TRANSFORM

sofia development association

Building Information Modelling: Energy Simulation Service

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Online Conference with Local Stakeholders

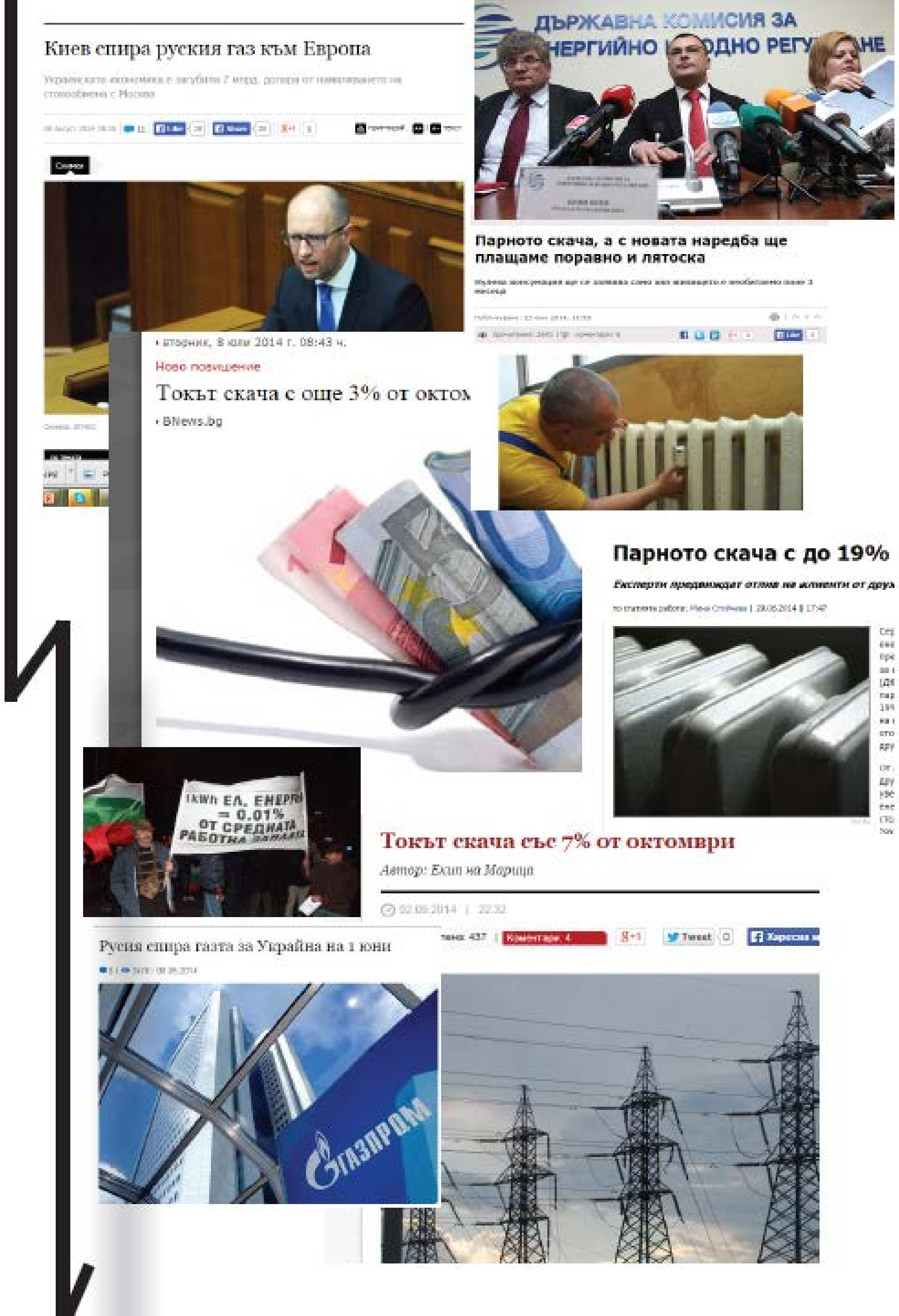
17 November 2020

Sofia

Supported by

eit Climate-KIC

Climate-KIC is supported by the EIT, a body of the European Union



Motivation Statement:

Energy efficiency and renewable energies in the building sector have become priority matter of future urban development. Nevertheless, it is not easy to take into account all the parameters that have influence on the building energy performance. In this sense, predictions, digital models and simulation are essential for the right design process from the very beginning of every architectural and HVAC project.

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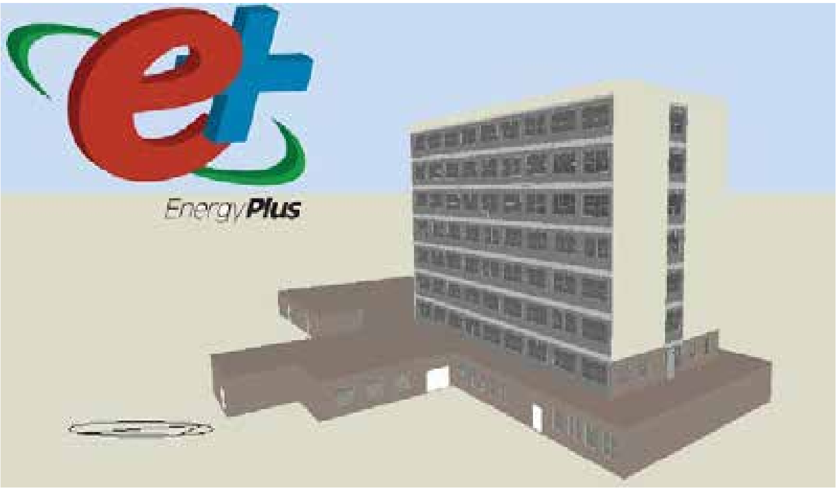
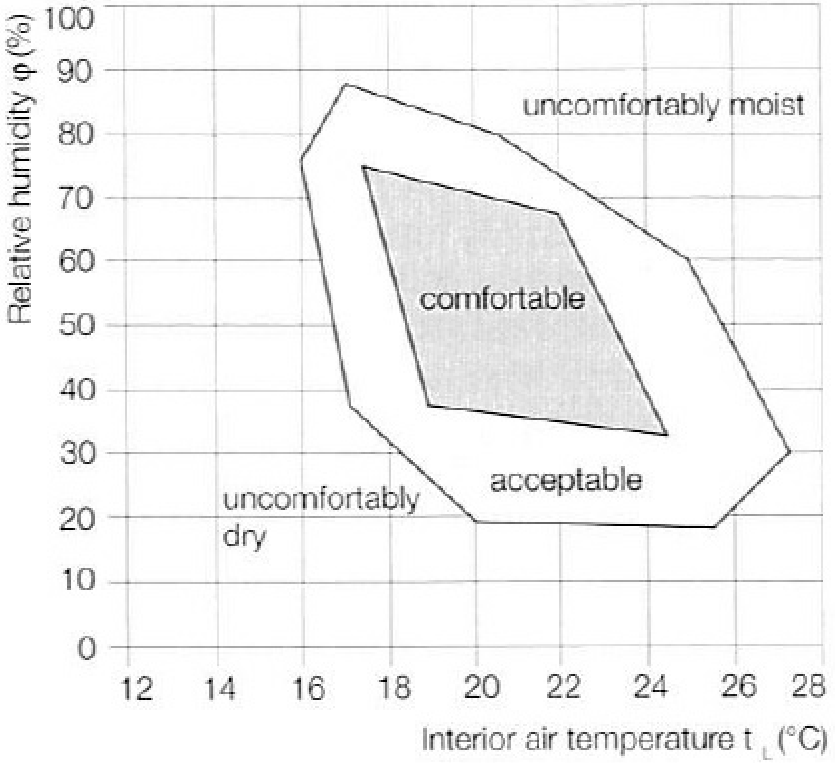




Building physics:

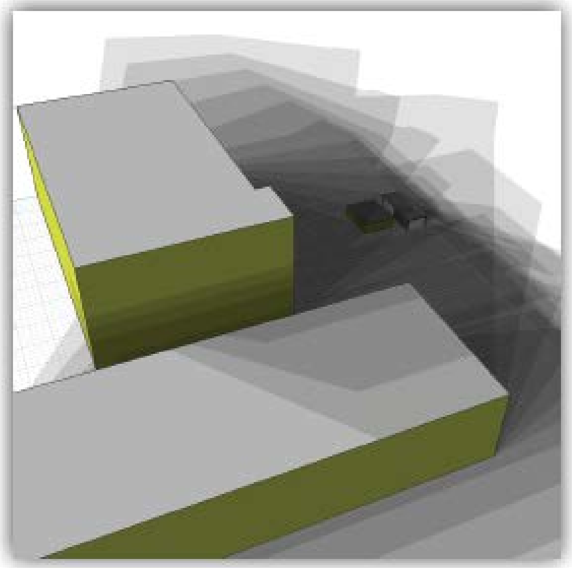
Deep understanding of the building physics is essential to use the digital calculation tools. Energy demand arises from the interior space comfort requirements, which can be summarized as:

- Visual comfort: 200-500 lx
- Thermal comfort: 20-25ºC at 40-60% relative humidity,
- Air quality index (AQI): between 0 and 50; 1.5-2 air changes per hour, 350-500 ppm CO_2 concentration; fine particle 50 µg/m^3 PM10 and 25 µg/m^3 PM2.5
- Acoustic comfort: 35-40 dB noise level

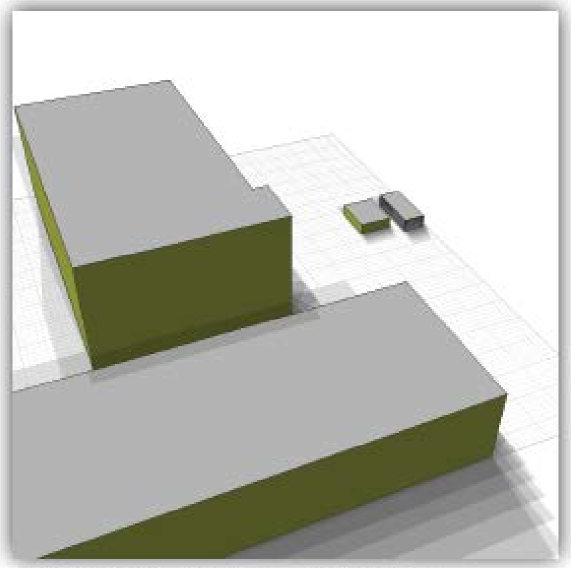
Methodology and tools:

A usual method to estimate the building performance is to introduce model input and using thermodynamic algorithms to simulate the heat transfer in terms of conduction, convection (fluid mass transfer), radiation (UV, visual and IR) and latent loads. Perhaps the most sophisticated and exact algorithms are called Energy Plus, developed by US Department of Energy introduced in different graphical interfaces. Usual input required is:

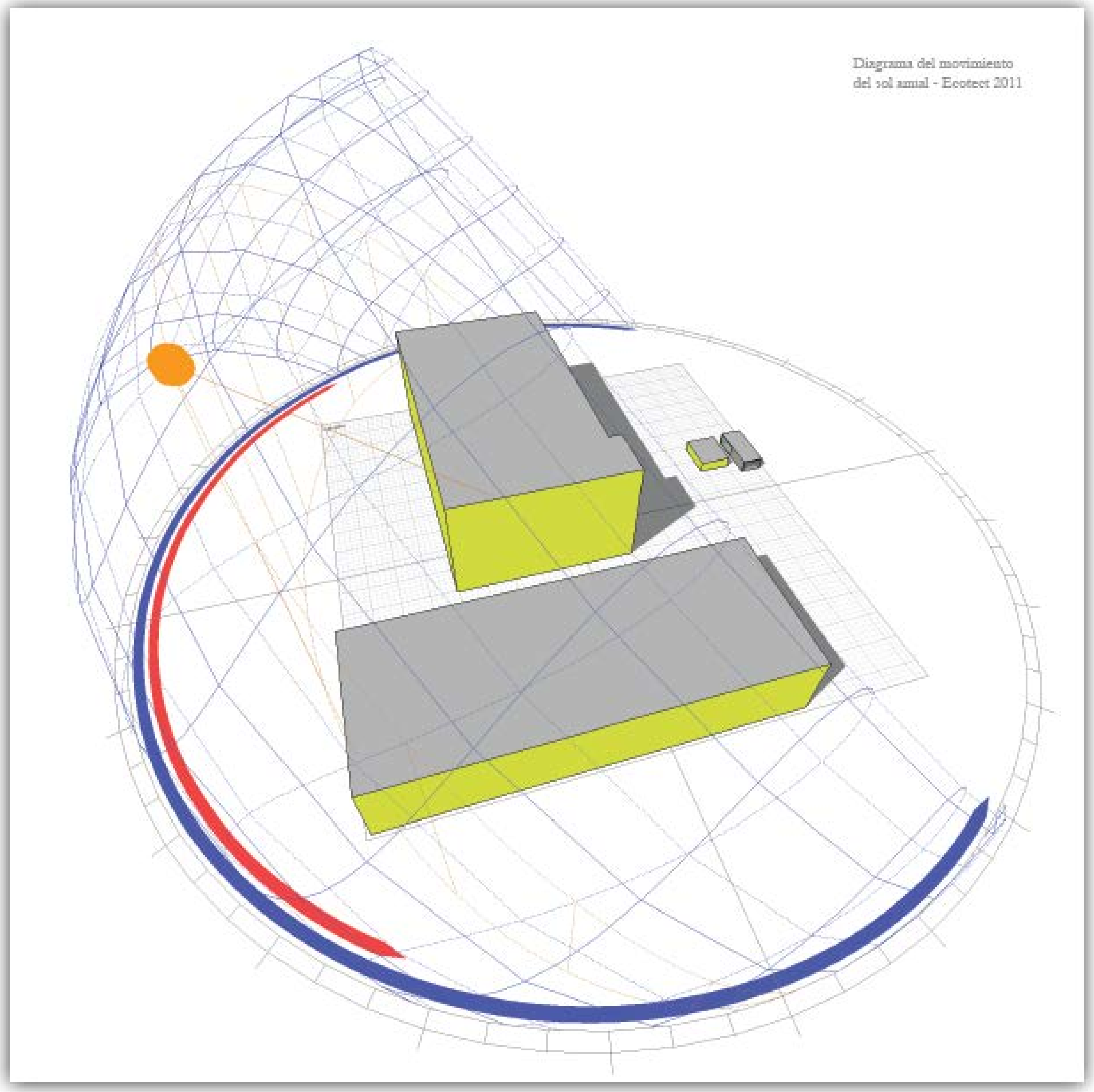
- Building geometry
- Climate data
- Site orientation and local shading
- Building enclosure and HVAC data
- User behavior and schedule of use
- Automation control

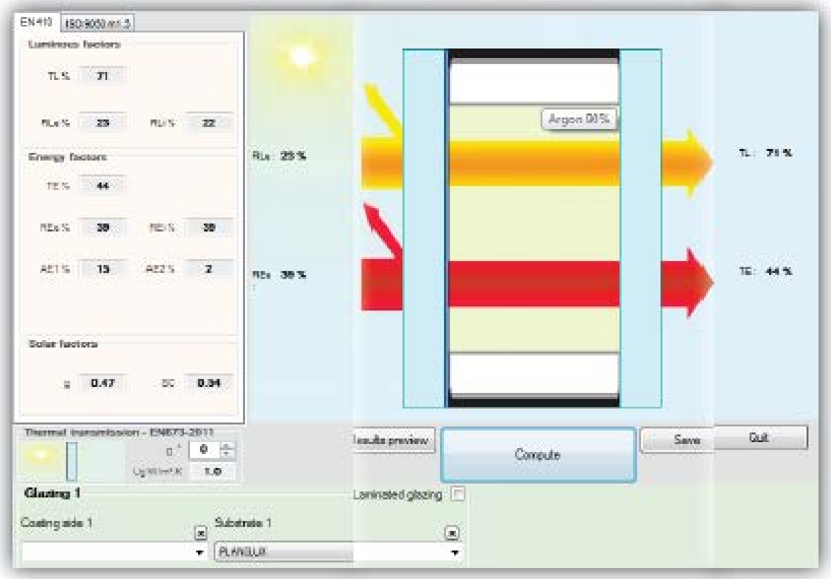


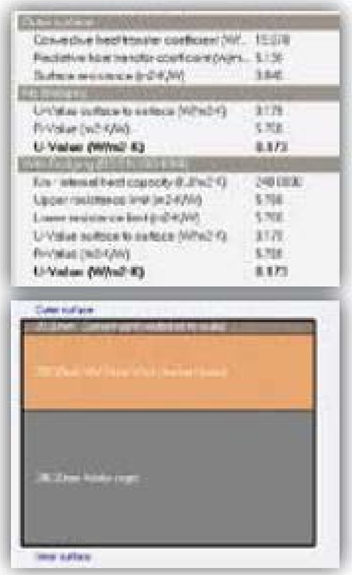
December 21st, 9:00-18:00 shadowing interval - 45min - Ecotect 2011



June 22nd, 9:00-18:00 shadowing interval - 45min - Ecotect 2011



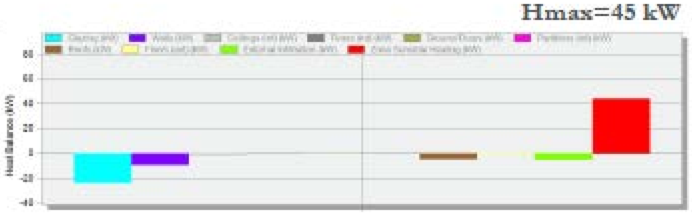


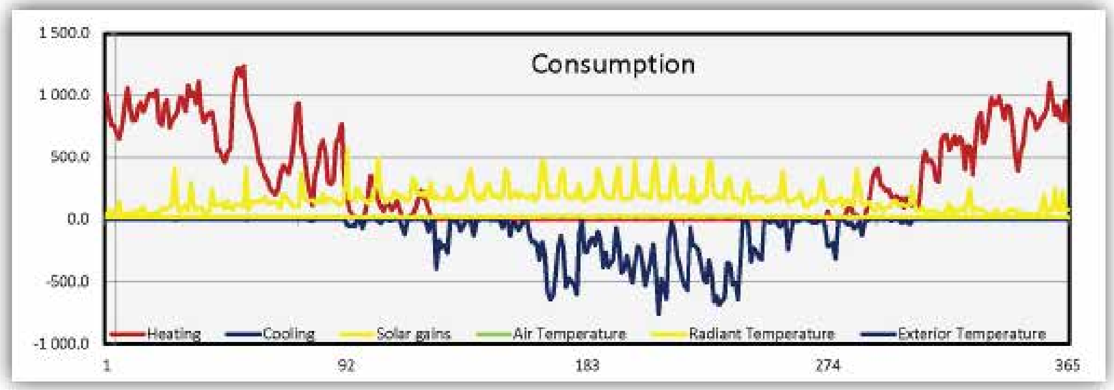


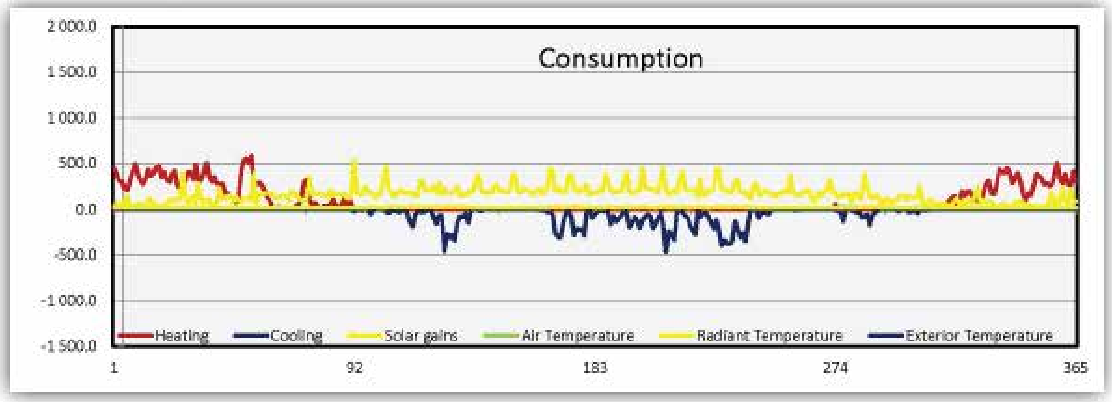
Shadowing and building enclosure analysis

Air Temperature (°C)	22.00
Radiant Temperature (°C)	19.47
Operative Temperature (°C)	20.73
Outside Dry-Bulb Temperature (°C)	-12.10
Glazing (kW)	-35.31
Walls (kW)	-12.44
Ceilings (int) (kW)	-1.68
Floors (int) (kW)	-0.12
Ground Floors (kW)	-0.31
Partitions (int) (kW)	0.02
Roofs (kW)	-5.97
Floors (ext) (kW)	-0.71
External Infiltration (kW)	-17.82
Zone Sensible Heating (kW)	74.32

Air Temperature (°C)	21.00
Radiant Temperature (°C)	18.11
Operative Temperature (°C)	20.05
Outside Dry-Bulb Temperature (°C)	-12.10
Glazing (kW)	-23.77
Walls (kW)	-9.37
Ceilings (int) (kW)	-1.21
Floors (int) (kW)	0.11
Ground Floors (kW)	-0.28
Partitions (int) (kW)	0.04
Roofs (kW)	-4.47
Floors (ext) (kW)	-0.47
External Infiltration (kW)	-5.19
Zone Sensible Heating (kW)	44.59





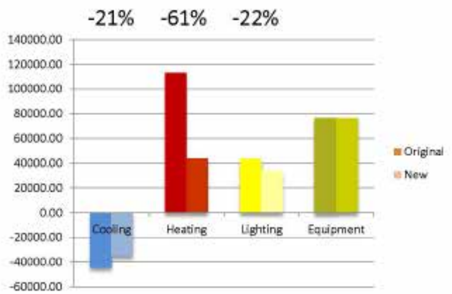


Energy simulation output:

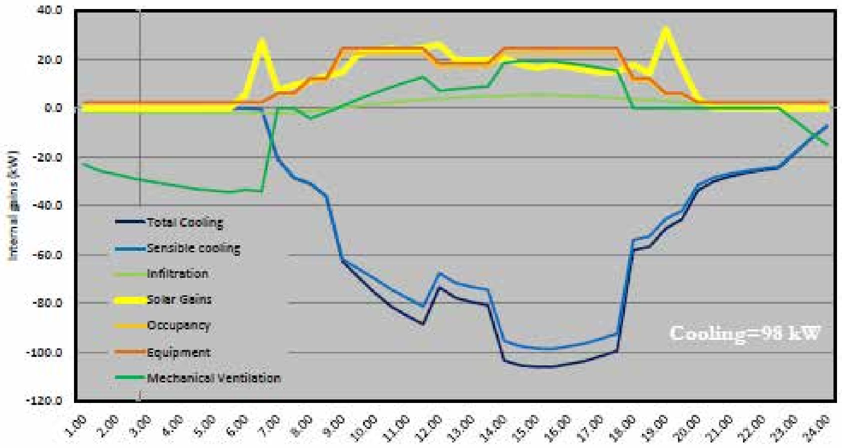
The approach for correct and realistic simulation results (margin of error between 5-10%) is to compare it with some benchmark. For existing buildings, the best way is to compare the energy demand with average energy bills and if needed – to calibrate the model accordingly. Possible mismatches may result from infiltration rate (unless Blower-Door test is performed, the infiltration is estimated qualitatively) or user behavior.

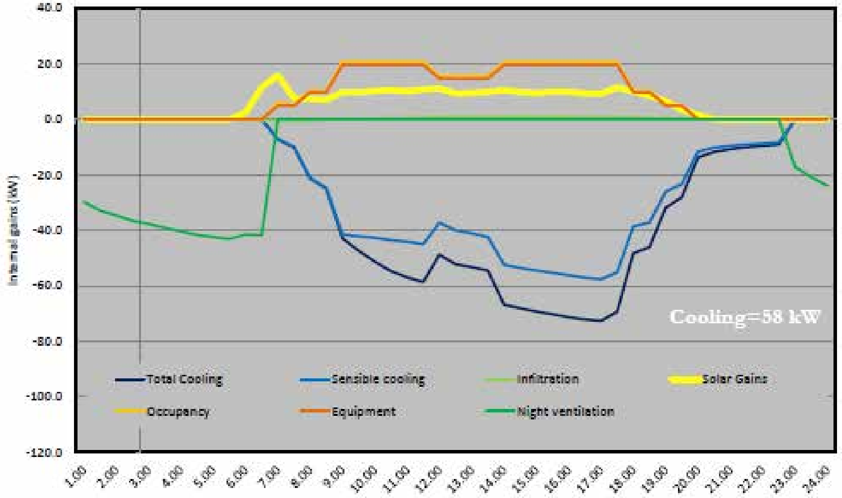
Usual output from the simulation procedure are:

- Heating load
- Cooling load
- Yearly, monthly, daily, or hourly energy consumption
- Primary and useful final energy
- Related CO2 emissions.



Клас	EPmin, kWh/m2	EPmax, kWh/m2	АДМИНИСТРАТИВНИ
A+	<	70	A+
A	70	140	A
B	140	280	B
C	280	340	C
D	340	400	D
E	400	500	E
F	500	600	F
G	>	600	G





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TRANSFORM preliminary results:

10 building sites are simulated, which should give a representative image for about 60-70% of the existing building stock in Sofia, situated in different part of Sofia, including superficial previous renovation efforts, where access and sufficient input data are available.


Home 1 - Centre
Home 2 - Bezden
Home 3 - Dragalevtsi
Home 4 - Gotse Delchev
Home 5 - Mladost 1 (Simeon)
Home 6 - Banishora
Home 7 - Iztok
Home 8 - Bistritsa
Home 9 - Mladost 2
Home 10 - Mladost 4
1
2
3
4
5
6
7
8
9
10
Sofia
София
Balsha
Балша
Petarch
Петърч
Kostinbrod
Костинброд
Dobroslavtsi
село
Доброславци
Novi Iskar
гр. Нови
Искър
Lukovo
Луково
SOFIA PROVINCE
Mramor
Мрамор
Voynegovtsi
Войнеговци
Svetovrachene
Световрачене
Prolesha
Пролеша
Bozhurishte
Божурище
Gurmazovo
Гурмазово
Chepintsi
Чепинци
Klisura
Клисура
Bankya
Банкя
Ivanyane
Иваняне
Malo Buchino
с. Мало
Бучино
Boyana Church Museum
Боянска църква музей
Krivina
Кривина
Kazichene
Казичене
Golemo
Buchino
Големо
Бучино
Vladaya
Владая
DRAGALEVTSI
German
Герман
Dragichevo
Драгичево
Pancharevo
Панчарево
Lozen
село Лозен
Bistritsa

Map of Sofia

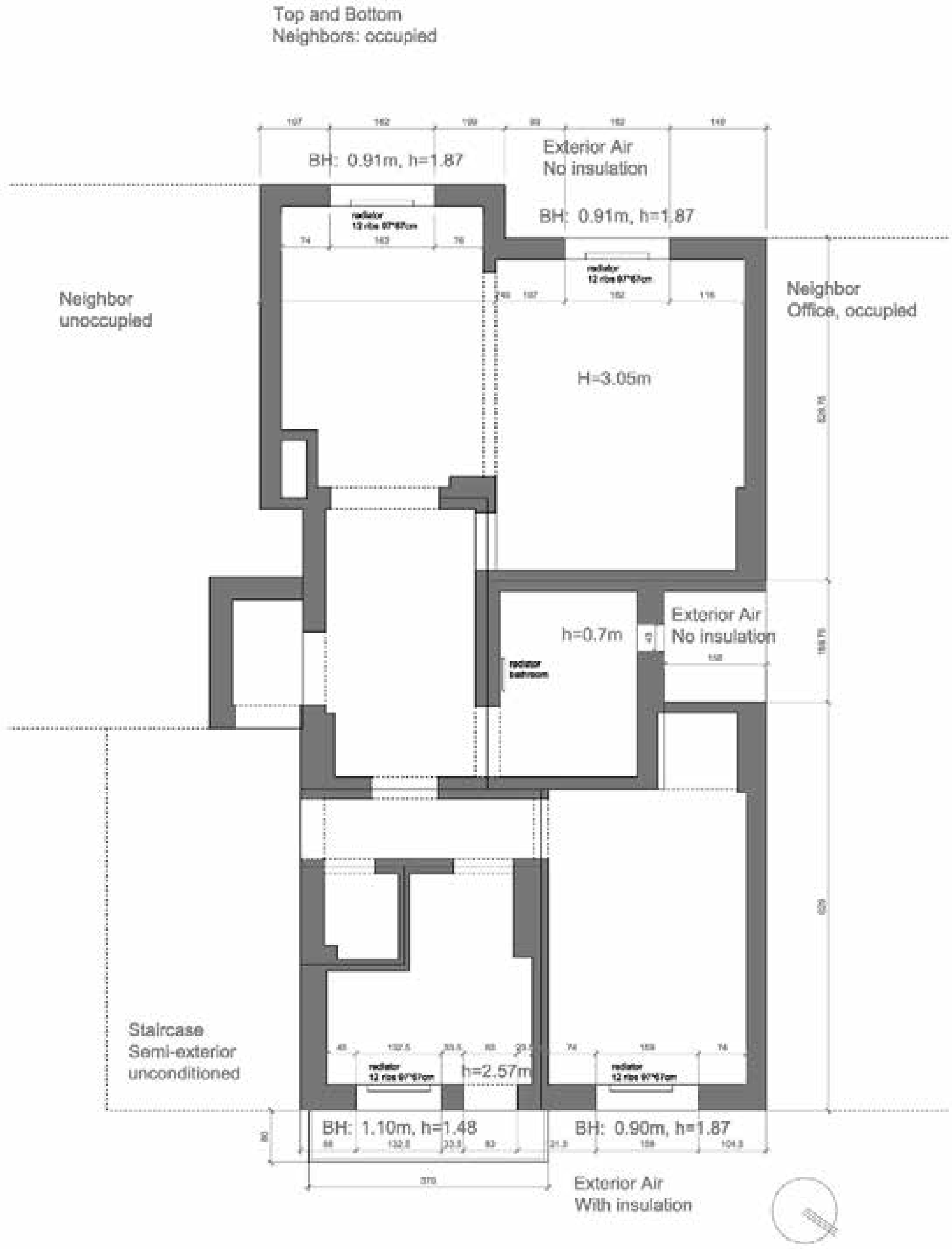
Building Site 1:

Now we will present the first building site situated in Gurko Str. 25a in the center of Sofia.

The building year is from the first decade of the 20^{th} century, occupied by Hans and Julia. The neighboring apartments except for one are constantly occupied. The staircase is unconditioned space with very low temperatures in the winter season.

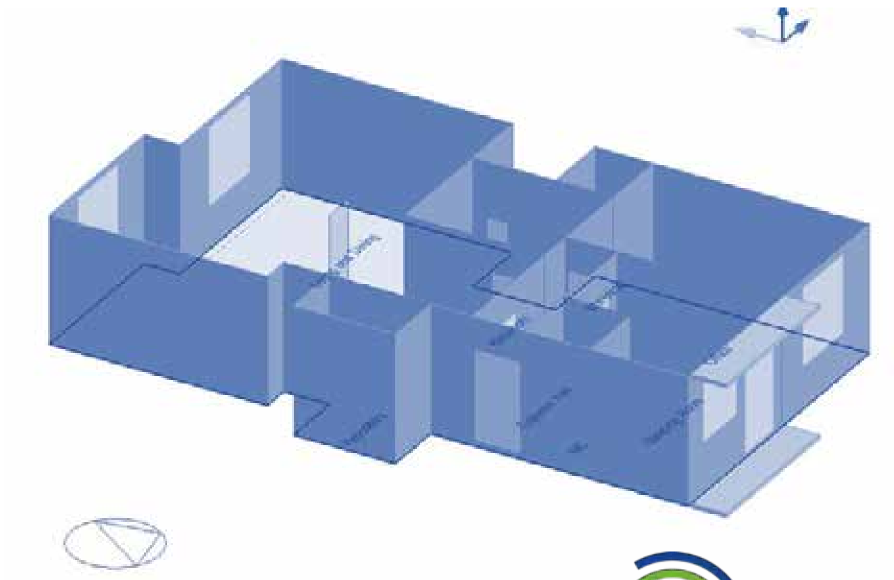
Building enclosure and user behavior

The main façade is cultural heritage, so there are no previous energy saving measures except for the glazing changed in the existing wooden frames. According to the users, the undesired infiltration is high. Precise occupation schedule and natural ventilation patterns were summarized and put into the digital energy model.



Building geometry and architectural record. Existing HVAC system

Due to the lack of architectural plans, the apartment was precisely recorded, including the existing HVAC connection points and some data for the internal gains (equipment, computers, lighting, etc.). The data was then exported to the BIM software.



Digital and Full Transformation – Definition

Digital transformation is defined by digitalization of the heating system only, introducing room thermostats and remotely controlled radiator valves. Due to a precise control of the heating system, we assume that the heating setpoint temperatures can be reduced by approx. 2 degrees, maintaining sufficient comfort levels, but without excessive use of energy.

The full transformation is cost intensive and includes:

- Linear light control.
- Interior insulation with 10cm XPS.
- Interior insulation in false ceiling – 10cm mineral wool.
- Exterior insulation on the façade facing the yard – 15cm EPS
- Insulation towards building block staircase – 5cm EPS
- Replacement of window frames + glazing: PVC frames with triple glazing with two low-e coatings and warm-edge spacer
- Decentralized heat recovery units – produced in Bulgaria. 5 units.
- Rooftop PV panels

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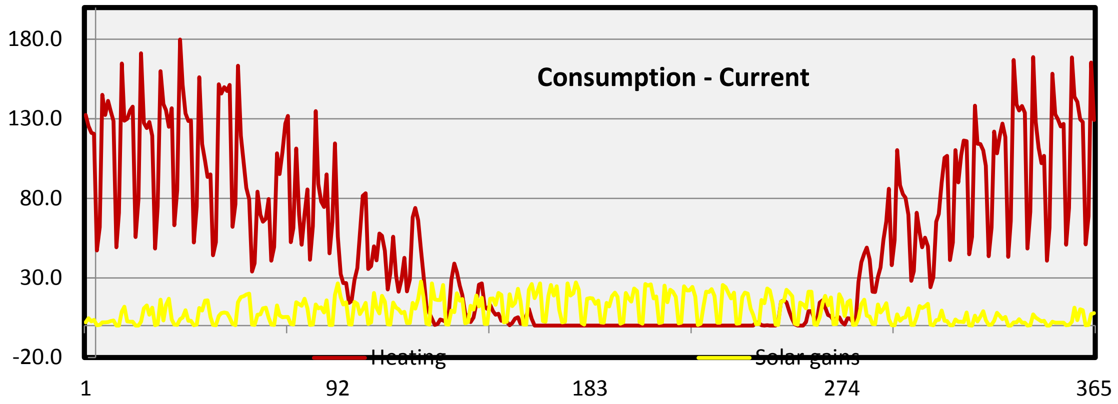
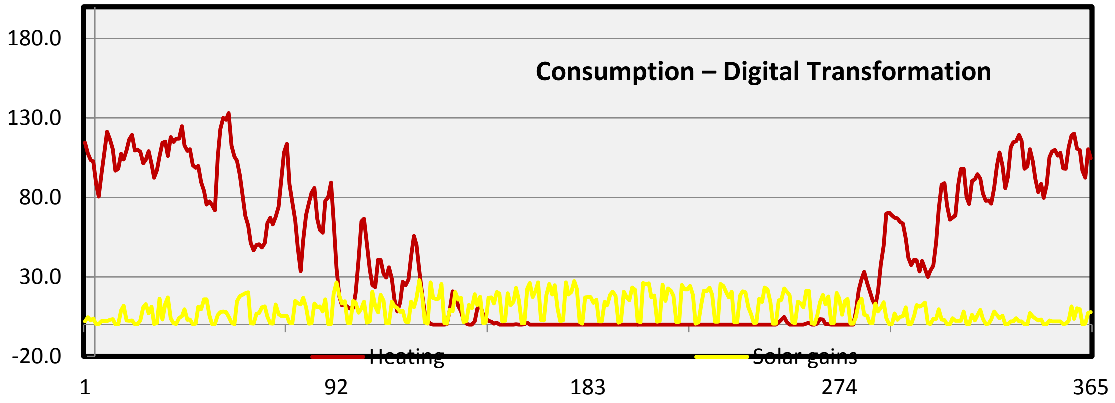
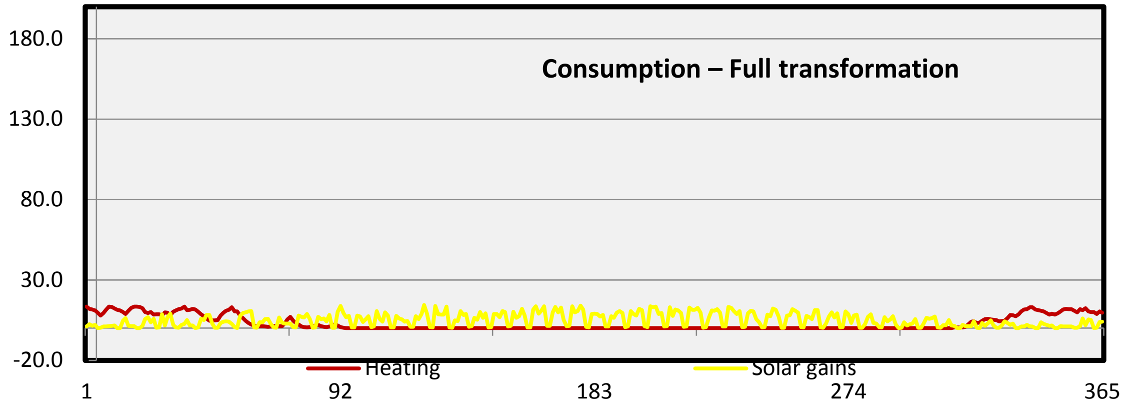
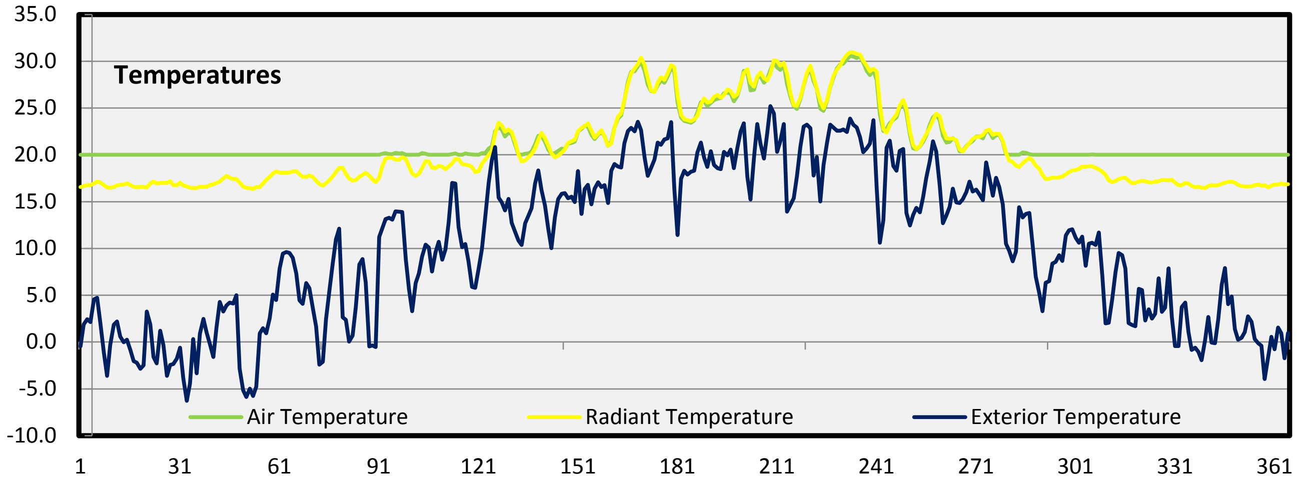








Digital and Full Transformation – Results

The results for this site show slight reduction of the heating loads (from 10.4 down to 9.6 kW) after digital transformation with moderate reduction of the annual consumption (from 181 down to 156 kWh/m2a, approx. 14%).

If a full transformation is applied, there is a significant reduction in both – heating load (from 10.4 down to 1.8 kW) and annual consumption (from 181 down to approx. 94%).

Carbon neutral considerations on district level

If the full transformation (deep renovation on massive scale) is applied on a whole district, we can significantly reduce the total heating load for whole urban area.

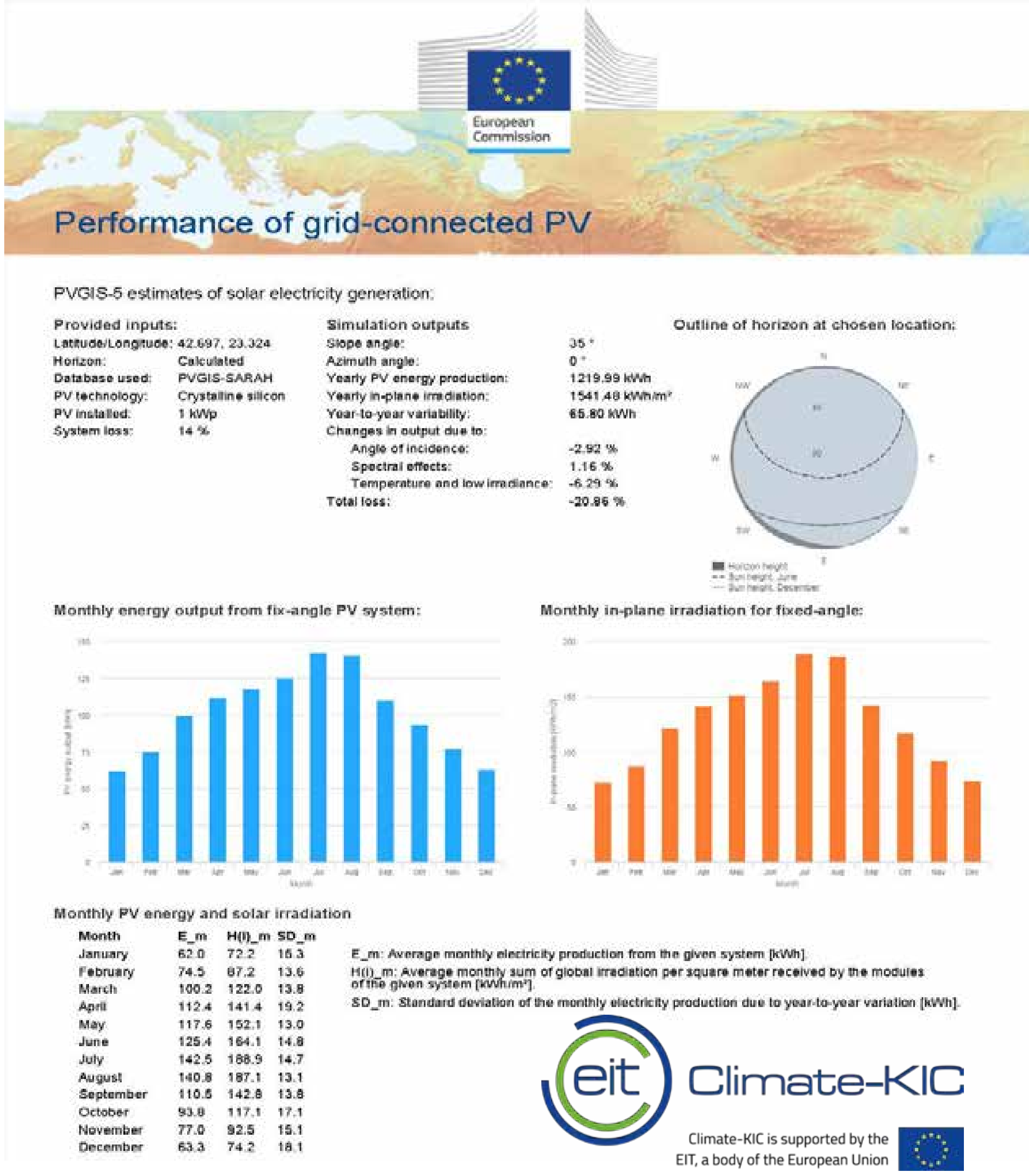
Lower heating load means easier transition to a **low temperature heating**, which allows more sources to be included in the grid (waste heat, RES, etc.) and **lower energy losses**.

If local heat pumps are installed in each building and the radiators are changed to fan coil units, and if district heating delivery temperature is low enough (say 16-20 degrees) we can potentially use the **district heating grid also as district cooling grid**, the transport infrastructure will be much cheaper (at low temperatures no thermal insulation is required). Furthermore, the surrounding thermal soil can be used as thermal mass – **the grid becomes also a horizontal ground heat exchanger**.

Carbon neutral considerations on district level

The final electrical demand of such buildings based on the apartment studied and applying full package of EE measurements, will be predominantly based on the electrical consumption for lighting and home appliances. The total electrical demand for heating, lighting and appliances in a hypothetical situation of fully transformed apartment with local / district heat pump is about 37 ekWh/m2a, or 3700 ekWh for 100 m2 living unit.

The estimated annual production from 1 kWp photovoltaic panels for this region of Sofia with 35 degrees slope facing south is 1220 ekWh. This means that 3 kWp of optimally positioned PV panels will cover the total annual energy demand and will contribute for net carbon neutrality. The total surface area on pitched roof with such slope facing south with the state of the art monocrystalline PV panels will be approx. 15m2. Horizontally installed panels will produce 1058 ekWh. This will result in 3.5kWp or 17m2.


European Commission

Performance of grid-connected PV

PVGIS-5 estimates of solar electricity generation:

Provided inputs:

Latitude/Longitude: 42.697, 23.324
Horizon: Calculated
Database used: PVGIS-SARAH
PV technology: Crystalline silicon
PV installed: 1 kWp
System loss: 14 %

Simulation outputs

Slope angle: 35 °
Azimuth angle: 0 °
Yearly PV energy production: 1219.99 kWh
Yearly in-plane irradiation: 1541.48 kWh/m²
Year-to-year variability: 65.80 kWh
Changes in output due to:
Angle of incidence: -2.92 %
Spectral effects: 1.16 %
Temperature and low irradiance: -6.29 %
Total loss: -20.86 %

Outline of horizon at chosen location:

Monthly energy output from fix-angle PV system:

Monthly in-plane irradiation for fixed-angle:

Monthly PV energy and solar irradiation

Month	E_m	H(i)_m	SD_m
January	62.0	72.2	16.3
February	74.5	87.2	13.6
March	100.2	122.0	13.8
April	112.4	141.4	19.2
May	117.6	152.1	13.0
June	125.4	164.1	14.8
July	142.5	188.9	14.7
August	140.8	187.1	13.1
September	110.5	142.8	13.8
October	93.8	117.1	17.1
November	77.0	92.5	15.1
December	63.3	74.2	18.1

E_m: Average monthly electricity production from the given system [kWh].
H(i)_m: Average monthly sum of global irradiation per square meter received by the modules of the given system [kWh/m²].
SD_m: Standard deviation of the monthly electricity production due to year-to-year variation [kWh].

Climate-KIC

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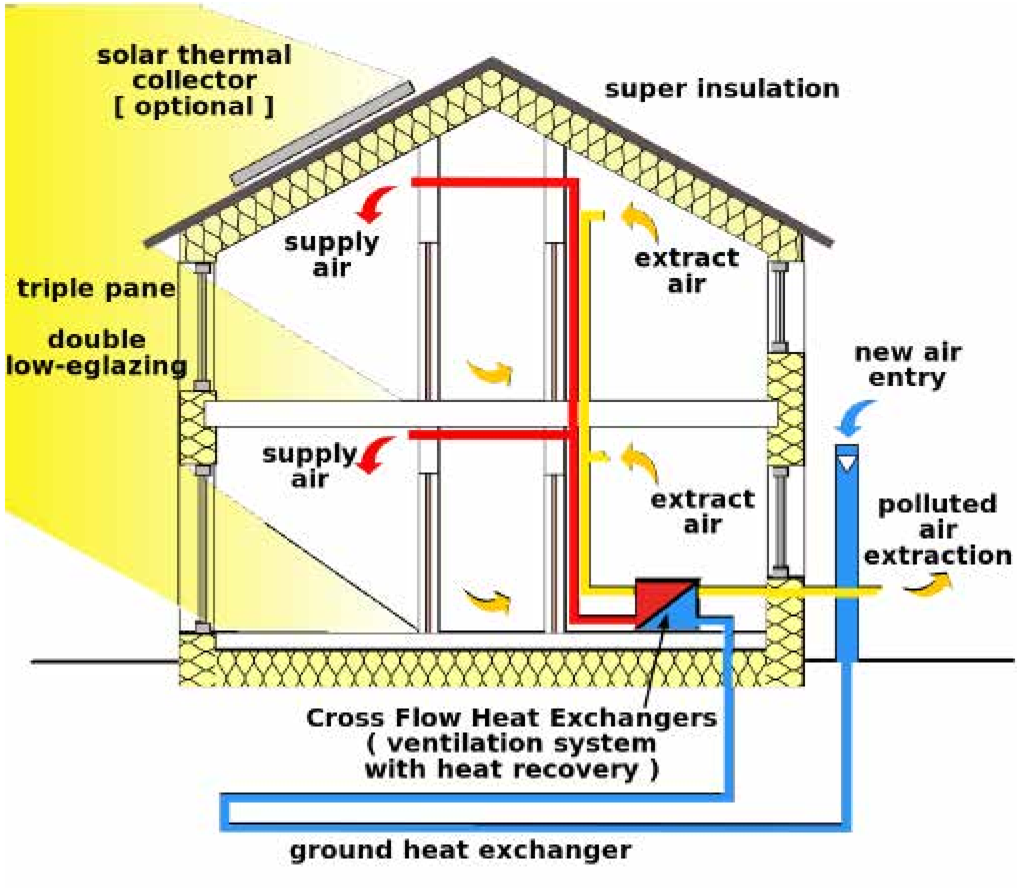
General consideration for full retrofit of an arbitrary building for the Sofia climate zone

The energy saving measurements are divided in active and passive measurements. The usual way is to start with the passive measurements (no control, no maintenance, long life span), such as:

- **Improved airtightness** – down to 0.6 [1/h]
- **Super insulation on the opaque enclosure** –20-50 cm (U=0.06-0.15 W/m2K)
- **Absence of thermal bridges** when possible
- **Tripple glazing** with at least **two low emissivity coatings** and warm edge spacer

Once the maximum energy was saved, additional active measurements are taken, such as:

- **Home automation** – digitally transformed homes.
- **Mechanical ventilation with efficient heat recovery units** centralized of decentralized (up to 90%)
- Integration of **renewable energy sources**
- **Improved HVAC design** and fuel considerations
- **Active solar protection**



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Thank you for your attention!

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