Energy Efficiency Recommendations for Dar Al Oqoud, Jordan

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

April 2021

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Introduction

The Dar Al Auqood Project
Boundary conditions

Dar Al Aqoud

Aims

Creating a unique family house in Islamic architecture style and utilises natural sources of heating and cooling.

Target Groups / User

Single family house located in the northern area of Amman to be used during summer for vacations

Function

Residential single-family houses built with courtyard and swimming pool.

Size

Total built-up are of 250m².

Boundary conditions

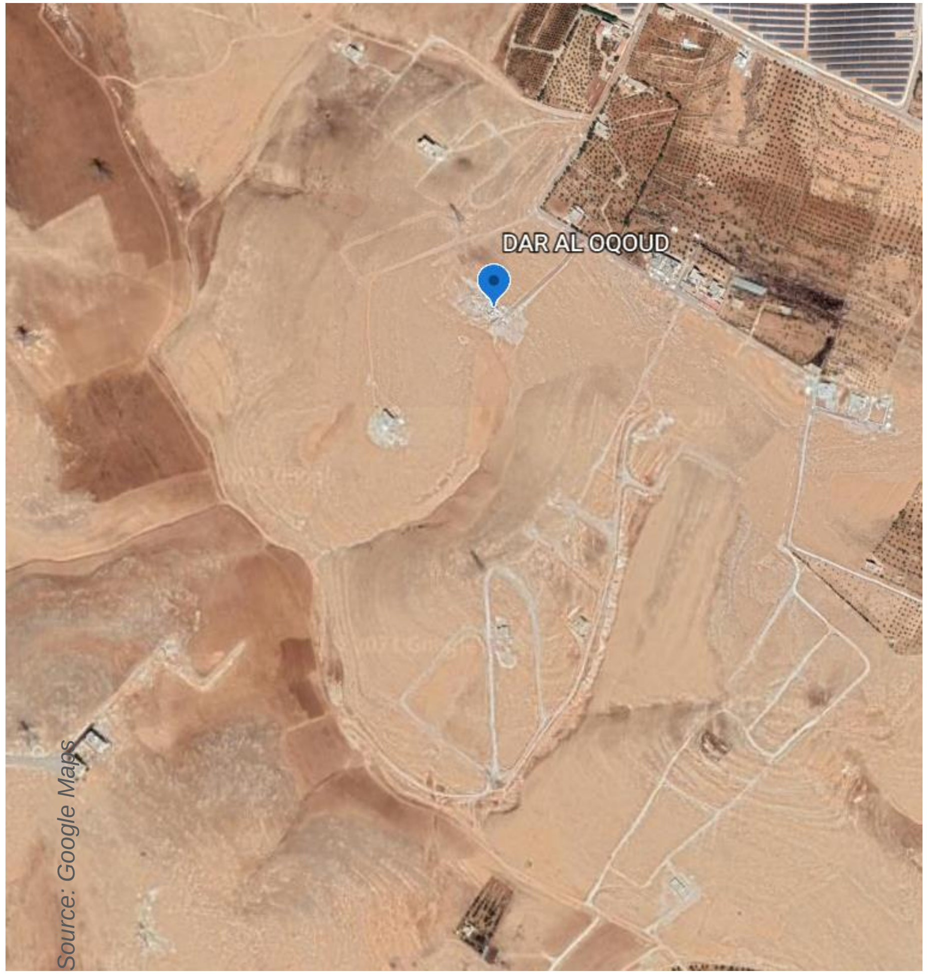
Site : Context matters

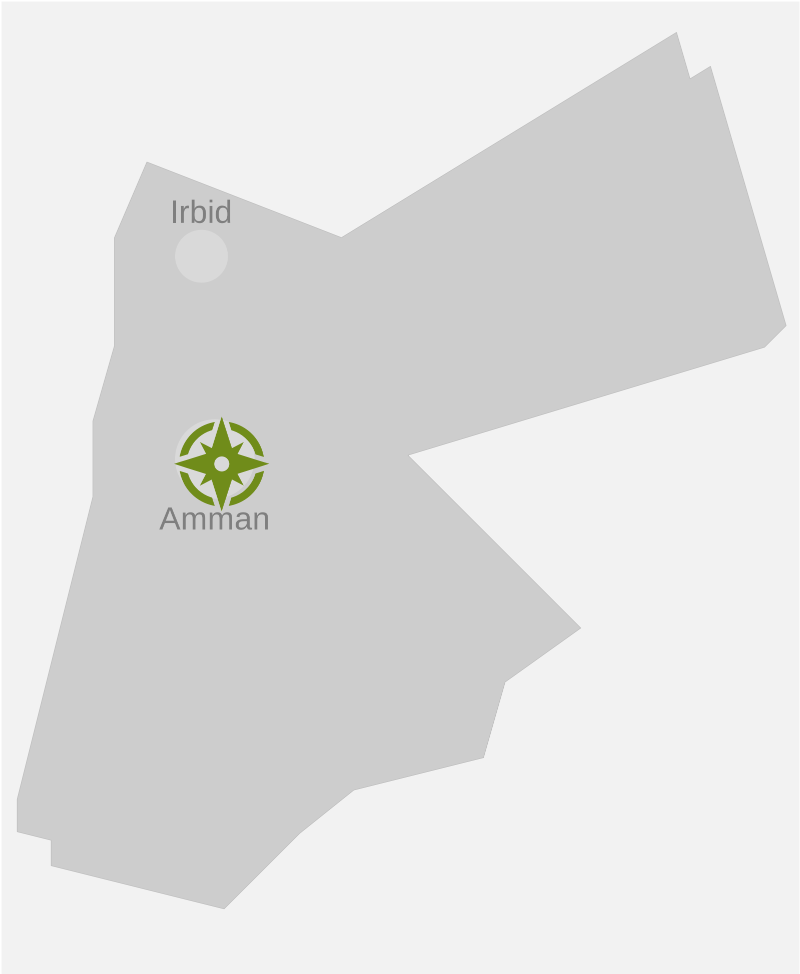
City : Amman

Location : 12 KM north from central Amman

Context

The northern outskirts of ‘Amman, central Jordan, Shafa Badran’ lies on one of the rocky hills encompassing central Amman. On a preserved natural landscape of Mediterranean climate, sits the remains of a Roman encampment.





Boundary conditions I Climate Analysis

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

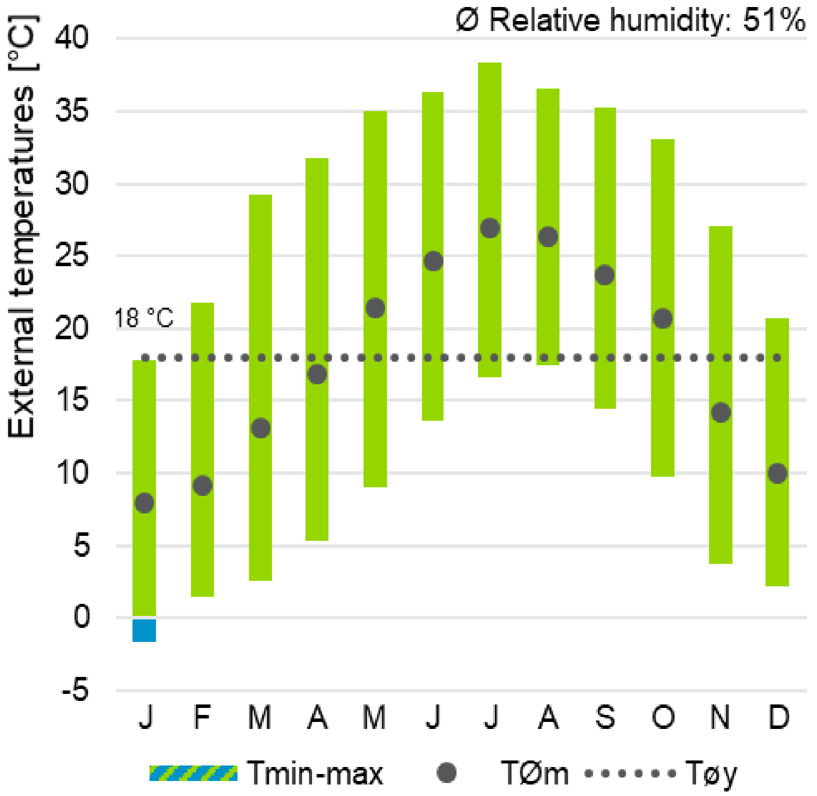
Description

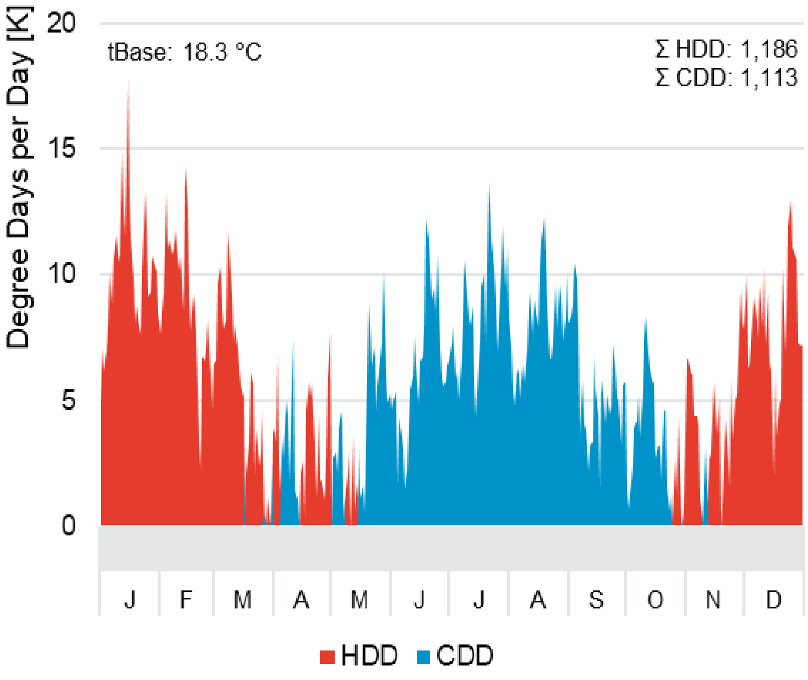
The climate in Amman is moderate. The annual average temperatures are about 18°C

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

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Boundary conditions I Climate

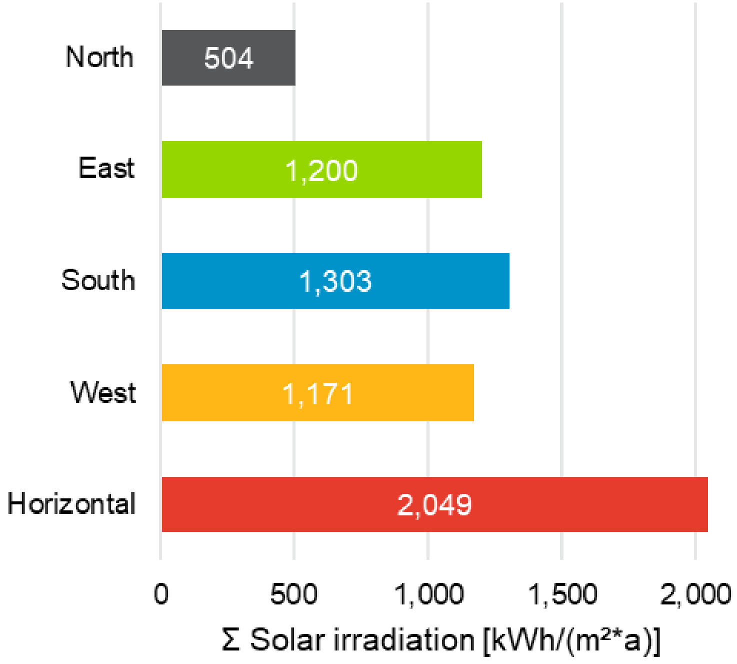
Solar Irradiation in Amman (Jordan)

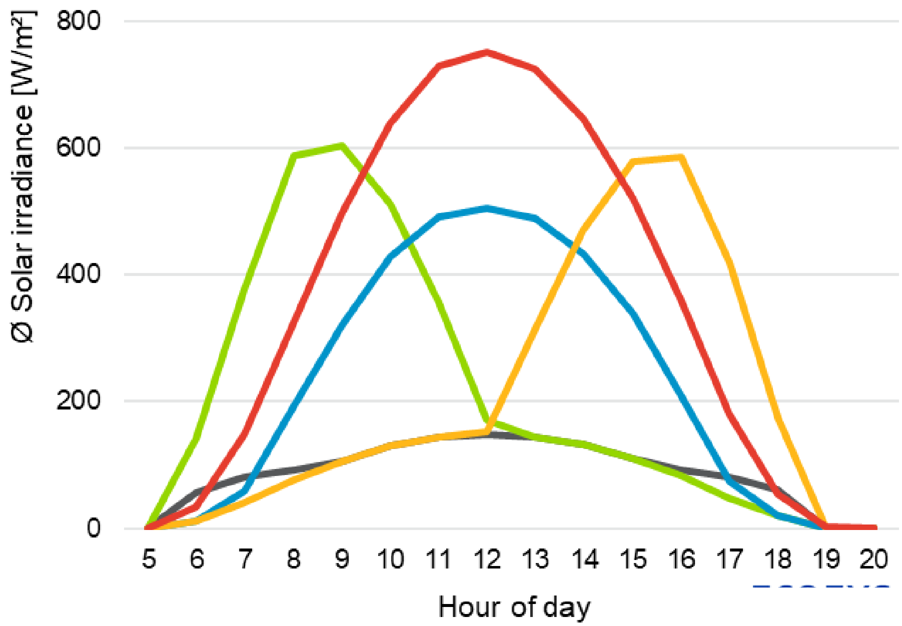
Description

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	Diesel
Energy price	JOD/kWh	Mean 0.04	0.048
Energy price	EUR/kWh†	0.055	0.06
Price development	%/year	3	6
CO_2 emission factor	gCO_2/kWh	635	300
Economic parameters			
Interest rate (real)	%/year	5	
Calculation period	years	20	

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

Boundary Conditions I Building

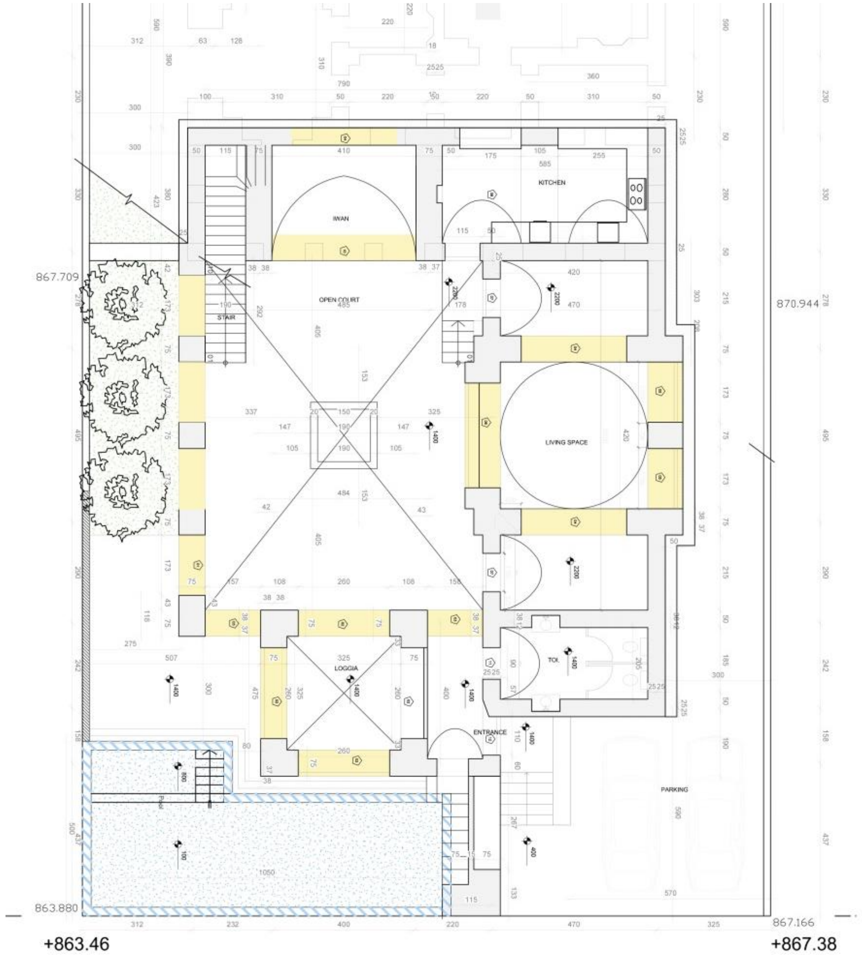
Building Data

Status

Small Single-Family houses in a vernacular Islamic architecture style.

Specific Challenge

Located in remote areas. It is significant to reduce on-site workmanship to the minimum aiming to reduce human impact on the environment and reduce need for maintenance.



Building Key Information	
Data	Input
Latitude	32.0496081
Longitude	35.9565306
Elevation [m]	+864
Utilization	SFH
Number of floors	1
Number of apartment	1
Conditioned floor area [m²]	47 (1 zone = living room
Clear room height [m]	Aver. 5.7
Conditioned volume [m³]	266
Number of inhabitants [#]	4
Year of construction	2021

Analysis

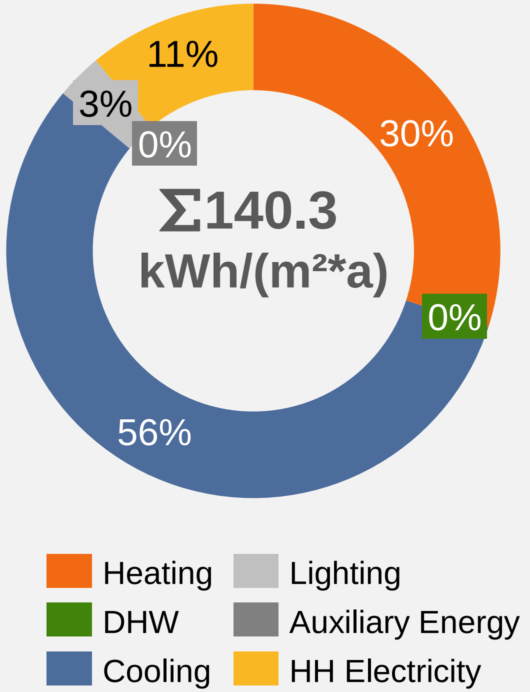
Starting Situation - Baseline and Current planning

Business as Usual

Baseline in the country

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)	1.2 W/m²K
Windows (U-Value; G-Value)	3.0 W/m²K; 0.78
Window fraction	Ø 30%
Shading	Manual
Air tightness	0.25 1/h
Heat supply	reversible split unit - COP 3.5
Cold supply	reversible split unit - COP 3.4
Hot water	-
Ventilation systems	Natural ventilation
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	24°C / 21°C



Energy Cost
13.6 EUR / (m²*a)

CO2 - Emission
4.7 kg / (m²*a)

Current situation

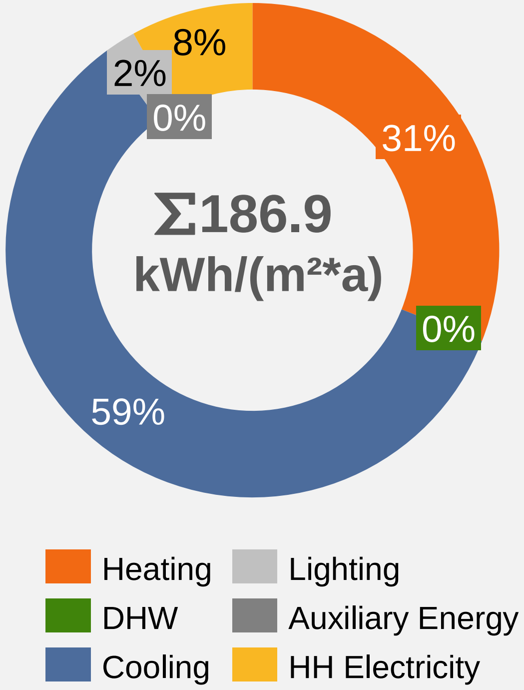
Building Characteristics as planned

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)	**1.6** W/m²K
Wall insulation (U-Value)	**0.67** W/m²K
Floor insulation (U-Value)	1.2 W/m²K
Windows (U-Value; G-Value)	3.0 W/m²K; 0.78
Window fraction	Ø 30%
Shading	Fixed Shading
Air tightness	0.25 1/h
Heat supply	reversible split unit* - COP 3.5
Cold supply	reversible split unit - COP 3.6
Hot water	-
Ventilation systems	Natural ventilation
Lighting systems	LED
Renewable energy	-
Set temperature cooling/heating	24°C / 21°C



Energy Cost
24.1 EUR / (m²*a)

CO_2 - Emission
6.3 kg / (m²*a)

*LPG Heater would cause higher final energy use

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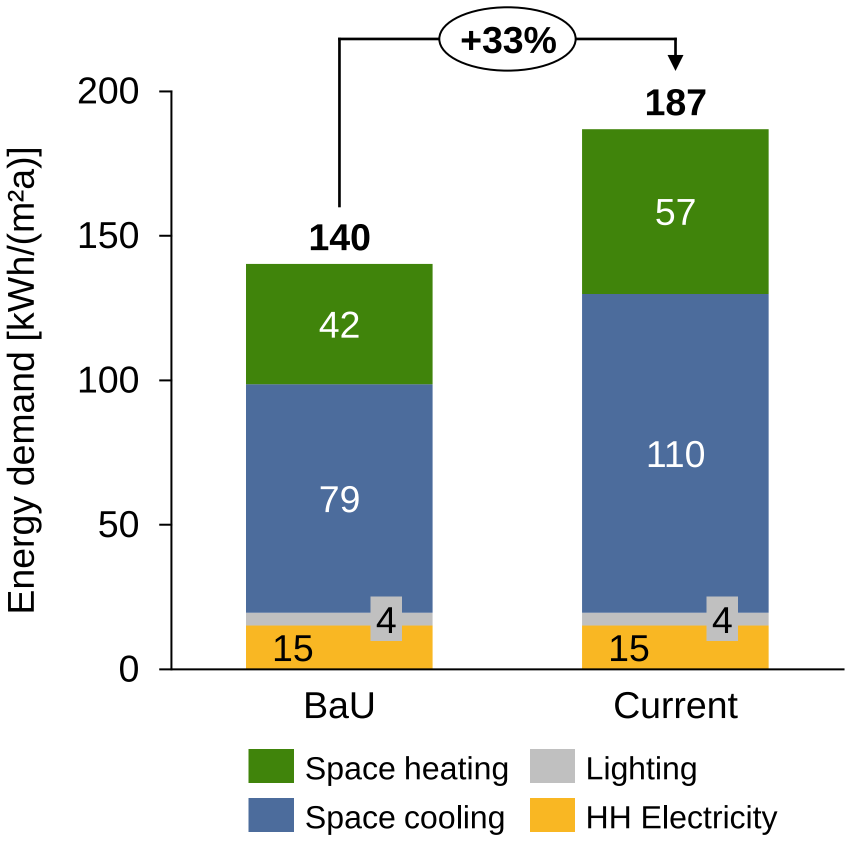
Current situation (project developer)

Results VS. BaU

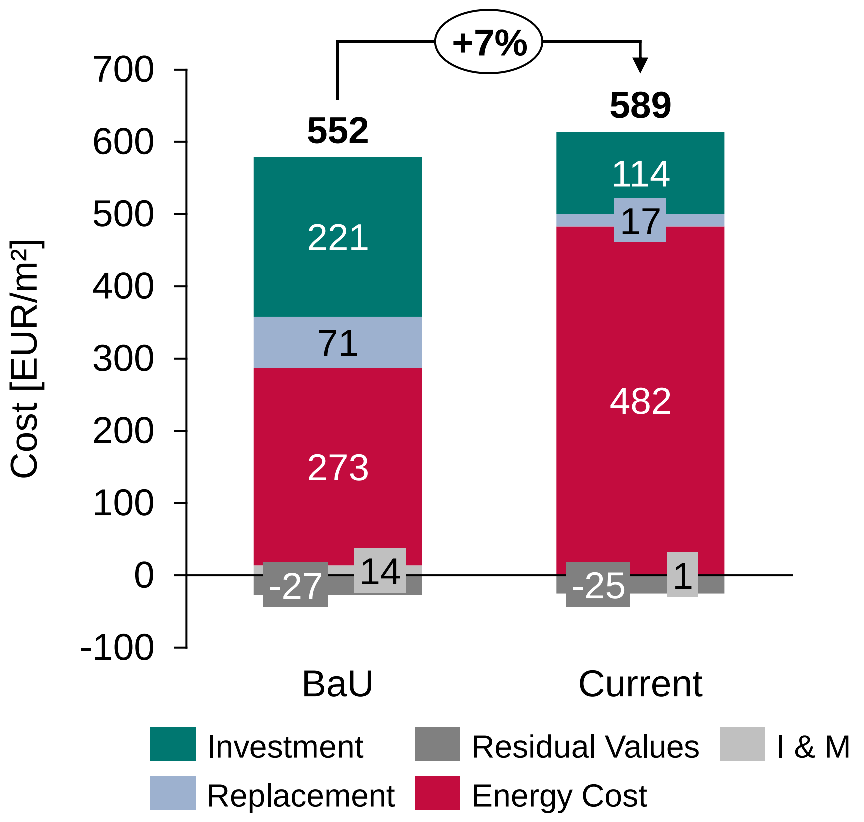
The proposed design seems to be less energy efficient in comparison to the BAU cases.

The energy consumption of this traditional Arabic architecture is difficult to estimated without a dynamic thermal simulation.

Final Energy Demand



Global Cost



Analysis

Investigation of Possible Measures

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

Overview of Analyzed Measures

Scope of Measures

Envelope

- Roof insulation
- External wall insulation
- Windows

Renewables

- PV
- Solar water heaters

Out of the Box

- Solar winter garden
- Earth ground heat exchanger

External wall

Current Variants

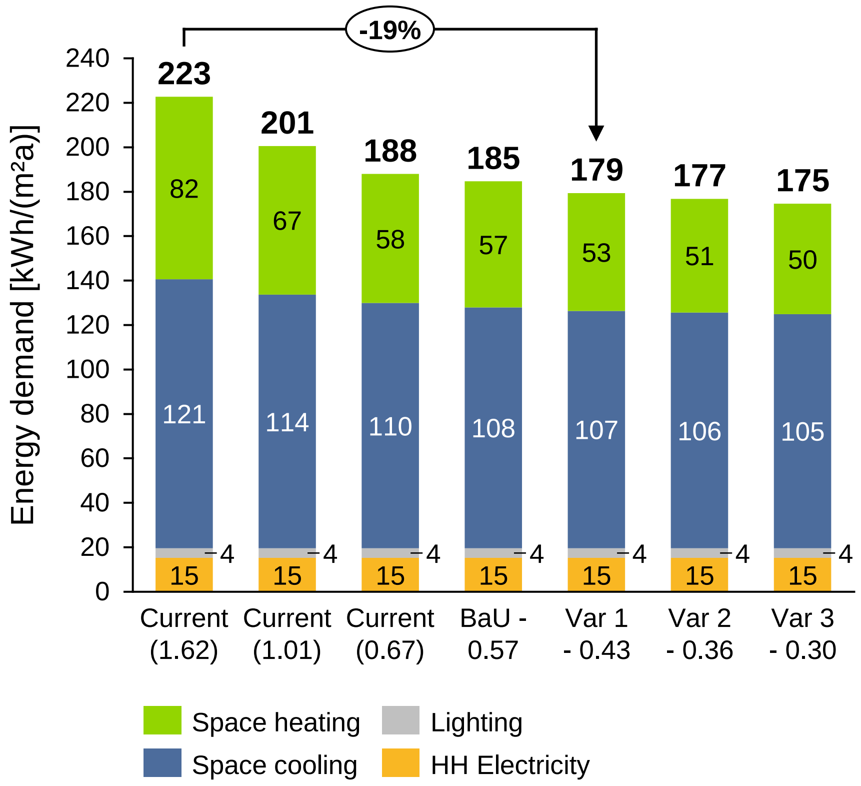
- 100 cm wall: U-Value = 0.67 W/m2K.
- 75 cm wall: U-Value = 1.01 W/m2K.
- 50 cm wall: U-value = 1.62 W/m2K

The BaU and improved variants

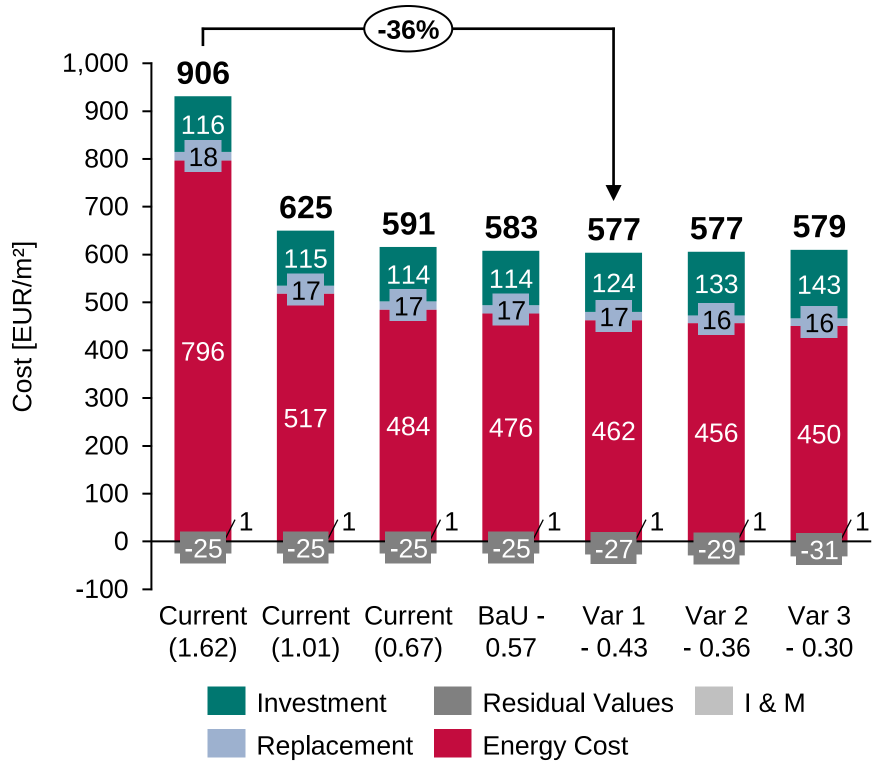
- BaU: 8 cm insulation
- Var 1 – 3: 10 – 15 cm insulation

Result: The **Var 1** is the most cost effective measure with 10 cm insulation.

Final Energy Demand



Global Cost



Roof

Current Variants

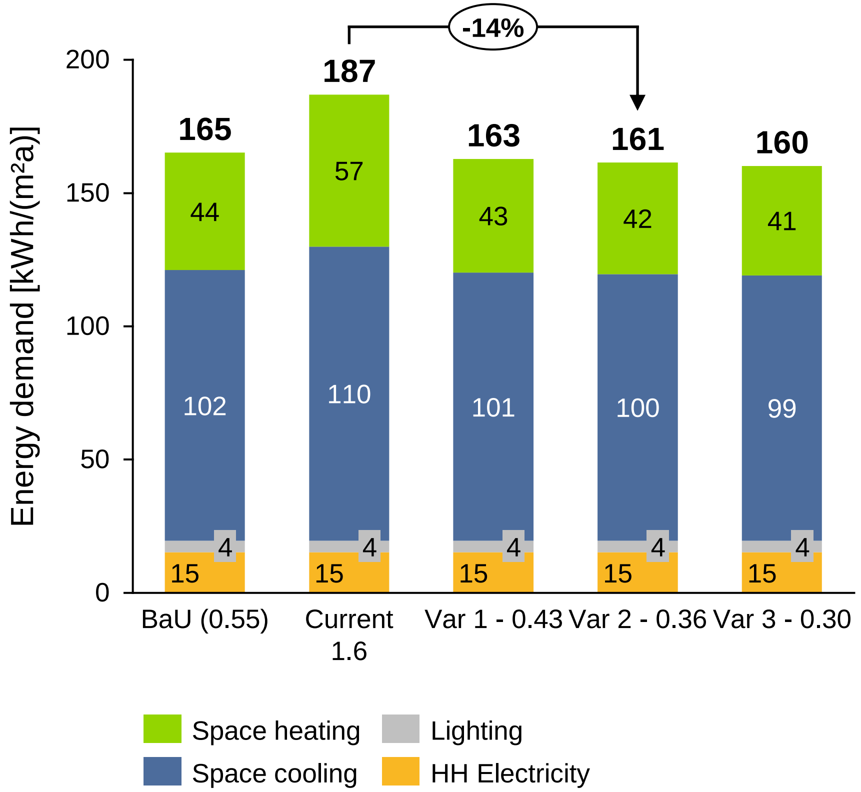
- Roof with U-value = 1.62 W/m2K

The BaU and improved variants

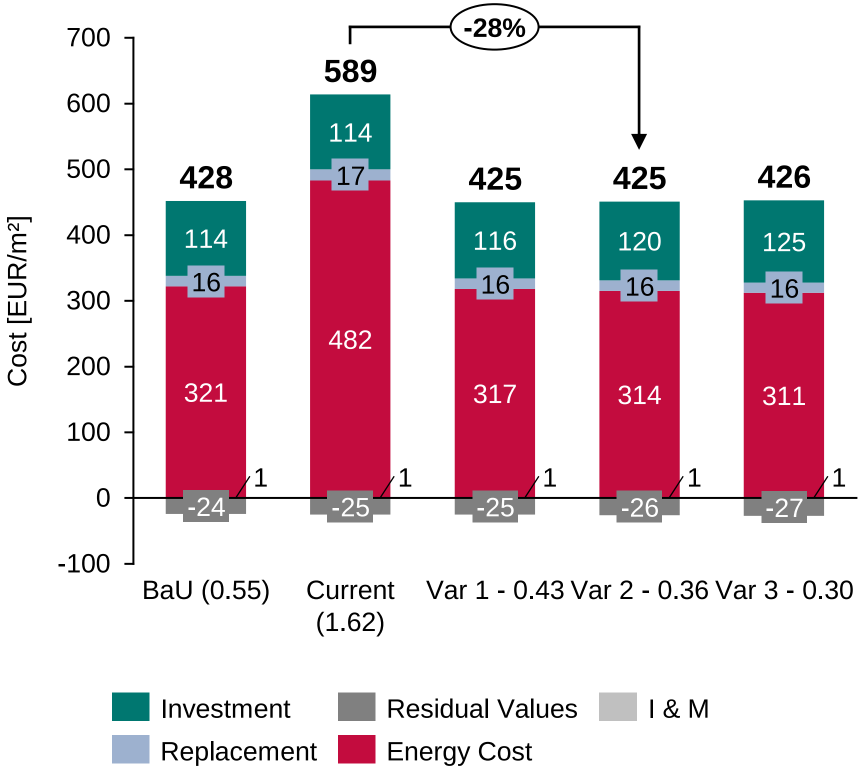
- BaU: 8 cm insulation
- Var 1 – 3: 10 – 15 cm insulation

Result: Var 2 is the most cost effective measure, with 12 cm insulation.

Final Energy Demand



Global Cost



Windows

Bau / Current case

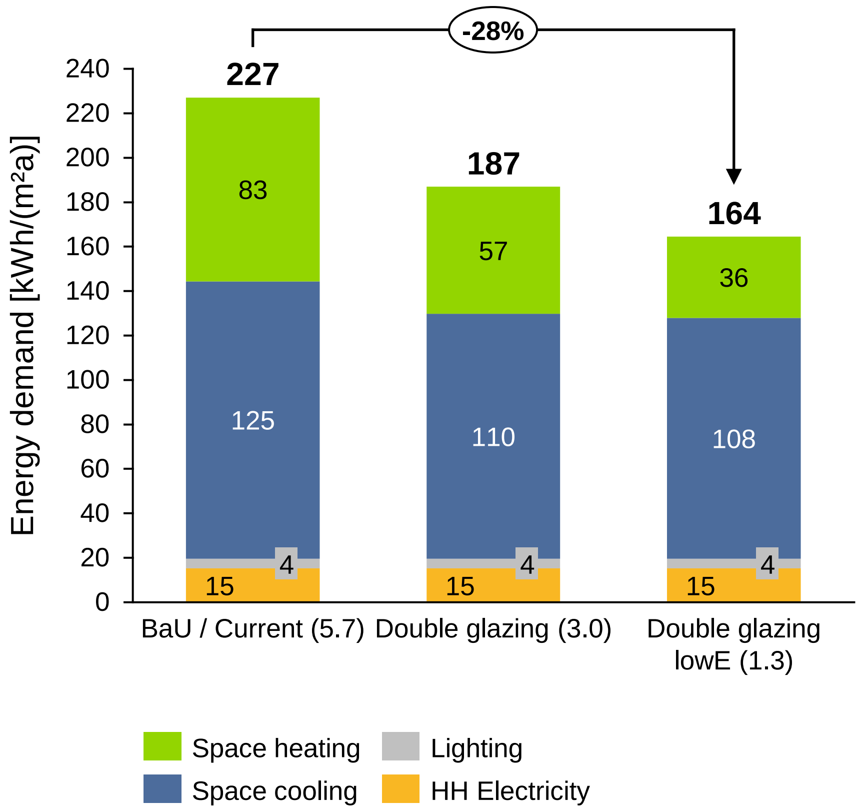
- Single glazing (U value 5.8 W/m²K)

Improved Variants

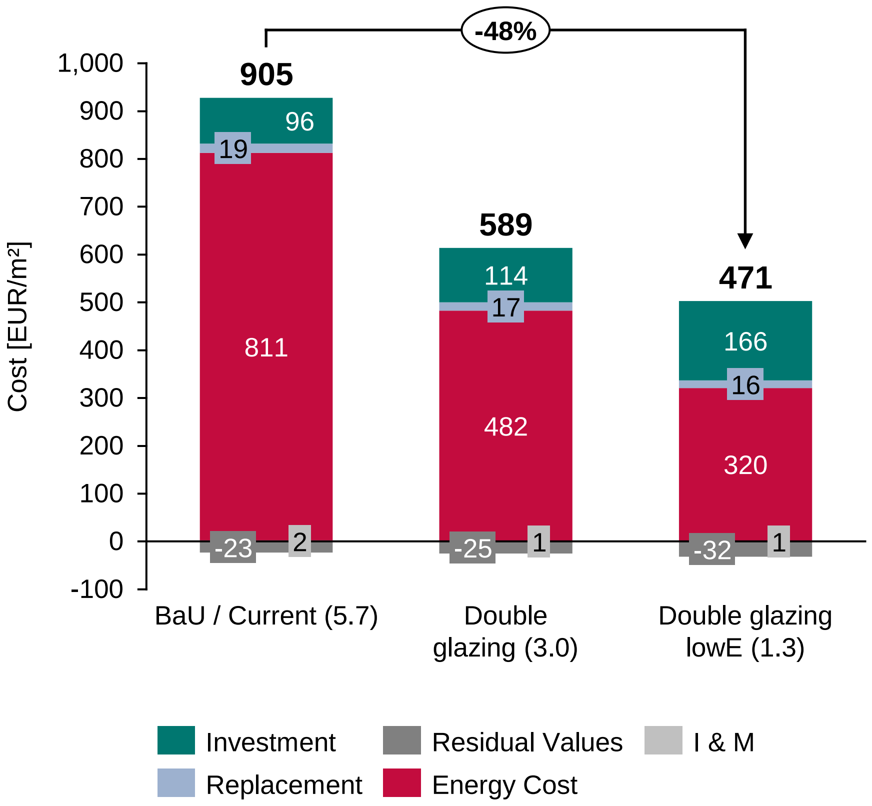
- Double glazing (U value 2,8 W/m²K),
- Double glazing lowE (U value 1,3 W/m²K)

Result: Var 2 – Double glazing lowE is the most cost effective measure and has 28% energy saving potential

Final Energy Demand



Global Cost



BUILD_ME Pilot ProJect Jordan

Renewables | ST
Analysis

ST utilization for DHW
- BaU: No solar collectors.
- Var 1: 50% coverage (2 m²)
- Var 2: 90% coverage (4 m²)

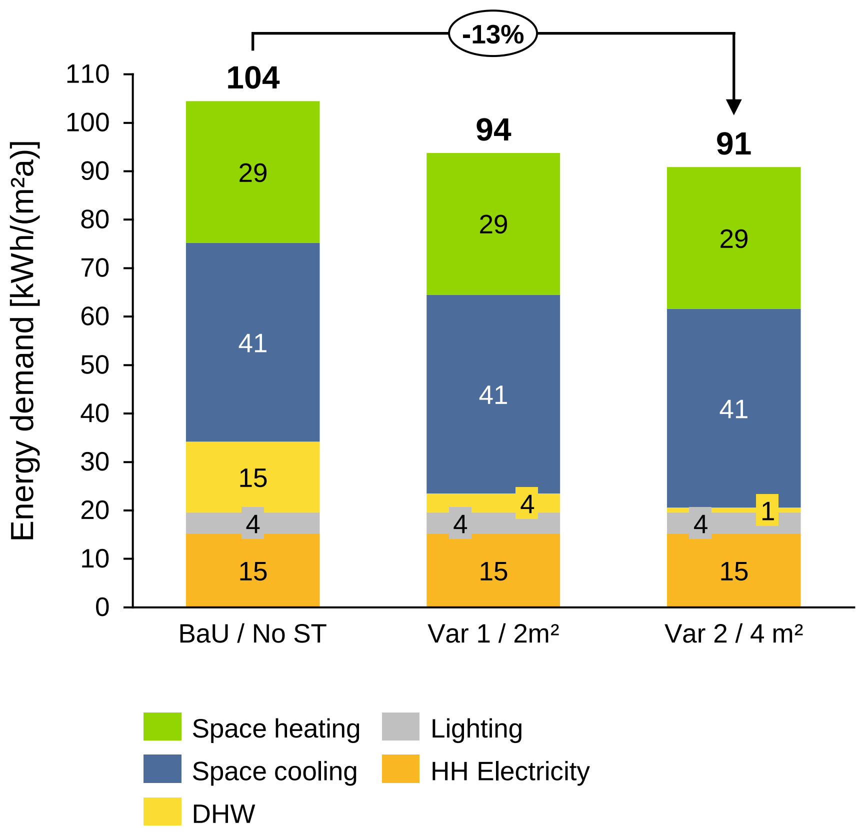
ST utilization for swimming pool[1]
Demand: 4500 kWh/a
Collector area needed: 5 m²
Cost: 200 €/m² -> 1000 €

Compared electricity cost:
0.11 ct/kWh -> 495 €/a

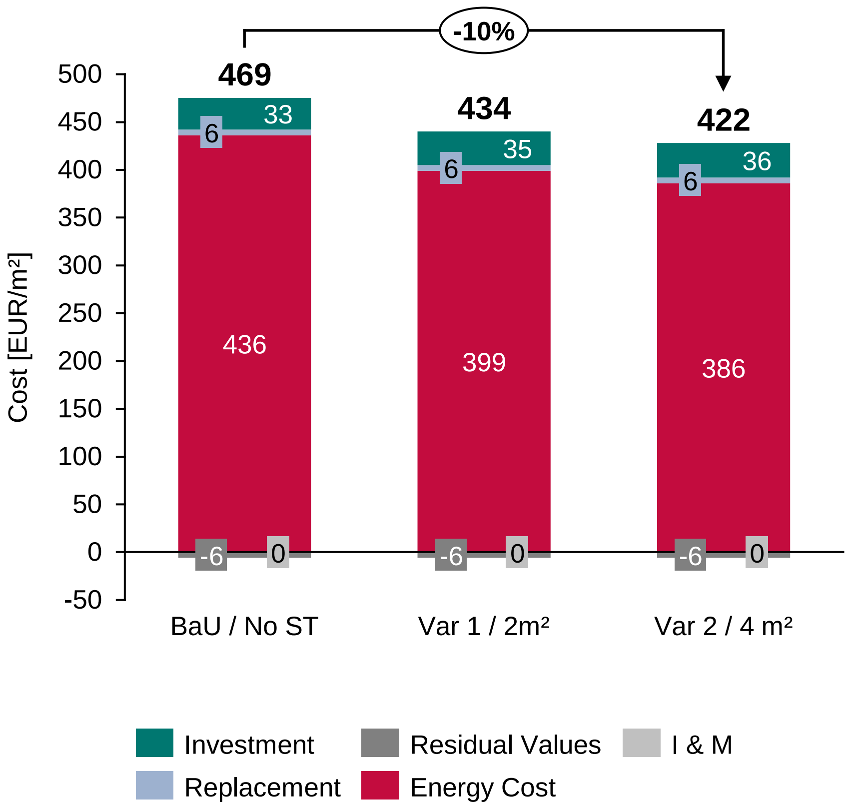
→ Solar thermal support for pool heating should be considered.

Result: Solar thermal collectors can cover the hot water demand and are a cost-effective measure.

Final Energy Demand



Global Cost



[1]Pool: L/W/H = 6/3/1.3 m; Temperature : 28°C; covered by night; only operated in summer

Renewables | PV
Analysis

Bau / Current case

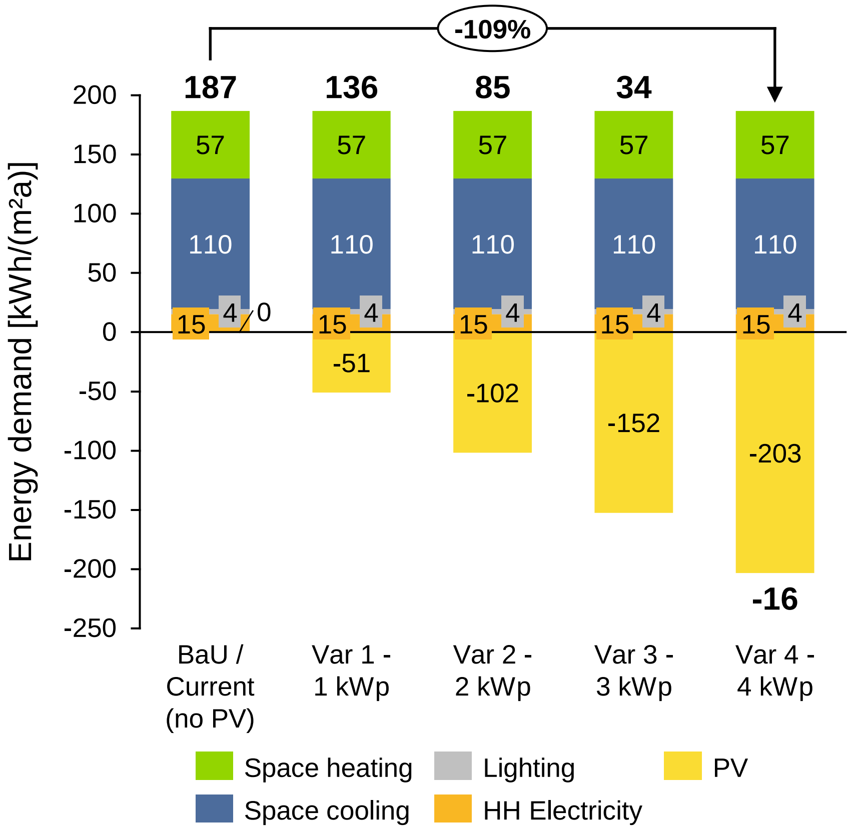
- No Photovoltaic

Improved Variants

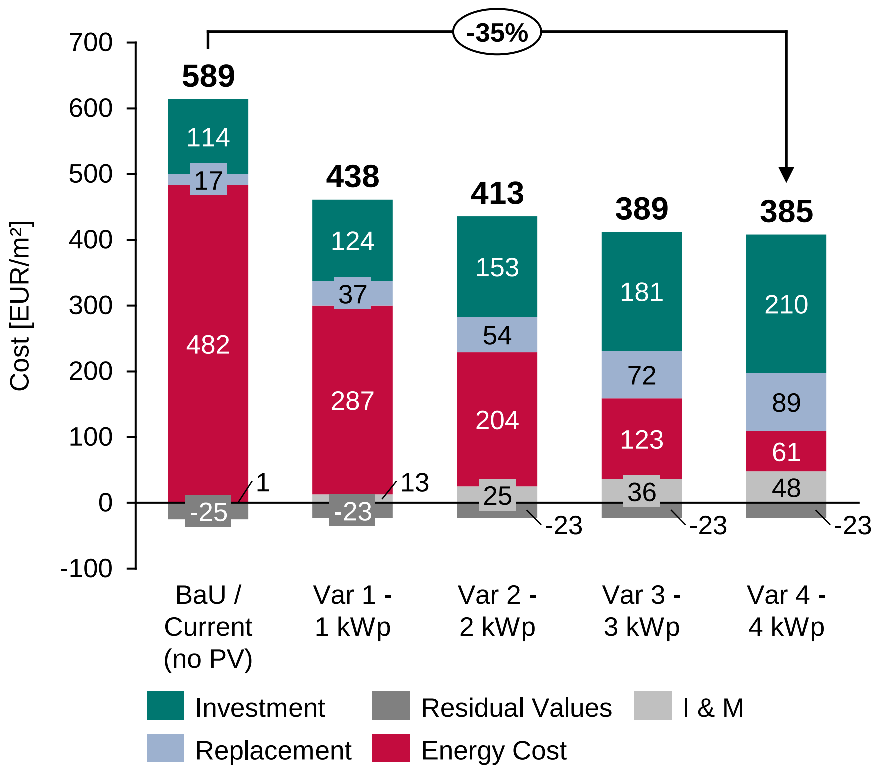
- Var 1 – 4: 1 kWp – 4 kWp
- 1 kWp needs around 7 m² of area.

Result: PV is cost-effective and 4 kWp would be optimal in this case.

Final Energy Demand



Global Cost



Results & Conclusion

Photo by Xan Griffin on Unsplash

Overview of recommended measures

Four steps to reduce energy demand significantly

Building envelope

- External wall -> U-Value 0.43 (10 cm insulation)
- Roof -> U-Value 0.43 (8 cm insulation)
- Windows -> double glazing low-E (U-Value 1.5 W/m²K, G-Value 0.78)

HVAC

- Use high efficient reversible split units

Renewable (Solar) Energy

- PV 3 kWp
- Solar thermal collectors (4 m²) for hot water

Behavior

- Regulate the setting temperature to an appropriate level

Optimized Solution

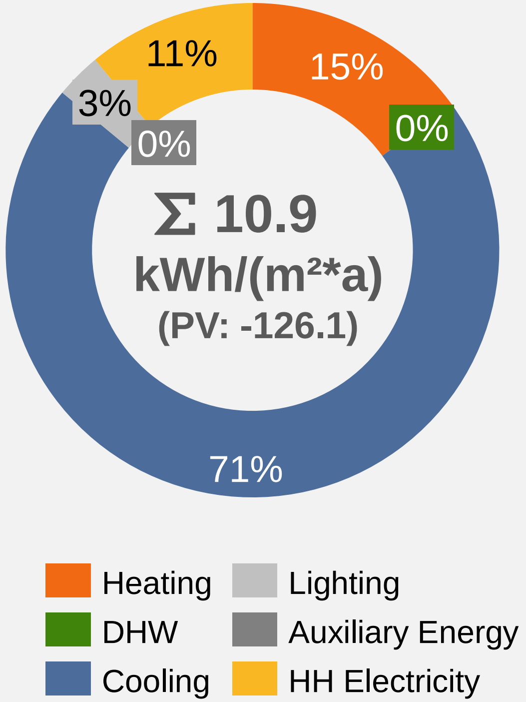
Results

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

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

This leads to energy savings and emission reduction.

Parameters	Optimized Building
Roof insulation (U-Value)	**0.43 W/m²K**
Wall insulation (U-Value)	**0.43 W/m²K**
Floor insulation (U-Value)	1.2 W/m²K
Windows (U-Value; G-Value)	**1.5** W/m²K; 0.78
Window fraction	Ø 30%
Shading	Fixed Shading
Air tightness	0.25 1/h
Heat supply	Reversible split unit - COP 3.5
Cold supply	Reversible split unit - COP 3.6
Hot water	-
Ventilation systems	Natural ventilation
Lighting systems	LED
Renewable energy	**3 kWp (PV)**
Set temperature cooling/heating	24°C / 21°C



Energy Cost
1.1 EUR / (m²*a)

CO_2 - Emission
0.4 kg / (m²*a)

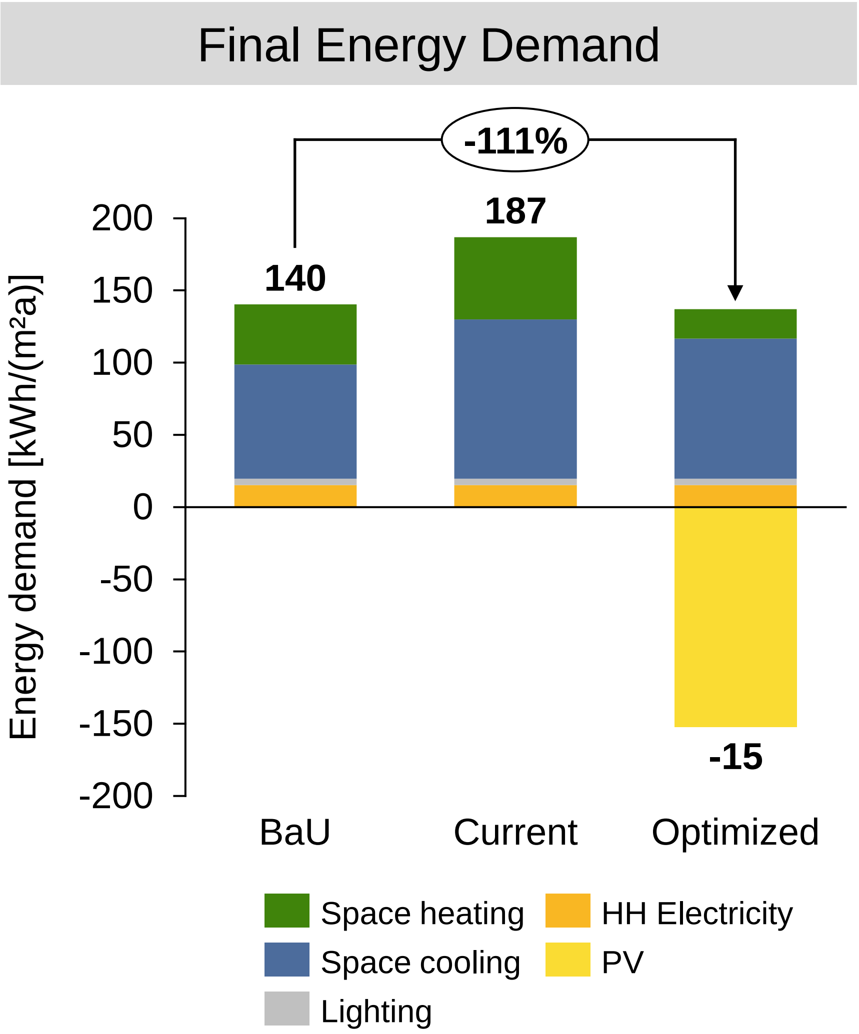
Comparative overview

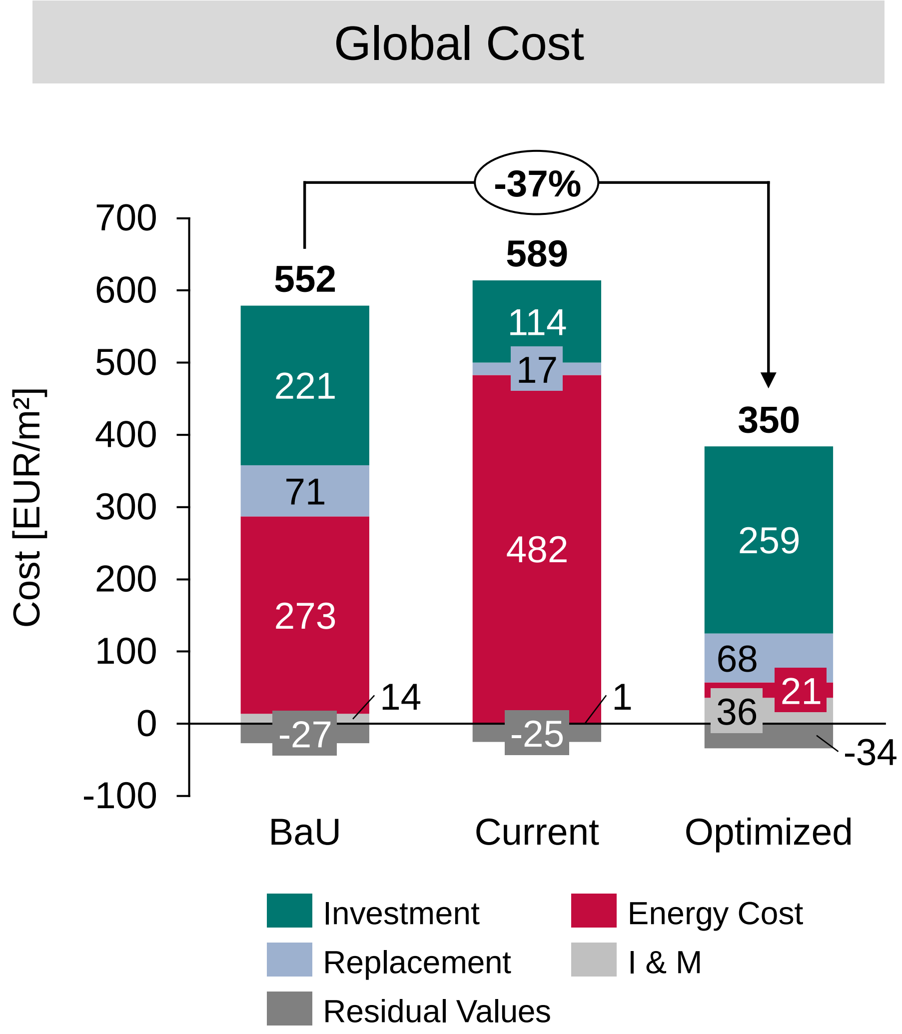
BaU vs. Current vs. Optimized vs. Selected measures

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 (Base vs. Optimized)
Energy: 90%
Cost: 37%





Recommendations

Four steps to reduce energy demand significantly

BEP tool has its limitations to calculate such unique building and might not illustrate (overestimating) the cooling demand correctly.

Building envelope

- The current U-Values are not compliant with existing Energy Efficiency Building Codes, it´s highly recommend to reconsider the use of thermal insulation in the building envelope and low E double glazing instead of single glazing.

HVAC

- Use high efficient reversible split units, ii will offer heating and cooling supply and more efficient than the planned LPG boiler

Renewable (Solar) Energy

- Integrate solar energy, PV and ST have shown to be cost-efficient

Behavior

- Use temperature ranges of appr. 20°C (winter) and 24-26°C (summer)

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