UPSCALE - NABTA TOWN, EGYPT

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

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INTRODUCTION

Perspective of Nabta Town

By combining a range of functions through defined but integrated neighbourhoods, Nabta Town serves as an inclusive and highly attractive community—offering lifestyle, work, education, culture, and play to its residents and visitors—with the premise of human growth at its core. Sustainability is the key to community development, and it is delivered through the harmonisation of urban and nature; with excellent public realm and open space elements creating a highly accessible and connected place which centres upon walking and cycling Utilising leading edge technology and building innovation, Nabta Town will allow residents to experience a world-class community that offers its inhabitants a seamless, modern, and knowledge-driven lifestyle for generations to come.

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) solution 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 (**P**ay**b**ack **p**eriod - PBP, **N**et **P**resent **V**alue - NPV)
  - Conceive a nZEB (nearly zero energy building) package

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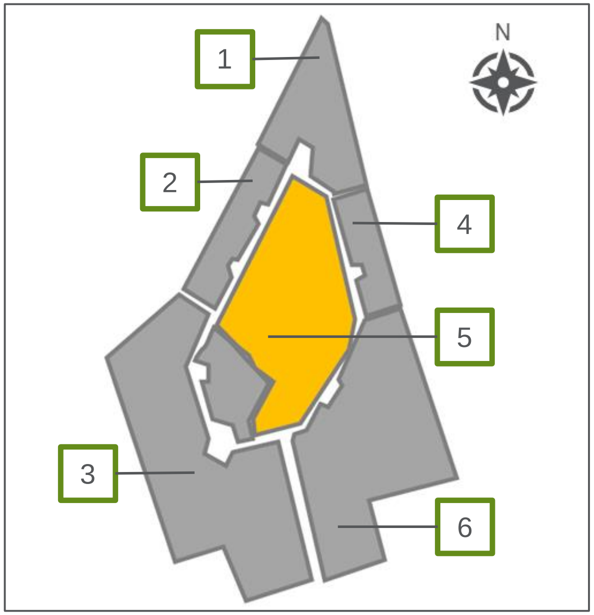
BOUNDARY CONDITIONS
SITE

Location of Project Site

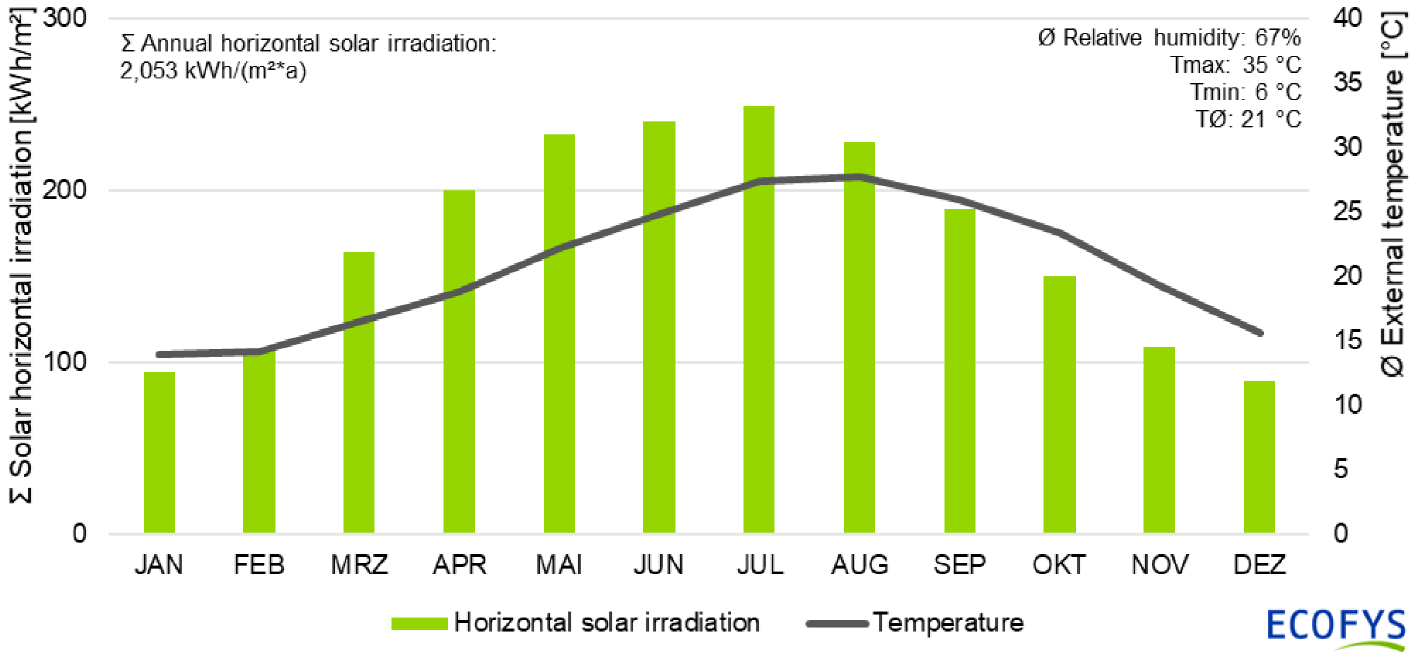
Sketch of Nabta Town



Nabta Town is planned to be realised about 45 km southwest from Alexandria, Egypt. The project is in its concept phase, the majority is settled. It is scheduled to roll out in three succeeding phases in 2 years. The Master Plan envisages six zones with different main usages: Business neighbourhood (1) / Cultural neighbourhood (2) / University neighbourhood (3) / Commercial neighbourhood (4) / Downtown neighbourhood (5) / Family neighbourhood (6) as shown in the sketch above.

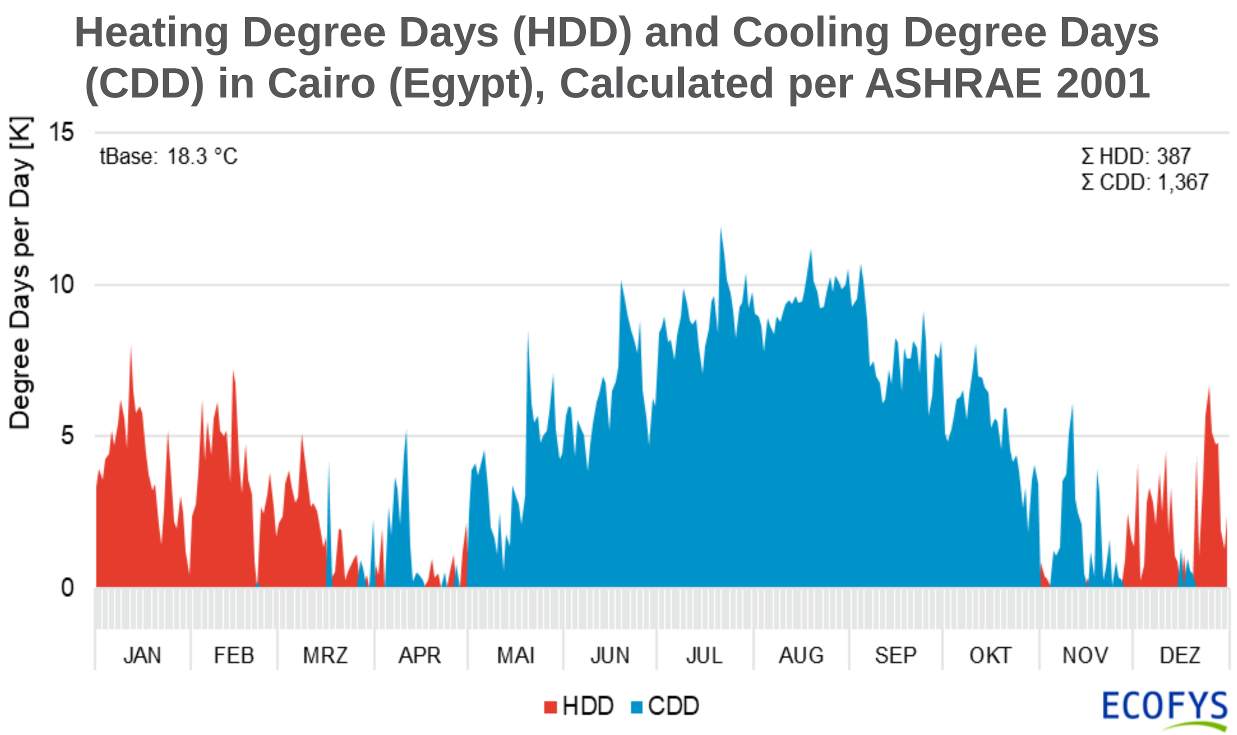
BOUNDARY CONDITIONS
CLIMATE

Monthly Solar Irradiation and Average External Temperature in Alexandria (Egypt)



The climate at the project site in Alexandria is primarily hot and humid. External temperatures range from above 0°C to 35°C with yearly average temperatures around 21°C. January is the coldest month, August is the hottest. The minimum temperature level does not fall below 0°C, which means that frost issues do not play a role in terms of construction projects.

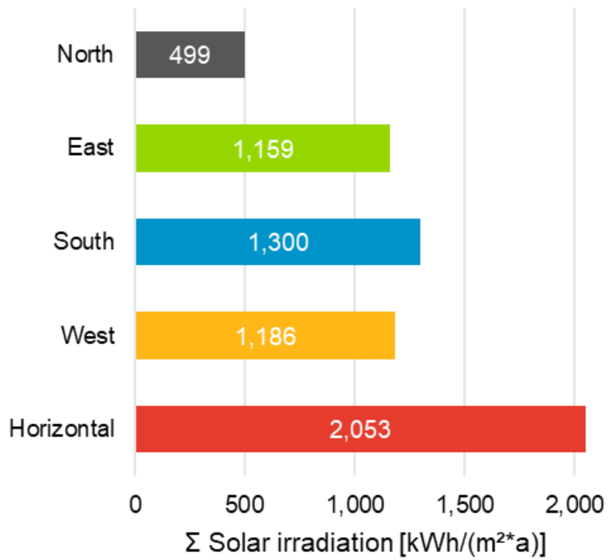
BOUNDARY CONDITIONS
CLIMATE

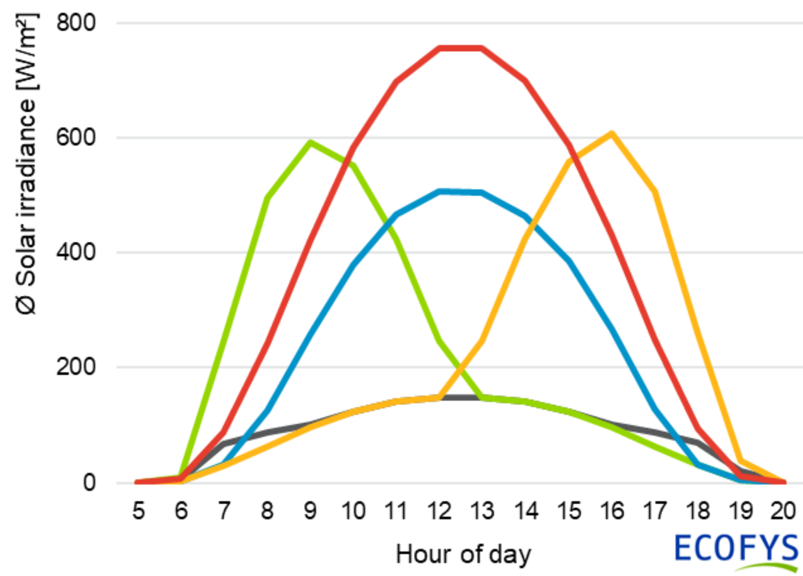


The demand for cooling prevails against heat demand as the high number of >1,300 CDDs indicates. The amount of cooling degree days are roughly 3 times higher compared with the HDDs. Therefore, a significantly larger amount of the energy demand accumulates for cooling.

BOUNDARY CONDITIONS
CLIMATE

Solar Irradiation in Alexandria





A big potential for renewable energy lies within the solar irradiation in Alexandria. Horizontal irradiation of >2,000 kWh/(m²*a) and >1000 kWh/(m²*a) for East, South, and West orientation bring opportunities for energy generation through solar radiation.

BOUNDARY CONDITIONS
ENERGY PRICE AND CO_2 FACTOR

Parameter	Unit	Electricity	Natural Gas	District Cooling
Energy price*	EGP/kWh	0.13-1.36	1.4 – 2 EGP/m³	0.13
Energy price*	EUR/kWh†	0.01-0.06	0.065-0.092 EUR/m³	0.01
Low energy price - A	EUR/kWh†	0.01	0.0065	0.003
High energy price - B	EUR/kWh†	0.03**	0.02**	0.01**
CO_2 emission factor	gCO_2/kWh	444	220	200

*Depending on consumption segment
†exchange rate: 1 EUR = 21.72 EGP
** rather conservative energy price increases have been take into account

Due to existing subsidies on energy, the energy prices are extremely low in Egypt. Local experts expect the removal of the subsidies in 2022; therefore, two cases for the economic feasibility have been calculated; a) low energy prices and b) high energy prices, without subsidies.

BOUNDARY CONDITIONS
BASELINE – BUILDING INFORMATION

Criteria	Input
Number of (expected) inhabitants	156
Utilisation	Residential/Commercial
Number of (expected) inhabitants	156
Year of construction	Starting in 2020
Number of floors	5
Number of apartments	24
Conditioned floor area	2,328 m^2
Clear room height	2.72 m^2
Conditioned volume	7,584 m^3
Roof area	977 m^2
Wall area	1,645 m^2
Floor area	987 m^2
Window fraction per orientation (N/E/S/W)	230 m^2/7 m^2/200 m^2/7 m^2

ANALYSIS
VARIANTS INTRODUCTION

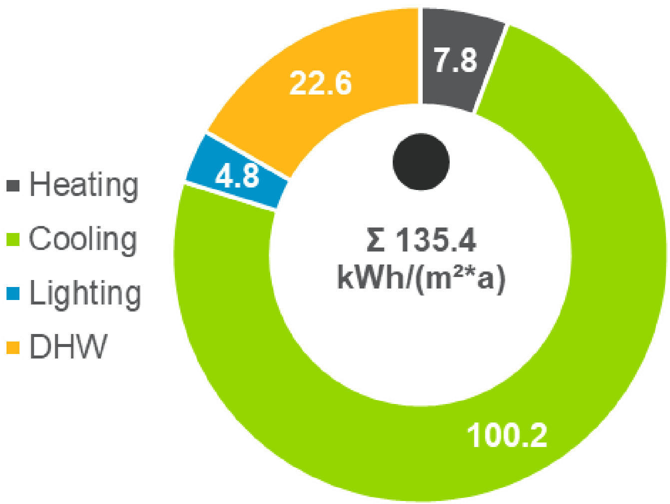
- **Baseline**
  - Business as Usual reflects the current state of art of construction of the respective country. It might even deviate from technical regulations if the construction practice is not respecting it. This variant will be seen in further analysis as the baseline.
- **Current Situation**
  - 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)	3 W/m²K
Wall insulation (U-Value)	1.8 W/m²K
Floor insulation (U-Value)	3 W/m²K
Windows (U-Value; G-Value)	5.7 W/m²K; 0.85
Window fraction	Ø 21%
Shading	No
Heat supply	Reversible split unit - COP 2.5
Cold supply	Reversible split unit - COP 2.5
Hot water	Electric instantaneous
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	23°C/21°C

The key components of the energy concept are illustrated in this table, it shows the current status quo of local building habits. It has been assumed that no thermal insulation and no renewable energy sources are considered.

ANALYSIS - BASELINE
ENERGY RELEVANT INFORMATION



Invest costs
923 EGP/m²
43 EUR/m²

Energy costs - low tariff
29.4 EGP/(m²*a)
1.4 EUR/(m²*a)

Energy costs - high tariff
88.2 EGP/(m²*a)
4.1 EUR/(m²*a)

Emissions
60.1 kg CO2e/(m²*a)

The final energy consumption is dominated by the cooling demand [100 kWh/m²a].

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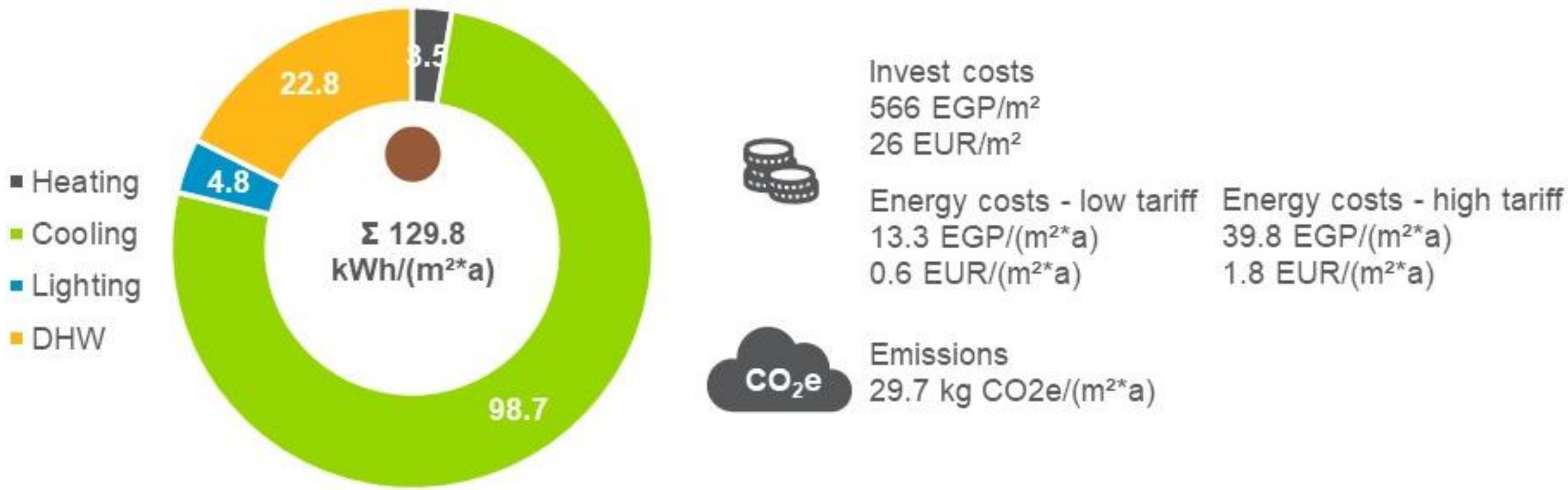
ANALYSIS - CURRENT SITUATION
ENERGY RELEVANT INFORMATION

Measure	Current planning
Roof insulation (U-Value)	**0.457 W/m²K**
Wall insulation (U-Value)	**1,14 W/m²K**
Floor insulation (U-Value)	**1.85 W/m²K**
Windows (U-Value; G-Value)	**1.69 W/m²K; 0.66**
Window fraction	Ø 21%
Shading	No
Heat supply	**District heating**
Cold supply	**District cooling**
Hot water	Natural gas
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	23°C/21°C

The current situation seeks to save more than 30% energy compared to the baseline, for this purpose the building envelope and the supply situation (introducing a district cooling) has been improved.

ANALYSIS - CURRENT SITUATION
ENERGY RELEVANT INFORMATION



The final energy demand of the current planning is lower than the baseline since the source for cooling is a district cooling network, in contrast to the commonly installed decentral cooling supply systems. And the energy costs and CO_2 emissions have been reduced by almost 50%.

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ANALYSIS

FINDINGS OF SENSITIVITY ANALYSIS OF EE/RE MEASURES

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

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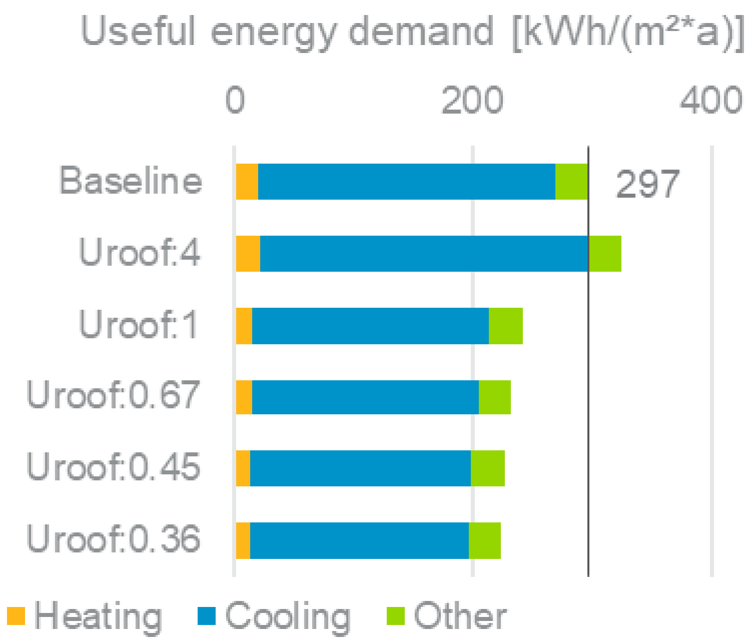
ANALYSIS
PASSIVE MEASURES - ROOF

Measure 1	Thermal Insulation
Roof insulation	What is the cost optimal thickness?

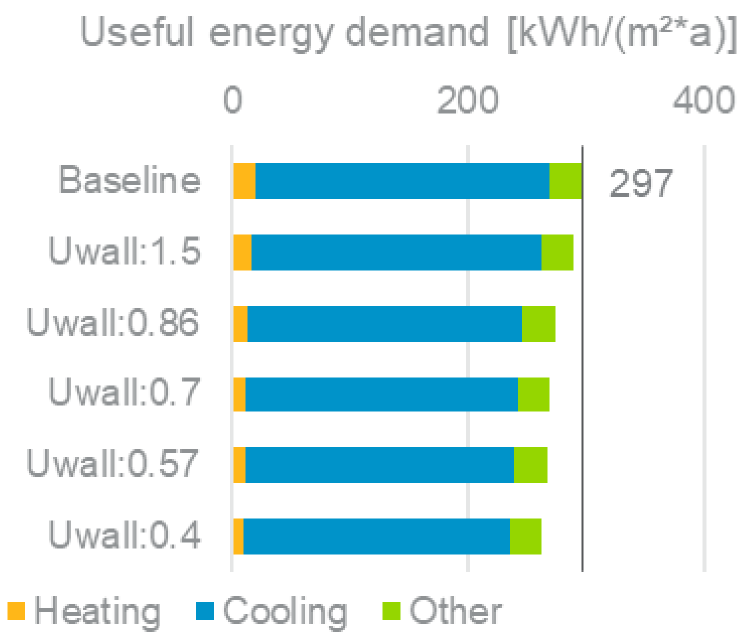


Thermal roof insulation is recommended up to the point where the energetic benefits outweigh the investment.

Reducing the roof's U-value towards 1 W/(m²*K) has a significant impact on the overall energy demand. However, the effect of even more ambitious roof insulation is low and does not appear reasonable.

ANALYSIS
PASSIVE MEASURES - EXTERNAL WALL

Measure 2	Thermal Insulation
External wall insulation	What is the cost optimal thickness?



External walls insulation that will reach an overall value of 1.5 W/m²*K will achieve a lower energy demand than the baseline approach, even though the current planning model is applied, which includes district cooling.

It is evident that, just like the roof U-value, the external walls are recommended to be insulated in a cost optimal way, to a value of 1.5–0.9 W/m²*K.

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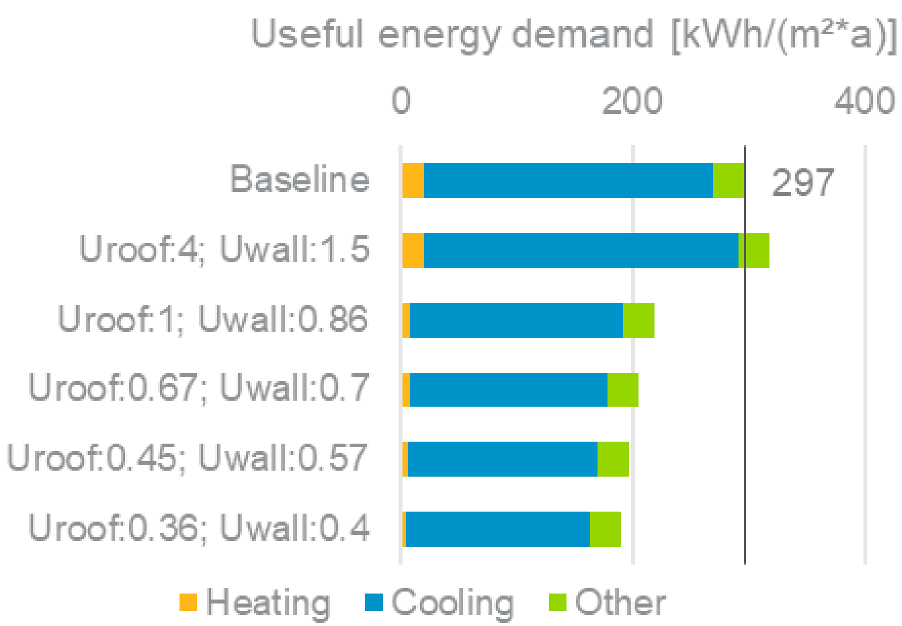
PASSIVE MEASURES - ROOF + EXTERNAL WALL

Measure 1 and 2	Thermal Insulation
Roof and wall combination	What is the cost optimal thickness?



This image shows the impact of the combination of roof and wall insulation on the overall demand.

By improving U-values large savings can be reached, especially in the cooling energy demand. The heating side, is not as significant, since the overall demand, without meaningful insulation, is not very high.

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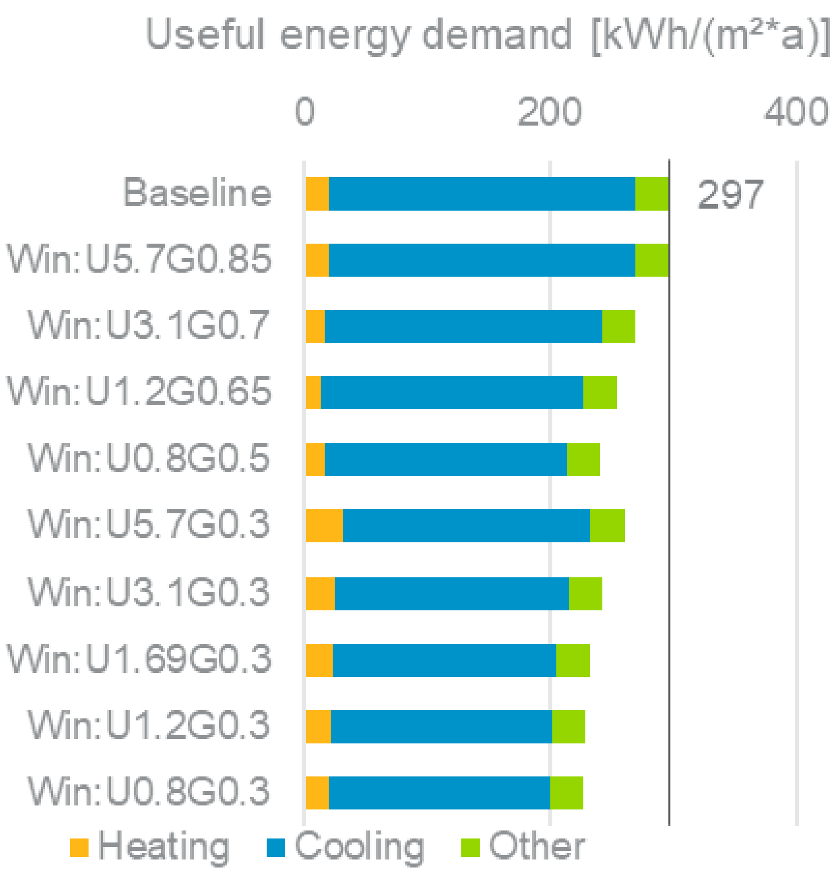
ANALYSIS

PASSIVE MEASURES - WINDOWS

Measure 3	Energy Efficient Windows
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
Orientation	The fractions develop as follows: 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 useful 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.

PASSIVE MEASURES – WINDOWS: U-VALUE AND G-VALUE

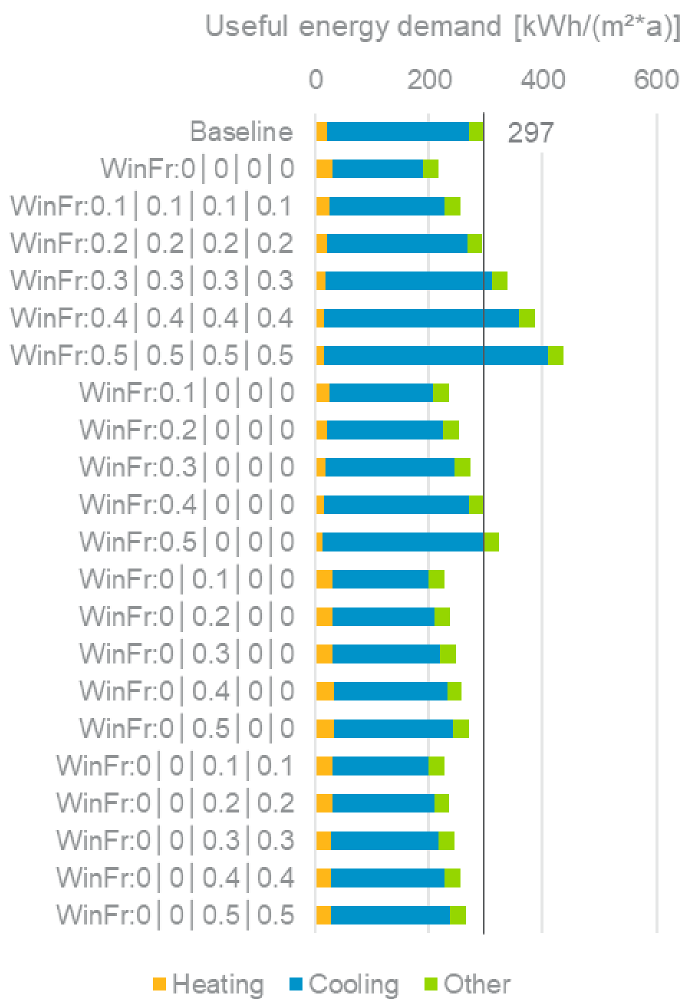


Better U- and G-values result in a lower final energy demand for cooling and heating. Therefore, it is recommend to use a cost optimal solution for windows in terms of thermal insulation.

To achieve an economic attractive solution, the system should not be too costly and good values between 1.6 and 0.8 for U-value and 0.3 for G-value should be reached.

ANALYSIS

PASSIVE MEASURES - WINDOWS: FRACTION



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

It is recommendable 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.

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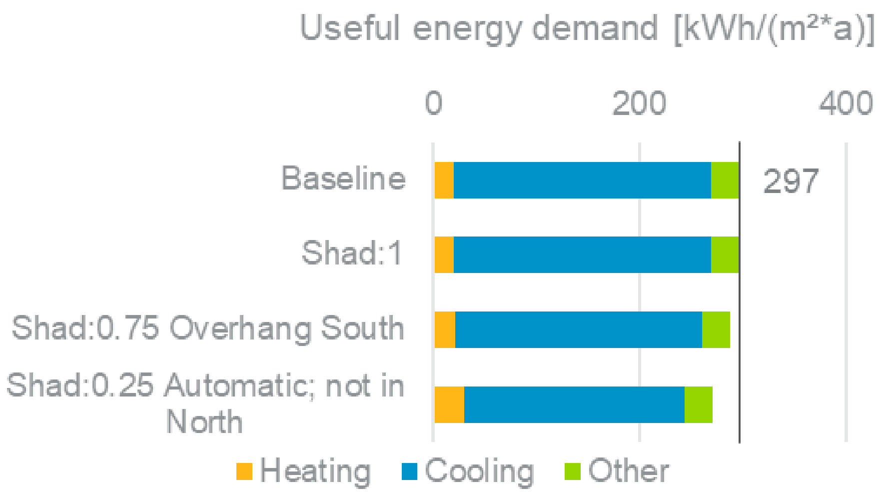
PASSIVE MEASURES - SHADING

Measure 4	Shading
Shading	The Shading was divided into three different variations. 1: 100% sunlight 0.75: 75% sunlight 0.25: 25% sunlight



The increase in shading area leads to a proportional decrease in the energy demand for cooling.

Shading devices that hold back about 75% and more of the direct sunlight should be installed.

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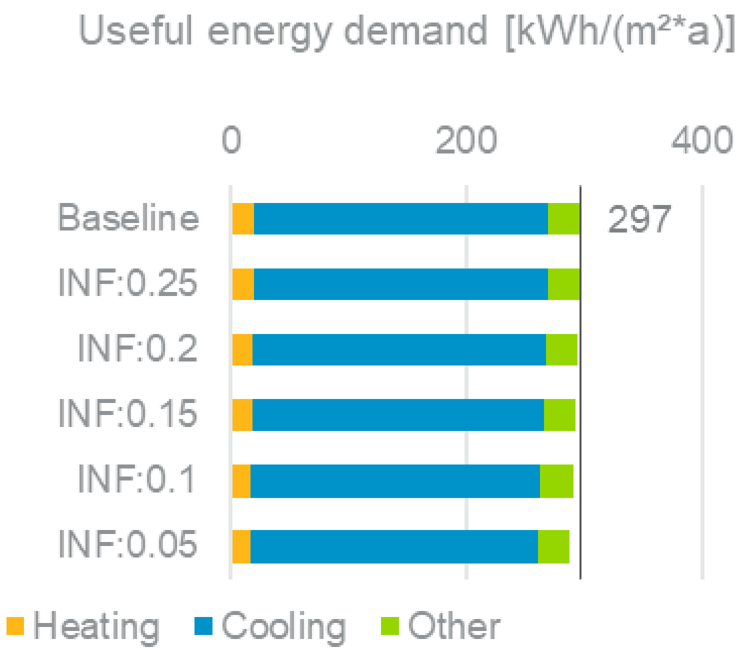
PASSIVE MEASURES – AIR TIGHTNESS

Measure 5	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.

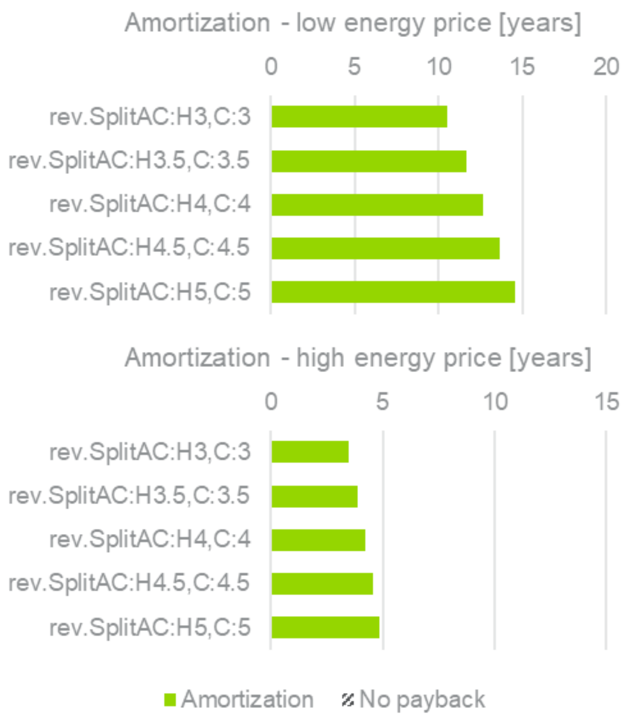


The infiltration rate has little effect on the heating energy demand and a bigger impact on cooling. Comparing the rate of 0.25 and 0.05.

Due to low differences, no further actions are recommended.

ANALYSIS
ACTIVE MEASURES (HVAC)

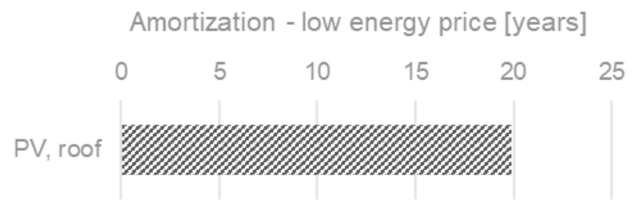
Measure 6	Cooling
Cooling	Due to high outside temperatures, the saving potential for cooling energy is significantly larger than the heating energy demand.

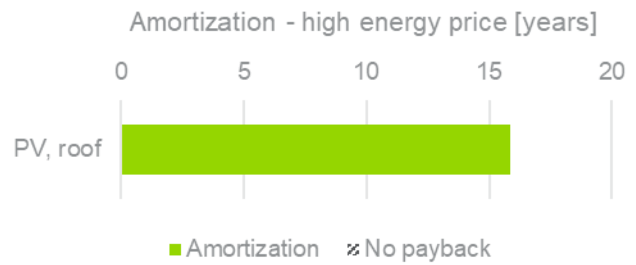


The future energy price development has major impact on the amortisation of investments. With current prices, high efficiency devices barely payback within their average lifetime. With growing prices, even air conditioners with COP 5 become economically beneficial.

ANALYSIS
RENEWABLES / SOLAR ENERGY

Measure 7a	Solar Energy
Photovoltaics	Is the installation of solar energy cost efficient?





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

Key Findings:
- Capacity: 70.5 kWp
- Simple payback:
  - Low energy price: No payback
  - High energy price: 16 years

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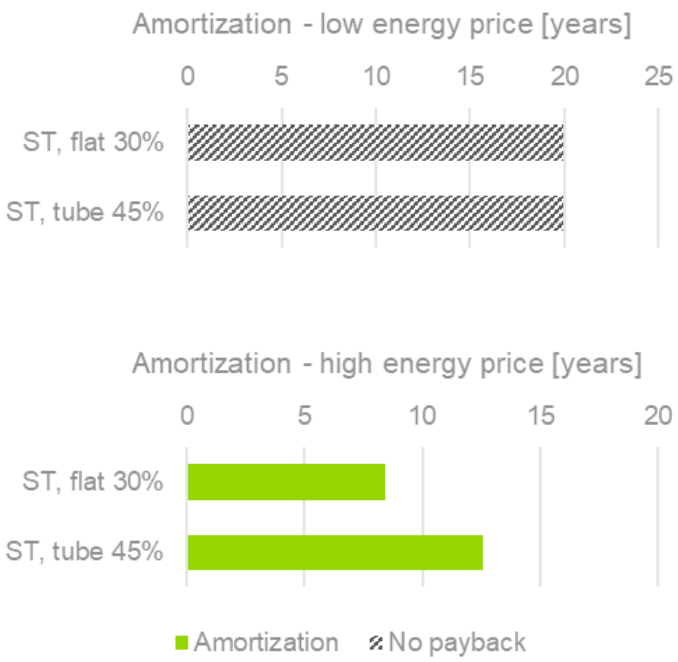
Measure 7b	Solar Energy
Solar thermal	Is the installation of solar energy cost efficient?



Key Assumptions:

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

Key Findings:

- Sizing: 31 m² (45%); 58 m² (30%)
- Simple payback:
  - Low energy price: No payback
  - High energy price: 13 years (45%);
    8 years (30%)

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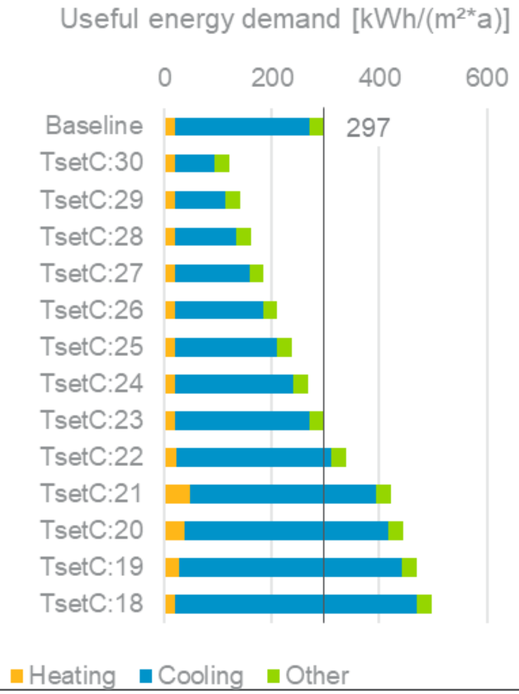
ANALYSIS

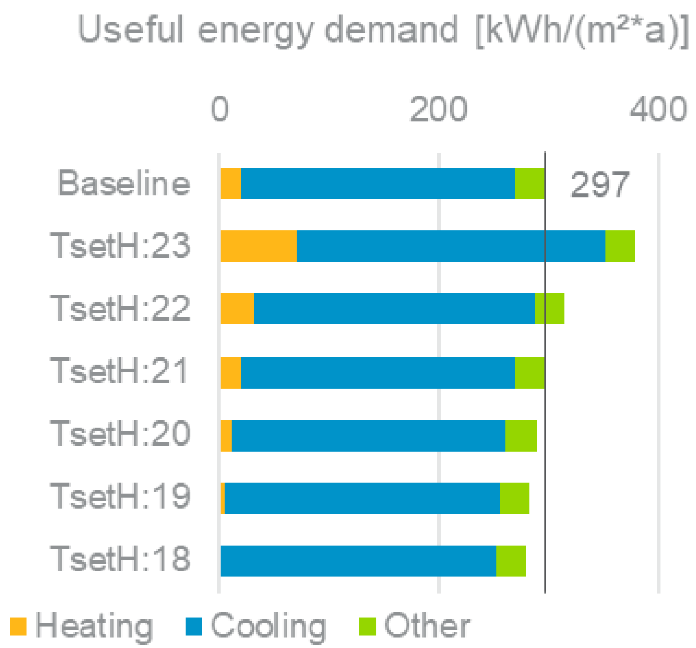
BEHAVIOR – TEMPERATURE - COOLING

Measure 8	Behaviour
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 to maintain a room temperature of 24°C-25°C. This temperature is still considered to be comfortable and brings a demand saving of 17% in comparison to the baseline.

ANALYSIS
BEHAVIOR – 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	Question	Result* A	Result* B
1	Roof insulation (U-Value)	What is the cost optimal thickness?	0.36	0.36
2	Wall insulation (U-Value)	What is the cost optimal thickness?	0.4	0.4
3	Windows (U-Value; G-Value)	What is the most energy efficient U-Value/G-Value	1.69/0.7	1.69/0.3
	Window fraction	What is the most energy efficient window fraction per orientation?	20%	
4	Shading	Should be shading measures applied?	No	Solar Glz.
5	Air tightness	What is the effect of air tightness?	min. effect	
6	Cooling supply system	What is the cost optimal efficiency for cooling? [COP]	5	5
7	RE (solar energy)	Is the installation of solar energy cost efficient?	No	Yes
8	A) Cooling B) Heating	What is the energy saving potential of an adjusted setting temperature?	Cooling 26°C Heating 20°C	

*different energy price levels:
A: Low energy price; B: High energy price

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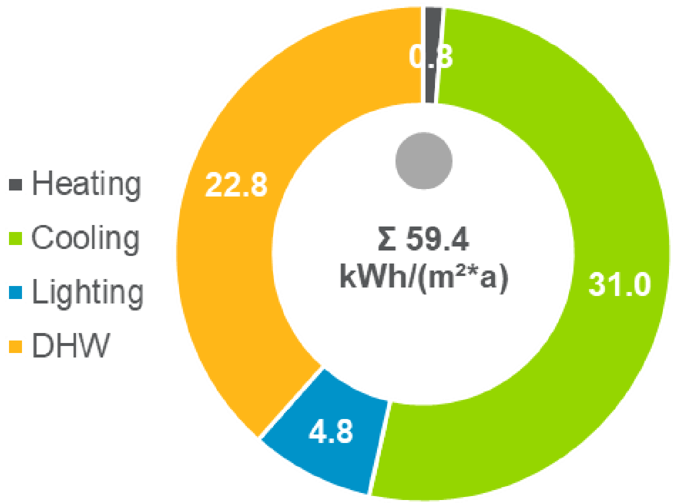
ANALYSIS – VARIANT 1A/1B
ENERGY RELEVANT INFORMATION

Measure	Current planning
Roof insulation (U-Value)	0.457 W/m²K
Wall insulation (U-Value)	1,14 W/m²K
Floor insulation (U-Value)	1.85 W/m²K
Windows (U-Value; G-Value)	1.69 W/m²K; 0.66
Window fraction	**Max 20% per orientation**
Shading	No
Heat supply	District heating
Cold supply	District cooling
Hot water	Natural gas
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	**26°C/20°C**

ANALYSIS – VARIANT 1A/1B

ENERGY RELEVANT INFORMATION



Invest costs
1,120 EGP/m²
52 EUR/m²

Energy costs - low tariff
12.9 EGP/(m²*a)
0.6 EUR/(m²*a)

Energy costs - high tariff
38.7 EGP/(m²*a)
1.8 EUR/(m²*a)

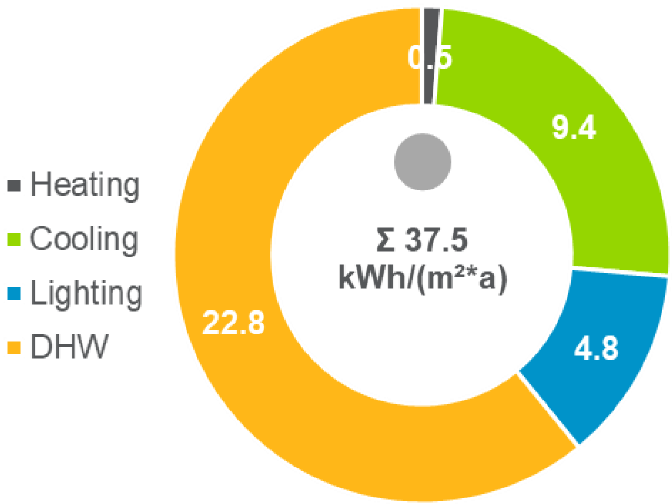
Emissions
26.4 kg CO2e/(m²*a)

With current energy prices, hardly any short-term measures are economically beneficial. However, the most effective free measure, adjusted indoor target temperatures, can cut energy spendings in half.

ANALYSIS – VARIANT 2A
ENERGY RELEVANT INFORMATION

Measure	nZEB
Roof insulation (U-Value)	**0.36 W/m²K**
Wall insulation (U-Value)	**0.4 W/m²K**
Floor insulation (U-Value)	1.85 W/m²K
Windows (U-Value; **G-Value**)	1.69 W/m²K | **G-Value 0.3**
Window fraction	**Ø 20%**
Shading	No
Heat supply	**Split AC COP 5.0**
Cold supply	**Split AC COP 5.0**
Hot water	Natural Gas
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	**26°C/20°C**

ANALYSIS – VARIANT 2A
ENERGY RELEVANT INFORMATION



Invest costs
1,502 EGP/m²
69 EUR/m²

Energy costs - low tariff
8.2 EGP/(m²*a)
0.4 EUR/(m²*a)

Energy costs - high tariff
24.5 EGP/(m²*a)
1.1 EUR/(m²*a)

CO_2e

Emissions
16.7 kg CO2e/(m²*a)

Further reducing solar gains can save additional 70% savings for cooling demand.

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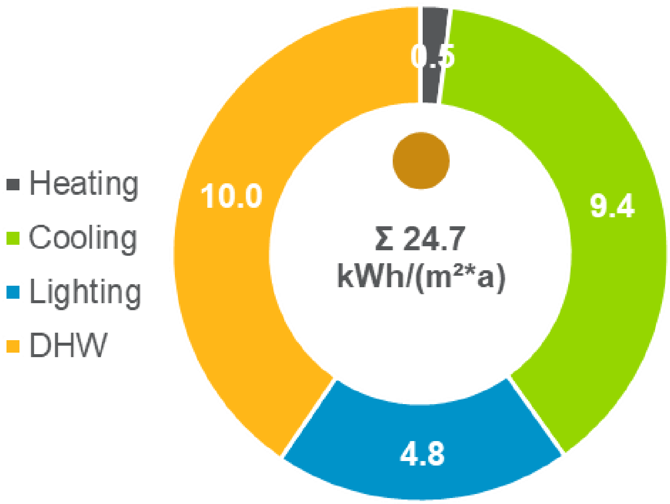
ANALYSIS – VARIANT 2B
ENERGY RELEVANT INFORMATION

Measure	nZEB
Roof insulation (U-Value)	**0.36 W/m²K**
Wall insulation (U-Value)	**0.4 W/m²K**
Floor insulation (U-Value)	1.85 W/m²K
Windows (U-Value; **G-Value**)	1.69 W/m²K | **G-Value 0.3**
Window fraction	**Ø 20%**
Shading	No
Heat supply	**Split AC COP 5.0**
Cold supply	**Split AC COP 5.0**
Hot water	Electric /**Solar thermal 45%**
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	**PV**
Set temperature cooling/heating	**26°C / 20°C**

ANALYSIS – VARIANT 2B
ENERGY RELEVANT INFORMATION

Full PV coverage



Invest costs
2,039 EGP/m²
94 EUR/m²

Energy costs - low tariff
0.0 EGP/(m²*a)
0.0 EUR/(m²*a)

Energy costs - high tariff
0.0 EGP/(m²*a)
0.0 EUR/(m²*a)

CO_2e

Emissions
0.0 kg CO2e/(m²*a)

The remaining reduced energy demand can be completely covered by onsite renewable energies.

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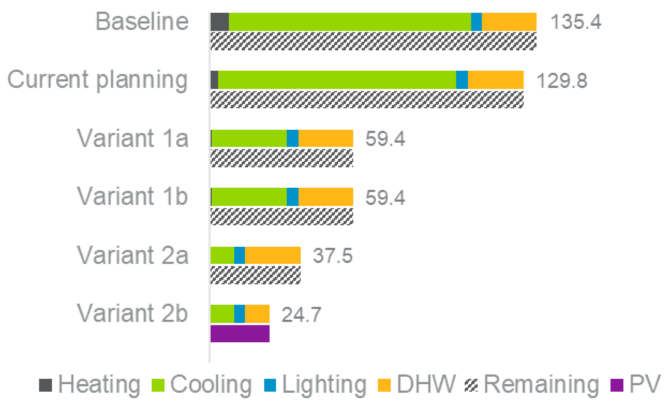
RESULTS
COMPARATIVE OVERVIEW

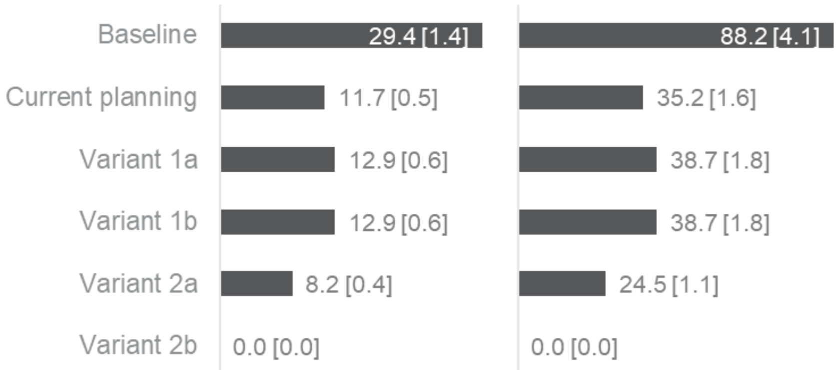
Specific final energy demand [kWh/(m²*a)]



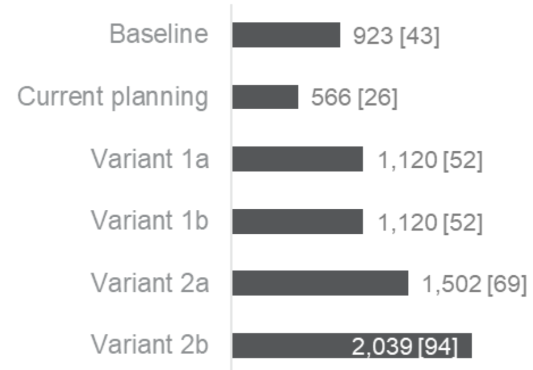
Specific emissions [kg CO2e/(m²*a)]

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

Low tariff | **High tariff**



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



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RECOMMENDATIONS

- As the planning and the construction of the buildings will be in near the future (starting from 2020) and further energy price increases can be expected by then (decrease of subsidies), it is recommended to aim for a nearly zero energy variant (nZEB).
- The „interdependencies“ of the nZEB with the envisaged district cooling supply system should be rechecked, as the lower demand will influence the feasibility of the central supply system (district cooling).
- In anyway the cornerstones of the energy concept should be:
  - Behaviour (awareness campaign to use the „appropriate“ setting temperature
  - Passive measures (thermal insulation and shading elements)
  - A high efficiency of cooling supply
  - Solar themal systems

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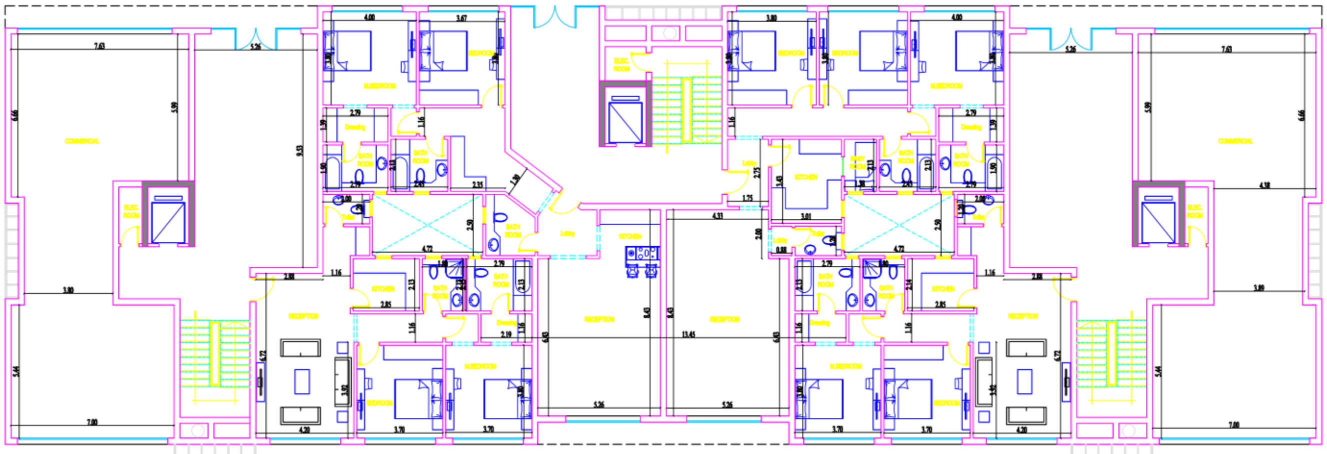
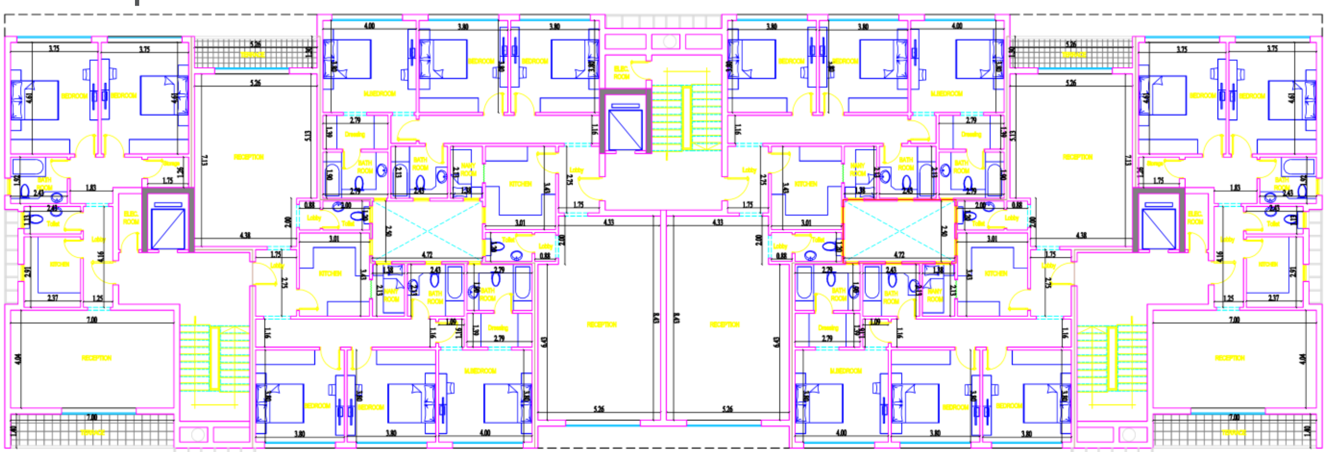
ANNEX
PLANS

Floor plan: Ground floor



Floor plan: Second floor



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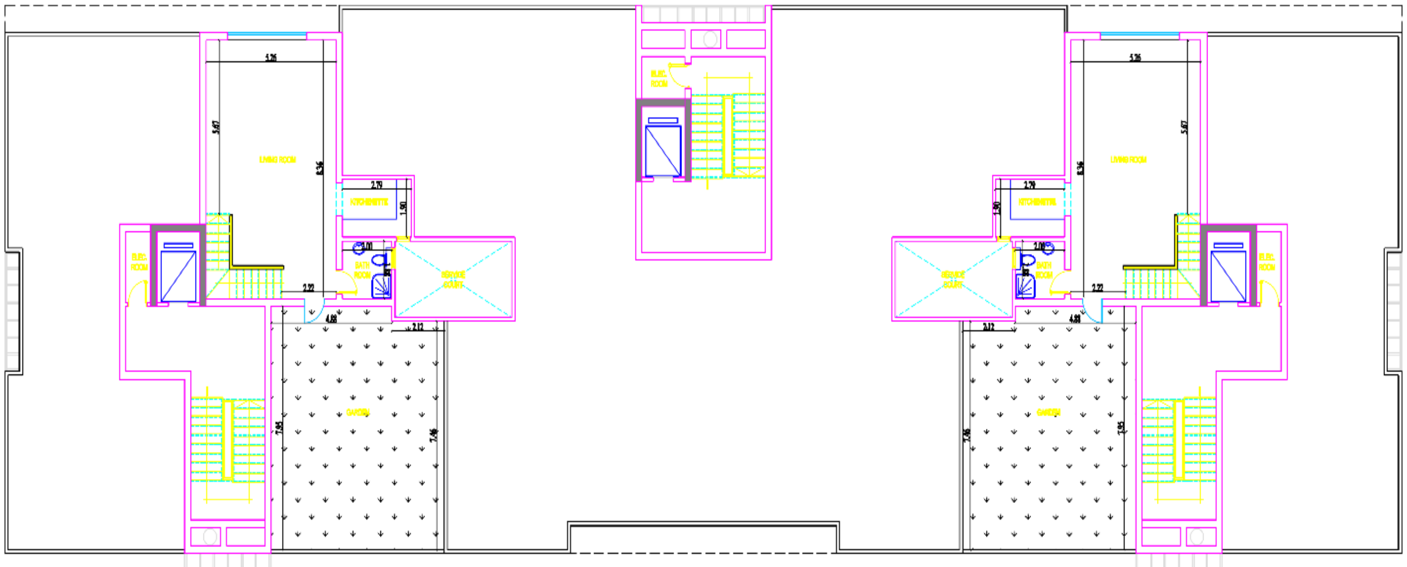
Floor plan: Roof top



ANNEX

FINANCIAL ASSUMPTIONS

Measures	Cost				Comments
Thermal Insulation					
	Base cost		Per additional cm		
Facade	x	€/m²	1,13	€/m²	Specific envelope
Rooftop	x	€/m²	0,90	€/m²	Surface as
Ground	x	€/m²	0,89	€/m²	Reference area
Windows					
Single glazing	5,7	W/m²k	55,15	€/m²	Window surface as reference area
Double glazing	3,2	W/m²k	68,94	€/m²	
Double glazing (low E)	1,2	W/m²k	129,00	€/m²	
Triple glazing	0,8	W/m²k	175,00	€/m²	
Solar glazing	0,3	G-value	30	€/m²	
Shading measures					
Fixed shading elements (Louvres)	50			€/m²	Window surface as reference area
Reflective coating on the roof	10			€/m²	

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ANNEX

FINANCIAL ASSUMPTIONS

Measures	Costs				Comments
Space cooling technologies					
Split air conditioner	3	COP	25	€/m²	Conditioned area as referenced area
Split air conditioner	4	COP	27,5	€/m²	
Split air conditioner	5	COP	30	€/m²	
Space heating technologies					
	efficiency		costs		
Gas boilers - conventional	85	%	9	€/m²	Conditioned area as reference area
Gas boilers - condensing	103	%	10,5	€/m²	
Heat Pumps (any source) – COP 3	300	%	.n.a.	€/m²	
Heat Pumps (any source) – COP 4	400	%	n.a.	€/m²	
Heat Pumps (any source) – COP 5	500	%	n.a.	€/m²	
Fuel boilers - conventional	80	%	9	€/m²	
Water heating technologies					
Fossil - conventional	2,50			€/m²	Conditioned area as reference area
Fossil - efficient	3,25			€/m²	
Electric	1,25			€/m²	
Solar water heaters (Solar thermal collectors)	7,67			€/m²	
Lighting					
Compact fluorescent lamps	2.3			€/lamp	per lamp
LED lights	8			€/lamp	per lamp
Renewable energy					
PV, whole system (without batteries)	600			€/kWp	per capacity

ANNEX

OVERVIEW OF ENERGY RELEVANT INFORMATION (SCENARIO A)

Parameter	Unit	BAU	Current planning	Variant 1a	Variant 2a
External wall u-value	W/(m²*K)	1,8	1,14	1,14	0,4
Roof u-value	W/(m²*K)	3	0,457	0,457	0,36
Floor u-value	W/(m²*K)	3	1,85	1,85	1,85
Windows u-value	W/(m²*K)	5,7	1,69	1,69	1,69
Windows g-value	-	0,85	0,66	0,66	3
Window fraction	%	21	21	Max 20	20
Shading elements		No	No	No	No
Thermal mass		heavy	heavy	heavy	heavy
Heating systems		COP 2,5	District heating	District heating	COP 5,0
Cooling systems		COP 2,5	District cooling	District cooling	COP 5,0
Hot water		Electric instantaneous	Natural gas	Natural gas	Natural gas
Ventilation systems		Natural	Natural	Natural	Natural
Lighting systems		LED	LED	LED	LED
Renewable energy		No	No	No	No
Temperature setpoint: Heating	°C	21	21	20	20
Temperature setpoint: Cooling	°C	23	23	26	26

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ANNEX

OVERVIEW OF ENERGY RELEVANT INFORMATION (SCENARIO B)

Parameter	Unit	BAU	Current planning	Variant 1b	Variant 2b
External wall u-value	W/(m²*K)	1,8	1,14	1,14	0,4
Roof u-value	W/(m²*K)	3	0,457	0,457	0,36
Floor u-value	W/(m²*K)	3	1,85	1,85	1,85
Windows u-value	W/(m²*K)	5,7	1,69	1,69	1,69
Windows g-value	-	0,85	0,66	0,66	0,3
Window fraction	%	21	21	Max 20	20
Shading elements		No	No	No	Solar Glazing
Thermal mass		heavy	heavy	heavy	Heavy
Heating systems		COP 2,5	District heating	District heating	COP 5,0
Cooling systems		COP 2,5	District cooling	District cooling	COP 5,0
Hot water		Electric instantaneous	Natural gas	Natural gas	Electric / solar thermal 45%
Ventilation systems		Natural	Natural	Natural	Natural
Lighting systems		LED	LED	LED	LED
Renewable energy		No	No	No	PV
Temperature setpoint: Heating	°C	21	21	20	20
Temperature setpoint: Cooling	°C	23	23	26	26

