DOLMEN - LAMARTINE HILLS, BHAMDOUN, 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
LEBANESE CENTER FOR ENERGY CONSERVATION
المركز اللبناني لحفظ الطاقة

NAVIGANT

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INTRODUCTION

Perspective of Lamartine Hills

The Lamartine Hills residence is located in the green Lamartine valley. The project offers 21 different types of apartments in 4 blocks, with a private staircase and an elevator. Each block contains 4 stories and one basement floor with a service area. It is built on approximately 600 m² of land and rises 1,050 m above sea level, 25 km from downtown Beirut. The prestigious Bhamdoun market is only a 3-minute drive away and features a medical centre.

METHODOLOGY

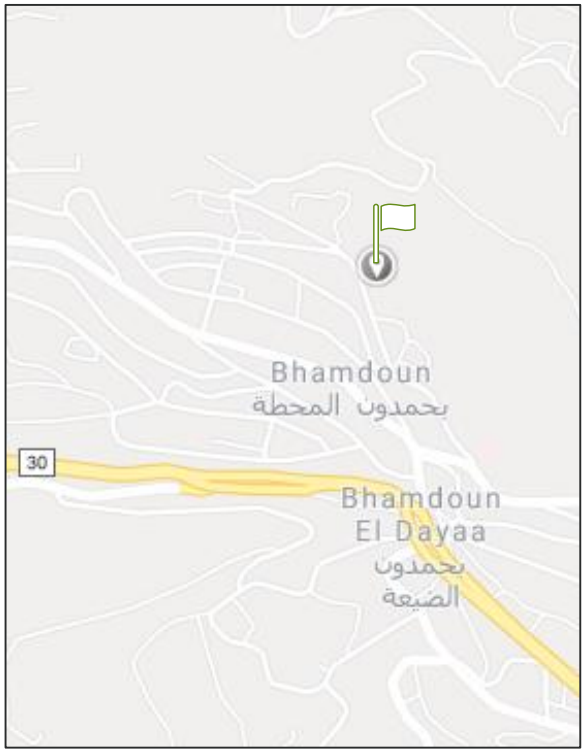
- Objectives
  - Identify the baseline (energy consumption of **B**usiness **a**s **U**sual - BaU) and its comparison with the current planning
  - Determine low hanging fruits
  - Elaborate nearly zero-energy building (nZEB) solutions and its incremental costs

- 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 the Project Site

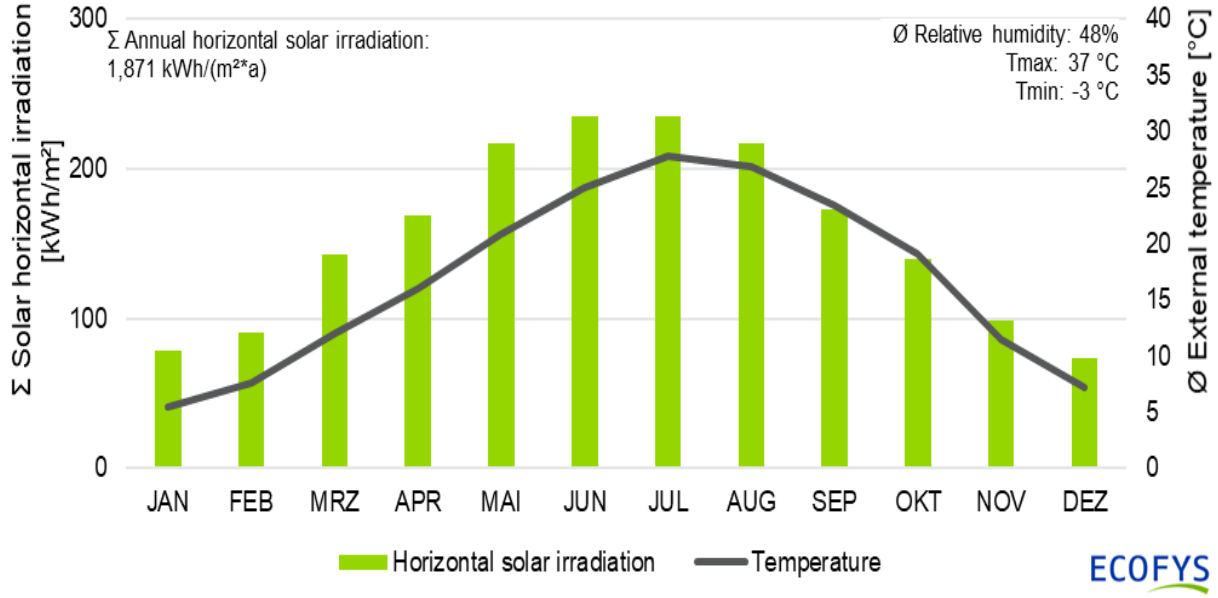
Location of the Apartment Complex



Source: Google Maps

BOUNDARY CONDITIONS
CLIMATE

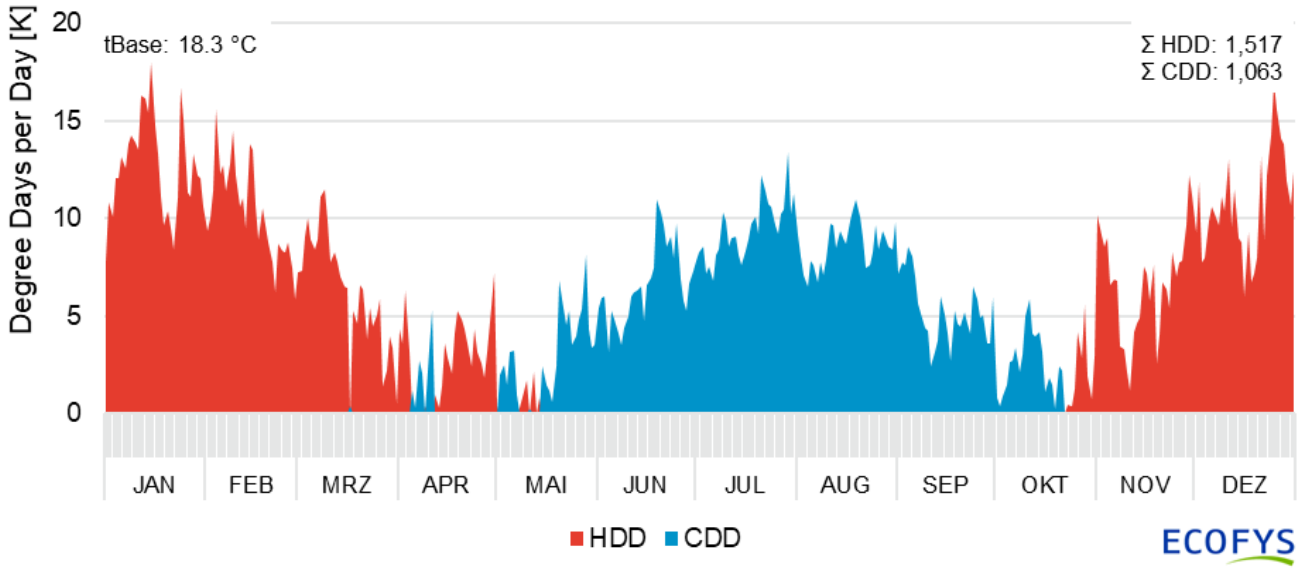
Monthly Solar Irradiation and Average External Temperature in Bhamdoun



The climate at the project site in Bhamdoun is balanced. However, the temperatures can drop to below zero during the winter. External temperatures range from below 0°C to 37°C with average temperatures around 20°C. January is the coldest month, July is the hottest. The minimum temperature level falls below 0°C which means that frost issues play a role in terms of construction projects.

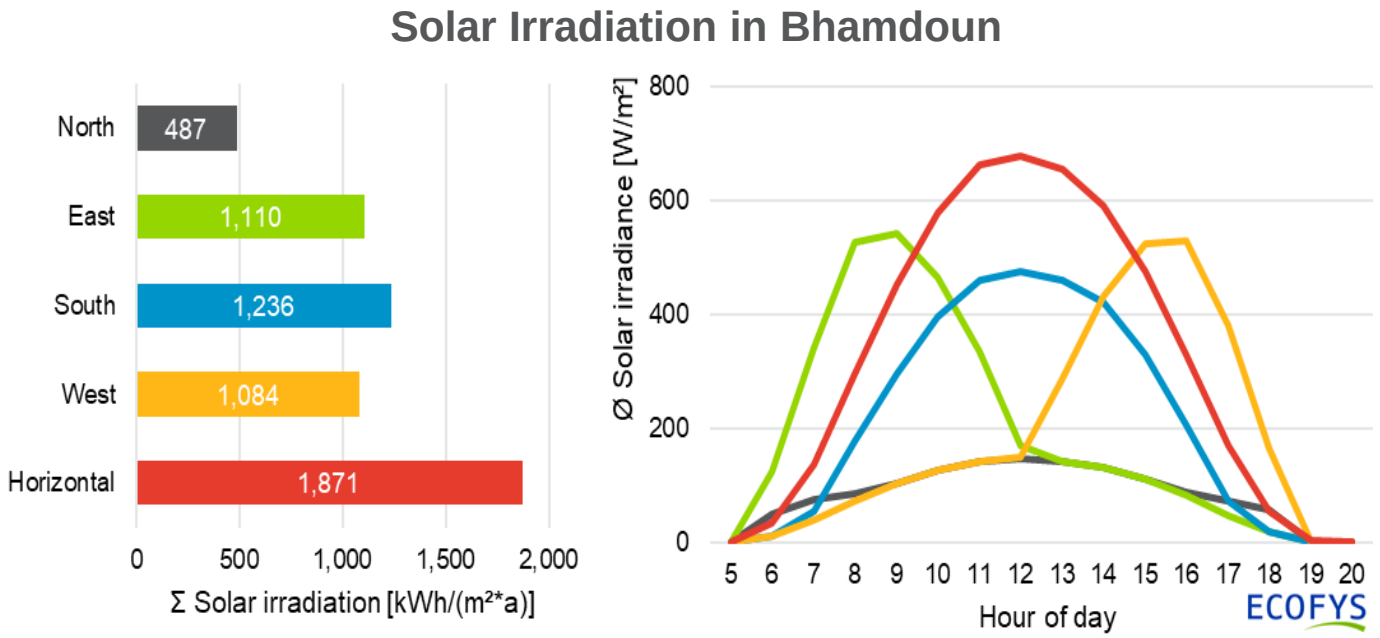
BOUNDARY CONDITIONS
CLIMATE

Heating Degree Days (HDD) and Cooling Degree Days (CDD) in Bhamdoun, Calculated per ASHRAE 2001



This graph displays the calculated HDD and CDD per year. The clear distinction between the heating and cooling periods throughout a year is rather obvious and indicates the demand for both heating and cooling systems within the buildings. Given the high solar irradiation and low precipitation rate, building development can happen in respect to those foreseeable conditions.

BOUNDARY CONDITIONS
CLIMATE



A big potential for renewable energy lies within the solar irradiation in Bhamdoun. Horizontal irradiation of >1,800 kWh/(m²*a) and >1,000 kWh/(m²*a) for each East, South, and West orientation bring opportunities for energy generation through solar radiation and solar air conditioning. The solar thermal potential in particular appears promising.

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	≈32
Year of construction	2018/2020
Number of floors	4
Number of apartments	4
Conditioned floor area	1,408 m²
Clear room height	2.90 m
Conditioned volume	4,083 m³
Roof area	352 m²
Net wall area	704 m²
Floor area	352 m²
Window fraction per orientation (NW/NE/SW) in m²	33/47/27

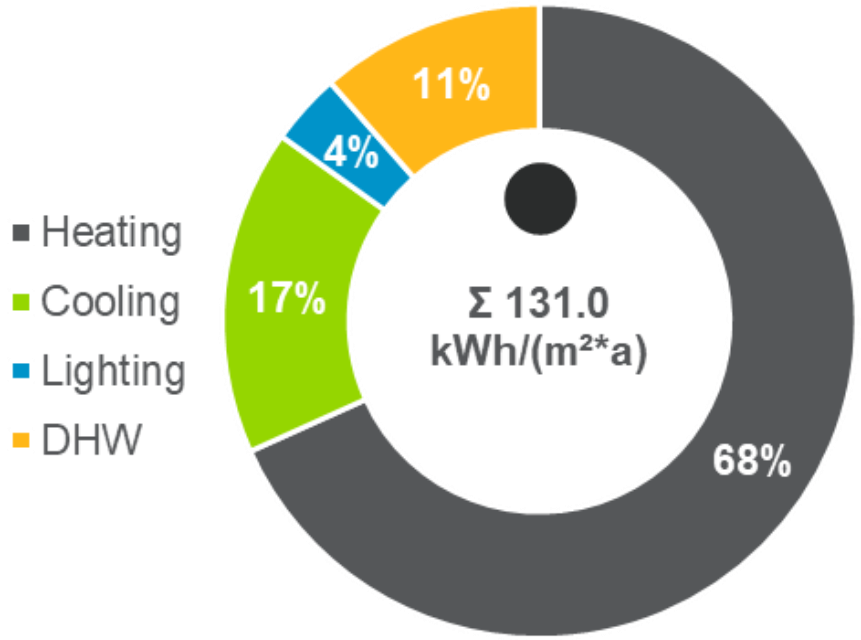
ANALYSIS
VARIANTS INTRODUCTION

- **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).
- **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 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 (U-Value)	4.0 W/m²K
Wall insulation (U-Value)	1.0 W/m²K
Floor insulation (U-Value)	3.0 W/m²K
Windows (U-Value; G-Value)	5.7 W/m²K, g = 0.85
Window fraction	15%
Shading	No
Heat supply	Diesel boiler
Cold supply	Split unit - COP 2.5
Hot water	Electric instantaneous
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	24°C/21°C
Air leakages/infiltration	0.25 1/h

ANALYSIS - BASELINE
ENERGY CONSUMPTION



Energy costs
18,184 LBP/(m²*a)
10.4 EUR/(m²*a)

CO_2e

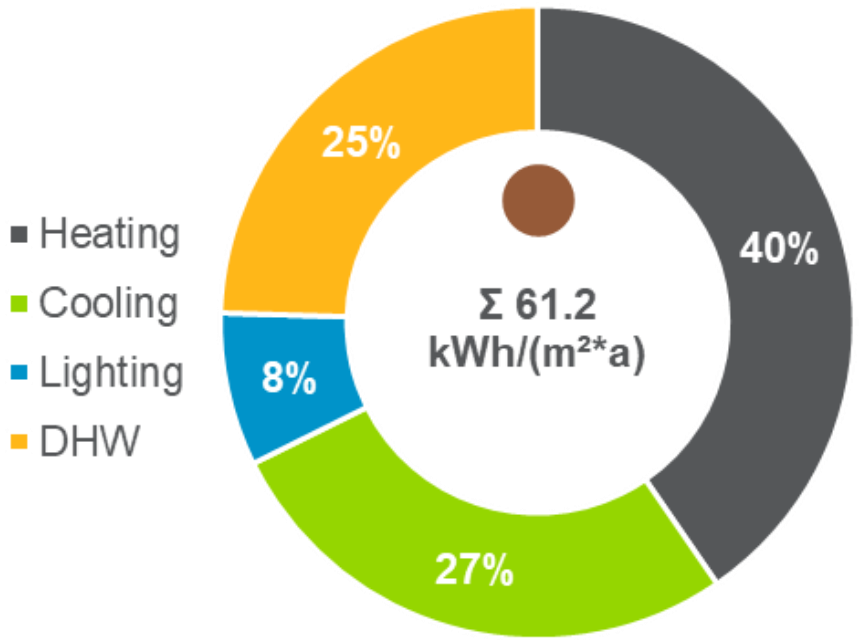
Emissions
61.2 kg CO2e/(m²*a)

In the baseline case, two-thirds of the final energy demand of 131 kWh/(m²*a) account for space heating.

ANALYSIS - CURRENT SITUATION
ENERGY RELEVANT INFORMATION

Measure	Current situation
Roof insulation (U-Value)	**1.13 W/m²K**
Wall insulation (U-Value)	**0.7 W/m²K**
Floor insulation (U-Value)	**1.13 W/m²K**
Windows (U-Value; G-Value)	**2.0 W/m²K, g = 0.65**
Window fraction	15%
Shading	**Overhangs**
Heat supply	**Gas condensing boiler - 103%**
Cold supply	**VRF - COP 3.2**
Hot water	Electric instantaneous
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	24°C/21°C
Air leakages/infiltration	0.25 1/h

ANALYSIS – CURRENT SITUATION
ENERGY CONSUMPTION



Energy costs
8,520 LBP/(m²*a)
4.9 EUR/(m²*a)

CO_2e

Emissions
34.8 kg CO2e/(m²*a)

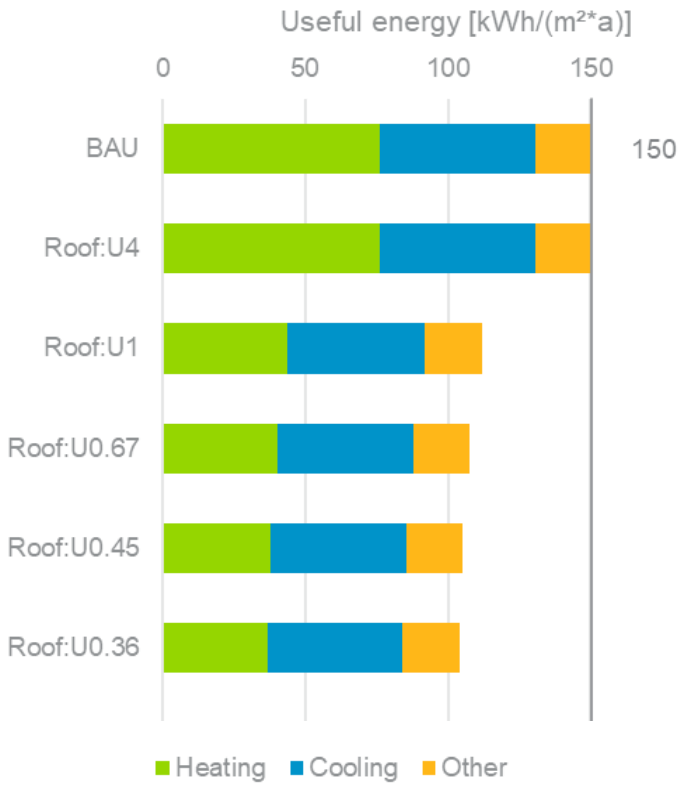
The pilot project as currently planned already saves 60% of final energy compared to the common construction practice in Lebanon.

ANALYSIS
SENSITIVITY ANALYSIS OF EE/RE MEASURES

No	Measure	Question
1a	Wall insulation (U-Value)	What is the effect of higher energy efficiency?
1b	Roof 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 most energy efficient 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 optimal efficiency for heating and cooling?
6	RE (solar energy)	Is the installation of solar energy cost efficient?
7a	Set temperatures - Cooling	What is the energy saving potential of an adjusted setting temperature?
7b	Set temperatures - Heating	What is the energy saving potential of an adjusted setting temperature?

ANALYSIS
PASSIVE MEASURES - ROOF

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

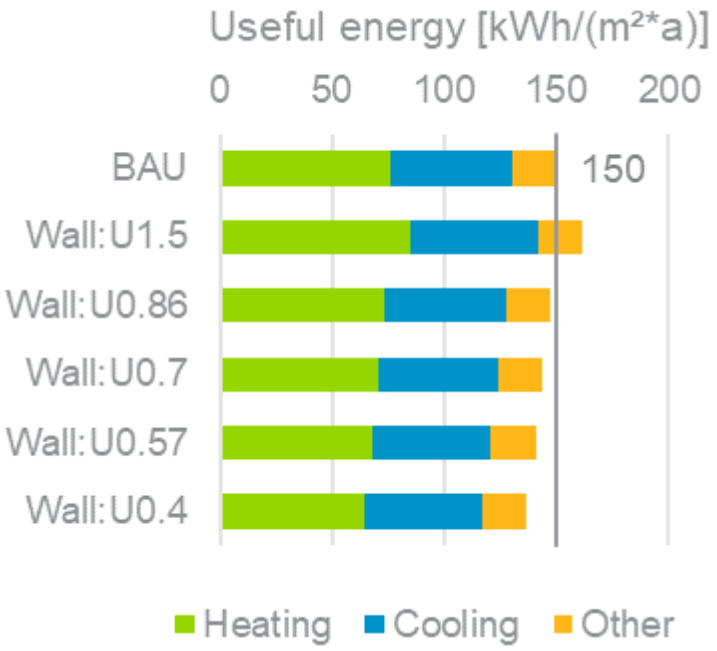


Thermal roof insulation is recommended up to the point where the energetic benefits outweigh the investment.

A U-value of 1 W/m²*K has a significant impact on the overall energy demand. However, the saving span between 1 and 0.36 W/m²*K is not so high that it would make sense to insulate as much as possible. This is also due to the moisture development within the building shell.

ANALYSIS
PASSIVE MEASURES - EXTERNAL WALL

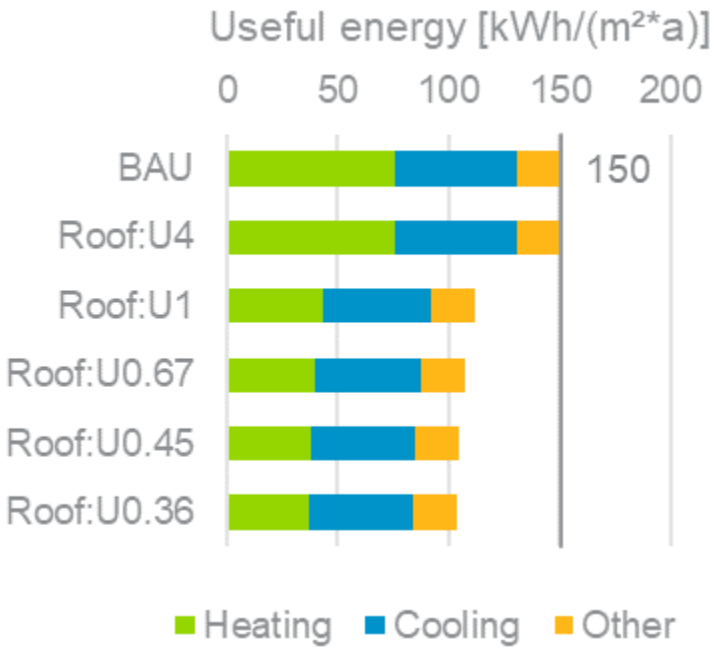
Measure 1a	Thermal Insulation
External wall insulation	What is the effect of higher energy efficiency?



Under Aaleys' climate conditions, a reduction of the U-value of the wall by 1 W/(m²*K) can save 2% of heating energy and about 1% of cooling energy.

ANALYSIS
PASSIVE MEASURES - EXTERNAL WALL

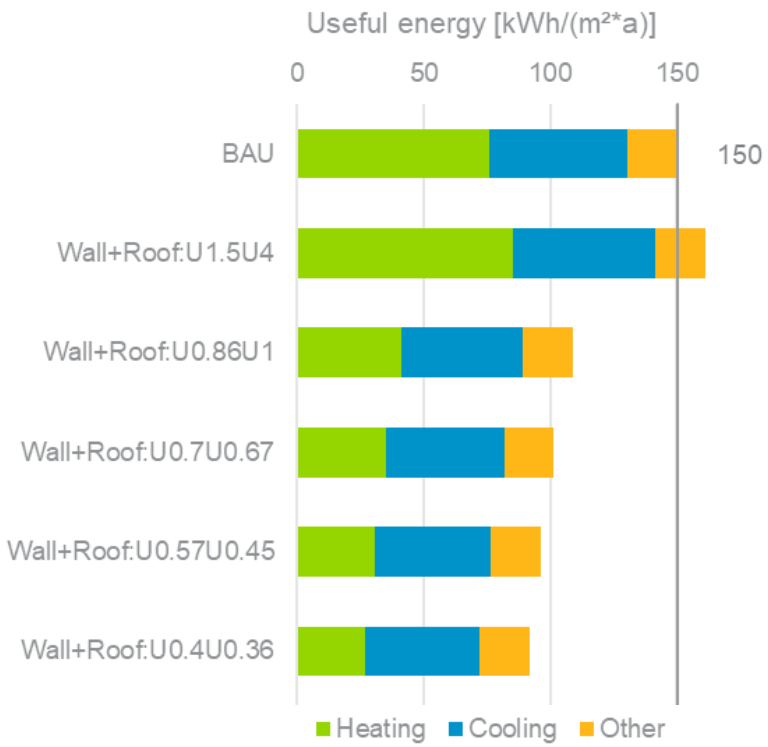
Measure 1b	Thermal Insulation
Roof insulation	What is the effect of higher energy efficiency?



Reducing the roof's heat transfer by 1 W/(m²*K) can save 1% of useful energy for heating.
Since well roof insulation is uncommon in Lebanon, here lie huge saving potentials.

ANALYSIS
PASSIVE MEASURES - ROOF + EXTERNAL WALL

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



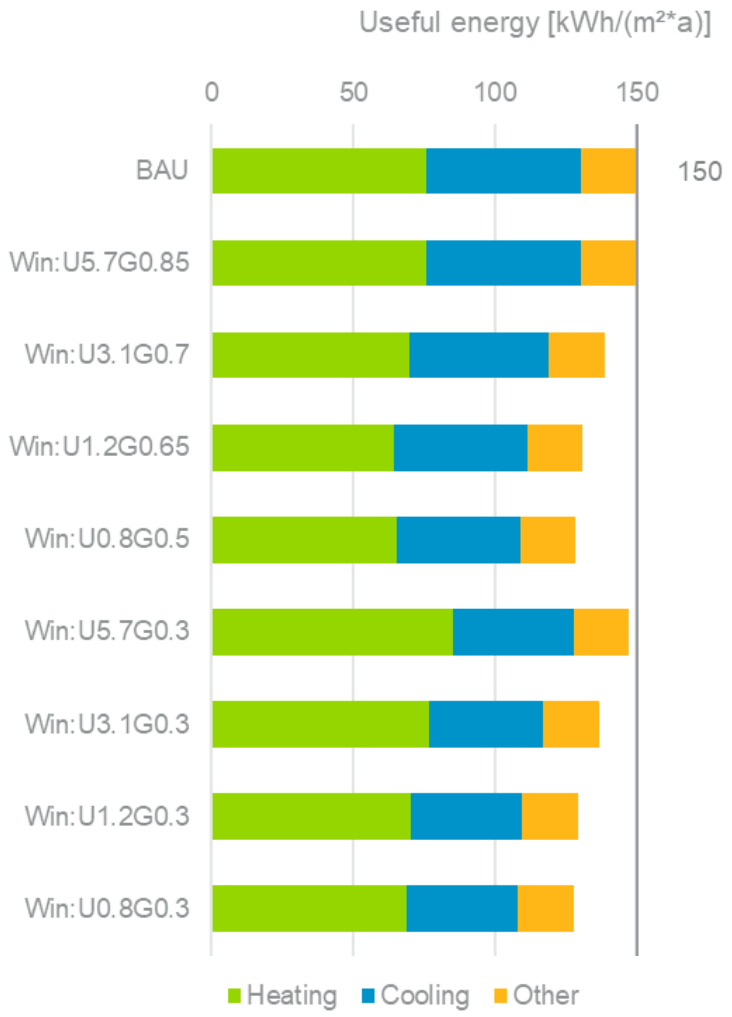
Reducing the heat transfer of wall and roof together can add up the individual affects and also create (small) synergy effects.

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) Window fraction	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 chart 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.

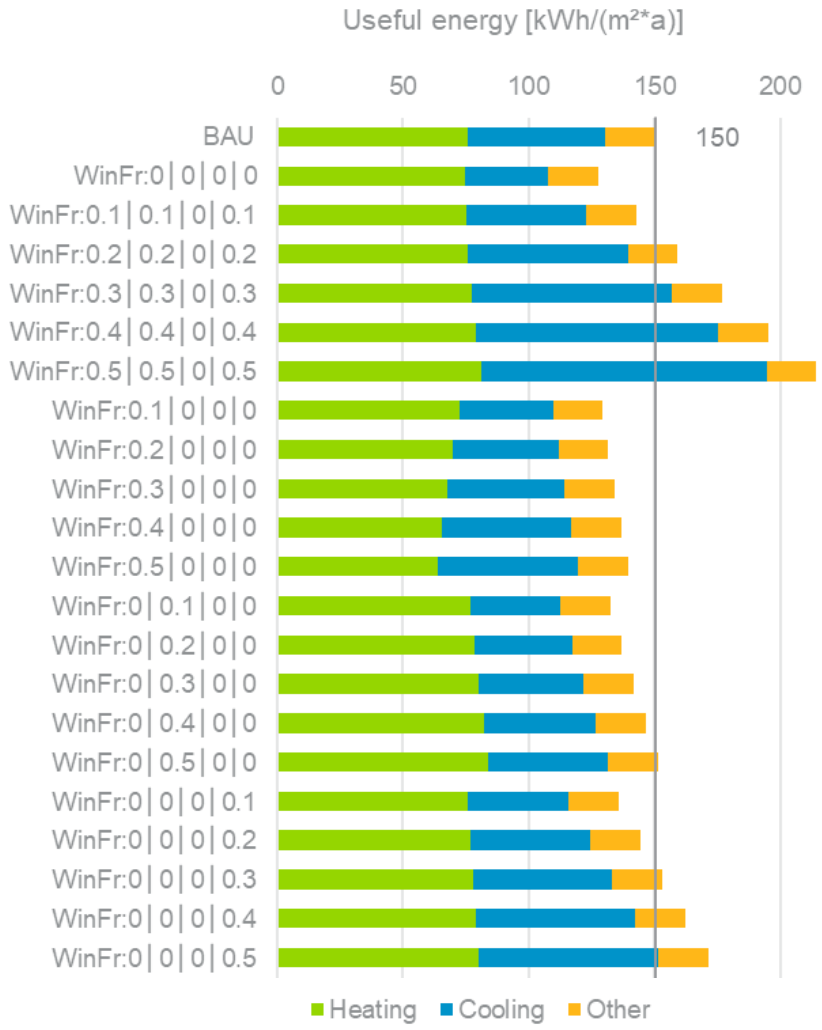
ANALYSIS
PASSIVE MEASURES – U-VALUE AND G-VALUE



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 U-values between 1.6 and 0.8.

ANALYSIS
PASSIVE MEASURES - WINDOW FRACTION

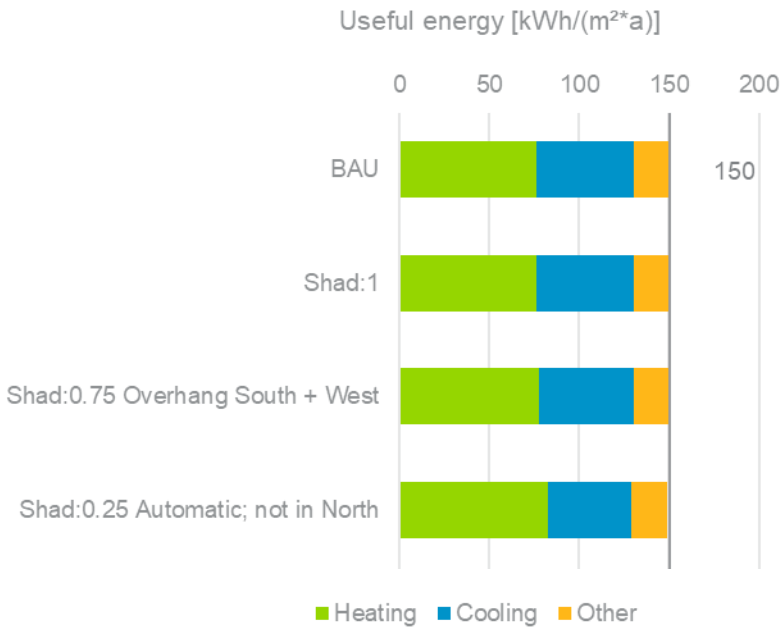


The southern orientations entail a higher energy demand than the other orientations. The western and eastern sides still offer a low energy demand even though the fraction share is at 50%

It is recommended to keep the southern window fractions as little as possible and rather find a combined solution of windows on the east and the west sides of the building.

ANALYSIS
PASSIVE MEASURES - SHADING

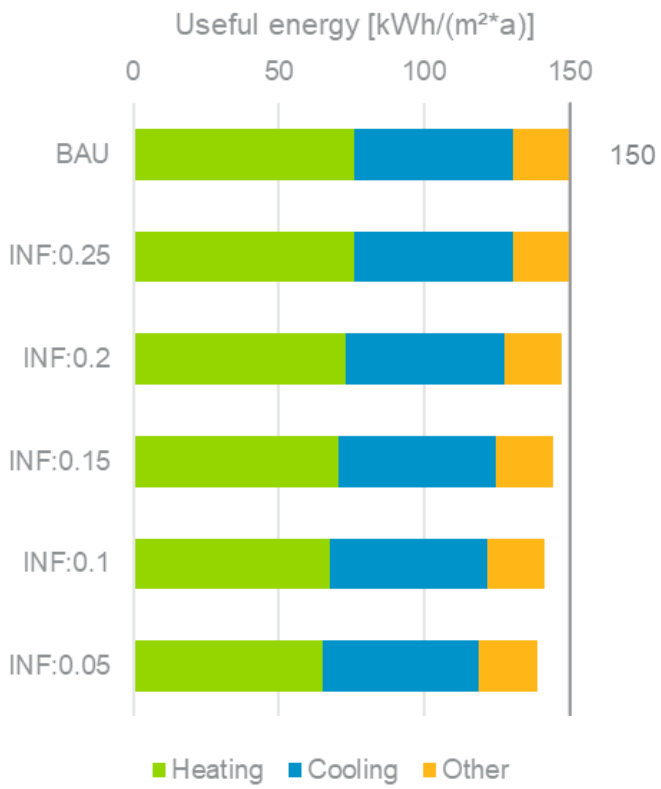
Measure 3	Shading
Shading	What is the cost optimal type of shading?



Due to the shading, an increase in useful energy demand for heating can be estimated. However, at the same time, a decrease in cooling can be expected, which keeps it overall level.

ANALYSIS
PASSIVE MEASURES – AIR TIGHTNESS

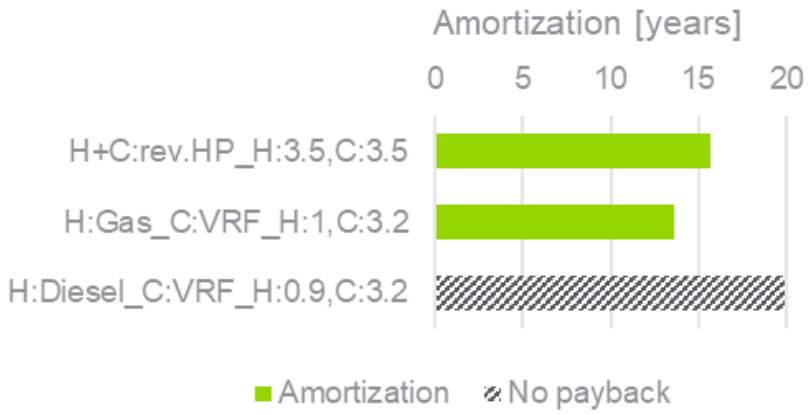
Measure 4	Air Tightness
Air tightness	What is the effect of air tightness?



The infiltration rate has only a slight effect on the heating energy demand and a bigger impact on cooling. Comparing the rate of 0.25 and 0.05.

ANALYSIS
ACTIVE MEASURES - COOLING

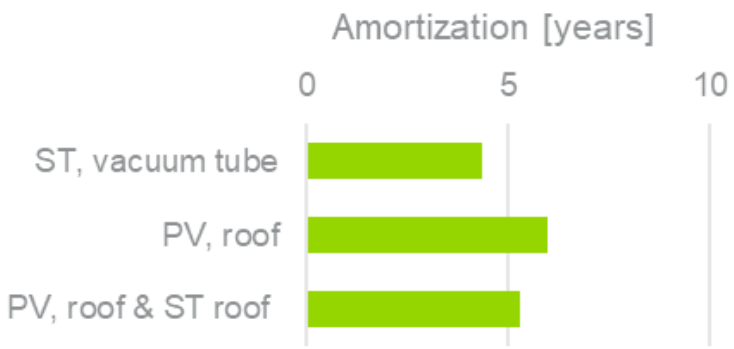
Measure 5	Cooling and Heating
Cooling and heating	The cooling demand remains similar, even if different systems are applied.



Alternate heating and cooling supply solutions like reversible heat pumps and gas condensing boilers appear economically beneficial.
Improved diesel technology, however, does not payback within its lifetime.

ANALYSIS
ACTIVE MEASURES (RENEWABLE ENERGY)

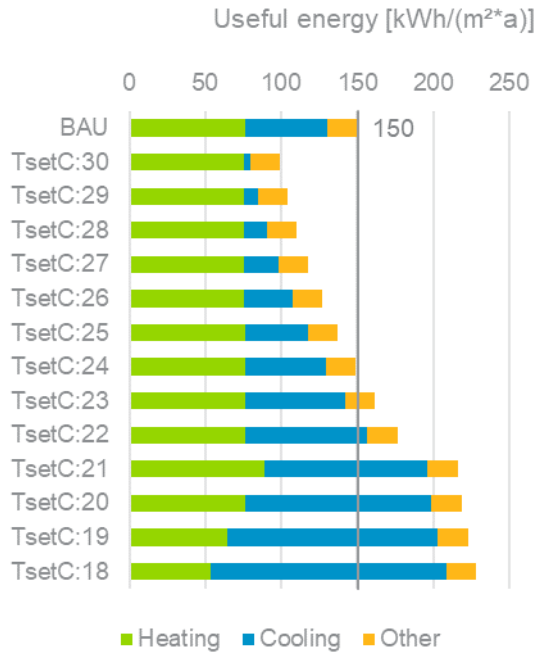
Measure 6	Solar Thermal and PV
Generation	Are renewables economically feasible?



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

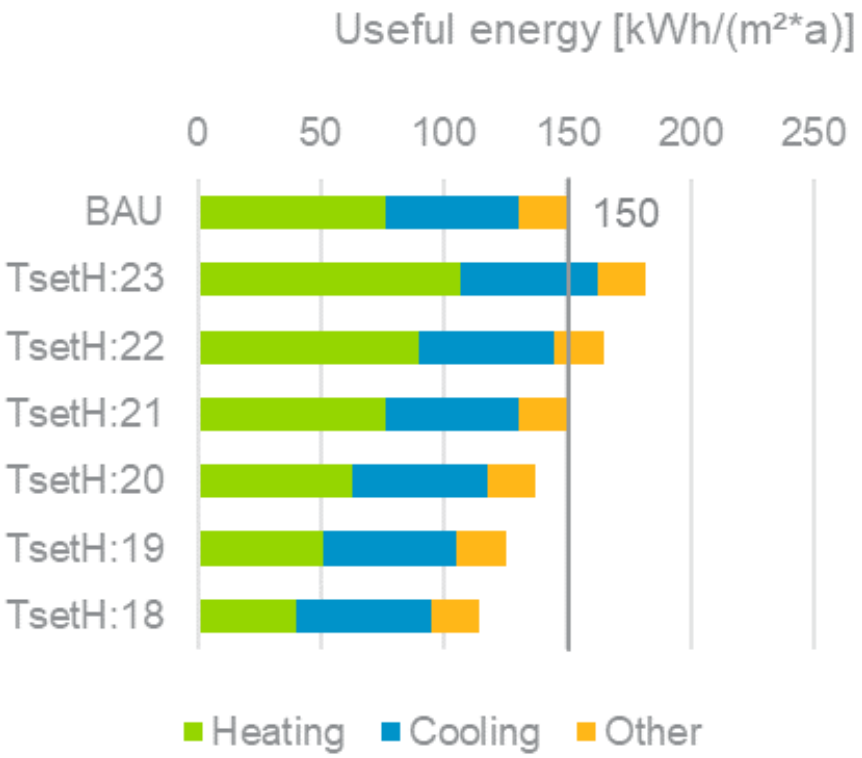
ANALYSIS
BEHAVIOR - SET TEMPERATURE - COOLING

Measure 12	Set Temperatures
Adjustments	The saving potential for set temperatures is big. For extreme cases, the demand can be cut in less than half. However, it is necessary to mention that those conditions are not within the comfort table. H: Heating | C: Cooling



In respect to the comfort table, it is recommended room temperatures are maintained at 25°C. This temperature is still considered to be comfortable and brings a cooling demand savings of 20% in comparison to the baseline.

ANALYSIS
BEHAVIOR - SET TEMPERATURE - HEATING



The heating periods should not exceed a set temperature of 21°C. Otherwise the baseline model would become more efficient.

1°C more in heating, already leads to a 40% increase of the energy demand for heating.

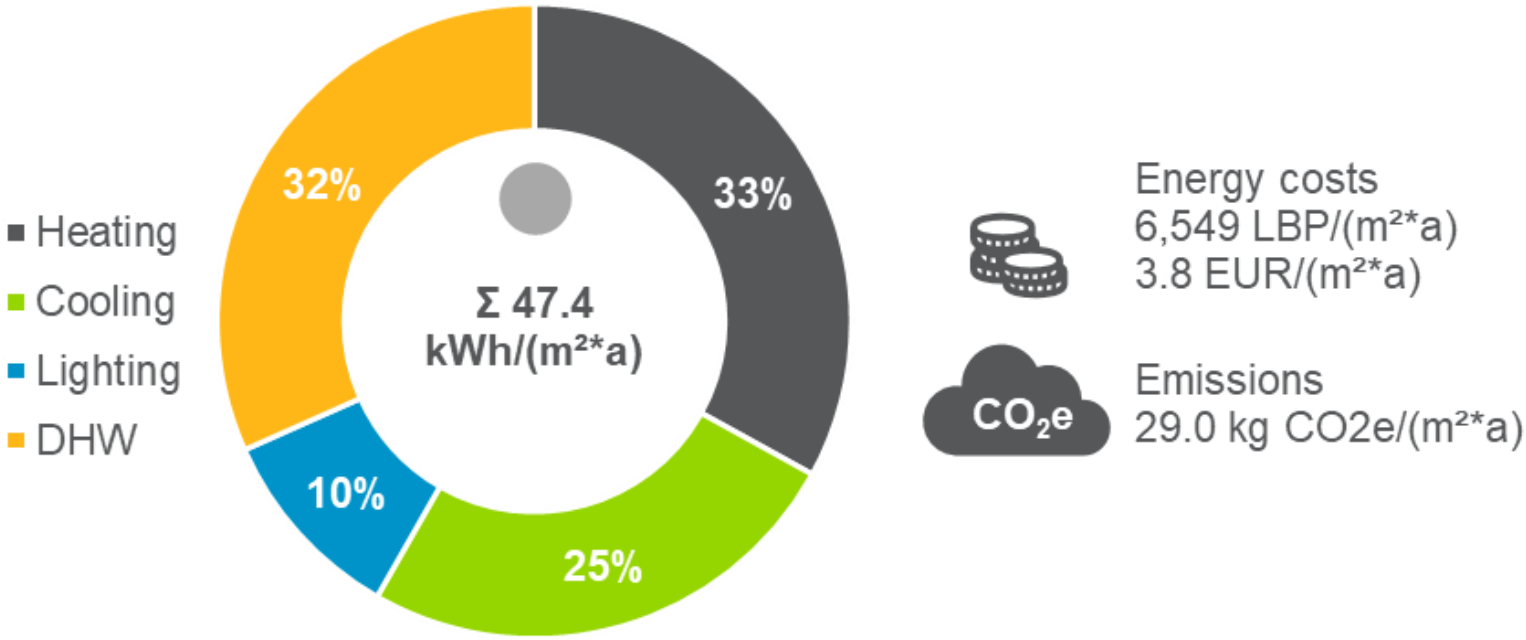
ANALYSIS
FINDINGS OF SENSITIVITY ANALYSIS OF EE/RE MEASURES

No	Measure	Results
1a	Wall insulation (U-Value)	0.86 W/m²K - 0.4 W/m²K
1b	Roof insulation (U-Value)	1 W/m²K - 0.36 W/m²K
2a	Windows (U-Value; G-Value)	1.2 W/m²K / 0.65 - 0.8 W/m²K / 0.5
2b	Window fraction	30 % - 15%
3	Shading	Overhangs
4	Air tightness	0.1 – 0.05
5	Varied heating and cooling supply system	VRF + Gas condensing
6	RE (solar energy)	Solar water heater (SWH) and PV
7a	Set temperatures - Cooling	26°C
7b	Set temperatures - Heating	20°C

ANALYSIS - SHORT PAYBACK
ENERGY RELEVANT INFORMATION

Measure	Variant 1
Roof insulation (U-Value)	**0.67 W/m²K**
Wall insulation (U-Value)	0.7 W/m²K
Floor insulation (U-Value)	1.13 W/m²K
Windows (U-Value; G-Value)	**1.2 W/m²K, g = 0.65**
Window fraction	15%
Shading	Overhangs
Heat supply	Gas condensing boiler - 103%
Cold supply	VRF - COP 3.2
Hot water	Electric instantaneous
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	**20°C/26°C**
Air leakages /infiltration	0.25 1/h

VARIANT 1 – SHORT PAYBACK
ENERGY CONSUMPTION

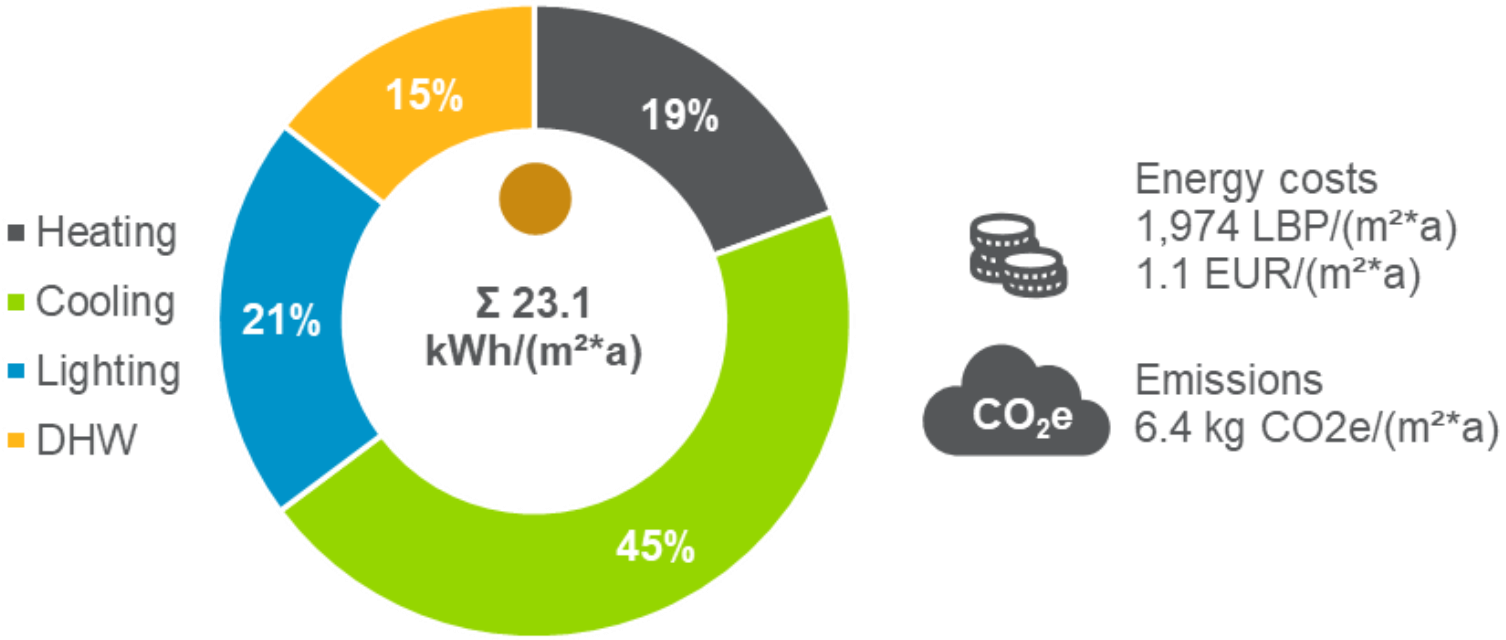


Almost 75% of the final energy demand for space heating and cooling can be saved with low cost measures.

ANALYSIS – VARIANT 2
ENERGY RELEVANT INFORMATION

Measure	Variant 2
Roof insulation (U-Value)	**0.36 W/m²K**
Wall insulation (U-Value)	**0.4 W/m²K**
Floor insulation (U-Value)	**1.13 W/m²K**
Windows (U-Value; G-Value)	**0.8 W/m²K, g = 0.5**
Window fraction	15%
Shading	**Automatic shading**
Heat supply	Gas condensing boiler - 103%
Cold supply	VRF - COP 3.2
Hot water	electric and **solar thermal**
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	**PV and solar thermal**
Set temperature cooling/heating	**20°C/26°C**
Air leakages/infiltration	**0.05 1/h**

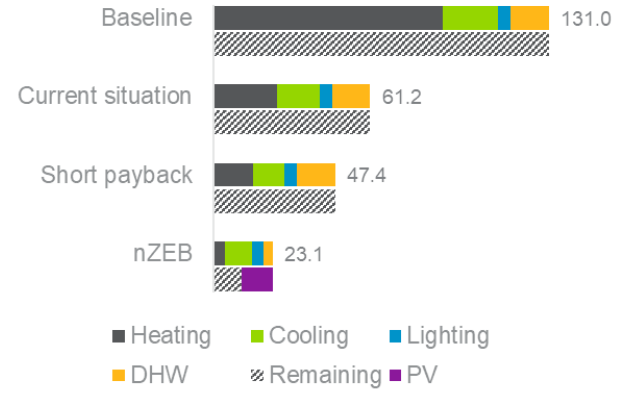
VARIANT 2 – NZEB
ENERGY CONSUMPTION



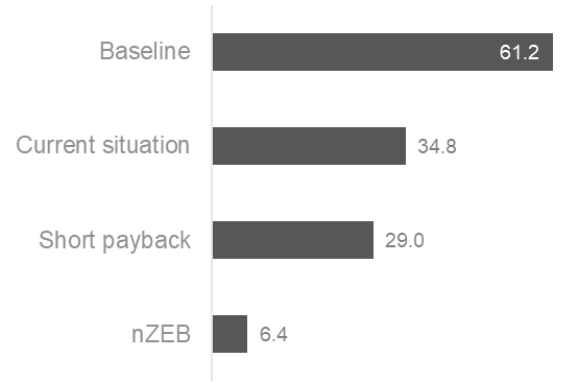
The measures included in the nZEB package allow reducing the building's final energy demand towards 23 kWh/(m²*a) of which half can be covered by onsite PV.

RESULTS
COMPARATIVE OVERVIEW

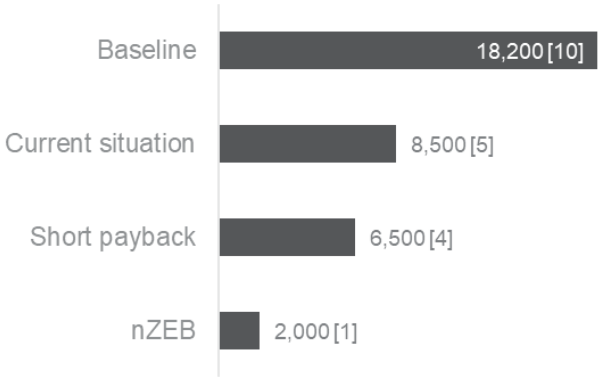
Specific final energy demand [kWh/(m²*a)]



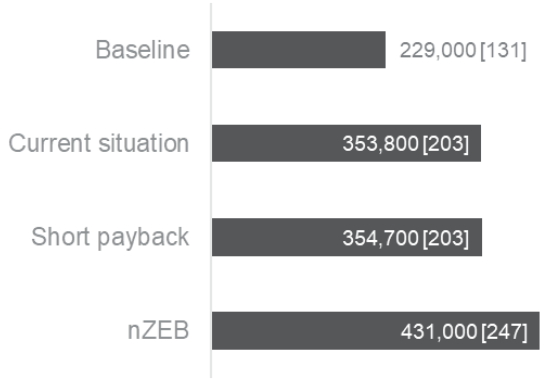
Specific emissions [kg CO2e/(m²*a)]



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%
    - Dissemenating 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.

RECOMMENDATIONS

- Short-term considerations
  - Consider all short payback measures defined in Variant 1:
    - Improve the roof insulation to a minimum U-Value of 0,67 W/m²K
    - Dissemenate the appropriate selection of setting temperature to end-users:
      - Heating: 20°C
      - Cooling: 26°C

    As these measures have low additional costs, 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.

- 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.

CONTACTS

RIADH BHAR
Managing Consultant
+49-221-27070-153
Riadh.Bhar@Navigant.com

DAVID KRETSCHMER
Analyst
+49-221-27070-165
David.Kretschmer@Navigant.com

navigant.com