BYBLOS SEASIDE RESIDENCE, LEBANON

PILOT PROJECT FOR THE IKI PROJECT: ACCELERATING ZERO-EMISSION BUILDING SECTOR AMBITIONS IN THE MENA REGION

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

LCEC

NAVIGANT

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INTRODUCTION

Byblos Seaside Residence

The Byblos Seaside Residence is the second project developed by Forefront Development. For this ambitious project, Forefront gathered a team with a sense of esthetics and sustainability. The team is composed of Samir Khairallah & Partners architects and Design Engineering Partners. The residence is situated in Byblos at the waterfront and offers chalets/apartments/villas ranging from 70 m^2-180 m^2. With these offerings, Forefront is responding to the current needs of the Lebanese real estate market. Due to the possibility of combining more than one unit, it serves functional and flexible solutions for its clients.

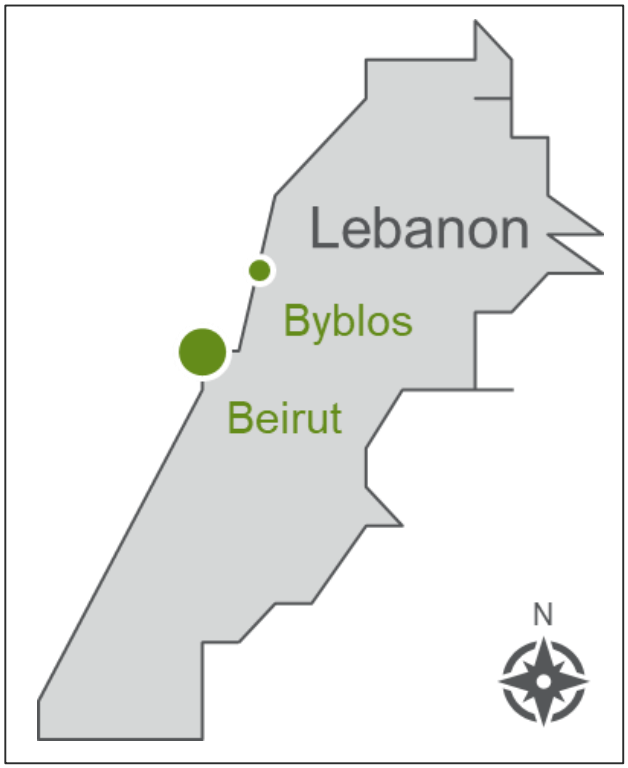
METHODOLOGY

- Objectives
  - Identify the baseline (energy consumption of **B**usiness **a**s **U**sual - BaU) and its comparison with the current planning
  - Determine low hanging fruits
  - Elaborate nearly zero-energy building (nZEB) solutions and its incremental costs

- Methodology
  - Data gathering (technical and economic inputs)
  - Simulate the Business as Usual (BaU) and current planning
  - Analyse sensitivities of energy efficiency (EE) measures
  - Check cost-benefits of promising EE/RE measures
  - Cluster EE/RE measures along its economic feasibility (Payback Period - PBP, NPV) (**P**ay**b**ack **p**eriod - PBP, **N**et **P**resent **V**alue - NPV)
  - Conceive a nZEB (nearly zero energy building) package

BOUNDARY CONDITIONS
SITE

Location of Project Site



Location of the Seaside Residences

Source: Google Maps

BOUNDARY CONDITIONS

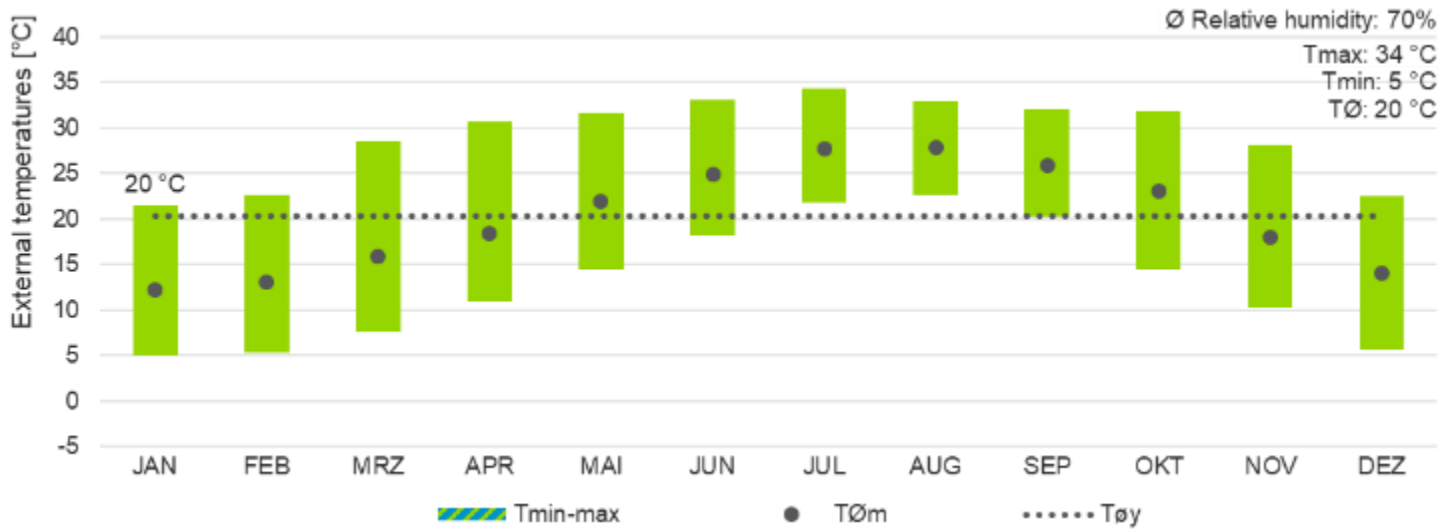
SITE

The project site of the Byblos Seaside Residence is located in the middle of two residential gated communities: Byblos Sud and Byblos Beach Village. Byblos Sud has been completed and is sold out, while Byblos Beach Village is almost completed.

The Seaside Residence has an area of around 9,100 m² and is easily accessible from the road. The site has a slight slope starting from around 3 m up until around 12 m.

BOUNDARY CONDITIONS
CLIMATE

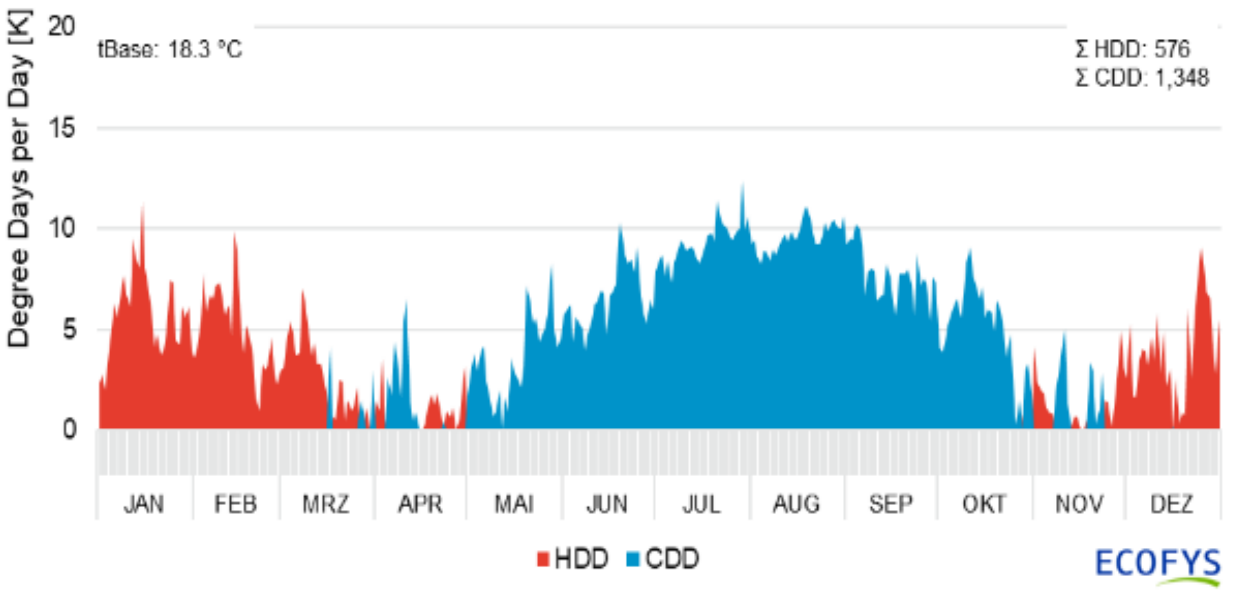
Monthly Average, Minimum, and Maximum External Temperatures in Byblos



The climate at the project site in Byblos is primarily warm and humid. External temperatures range from 5°C above 0°C to 34°C, with average temperatures around 20°C. January is the coldest month while temperatures on average are highest in August. Temperatures do not fall below 0°C which means that frost issues do not play a role in terms of construction projects.

BOUNDARY CONDITIONS
CLIMATE

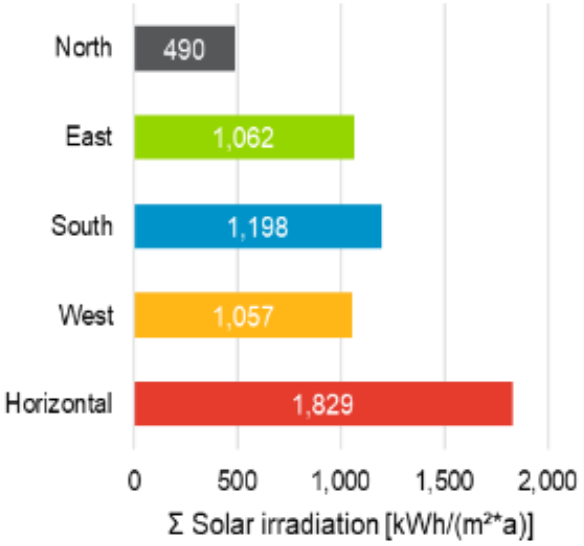
Heating Degree Days (HDD) and Cooling Degree Days (CDD) in Byblos (Lebanon), Calculated per ASHRAE

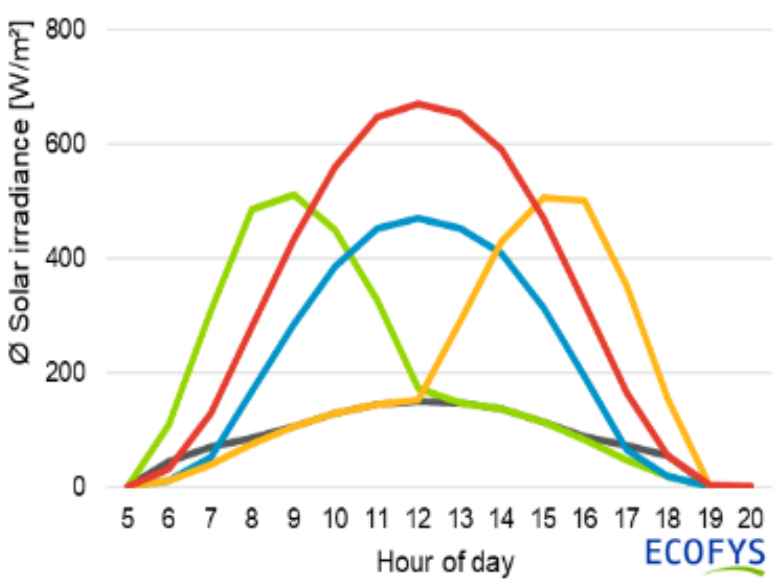


The demand for cooling prevails against heat demand as the high number of >1,300 CDDs. The cooling degree days are 2 times higher than the HDDs. The monthly average relative humidity is above 65% but may also reach >70% in the summer months.

BOUNDARY CONDITIONS
CLIMATE

Solar Irradiation in Byblos





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. Especially the horizontal solar radiation promises a high potential for the utilisation of solar energy.

BOUNDARY CONDITIONS

ENERGY PRICE AND CO2 FACTOR

Parameter	Unit	Electricity	Diesel	Natural gas	GenSets
Energy price	LBP/kWh	187	87	87	340
Energy price	EUR/kWh †	0.11	0.05	0.05	0.20
Price develop-ment	%/year	2%	2%	2%	2%
CO_2 emission factor	gCO_2/kWh	806	310	220	713

† applied exchange rate: 1 EUR = 1,700 LBP

BOUNDARY CONDITIONS
BASELINE – BUILDING INFORMATION

Criteria	Input
Utilisation:	Residential
Number of (expected) inhabitants	20
Year of construction	2018/2019
Number of floors	5 (3 residential plus garage)
Number of apartments	6
Conditioned floor area	567 m^2
Clear room height	2.85 m
Conditioned volume	2,022 m^3
Roof area	220 m^2
Net wall area	450 m^2
Floor area	220 m^2
Window fraction per orientation (N/E/S/W) in m^2	12/82/0/84

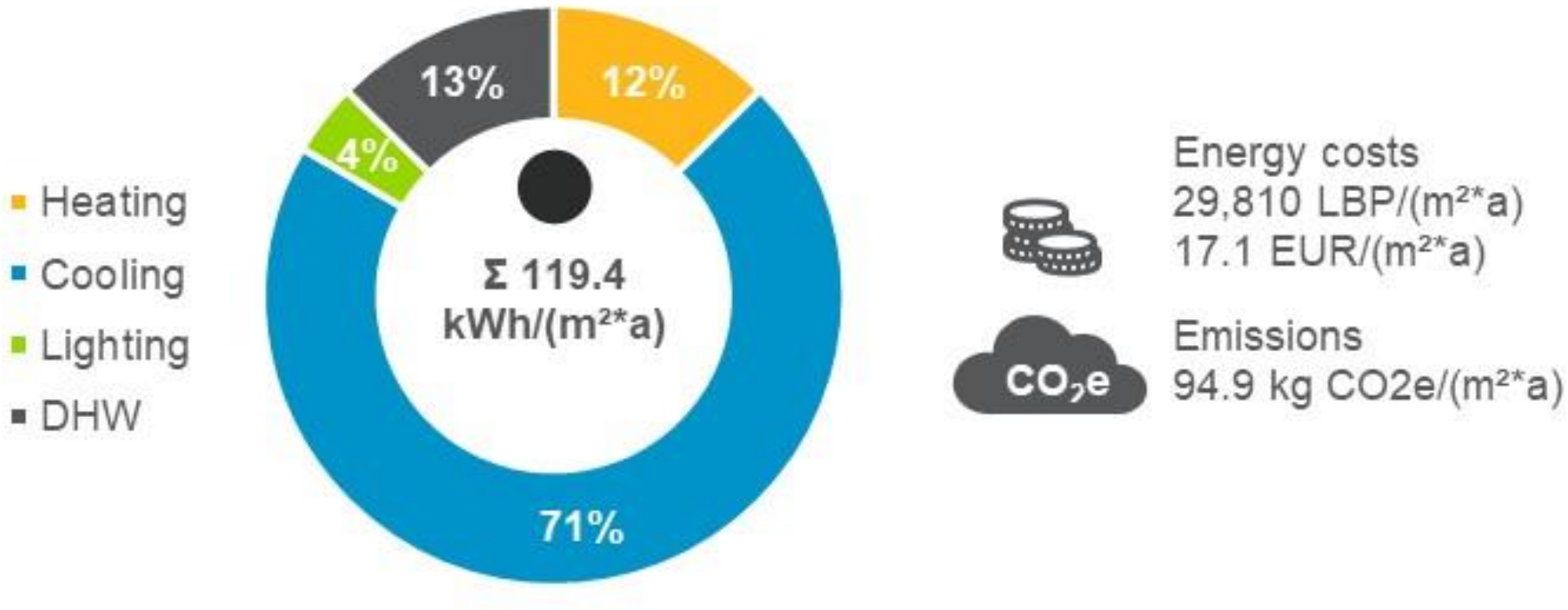
ANALYSIS
VARIANTS INTRODUCTION

- **Baseline**
  - Business as Usual reflects the current state of construction in the respective country. It might even deviate from technical regulations if the construction practice does not respect it. This variant will be seen in further analysis as the baseline.
- **Current Situation**
  - This variant illustrates the current planning of the project developer, including the selected energy concept (U-Values, HVAC efficiencies, lighting efficiencies etc.).
- **Variant 1: Short Payback**
  - This variant includes EE/RE measures with a simple payback lower than 2 years, so called low hanging fruits.
- **Variant 2: nZEB**
  - This variant describes a nearly zero energy building (nZEB), which reduces the energy consumption to a maximum and satisfies the limited demand with the renewable energies.

ANALYSIS - BASELINE
ENERGY RELEVANT INFORMATION

Measure	Baseline
Roof insulation	4 W/m²K
Wall insulation	1 W/m²K
Floor insulation	3 W/m²K
Windows	5.7 W/m²K, g = 0.85
Thermal mass	Medium
Shading	No
Heating systems	Reversible split unit - COP 2.5
Cooling systems	Reversible split unit - COP 2.5
Hot water	Electric
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Temperature setpoint: Heating	21°C
Temperature setpoint: Cooling	23.9°C
Air leakages/infiltration	0.25 1/h
Window fraction (average)	47%

ANALYSIS - BASELINE
ENERGY RELEVANT INFORMATION

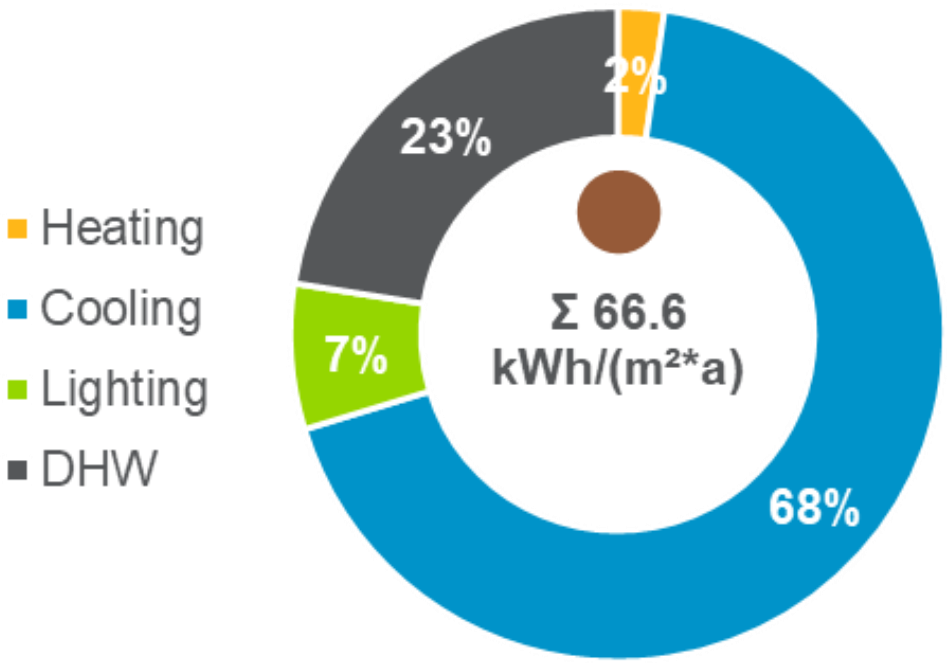


Almost three quarters of a buildings final energy demand in Byblos account for space cooling.

ANALYSIS – CURRENT SITUATION
ENERGY RELEVANT INFORMATION

Measure	Current Situation
Roof insulation	**1 W/m²K**
Wall insulation	**0.57 W/m²K**
Floor insulation	3 W/m²K
Windows	**2.5 W/m²K, g = 0.65**
Thermal mass	Medium
Shading	Overhangs
Heating systems	**4 pipe heat pump system - COP 3.5**
Cooling systems	**4 pipe heat pump system - COP 3.3**
Hot water	Electric
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Temperature setpoint: Heating	21°C
Temperature setpoint: Cooling	24°C
Air leakages /infiltration	0.25 1/h
Window fraction (average)	47%

ANALYSIS – CURRENT SITUATION
ENERGY RELEVANT INFORMATION



Energy costs
16,635 LBP/(m²*a)
9.5 EUR/(m²*a)

CO_2e

Emissions
53.0 kg CO2e/(m²*a)

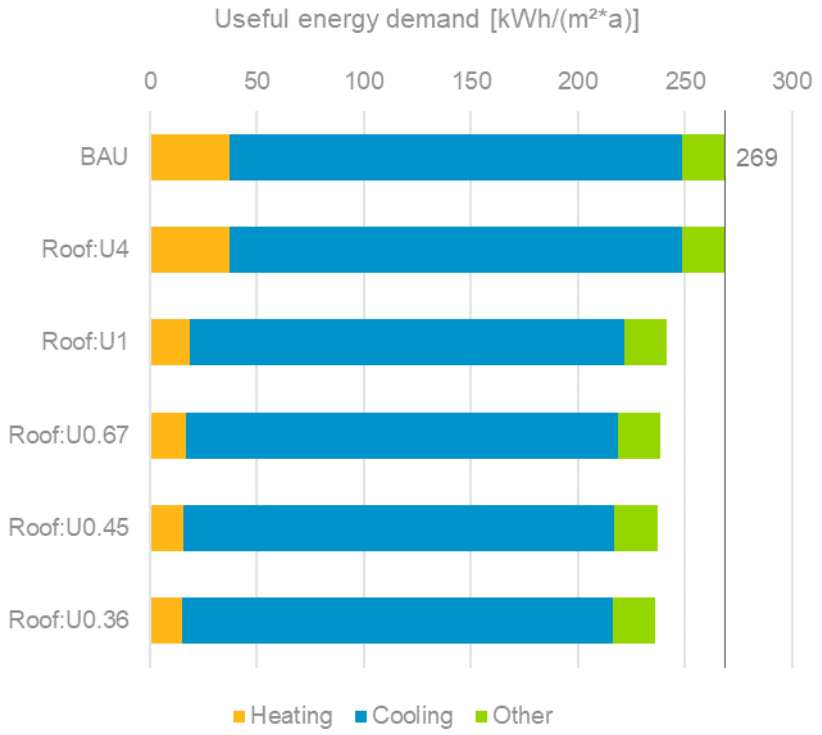
The pilot project as currently planned will consume only halve of the final energy than buildings representing the common construction practice in Byblos/Lebanon.

ANALYSIS
SENSITIVITY ANALYSIS OF EE/RE MEASURES

No	Measure	Question
1a	Roof insulation (U-Value)	What is the effect of higher energy efficiency?
1b	Wall insulation (U-Value)	What is the effect of higher energy efficiency?
1c	Roof and wall insulation (U-Value)	What is the effect of higher energy efficiency?
2a	Windows (U-Value; G-Value)	What is the effect of higher energy efficiency? U-Value/G-value
2b	Window fraction	What is the most energy efficient window fraction per orientation?
3	Shading	What is the effect of shading?
4	Air tightness	What is the effect of air tightness?
5	Varied heating and cooling supply system	What is the cost efficient heating and cooling system?
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
PASSIVE MEASURES ROOF

Measure 1a	Thermal Insulation
Roof insulation	What is the effect of higher energy efficiency?

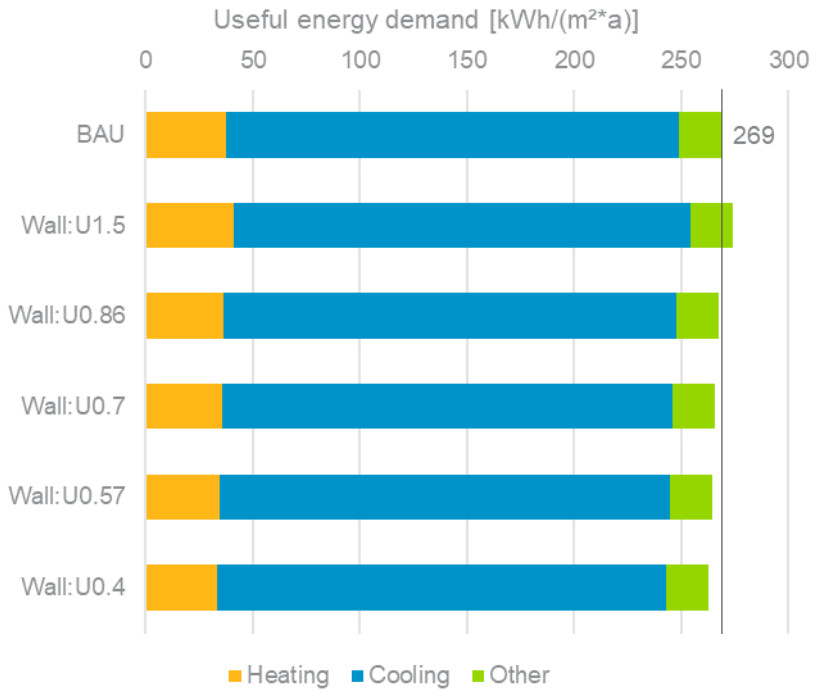


Thermal roof insulation is recommended up to the point where the energetic benefits outweigh the investment.

A reduced U-value of 1 W/m²*K has a significant effect on the overall energy demand. However, the saving span of 1 to 0.36 W/m²*K is not so high that it appears reasonable to implement further insulation.

ANALYSIS
PASSIVE MEASURES EXTERNAL WALL

Measure 1b	Thermal Insulation
External wall insulation	What is the effect of higher energy efficiency?

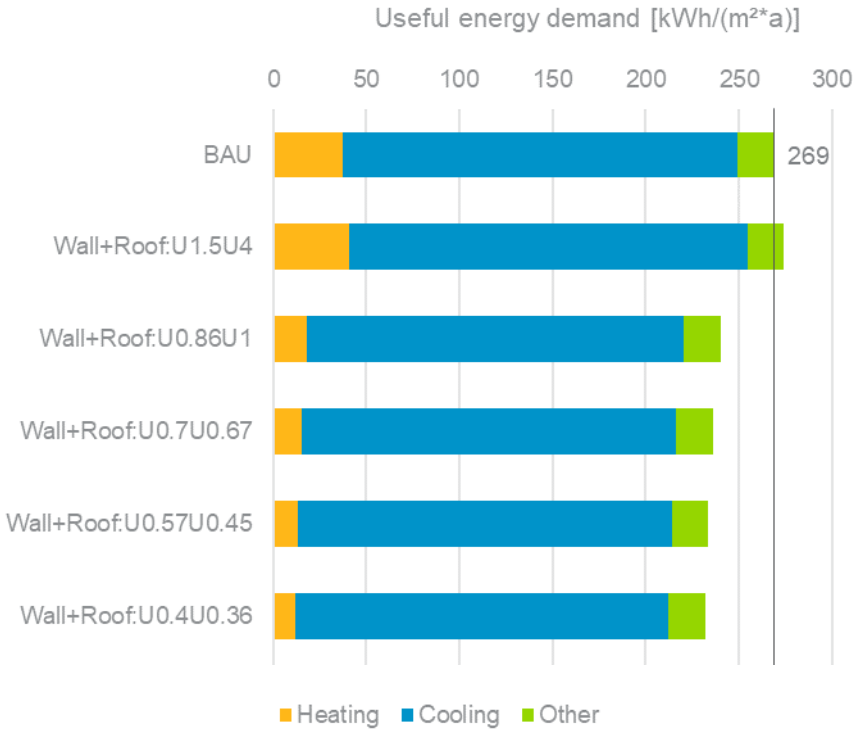


Insulation for the external walls that reach an U-value of 0.86 W/(m²*K) or lower will achieve a lower energy demand than the baseline approach. This stands for a large amount of insulation in comparison to the energetic gains.

It is evident that, just like the roof, external walls are recommended to be insulated. However, the gains that go along with the facade insulation are significantly smaller and therefore should be carefully considered with the costs.

ANALYSIS
PASSIVE MEASURES ROOF + EXTERNAL WALL

Measure 1c	Thermal Insulation
Roof & Wall combination	What is the effect of higher energy efficiency?



The chart shows the effects of the combination of roof and wall insulation on the overall demand for the baseline approach.

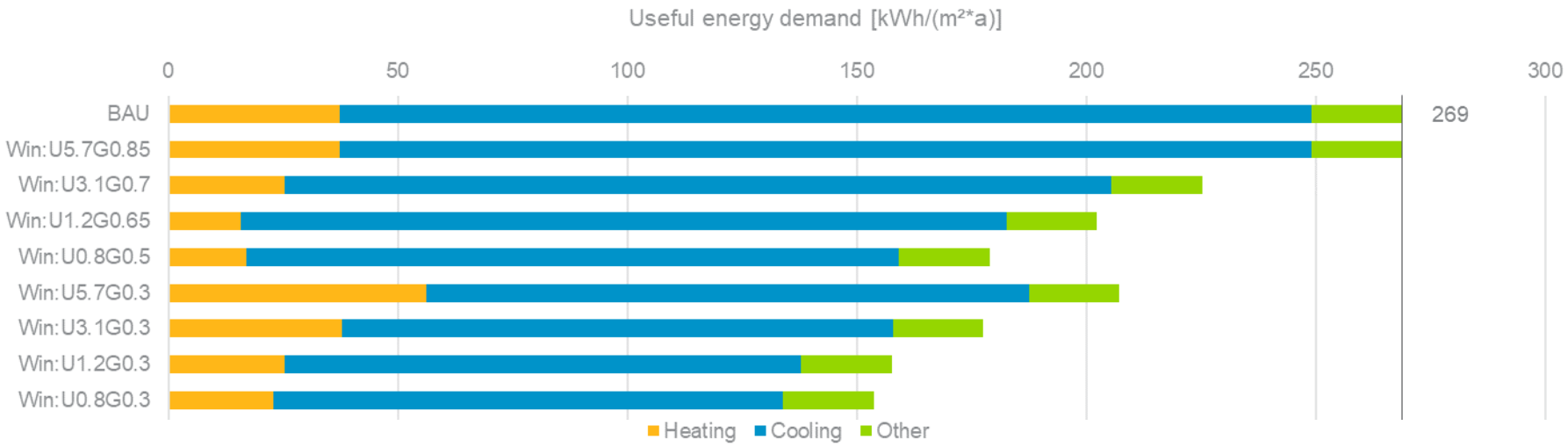
Improving protection against heat transfer will yield energy savings, especially from reducing the heating energy demand. The cooling side is also significant, but the overall impression is that the heating side benefits the most from the improvements.

ANALYSIS
PASSIVE MEASURES - WINDOWS

Measure 2	Energy Efficient Windows
a) Window type	Baseline: U-Value 5.7 | G-Value 0.85 Current Planning: 3.1 | 0.7 Efficiency Approach 1: 1.2 | 0.65 Efficiency Approach 2: 0.8 | 0.5
b) Orientation	The fractions develop the following way: S | N | E | W → 0 | 0 | 0 | 0 With a fraction of 0.1 | 0 | 0 | 0 the simulation calculates for a 10% window fraction on the south side of the building.

The following graph illustrates the final energy demands that go along with different variations of window fractions for the orientations, within the baseline model. The current planning approach is also demonstrated for comparison.

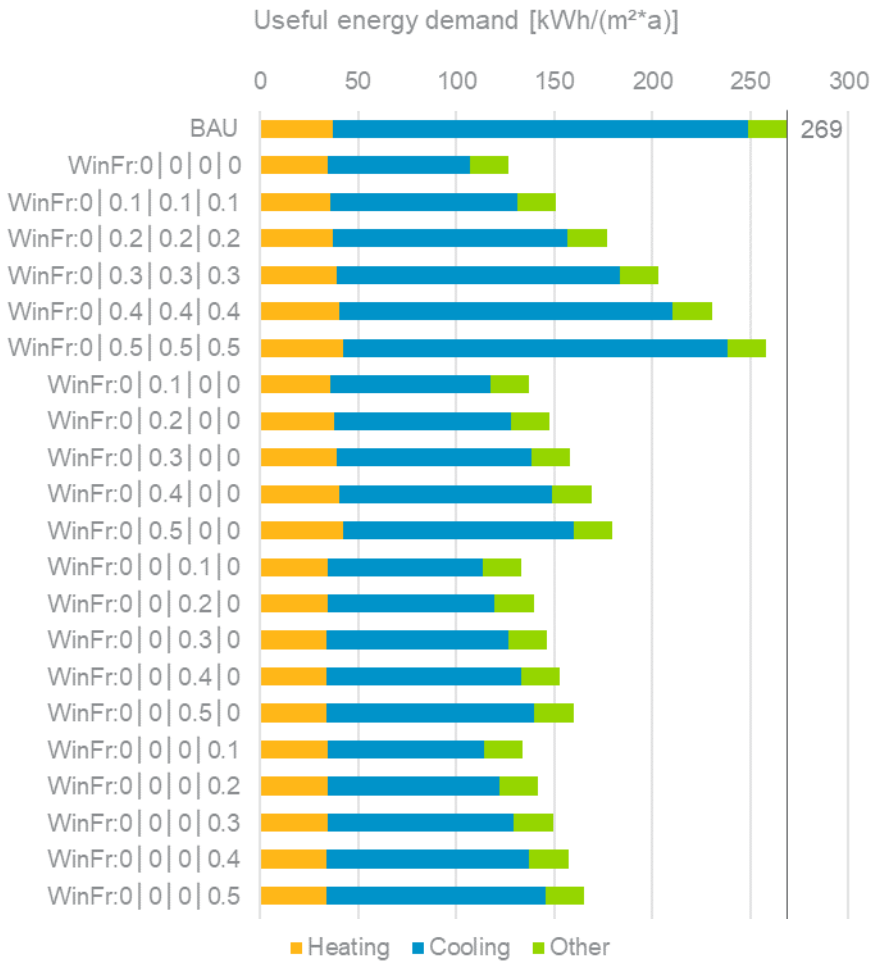
ANALYSIS
PASSIVE MEASURES – WINDOW U-VALUE AND G-VALUE



Better U-, and G-values result in a lower final energy demand for cooling and heating. Therefore it is recommend to use a cost optimal solution for windows, in terms of thermal insulation.

To maintain a good amortisation status, the system should not be too costly and it should reach values between 1.6 and 0.8 W/(m²*K) for U-value and 0.3 for G-value.

ANALYSIS
PASSIVE MEASURES – WINDOW FRACTION



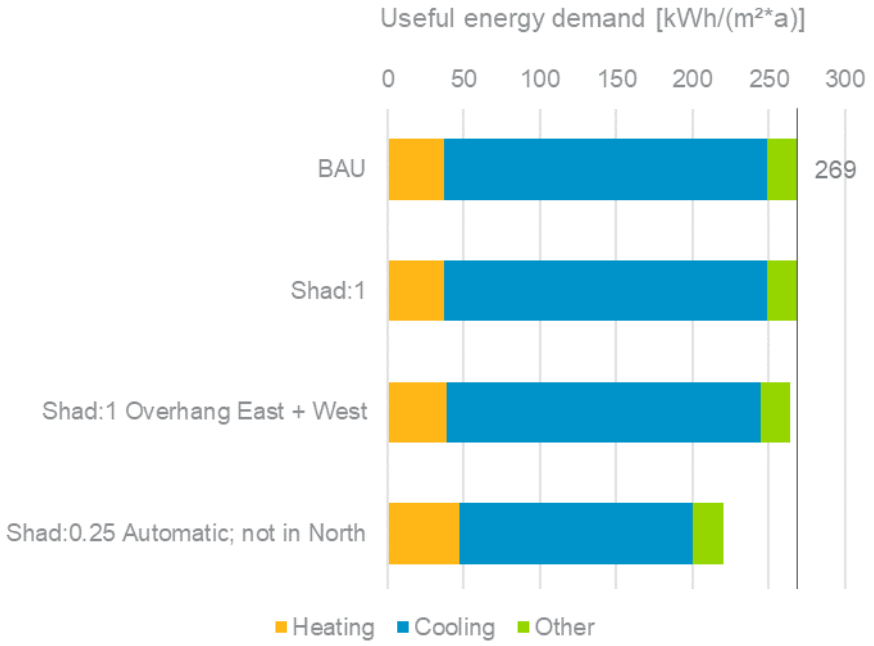
Solar gains are directly connected to a building's window fraction. Increasing the window fraction increases the demand for cooling and reduces the demand for heating. Decreasing the window fraction has the opposite effect.

Since in Byblos the cooling demand prevails, low window fractions are beneficial.

Usually, varying the southern window fraction has larger effects than for the other directions. Since the evaluated pilot project has an attached southern wall, an evaluation for this direction was not reasonable here.

PASSIVE MEASURES – SHADING

Measure 3	Shading
Shading	The shading effect was evaluated for three different variations.

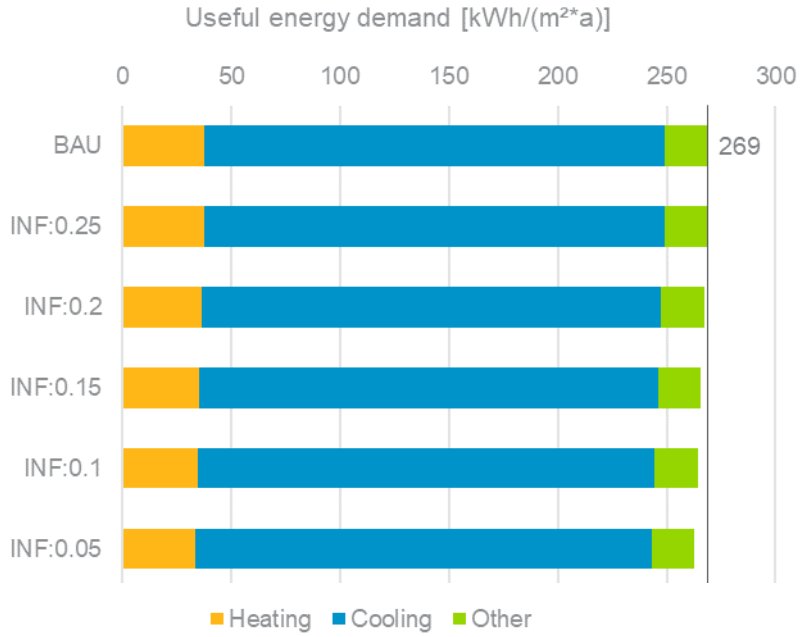


The increase in shading leads to a decrease in the energy demand for cooling. In parallel however, the heating energy demand rises.

It is recommended to install mobile shading devices that hold back about 75% of the direct sunlight. During heating periods, those devices should be moved in order to allow for solar gains.

ANALYSIS
PASSIVE MEASURES – AIR TIGHTNESS

Measure 4	Air Tightness
Air tightness	Infiltration rates have an impact on the energy demand for cooling and heating, as the next graph shows. The rates reach from 0.05 to 0.25 h^{-1}.

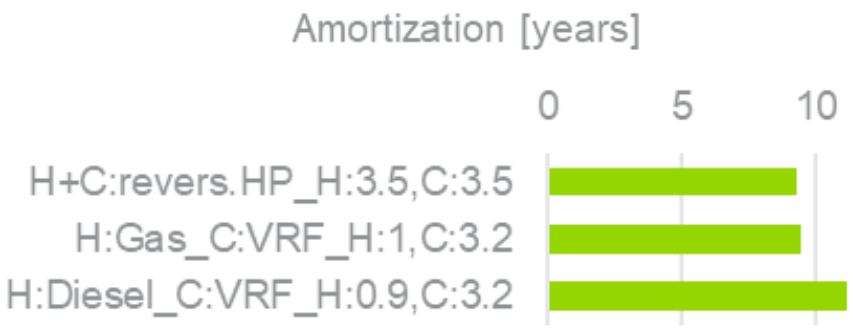


The infiltration rate has only a slight effect on the heating energy demand and a bigger impact on cooling in Byblos.

Due to low expected overall energy savings from improved air tightness, no further actions are recommended.

ANALYSIS
ACTIVE MEASURES (HVAC)

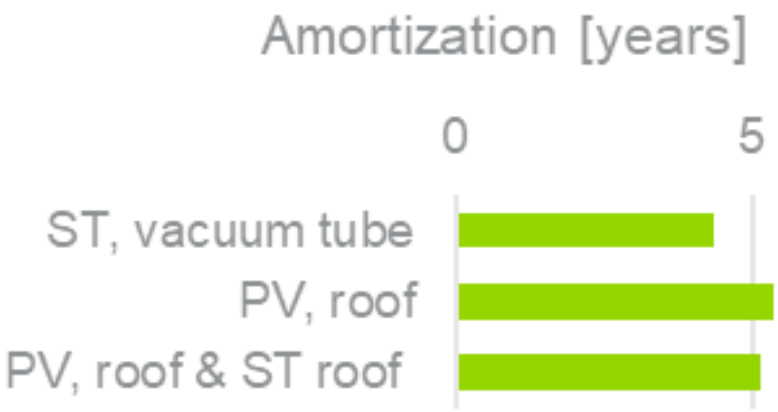
Measure 5	Heating
Active heating	What is the cost-efficient heating system?



Among the three analysed heating systems, reversible heat pumps and condensing gas boilers payback fastest within 10 years.

ANALYSIS
ACTIVE MEASURES (RENEWABLE ENERGY)

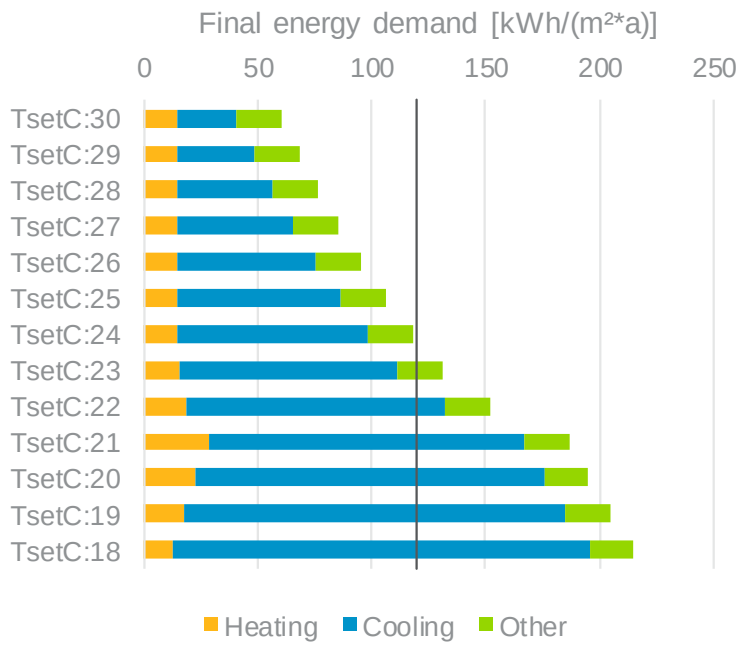
Measure 6	Solar Thermal and PV
Generation	Are renewables economically feasible?



Under local climate and market conditions, the solar thermal applications, PV, and combinations of both appear economically feasible and payback well within their respective lifetimes.

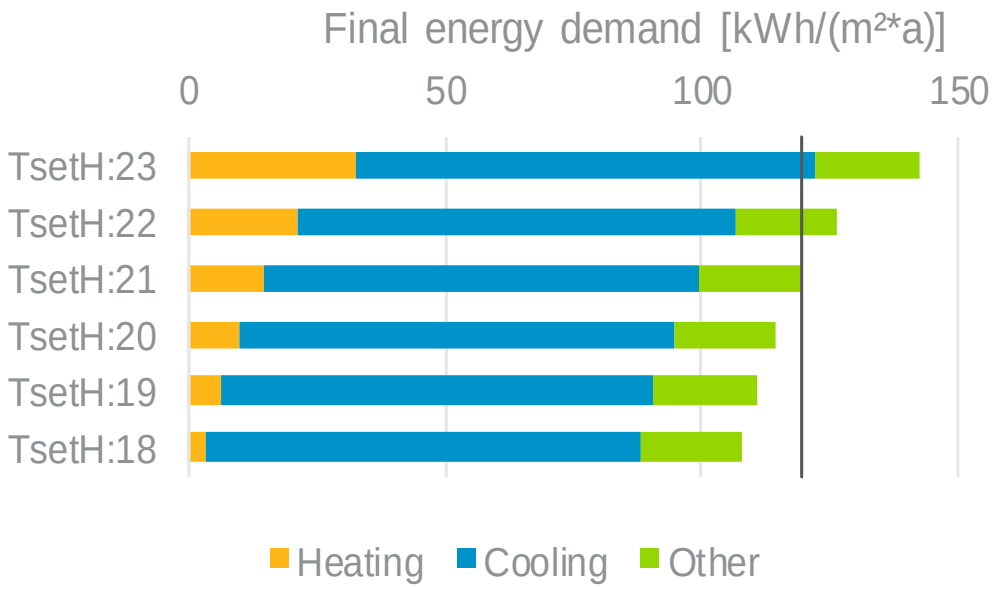
ANALYSIS
BEHAVIOR - SET TEMPERATURE - COOLING

Measure 7	Set Temperatures
Adjustments	The saving potential for set temperatures is huge. For extreme cases, the demand can be cut in less than half.



On average, increasing the set temperature for cooling by 1 K reduces the energy demand for cooling by ~11%.

ANALYSIS
BEHAVIOR - SET TEMPERATURE - HEATING



Lowering the target temperature for heating can yield significant energy savings.

Reducing the target temperature by 1 K leads to a 4% decrease of the energy demand for heating.

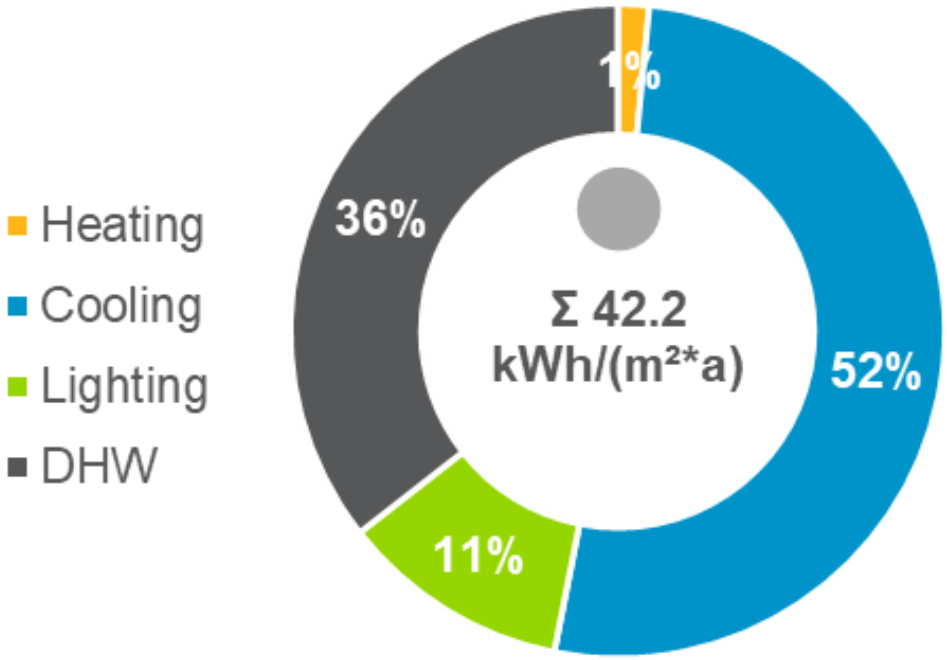
ANALYSIS
FINDINGS OF SENSITIVITY ANALYSIS OF EE/RE MEASURES

No	Measure	Recommendation
1a	Roof insulation (U-Value)	Current planning
1b	Wall insulation (U-Value)	Current planning
1c	Roof and wall insulation (U-Value)	Current planning
2a	Windows (U-Value; G-Value)	1.2/0.3
2b	Window fraction	20%
3	Shading	If no solar glazing/automatic blinds
4	Air tightness	Not strongly recommended
5	Varied heating and cooling supply system	Current planning
6	RE (solar energy)	Solar water heater (SWH) and PV
7	a) Setting temperature cooling	26°C - Possible savings of 4%/K
7	b) Setting temperature heating	20°C - Possible savings of 11%/K

ANALYSIS – SHORT PAYBACK
ENERGY RELEVANT INFORMATION

Measure	Short payback
Roof insulation	**1.0 W/m²K**
Wall insulation	0.57 W/m²K
Floor insulation	3.0 W/m²K
Windows	2.5 W/(m²*K), g = 0.65
Thermal mass	Medium
Shading	Overhangs
Heating systems	4 pipe heat pump system - COP 3.5
Cooling systems	4 pipe heat pump system - COP 3.3
Hot water	Electric
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Temperature setpoint: Heating	**20°C**
Temperature setpoint: Cooling	**26°C**
Air leakages /infiltration	0.25 1/h
Window fraction (average)	**30%**

VARIANTS 1
RESULTS OF SHORT PAYBACK MEASURES



Energy costs
10,537 LBP/(m²*a)
6.0 EUR/(m²*a)

CO_2e

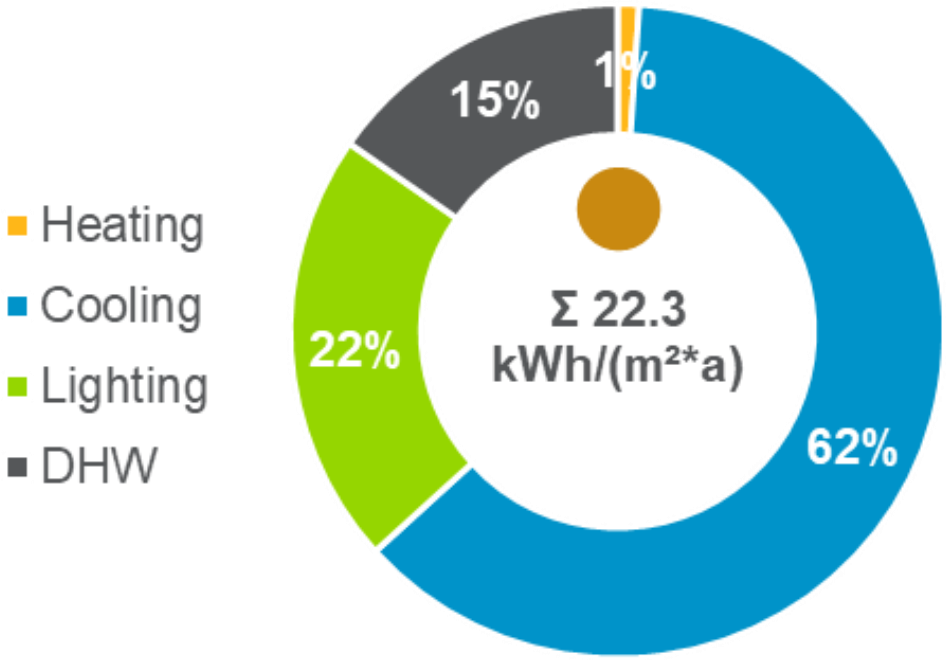
Emissions
33.5 kg CO2e/(m²*a)

The short payback approach results in an energy demand of 42.2 kWh/(m²*a)—a demand decrease of 37% compared to the current planning—and reduced energy cost of 10,537 LBP/(m²*a).

ANALYSIS – NZEB
ENERGY RELEVANT INFORMATION

Measure	nZEB
Roof insulation	**0.36 W/m²K**
Wall insulation	**0.4 W/m²K**
Floor insulation	3 W/m²K
Windows	**1.2 W/m²K, g = 0.6**
Thermal mass	Medium
Shading	**Automatic shading**
Heating systems	4 pipe heat pump system - COP 3.5
Cooling systems	4 pipe heat pump system - COP 3.3
Hot water	**Electric and solar thermal**
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	**PV and solar thermal**
Temperature setpoint: Heating	**20°C**
Temperature setpoint: Cooling	**26°C**
Air leakages /infiltration	0.25 1/h
Window fraction (average)	**30%**

VARIANTS 2
RESULTS OF NZEB VARIANT



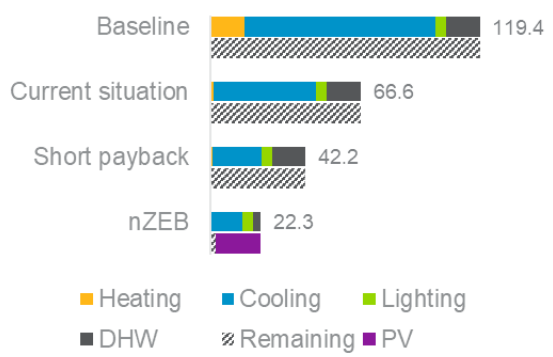
Energy costs
554 LBP/(m²*a)
0.3 EUR/(m²*a)

Emissions
1.8 kg CO2e/(m²*a)

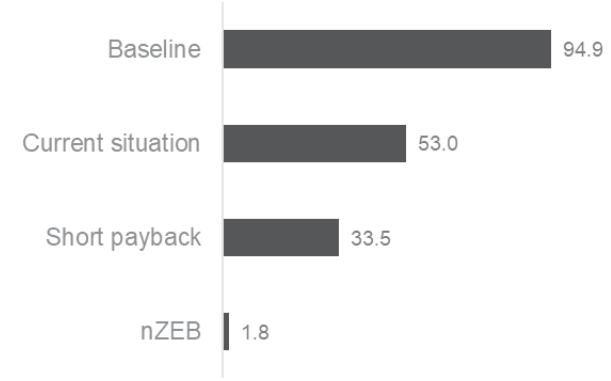
The nearly zero energy approach adds up to 22.3 kWh/(m²*a), that means an overall reduction of almost 67%.

RESULTS
COMPARATIVE OVERVIEW

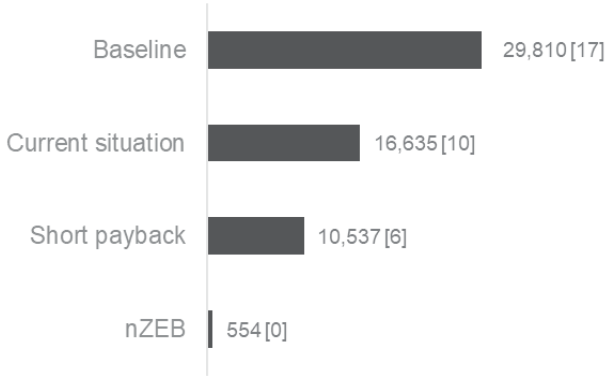
Specific final energy demand [kWh/(m²*a)]



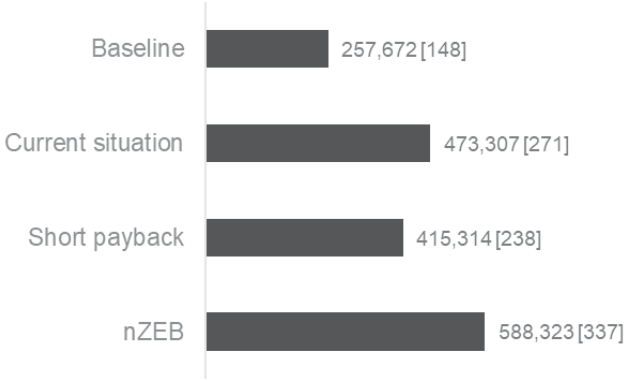
Specific emissions [kg CO2e/(m²*a)]



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



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



RECOMMENDATIONS

- Short-term considerations
  - Consider all short payback measures defined in Variant 1:
    - Reducing window fraction: max. 30%
    - Dissemenate the appropriate selection of setting temperature to end-users:
      - Heating: 20°C
      - Cooling: 26°C

    As these measures are almost cost neutral, it will be simple to implement them.
- Mid-term considerations
  - Consider the utilisation of solar energy (PV and solar thermal), the low PBP (of around 5 years) and the visibilty of solar energy on the roofs supports the sustainability of the site.
    - Furthermore the implementation of solar energy on the roof will enhance the comfort of the roof terraces, if the solar array is lifted in the height of 3 metres.
- Long-term considerations
  - Test-case a nZEB package to be frontrunner in the lebanese built environement and to market the site as a green development.

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