Guidehouse

Energy Efficiency Recommendations for KLEOS : Ashrafieh Apartments, Lebanon

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

BUILD_ME

December 2020

Introduction to the BUILD_ME project

Contents

Introduction

Background, Objectives and Methodology

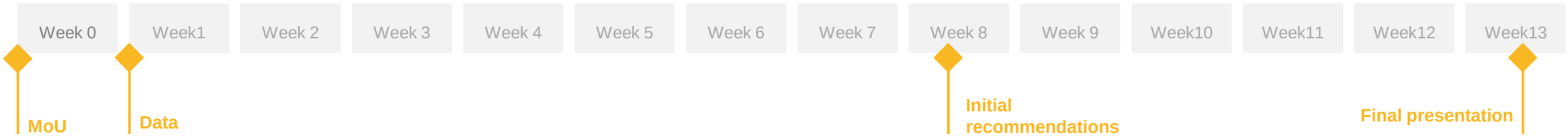
Introduction

BUILD_ME Project and the Objectives of Pilot Projects

Approach and Methodology

Steps Towards a Low Energy Building

1 Starting	2 Boundary Conditions	3 Analysis	4 Development	5 Final Recommendations
▪ Introduction of BUILD_ME ▪ Signing of MoU ▪ Kick-off Meeting (s) ▪ Provide Building Info.	▪ Climate Analysis ▪ Economic Aspects ▪ Building Baseline ▪ Definition of packages	▪ Building Envelope ▪ HVAC I Efficiencies ▪ Renewables ▪ Other Measures	▪ Discussion with Developers ▪ Local and Market inputs ▪ Costs and ROI	▪ Final presentation ▪ Final list of recommendations ▪ Site visits support



- **Initial timeline to be adjusted according to the demands and development of the pilot project.**
- **Remain in close exchange of data, information and concepts**
- **Field visits will be coordinated and executed by BUILD_ME National Partners and/or local experts.**

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
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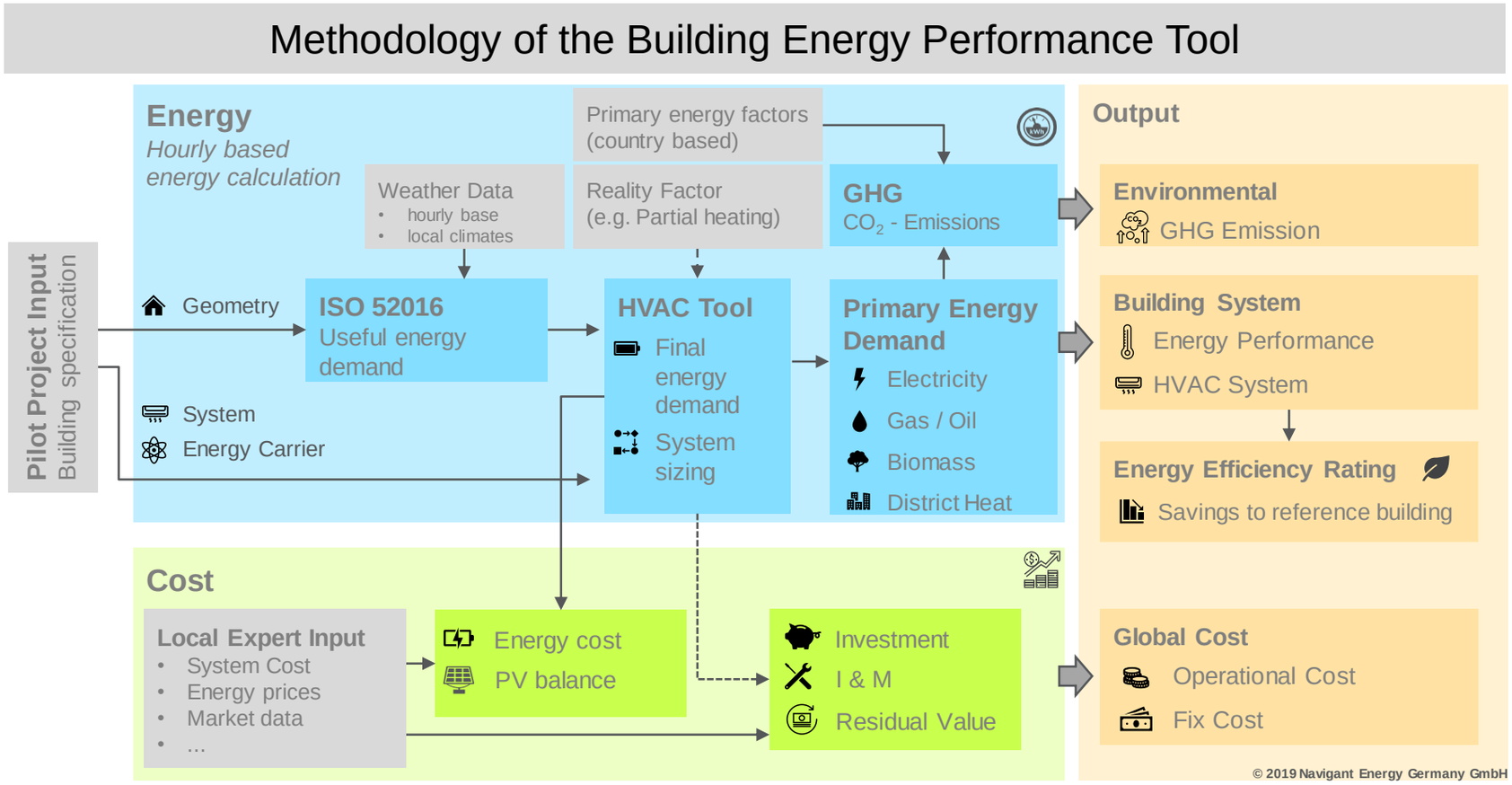

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Introduction

KLEOS : Achrafieh Apartments, Boundary conditions

KLEOS : Achrafieh Apartments

Aims

Creating multiapartment building with facilities and amenities. The developers will be responsible for the operation of the building. Therefore, there is a high interest in implementing EE measures.

Target Groups

Units for middle and upper middle class.

Function

Multiapartment buildings with several amenities and facilities.
.

Size

One building consists of 19 floors and a penthouse. This is in total is 15,000 m2 where 5,000 m2 underground area.

Boundary conditions

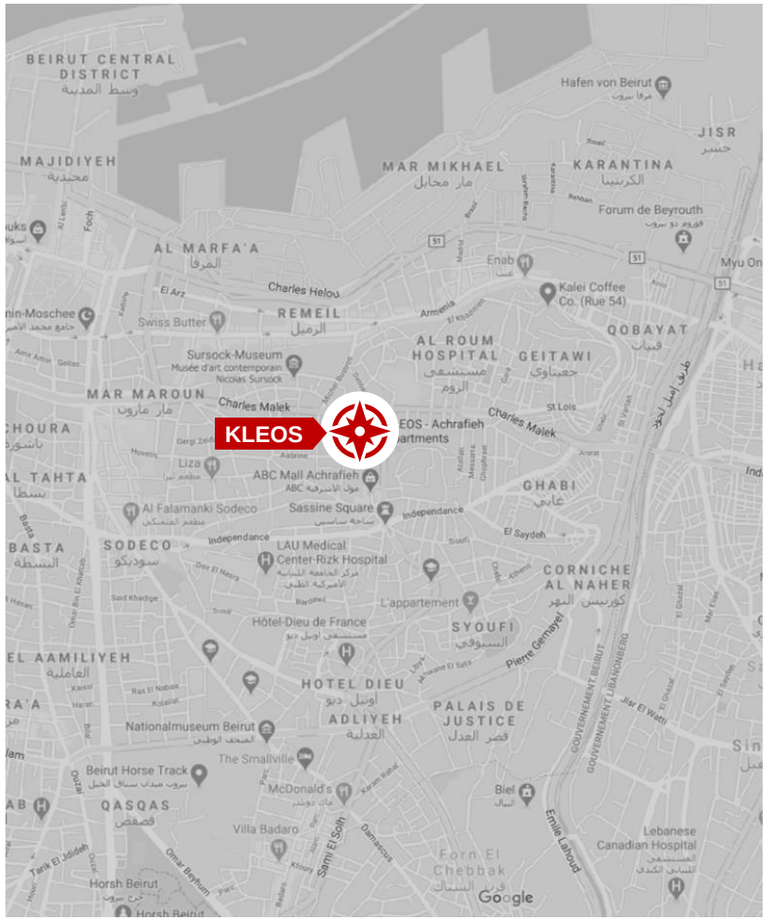
Site : Context matters

City : **Beirut**

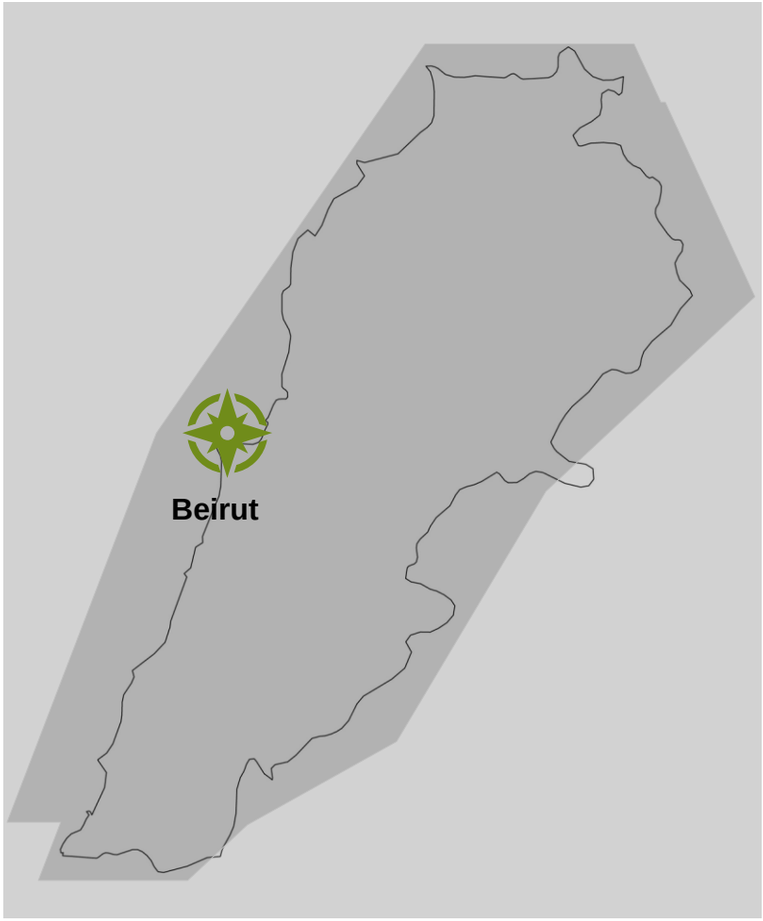
Location : Achrafieh

Context

The project located in Achrafieh in Al-Salam School Street and in a close proximity to Alfred Naccash Road and Charles Malek Road.



Source: Google Maps

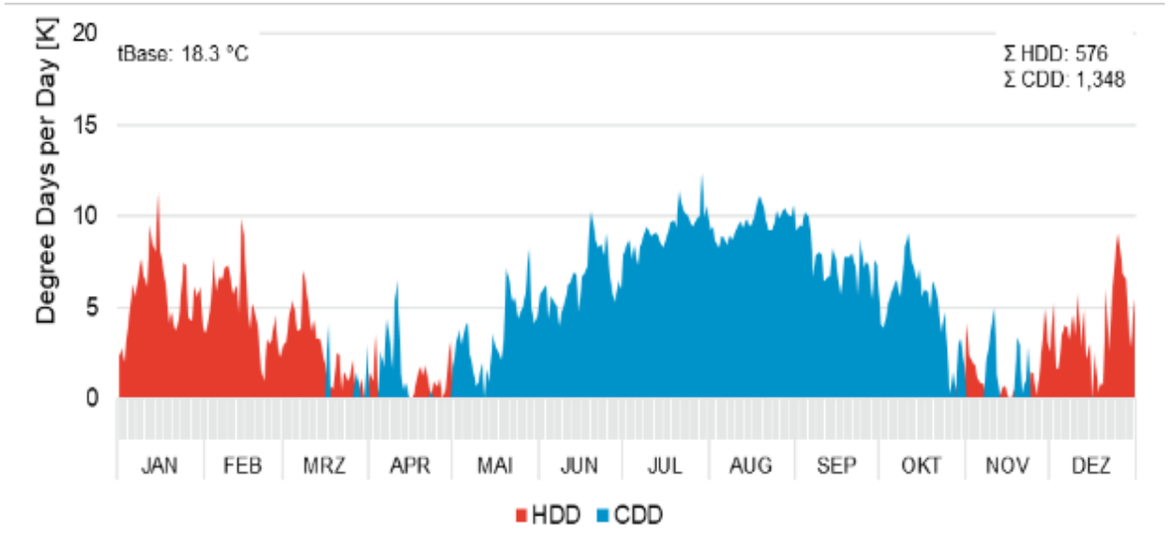


Boundary conditions I Climate Analysis

External temperatures and Relative Humidity *

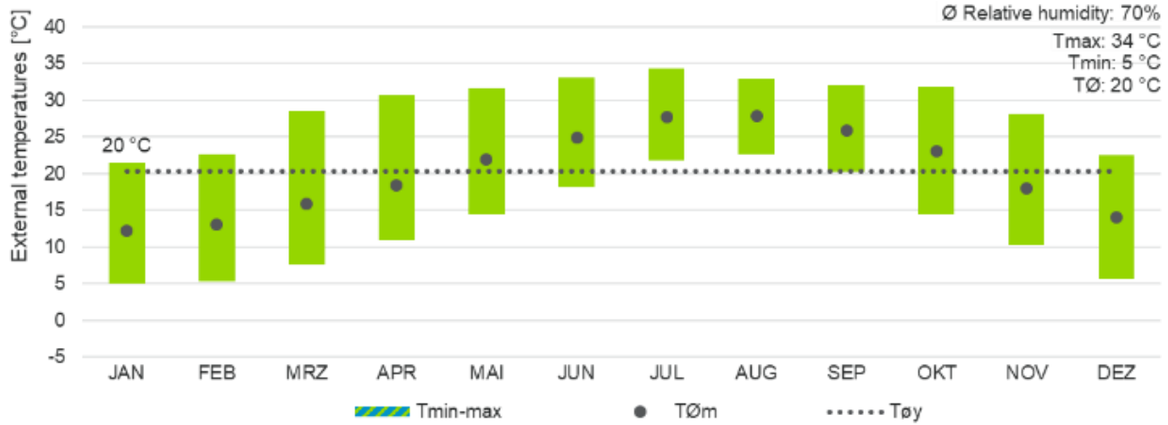
Description

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

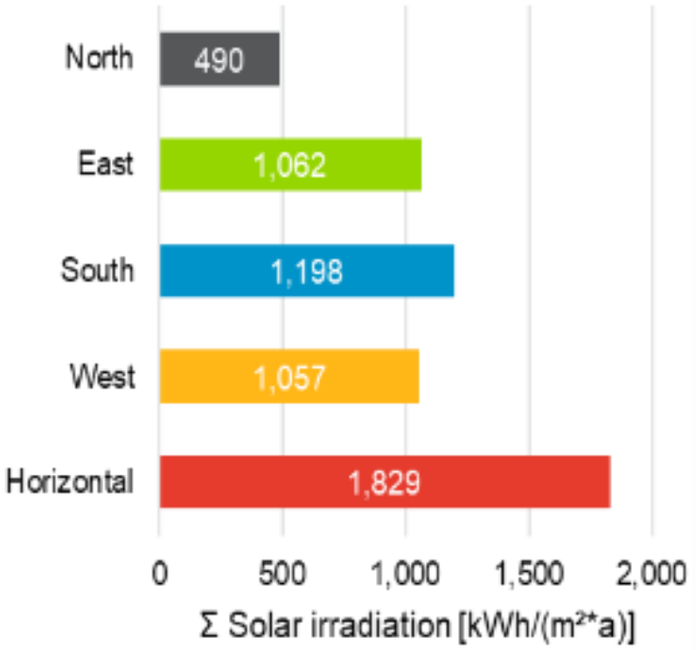
Solar Irradiation in Beirut (Lebanon)

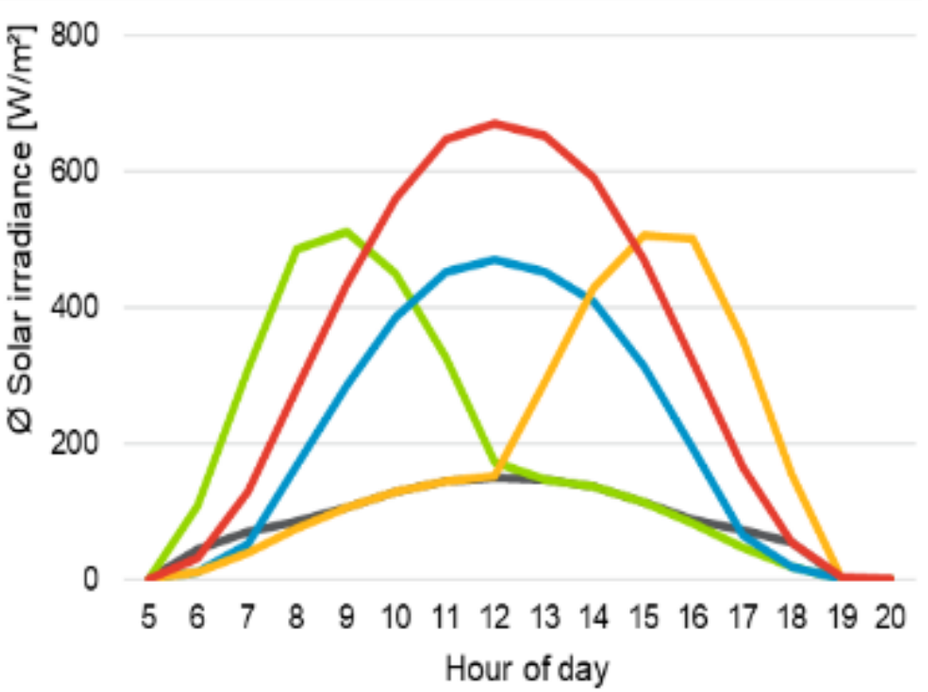
Description

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*	85 I 0.05
Energy price (Gen Set)	LBP/kWh I EUR/kWh*	510 I 0.3
Price development	%/year	10
CO2 emission factor	gCO2/kWh	806
Economic parameters		
Interest rate (real)	%/year	5
Calculation period	years	20

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

Boundary Conditions I Building

Building Data

Status

Modern multi-family houses in a heart of Beirut

Specific Challenge

Located close to the coast, 2 KM away from Port of Beirut. This provides potential of sea breeze but also a high Level of humidity.

Building Key Information – Sector A	
Data	Input
Latitude	33.890704
Longitude	35.520156
Elevation [m]	73
Utilization	MFH
Number of floors	19
Number of apartment	71
Conditioned floor area [m²]	6613
Clear room height [m]	2.95
Conditioned volume [m³]	33,508
Number of inhabitants [#]	4 per Unit
Year of construction	2020/2021

Analysis

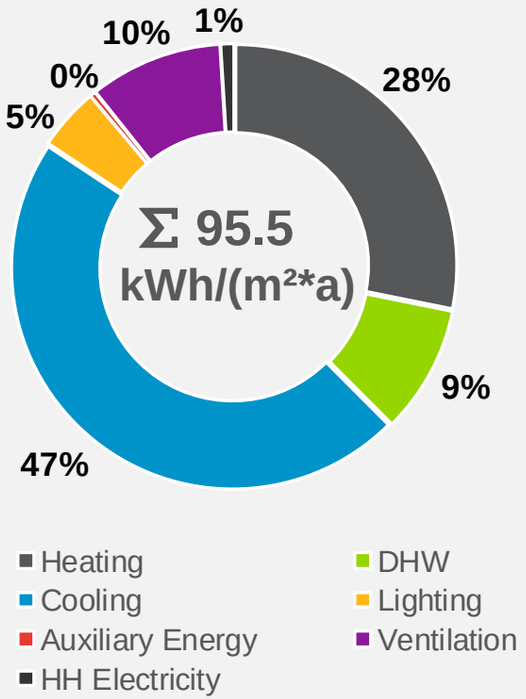
Starting Situation - Baseline and Current planning

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 the current building code. While no special attention is given to use renewable energy sources.

Parameters	Baseline
Roof insulation (U-Value)	2.0 W/m²K
Wall insulation (U-Value)	1.2 W/m²K
Floor insulation (U-Value)	2.4 W/m²K
Windows (U-Value; G-Value)	5.7 W/m²K; 0.85
Window fraction	Ø 21%
Shading	overhangs
Air infiltration through leakages	0.25 1/h
Heat supply	reversible Unit - COP 3
Cold supply	reversible Unit - COP 3
Hot water	electrical instantaneous
Ventilation system	mechanical ventilation
Lighting system	LED
Renewable energy	No
Set temperature cooling/heating	23°C / 22°C



Energy Cost
15.0 EUR / (m²*a)

CO2 - Emission
64.9 kg / (m²*a)

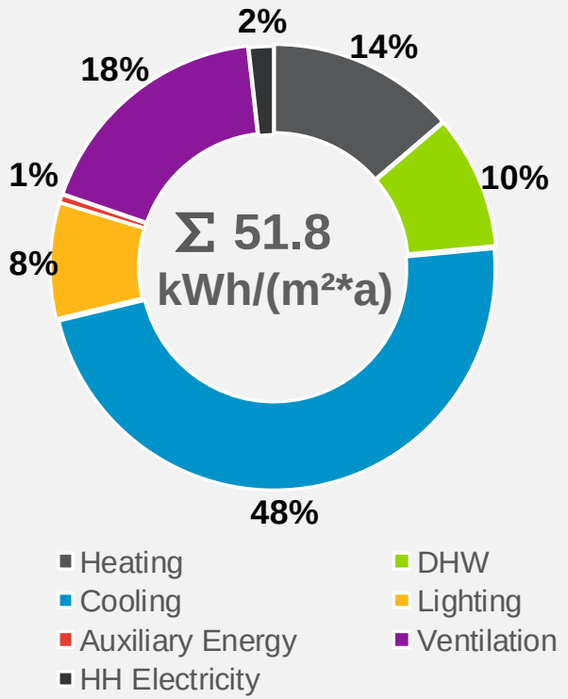
Current situation, KLEOS : Achrafieh Apartments

Results

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

This leads to energy savings and emission reduction.

Parameters	Current
Roof insulation (U-Value)	**0.6 W/m²K**
Wall insulation (U-Value)	1.2 W/m²K
Floor insulation (U-Value)	2.4 W/m²K
Windows (U-Value; G-Value)	**2.9 W/m²K; 0.70**
Window fraction	Ø 21%
Shading	overhangs
Air infiltration through leakages	0.25 1/h
Heat supply	**reversible Unit - COP 5**
Cold supply	**reversible Unit - COP 5**
Hot water	electrical instantaneous
Ventilation system	mechanical ventilation
Lighting system	LED
Renewable energy	No
Set temperature cooling/heating	23°C / 22°C



Energy Cost
6.9 EUR / (m²*a)

CO2 - Emission
35.2 kg / (m²*a)

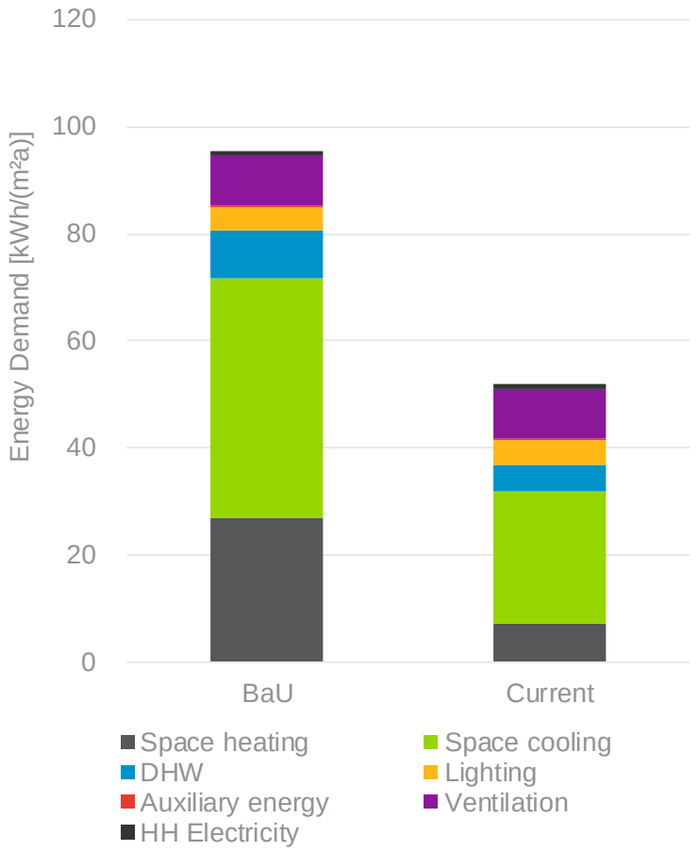
Current situation (project developer)

Results VS. BaU

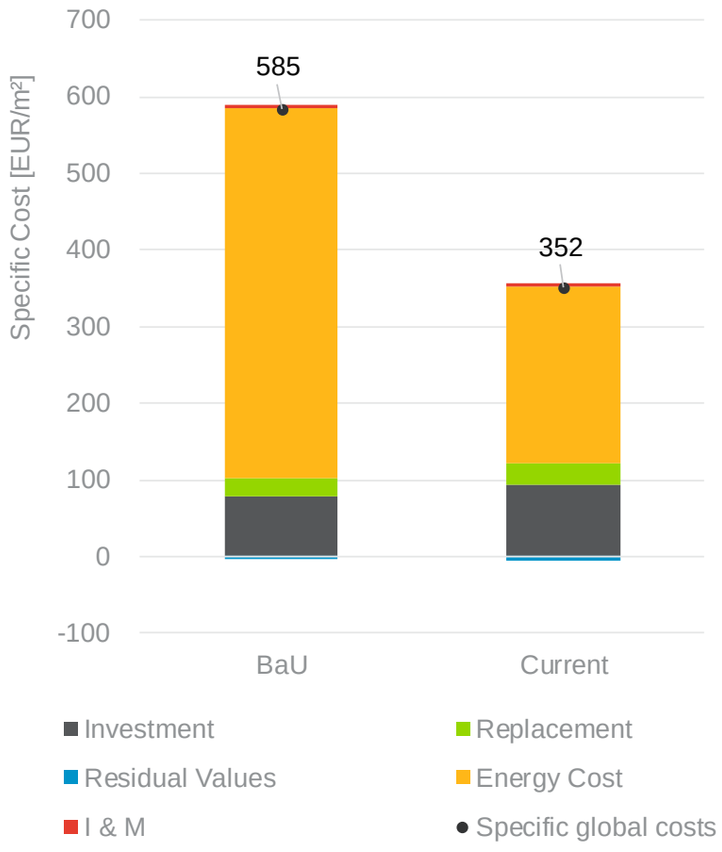
The proposed design is significantly more energy efficient in comparison to the BAU cases.

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



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Analysis
Investigation of Possible Measures

Overview of Analyzed Measures

Scope of Measures

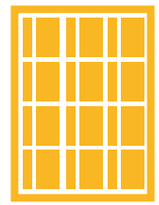
Envelope

- 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

Building Envelope I External wall

Thermal insulation

Var 1

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

BaU/Current

U-Value = 1.4 W/m²K
(double wall, no insulation)

Var 2

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

Var 3

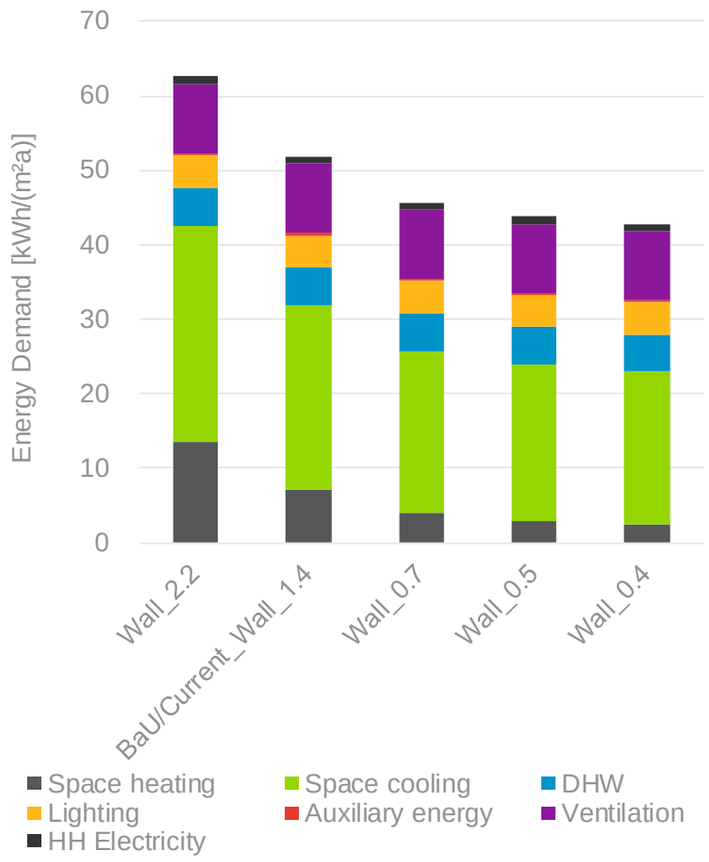
U-Value = 0.5 W/m²K
(double wall, 5 cm insulation)

Var 4

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

Result: Var 4 is the most cost effective measure

Final Energy Demand



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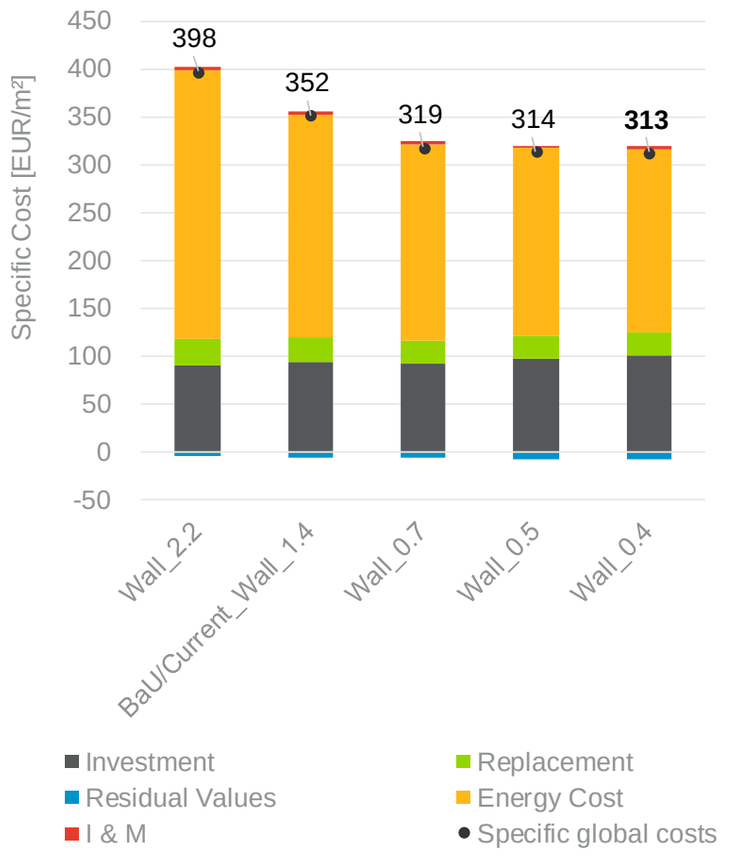


Building Envelope I Roof

Thermal insulation

Var 1

U-Value = 3.2 W/m²K (no insulation)

BaU

U-Value = 2.0 W/m²K (no insulation)

Var 2

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

Current

U-Value = 0.6 W/m²K (5 cm insulation)

Var 3

U-Value = 0.45 W/m²K (8 cm insulation)

Var 4

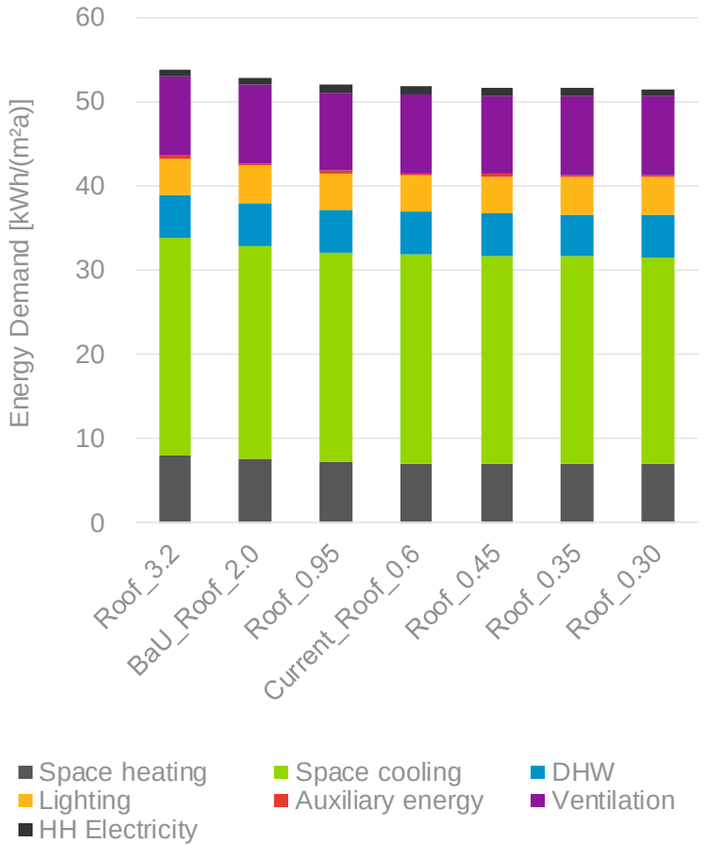
U-Value = 0.35 W/m²K (10 cm insulation)

Var 5

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

Result: Var 5 is the most cost effective measure

Final Energy Demand



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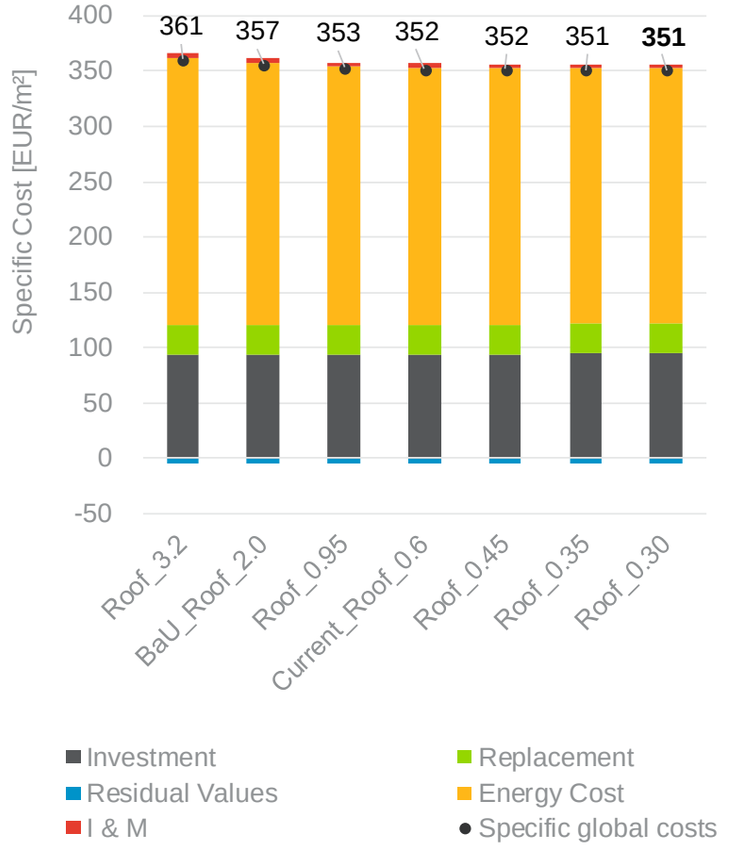


Building Envelope I Roof

Appropriate Color - Absorption factor

BaU / Current

Dark color (0.9)

Var 1

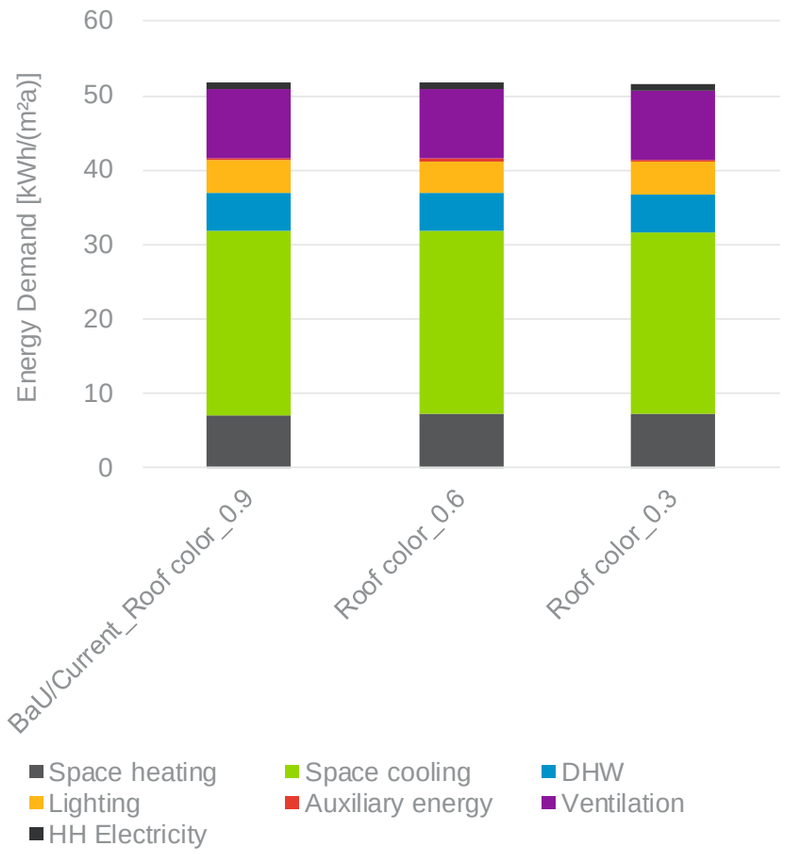
Intermediate color (0.6)

Var 2

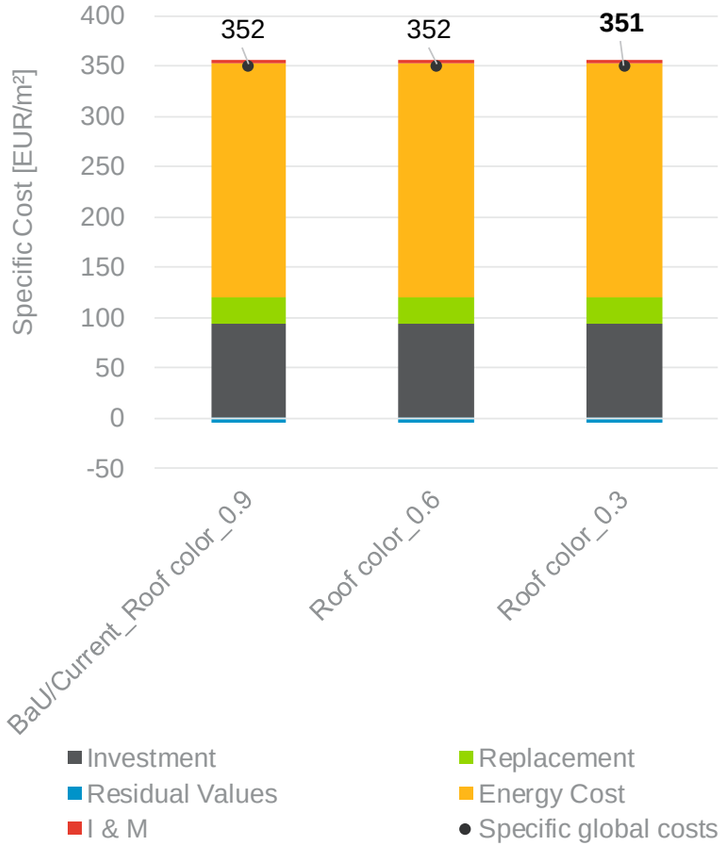
Light color (0.3)

Result: Var 2 is the most cost effective measure

Final Energy Demand



Global Cost



Building Envelope I Windows

U-Value

Single glazing (BaU)

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 – low E (Var 1)

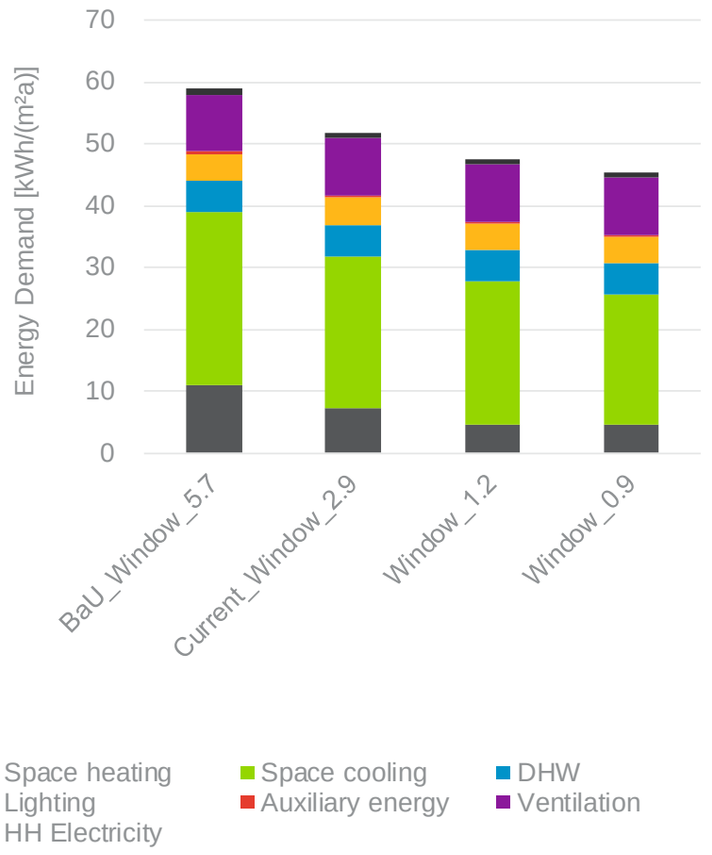
U-value 1.2 W/m²K, G-Value 0.65

Triple glazing (Var 2)

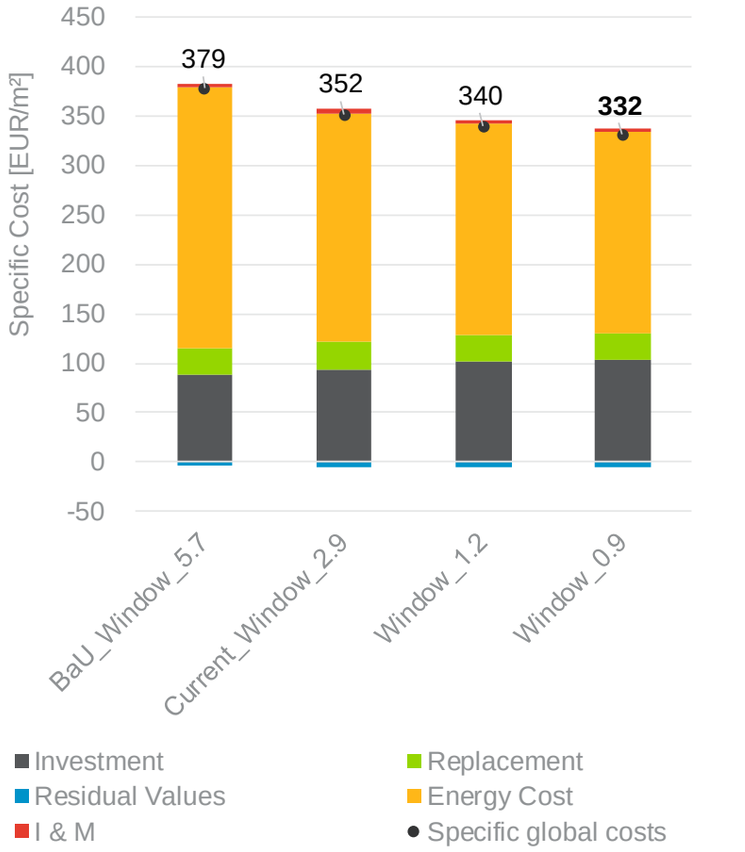
U-value 0.9 W/m²K, G-Value 0.5

Result: Var 2 is the most cost effective measure

Final Energy Demand



Global Cost



Building Envelope I Window

Window fraction

Var 1

40 %

Var 2

30 %

Var 3

25 %

BaU / Current

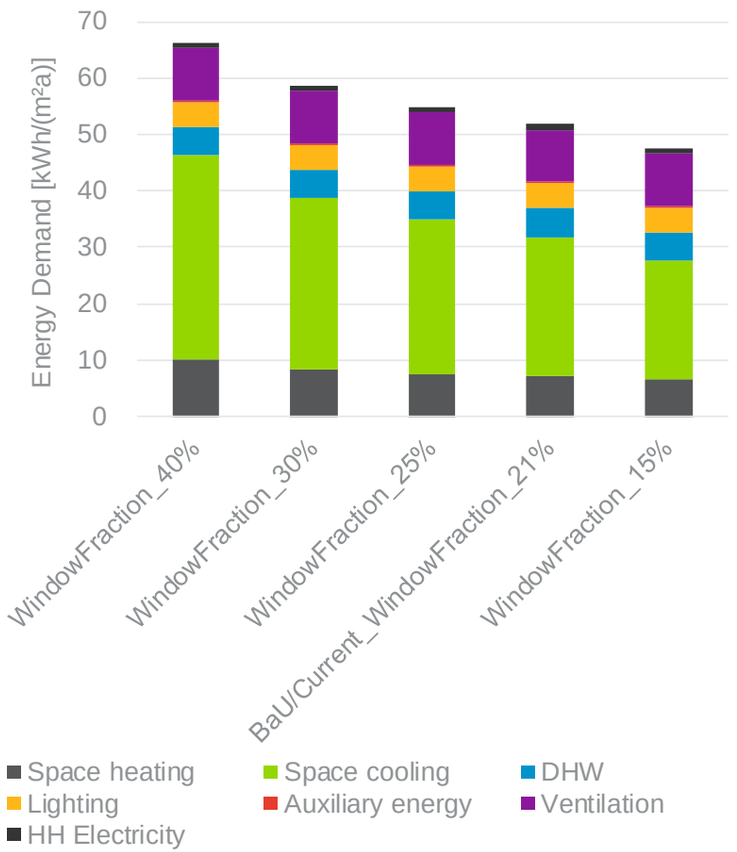
21 %

Var 4

15 %

Result: Var 4 is the most cost effective measure

Final Energy Demand



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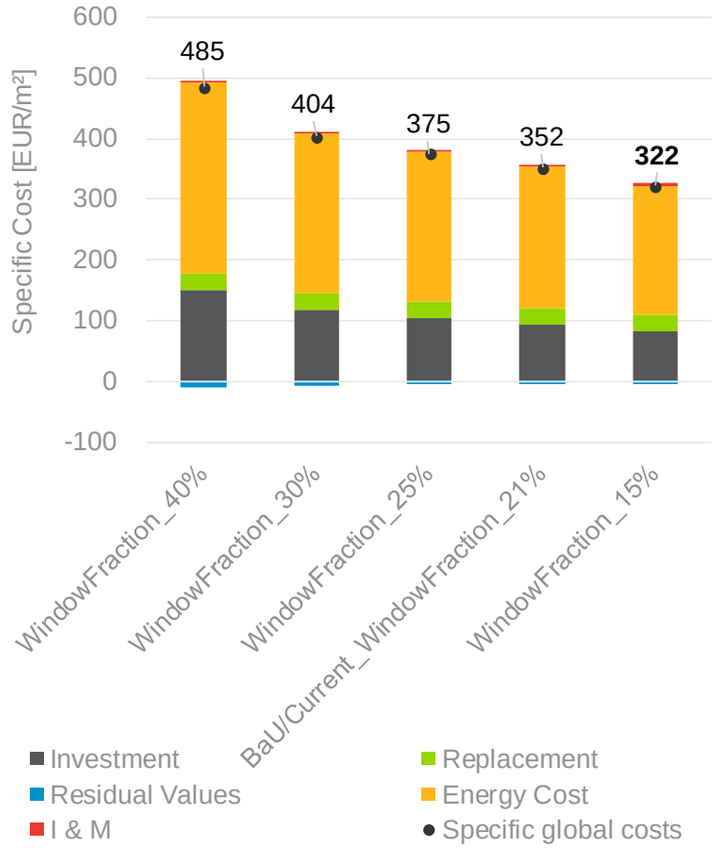


Air Tightness

What is the effect of air tightness?

BaU / Current

0.25

Var 1

0.20

Var 2

0.15

Var 3

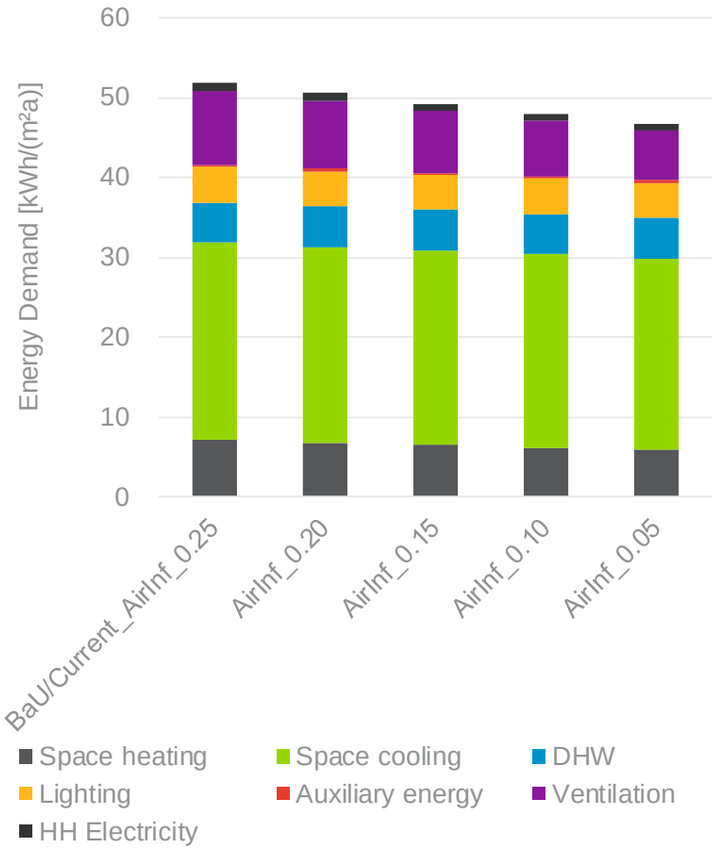
0.1

Var 4

0.05

Result: Var 4 is the most cost effective measure

Final Energy Demand



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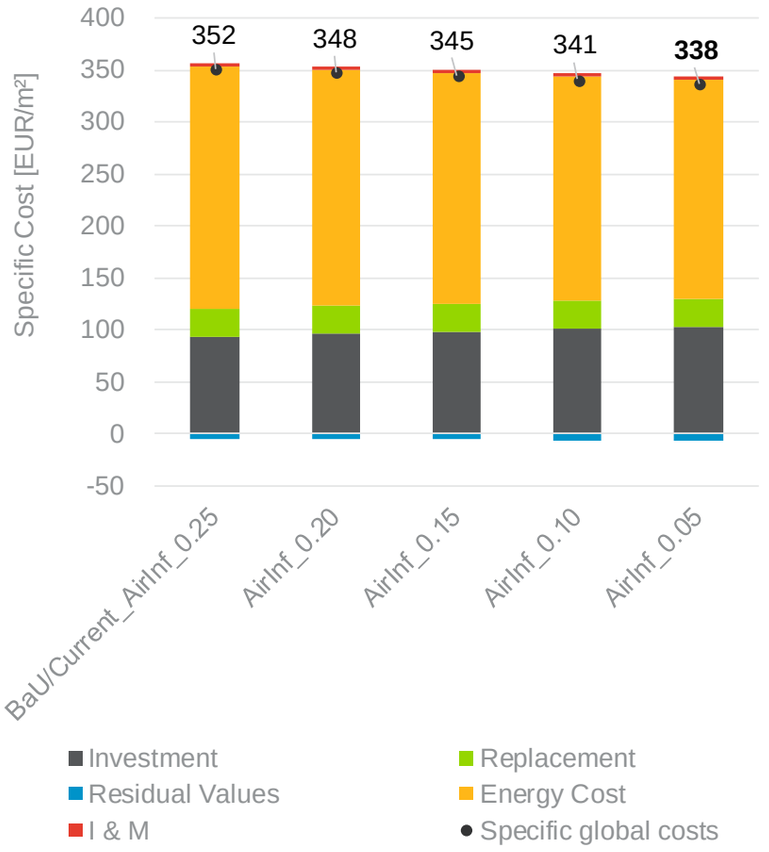

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Shading concept

Analysis

Var 1

No shading

BaU / Current

Fixed Overhangs

Var 2

Manual Shading

Var 3

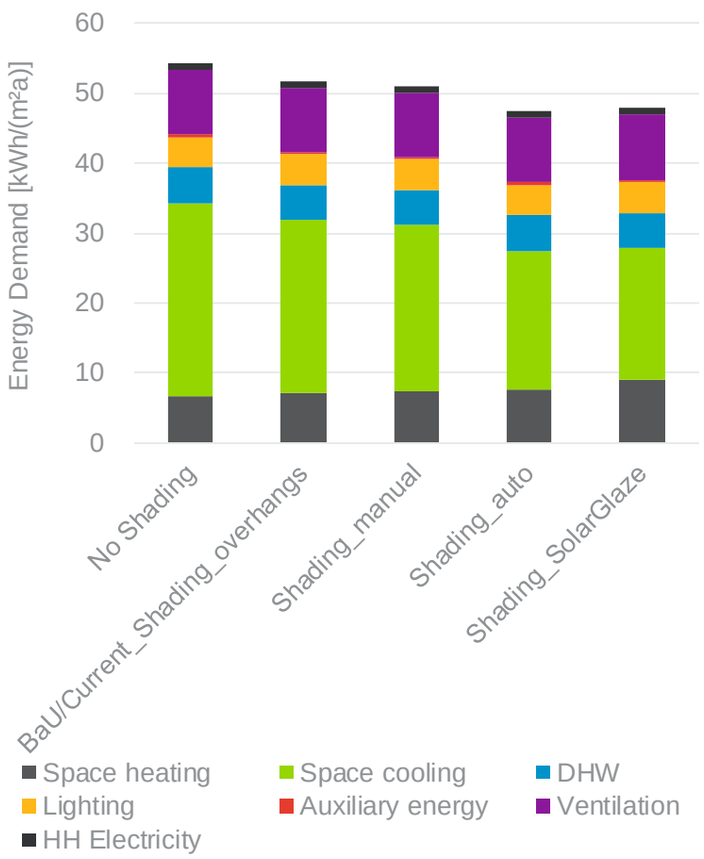
Automatic Shading

Var 4

Solar Glazing

Result: Var 4 is the most cost effective measures

Final Energy Demand



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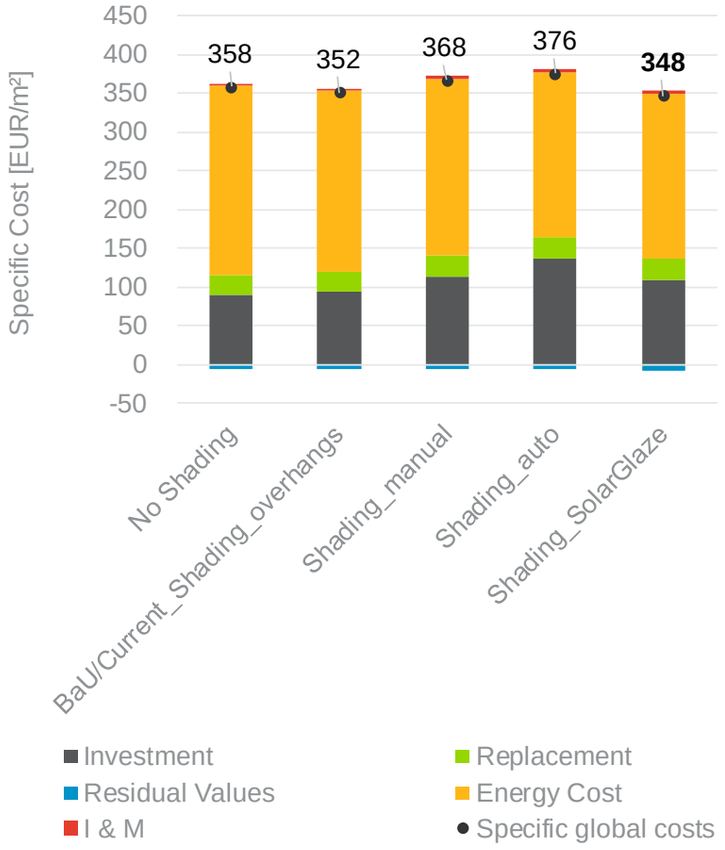


HVAC I Cooling

Analysis

BaU

Reversible Unit
(Cooling SEER 3)

Current

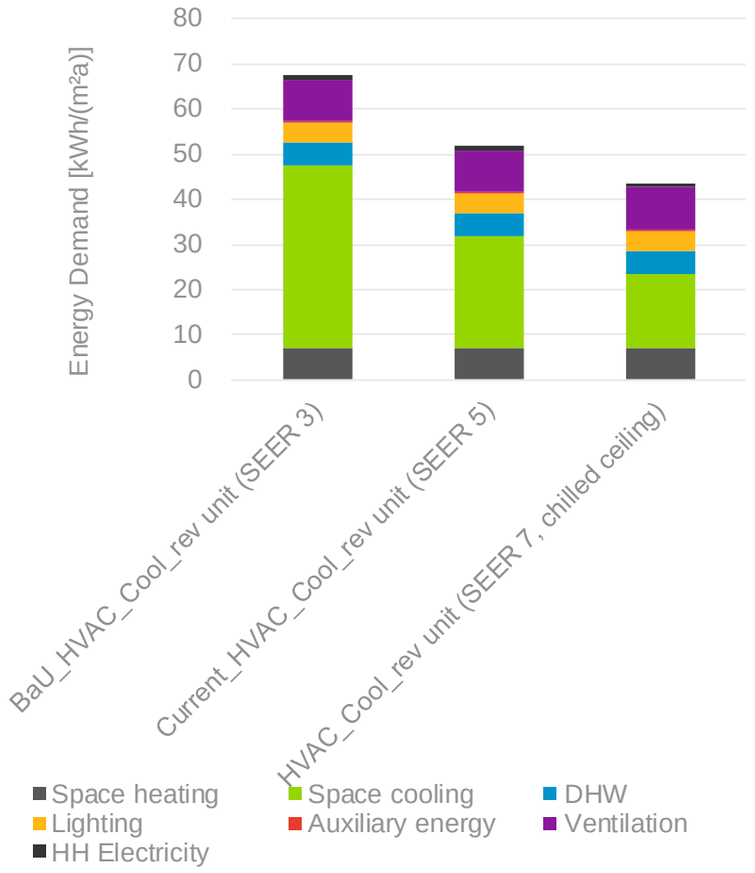
Reversible Unit
(Cooling SEER 5)

Var 1

Reversible Unit with chilled ceilings
(Cooling SEER 7)

Result: Var 1 is the most cost effective measure

Final Energy Demand



Global Cost

HVAC I Ventilation

Analysis

Var 1

Natural ventilation

BaU/Current

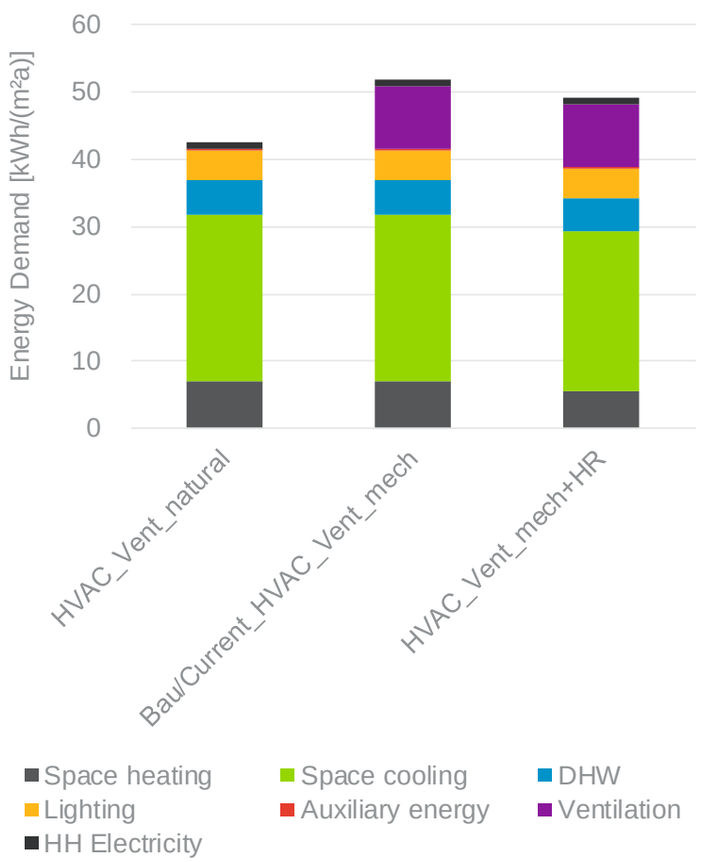
Mech. ventilation

Var 2

Mech. ventilation with heat recovery

Result: Var 1 (natural ventilation) is the most cost effective measure, but shows comfort deficiencies.

Final Energy Demand



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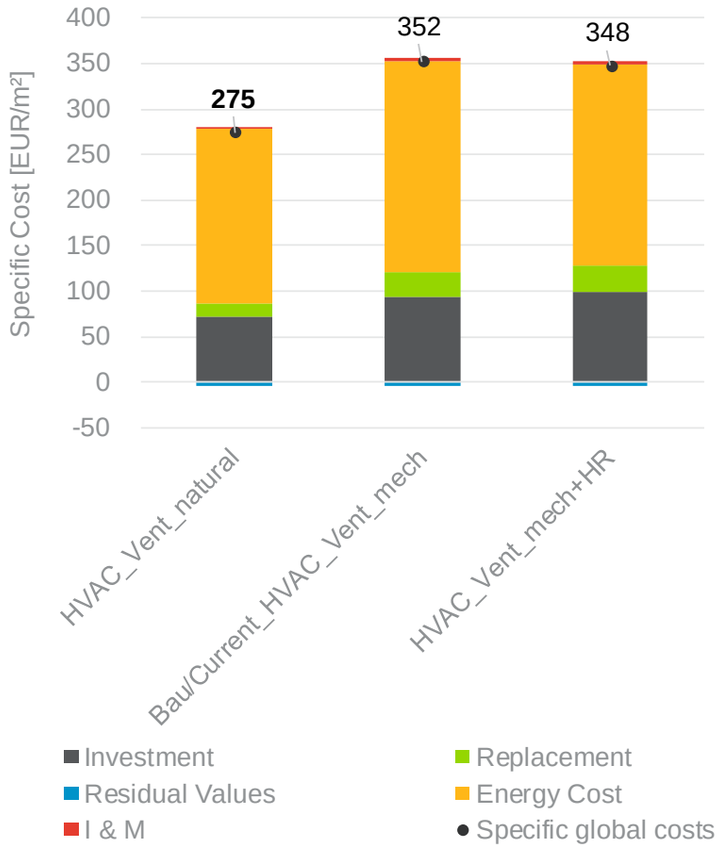


Operational Temperatures

Analysis

BaU / Current

Cooling Temperature: 23°C
Heating Temperature: 22°C

Variants cooling

Cooling: 23/24/25/26°C

Variants heating

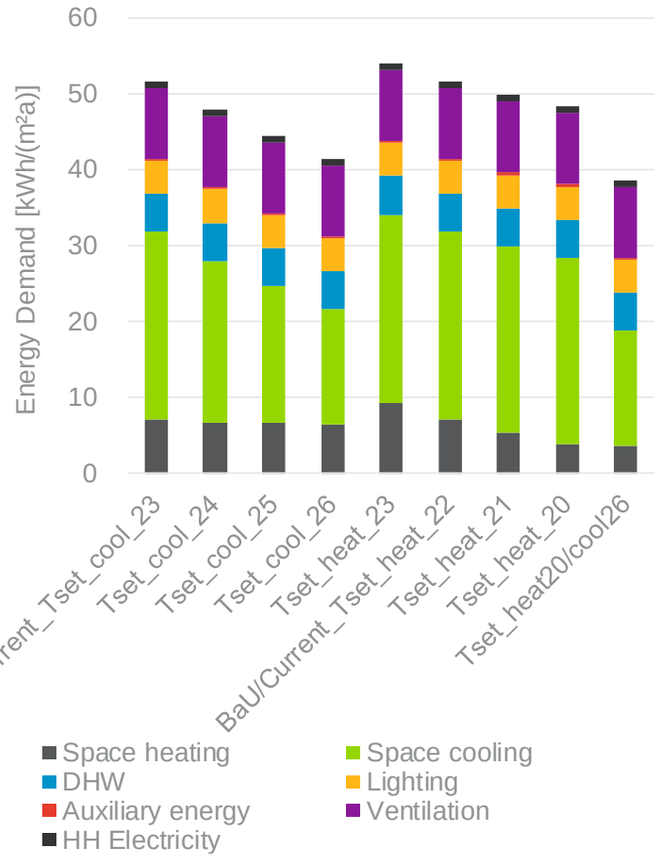
Heating: 20/21/22/23°C

Combined Variant

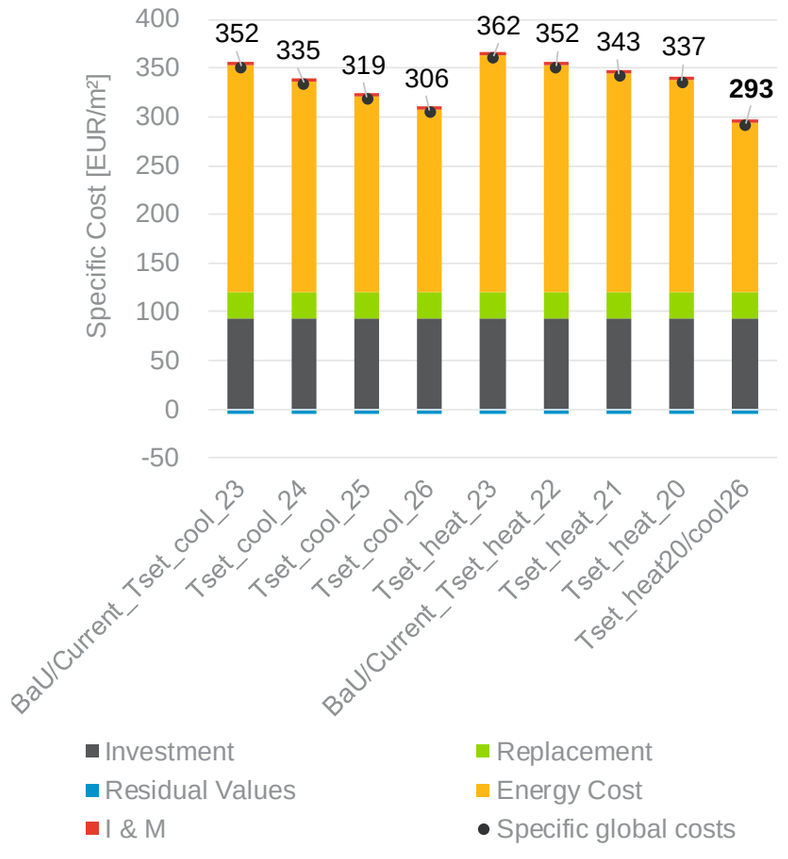
Cooling Temperature: 26°C
Heating Temperature: 20°C

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



Renewables I Solar Thermal

Analysis

BaU/Current

no ST = el. instantaneous

Var 1

ST – max. exploitation of roof surface

Var 2

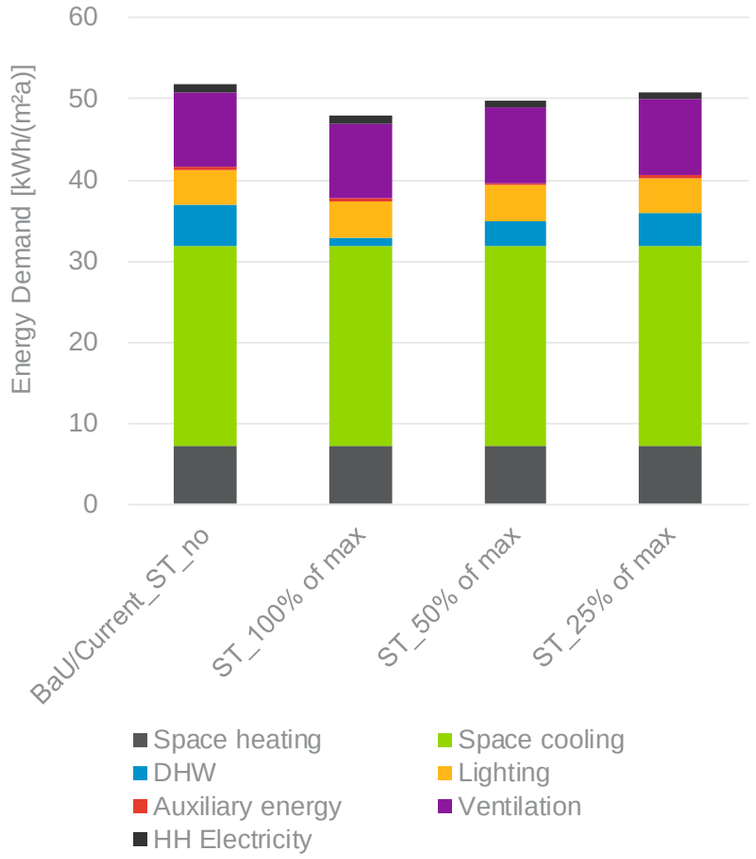
ST – 50% of max

Var 3

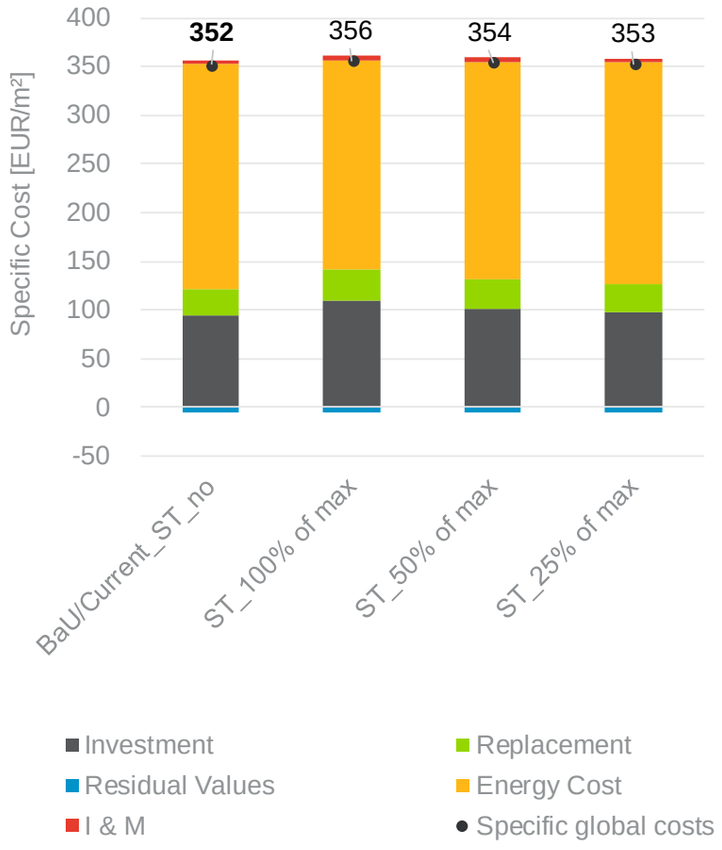
ST – 25% of max

Result: No ST is the most cost effective measure

Final Energy Demand



Global Cost



Renewables I PV

Analysis

BaU/Current

no PV

Var 1

PV – max. exploitation of roof surface

Var 2

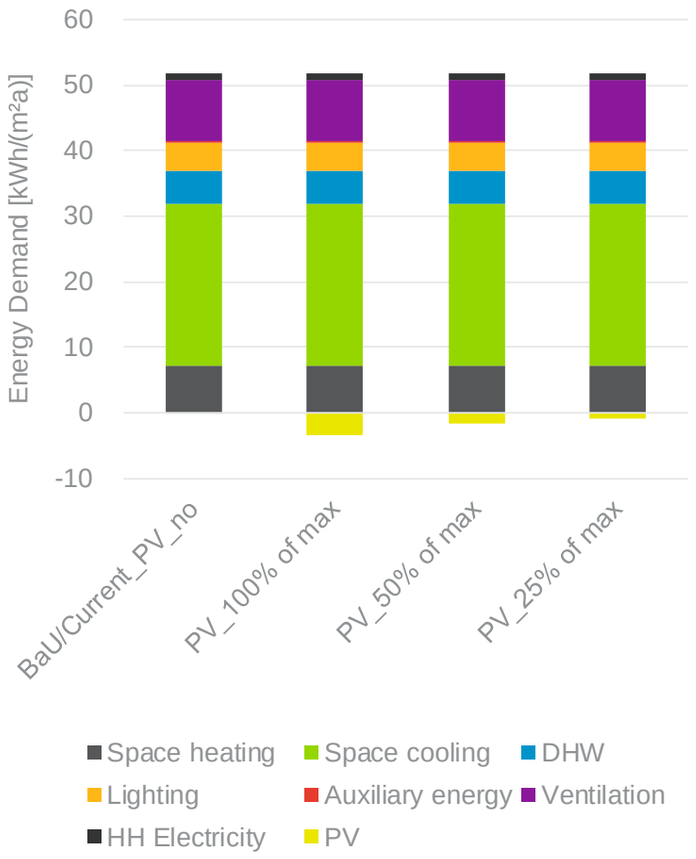
PV – 50% of max

Var 3

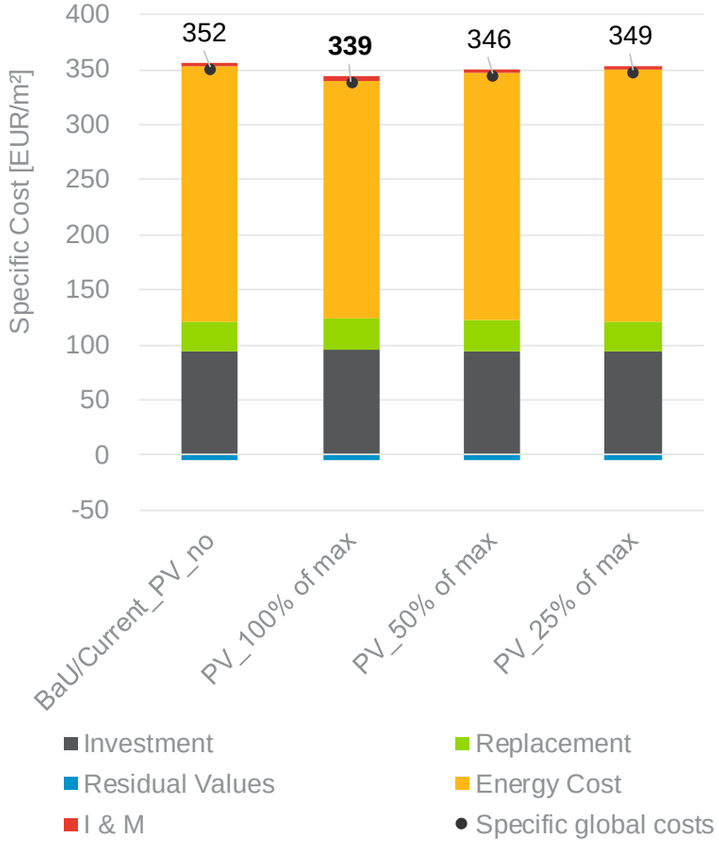
PV – 25% of max

Result: Var 1 is the most cost effective measure

Final Energy Demand



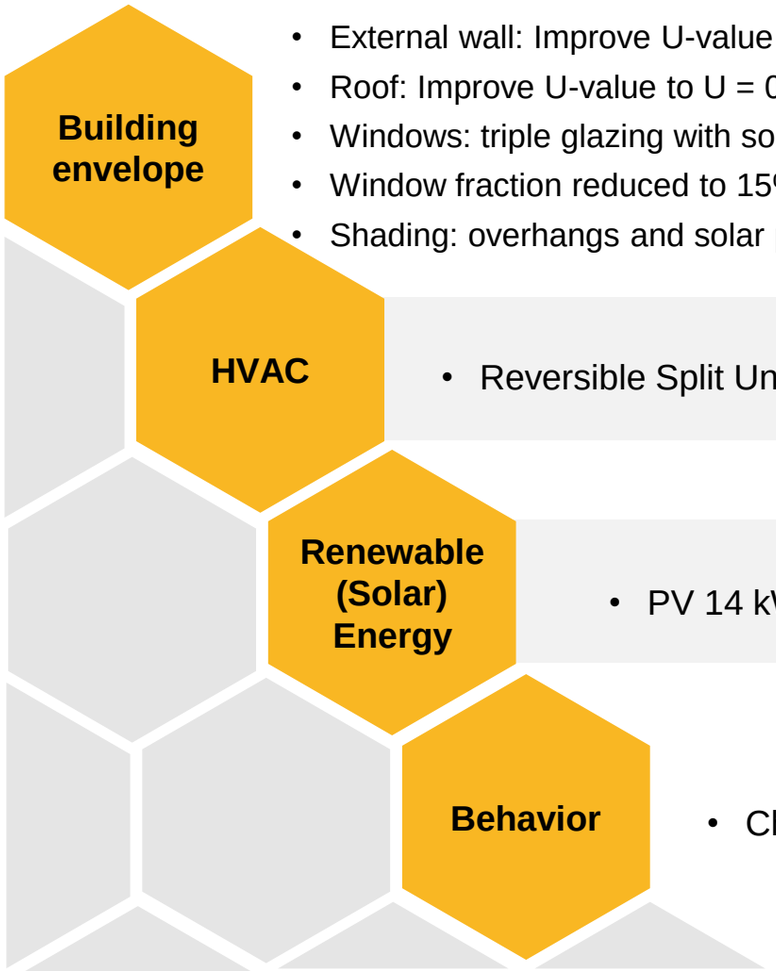
Global Cost



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} = 0.05 1/h)
- Window fraction reduced to 15%
- Shading: overhangs and solar protection glazing

HVAC

- Reversible Split Unit heating / cooling with chilled ceiling and high efficiency (COP ~ 7)

Renewable (Solar) Energy

- PV 14 kWp

Behavior

- Change set temperature from Cooling 23°C/ Heating 22°C to Cooling 26°C/ Heating 20°C

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Optimized Solution

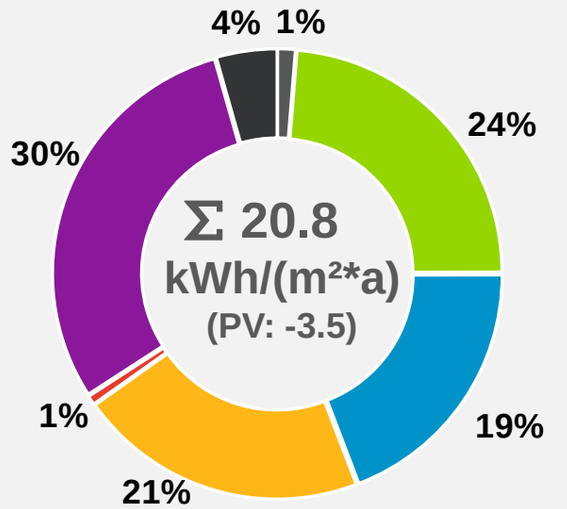
Results

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)	3.2 W/m²K
Windows (U-Value; G-Value)	**0.9 W/m²K; 0.3 (solar glazing)**
Window fraction	**Ø 15%**
Shading	overhangs and **solar glazing**
Air infiltration through leakages	**0.05 1/h**
Heat supply	**reversible split unit - COP 7**
Cold supply	**reversible split unit - COP 7**
Hot water	electric instantaneous
Ventilation systems	mechanical ventilation
Lighting systems	LED
Renewable energy	**14 kWp (PV, maximum)**
Set temperature cooling/heating	**26°C / 20°C**



Energy Cost (- PV)
2.2 EUR / (m²*a)

CO2 - Emission
11.8 kg / (m²*a)

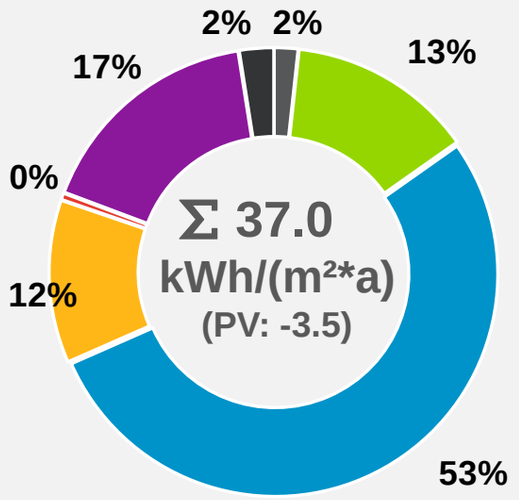
Selected Solution

Results

After the exchange with the project developer, the following components have been assessed as feasible and will be taken into account in the further planning:

- Improvement of the building envelope
- Improved air tightness of building envelope
- PV on the roof

Parameters	Optimized
Roof insulation (U-Value)	0.6 W/m²K (light color)
Wall insulation (U-Value)	**0.7 W/m²K**
Floor insulation (U-Value)	3.2 W/m²K
Windows (U-Value; G-Value)	**1.2 W/m²K; 0.65**
Window fraction	**Ø 21%**
Shading	overhangs
Air infiltration through leakages	**0.05 1/h**
Heat supply	reversible split unit - COP 5
Cold supply	reversible split unit - COP 5
Hot water	electric instantaneous
Ventilation systems	mechanical ventilation
Lighting systems	LED
Renewable energy	**14 kWp (PV, maximum)**
Set temperature cooling/heating	23°C / 22°C



Energy Cost (- PV)
4.4 EUR / (m²*a)

CO2 - Emission
22.8 kg / (m²*a)

Comparative overview

Baseline vs. Current vs. Optimized vs. Selected

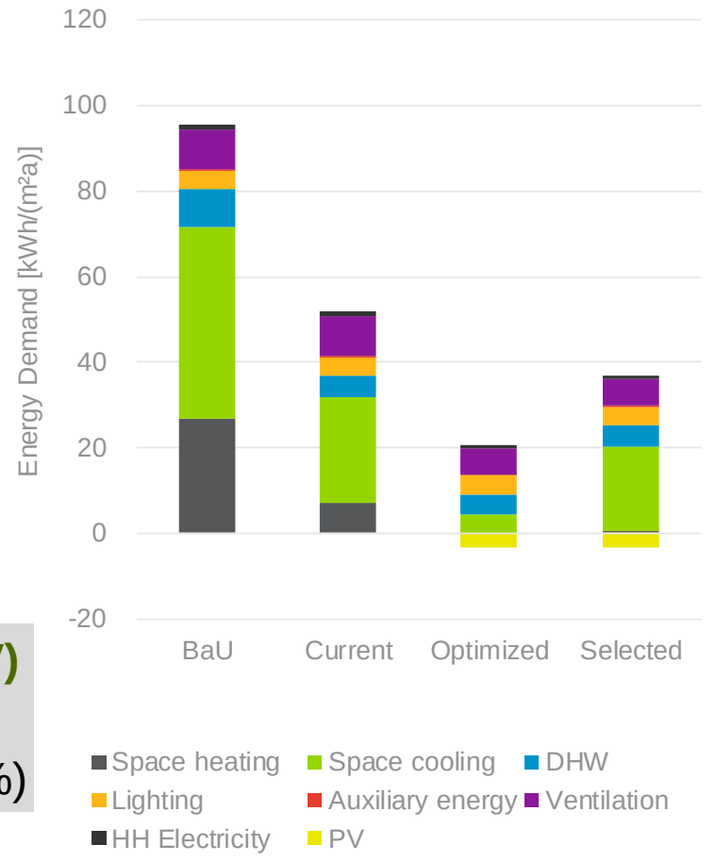
Conclusion

- 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**

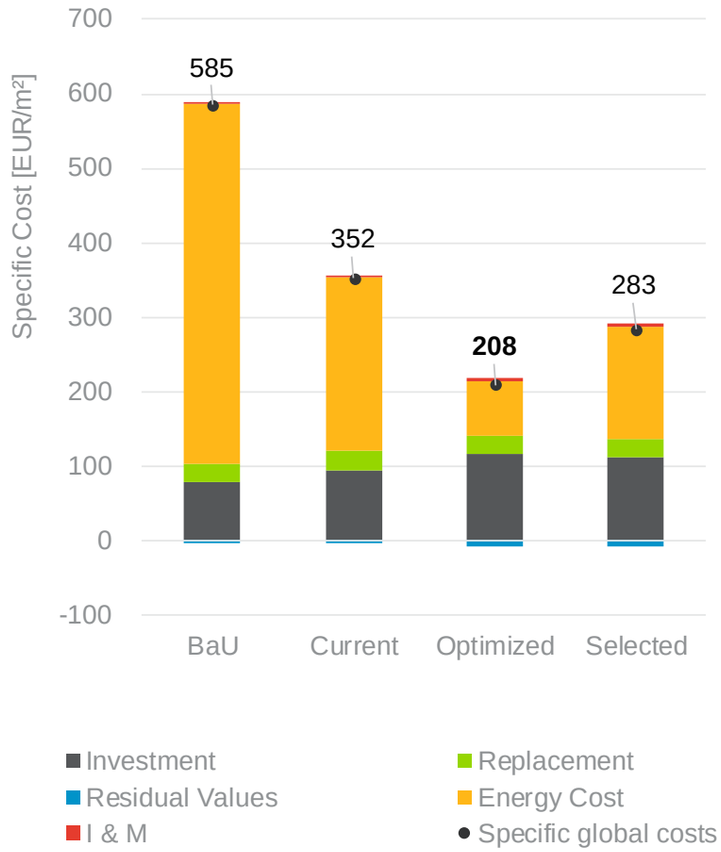
Savings BaU to Optimized (incl. PV)

- Energy: **95** => **21** kWh/m²a (-80%)
- E-Cost: **15.0** => **2.2** EUR/m²a (-85%)

Final Energy Demand



Global Cost



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]
Roof insulation (U-Value)	0.3 W/m²K	4,600	-200	22	40
Wall insulation (U-Value)	0.4 W/m²K	87,800	-7,900	11	40
Windows (U-Value; G-Value)	0.9 W/m²K; 0.5	63,200	-5,600	11	30
Window fraction	Ø 15%	-71,600	-3,700	immediately	30
Shading	Solar glazing	101,700	-3,500	29	30
Air infiltration through leakages	0.05 1/h	63,600	-4,400	14	-
Heat/Cold supply	reversible split unit - COP 7	49,600	-12,500	4	20
Renewable energy	14 kWp (PV, maximum)	11,500	-3,000	4	20
Set temperature cooling/heating	26°C / 20°C	0	-11,500	immediately	-
Total (current to optimized)**		**140,200 (4%)*****	**-27,500 (-60%)**	**5**	

* 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 Euro/m² (4 % additional costs).

Selected vs. current

Payback of single measures and whole package

Parameters	Selected	Investment (selected-current) [EUR]	Energy cost savings* [EUR / year]	Payback [years]	Lifetime [year]
Wall insulation (U-Value)	0.7 W/m²K	31,400	-5,400	6	40
Windows (U-Value; G-Value)	1.2 W/m²K; 0.65	51,800	-3,700	14	30
Air infiltration through leakages	0.05 1/h	63,600	-4,400	14	-
Renewable energy	14 kWp (PV, maximum)	11,500	-3,000	4	20
Total (current to selected)**		**118,600 (+3.6%)*****	**-13,000 (-30%)**	**9**	

* 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 Euro/m²

Key conclusion, selected package

Main take aways for the Kleos Project

- The additional costs for the selected energy efficiency and renewable energy package are in a „considerable“ range [4%] with an attractive PBP of 9 years
- The selected package is able to save 70% energy compared to the baseline and 45% energy related to the current planning
- Most attractive PBP are the installation of PV and the wall insulation (4 and 6 years of payback)
- Also attractive with PBP of 14 years are: improved windows and air infiltration

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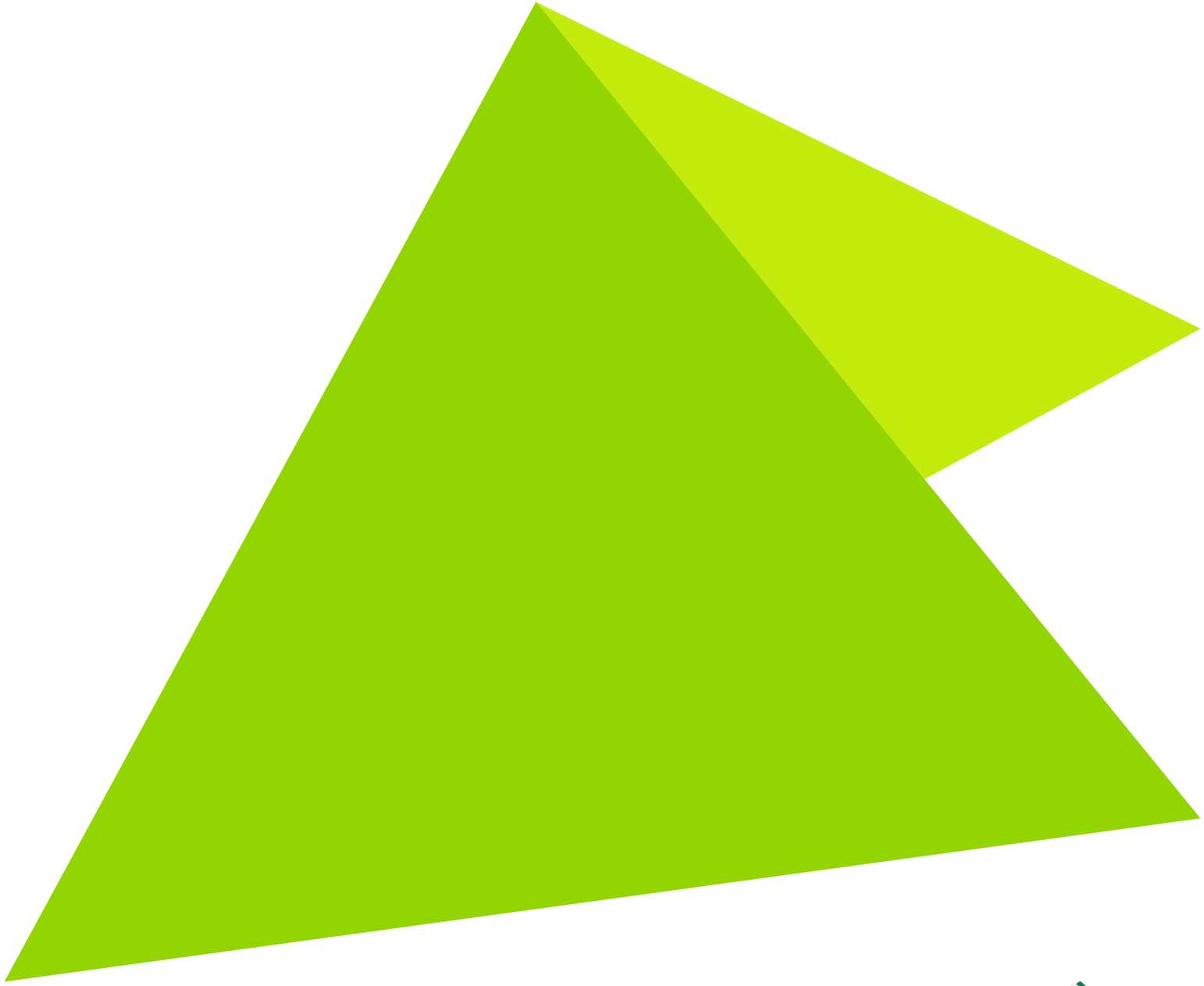

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