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Energy Efficiency Recommendations for Collège Notre Dame De Nazareth – Amphitheatre, Lebanon

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

BUILD_ME

February 2021

Introduction to the BUILD_ME project

BUILD_ME

Fund

IKI International Climate Initiative, German Federal Ministry of Environment

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag

MENA Region

EGY

JOR

LEB

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MOR

TUN

Team

IDG MATRIX Integrated Development Group

الجمعية العلمية الملكية Royal Scientific Society

LCEC Lebanese Center for Energy Conservation المركز اللبناني لحفظ الطاقة

European Bank for Reconstruction and Development

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EGYPT GBC Egypt Green Building Council

LGBC lebanon green building council مجلس لبنان للأبنية الخضراء

ALCOR Développeur d'avenir durable

RCREEE Regional Center for Renewable Energy and Energy Efficiency المركز الإقليمي للطاقة المتجددة وكفاءة الطاقة

TRACK

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Background, Objectives and Methodology

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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	▪ Climate Analysis	▪ Building Envelope	▪ Discussion with Developers	▪ Final presentation
▪ Signing of MoU	▪ Economic Aspects	▪ HVAC I Efficiencies	▪ Local and Market inputs	▪ Final list of recommendations
▪ Kick-off Meeting (s)	▪ Building Baseline	▪ Renewables	▪ Costs and ROI	▪ Site visits support
▪ Provide Building Info.	▪ Definition of packages	▪ Other Measures		

Week 0	Week1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week10	Week11	Week12	Week13
MoU	**Data**							**Initial recommendations**					**Final presentation**

- **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 (Lebanon)

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

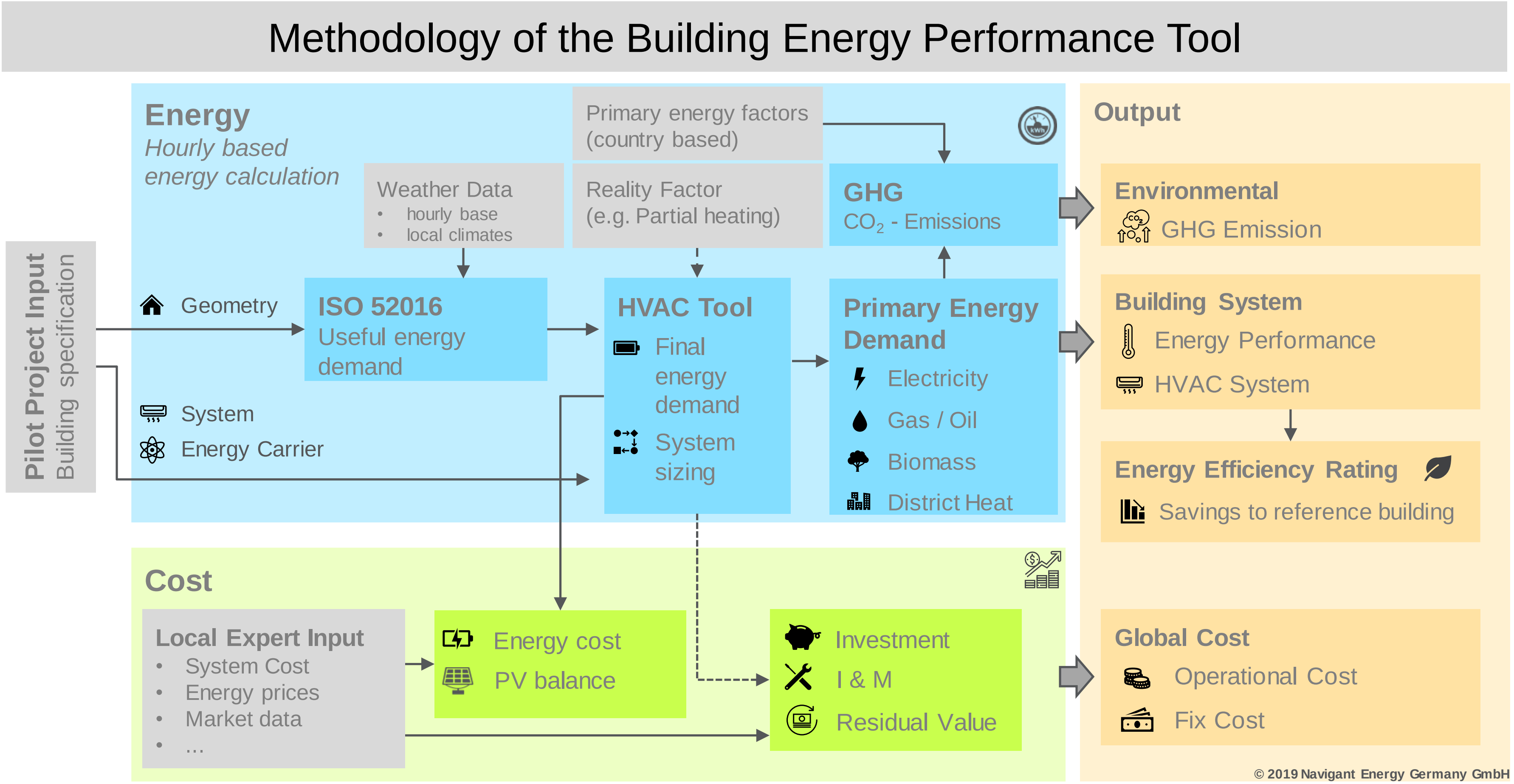
- Calculation of energy cost and investment cost of the systems, based on the HVAC system sized in the energy calculation
- Energy price systematic and PV clearing can be adapted to local situation (here: Lebanon)
- Residual values at the end of the calculation period for the systems are considered

Methodology

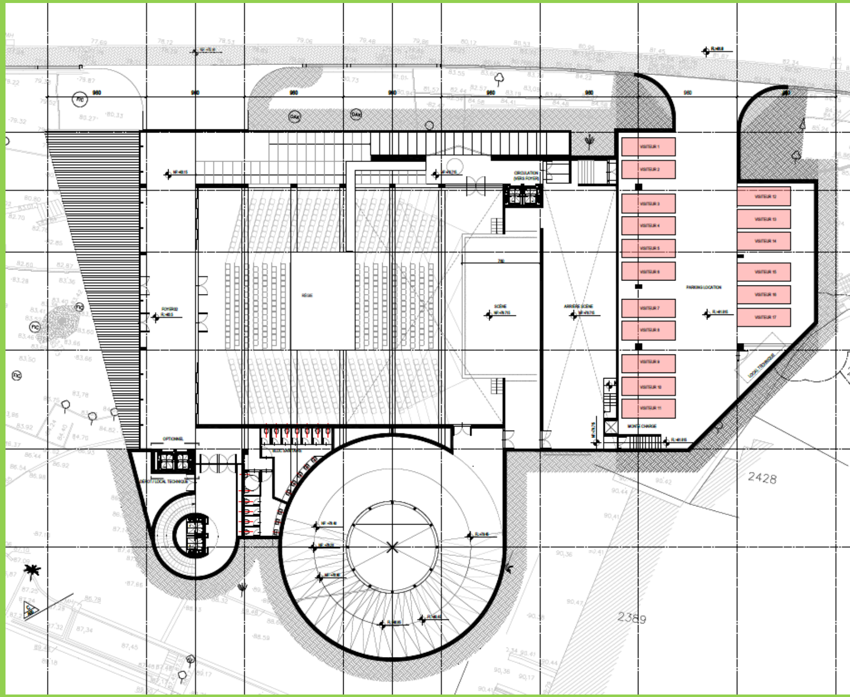
Cost Benefit Analysis

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



Collège Notre Dame De Nazareth – Amphitheatre

Aims

Creating a multipurpose hall to serve the Collège Notre Dame De Nazareth – Amphithéâtre.

Target Groups

Units for middle and upper middle class.

Function

Amphitheatre, open plazas and parking areas.

Size

One building consists of 5 floors. The total area will cover around 11,000 sqm.

Boundary conditions

Site : Context matters

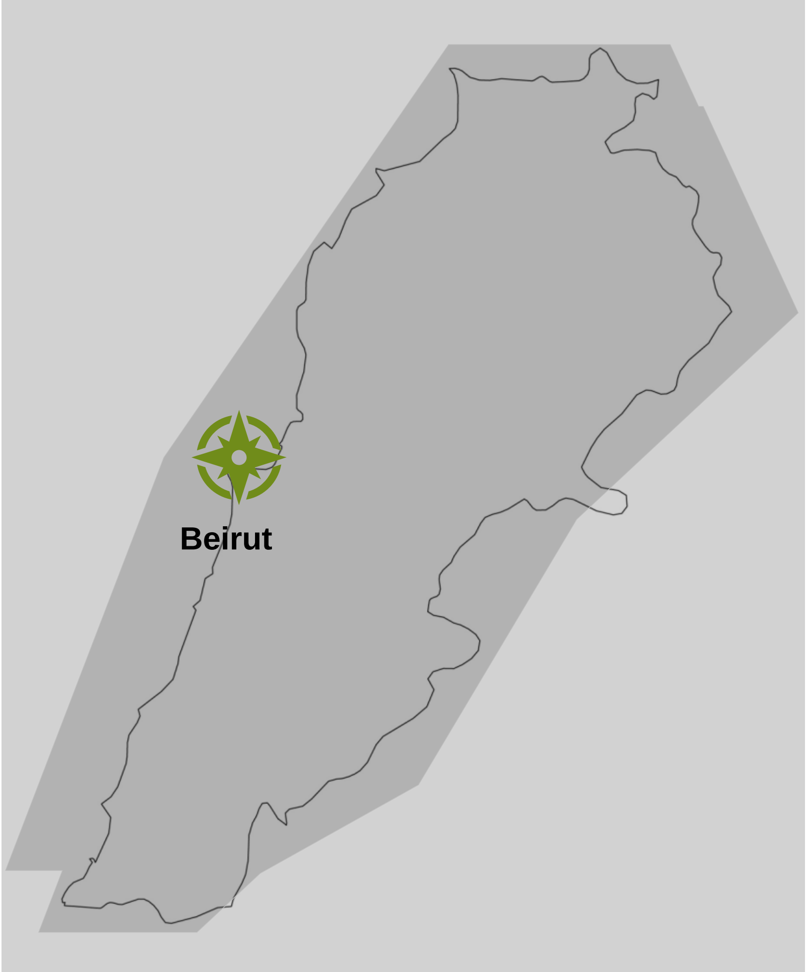
City : **Beirut**

Location : Achrafieh

Context

The project located in Achrafieh in in the heart of Beirut.

Source: Google Maps

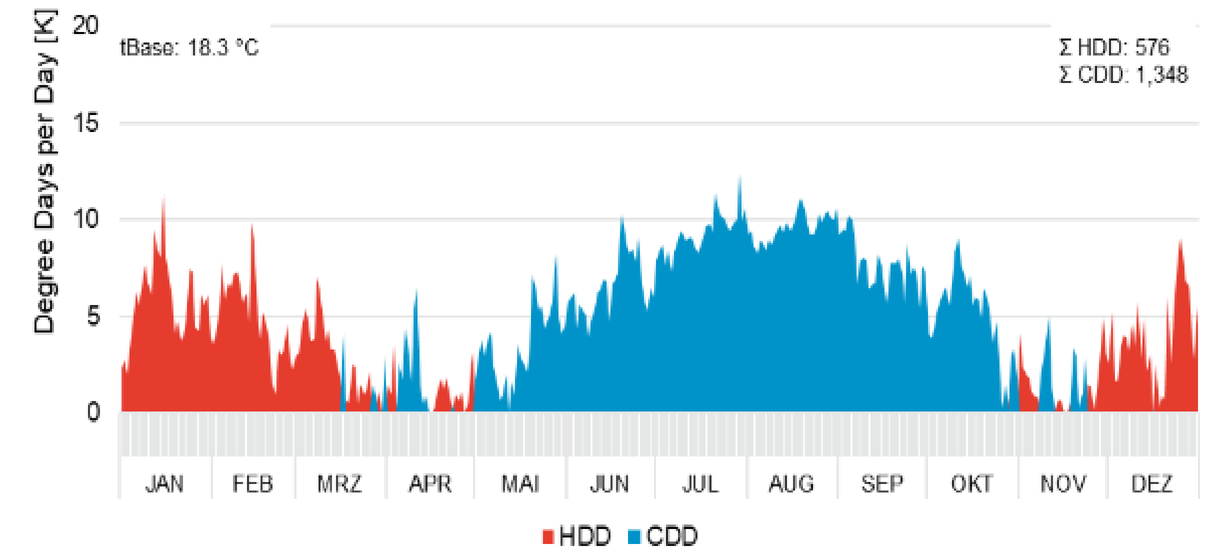


Boundary conditions I Climate Analysis

External temperatures and Relative Humidity *

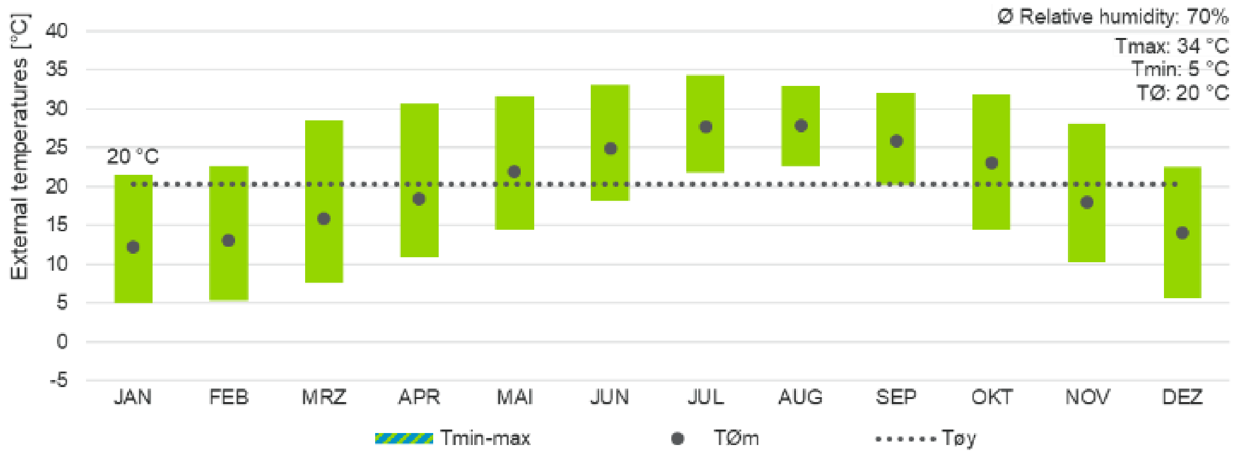
Description

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

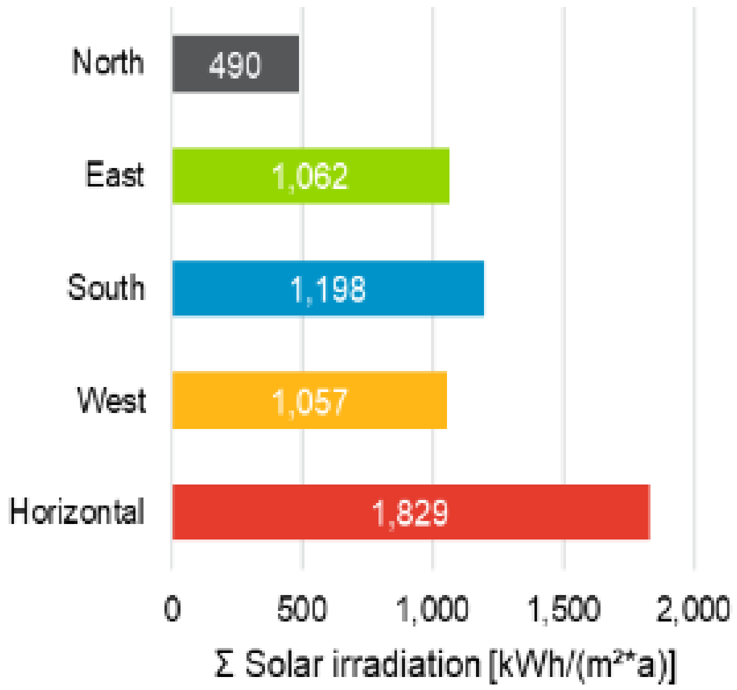
Solar Irradiation in Beirut (Lebanon)

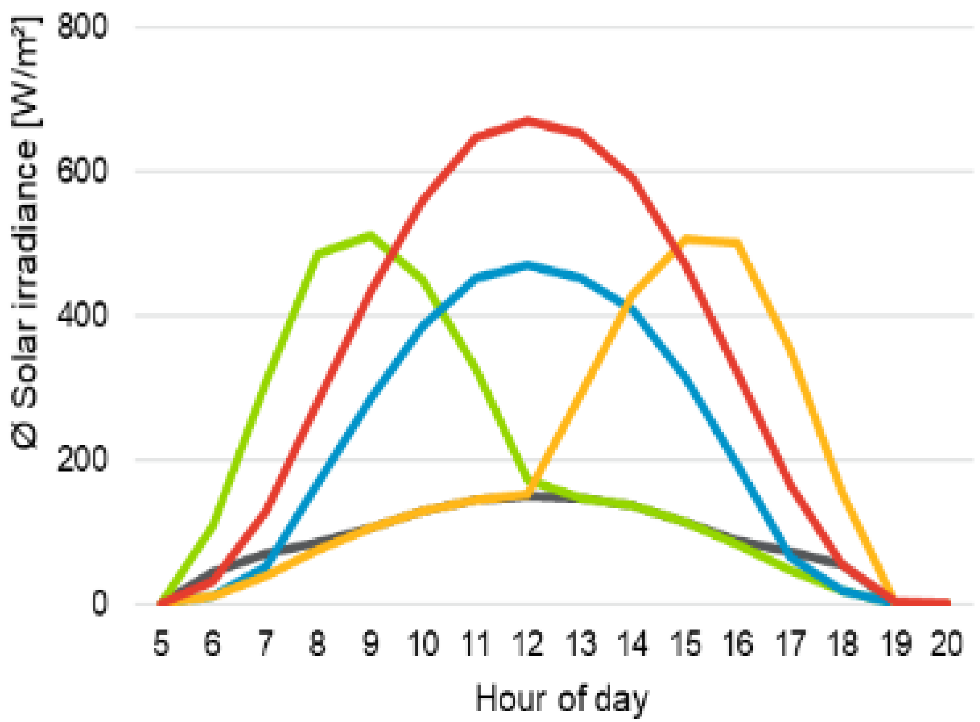
Description

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 0.175 Eur/kWh (incl. 9h generator)
- Price development of electricity = 3%/a,
- Interest rate = 5%.

Energy prices and CO_2 emissions		
Parameter	Unit	Electricity
Energy price (EDL)	LBP/kWh I EUR/kWh*	0.175 Euro/kWh
Energy price (Gen Set)	LBP/kWh I EUR/kWh*	510 I 0.3
Price development	%/year	3
CO_2 emission factor	gCO_2/kWh	806
Economic parameters		
Interest rate (real)	%/year	5
Calculation period	years	20

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

Boundary Conditions I Building

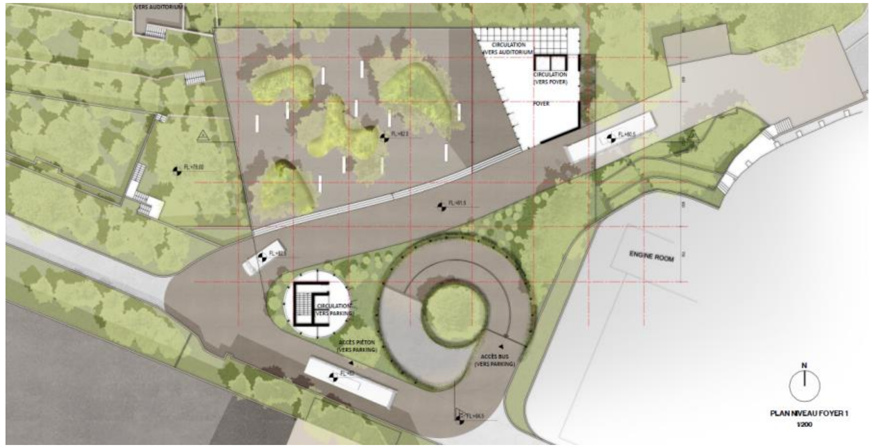
Building Data

Status

Amphitheatre for the events of the school in the design phase.

Specific Challenge

- To optimize the building systems for the Amphitheatre changing occupancy rates.
- Located near 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	
Data	Input
Latitude	33.885765
Longitude	35.513194
Elevation [m]	95
Utilization	Hall
Number of floors	5
Number of apartment	NA
Conditioned floor area [m²]	1,468
Clear room height [m]	appr. 6.30
Conditioned volume [m³]	9,248
Number of persons [#]	560 (max)
Year of construction	2021

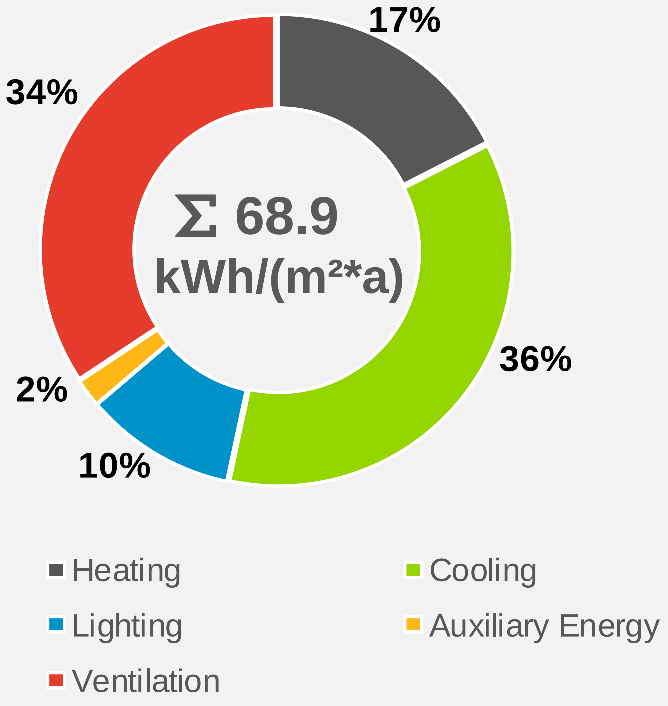
Analysis

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 includes some special assumptions for the non-residential case of the auditorium. No special attention is given to use renewable energy sources.

Parameters	Baseline
Roof insulation (U-Value)	0.5 W/m²K
Wall insulation (U-Value)	0.5 W/m²K
Floor insulation (U-Value)	2.2 W/m²K
Windows (U-Value; G-Value)	2.9 W/m²K; 0.7
Window fraction	Ø 76%
Shading	automatic shading
Air infiltration through leakages	0.25 1/h
Heat supply	Central unit - COP 3
Cold supply	Central unit - EER 3.5
Hot water	No
Ventilation system	mechanical ventilation
Lighting system	LED
Renewable energy	No
Set temperature cooling/heating	24°C / 21°C



Energy Cost
12.4 EUR / (m²*a)

CO2 - Emission
48.1 kg / (m²*a)

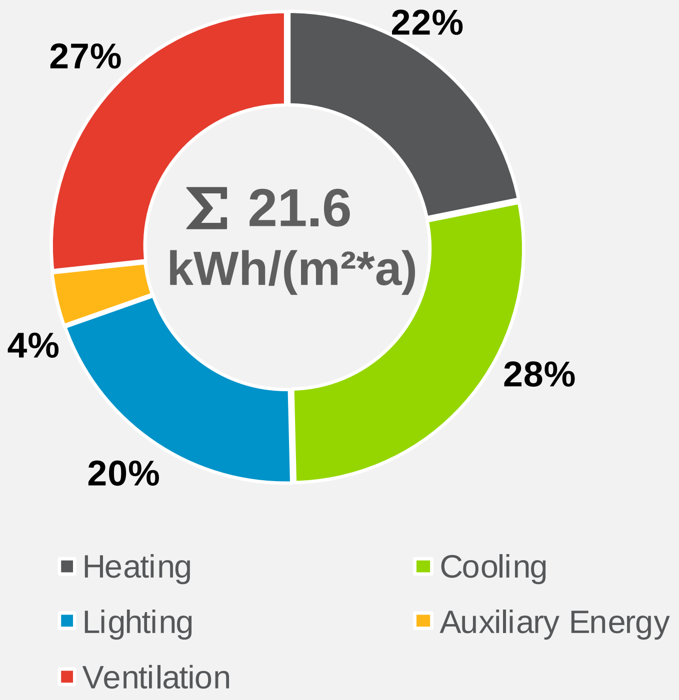
Current situation

Results

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

This leads to energy savings and emission reduction.

Parameters	Current
Roof insulation (U-Value)	**0.35 W/m²K**
Wall insulation (U-Value)	**0.9 W/m²K**
Floor insulation (U-Value)	2.4 W/m²K
Windows (U-Value; G-Value)	**3.2 W/m²K; 0.65**
Window fraction	Ø 76%
Shading	automatic shading
Air infiltration through leakages	**0.2** 1/h
Heat supply	Central unit - COP 3
Cold supply	**Central unit - EER 5**
Hot water	No
Ventilation system	mechanical ventilation**+HR+CO2**
Lighting system	LED
Renewable energy	No
Set temperature cooling/heating	24°C / 21°C



Energy Cost
4.1 EUR / (m²*a)

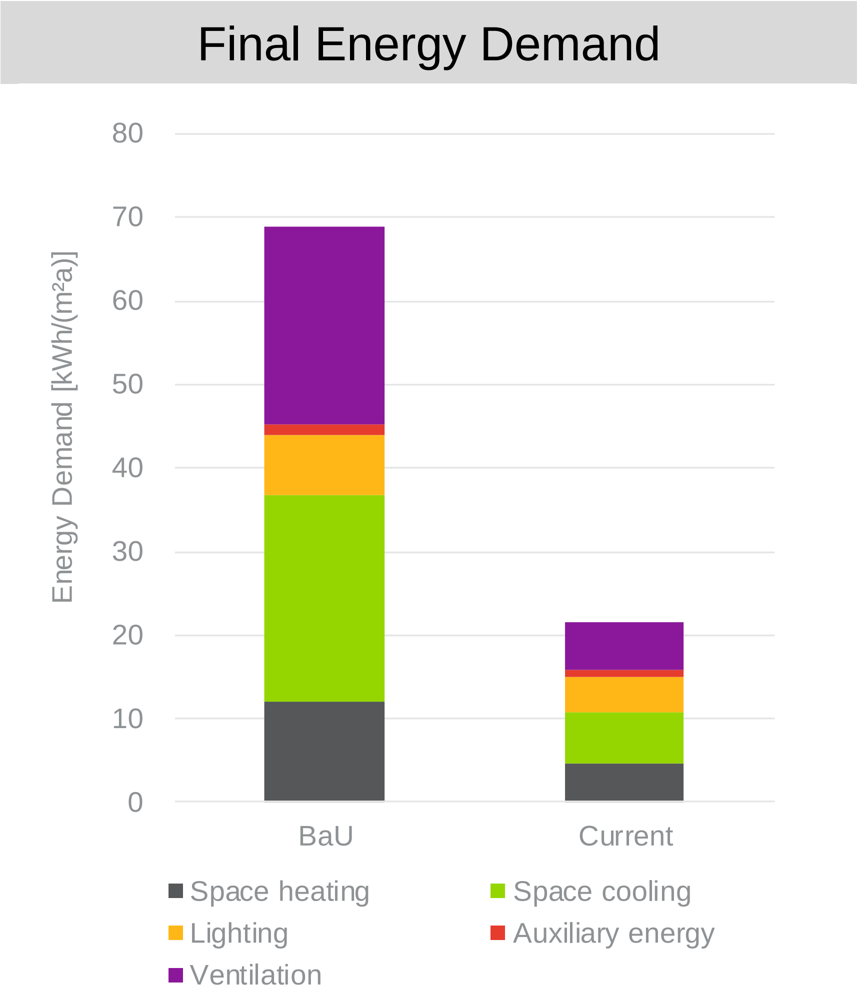
CO_2 - Emission
16.0 kg / (m²*a)

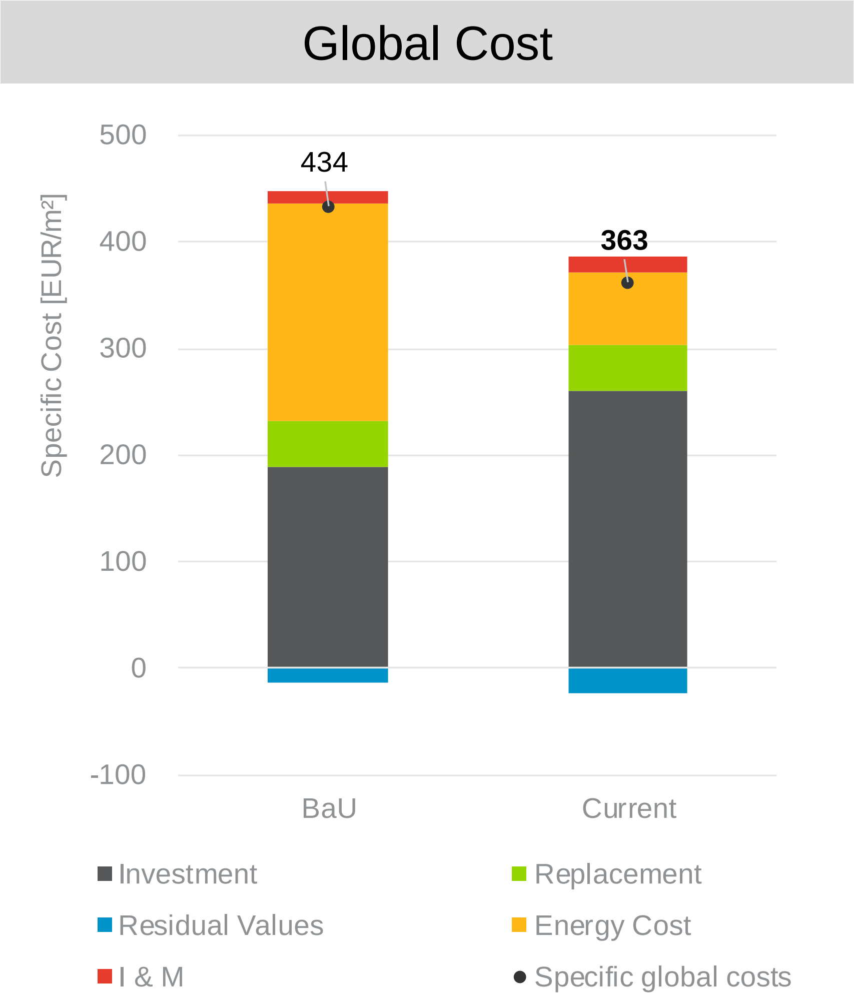
Current situation (project developer)

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.





Analysis

Investigation of Possible Measures

Overview of Analyzed Measures

Scope of Measures

Envelope

- Roof insulation
- External wall insulation
- Windows (U, g, window fraction)
- Shading

Systems

- Cooling
- Ventilation systems
- Operational temperatures

Renewables

- PV

Overview of Analyzed Measures

Scope of Measures

Envelope

- Roof insulation
- External wall insulation
- Windows (U, g, window fraction)
- Shading

Systems

- Cooling
- Ventilation systems
- Operational temperatures

Renewables

- PV

Building Envelope I External wall

Thermal insulation

BaU

U-Value = 2.2 W/m²K

Var 1

U-Value = 1.1 W/m²K

Current

U-Value = 0.9 W/m²K

Var 2

U-Value = 0.7 W/m²K

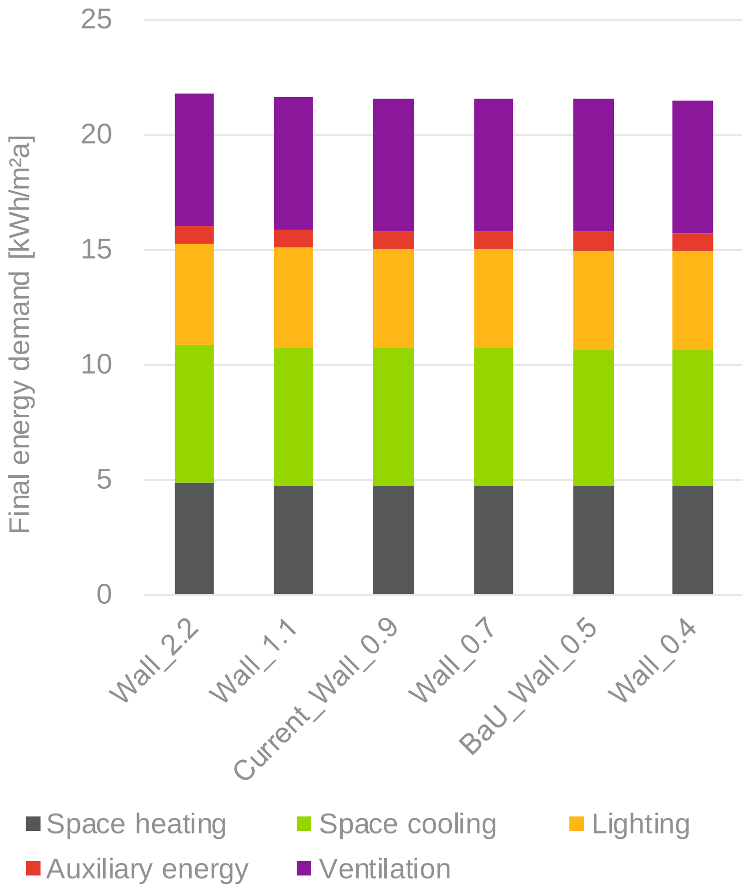
Var 3

U-Value = 0.5 W/m²K

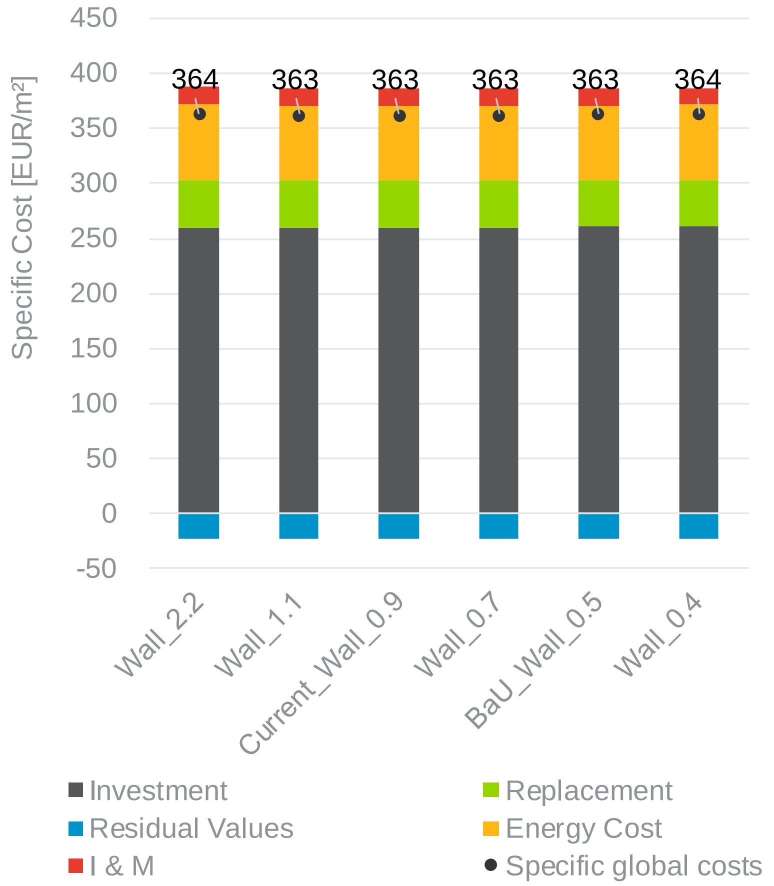
Var 4

U-Value = 0.4 W/m²K

Final Energy Demand



Global Cost



Result: No cost effective measure as wall area is very small.

Building Envelope I Roof

Thermal insulation

Var 1

U-Value = 3.2 W/m²K

Var 2

U-Value = 1.0 W/m²K

Var 3

U-Value = 0.6 W/m²K

BaU

U-Value = 0.45 W/m²K

Current

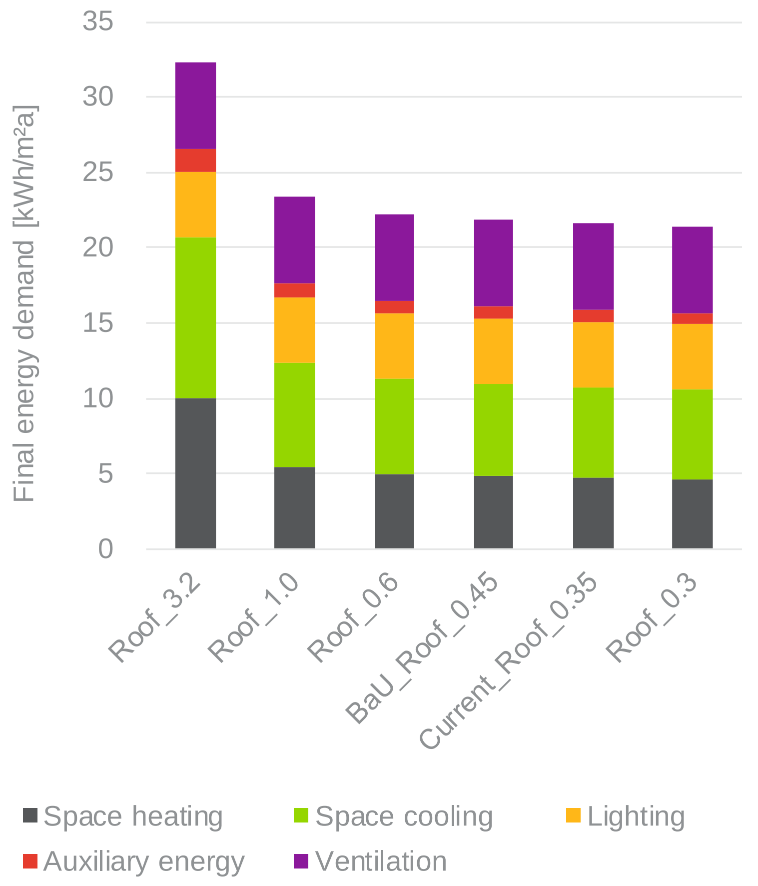
U-Value = 0.35 W/m²K

Var 4

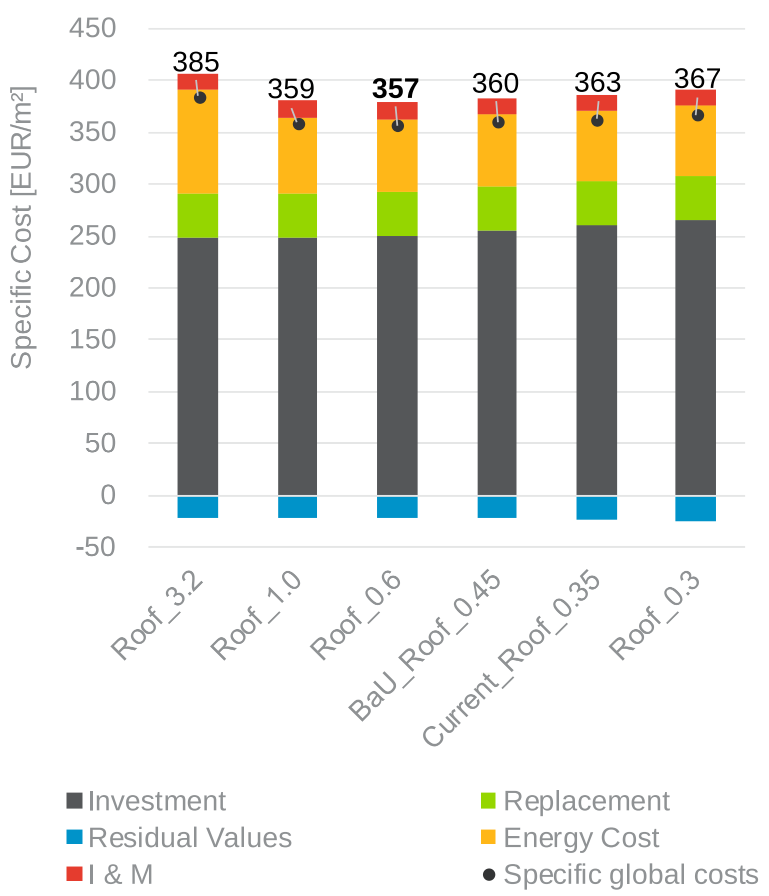
U-Value = 0.3 W/m²K

Result: Var 3 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 3.2 W/m²K, G-Value 0.65

Double glazing – low E (Var 1)

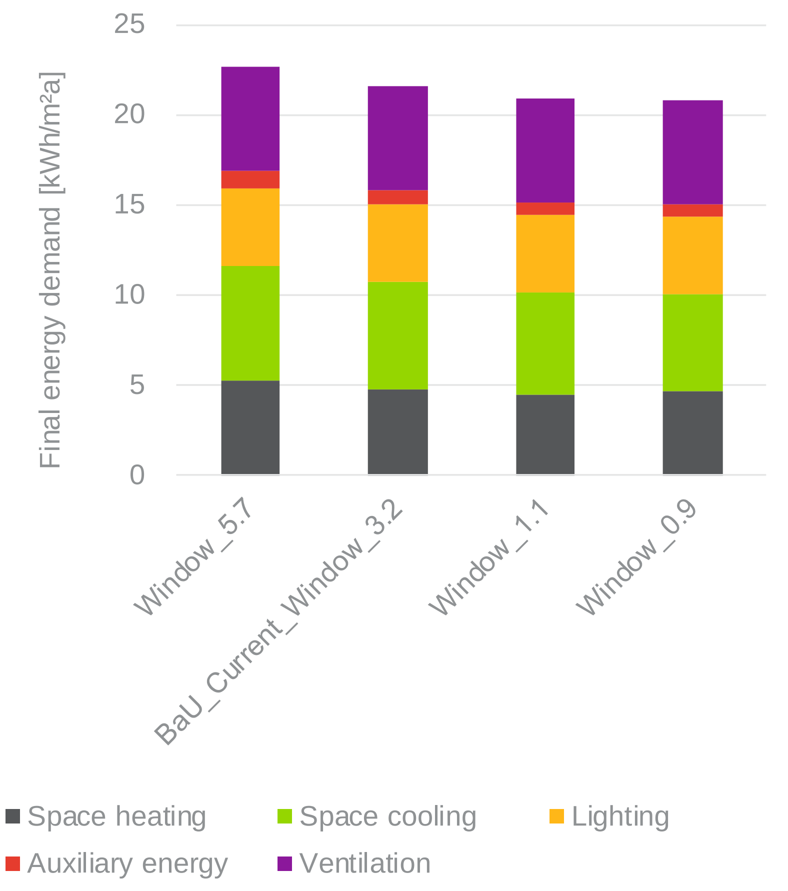
U-value 1.1 W/m²K, G-Value 0.6

Triple glazing (Var 2)

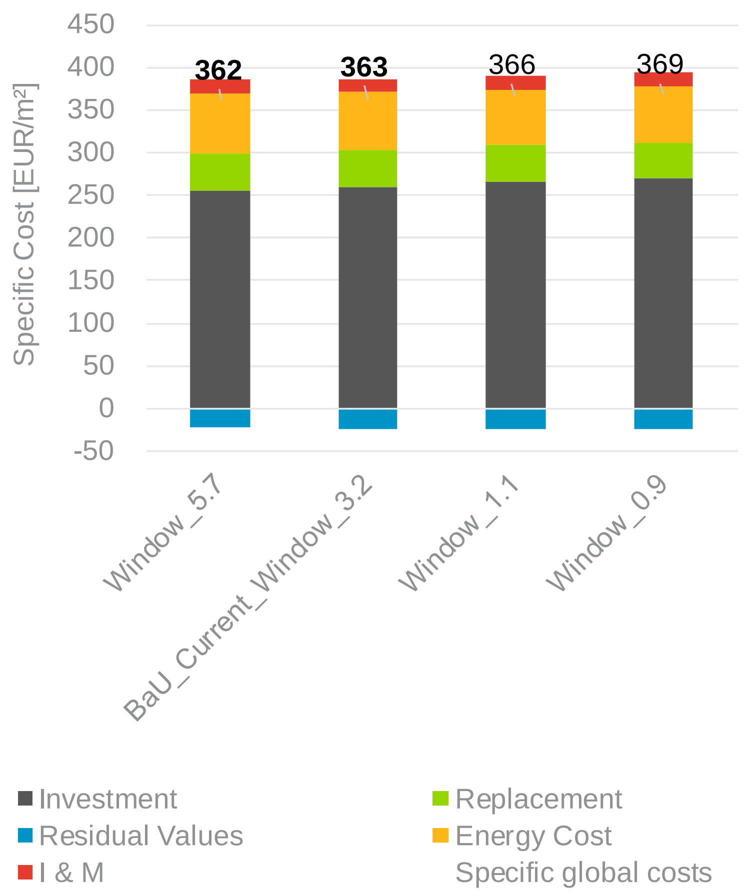
U-value 0.9 W/m²K, G-Value 0.5

Result: Single glazing is the most cost effective measure, but due to comfort reasons **Current/Double glazing** is used (e.g. condensation).

Final Energy Demand



Global Cost



Building Envelope I Window

Window fraction

BaU / Current

76 %

Var 1

60 %

Var 2

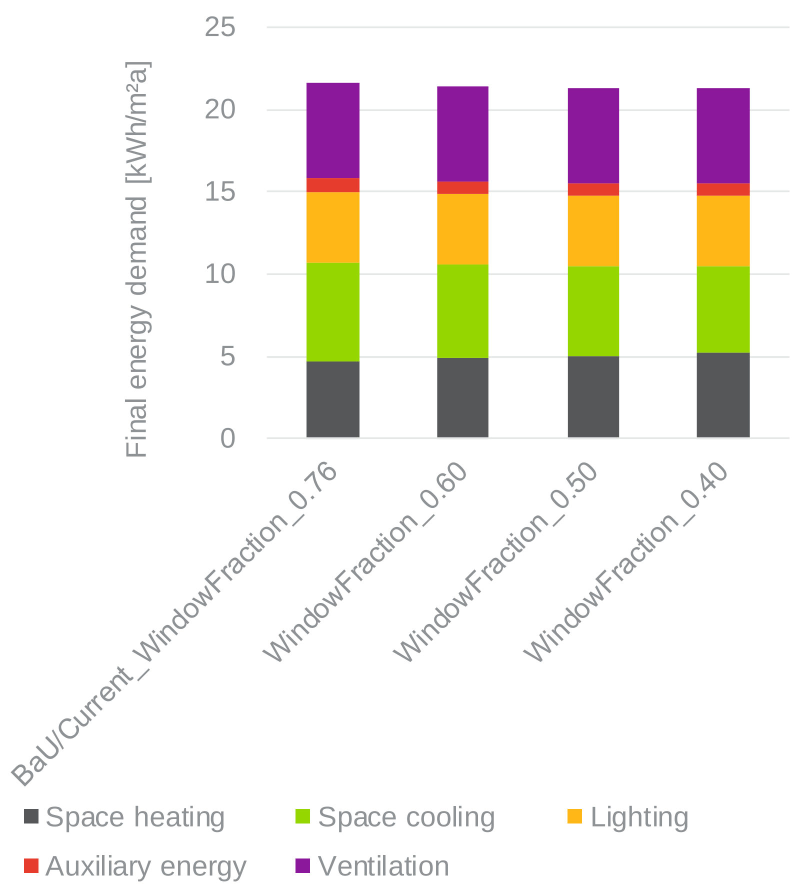
50 %

Var 3

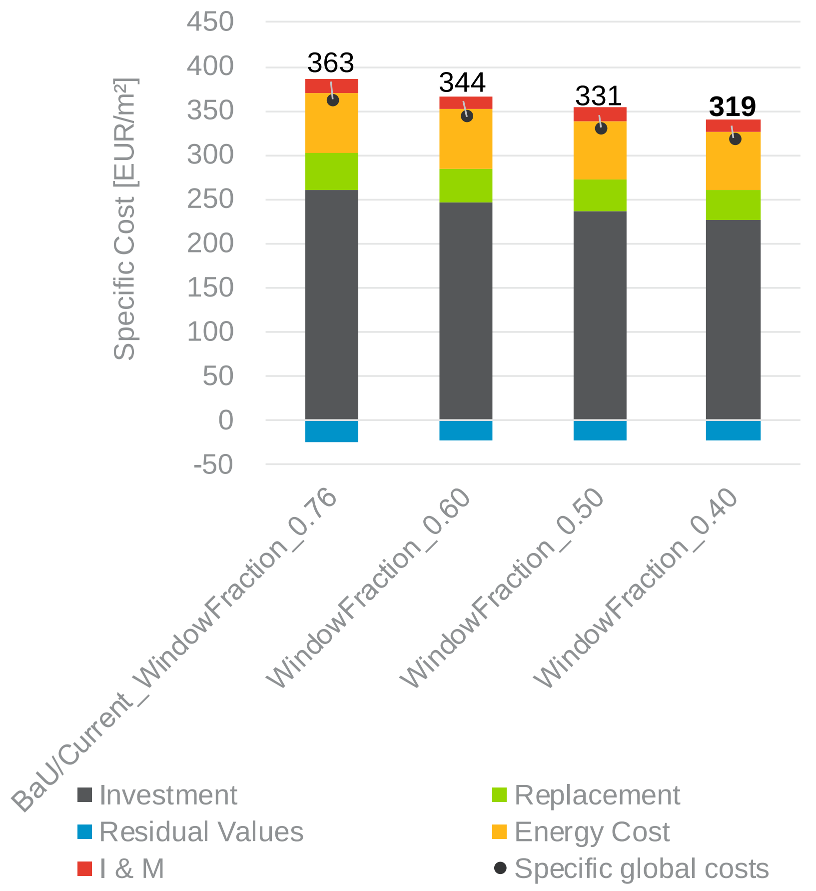
40 %

Result: Var 3 is the most cost effective measure.

Final Energy Demand



Global Cost



Shading concept
Analysis

Var 1

No shading

BaU / Current

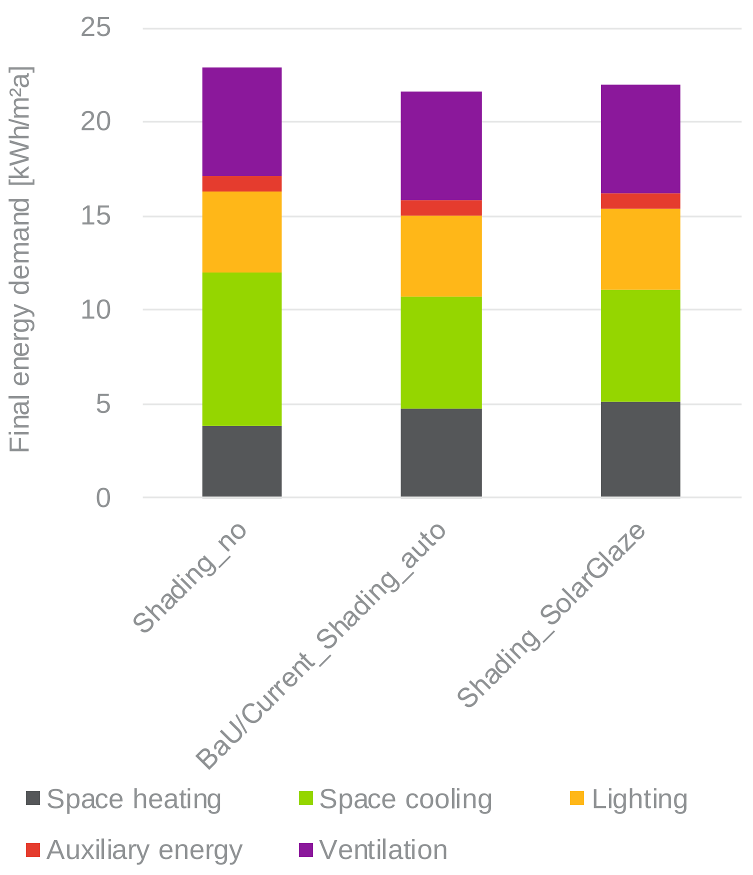
Automatic Shading

Var 2

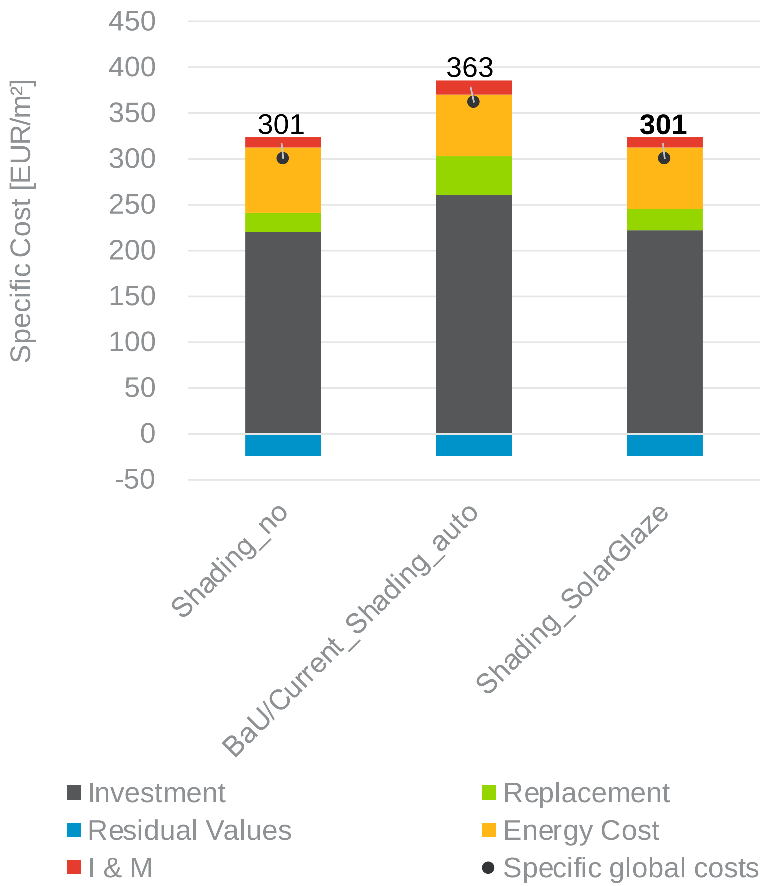
Solar Glazing

Result: Var 2 is the most cost effective measure.

Final Energy Demand



Global Cost



Overview of Analyzed Measures

Scope of Measures

Envelope

- Roof insulation
- External wall insulation
- Windows (U, g, window fraction)
- Shading

Systems

- Cooling
- Ventilation systems
- Operational temperatures

Renewables

- PV

HVAC I Cooling
Analysis

BaU

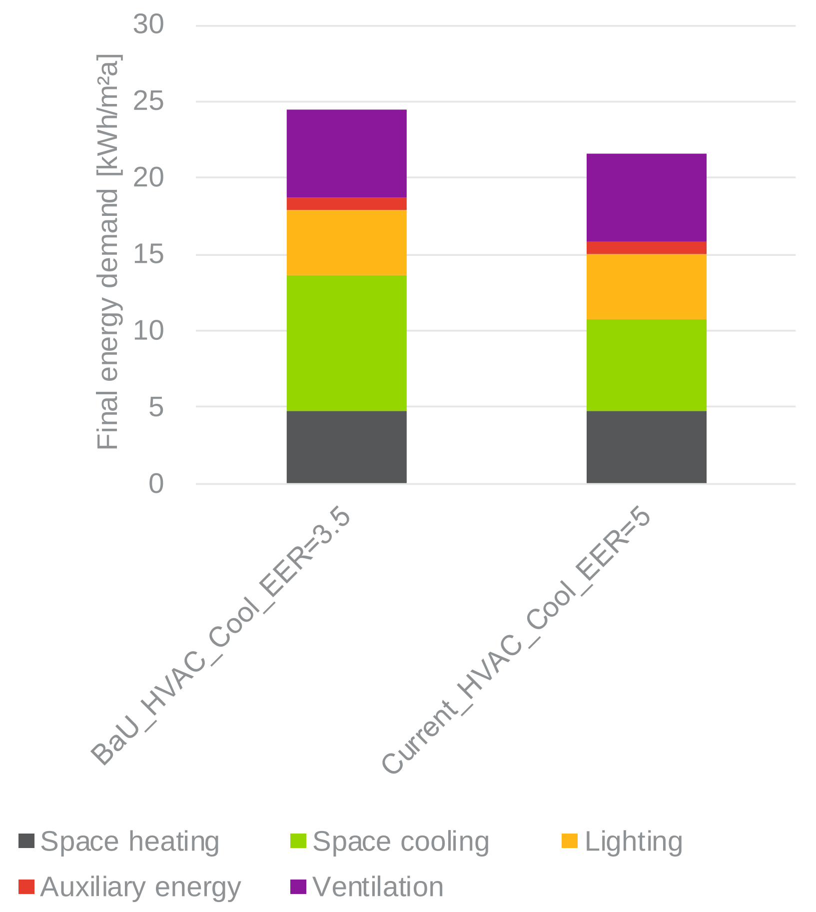
Central Unit
(Cooling EER 3.5)

Current

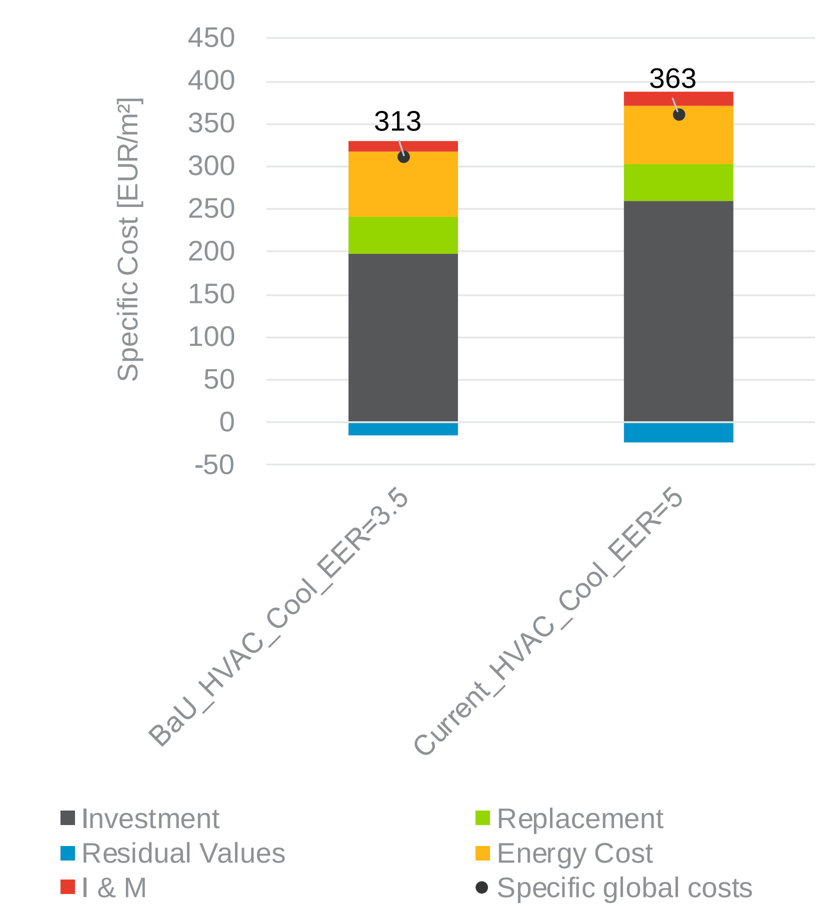
Central Unit
(Cooling EER 5)

Result: BaU is the most cost effective measure as the cooling demand is relatively low. But the **Current** system is chosen as with additional consideration of dehumidification demand the cost gap would further decrease.

Final Energy Demand



Global Cost



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Remark: All figures for the cooling demand in this presentation do not include demand for dehumidification.

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HVAC I Ventilation

Analysis

BaU

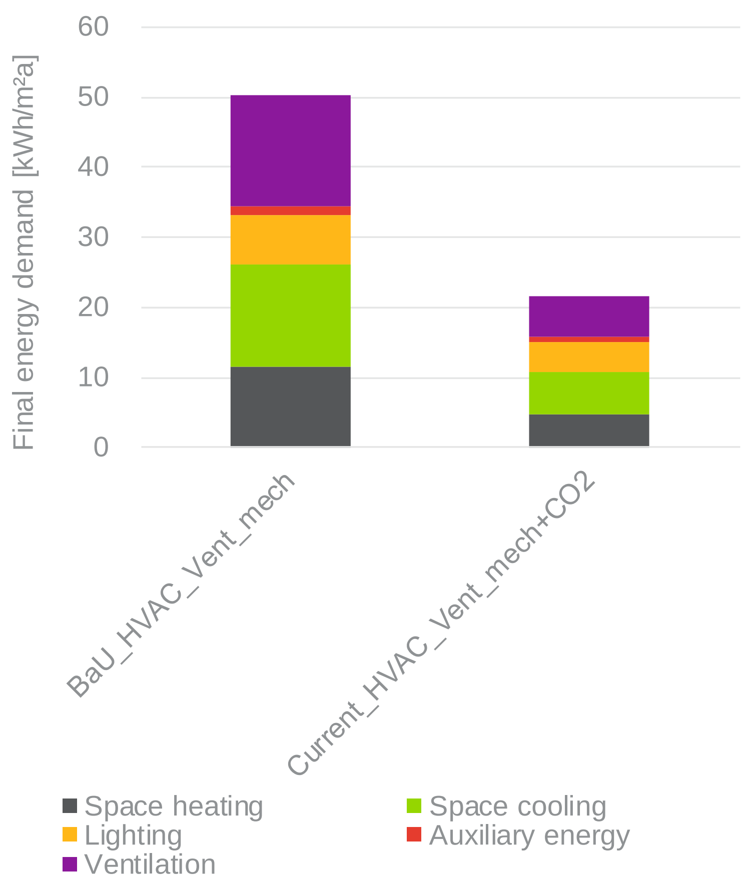
Mech. ventilation

Current

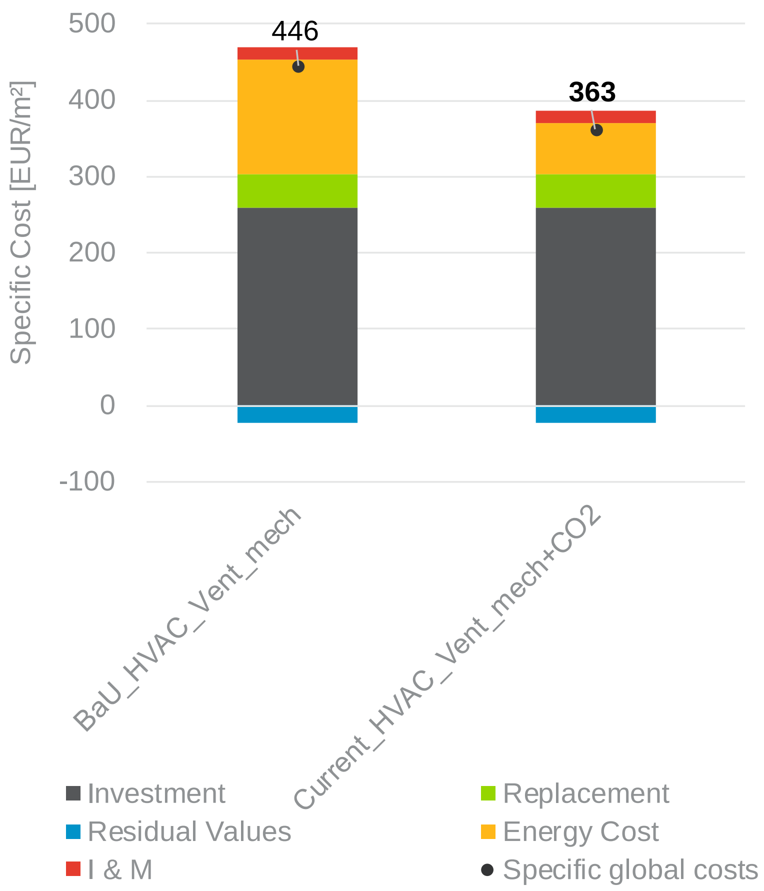
Mech. Ventilation + CO_2 control

Result: Current is the most cost effective measure.

Final Energy Demand



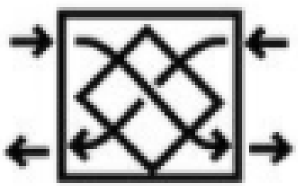
Global Cost



Remark: All figures for the cooling demand in this presentation do not include demand for dehumidification.

HVAC I Cold recovery

Analysis



Current cold recovery planned:

CO_2-controlled mechanical ventilation with cold recovery unit

➔ Cooling supply air specifications: 13°C / 100% r.H.

Effect of current cold recovery planned (based on annual hourly energy balance model):

Saved cooling electricity: 0.8 kWh/m²a

Additional ventilation demand: 0.2 kWh/m²a (resulting from pressure drop of ventilation system with cold recovery unit)

➔ **Resulting savings: 0.6 kWh/m²a**

Recommendation:

Due to the already very efficient ventilation and cooling systems (CO_2-controlled, EER = 5) the potential savings of a cold recovery unit are very limited.

Therefore, we do not recommend to invest in a cold recovery unit.

Remark: We recommend additional humidity control as our model shows high humidity loads over the year (➔ threat of condensation issues)

Operational Temperatures

Analysis

BaU / Current

Cooling Temperature: 24°C
Heating Temperature: 21°C

Set temperature cooling

Cooling: 26°C

Set temperature heating

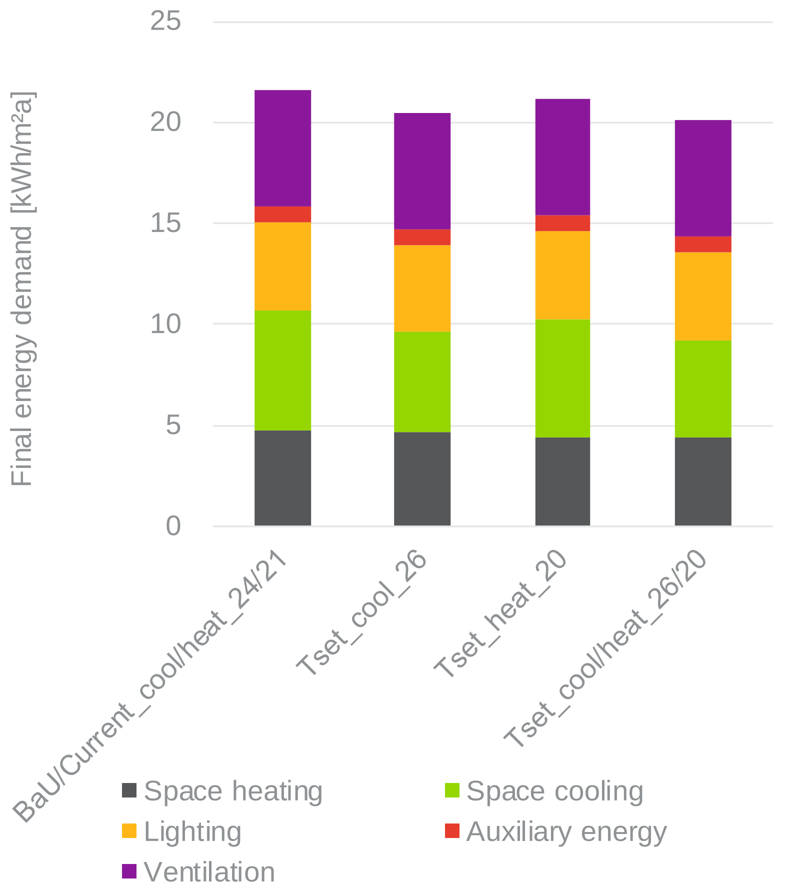
Heating: 20°C

Combined Variant

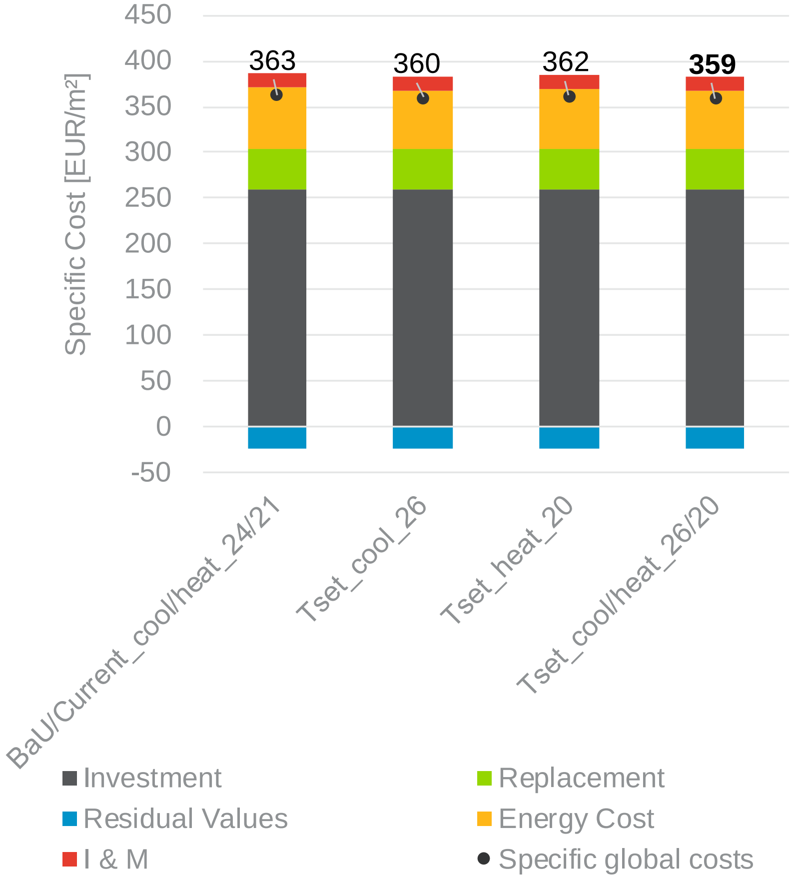
Cooling Temperature: 26°C
Heating Temperature: 20°C

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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Overview of Analyzed Measures

Scope of Measures

Envelope	Systems	Renewables
Roof insulation	Cooling	PV
External wall insulation	Ventilation systems	
Windows (U, g, window fraction)	Operational temperatures	
Shading		

Renewables I PV

Analysis

BaU/Current

no PV

Var 1

PV – 25% of roof space

Var 2

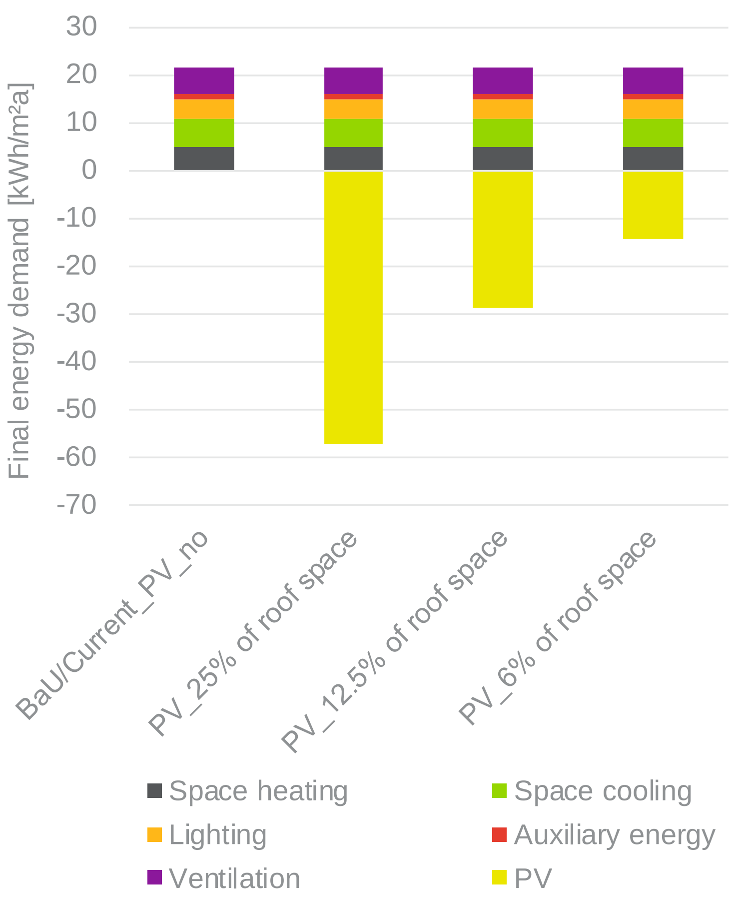
PV – 12.5% of roof space

Var 3

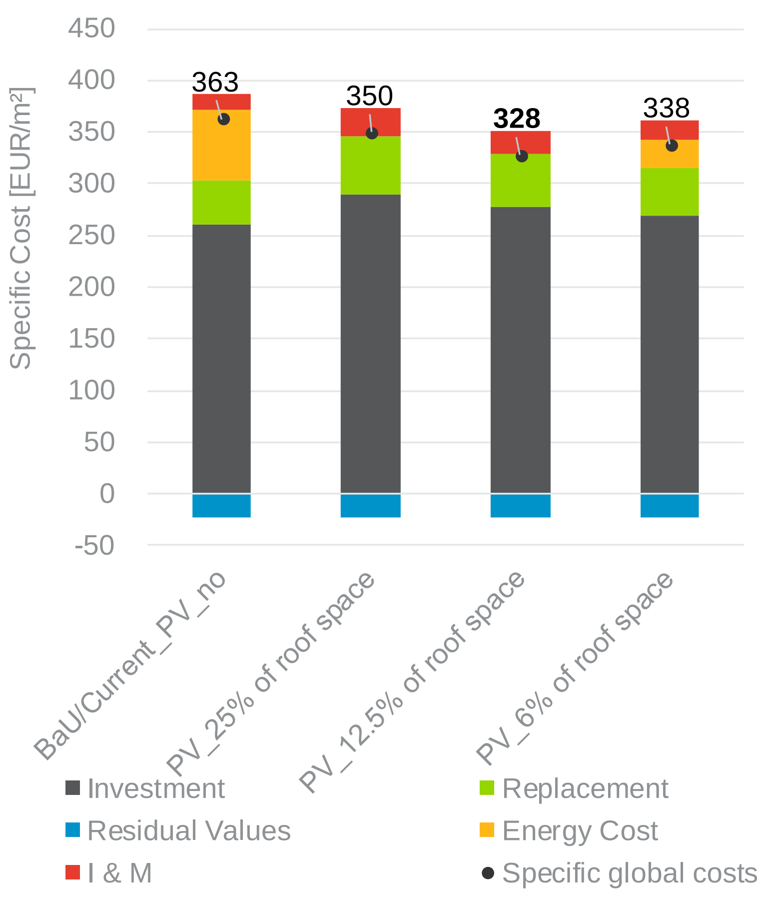
PV – 6% of roof space

Result: Var 2 is the most cost effective measure.

Final Energy Demand



Global Cost



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Results &Conclusion

Optimized Solution

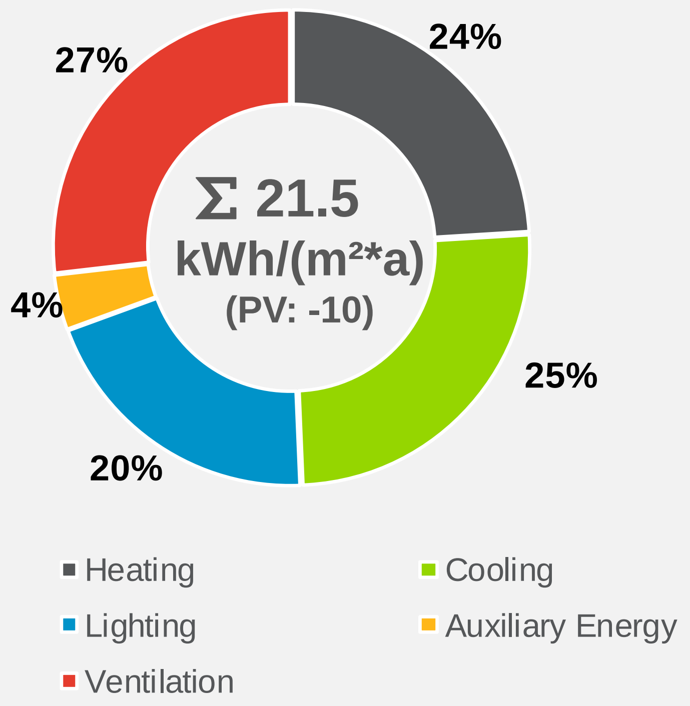
Results

The key components of the energy concept are illustrated in this table, it shows that the building envelope is not the key component of the concept.

Special attention is given to the solar glazing and the window fraction and the renewable energy on the roof (PV).

This leads to energy savings and emission reduction.

Parameters	Optimized
Roof insulation (U-Value)	**0.6 W/m²K**
Wall insulation (U-Value)	0.9 W/m²K
Floor insulation (U-Value)	2.4 W/m²K
Windows (U-Value; G-Value)	3.2 W/m²K; **0.3 (solar glazing)**
Window fraction	**Ø 40%**
Shading	**solar glazing**
Air infiltration through leakages	0.20 1/h
Heat supply	Central unit - COP 3 (air vent)
Cold supply	Central unit - EER 5 (air vent)
Hot water	none
Ventilation systems	mechanical CO_2 controlled ventilation **(without HR)**
Lighting systems	LED
Renewable energy	**26 kWp (PV, 12.5% of roof)**
Set temperature cooling/heating	**26°C / 20°C**



Energy Cost (- PV)
2.1 EUR / (m²*a)

CO2 - Emission
8.1 kg / (m²*a)

Comparative overview

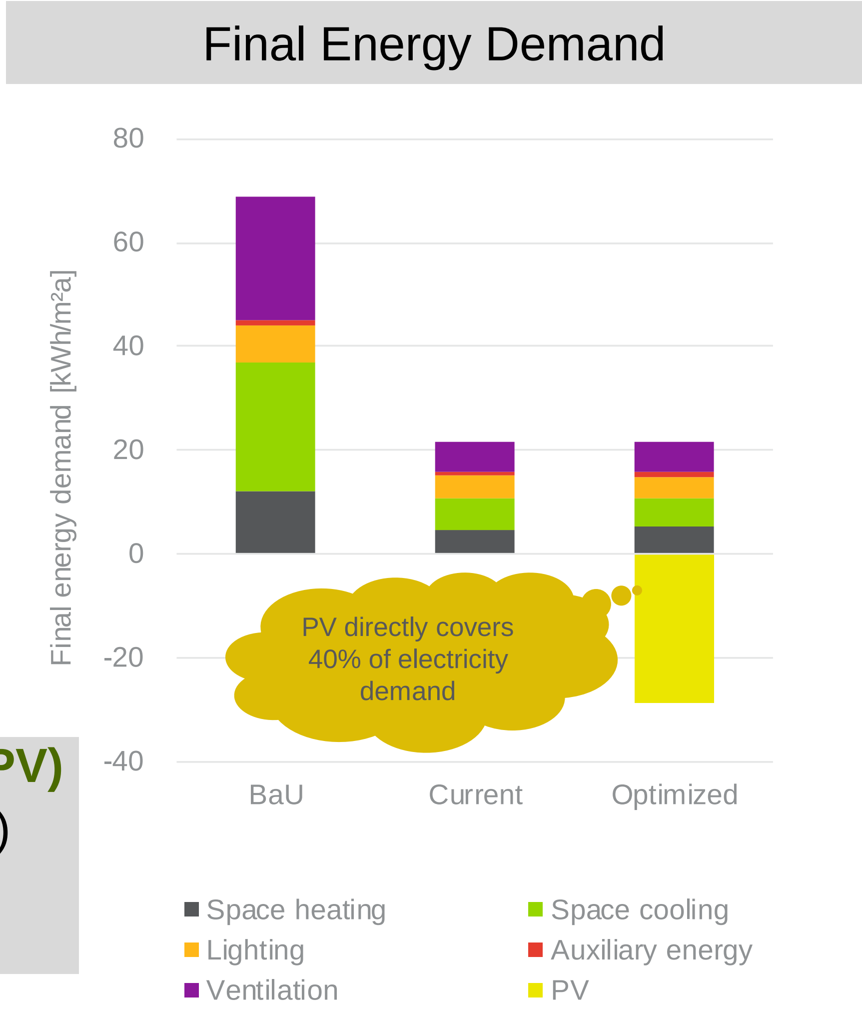
Baseline vs. Current vs. Optimized

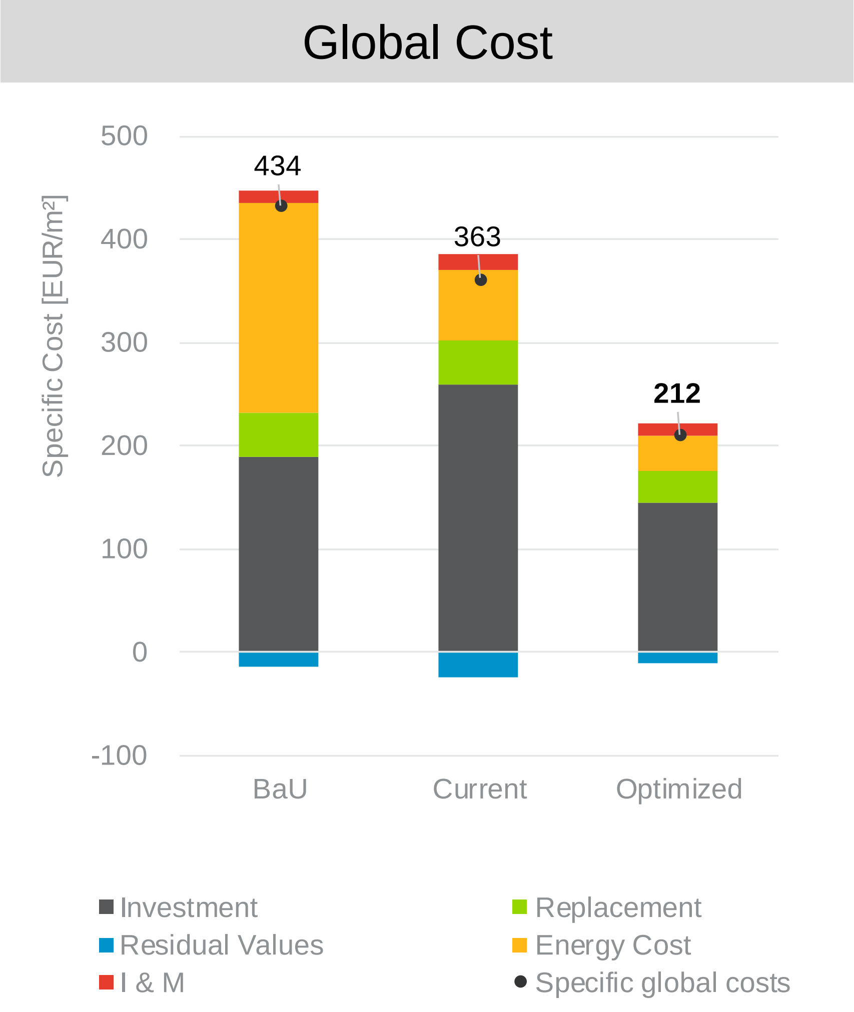
Conclusion

- 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 BaU to Optimized (incl. PV)

- Energy: **69** ► **22** kWh/m²a (-70%)
- E-Cost: **12.4** ► **2.1** EUR/m²a (-83%)N





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)	0.6 W/m²K	-14,100 (lower investment)	+165 (no savings)	immediately	40
Window fraction	Ø 40%	-21,000 (lower investment)	-83	immediately	30
Shading	Solar glazing (instead of automatic shading)	-55,400 (lower investment)	+94 (no savings)	immediately	30
Renewable energy	26 kWp (PV, 12.5% of roof)	12,800	-3,700	3	20
Set temperature cooling/heating	26°C / 20°C	0	-400	immediately	-
Total (current to optimized)**		**-182.700 (-22%)*****	**-3,000**	immediately	

* Remark: The energy cost savings have been calculated conservatively based on the current electricity starting price (appr. 17.5 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.

*** Remark: Compared to costs of current case and overall construction cost assumptions of 500 Euro/m² (-25% less costs).

Please note: The costs for the cooling supply has been lowered in the optimized variant only, as the proposed measures reduce the cooling power by appr. 100 kW.

Key conclusion

Main take aways for the Notre Dame Project

- The **current** planning is already very energy efficient!
- Our **optimized** solution suggests cost saving measures (-22%) and renewable energies (PV) that are able to produce more electricity than required with a direct coverage of 40%.

- The recommended package is able to save **70%** energy compared to the baseline and **50%** energy related to the current planning (incl. PV).

- Therefore, the **cooling unit** can be reduced from 400 kW to 200 kW.
- Furthermore, a **cold recovery unit** is not recommended as the potential savings are too low due to the already very efficient ventilation and cooling system (CO_2-controlled, EER = 5).

- Most attractive with **immediate payback** are: replace the automatic shading by solar glazing, reduce the window fraction, slightly reduce the thermal quality of the roof, change set temperatures for heating/cooling
- Also attractive with **short payback** time is the installation of PV (3 years).

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