EA´TEDAL COMPLEX ZARQA, JORDAN

PILOT PROJECT SUPPORTED BY THE IKI PROJECT:

ACCELERATING ZERO-EMISSION BUILDING SECTOR AMBITIONS IN THE MENA REGION

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

NAVIGANT

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INTRODUCTION
PROJECT DEVELOPER

Ea´tedal Complex, Zarqa

The Al-Urwa Al-Whathqa Charity Association was founded in 1965 and is working towards the establishment of several social projects and residential buildings for comfort and development of orphans and people in need. Its activities cover all areas of the Hashemite Kingdom of Jordan.

INTRODUCTION
PROJECT TEAM

Construction Site, Zarqa

As the residential buildings are spread throughout Jordan, the project developer has many projects including 19 buildings of which many of them are still under construction. The multidisciplinary team consists of 20 civil engineers and six electrical and mechanical engineers who work cohesively to achieve the best results. The association has collaborated with ASAS bureau; is a third party which is responsible of any consultation, design, drawings, and supervision of the project.

METHODOLOGY
OBJECTIVE AND APPROACH

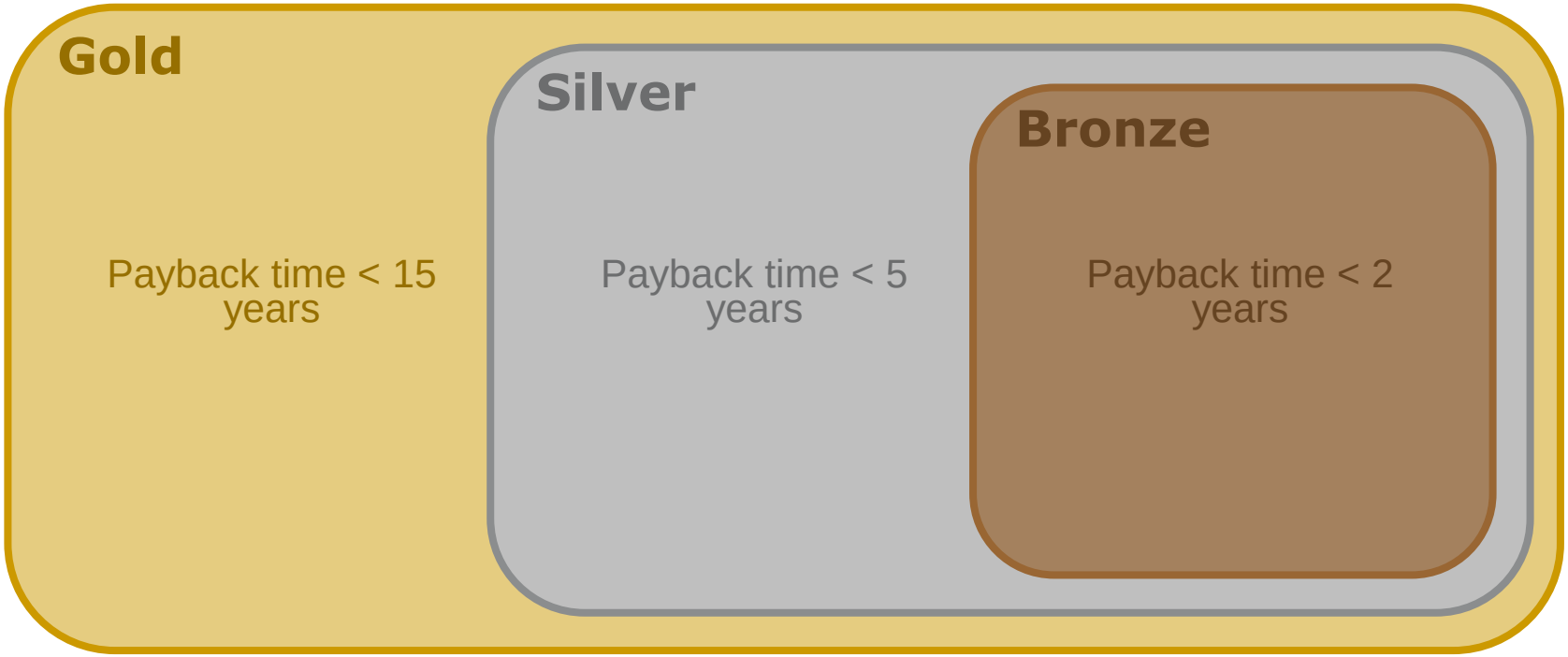
The main objective of the assignment was to evaluate cost-benefits of energy efficiency and renewable energy measures and to develop of packages based on their payback period. These should ensure transparent solutions that can be selected by the pilot project team.

After a kick-off meeting with the project team of the pilot project and a data gathering phase, the calculations of possible energy efficiency and renewable energy measures have been performed.

All measures are grouped according to their payback time. All measures with a payback time of lower than 2 years are implemented with the low cost variant (bronze). For the moderate variant (silver) all measures with a payback time lower than 5 years are taken. Therefore, all measures from the bronze package are included. With the highly energy efficient variant (gold) all proposed measures are implemented, while measures with a payback time greater than 15 years were excluded from all packages.

METHODOLOGY
DEFINITION OF PACKAGES

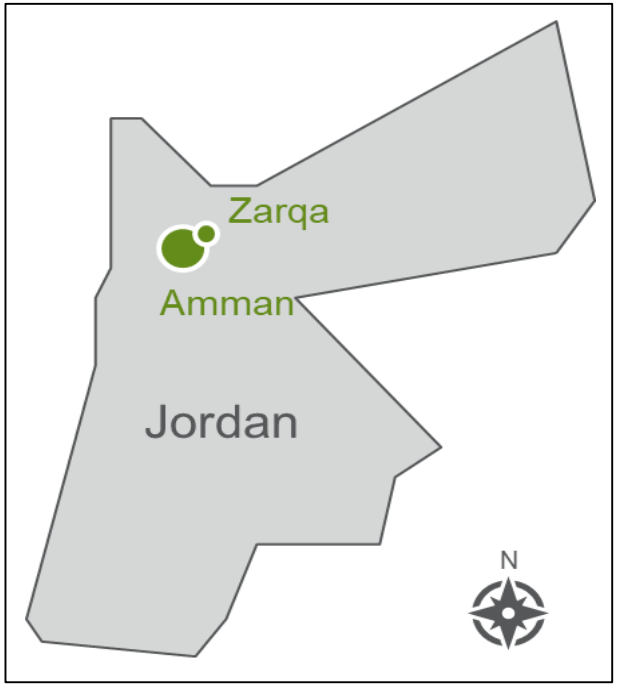
Rationale for Compiling the Three Packages



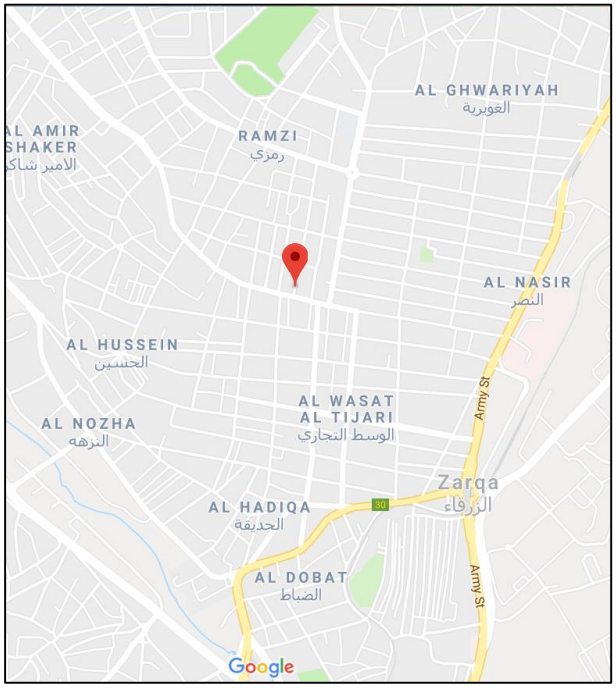
BOUNDARY CONDITIONS

SITE

Map of Jordan



Map of Zarqa

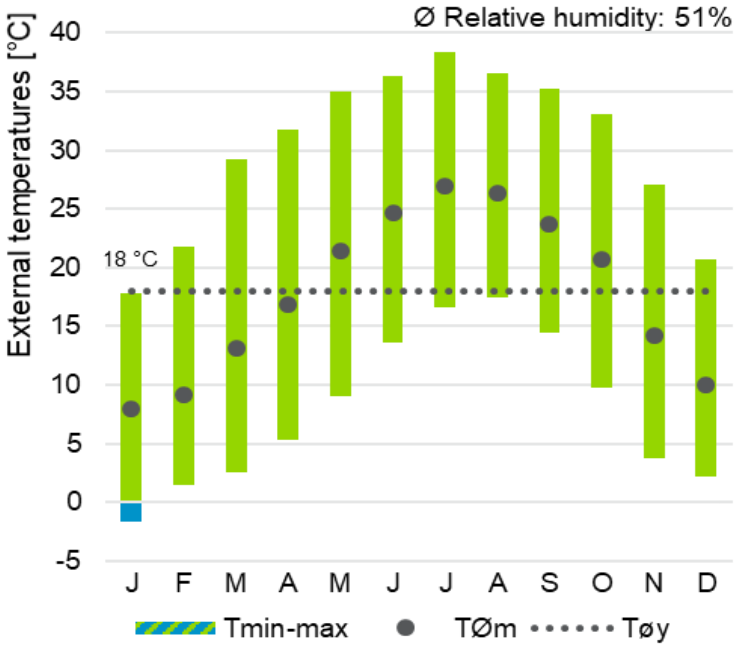


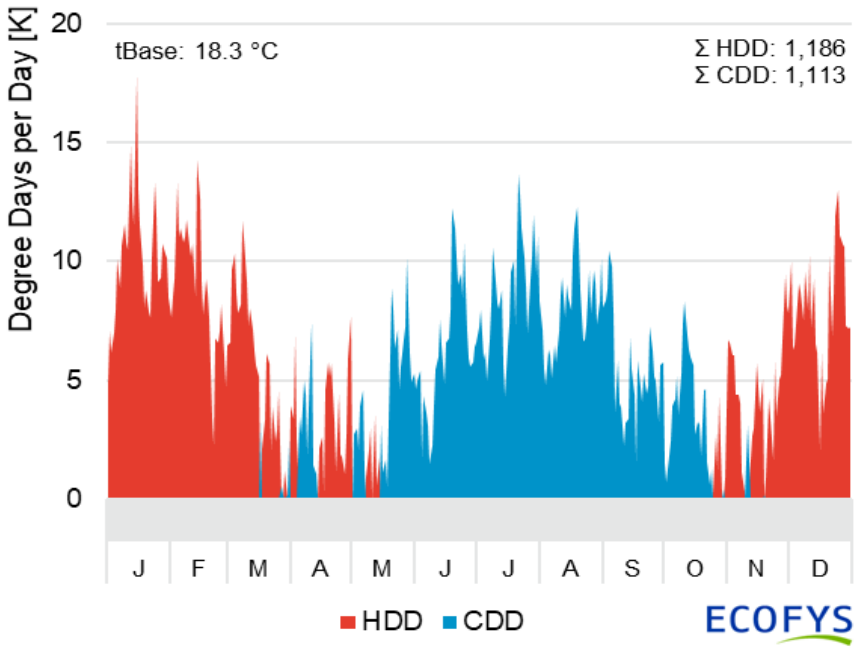
Source: Google Maps

Zarqa is Jordan's third-largest city after Amman and Irbid with approximately 1.36 million citizens in 2015 and a total area of 4,761 km^2. Zarqa is considered a residential and industrial city. It is located 15 miles (24 km) northeast of Amman. The pilot project site is in one of the main residential areas in the heart of the city.

BOUNDARY CONDITIONS
CLIMATE

External Temperatures (left) and Degree Days (right) in Amman (Jordan)*



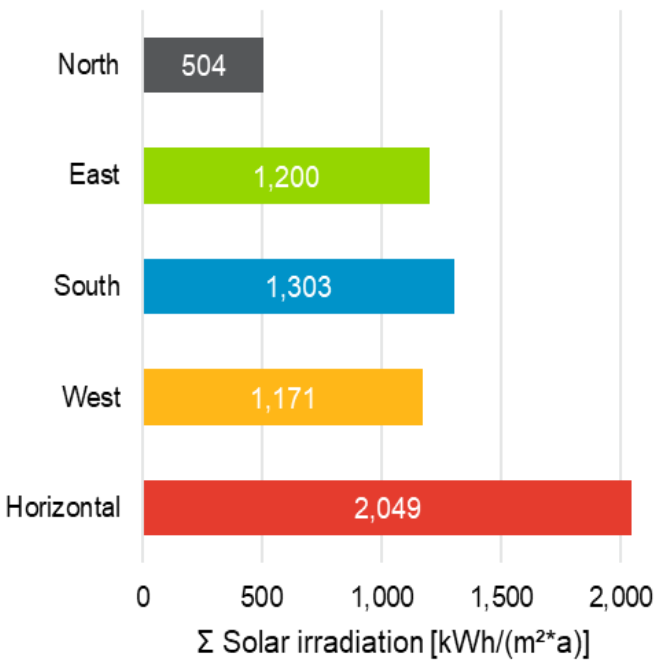


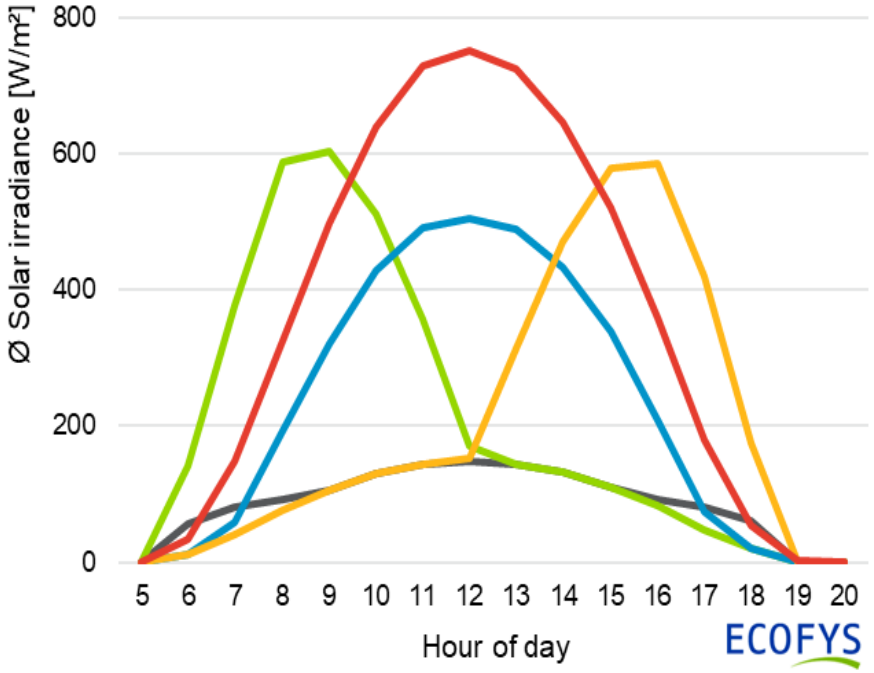
*The following paragraphs refer to Amman due to data availibility
*HDD: heating degree days; CDD: cooling degree days; according to ASHREA methodology

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

BOUNDARY CONDITIONS
CLIMATE

Solar Irradiation in Amman (Jordan)





High horizontal irradiation of >2,000 kWh/(m²*a) and >1,100 kWh/(m²*a) for East, South, and West orientations bring opportunities for solar-based energy generation.

BOUNDARY CONDITIONS
ENERGY PRICE AND CO_2 FACTOR

	Unit	Electricity	Diesel
Energy price	JOD/kWh	Mean 0.13	0.048
Energy price	EUR/kWh†	Mean 0.155	0.06
Price development	%/year	1-2%	2%
CO_2 emission factor	gCO_2/kWh	635	300

†exchange rate: 1 EUR = 0.84 JOD

In Jordan, natural gas is mainly used for power generation plants, while liquid petroleum gas (LPG), diesel fuel, and electricity are used in space heating.

CURRENT SITUATION
BUILDING INFORMATION

Unit	Climate data location
Latitude	32.068 °N
Longitude	36.087 °E
Elevation	688 m
Utilisation:	Residential/Mosque
Number of floors	5+ parking
Number of apartment	24
Conditioned floor area	3,870 m^2
Clear room height	3.2 m
Conditioned volume	11,500 m^3
Number of (expected) inhabitants	95-120
Year of construction	2017-2019

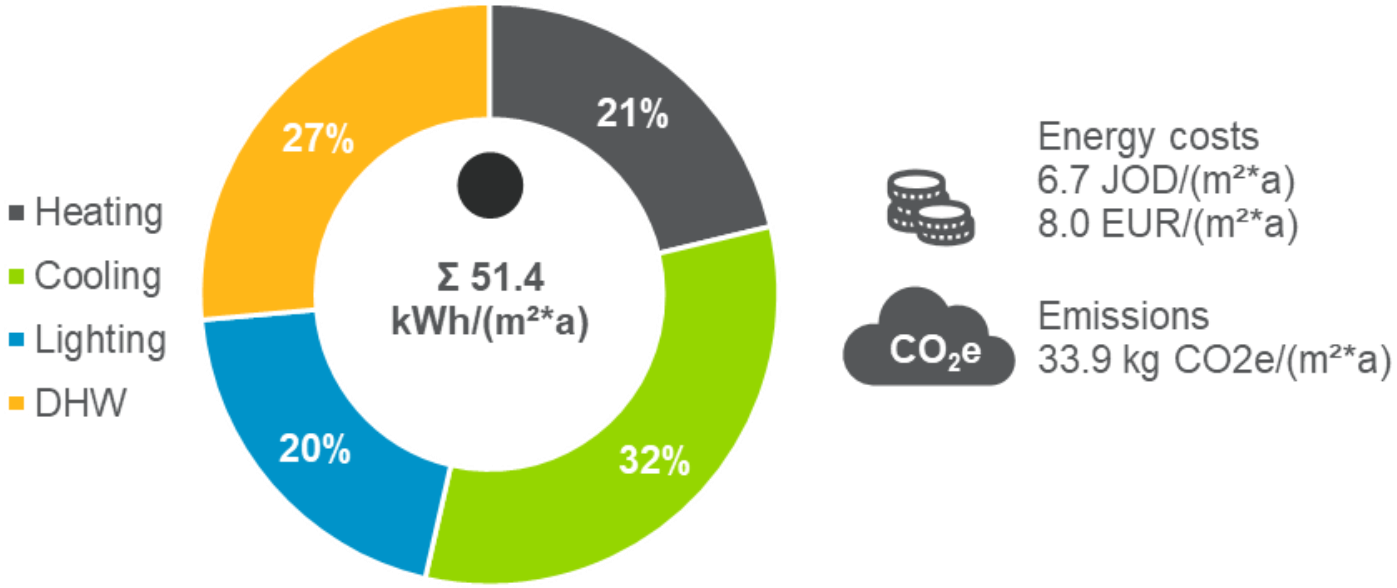
CURRENT SITUATION
BUILDING INFORMATION

Measure	Baseline
Roof insulation (U-Value)	0.55 W/m²K
Wall insulation (U-Value)	0.57 W/m²K
Floor insulation (U-Value)	0.8 W/m²K
Windows (U-Value; G-Value)	5.7 W/m²K; 0.85
Window fraction	Ø 11%
Shading	No
Air tightness	0.25 1/h
Heat supply	Reversible split unit - COP 2.5
Cold supply	Reversible split unit - COP 2.5
Hot water	Electric instantaneous
Ventilation systems	Natural ventilation
Lighting systems	CFL
Renewable energy	No
Set temperature cooling/heating	24°C/21°C

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. No special attention is given to use of renewable energy sources.

CURRENT SITUATION
ENERGY RELEVANT INFORMATION

Energy Demand, Energy Costs, and GHG Emissions: Current Situation



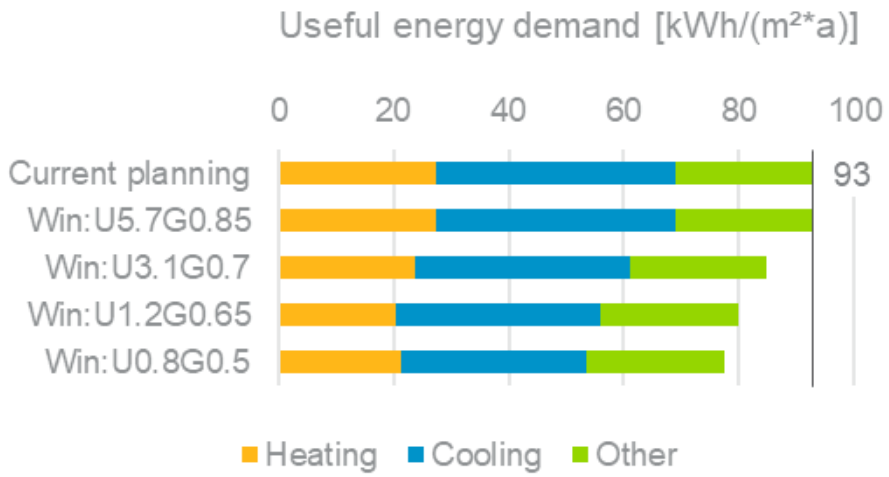
The chart above shows current shares for energy costs and the greenhouse gas emissions. With a total share of 32% the cooling energy represents the largest portion of energy demand. The domestic hot water demand reaches 27% of the total demand and the smallest shares with 21% and 20% are heating and lighting. In its combination the current situation reaches an energy demand of 51.4 kWh/(m²*a) and an environmental impact of 33.9 kg CO_2e/(m²*a). For a unit of 90 m² the energy cost will reach about €59.63 per month or 50.11 JOD. This represents the standard building package.

ANALYSIS
FINDINGS OF SENSITIVITY ANALYSIS OF EE/RE MEASURES

No	Measure	Question
1a	Windows (U-Value; G-Value)	What is the most energy efficient U-Value/G-Value
1b	Window fraction	What is the most energy efficient window fraction per orientation?
2	Shading	What is the effect of shading?
3	Air tightness	What is the effect of air tightness?
4	Cooling supply system	What is the cost optimal efficiency for cooling? [COP]
5	Lighting	What is the cost optimal type of lighting?
6	RE (solar energy)	Is the installation of solar energy cost efficient?
7	A) Cooling B) Heating	What is the energy saving potential of an adjusted setting temperature?

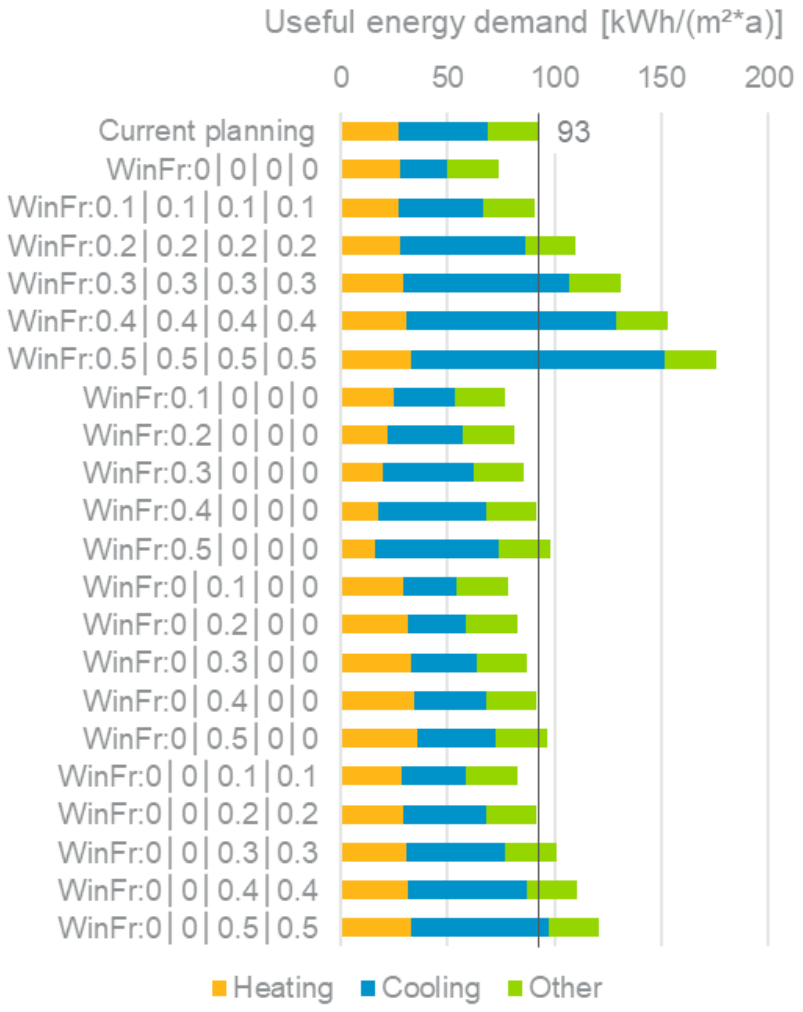
ANALYSIS
BUILDING ENVELOPE PASSIVE MEASURES

Measure 1a	Energy Efficient Windows
Window type	Current Planning: U-value 5.7; G-value 0.85 Efficiency Approach Bronze: 5.7; 0.85 Efficiency Approach Silver: 1.2; 0.65 Efficiency Approach Gold: 0.8; 0.50



Lowering the U-Value reduces the heat transmission losses. For this pilot project the optimal range of the U-Value is around 0.8-1.2 W/(m²*K).

ANALYSIS
BUILDING ENVELOPE PASSIVE MEASURES



Measure 1b - Optimal Window Fraction

Varied window fraction in South | North | East | West from:

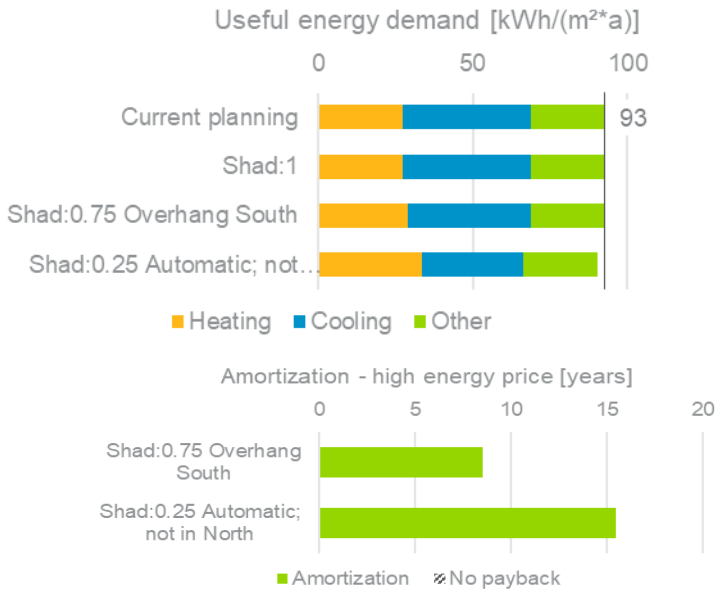
- 0 (no window) to
- 0.5 (50% window share)

Reducing window fractions significantly reduces the energy demand for cooling. The effect on the heating demand differs per orientation.

The projects' window fraction is already close to optimal. Increasing the overall window area by 10% can raise energy demand by 25%.

ANALYSIS
BUILDING ENVELOPE PASSIVE MEASURES

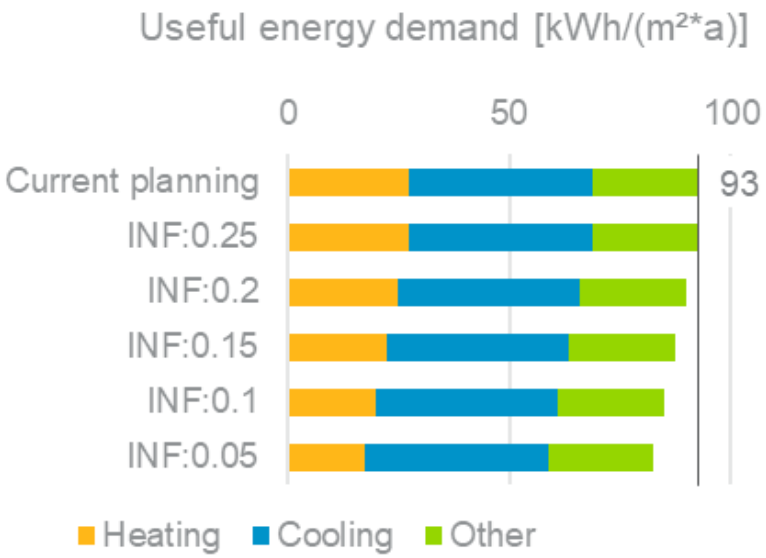
Measure 2	Shading
Shading	Shading was evaluated for • Sc = 1: no shading • 75% transmittance in South, rest 100% • 100% transmittance in North, rest 25%



Though the effect of shading on the overall useful energy demand is limited due to contrary effects on cooling and heating, shading measures pays back within measure´s lifetime.

ANALYSIS
BUILDING ENVELOPE PASSIVE MEASURES

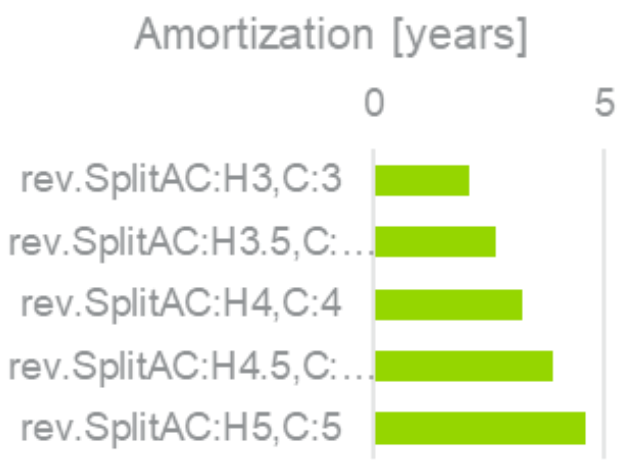
Measure 3	Air Tightness
Air tightness	What is the effect of air tightness?



Reducing air leakages by 0.05 1/h can reduce the building's energy demand for heating and cooling by 4%.

ANALYSIS
BUILDING ENVELOPE HVAC

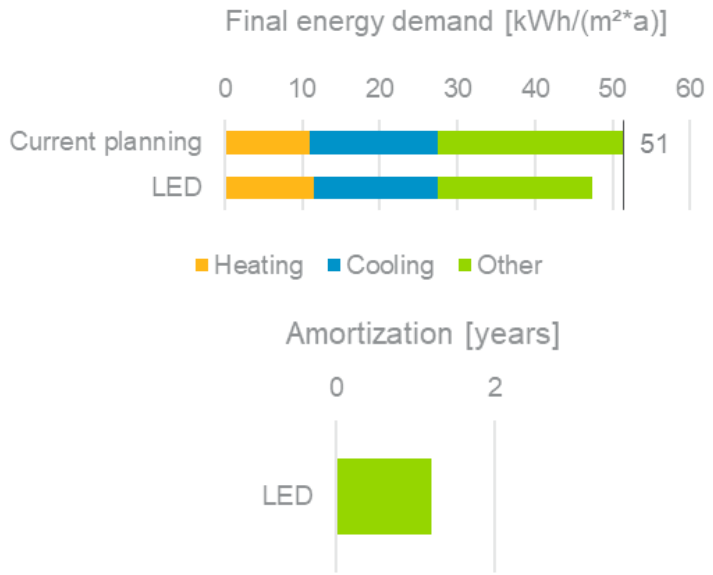
Measure 4	Cooling
Cost optimal cooling	Reversible split air conditioning with COP 3.0 to 5.0 for heating and cooling compared to current planning with COP 2.5



Under Jordan's conditions, even high efficient air conditioning systems (COP 5.0) can payback with one-third of their lieftimes.

ANALYSIS
BUILDING ENVELOPE HVAC

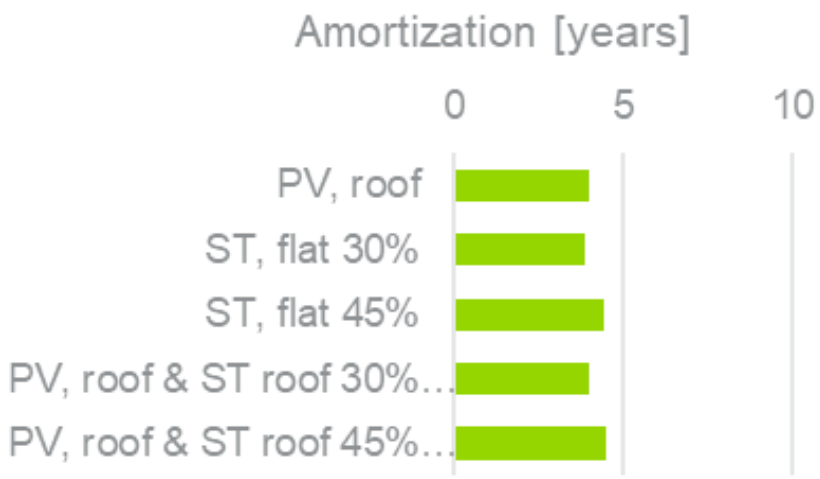
Measure 5	Lighting
Lighting supply	What is the cost optimal type of lighting? - CFL - LED



Compared to common CFL, LED can save up to 35% of final energy and payback shortly after 1 year.

ANALYSIS
RENEWABLES/SOLAR ENERGY

Measure 6	Solar Energy
PV and solar thermal	Is the installation of solar energy cost efficient?



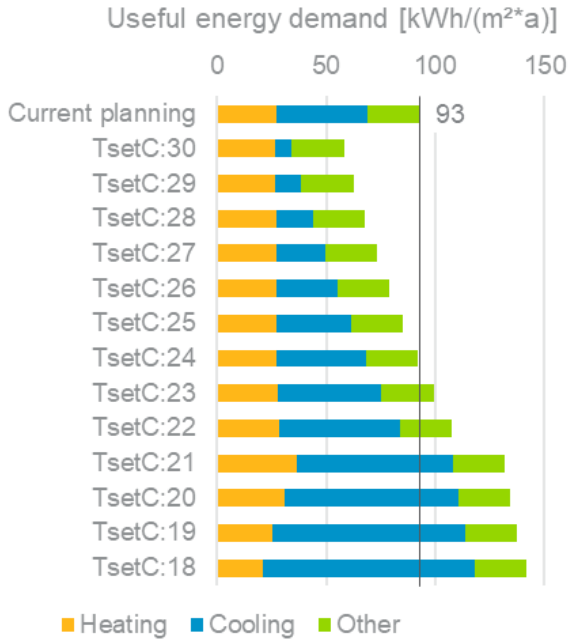
Standalone and combined solar thermal and PV solutions can payback within 5 years.

Key Assumptions (PV):
- Roof fraction: 50%
- Solar azimuth: 0° (South)
- PV modules angle: 20°
- Module type: Crystalline
- Capex: 800 €/kWp

Key Assumptions (Solar Thermal):
- Solar thermal collector sizing for water heating:
  - 1m²/one inhabitant
- Solar azimuth: 0° (South)
- Collector angle: 30°
- Efficiencies:
  - Flat plate collector: 30%
  - Vacuum tube collector: 45%

ANALYSIS
BEHAVIOUR – TEMPERATURE – COOLING

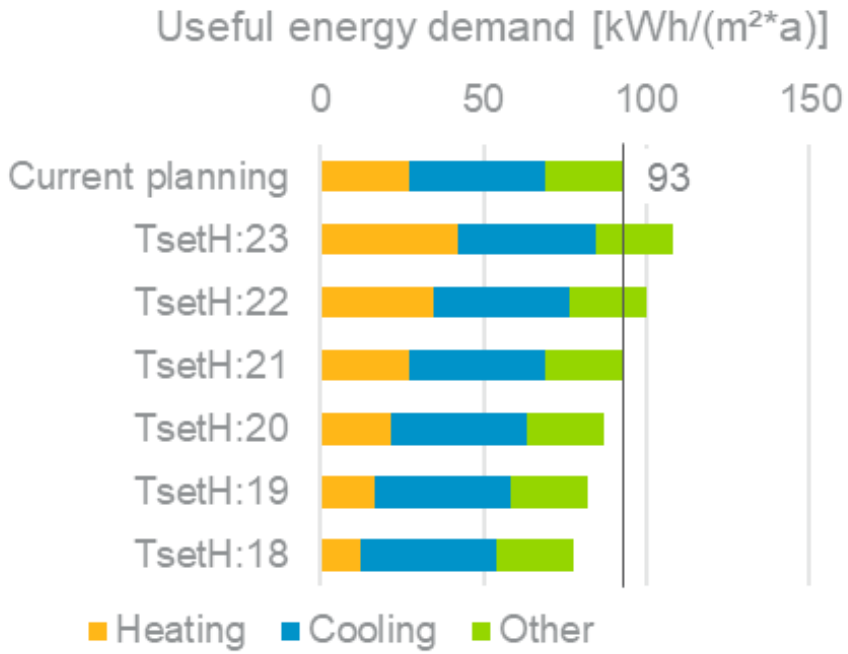
Measure 7a	Behaviour
Adjustments: Cooling	What is the cost saving potential of an adjusted setting temperature



Increasing the set temperature for cooling by 1 K can save up to 16% of energy for cooling. Up to 26°C can still be considered a healthy indoor climate.

ANALYSIS
BEHAVIOUR – TEMPERATURE – HEATING

Measure 7b	Behaviour
Adjustments: Heating	What is the cost saving potential of an adjusted setting temperature



Allowing for lower set temperatures for heating than the current baseline of 21°C can save up to 20% of heating energy per 1 K.

ANALYSIS
FINDINGS OF SENSITIVITY ANALYSIS OF EE/RE MEASURES

No	Measure	Question	
1a	Windows (U-Value; G-Value)	What is the most energy efficient U-Value/G-Value?	
1b	Window fraction	What is the most energy efficient window fraction per orientation?	As little as possible
2	Shading	What is the effect of shading?	
3	Air tightness	What is the effect of air tightness?	-4% per 0.05/h
4	Cooling supply system	What is the cost optimal efficiency for cooling? [COP]	5.0
5	Lighting	What is the cost optimal type of lighting?	LED
6	RE (solar energy)	Is the installation of solar energy cost efficient?	Yes: PV, ST, PV+ST
7	A) Cooling	What is the energy saving potential of an adjusted setting temperature?	-16% per +1K
	B) Heating	What is the energy saving potential of an adjusted setting temperature?	-20% per – 1K

BRONZE PACKAGE
MEASURES

Measure	Baseline
Roof insulation (U-Value)	0.55 W/m²K
Wall insulation (U-Value)	0.57 W/m²K
Floor insulation (U-Value)	0.8 W/m²K
Windows (U-Value; G-Value)	5.7 W/m²K; 0.85
Window fraction	Ø 11%
Shading	No
Air tightness	0.25 1/h
Heat supply	**Reversible split unit - COP 3.0**
Cold supply	**Reversible split unit - COP 3.0**
Hot water	Electric instantaneous
Ventilation systems	Natural ventilation
Lighting systems	**LED**
Renewable energy	No
Set temperature cooling/heating	**26°C/20°C**

The Bronze package incorporates improved heat and cold supply efficiencies, LED lighting, and adapted set temperatures.

BRONZE PACKAGE
RESULTS

Variant Bronze: Low Cost

The low cost package (bronze) consists of three main measures:

Setting temperature

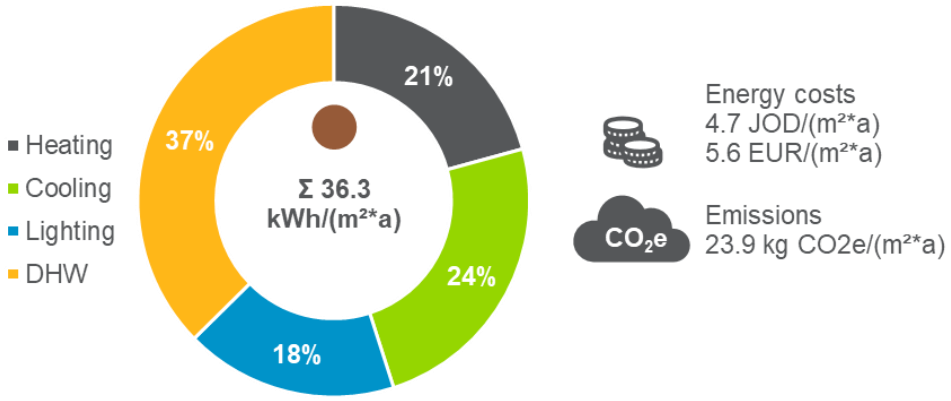
- Reduce heating setting temperature to 20°C
- Increase cooling setting temperature to 26°C

Lighting efficiency: Use LEDs

Cooling and heating efficiency: Increase COP to 3.0

They offer the best cost-efficiency in terms of energy savings and paybacks due to lower energy costs. The payback time for this variant is lower than 2 years.

Energy Demand, Energy Costs, and GHG Emissions: Bronze Package



The chart shows the various shares for energy costs and the greenhouse gas emissions that go along with the bronze package. With a total share of 37%, the domestic hot water supply represents the largest portion of the energy demand. It is almost as high as cooling and heating combined. These areas, with the specific setting temperatures, add up to 24% on the cooling and 21% on the heating side. The smallest, with 18% share, is lighting. In its combination the bronze package will reach an energy demand of 36.3 kWh/(m²*a) and an environmental impact of 23.9 kg CO_2e/(m²*a). Taken a unit of 90 m² the energy cost will reach approximately a monthly rate of €42.11 or 35.39 JOD. In comparison to the investment costs of the standard package, the grand total is increased by 23.93%. However, the energy costs are reduced by 29.38%. The reductions only take place in the heating, cooling, and lighting sector and lead to a high domestic hot water share.

SILVER PACKAGE
MEASURES

Measure	Baseline
Roof insulation (U-Value)	0.55 W/m²K
Wall insulation (U-Value)	0.57 W/m²K
Floor insulation (U-Value)	0.8 W/m²K
Windows (U-Value; G-Value)	**1.2 W/m²K; 0.65**
Window fraction	Ø 11%
Shading	**Overhang South**
Air tightness	0.25 1/h
Heat supply	**Reversible split unit - COP 5.0**
Cold supply	**Reversible split unit - COP 5.0**
Hot water	Electricity /**solar thermal 45%**
Ventilation systems	Natural ventilation
Lighting systems	**LED**
Renewable energy	**PV**
Set temperature cooling/heating	**26°C/20°C**

The Silver package incorporates more efficient windows, static shading, further improved heat and cold supply efficiencies, LED lighting, and adapted set temperatures.

SILVER PACKAGE
RESULTS

Variant Silver: Moderate

The moderate package (silver) consists of some implemented measures from the bronze variant and further additional measures:

Setting temperature

- Reduce heating setting temperature to 20°C
- Increase cooling setting temperature to 26°C

Lighting efficiency: Use LEDs

Cooling and heating efficiency: Increase COP to 5.0

PV modules on roof

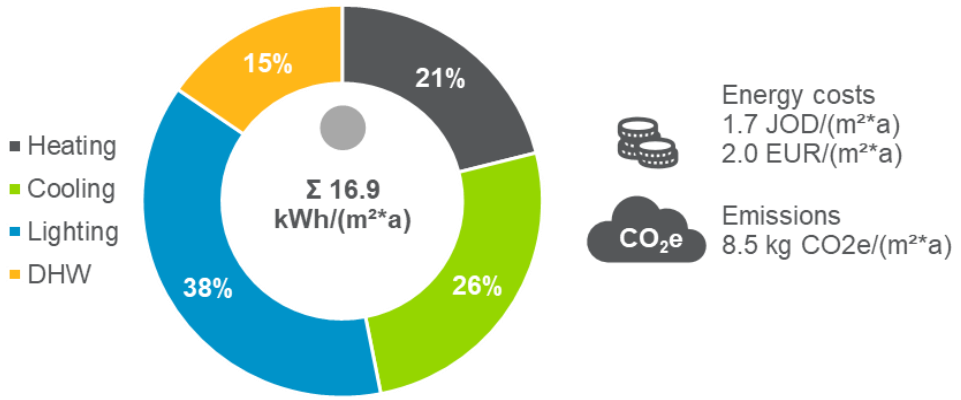
Solar thermal (vacuum tubes)

Low E Glazing (U-value 1.2 W/m²K)

Overhangs for south orientated windows

These measures still offer high energy savings and moderate paybacks, while the payback time for the package is lower than 5 years.

Energy Demand, Energy Costs, and GHG Emissions: Sliver Package



With a total share of 38%, the lighting represents the largest portion of the energy demand. The cooling demand follows with 26% and the heating with 21%. The domestic hot water supply generates a 15% share. With this combination the silver package will reach an energy demand of 16.9 kWh/(m²*a) and an environmental impact of 8.5 kg CO_2e/(m²*a). Taking a unit of 90 m² the energy cost will reach approximately a monthly rate of €14.96 or 12.57 JOD. In comparison to the investment costs of the standard package, the grand total is increased by 290.5%. However, the energy costs are reduced by 75%. The reductions happen in all sectors that are represented in the chart. Unlike the standard and bronze approaches, the silver approach also achieves reductions for domestic hot water and additional savings using PV.

Given the higher investment costs and the decreased monthly energy cost rates, an approximatively payback time is set at 4 years.

GOLD PACKAGE
MEASURES

Measure	Baseline
Roof insulation (U-Value)	0.4 W/m²K
Wall insulation (U-Value)	0.55 W/m²K
Floor insulation (U-Value)	0.8 W/m²K
Windows (U-Value; G-Value)	**0.8 W/m²K; 0.50**
Window fraction	Ø 11%
Shading	**Automatic; not towards North**
Air tightness	**0.05 1/h**
Heat supply	**Reversible split unit - COP 5.0**
Cold supply	**Reversible split unit - COP 5.0**
Hot water	Electricity/**solar thermal 45%**
Ventilation systems	Natural ventilation
Lighting systems	**LED**
Renewable energy	**PV**
Set temperature cooling/heating	**26°C/20°C**

The Gold package incorporates more high performance windows, automated shading, highly efficient heat and cold supply efficiencies, LED lighting, adapted set temperatures, and onsite solar heat and power generation.

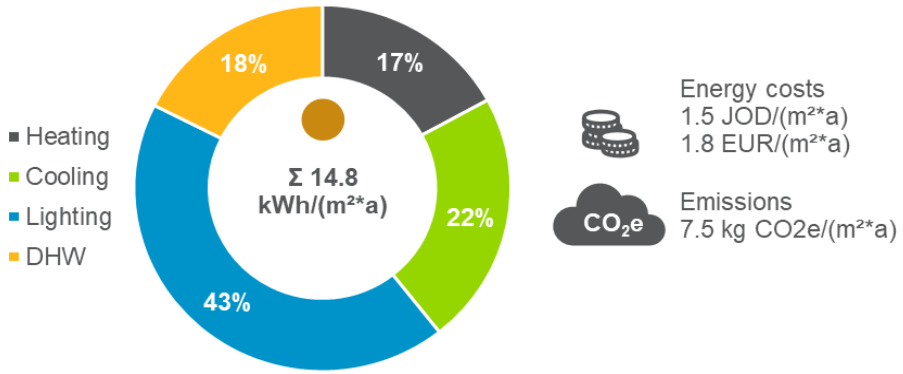
GOLD PACKAGE
RESULTS

Variant Gold: Highly Energy Efficient
The highly energy efficient package (gold) consists of the following measures:

- Setting temperature (20°C heating/26°C cooling)
- Lighting efficiency (LED‘s)
- Cooling and heating efficiency (COP at 5.0)
- PV modules on roof
- Solar thermal (vacuum tubes)
- Triple Glazing (U-Value 0.8 W/m²K)
- Automatic shading
- Higher air tightness (air infiltration rate 0.05 1/h)

These measures offer high energy savings but are bound to high investments costs, which leads to payback times of 15 years.

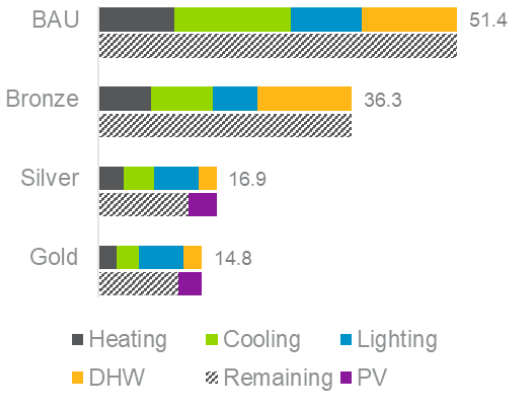
Energy Demand, Energy Costs and GHG Emissions: Gold Package



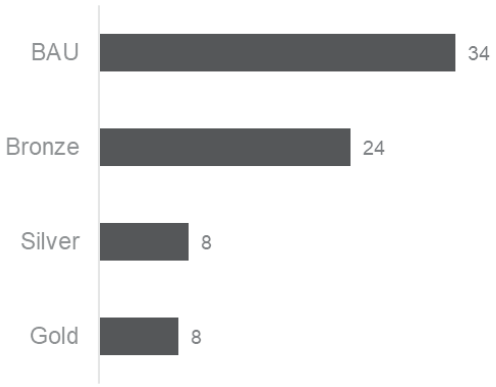
The chart above shows the various shares for the different demand aspects. In this scenario the lighting share generates by far the biggest portion on the demand side with 43%. Cooling with 22% and heating with 17% are not even in combination as high as the lighting share. The domestic hot water share reaches 18%. In total, 14.8 kWh/(m²*a) are used in this approach and 7.5 kg of CO_2e/(m²*a) are released.
The investment costs are about 445.2% higher than the standard approach and the energy cost reduction reaches 77.8%. For a unit of 90m², this would lead to a monthly energy rate of €13.23 or 11.12 JOD.

RESULTS
COMPARATIVE OVERVIEW

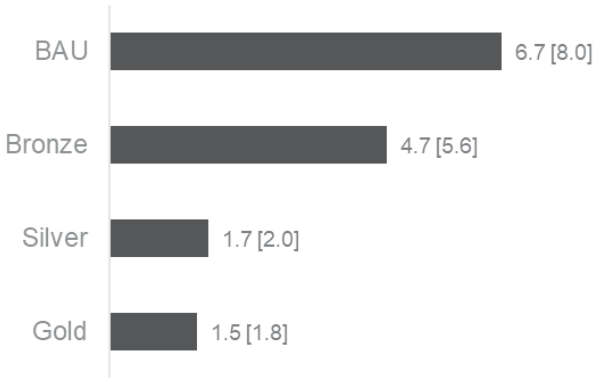
Specific final energy demand [kWh/(m²*a)]



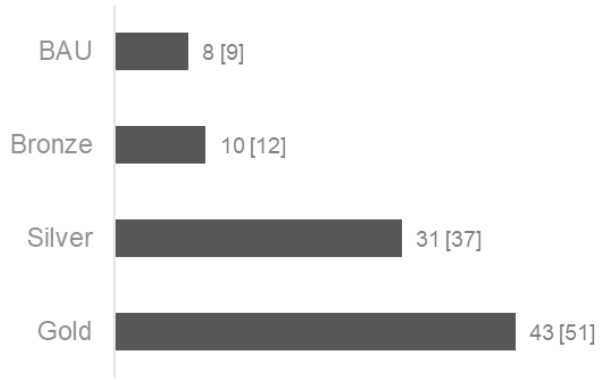
Specific emissions [kg CO2e/(m²*a)]



Specific energy costs JOD/(m²*a) [EUR/(m²*a)]



Specific investment costs JOD/(m²*a) [EUR/(m²*a)]



RECOMMENDATIONS AND NEXT STEPS

- The silver package combines high energy and CO_2 savings with reasonable investment efforts. To achieve the calculated results the following approach should be followed:
  - Reduce energy demand:
    - Raise the awareness of the inhabitants for the appropriate setting temperature
      - Conceive flyers and trainings
    - Invest in low energy windows (U-values 1.2 W/m²K)
    - Investigate in overhangs towards the south
      - Recheck the shading of the surrounded buildings on the southern facade
  - Utilise solar energy on the roof
    - Foresee not shaded space on the roof towards the south (e.g., water tanks, satellite dishes) for the installation of PV/solar collectors
    - Verify the cost benefits of PV and solar thermal, checking offers of local suppliers
  - Maximise energy efficient appliances and lighting
    - Utilise reversible split units with a COP minimum of 5
    - Use LED for lighting purposes

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