Guidehouse

Energy Efficiency Recommendations for A Private Villa, Jordan

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

BUILD_ME

September 2120

Introduction to the BUILD_ME project

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

ALG

MOR

TUN

Team

IDG MATRIX Integrated Development Group

الجمعية العلمية الملكية Royal Scientific Society

LCEC Lebanese Center for Energy Conservation

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

Contents

Introduction

Background, Objectives and Methodology

Photo by Scott Graham on Unsplash

Introduction

BUILD_ME Project and the Objectives of Pilot Projects

WP1 Preparatory Steps

Software tool
MENA building Typology
Baseline definition

WP3 Framework Conditions

Building codes
NDC and Strategies
Classification scheme
Access financing

WP2 Support the Implementation of Pilot Projects

WP4 Capacity Building and Dissemination

Project website
National Workshops
Regional Workshop
Training and webinars

Objectives

- Test classification schemes
  Facilitate finance
  Conclusions to Gov.
- Demonstrate technical and financial feasibility of EE buildings
- Provide training(s) for the staff implementing EE/RE measures

Green Marketing
Dissemination via Web.
Share experiences in WS

Benefits for PP

- **Free technical assistance**
  Economic assessment
  Cost-benefit analysis
  Simulation
  On-site checks
- **Potential financial support**
- **Enhance your projects visibility**
  Calculation of economic performance
  Support with application to funds

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

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 (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

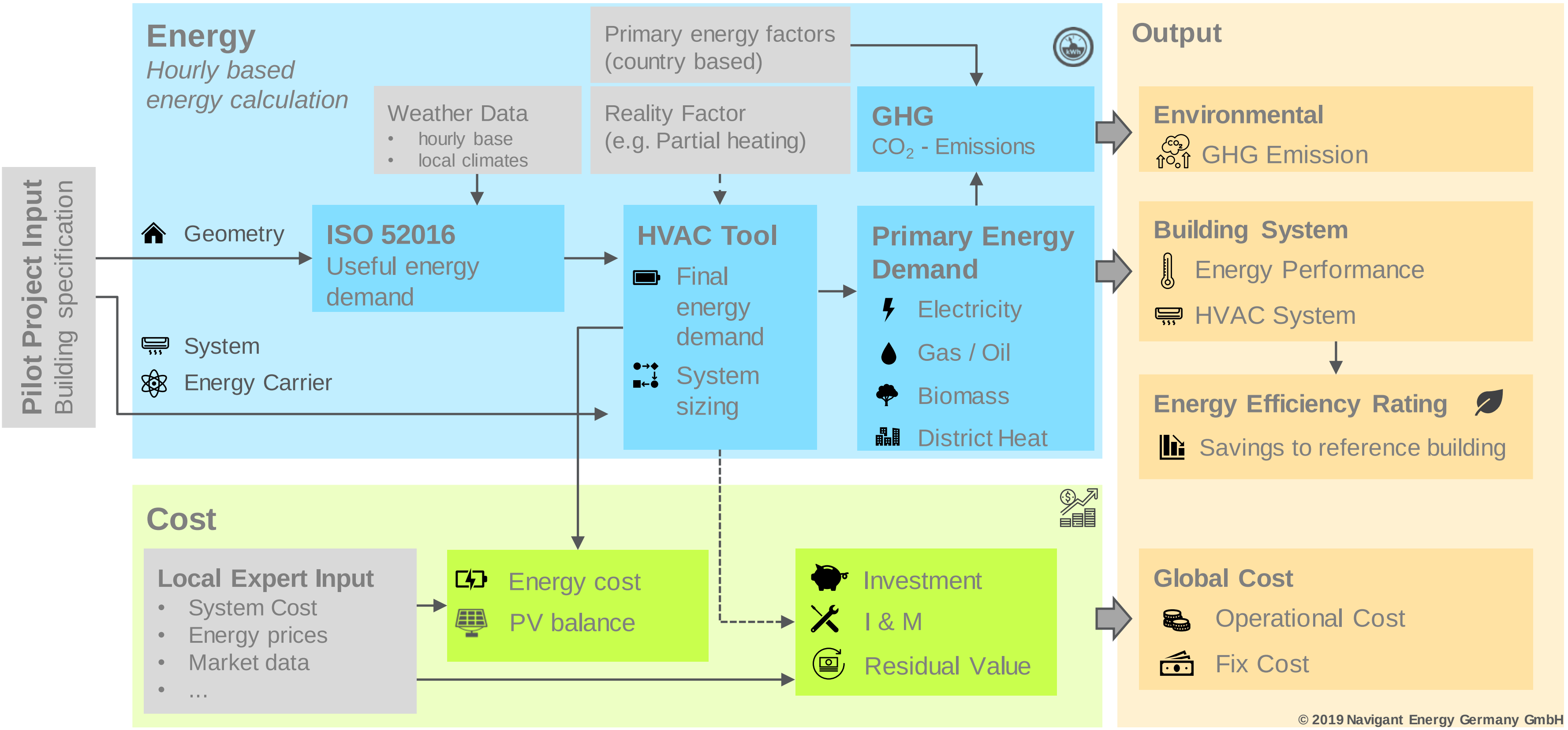
Methodology

Cost Benefit Analysis

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)

Methodology of the Building Energy Performance Tool



Introduction

The Project
Boundary conditions

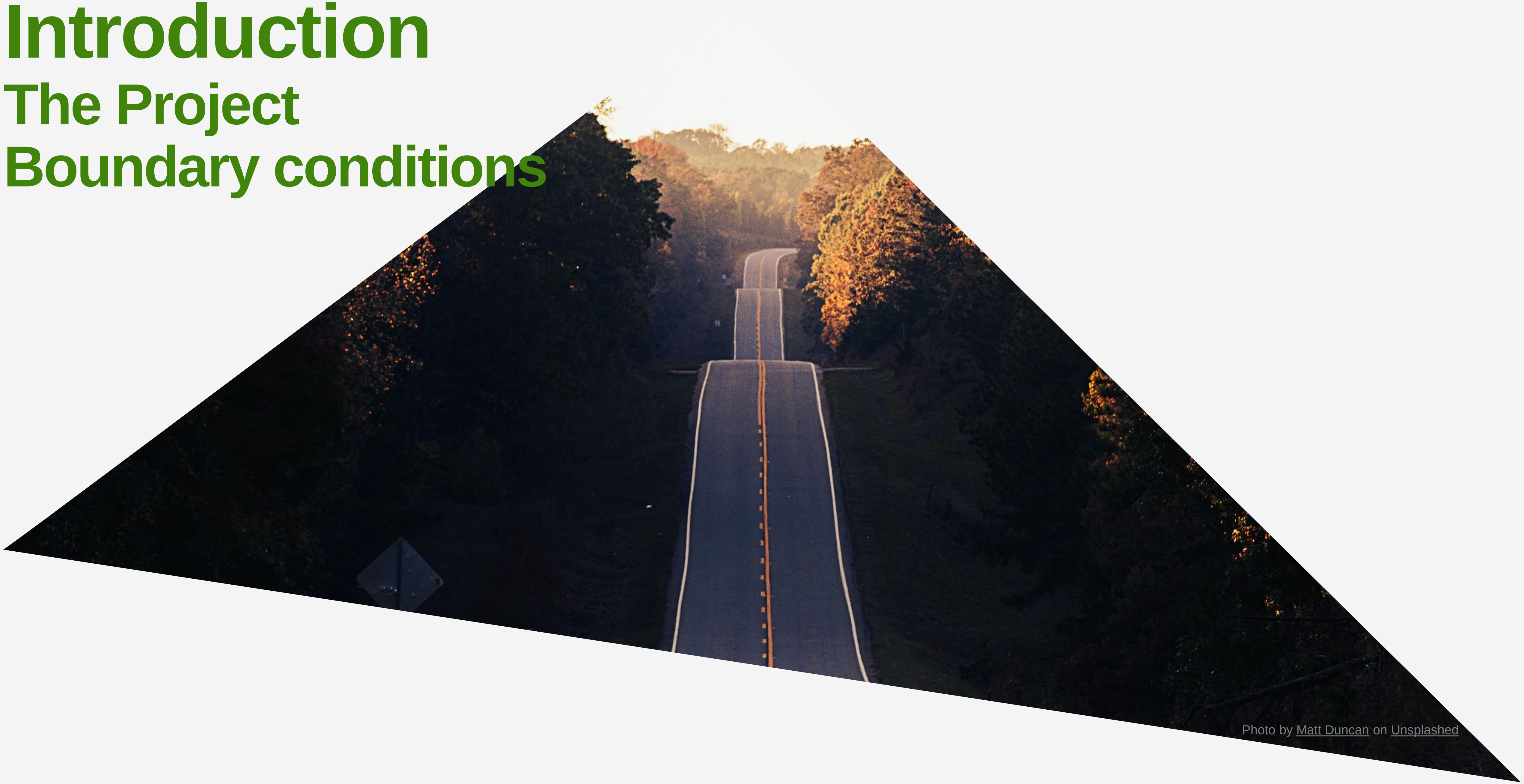


Photo by Matt Duncan on Unsplashed

The Project Key Information

Aims

Building a single family house in Jordan. The building will represent the modern lifestyle of Jordanian families.

Target Groups

An upper-middle class house in Amman, the Capital of Jordan.

Function

Residential single family house including a small garden and a swimming pool.

Size

The villa will be 455 square meters on two floors and roof rooms.

Boundary conditions

Site : Context matters

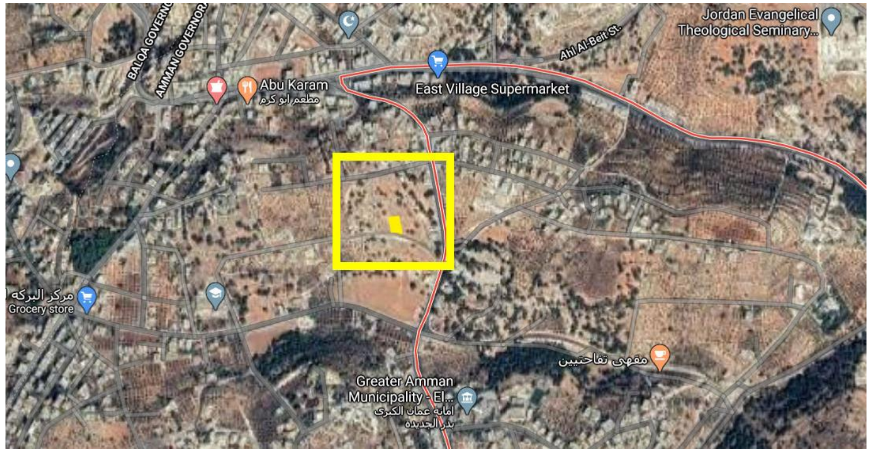
City : Amman

Location : Suburbs of Amman City

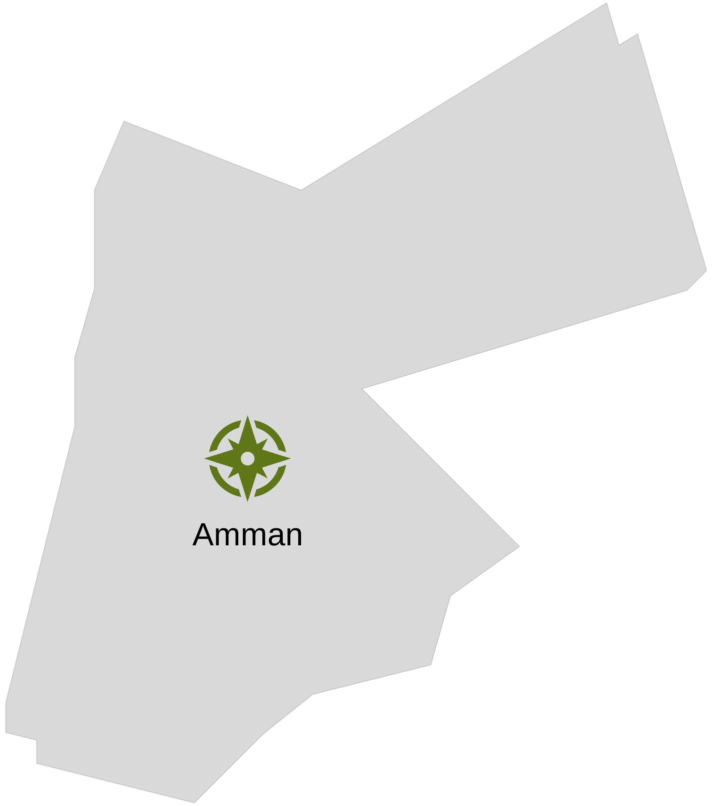
Context

The villa is located in a town called Bilal (north-western part of Amman Governorate Jordan. It is considered to be a low density populated area.

The land is surrounded by a few oak trees with some scattered olive trees.



Source: Google Maps



Boundary conditions I Climate Analysis

External temperatures (left) and degree days (right) in Amman (Jordan)*

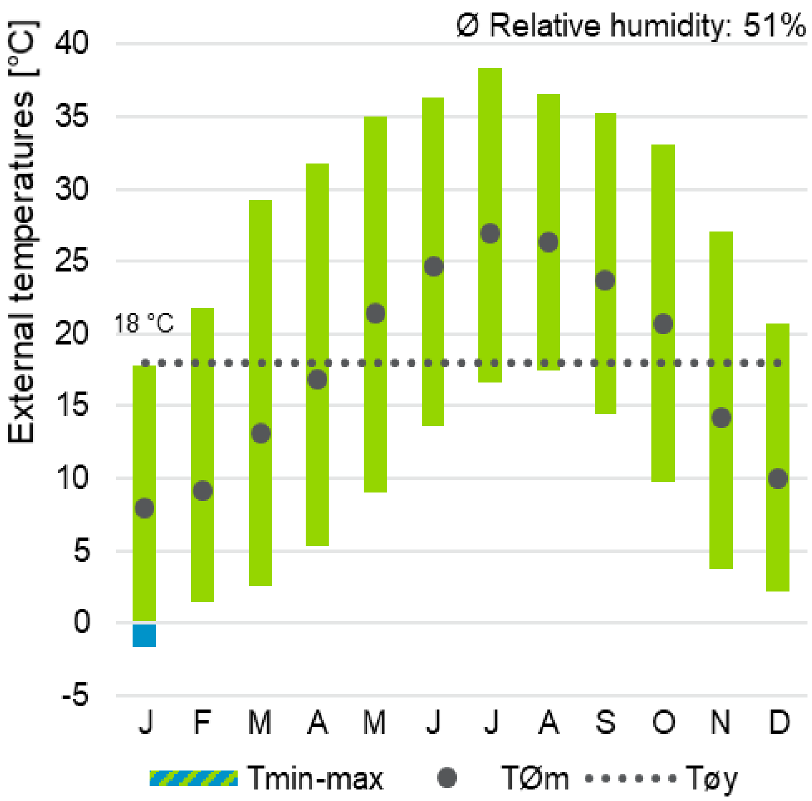
Description

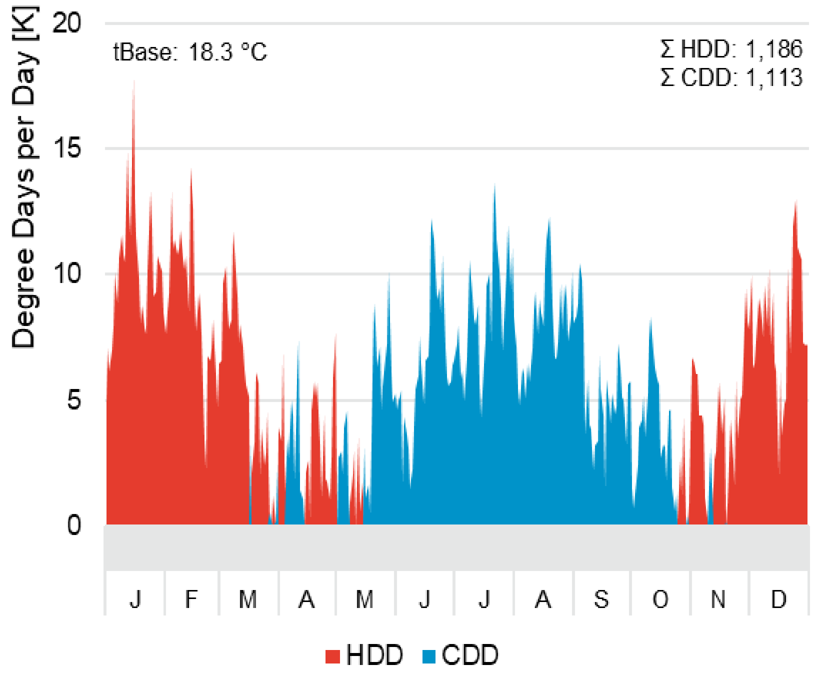
The climate in Amman is moderate. The annual average temperatures are about 18°C

Challenges and Potentials

A few hours per year undercut the freezing point.

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





* The following paragraphs refer to Amman due to data availibility

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

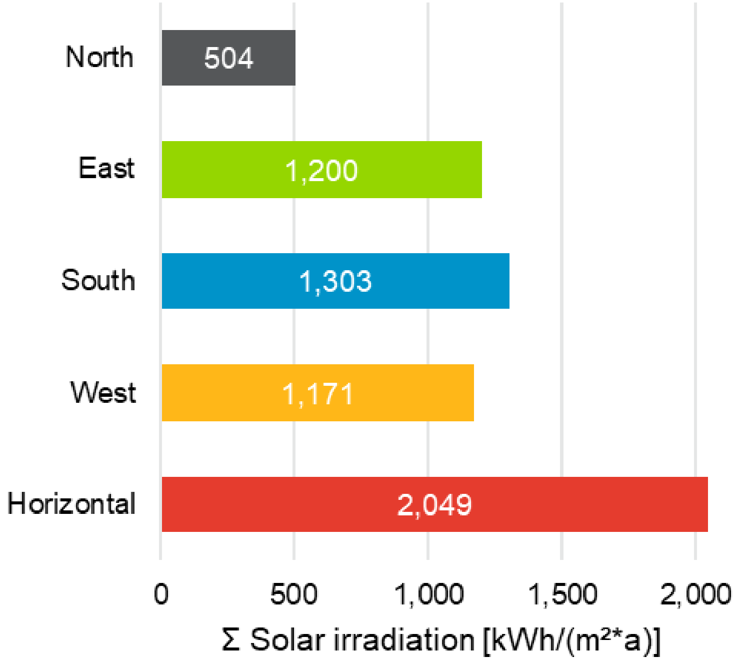
Boundary conditions I Climate
Solar Irradiation in Amman (Jordan)

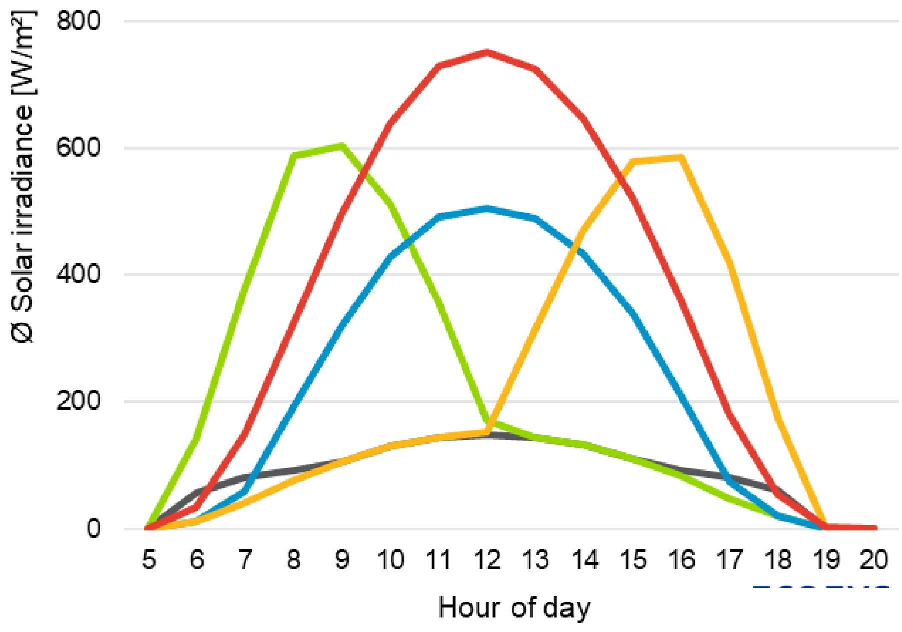
Description

High horizontal irradiation of > 2,000 kWh/(m²*a)

Challenges and Potentials

and > 1,100 kWh/(m²*a) for East, South and West orientation bring opportunities for solar based energy generation.





Boundary conditions I Economic and Emissions Inputs

Cost of Energy and Environmental impact

Status

In Jordan, natural gas is only used for power generation plants, while the LPG, diesel fuel and electricity are used in space heating.

Objectives

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

Energy prices and CO_2 emissions			
Parameter	Unit	Electricity	LPG
Energy price	JOD/kWh	Mean 0.04	0.038
Energy price	EUR/kWh†	0.055	0.05
Price development	%/year	3	3
CO_2 emission factor	gCO_2/kWh	635	230
Economic parameters			
Interest rate (real)	%/year	5	
Calculation period	years	20	

- **Exchange rate: 1 EUR = 1.3 JOD**

Boundary Conditions I Building

Building Data

Status

Single Family house in the design phase

Specific Challenge

To reduce the operational costs and energy consumption while keeping the extra costs to the minimum.

Building Key Information	
Data	Input
Utilization	SFH
Number of floors	2
Number of apartment	1
Conditioned floor area [m²]	360
Clear room height [m]	2.95 m
Conditioned volume [m³]	1062
Number of inhabitants [#]	4
Year of construction	2021

Analysis
Starting Situation - Baseline and Current planning

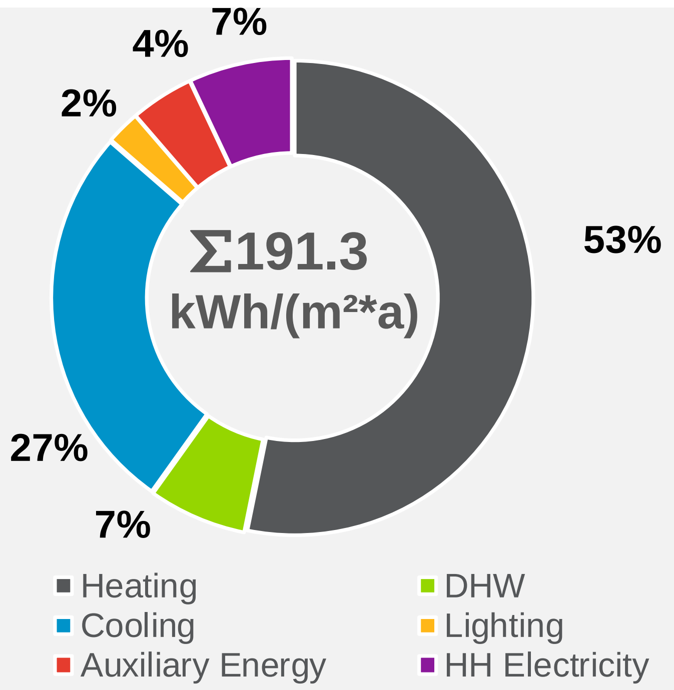
Photo by Jonathan Klok on Unsplashed

Business as Usual

Building Characteristics

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)	0.55 W/m²K
Wall insulation (U-Value)	0.57 W/m²K
Floor insulation (U-Value)	2.2 W/m²K
Windows (U-Value; G-Value)	5.7 W/m²K; 0.85
Window fraction	Ø 15%
Shading	No
Air tightness	0.25 1/h
Heat supply	Multi-split unit - COP 2.5
Cold supply	Multi-split unit - COP 2.5
Hot water	Gas instantaneous
Ventilation systems	Natural ventilation
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	23°C / 23°C



Energy Cost
39.4 EUR / (m²*a)

CO2 - Emission
3.6 kg / (m²*a)

Current Situation as Designed

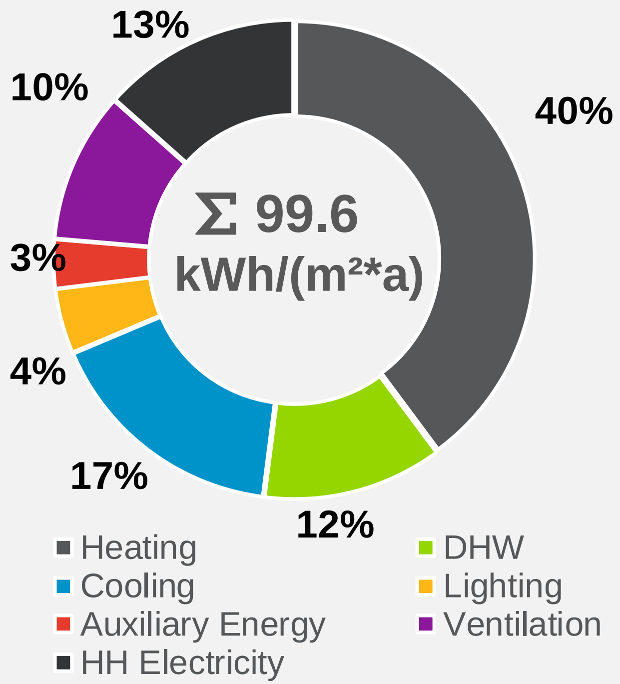
Results

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) and Solar collectors (for hot water).

This leads to energy savings and emission reduction.

Parameters	Baseline
Roof insulation (U-Value)	**0.42 W/m²K**
Wall insulation (U-Value)	**0.52 W/m²K**
Floor insulation (U-Value)	**0.72 W/m²K**
Windows (U-Value; G-Value)	**2.8 W/m²K; 0.7**
Window fraction	Ø 15%
Shading	**Manual**
Air tightness	0.25 1/h
Heat supply	**LPG Boiler**
Cold supply	reversible split unit - **COP 3.2**
Hot water	**Combined gas boiler**
Ventilation systems	**Mechanical Ventilation**
Lighting systems	LED
Renewable energy	-
Set temperature cooling/heating	**24°C / 21°C**



Energy Cost
15.7 EUR / (m²*a)

CO2 - Emission
1.6 kg / (m²*a)

Current situation (project developer)

Results VS. BaU

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

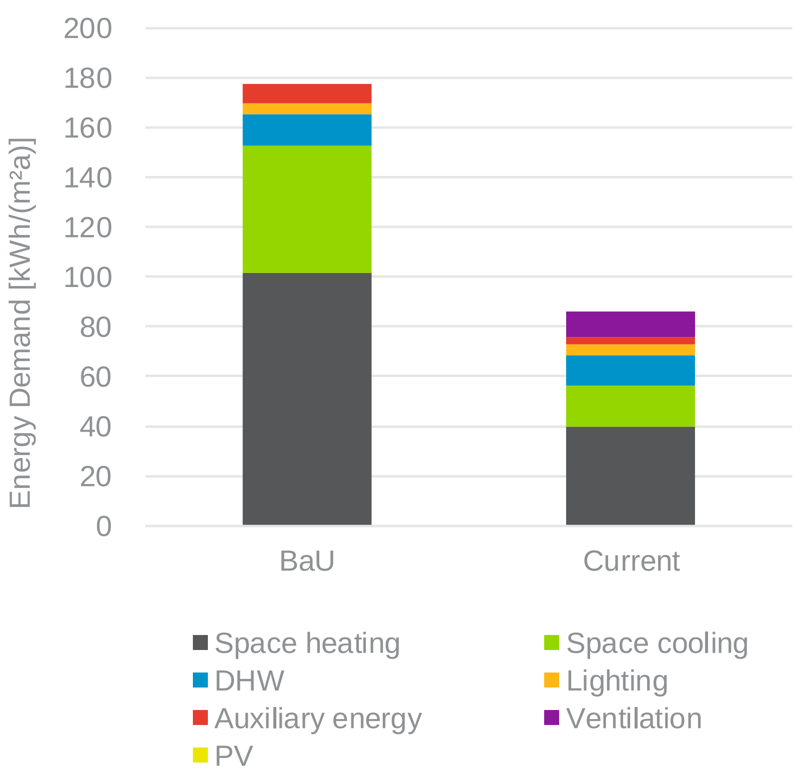
Although the energy cost decrease, the proposed measures will result in a cost increase due to the high investment cost.

The proposed measures seem not to hit the cost optimal point for optimization

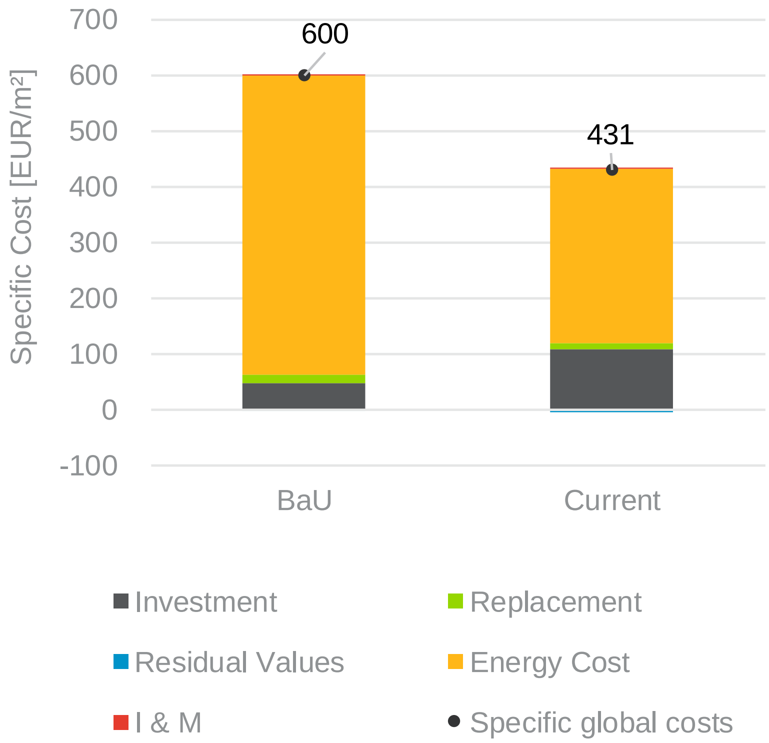
50% Energy savings

30% Cost savings

Final Energy Demand



Global Cost



Analysis

Investigation of Possible Measures

Photo by Dan Dimmock on Unsplashed

Overview of Analyzed Measures

Scope of Measures

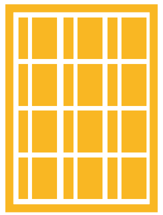
Envelope

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

Systems

- Cooling
- Heating
- Mechanical ventilation
- Operational temperatures

Renewable



- PV
- Solar Thermal

Building Envelope | External wall

Results

BaU
No insulation (U-Value = 2.2 W/m²K)

Var 1
Double wall, no insulation (U-Value = 1.1 W/m²K)

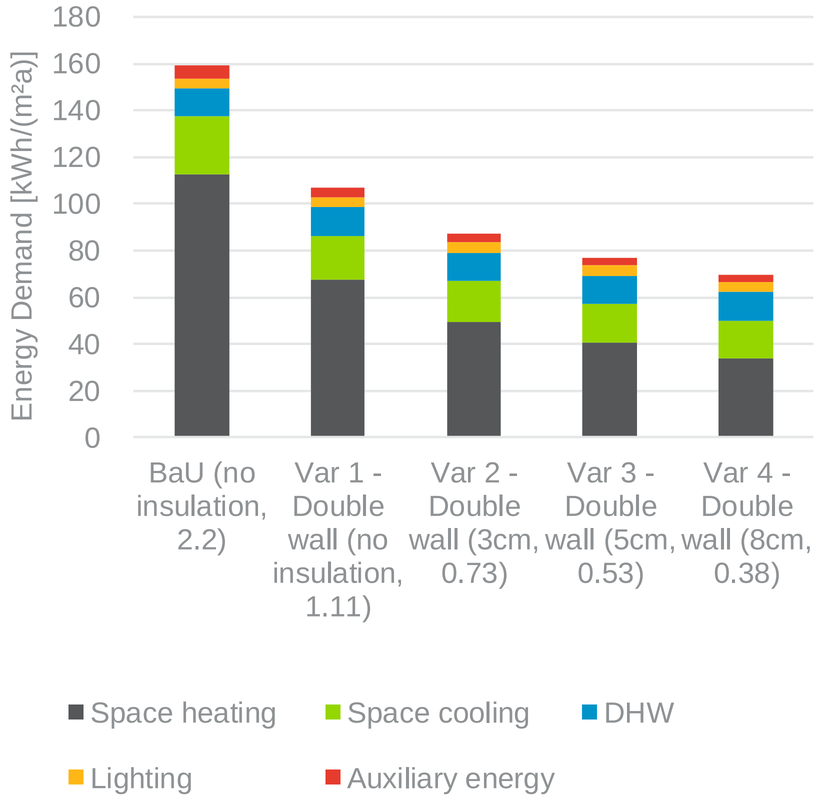
Var 2
3 cm insulation (U-Value = 0.73 W/m²K)

Var 3
5 cm insulation (U-Value = 0.53 W/m²K)

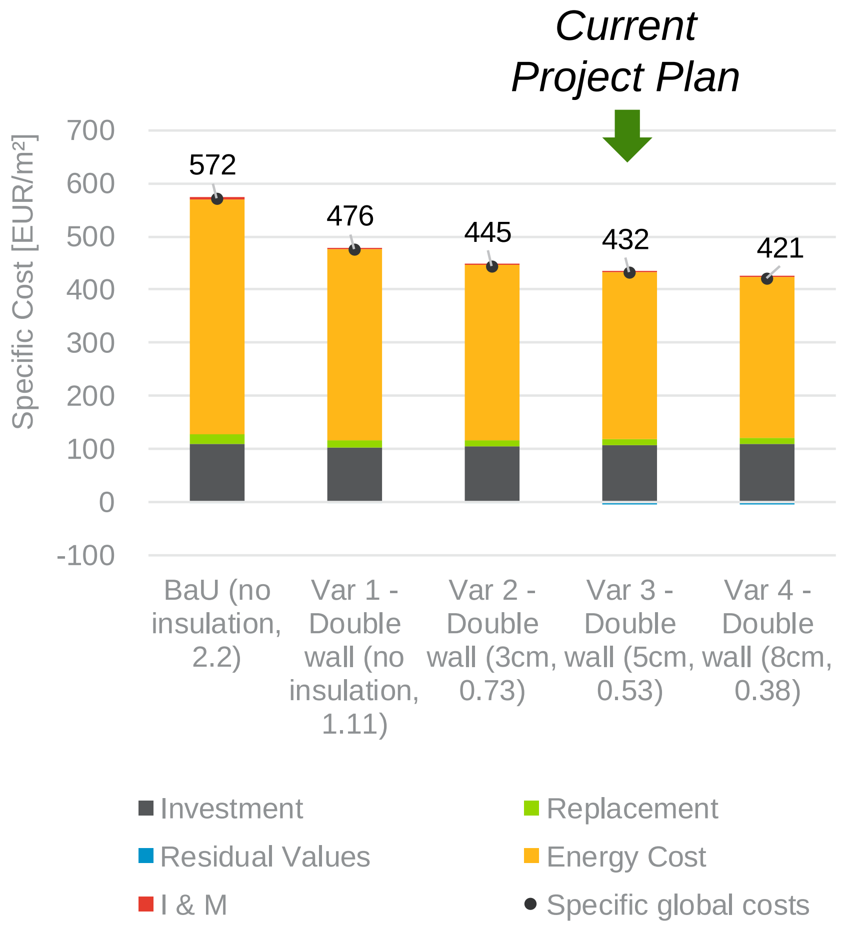
Var 4
8 cm insulation (U-Value = 0.38 W/m²K)

Result: Var 4 is the most cost effective measure

Final Energy Demand



Global Cost



Building Envelope | Roof

Results

BaU

no insulation

Current

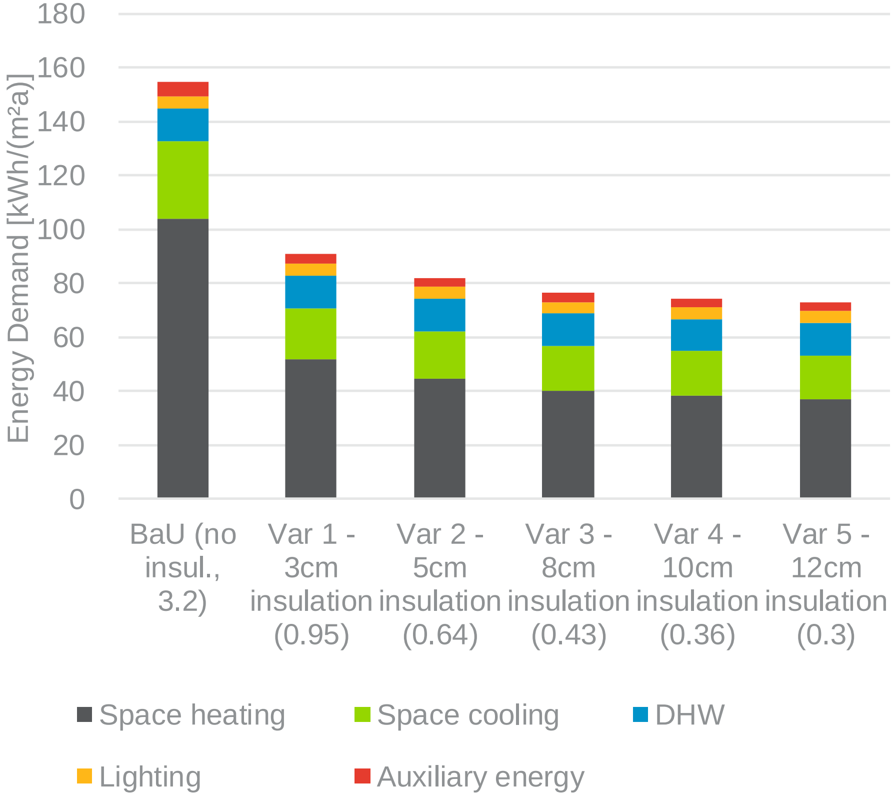
8 cm insulation (U-Value = 0.42 W/m²K)

Var 1 - 5

3 – 12 cm insulation (U-Value = 0.92 – 0.25 W/m²K)

Result: Var 4 with 10 cm is the most cost effective measure. However, the current project plan is already close.

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

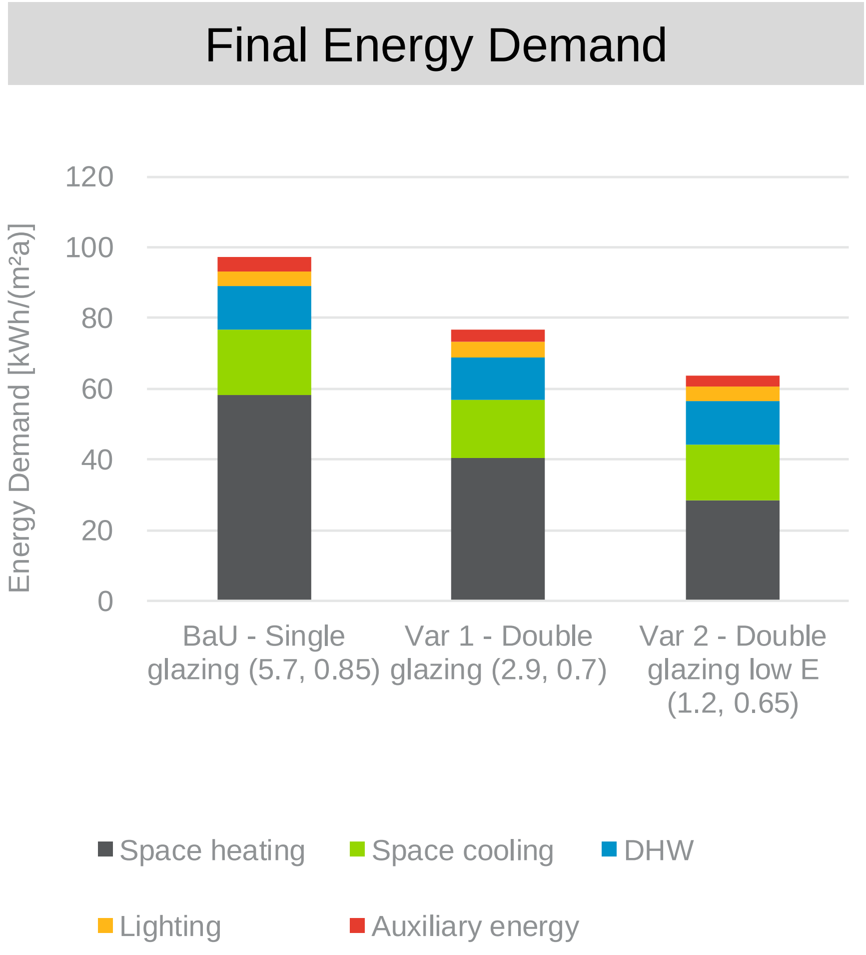
Double glazing (Var 1)

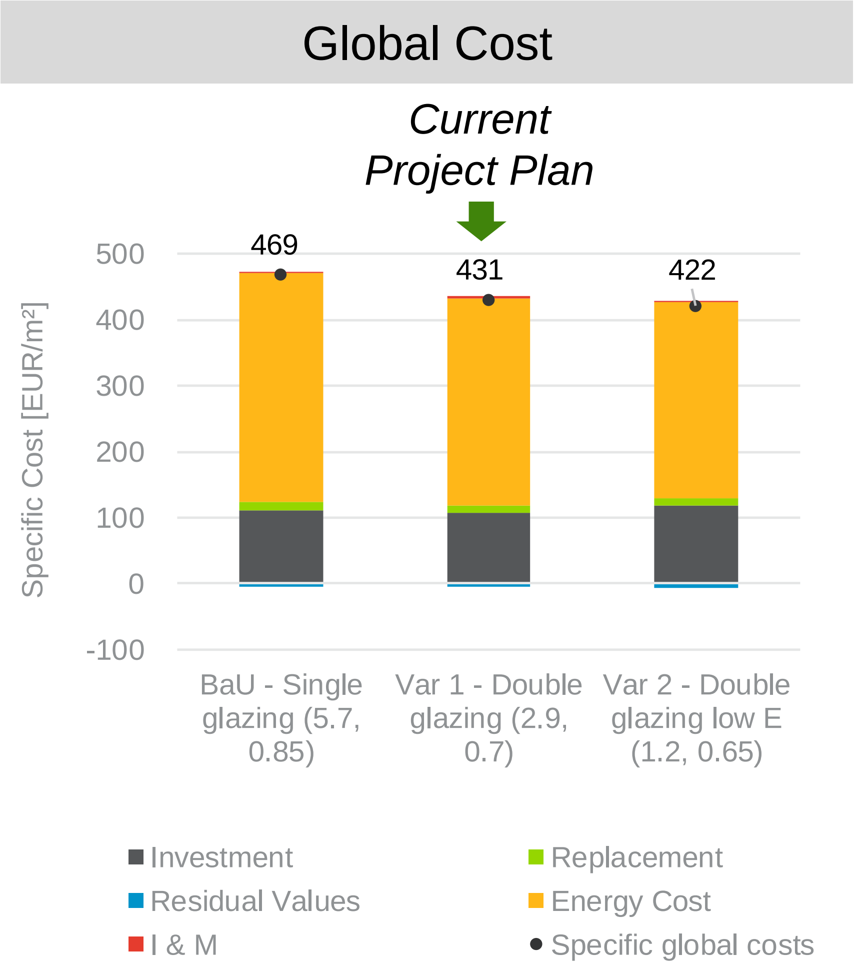
U value 2.8 W/m²K
G-Value 0.7

Double glazing low E (Var 2)

U value 1.1 W/m²K,
G-Value 0.65

Var 3 is the more cost-effective case.





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Window Fraction

Analysis

Var 1
Window fraction 40 %

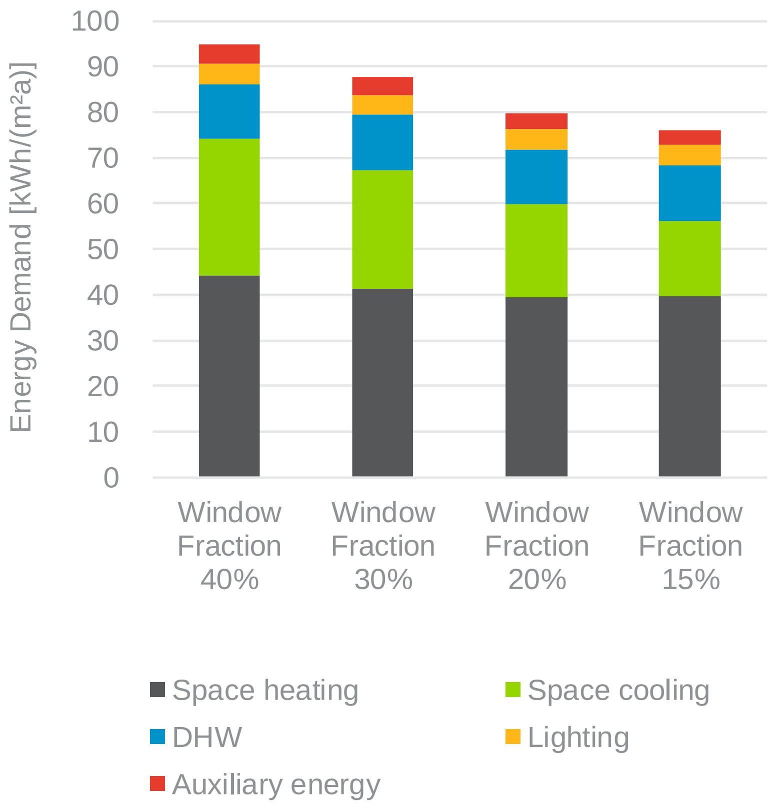
Var 2
Window fraction 30 %

Var 3
Window fraction 20 %

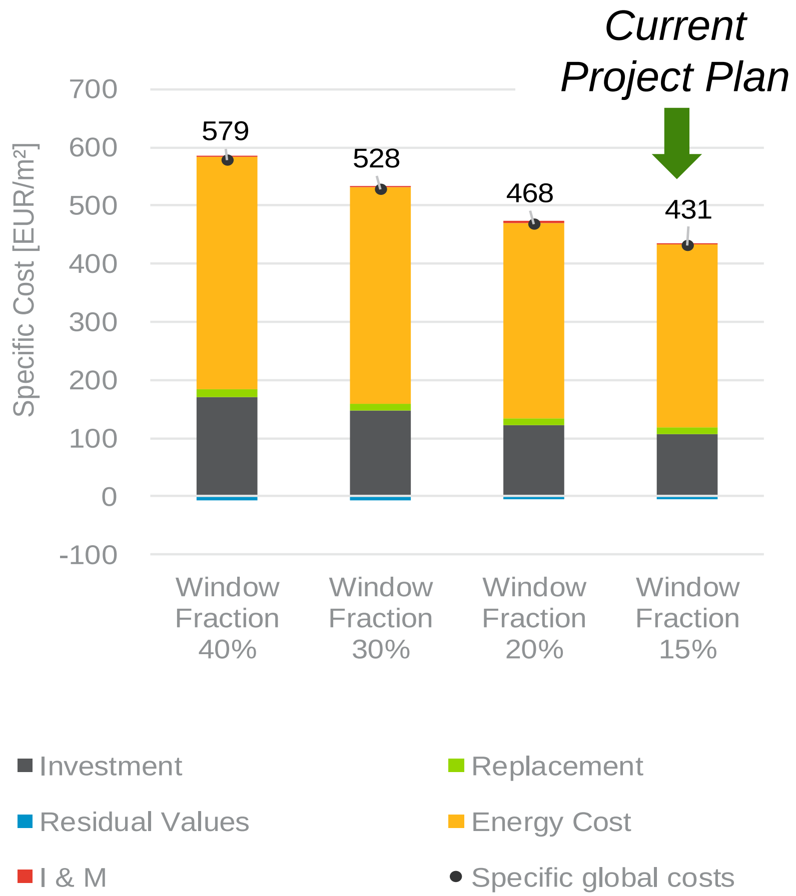
Var 4
Window fraction 15 %

The current with the least window fraction has the lowest energy consumption and lowest global cost.

Final Energy Demand



Global Cost



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Air Tightness

What is the effect of air tightness?

BaU
0.25

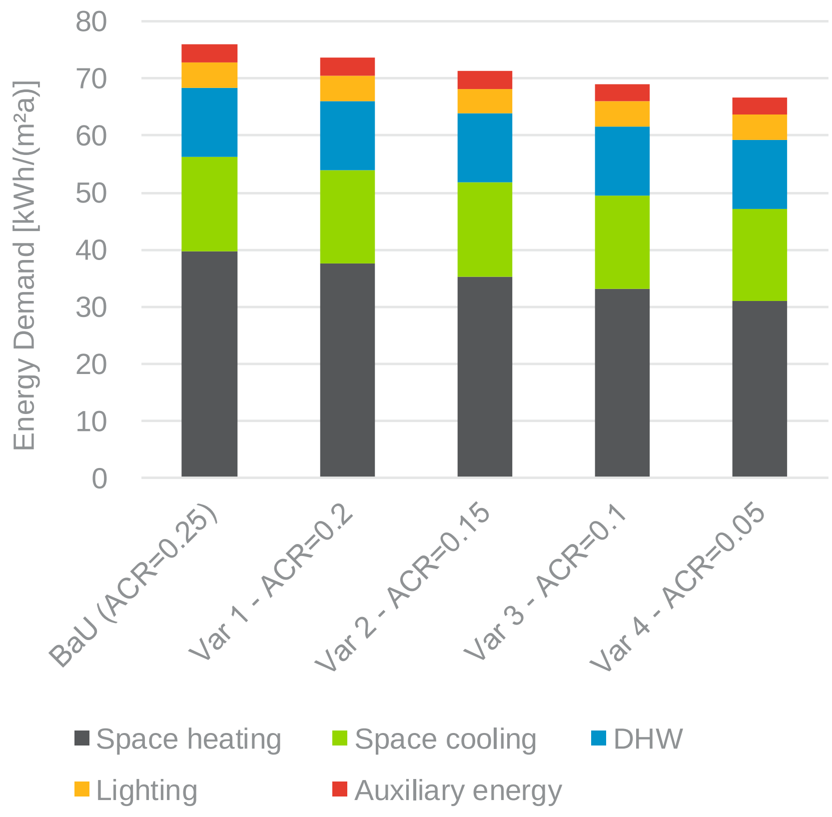
Var 1
0.20

Var 2
0.15

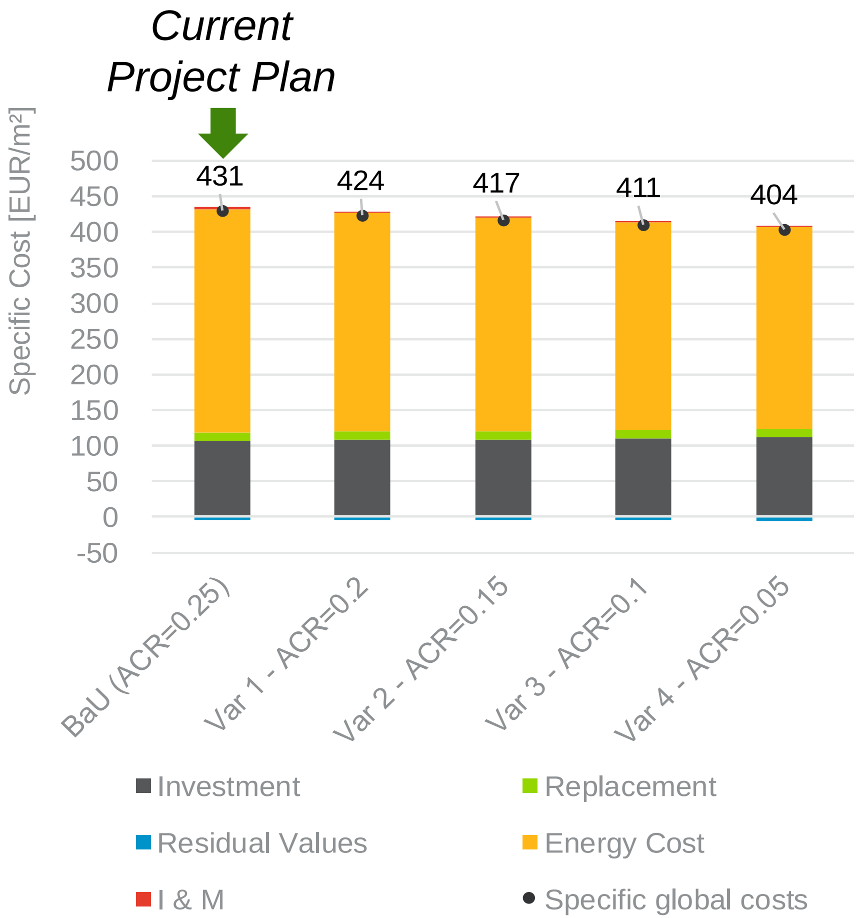
Var 3
0.1

Var 4
0.05

Final Energy Demand



Global Cost



Var 4 (ACR=0.05) is the most cost effective measure.

Shading concept

Analysis

BaU
No shading

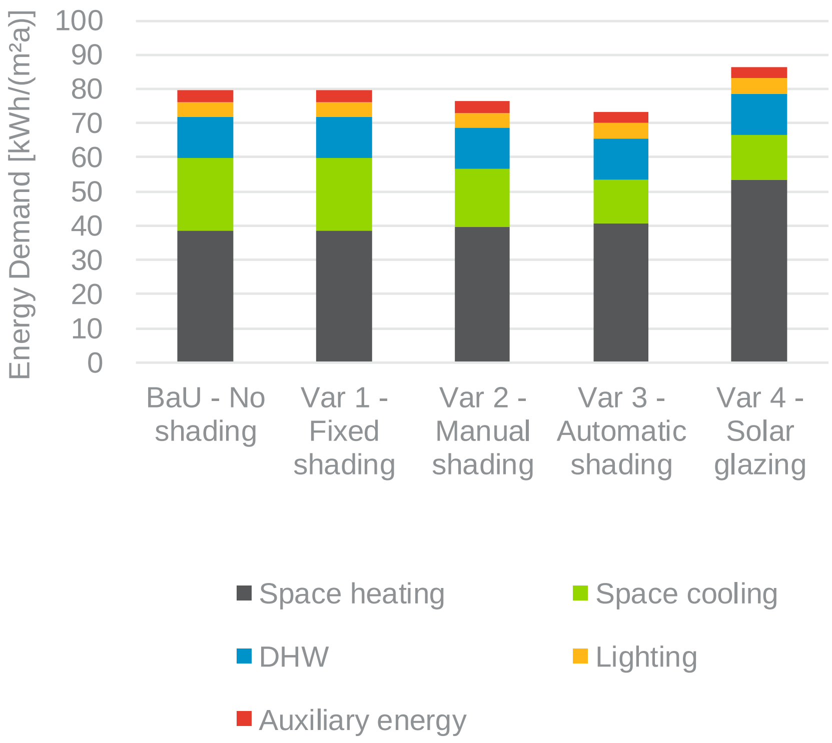
Var 1
Fixed Overhangs

Var 2
Manual Shading

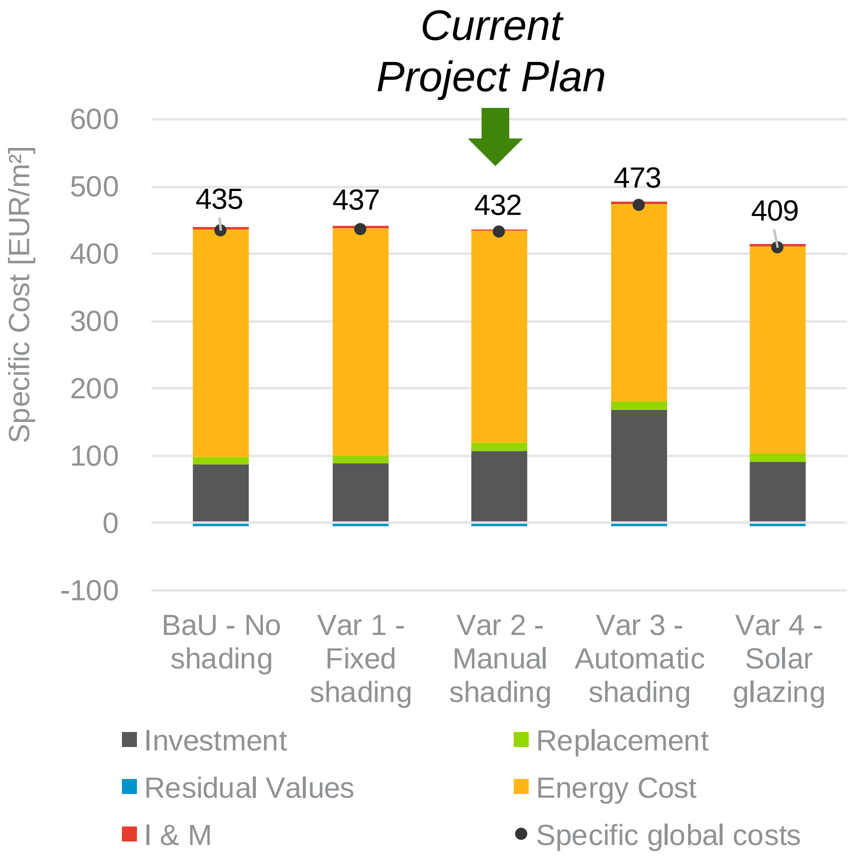
Var 3
Automatic Shading

Var 4
Solar Glazing

Final Energy Demand



Global Cost



Var 4 is the most cost effective measure.

HVAC | Heating Efficiencies

Analysis

BaU
Split Unit

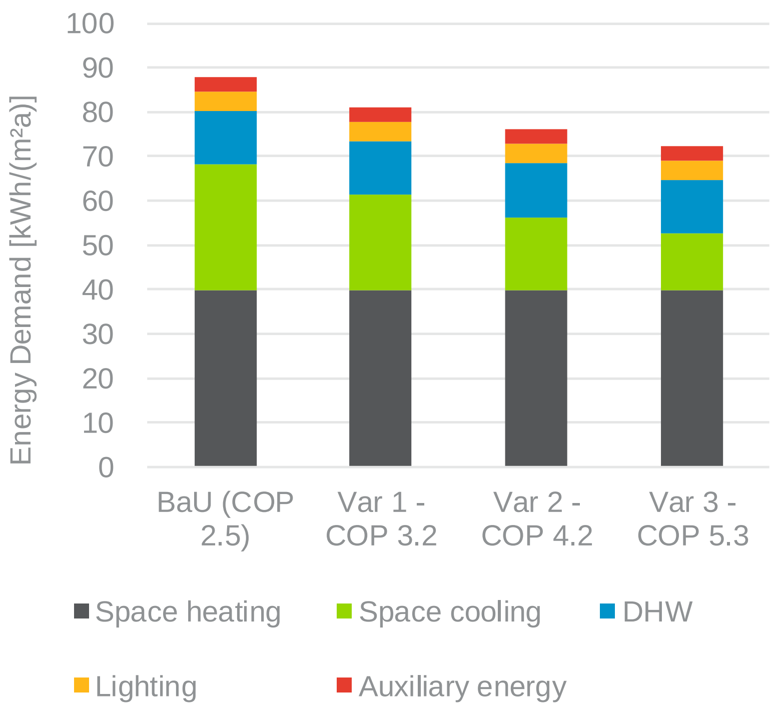
Var 1
VRF System

Var 2
VRF System

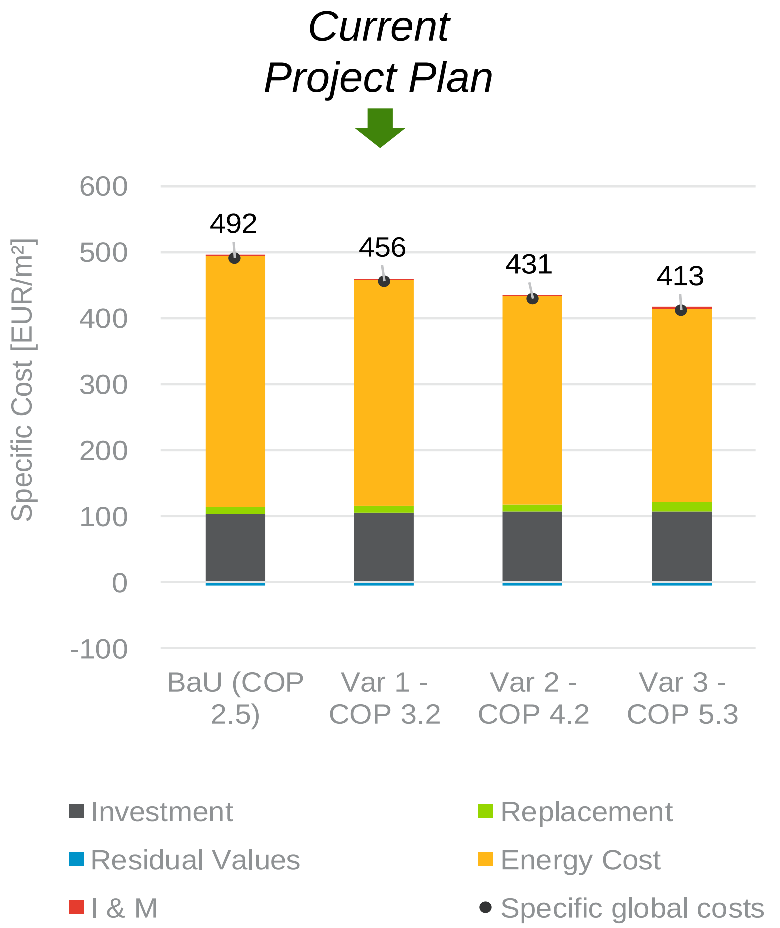
Var 3
VRF System

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

Final Energy Demand



Global Cost



HVAC | Heating
Analysis

Current

- LPG Boiler (5,000 EUR)
- Split-unit (3,980 EUR)

Var 1 (LPG boiler only back-up)

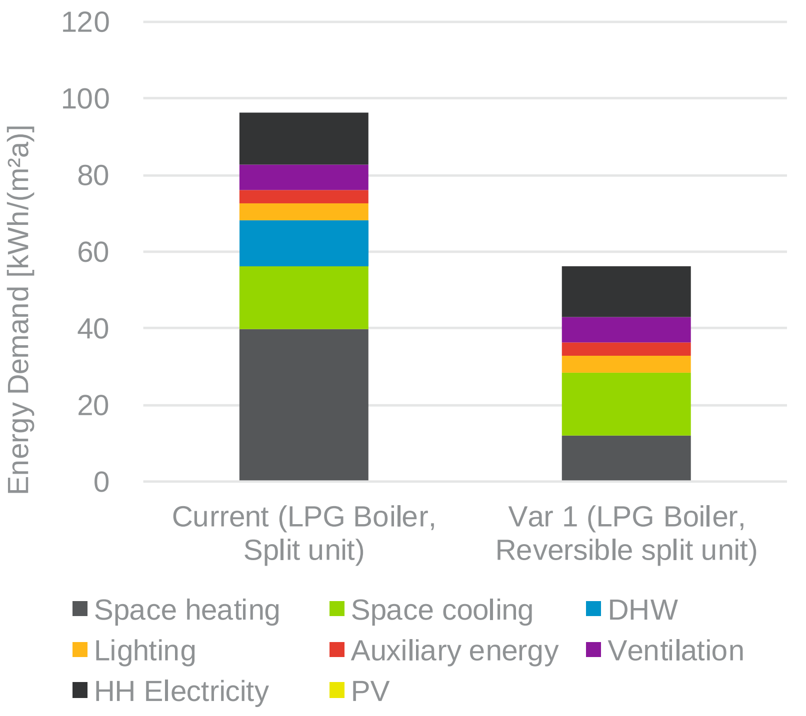
- LPG Boiler (5,000 EUR)
- Reversible split-unit (5,700 EUR)

Electricity: 0.33 EUR/kWh (1st year) – 0.60 EUR/kWh (2nd year)

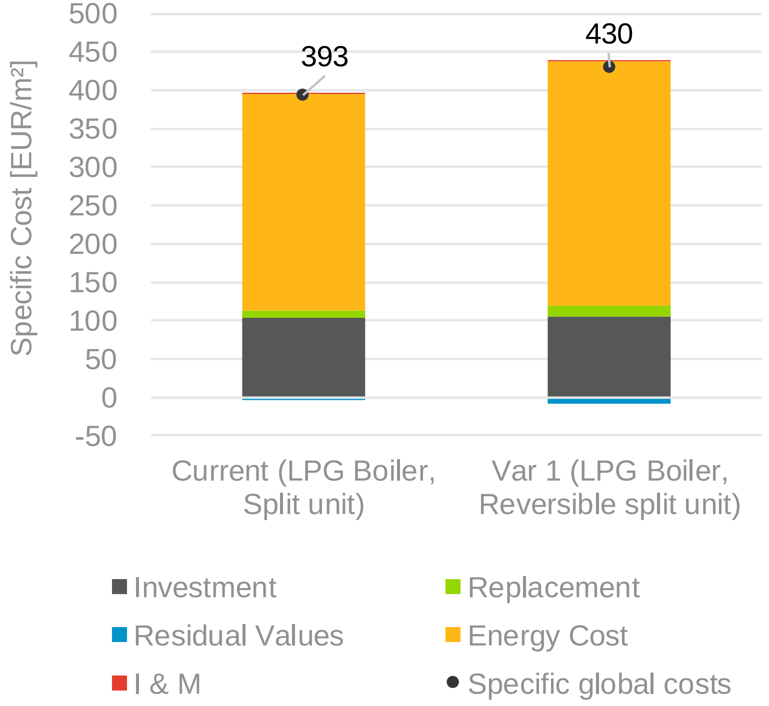
LPG: 0.045 EUR/kWh (1st year) – 0.081 EUR/kWh (2nd year)

Current system of LPG boiler is will result in higher energy consumption, yet it is slightly cost effective.

Final Energy Demand



Global Cost



HVAC | Cooling Efficiencies

Analysis

BaU

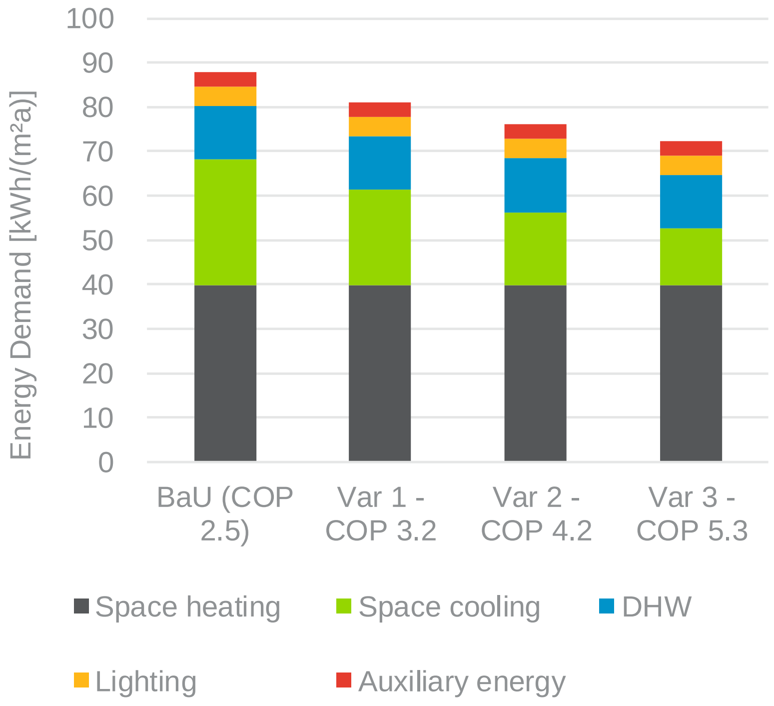
Cooling: 2.5 COP

Var 1 | 2 | 3

Multi-Split Unit with increased efficiency (COP: 3.2 | 4.2 | 5.3)

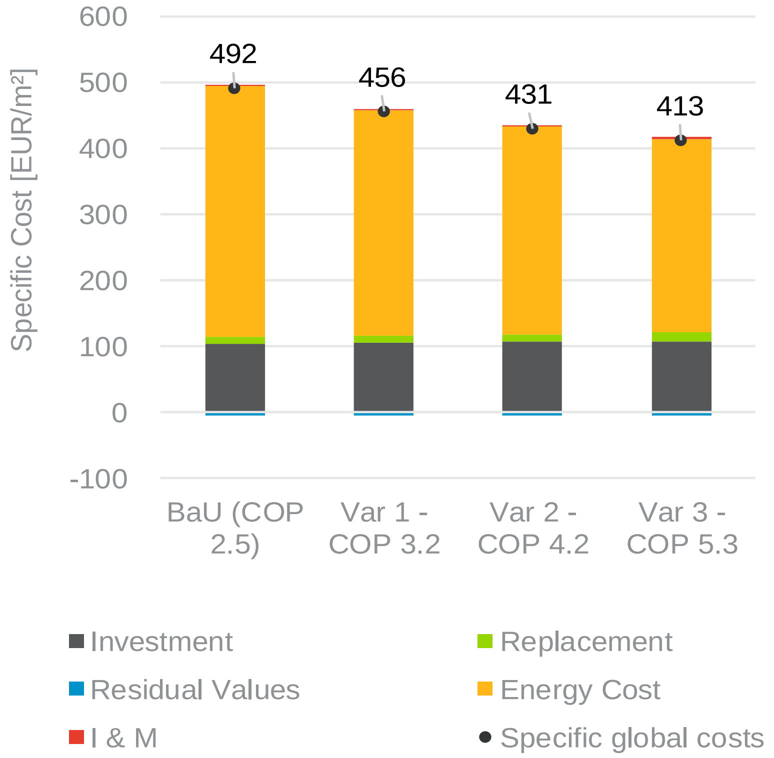
Var 3 (System with best COP) has the highest effect and is very cost-effective.

Final Energy Demand



Global Cost

Current Project Plan



HVAC | Mechanical Ventilation

Analysis

BaU

No mechanical ventilation

Var 1

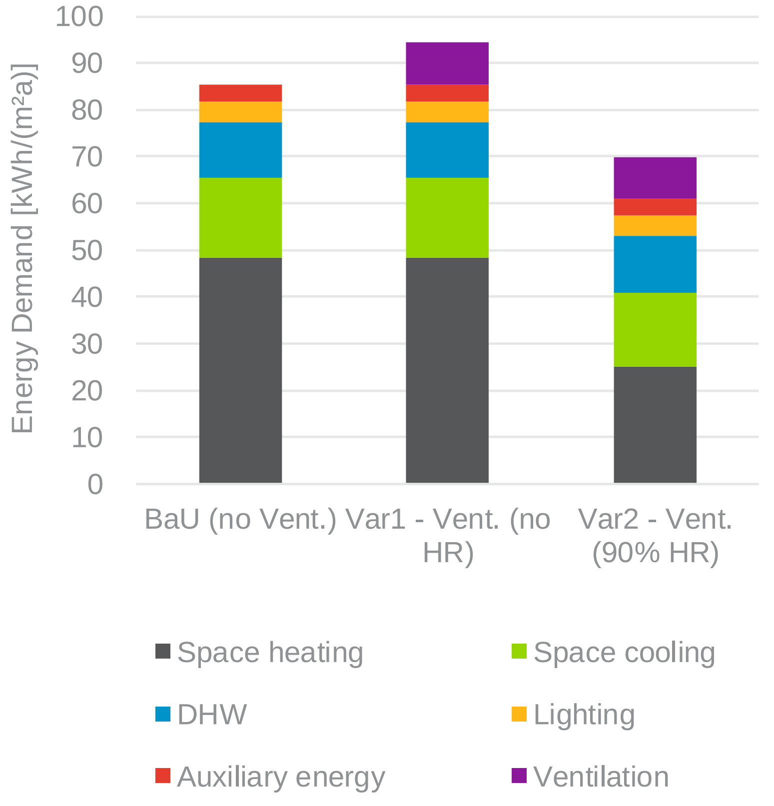
Mechanical ventilation without heat recovery.

Var 2

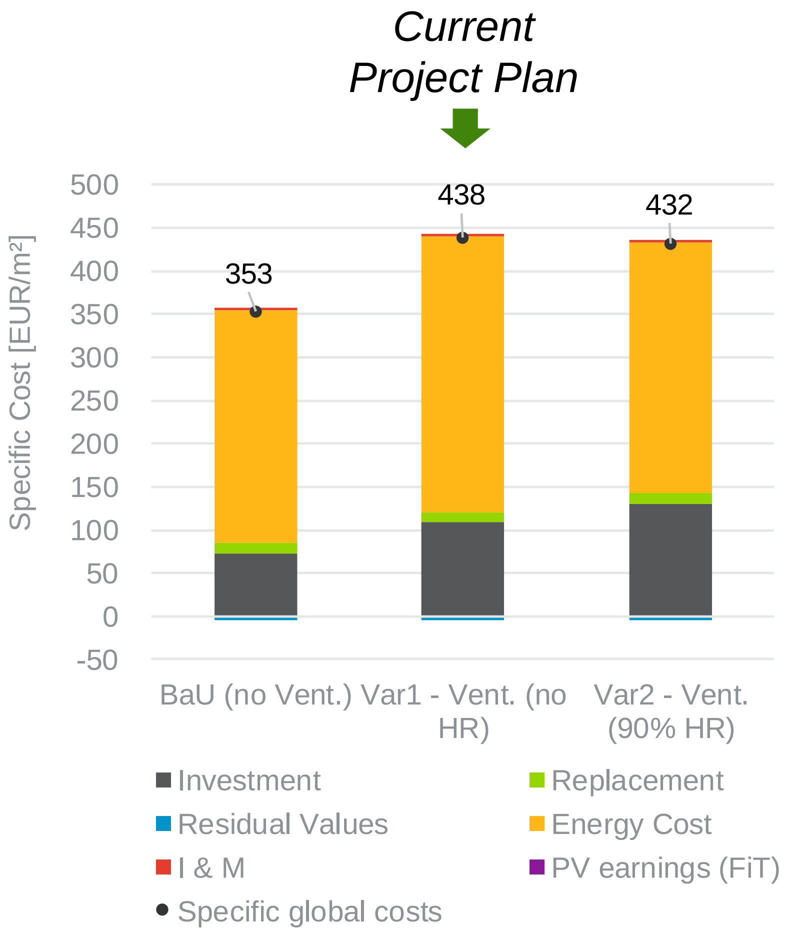
Mechanical ventilation with heat recovery (ca. 90%)

BaU (no mech. ventilation) is the most cost-effective. However, if a mech. ventilation system is installed, a heat recovery is cost-effective.

Final Energy Demand



Global Cost



Operational Temperatures

Analysis

BaU

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

Var 1 - 3

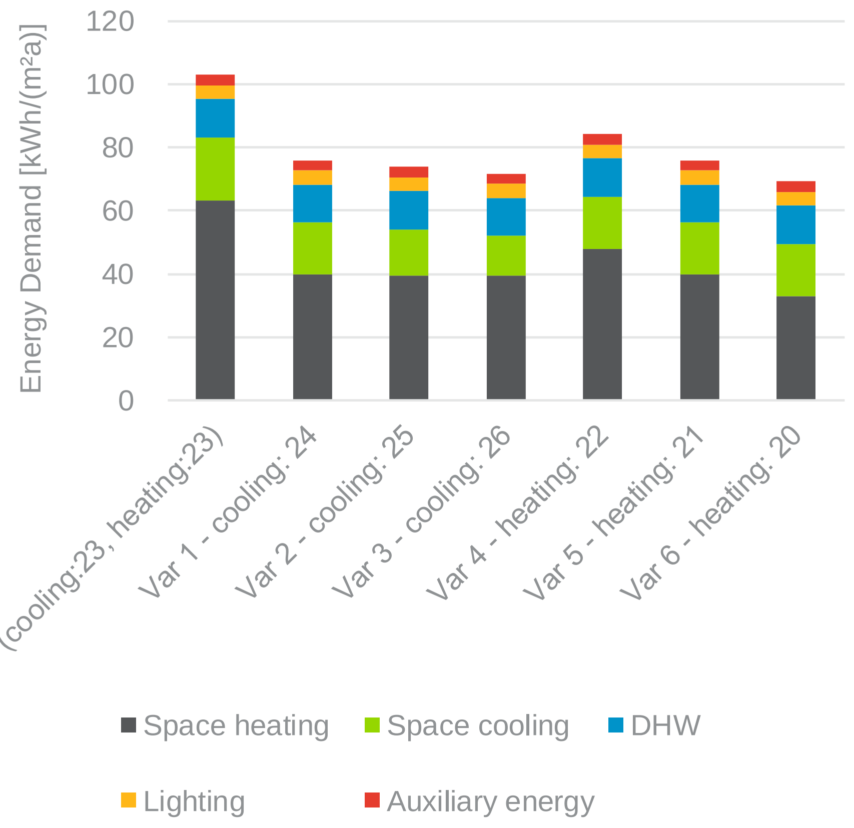
Cooling Temperature adapted (24°C - 26°C)

Var 4 - 6

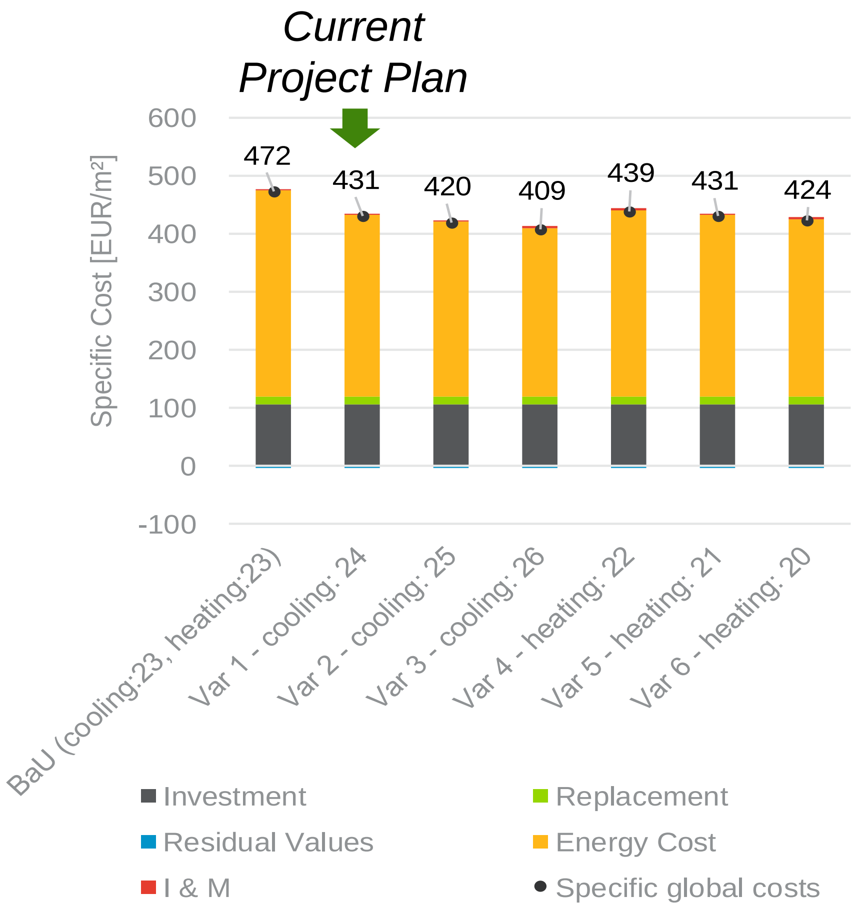
Heating Temperature adapted (22°C - 20°C)

This measure is very effective and not related to any cost

Final Energy Demand



Global Cost



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Renewables I Solar Thermal

Analysis

Baseline

no ST

Var 1

ST - 4.5 m² (90% of demand covered)

Var 2

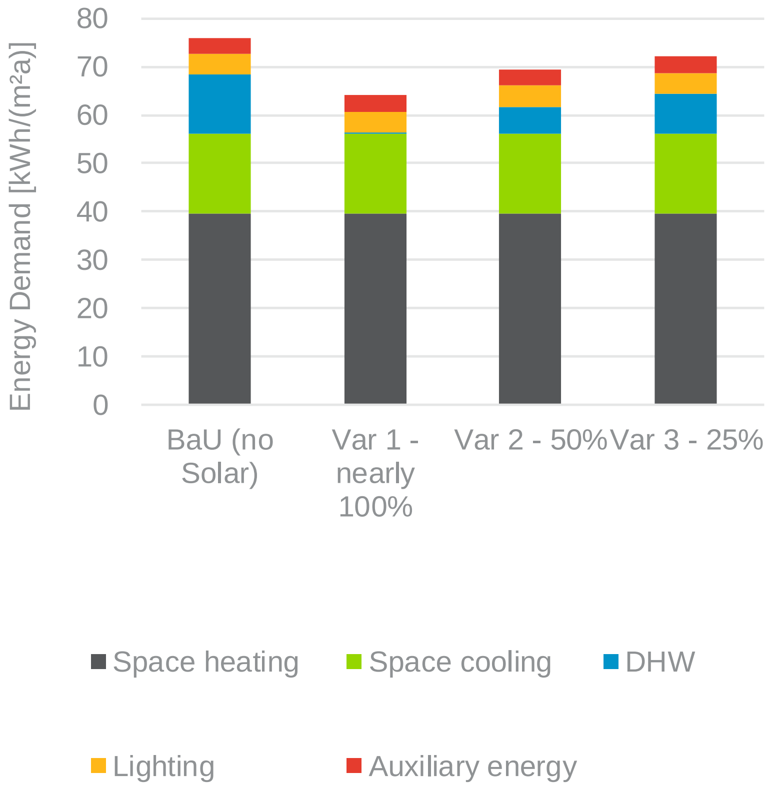
ST – 2.5 m² (50% of demand covered)

Var 3

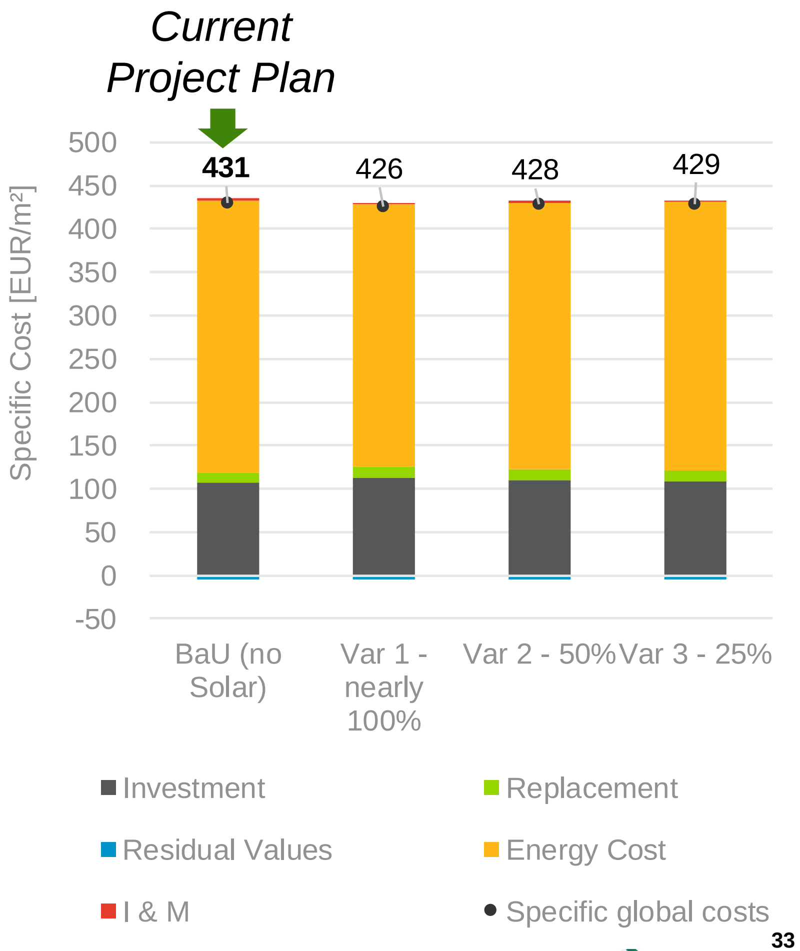
ST – 1.5 m² (25% of demand covered)

Var 1 (4.5 m² collector area) is the most cost effective measure

Final Energy Demand



Global Cost



Renewables I PV
Analysis

Sizing (net metering as assumption)

Current

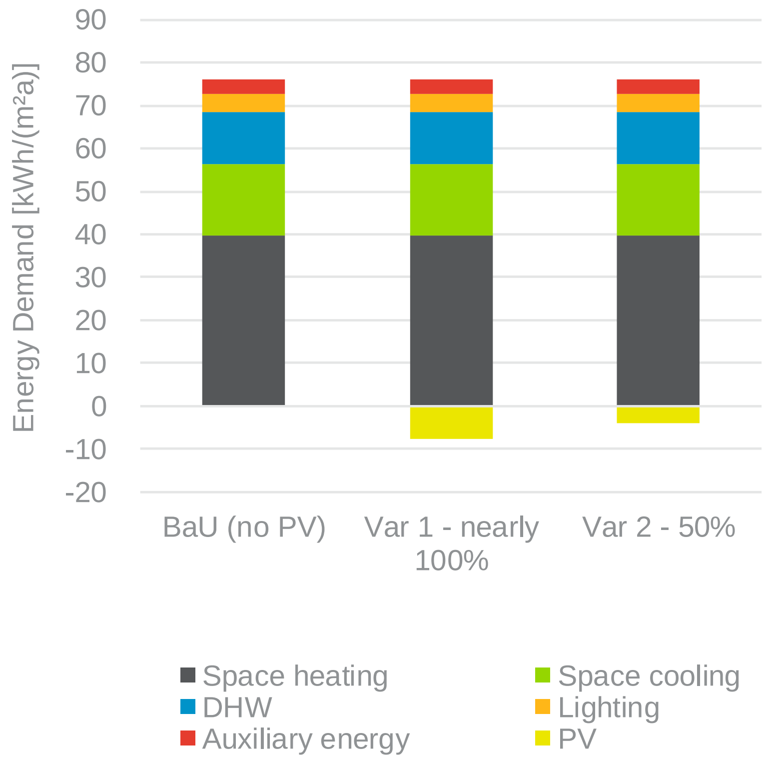
no PV

Var 1 | 2

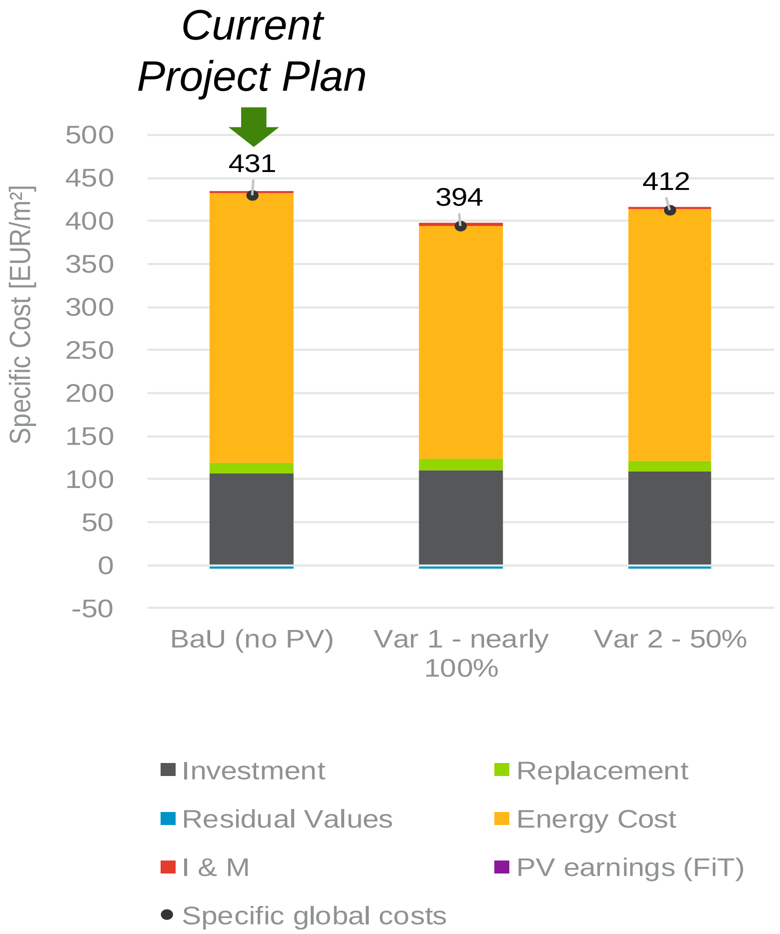
PV 2 | 1 kWp
(Roof area 14 | 7 m²)

Var 1 with **2 kWp** PV is the most cost effective measure. (based on the electricity consumption of the Current!)

Final Energy Demand



Global Cost



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Renewables I PV

Analysis

Sizing (net metering as assumption)

Current

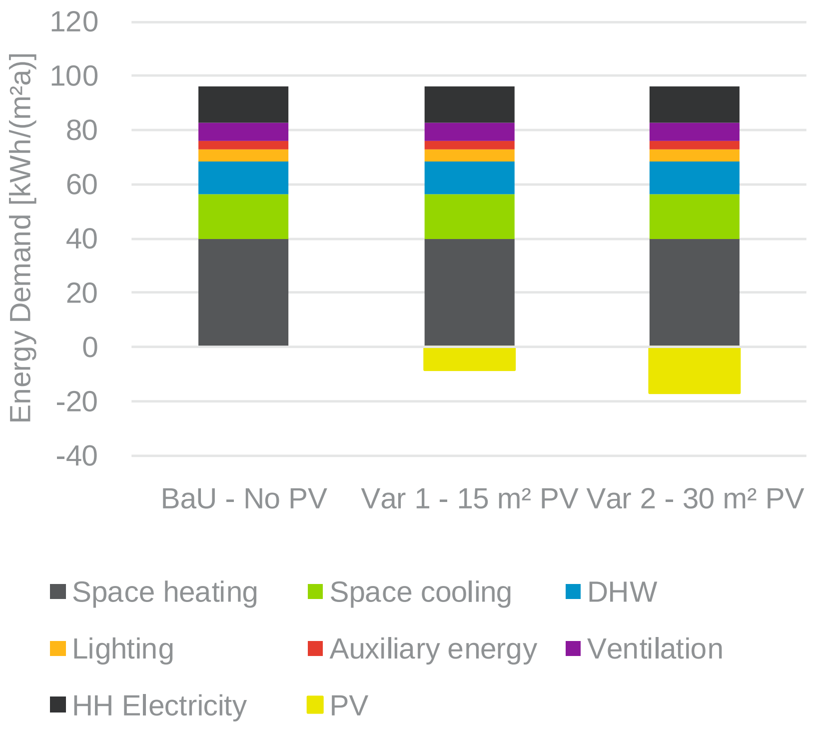
no PV

Var 1 | 2

PV 15 | 30 m²
(2.15 kWp | 4.3 kWp)

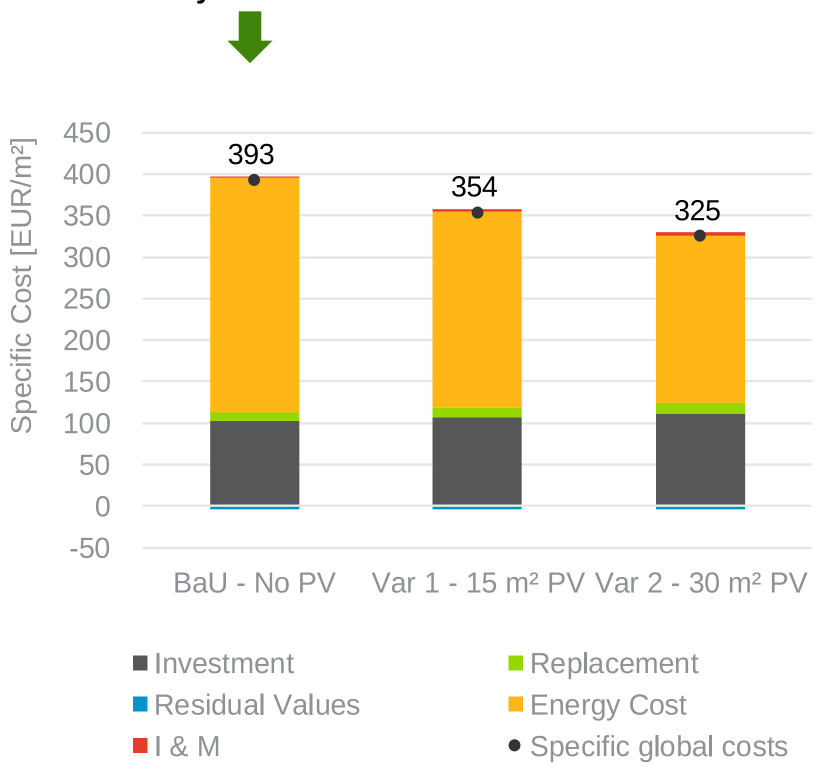
Var 2 with **2 kWp** PV is the most cost effective measure. (based on the electricity consumption of the Current!)

Final Energy Demand



Global Cost

Current Project Plan



Results &Conclusion

Photo by Xan Griffin on Unsplashed

Overview of recommended measures

Four steps to reduce energy demand significantly

Building envelope

- External wall -> insulation thickness 8 cm; Roof (U-Value = 0.38 W/m²K)
- Windows -> Use double glazing low E (Var 2) with U value of 1.1 W/m²K and G-Value 0.65.
- Air tightness: Improve air-infiltration to 0.05 1/h
- Shading -> manual shading

HVAC

- Split Unit cooling with high efficiency (COP ~5)
- Mechanical Ventilation: If mechanical ventilation is used, heat recovery of 90% is recommended

Renewable (Solar) Energy

- PV of 30 m2 will be optimum over the lifetime of 20 years.

Behavior

- Change set temperature from Cooling 23°C/ Heating 21°C to Cooling 26°C/ Heating 20°C

Optimized Solution

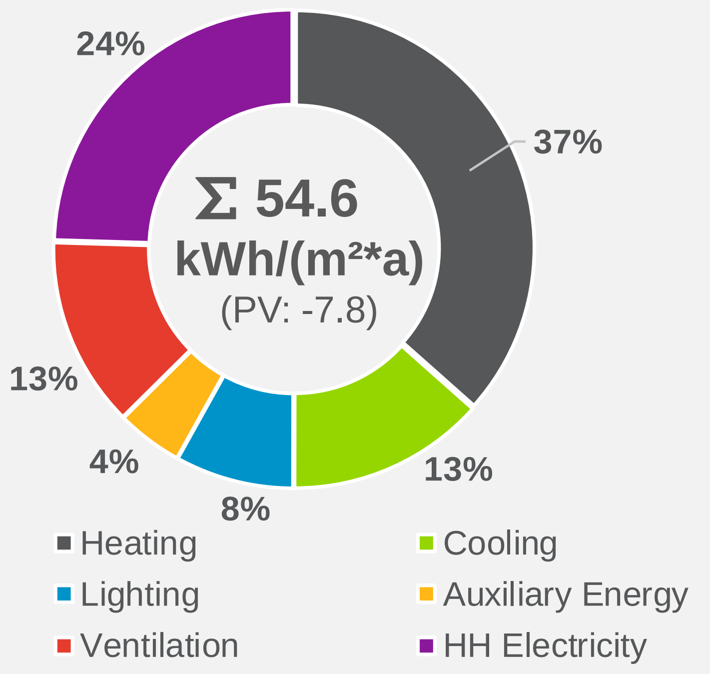
Results

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) and Solar collectors (for hot water).

This leads to energy savings and emission reduction.

Parameters	Optimized
Roof insulation (U-Value)	**0.38 W/m²K**
Wall insulation (U-Value)	**0.36 W/m²K**
Floor insulation (U-Value)	0.7 W/m²K
Windows (U-Value; G-Value)	**0.9 W/m²K; 0.3**
Window fraction	Ø 15%
Shading	**Manual Shading**
Air tightness	**0.05 1/h**
Heat supply	Multi-split unit - **COP 5**
Cold supply	Multi-split unit - **COP 5**
Hot water	Gas combi | **Solar**
Ventilation systems	Mechanical Ventilation
Lighting systems	LED
Renewable energy	**2 kWp (PV) | 4.5m² (Solar Thermal)**
Set temperature cooling/heating	**26°C / 20°C**



Energy Cost
8.4 EUR / (m²*a)

CO_2 - Emission
0.9 kg / (m²*a)

Comparative overview

Baseline vs. Current vs. Optimized

Conclusion

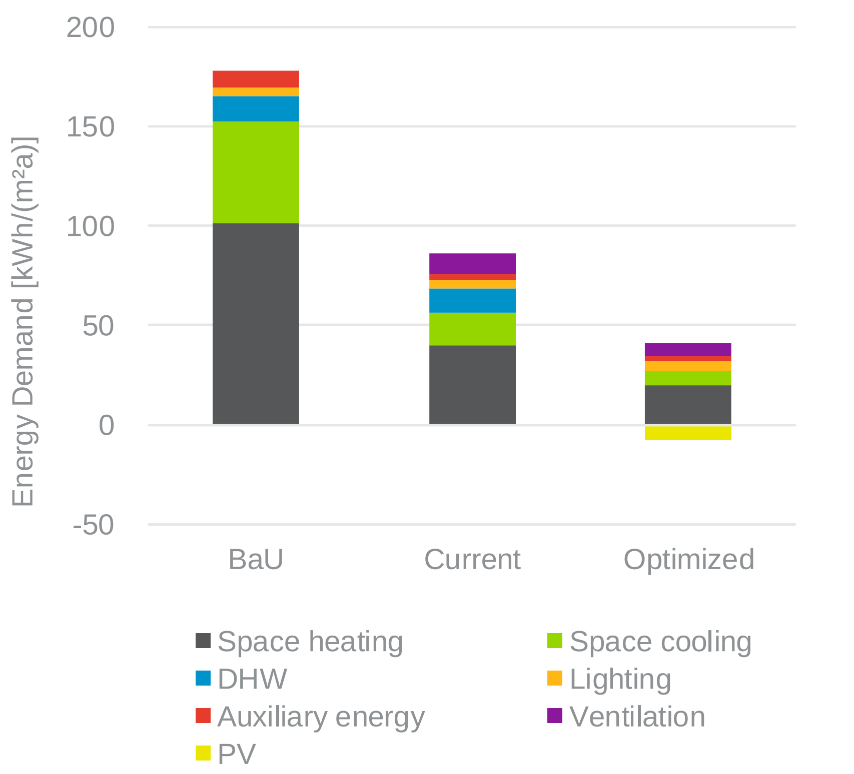
- The suggested measures and the current situation lead to a **significant decrease in energy demand**
- The optimized solution, detected **the most cost effective efficiency measures**

Savings Opt. vs BaU

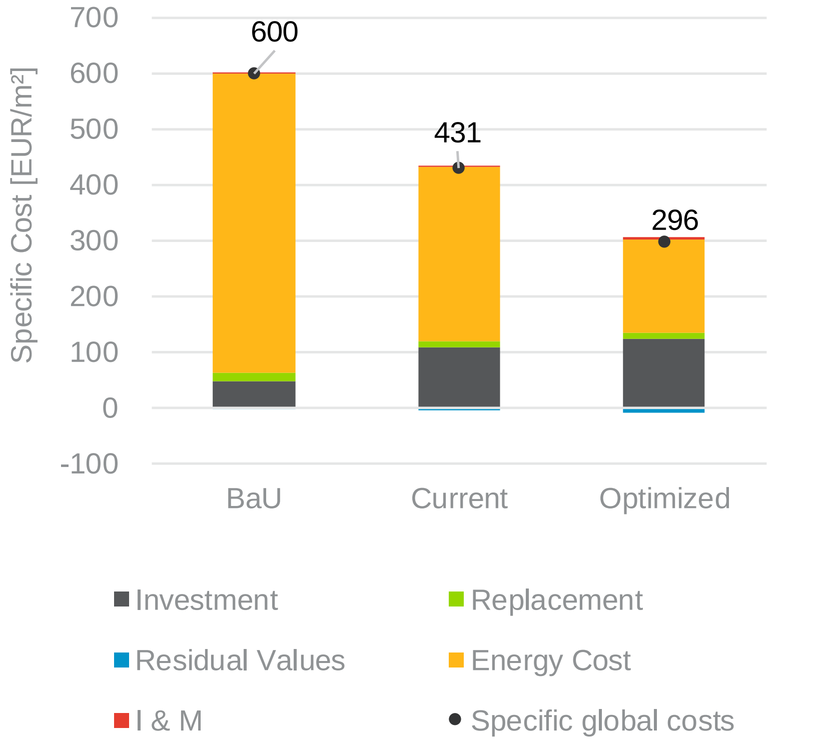
Energy: **73%**

Cost: **51%**

Final Energy Demand



Global Cost



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