PORTO PYRAMIDS, EGYPT

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

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INTRODUCTION

Perspective of the Porto Pyramids Master Plan

Porto Pyramids was launched in 2016 and is a project built on an inspiration. Living in a world characterized by changing lifestyles, busier schedules, and greater responsibilities, the need for a balance of tranquil natural landscapes and serene family living has become essential to balance the demands from today's professionals. Porto Pyramids is conveniently located close to major business and shopping centres to help ensure a short drive to the office or a quick stop to pick something up from the local shops or malls.

METHODOLOGY

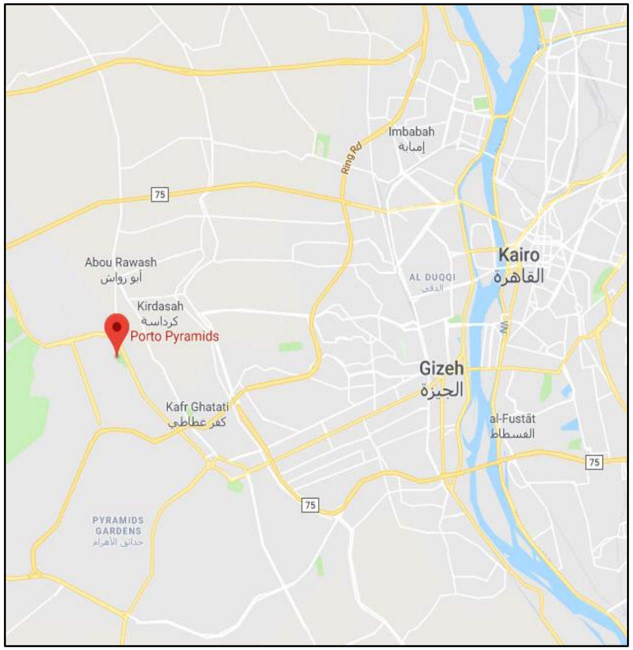
- Objectives
  - Identify the baseline (energy consumption of **B**usiness **a**s **U**sual - BaU) and its comparison with the current planning
  - Determine low hanging fruits
  - Elaborate nearly zero-energy building (nZEB) solutions and its incremental costs

- 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 Porto Pyramids



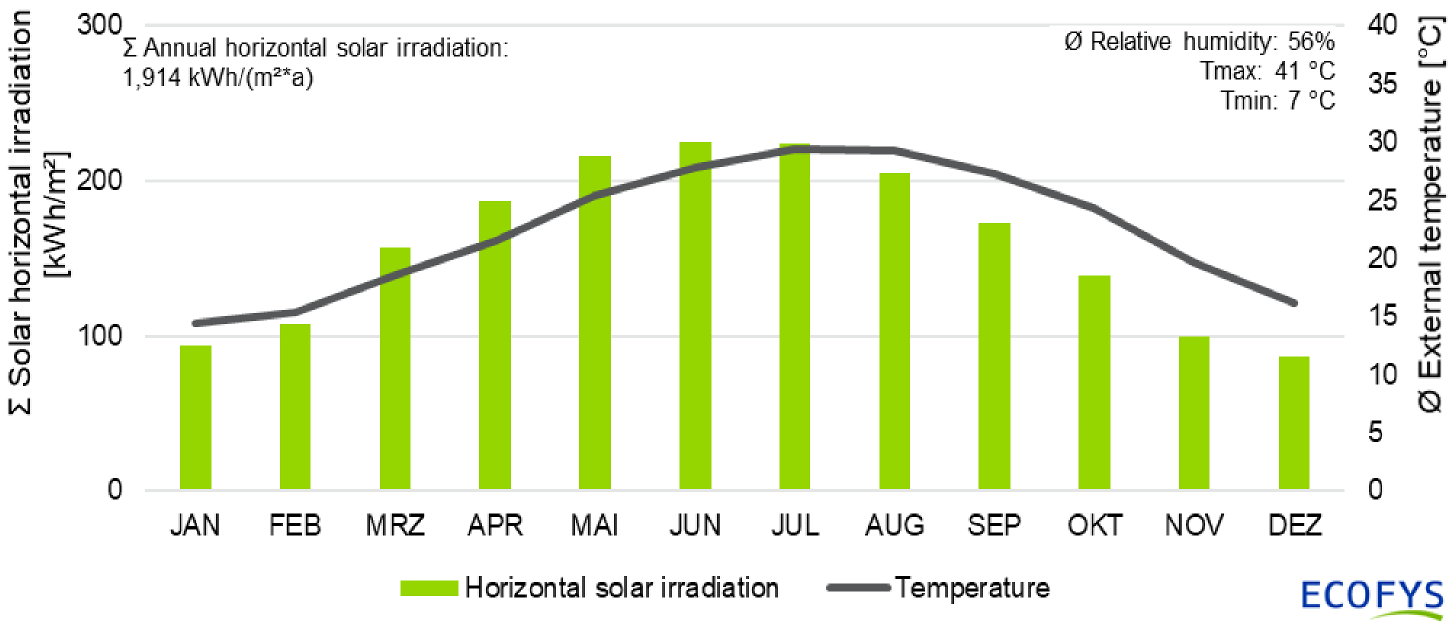
Source: Google Maps

Porto Pyramids is planned to be realised about 18 km from Cairo, Egypt. The project is already in construction phase. The Master Plan includes 16 different unit types, a 5-star hotel, spa and gym, swimming pools, dancing fountain, and a club house. The project site is located close to major businesses and shopping centres and therefore ensures short commutes.

NAVIGANT

BOUNDARY CONDITIONS
CLIMATE

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

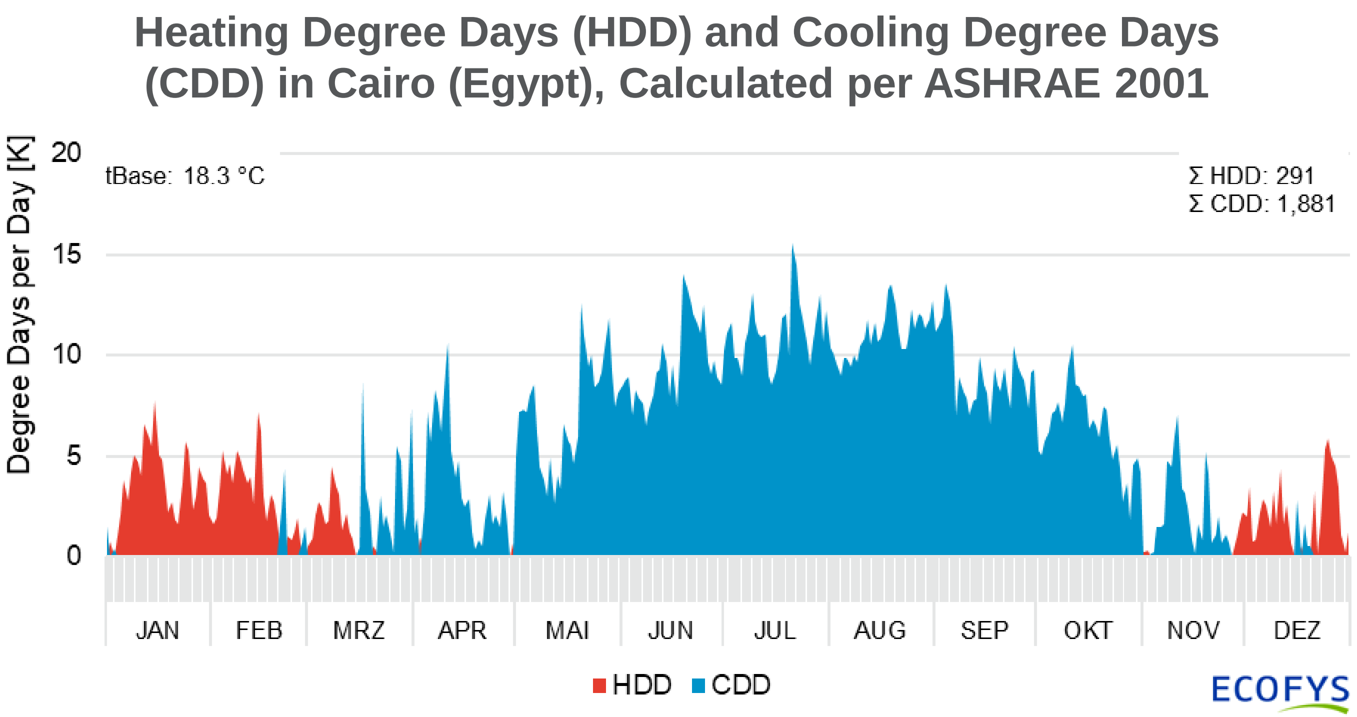


The climate at the project site in Cairo is primarily hot and reaches an average humidity rate of 56%. External temperatures range from above 0°C to 41°C with average temperatures around 24°C. December is the coldest month, July is the hottest. The minimum temperature level does not fall below 0°C which means that frost issues do not play a role in terms of construction projects.

NAVIGANT

BOUNDARY CONDITIONS

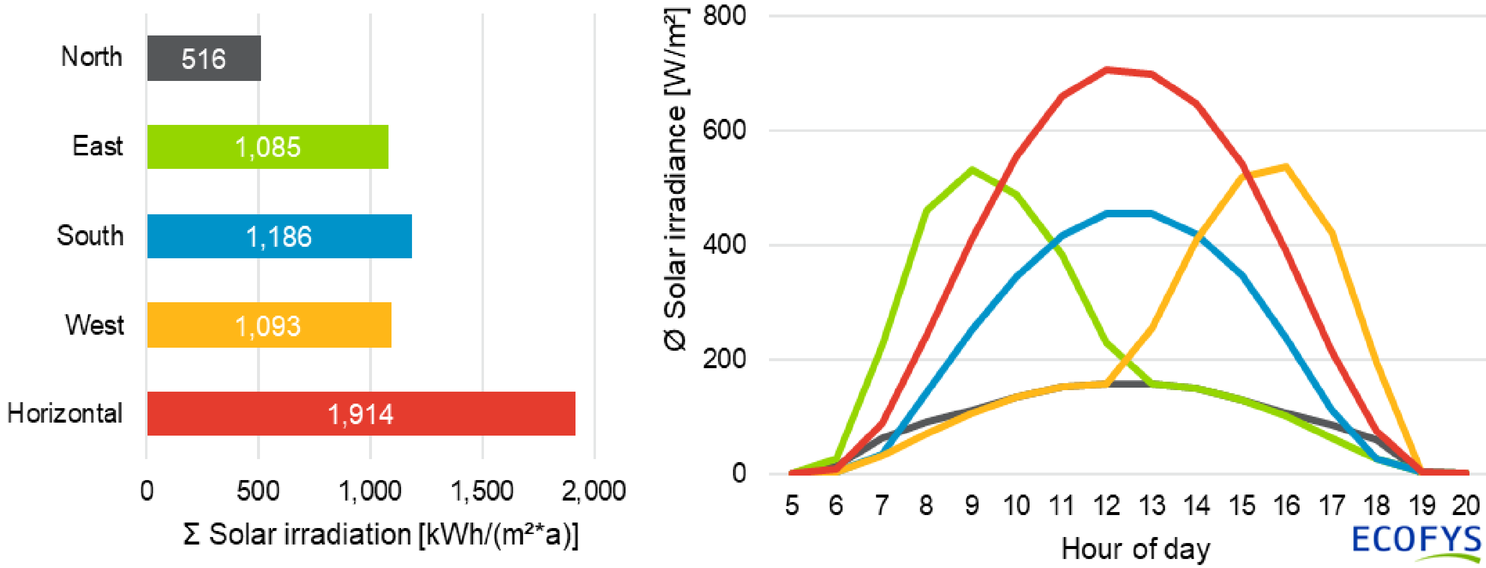
CLIMATE



The demand for cooling prevails against heat demand as the high number of >1,800 CDDs indicate. The amount of cooling degree days is more than 6 times higher than the HDDs. Therefore, the major share of the energy demand accumulates for cooling.

BOUNDARY CONDITIONS
CLIMATE

Solar Irradiation in Cairo



A big potential for renewable energy lies within the solar irradiation in Cairo. Horizontal irradiation of 1,914 kWh/(m²*a) and >1000 kWh/(m²*a) for the East, South, and West orientations bring opportunities for energy generation through solar radiation.

BOUNDARY CONDITIONS

ENERGY PRICE AND CO_2 FACTOR

Parameter	Unit	Electricity	Oil	Natural Gas
Energy price*	EGP/kWh	0.13-1.36	3.65-6.6	1.4 – 2 EGP/m³
Energy price*	EUR/kWh†	0.01-0.06	0.168-0.3	0.065-0.092 EUR/m³
Low energy price - A	EUR/kWh†	0.01	0.168	0.0065
High energy price - B	EUR/kWh†	0.03**	0.3**	0.02**
CO_2 emission factor	gCO_2/kWh	444	310	220

*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
Utilisation:	Residential (part of Building #5)
Number of (expected) inhabitants	270
Year of construction	2016-2018
Number of floors	5 plus parking
Number of apartments	54
Conditioned floor area	10,800 m²
Clear room height	2.7 m
Conditioned volume	29,160 m³
Roof area	2,400 m²
Wall area	3,906 m²
Ground floor area	2,400 m²
Window fraction per orientation (N/E/S/W)	Not available / 691 m² / 113 m² / 691 m²

ANALYSIS
VARIANTS INTRODUCTION

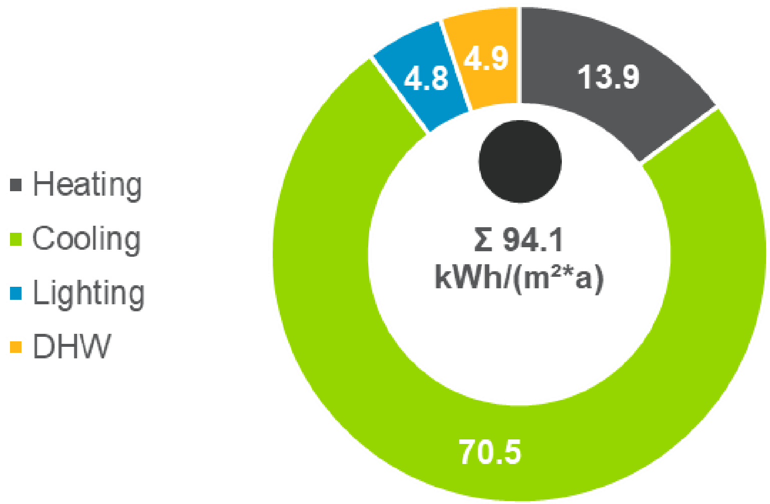
- **Baseline**
  - Business as Usual reflects the current state of construction in the respective country. It might even deviate from technical regulations if the construction practice does not respect it. This variant will be seen in further analysis as the baseline.
- **Current Situation**
  - This 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 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 (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 40%
Shading	No
Heating systems	Reversible split unit - COP 2.5
Cooling systems	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/23°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 CONSUMPTION



Invest costs
925 EGP/m²
43 EUR/m²

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

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

CO_2e

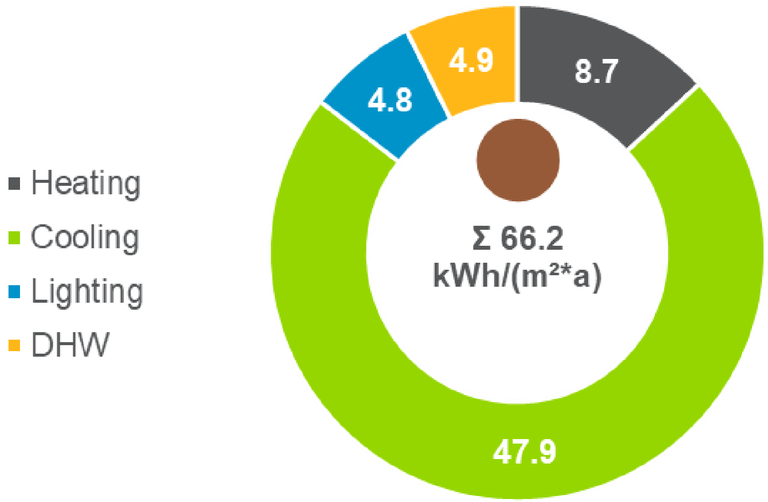
Emissions
62.0 kg CO2e/(m²*a)

The energy consumption is dominated by its cooling demand [70 kWh/m²a].

ANALYSIS – CURRENT SITUATION
ENERGY RELEVANT INFORMATION

Measure	Current situation
Roof insulation (U-Value)	0.63 W/m²K
Wall insulation (U-Value)	0.44 W/m²K
Floor insulation (U-Value)	3 W/m²K
Windows (U-Value; G-Value)	5.7 W/m²K; 0.85
Window fraction	Ø 40%
Shading	Overhangs, balconies, fixed louvres
Heating systems	Reversible split unit 2.5
Cooling systems	Reversible split unit 2.5
Hot water	Electric instantaneous
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	23°C/23°C

ANALYSIS – CURRENT SITUATION
ENERGY CONSUMPTION



Invest costs
1,103 EGP/m²
51 EUR/m²

Energy costs - low tariff	Energy costs - high tariff
14.4 EGP/(m²*a)	43.1 EGP/(m²*a)
0.7 EUR/(m²*a)	2.0 EUR/(m²*a)

CO_2e

Emissions
43.6 kg CO2e/(m²*a)

The current planning is already saving **30%** final energy compared to the baseline.

ANALYSIS –
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
4	Window fraction	What is the most energy efficient window fraction per orientation?
5	Air tightness	What is the effect of air tightness?
6	Cooling supply system	What is the cost optimal solution for cooling?
7	Set temperature: A) Cooling B) Heating	What is the energy saving potential of an adjusted set temperature?
8	Solar energy	Is the installation of solar energy cost efficient?

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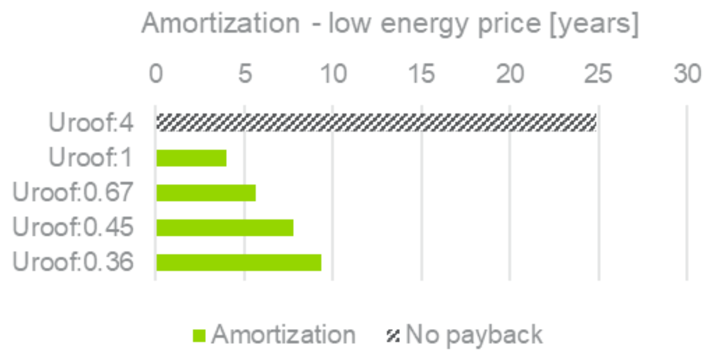
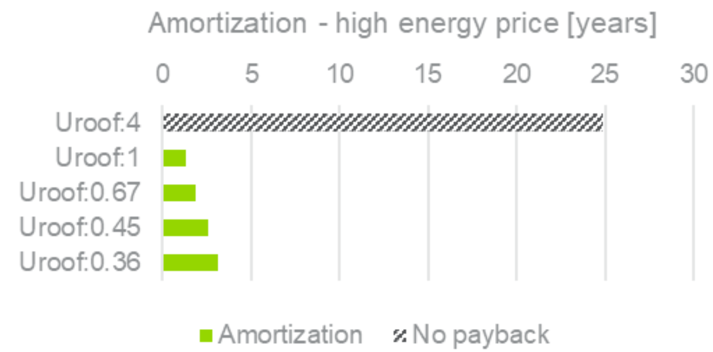
ANALYSIS
PASSIVE MEASURES

Measure 1	Energy Efficient Opaque Surface
Roof insulation	What is the cost optimal thickness?

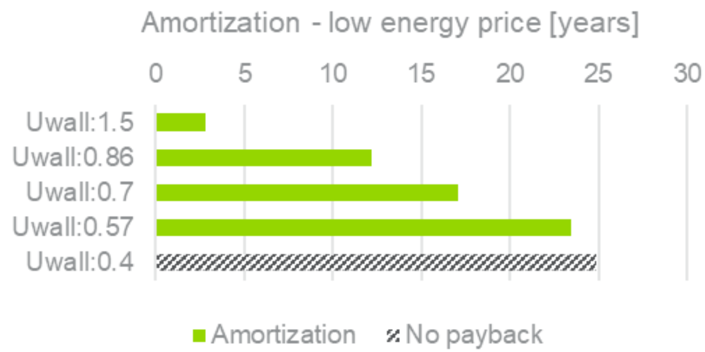


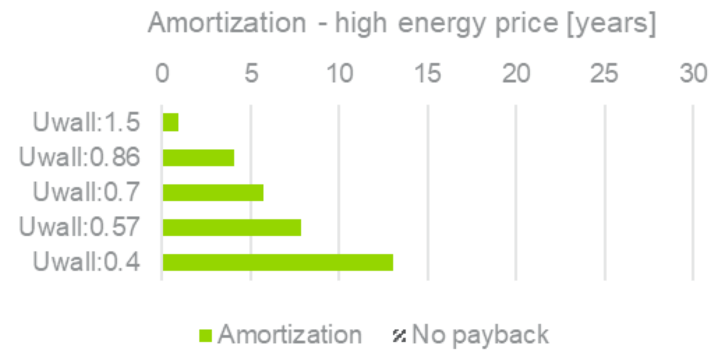


Improved roof insulation appears benefitial in both energy cost scenario. Poor insulation, however, does not even compensate the base costs over its lifetime.

ANALYSIS
PASSIVE MEASURES

Measure 2	Energy Efficient Opaque Surface
External wall insulation	What is the cost optimal thickness?





The current planning alreading applies efficient wall insulation. Further improvements may be economically reasonable with increasing energy prices.

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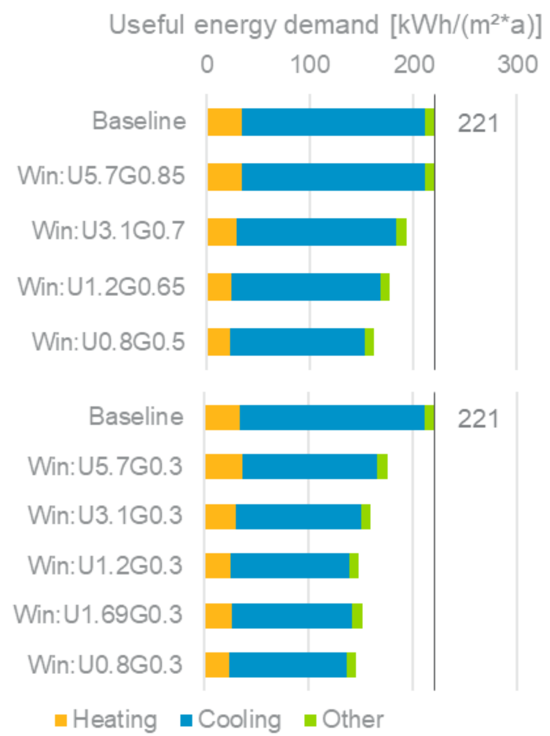
Measure 3	Energy Efficient Windows
Transmission and transmittance	What is the most energy efficient U-Value/G-Value

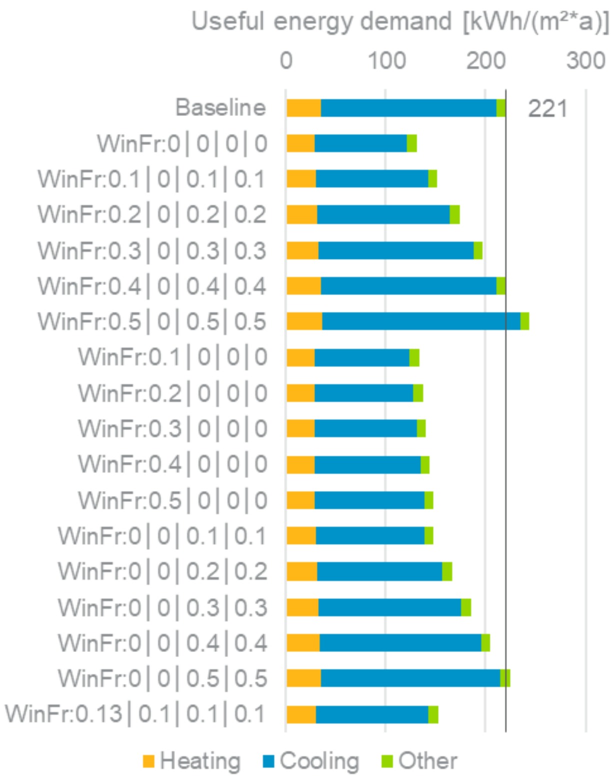


Improving the windows' U-values can save 5% useful energy per 1 $W/(m^{2*}K)$.

Applying solar glazing (G-value: 0.3) can save an additional 10%-20% of useful energy.

ANALYSIS
PASSIVE MEASURES

Measure 4	Energy Efficient Windows
Window fraction	What is the most energy efficient window fraction per orientation?



Reducing the overall window fraction by 10% can reduce the cooling demand by 10% while barely increasing the heating demand.
The effect is significantly larger towards East and West than towards South.
However, eliminating energy flow through windows can only halve the cooling demand. Other sources for heat/cold exchange have to be connsidered, too.

Note: The reference building has an attached nothern wall, thus no window fraction is considered there. Directions in chart: S|N|E|W

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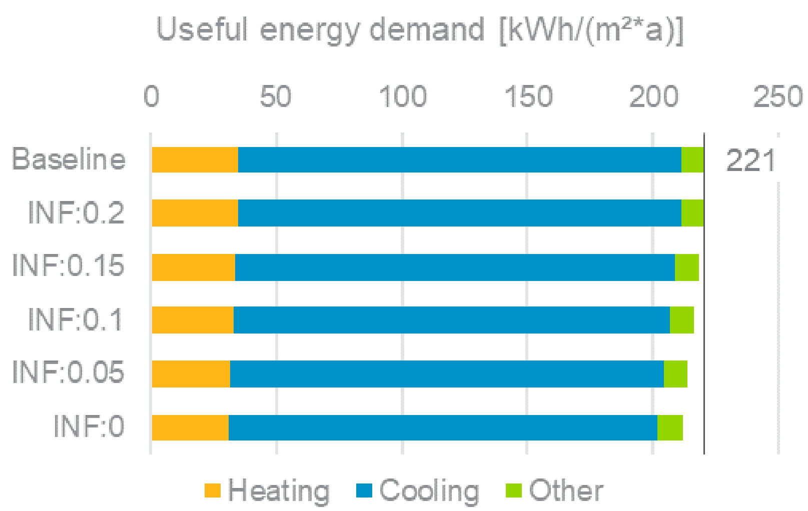
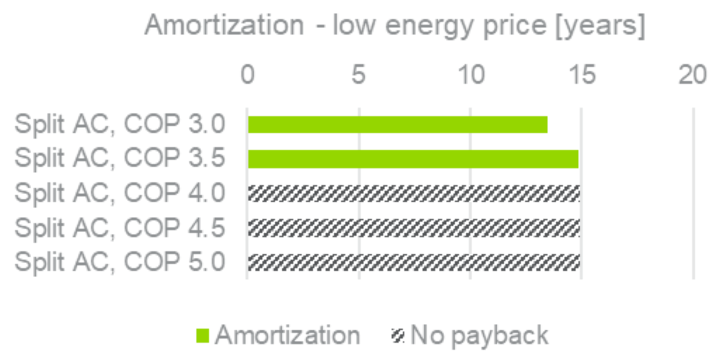
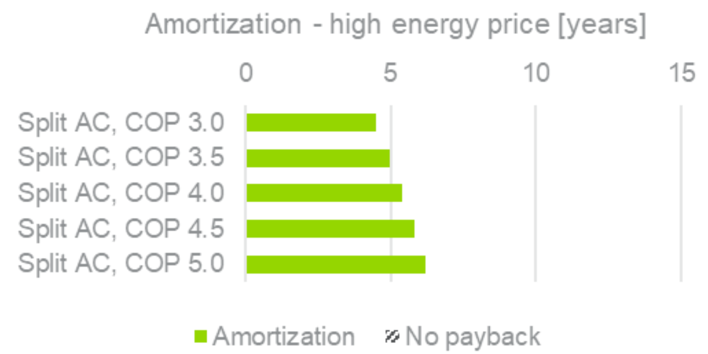
Measure 5	Air Tightness
Air tightness	What is the effect of air tightness?



The effect of improved air tightness, i.e., reduced infiltration, is limited. Reducing the infiltration by 0.5 1/h can save 2 kWh/(m^2*a)

Measure 6	Cooling
Cost optimal cooling	What is the cost optimal solution for cooling?





The future energy price development has a major impact on the amortisation of investments. With current prices, high efficiency devices do not payback within their average lifetime. With growing prices, even air conditioners with COP 5 become benefitial.

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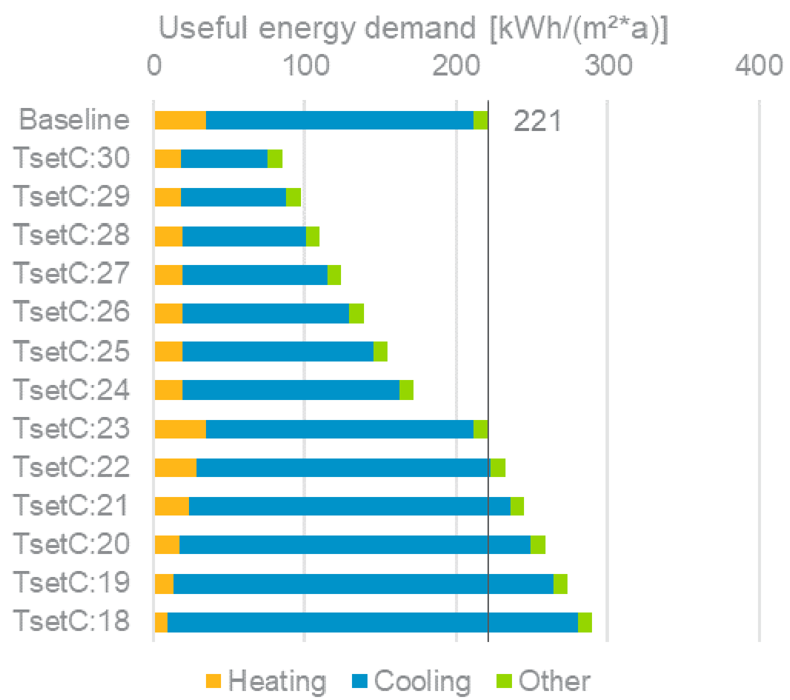
Measure 7a	Behaviour
Setting temperature, cooling	What is the energy saving potential of an adjusted set temperature?



Raising the set temperature for cooling by 1 K can save 12% of useful energy from cooling.

Note: The baseline setting temperature for both, heating and cooling, is 23°C.

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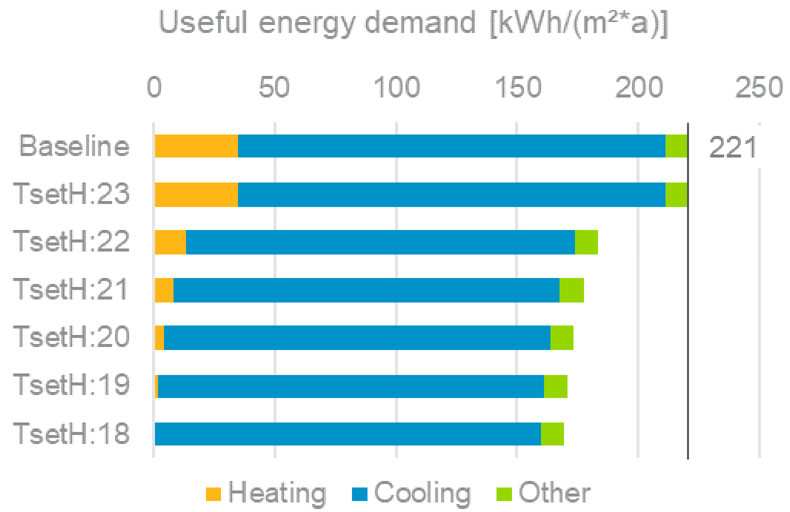
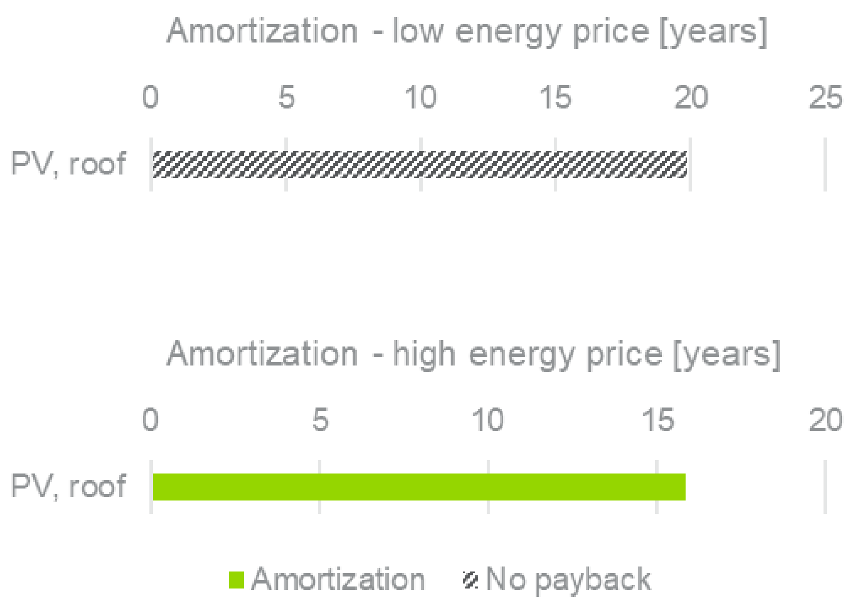
Measure 7b	Behaviour
Setting temperature, heating	What is the energy saving potential of an adjusted set temperature?



Decreasing the set temperature for heating in the warm climate of Cairo can almost annihilate the energy demand for heating.

Measure 8a	Solar Energy
Photovoltaics	Is the installation of solar energy cost efficient?



Key Assumptions:

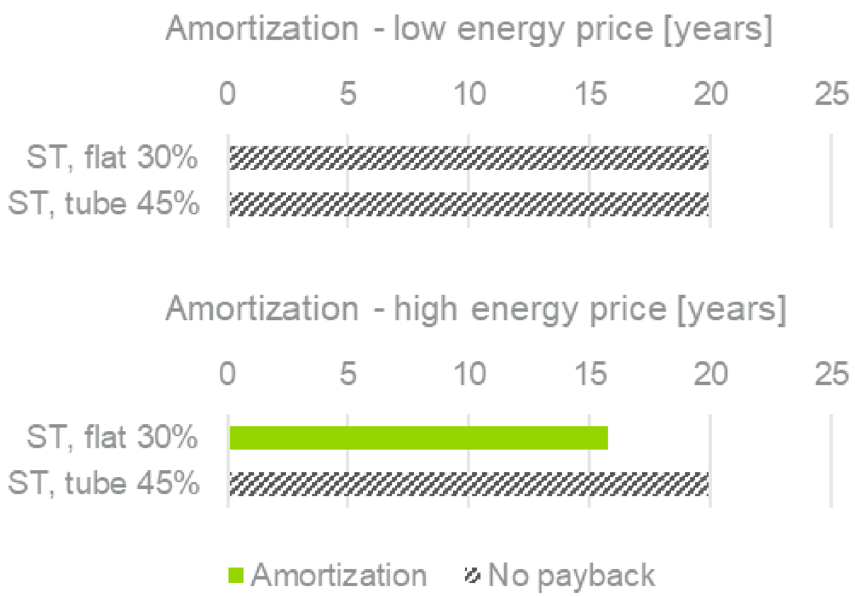
- Roof fraction: 50%
- Solar azimuth: 0° (South)
- PV modules angle: 25°
- Module type: Crystalline
- CAPEX: 800 EUR/kWp

Key Findings:

- Capacity: 171 kWp
- Simple payback:
  - Low energy price: No payback
  - High energy price: 16 years

ANALYSIS
RENEWABLES / SOLAR ENERGY

Measure 8b	Solar Energy
Solar thermal	Is the installation of solar energy cost efficient?



Key Assumptions:
- Solar thermal collector sizing for water heating:
  - 1m²/one inhabitant
- Solar azimuth: 0° (South)
- Collector angle: 25°
- Efficiencies:
  - Flat plate collector: 30%
  - Vacuum tube collector: 45 %

Key Findings:
- Sizing: 144 m² (45%); 270 m² (35%)
- Simple payback:
  - Low energy price: No payback
  - High energy price: 16 years (30% only)

NAVIGANT

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?	0.4	
2	Wall insulation (U-Value)	What is the cost optimal thickness?	0.36	
3	Windows (U-Value; G-Value)	What is the most energy efficient U-Value/G-Value	3.1/0.3	0.8/0.3
4	Window fraction	What is the most energy efficient window fraction per orientation?	20%	
5	Air tightness	What is the effect of air tightness?	No effect	
6	Cooling supply system	What is the cost optimal efficiency for cooling? [COP]	3.5	5
7	A) Cooling B) Heating	What is the energy saving potential of an adjusted setting temperature?	Cooling 26°C Heating 20°C	
8	RE (solar energy)	Is the installation of solar energy cost efficient?	No	Yes

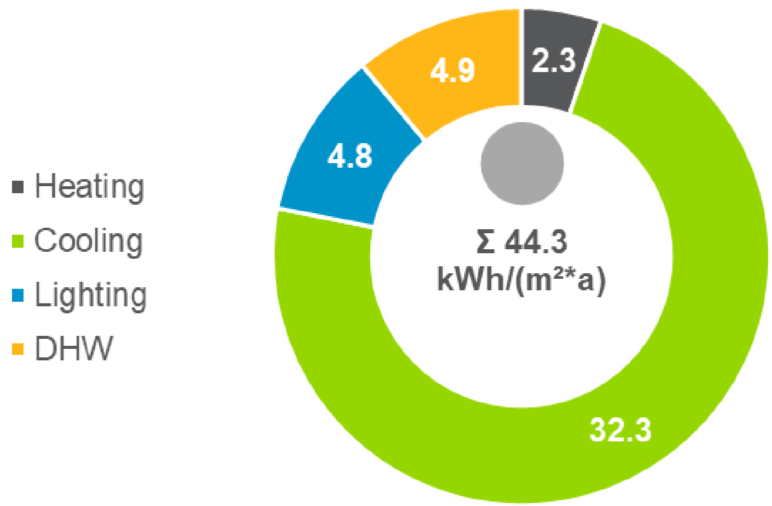
*different energy price levels:
A: Low energy price
B: High energy price

NAVIGANT

ANALYSIS – VARIANT 1 A – LOW ENERGY PRICE
ENERGY RELEVANT INFORMATION

Measure	Variant 1A
Roof insulation (U-Value)	0.63 W/m²K
Wall insulation (U-Value)	0.44 W/m²K
Floor insulation (U-Value)	3 W/m²K
Windows (U-Value; G-Value)	Single 5.7 W/m²K; 0.85
Window fraction	**Ø 20%**
Shading	Overhangs, balconies, fixed louvres
Heating systems	Reversible split unit 2.5
Cooling systems	Reversible split unit 2.5
Hot water	Electric instantaneous
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	**26°C/20°C**

ANALYSIS – VARIANT 1 A – LOW ENERGY PRICE
ENERGY CONSUMPTION



Invest costs
806 EGP/m²
37 EUR/m²

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

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

CO_2e

Emissions
29.2 kg CO2e/(m²*a)

This variant is saving more than **50%** final energy compared to the baseline.

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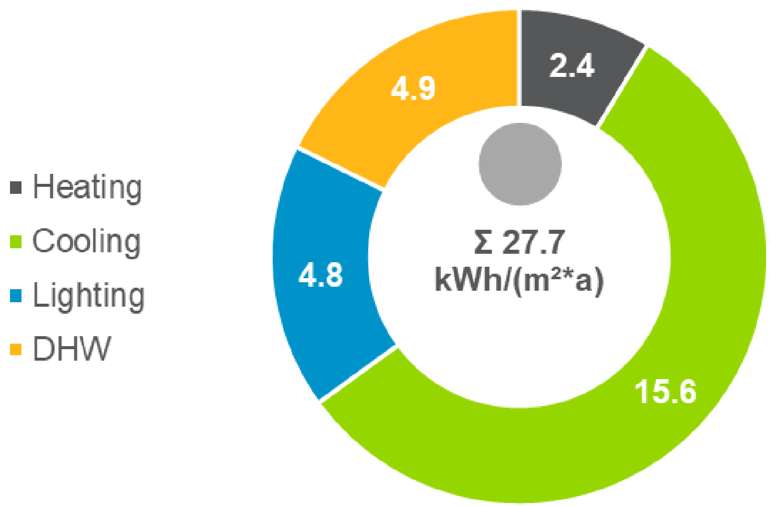
ANALYSIS – VARIANT 1 B – HIGH ENERGY PRICE
ENERGY RELEVANT INFORMATION

Measure	Variant 1B
Roof insulation (U-Value)	**0.45 W/m²K**
Wall insulation (U-Value)	0.44 W/m²K
Floor insulation (U-Value)	3 W/m²K
Windows (U-Value; G-Value)	5.7 W/m²K; 0.85
Window fraction	**Ø 20%**
Shading	Overhangs, balconies, fixed louvres
Heating systems	Reversible split unit 2.5
Cooling systems	Reversible split unit 2.5
Hot water	Electric instantaneous
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	**26°C/20°C**

ANALYSIS – VARIANT 1 B – HIGH ENERGY PRICE
ENERGY CONSUMPTION



Invest costs
905 EGP/m²
42 EUR/m²

Energy costs - low tariff	Energy costs - high tariff
6.0 EGP/(m²*a)	18.0 EGP/(m²*a)
0.3 EUR/(m²*a)	0.8 EUR/(m²*a)

Emissions
18.3 kg CO2e/(m²*a)

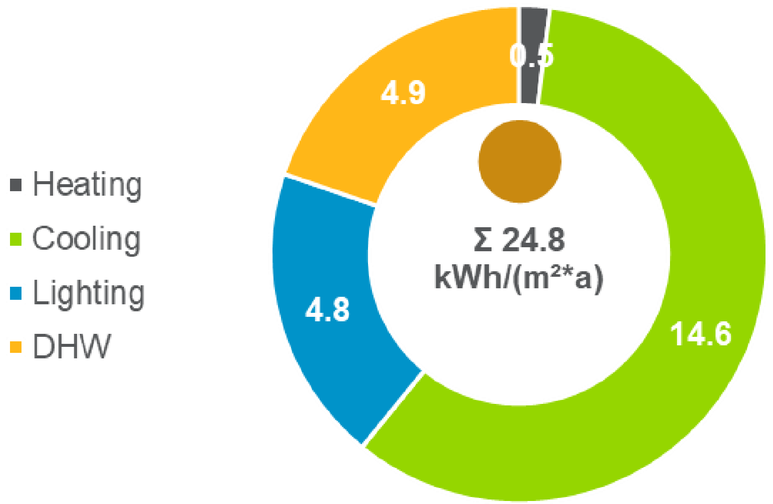
This variant saves more than **70%** final energy compared to the baseline.

ANALYSIS – VARIANT 2A – LOW ENERGY PRICE

ENERGY RELEVANT INFORMATION

Measure	Variant 2A
Roof insulation (U-Value)	**0.36 W/m²K**
Wall insulation (U-Value)	**0.4 W/m²K**
Floor insulation (U-Value)	3 W/m²K
Windows (U-Value; G-Value)	**3.1 W/m²K; 0.3**
Window fraction	**Ø 20%**
Shading	**No (solar glazing)**
Heating systems	**Reversible split unit 3.5**
Cooling systems	**Reversible split unit 3.5**
Hot water	Electric instantaneous
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	No
Set temperature cooling/heating	**26°C / 20°C**

ANALYSIS – VARIANT 2A – LOW ENERGY PRICE
ENERGY CONSUMPTION



Invest costs
982 EGP/m²
45 EUR/m²

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

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

CO_2e

Emissions
16.3 kg CO2e/(m²*a)

This variant is saving more than **73%** final energy compared to the baseline.

ANALYSIS – VARIANT 2B – HIGH ENERGY PRICE
ENERGY RELEVANT INFORMATION

Measure	Variant 2B
Roof insulation (U-Value)	**0.36 W/m²K**
Wall insulation (U-Value)	**0.4 W/m²K**
Floor insulation (U-Value)	3 W/m²K
Windows (U-Value; G-Value)	**Triple 0.8 W/m²K; 0.3**
Window fraction	**Ø 20%**
Shading	**No (solar glazing)**
Heating systems	**Reversible split unit 5**
Cooling systems	**Reversible split unit 5**
Hot water	**Solar Thermal (tubes)**
Ventilation systems	Natural
Lighting systems	LED
Renewable energy	**Photovoltaics**
Set temperature cooling/heating	**26°C/20°C**

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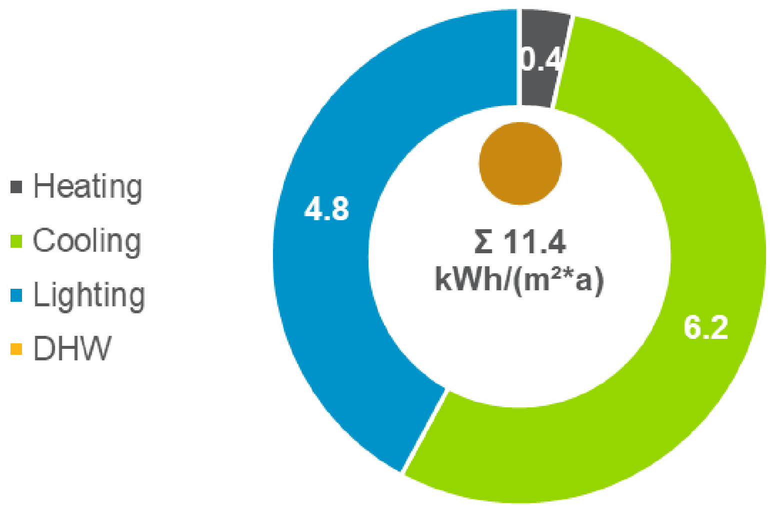
ANALYSIS – VARIANT 2B – HIGH ENERGY PRICE
ENERGY CONSUMPTION



Invest costs
1,573 EGP/m²
72 EUR/m²

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

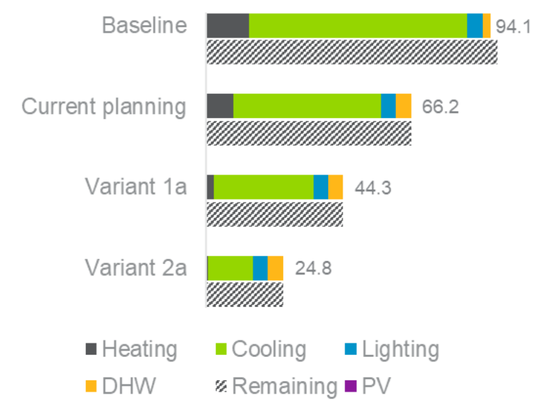
Emissions
0.0 kg CO2e/(m²*a)

Variant 2b is saving more than **88%** final energy compared to the baseline and the rest can be completely covered by solar energy.

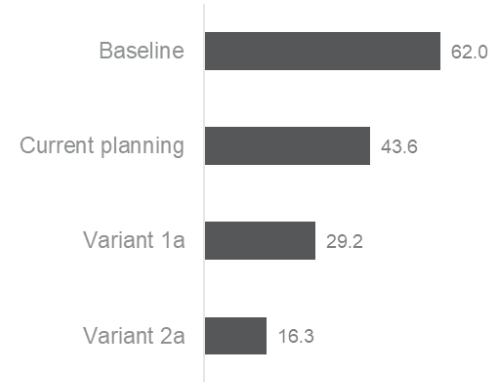
RESULTS

COMPARATIVE OVERVIEW A – LOW ENERGY PRICES

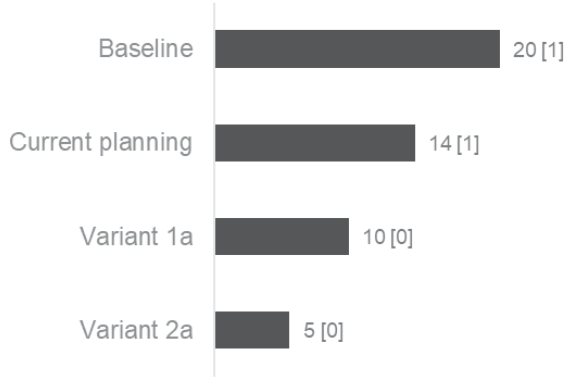
Specific final energy demand [kWh/(m²*a)]



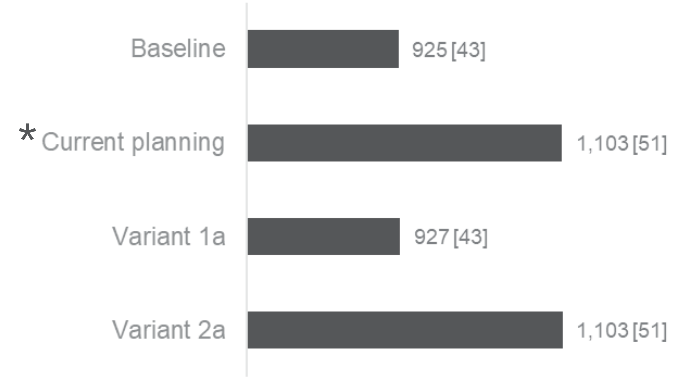
Specific emissions [kg CO2e/(m²*a)]



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



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



*As the current planning foresees a large window fraction, higher investment costs are expected

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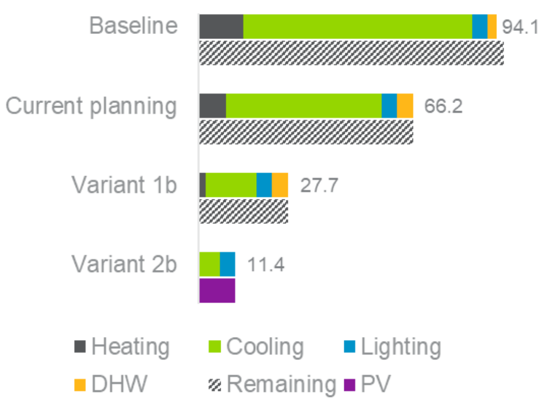
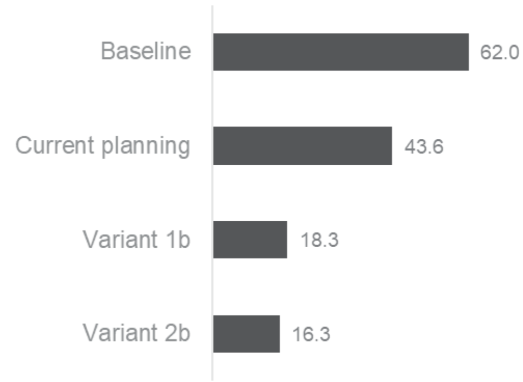
RESULTS
COMPARATIVE OVERVIEW B – HIGH ENERGY PRICES

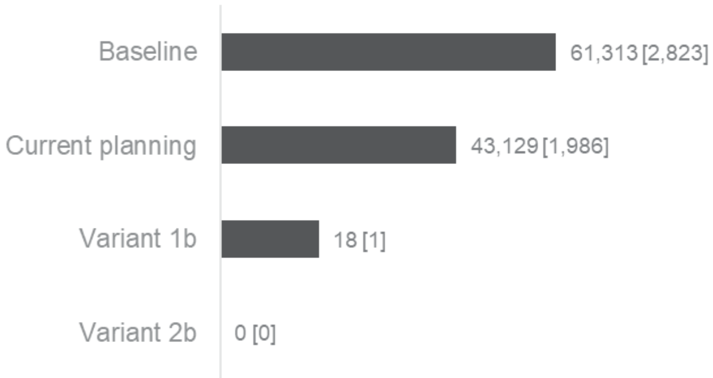
Specific final energy demand [kWh/(m²*a)]



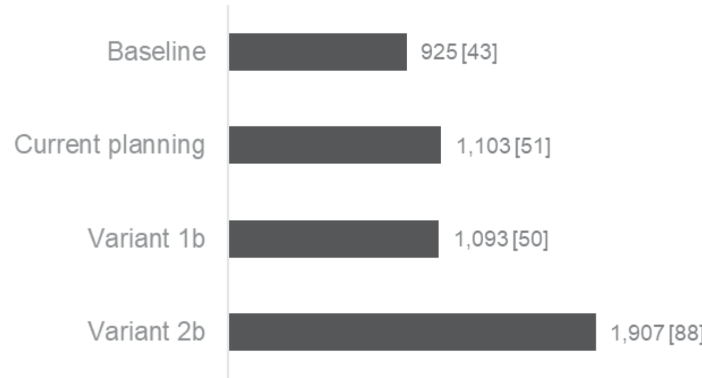
Specific emissions [kg CO2e/(m²*a)]



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



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



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RECOMMENDATIONS

Recommendations for ***ongoing construction activities:***

1. Inititiate **awareness campaign (flyer, hand outs)** addressing future flat owners to consider appropriate **set temperature cooling/heating** [**26°C/20°C**]

2. Improve **thermal insulation of the roof**, aiming for a **U-Value of 0.45 W/m²K** or better

Recommendations for ***future planning***:

Aim for zero-energy buildings

- Highly insulated envelope
- Window fraction - Ø 20%
- Effective Shading
- Heating/ Cooling systems
  - Reversible split unit with min COP=5
- Hot water
  - Solar Thermal (vacuum tubes)
- Photovoltaics
- Set temperature cooling/heating
  - 26°C/20°C

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