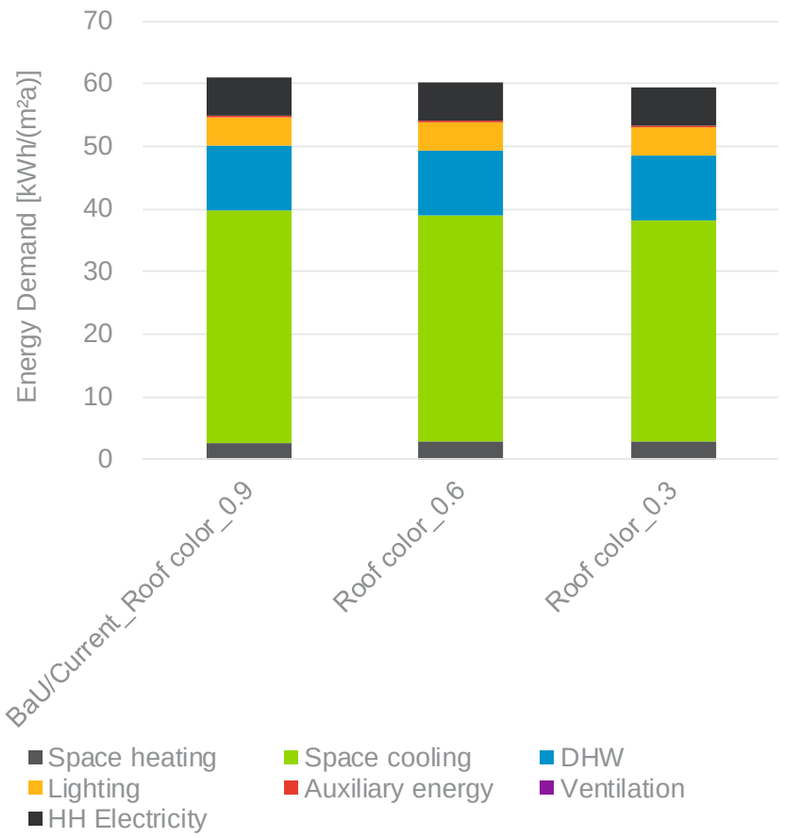
Intermediate color (0.6)

Var 2

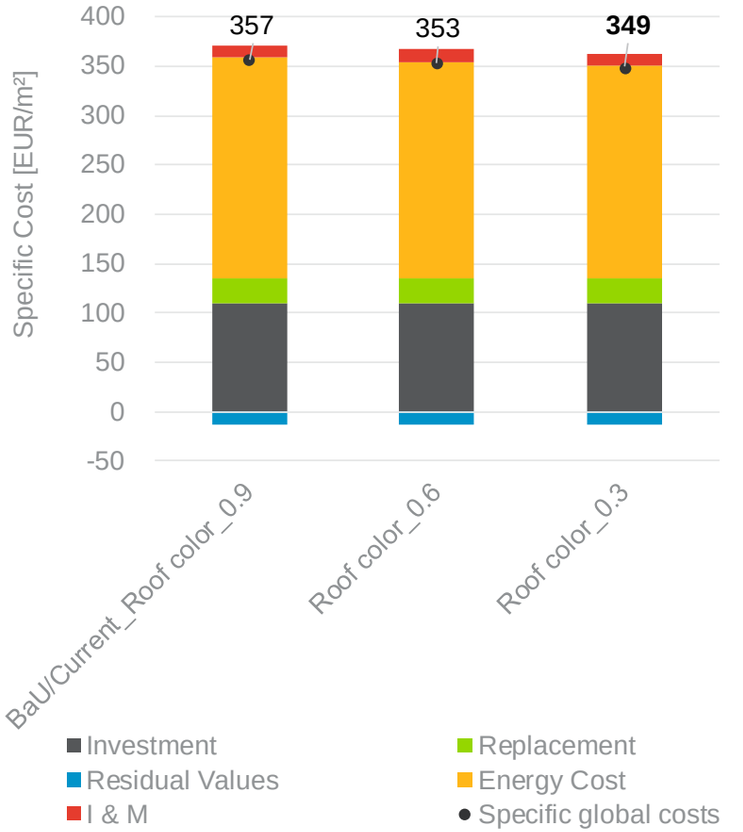
Light color (0.3)

Result: Var 2 is the most cost effective measure.

Final Energy Demand



Global Cost



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Building Envelope I Windows

U-Value

Single glazing (Var 1)

U-value 5.7 W/m²K, G-Value 0.85

Double glazing (Current)

U-value 2.9 W/m²K, G-Value 0.70

Double glazing (BaU)

U-value 2.0 W/m²K, G-Value 0.60

Double glazing – low E (Var 2)

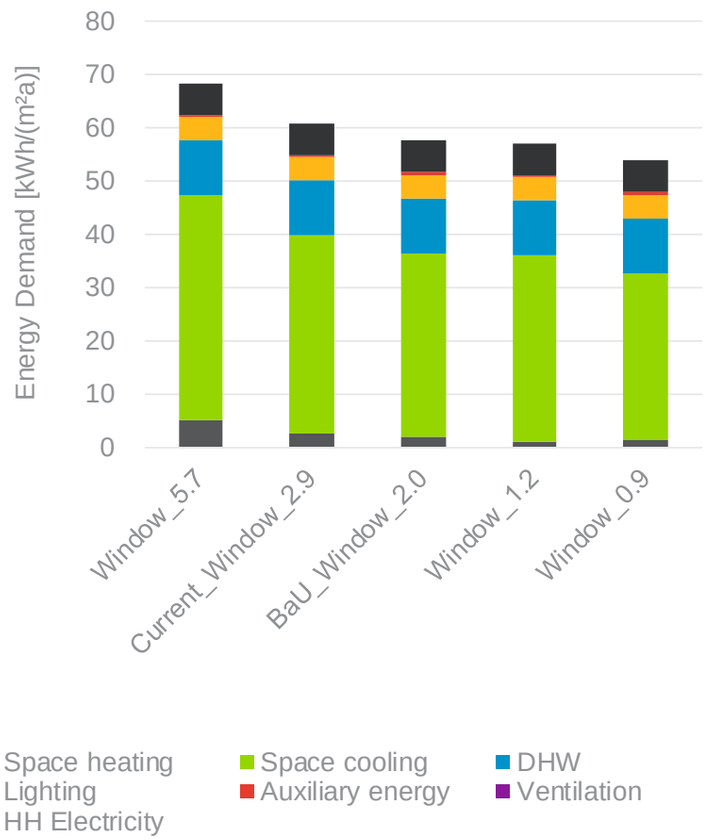
U-value 1.2 W/m²K, G-Value 0.65

Triple glazing (Var 3)

U-value 0.9 W/m²K, G-Value 0.5

Result: Var 3 is the most cost effective measure.

Final Energy Demand



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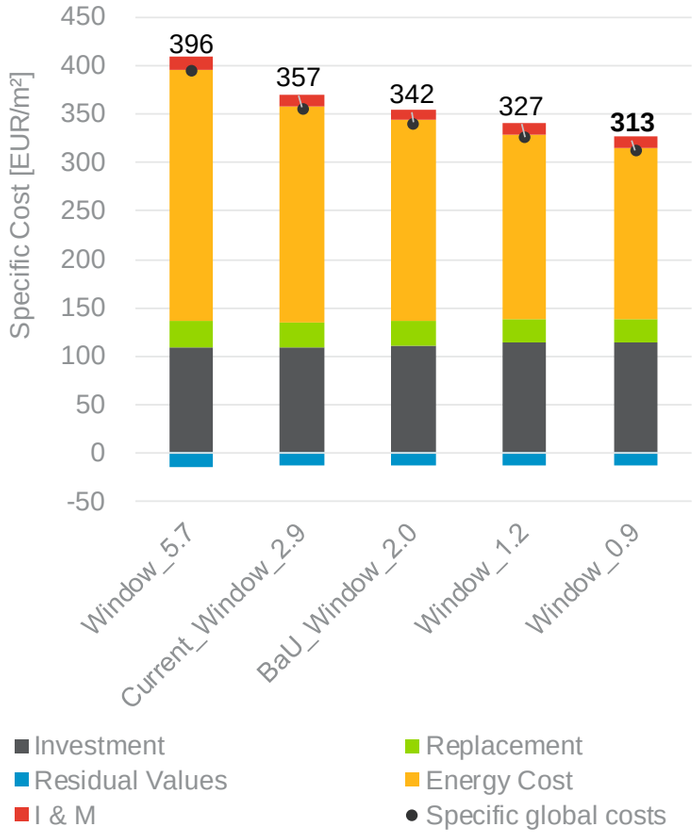

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Building Envelope I Window

Window fraction

Var 1

50 %

Var 2

40 %

Var 3

30 %

BaU / Current

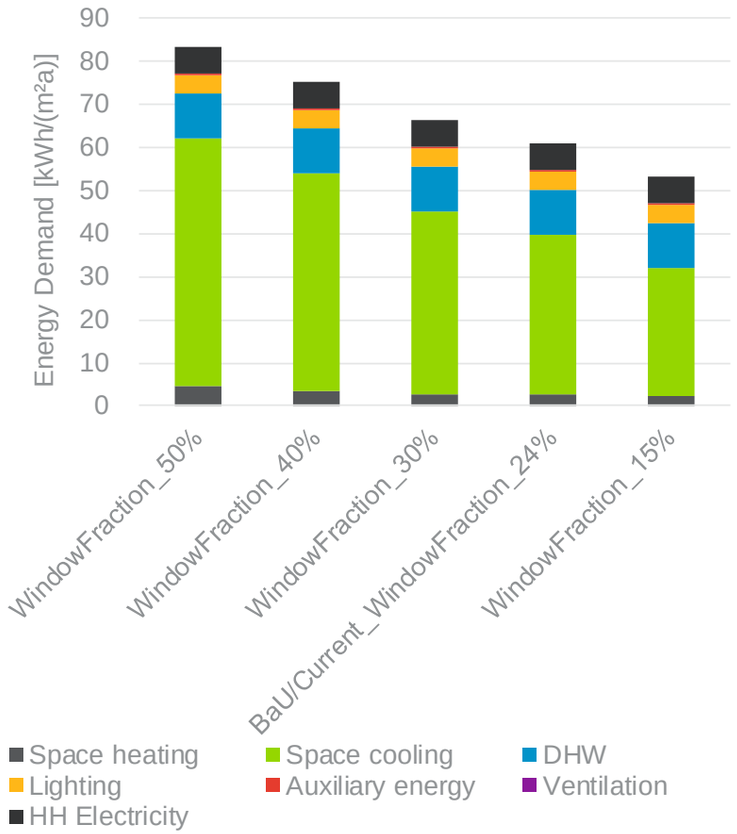
24 %

Var 4

15 %

Result: Var 4 is the most cost effective measure.

Final Energy Demand



Global Cost

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Air Tightness

What is the effect of air tightness?

BaU / Current

0.40

Var 1

0.35

Var 2

0.30

Var 3

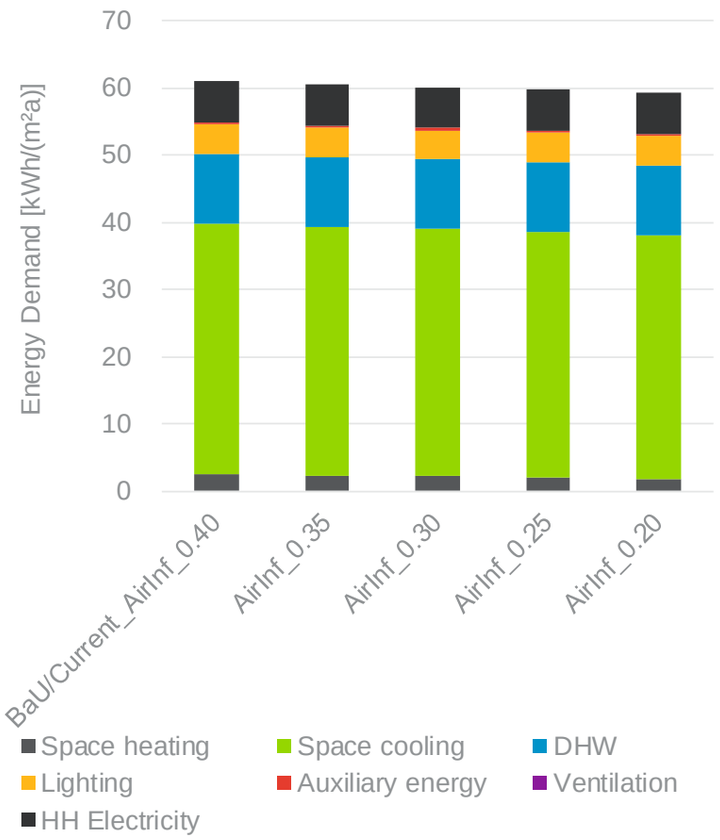
0.25

Var 4

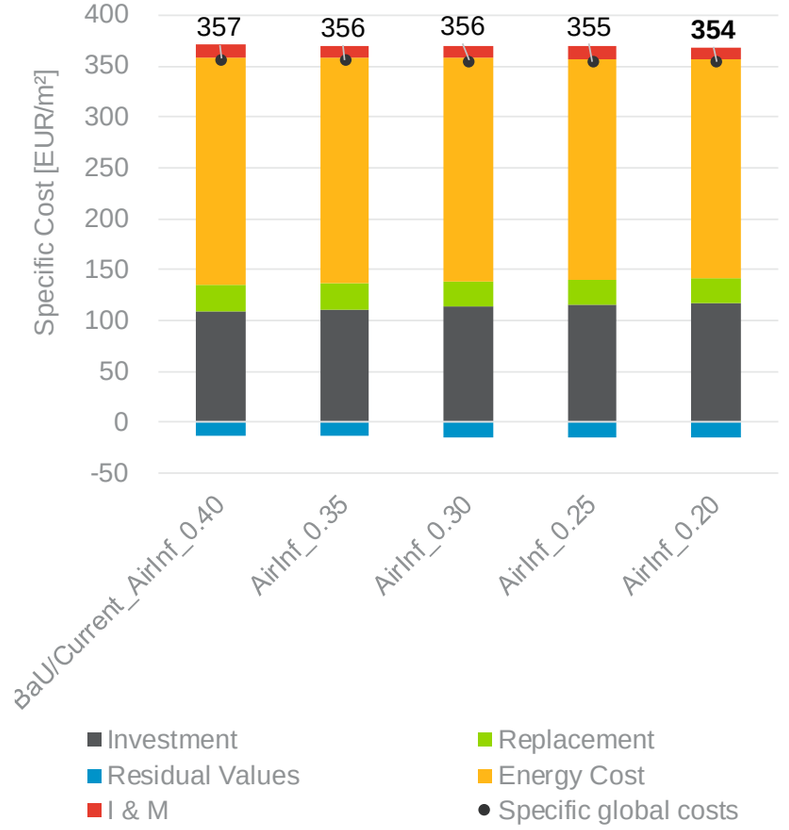
0.20

Result: Var 4 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

Current

Manual Shading

Var 2

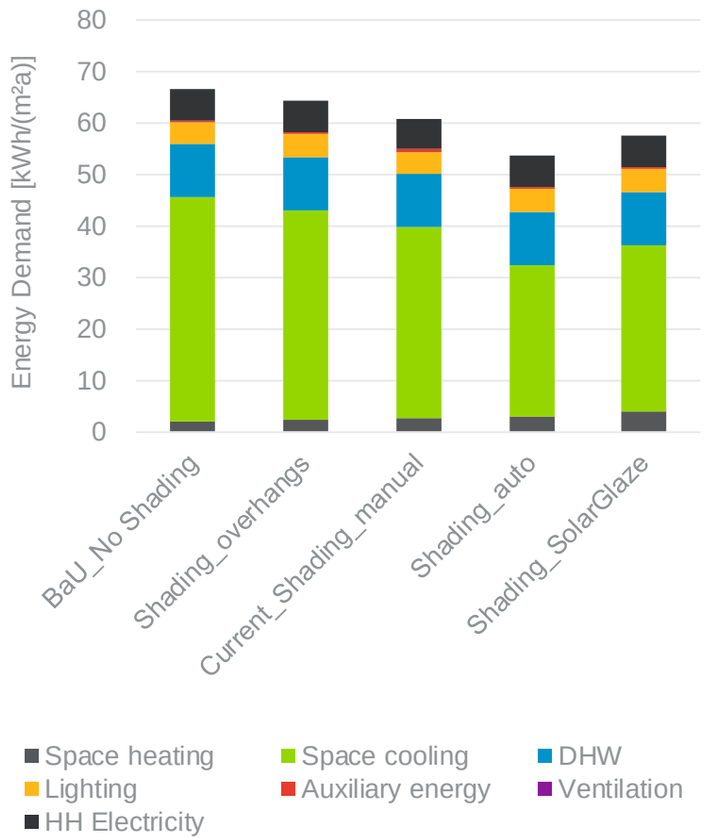
Automatic Shading

Var 3

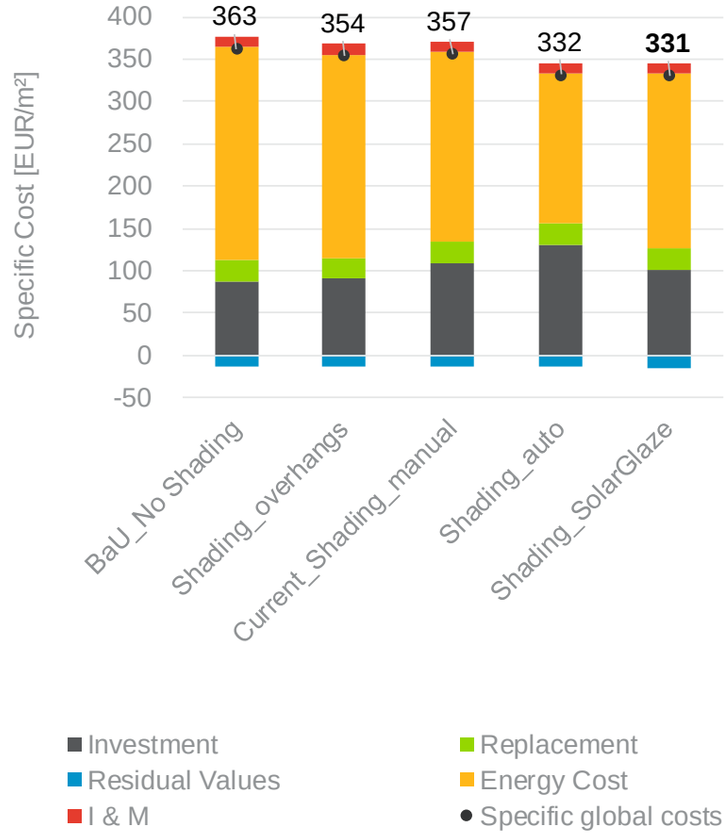
Solar Glazing

Result: Var 3 is the most cost effective measures.

Final Energy Demand



Global Cost



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HVAC I Cooling

Analysis

BaU / Current

Reversible Unit
(Cooling EER 3)

Var 1

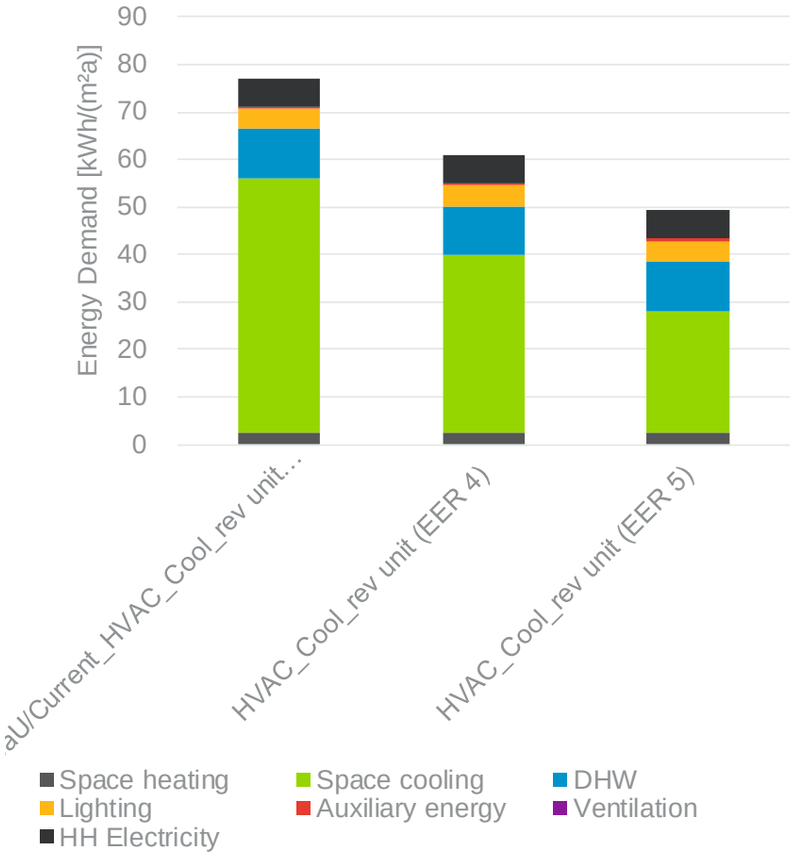
Reversible Unit
(Cooling EER 4)

Var 2

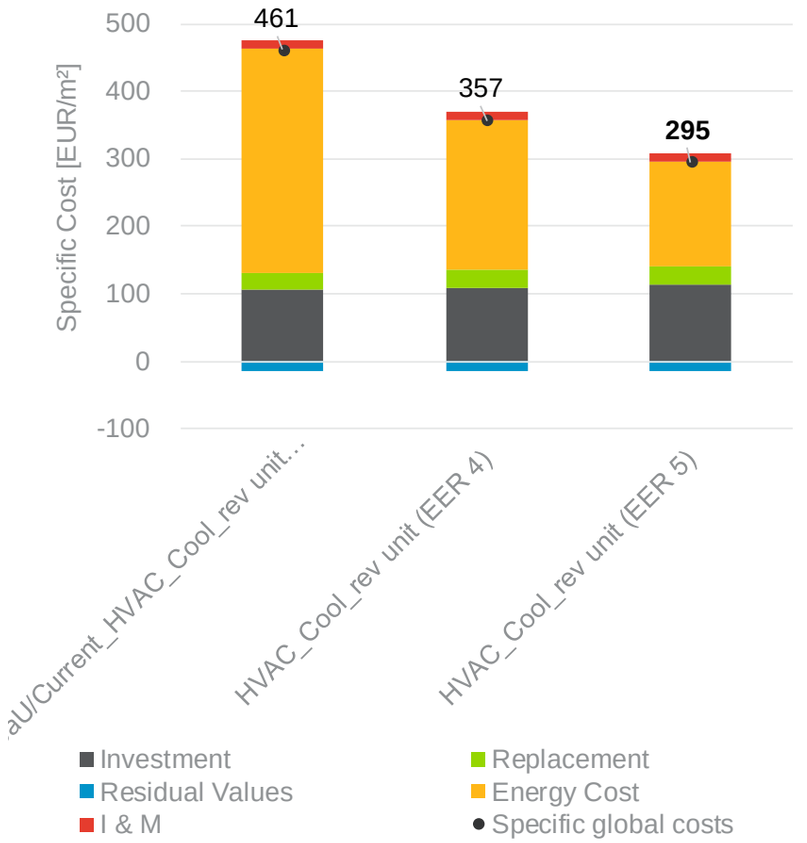
Reversible Unit with chilled ceilings
(Cooling EER 5)

Result: Var 2 is the most cost effective measure.

Final Energy Demand



Global Cost



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Operational Temperatures

Analysis

BaU / Current

Cooling Temperature: 22°C
Heating Temperature: 21°C

Variants cooling

Cooling: 22/24/25/26°C

Variants heating

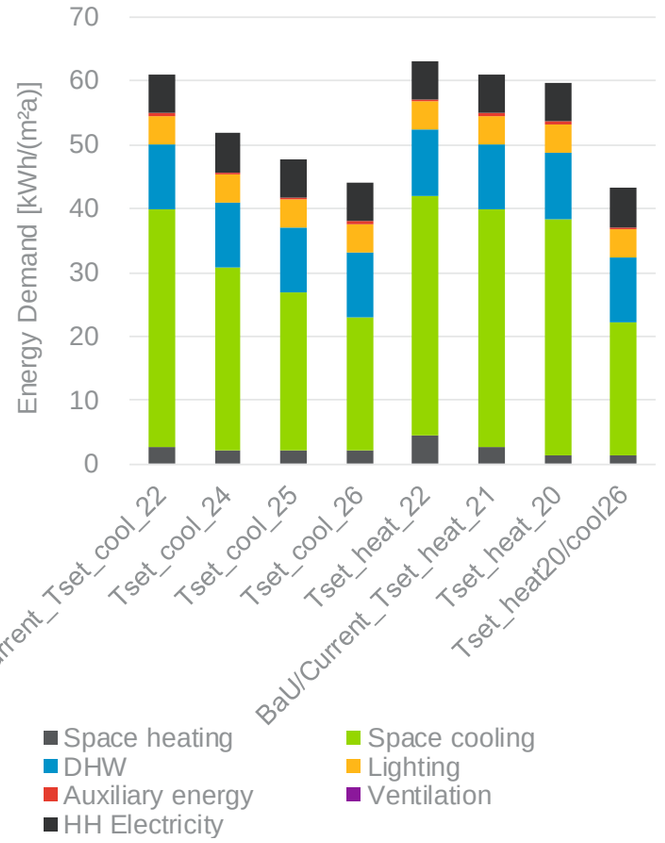
Heating: 20/21/22°C

Combined Variant

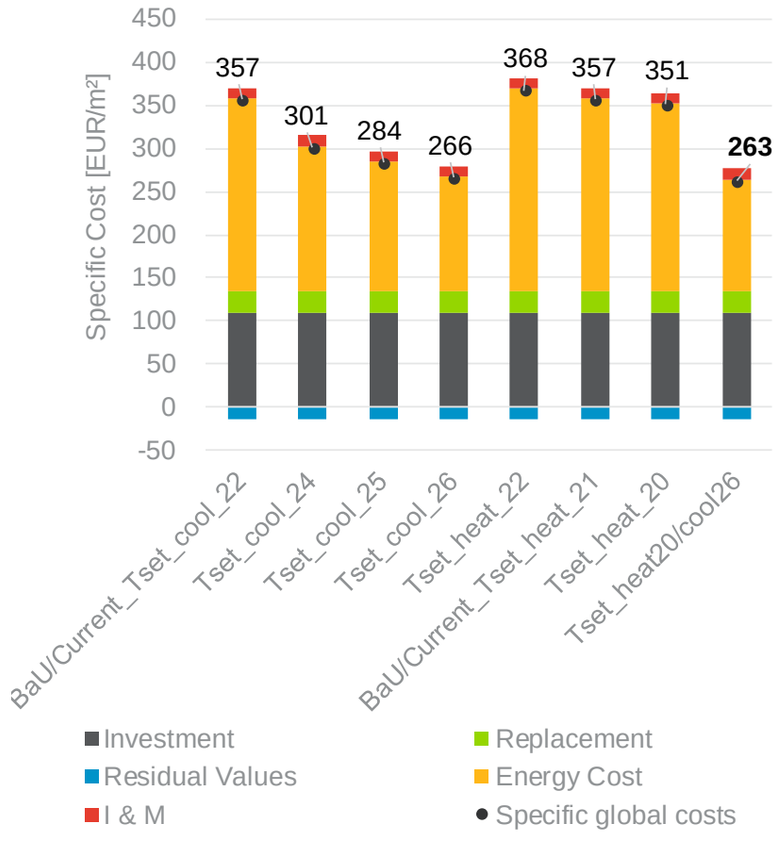
Cooling Temperature: 26°C
Heating Temperature: 20°C

Result: This measure is very effective and not related to any cost. The **combined variant** is the most cost-effective variant.

Final Energy Demand



Global Cost



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Renewables I Solar Thermal

Analysis

BaU/Current

no ST = el. instantaneous

Var 1

ST – max. exploitation of roof surface (100%)

Var 2

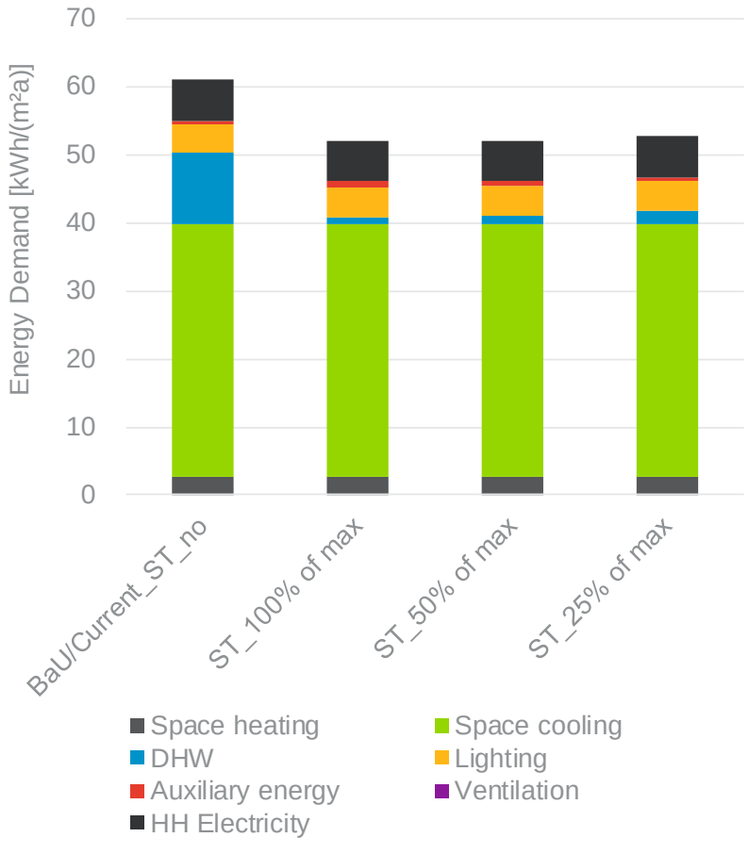
ST – 50% of max

Var 3

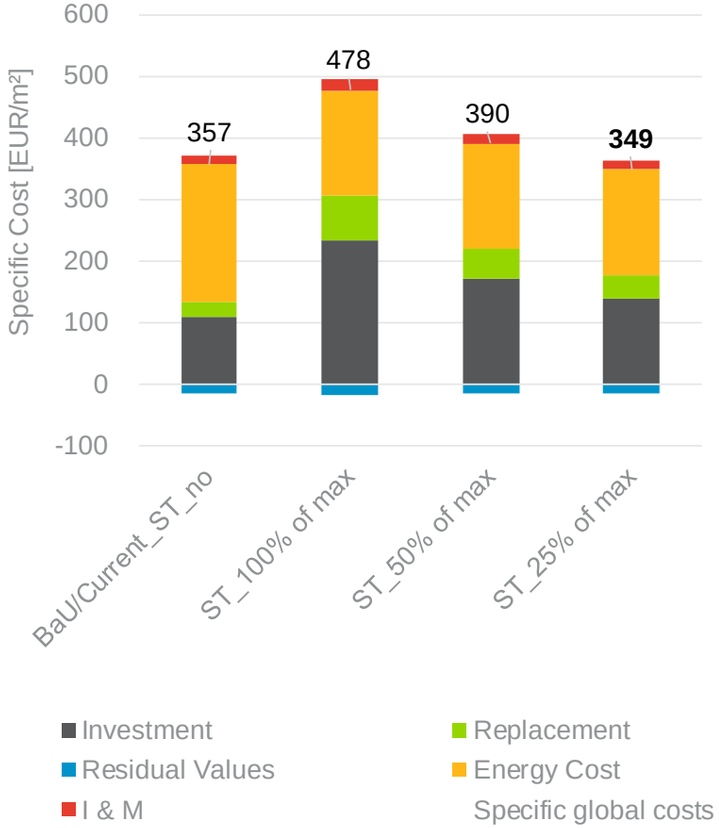
ST – 25% of max

Result: Var 3 is the most cost effective measure, but still less favourable than PV.

Final Energy Demand



Global Cost



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Renewables I PV

Analysis

BaU

no PV

Var 1

PV – max. exploitation of roof surface (100%)

Current

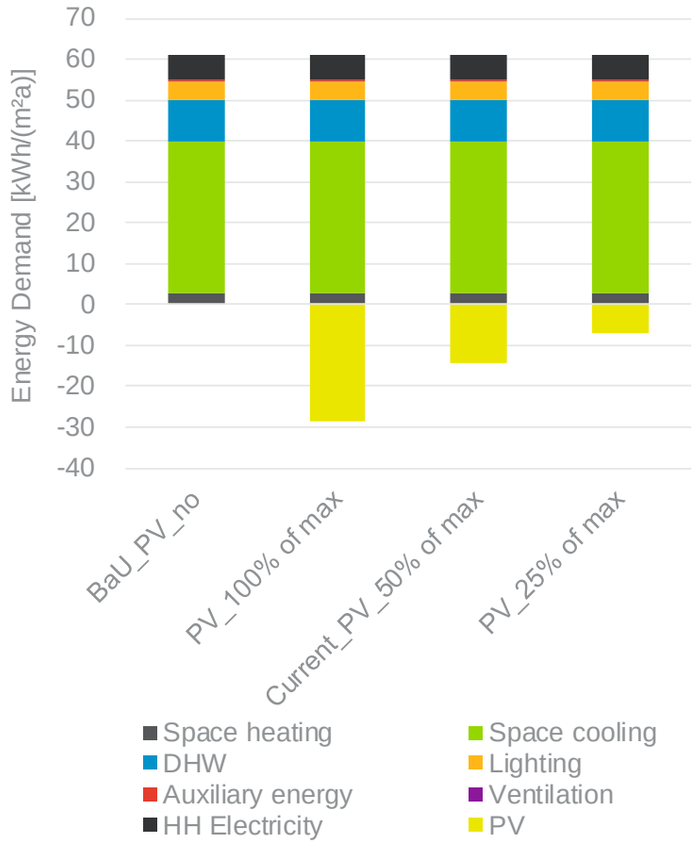
PV – 50% of max

Var 2

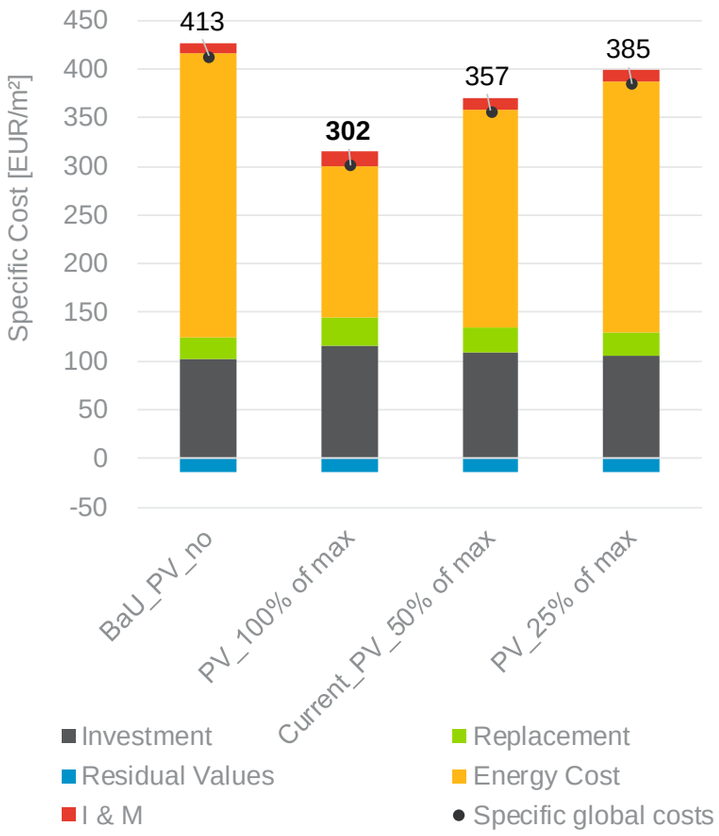
PV – 25% of max

Result: Var 1 is the most cost effective measure.

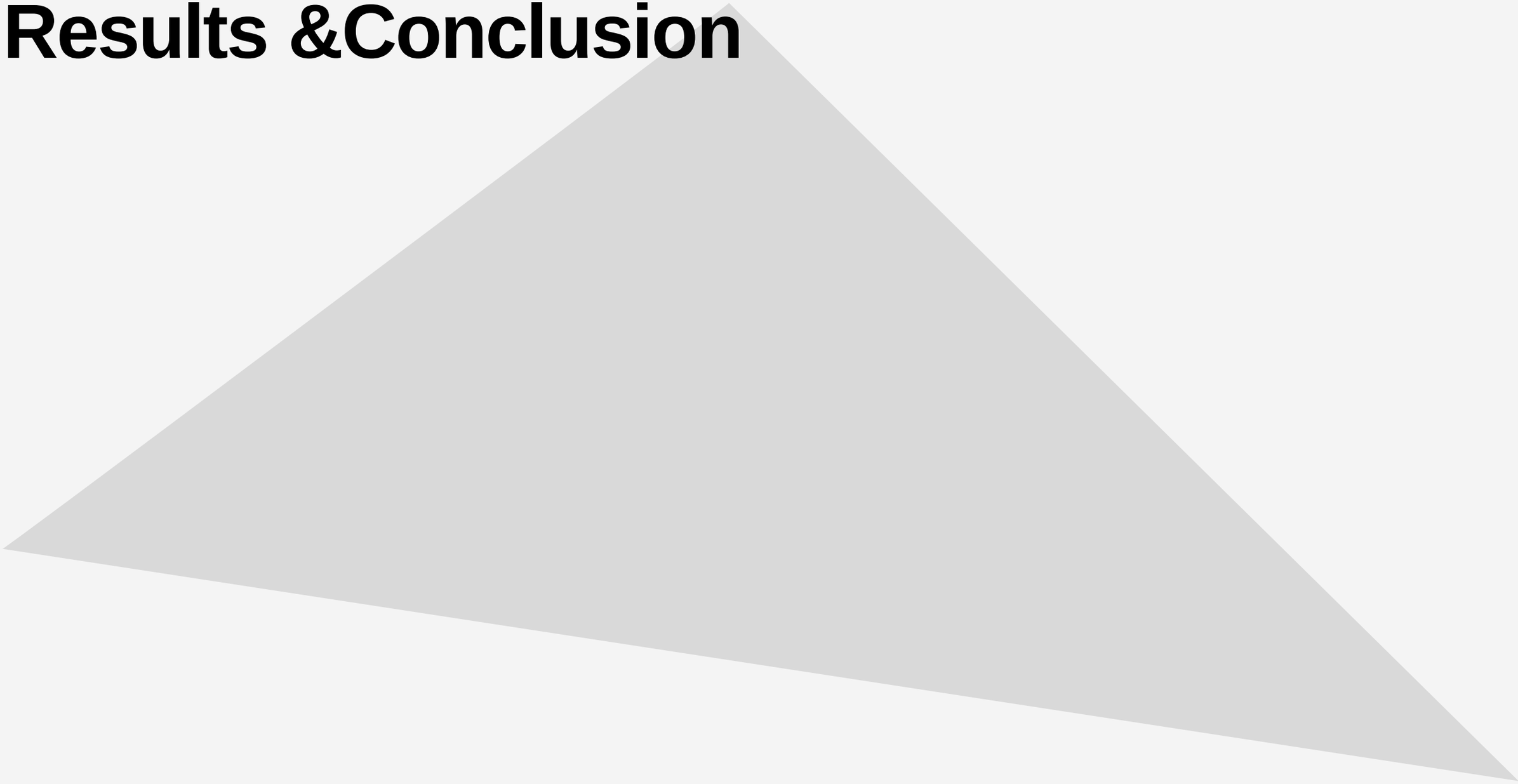
Final Energy Demand



Global Cost

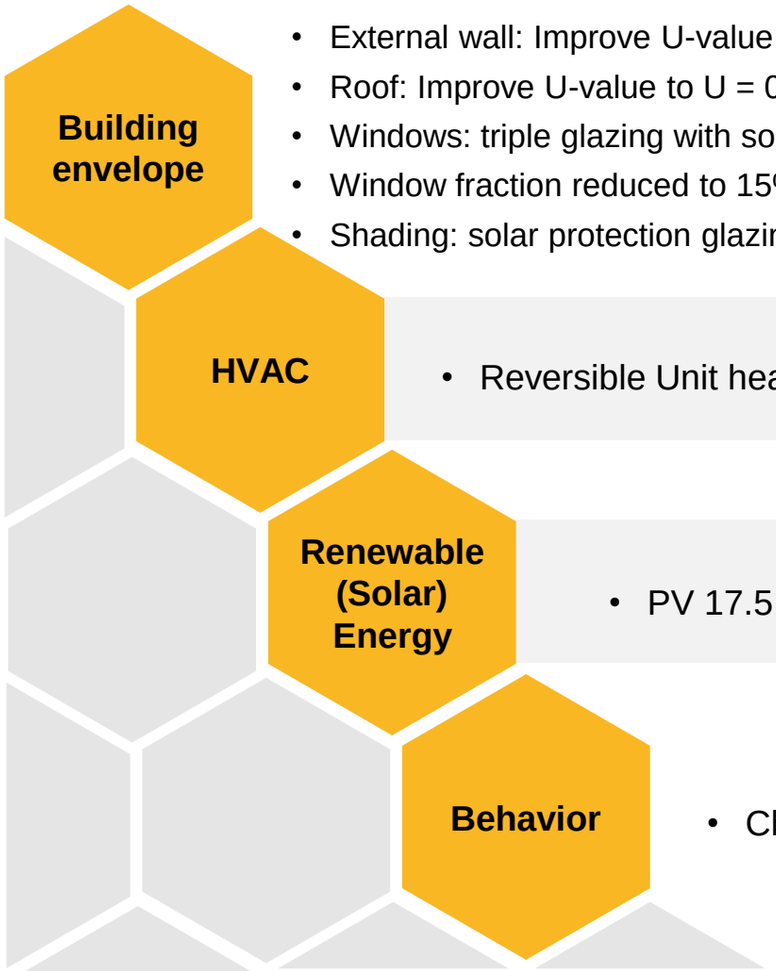


Results &Conclusion



Overview of recommended measures

Four steps to reduce energy demand significantly



Building envelope

- External wall: Improve U-value to U = 0.4 W/m²K
- Roof: Improve U-value to U = 0.3 W/m²K, choose light roof color
- Windows: triple glazing with solar protection glazing (U-Value 0.9 W/m²K, G-Value 0.3), improve air tightness (aim: n_{inf} = 0.20 1/h)
- Window fraction reduced to 15%
- Shading: solar protection glazing

HVAC

- Reversible Unit heating / cooling and high efficiency (EER ~ 5)

Renewable (Solar) Energy

- PV 17.5 kWp

Behavior

- Change set temperature from Cooling 22°C/ Heating 21°C to Cooling 26°C/ Heating 20°C

Optimized Solution

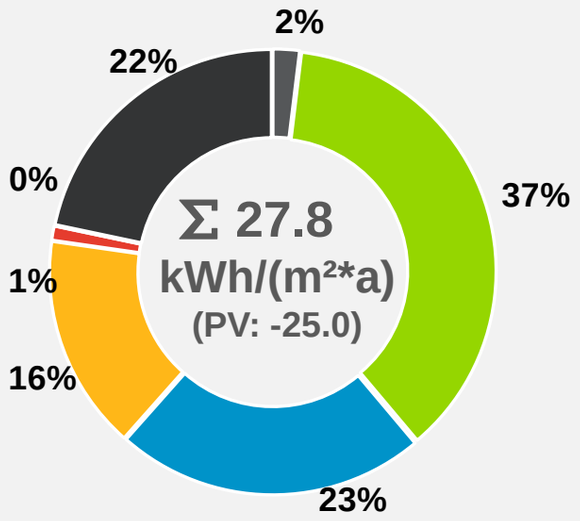
Results

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
Roof insulation (U-Value)	**0.3 W/m²K (light color)**
Wall insulation (U-Value)	**0.4 W/m²K**
Floor insulation (U-Value)	1.78 W/m²K
Windows (U-Value; G-Value)	**0.9 W/m²K; 0.3 (solar glazing)**
Window fraction	**Ø 15%**
Shading	**solar glazing**
Air infiltration through leakages	**0.20 1/h**
Heat supply	**reversible unit - COP 5**
Cold supply	**reversible unit - COP 5**
Hot water	electric instantaneous
Ventilation systems	No
Lighting systems	LED
Renewable energy	**17.5 kWp (PV, maximum)**
Set temperature cooling/heating	**26°C / 20°C**



Energy Cost (- PV)
0.4 EUR / (m²*a)

CO2 - Emission
1.9 kg / (m²*a)

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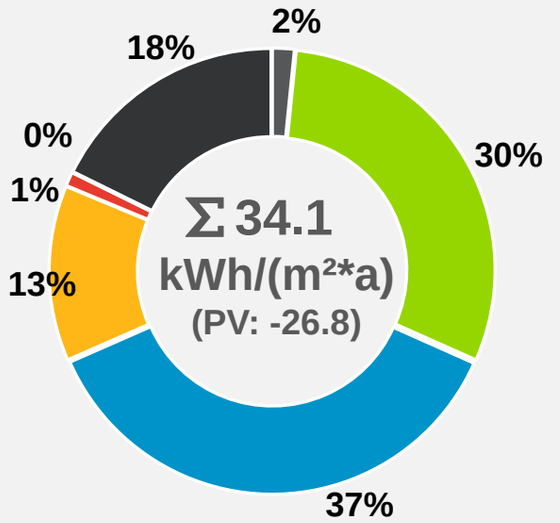
Selected Package

Results

The key components of the energy concept are illustrated in this table, it shows that the building envelope is enhanced to the baseline of the BUILD_ME building typology and shading and renewable energy (PV) has been added.

This leads to energy savings and emission reduction.

Parameters	Selected
Roof insulation (U-Value)	**0.3 W/m²K (light color)**
Wall insulation (U-Value)	**0.4 W/m²K**
Floor insulation (U-Value)	1.78 W/m²K
Windows (U-Value; G-Value)	2.9 W/m²K; 0.70
Window fraction	Ø 24%
Shading	**manual shading**
Air infiltration through leakages	**0.20 1/h**
Heat supply	**reversible unit - COP 5**
Cold supply	**reversible unit - COP 5**
Hot water	electric instantaneous
Ventilation systems	No
Lighting systems	LED
Renewable energy	**17.5 kWp (PV, maximum)**
Set temperature cooling/heating	**26°C / 20°C**



Energy Cost
1.0 EUR / (m²*a)

CO2 - Emission
5.0 kg / (m²*a)

Comparative overview

Baseline vs. Current vs. Selected vs. Optimized

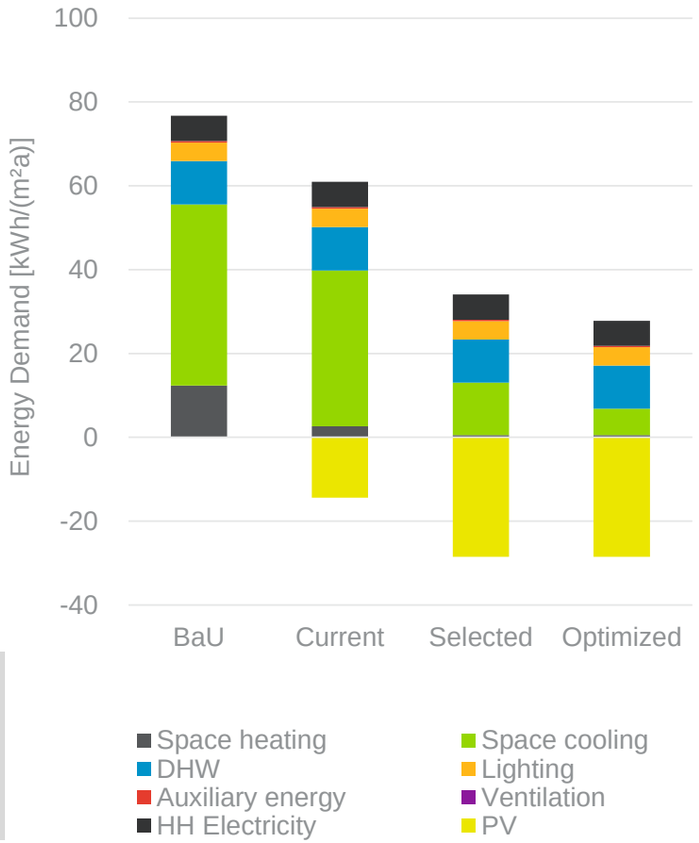
Conclusion

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

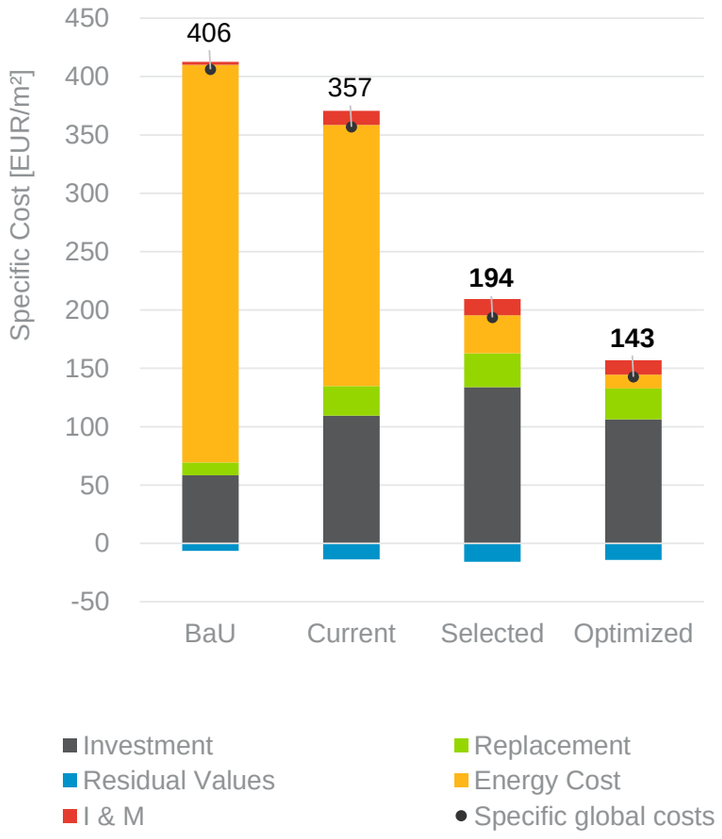
Savings BaU to Optimized (incl. PV)

- Energy: **77** ► **3** kWh/m²a (-95%)
- E-Cost: **10.1** ► **0.4** EUR/m²a (-95%)

Final Energy Demand



Global Cost



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Selected vs. current

Payback of single measures and whole package

Parameters	Optimized	Investment (selected-current) [EUR]	Energy cost savings* [EUR / year]	Payback [years]	Lifetime [year]
Roof insulation (U-Value)	0.3 W/m²K	4,900	-200	24	40
Wall insulation (U-Value)	0.4 W/m²K	2,600	-100	28	40
Air infiltration through leakages	0.20 1/h	8,900	-225	40	-
Heat/Cold supply	reversible unit – EER 5	6,500	-1,800	4	20
Renewable energy	17.5 kWp (PV, maximum) (instead of PV 8.8 kWp)	7,300	-3,800	2	20
Set temperature cooling/heating	26°C / 20°C	0	-2,400	Immediately	-
Total (current to selected)**		**28,000 (3-5%)*****	**-3,600**	**8**	

* Remark: The energy cost savings have been calculated conservatively based on the current electricity starting price (appr. 13 Cent/kWh, incl. 9h of diesel generator outage time).

** 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 500 or 1000 Euro/m² (5% or 3% additional costs).

Key conclusion

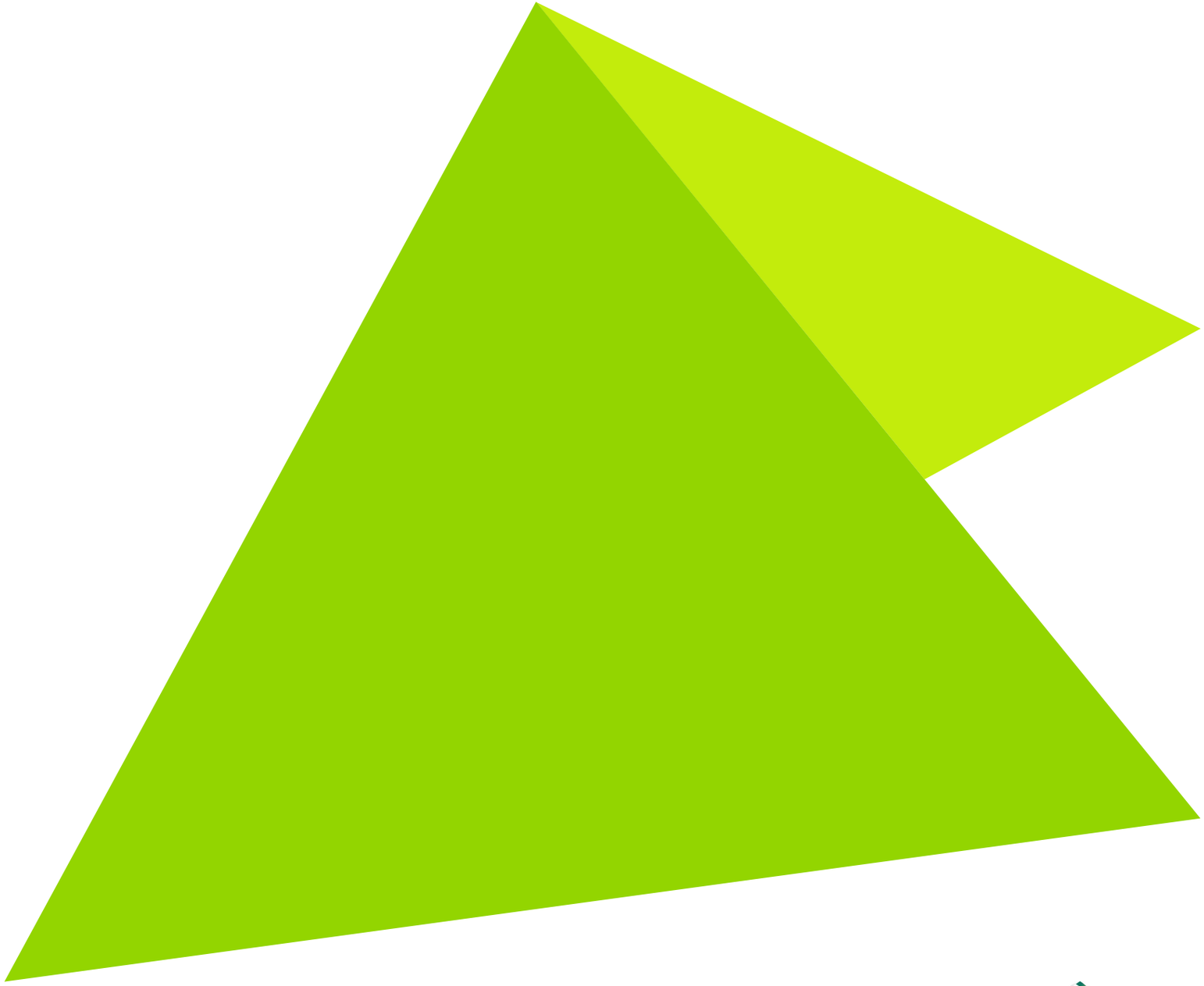
Main take aways for the Frames Project

- The additional costs for the energy efficiency and renewable energy package do show a payback time of 8 years.
- The recommended package is able to save 90% energy compared to the baseline and 85% energy related to the current planning.
- Most attractive with immediate PBP is the adjustment of the heating and cooling set temperatures.
- Also attractive with low PBP are: the installation of PV and a highly efficient HVAC system.

Contact

Riadh Bhar
Managing Consultant
riadh.bhar@guidehouse.com

Eslam Mahdy
Senior Consultant
eslam.mahdy@guidehouse.com



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