TIMEPAC The new EPC for Europe

# Analysis and visualization of EPC data and development of innovative energy service

## Calibration of dynamic energy consumption model with real data

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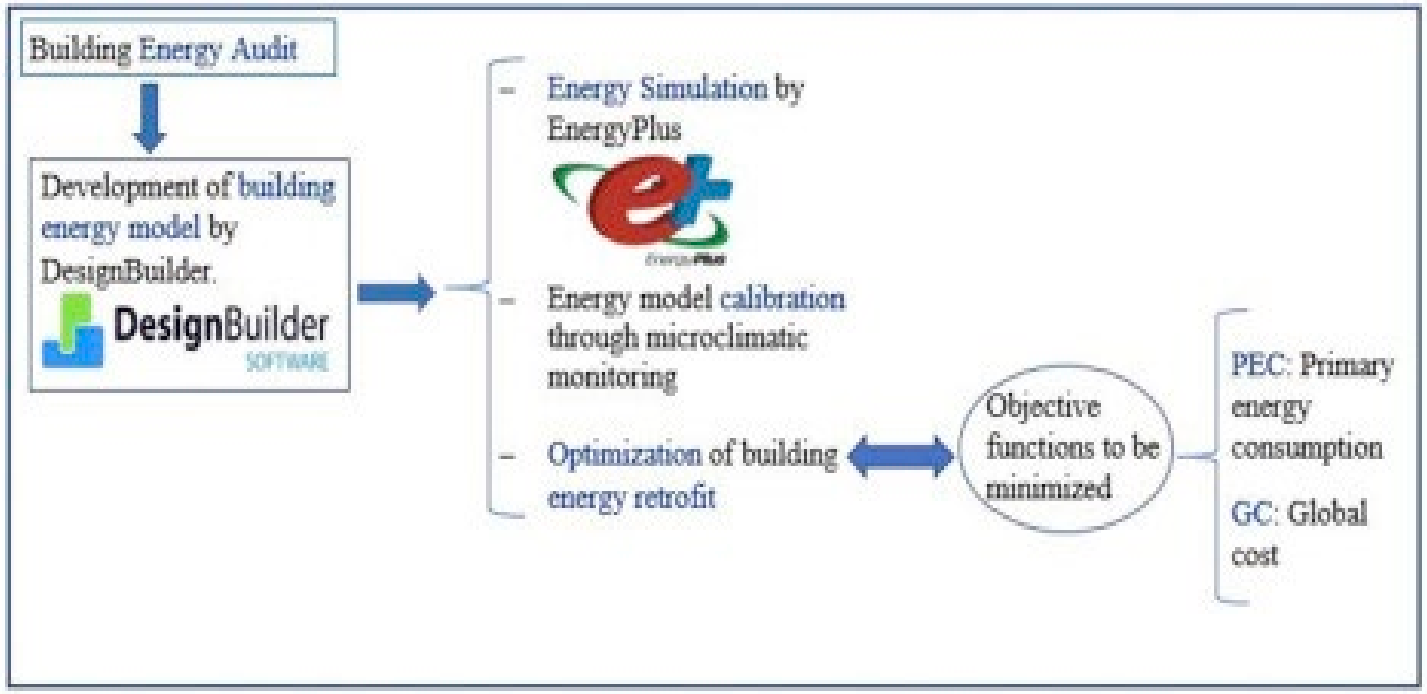
# What is Building Model Calibration?

- Process of **improving the accuracy** of **Building Energy Model simulation** to reflect the as-built status and actual operating conditions.




*Source: A real industrial building: Modeling, calibration* and Pareto optimization of energy retrofit

# Review of dynamic tools

- The most famous software tools for dynamic modeling and performing dynamic simulations:
  - EnergyPlus
  - TRNSYS
  - IDA-Indoor Climate Energy (IDA-ICE)
  - VIP-Energy
  - Modellica
  - …

# Why EnergyPlus?

- Software for carrying out energy simulations of the entire building for modeling energy consumption - for heating, cooling, ventilation, lighting and preparation of DHW
- The program is based on a console that reads input (data) and writes output (data) to text files
- Advanced exterior opening models including controllable window blinds, electrochromic glazing and layer-by-layer heat balances that calculate solar energy absorbed by window panes
- Component-based HVAC that supports standard and new system configurations
- Extensive and comprehensive documentation

# Why EnergyPlus & DesignBuilder?

- Excellent simulation results between real and modeled heating and cooling loads, 3 % and 5 % respectively *
- Automation possibilities and use of APIs
- GUI DesignBuilder with easier modelling options and interpretation of results

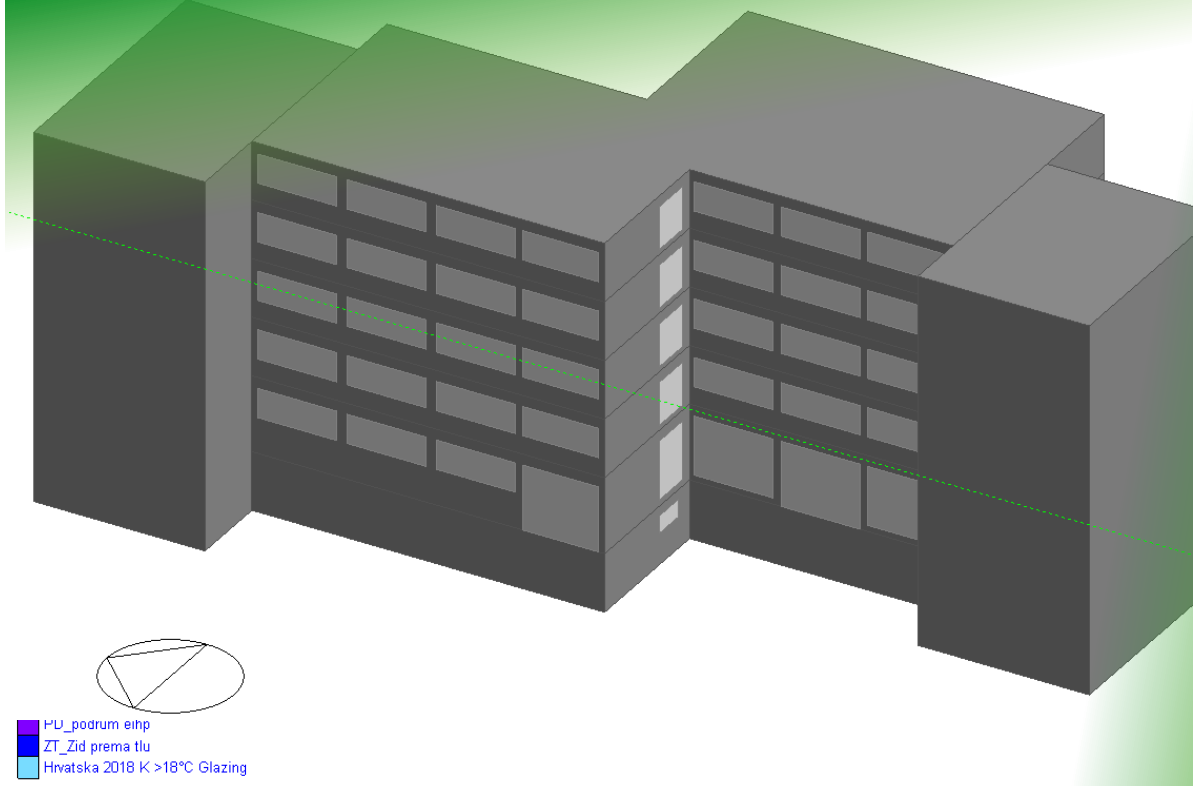
## MOST IMPORTANT:

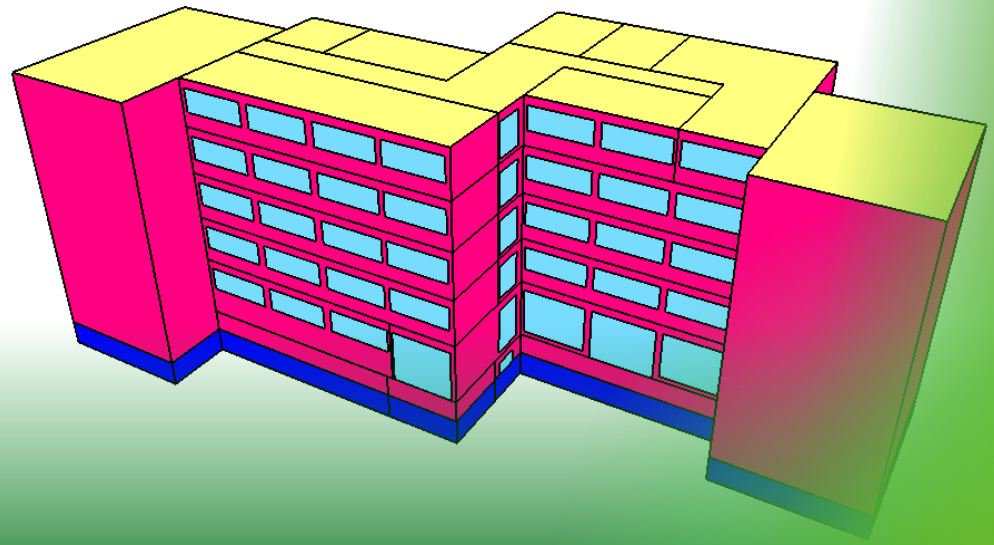
**We have previous experience and know how to use it!**

*N. Eskin, H. Torkmen, Analysis of annual heating and cooling energy requirements for office buildings in different climates in Turkey, Energy Build. 40 (5) (2008) 763–773*

# Building model

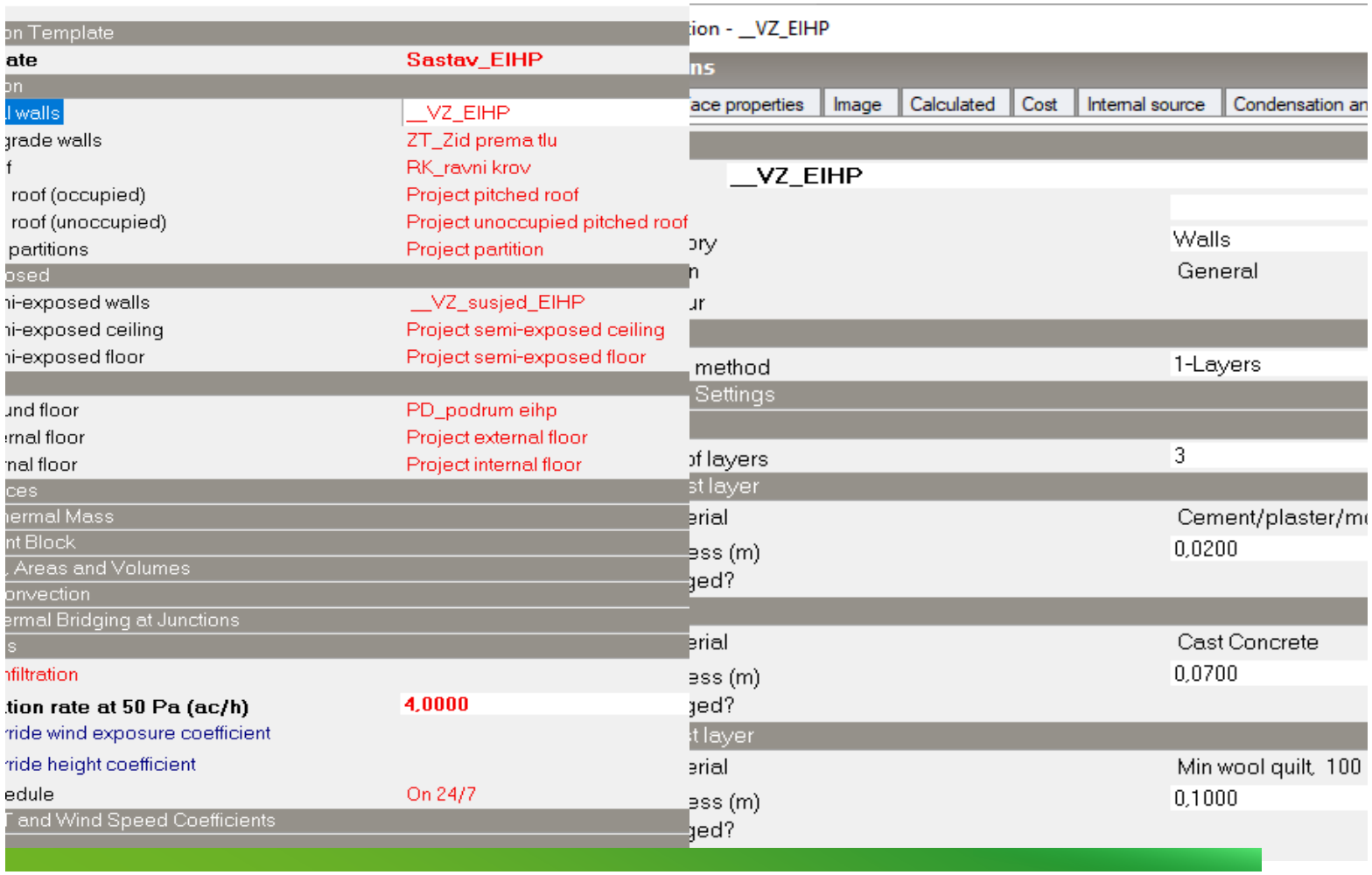
- First step is to model geometry and construction part of existing building model



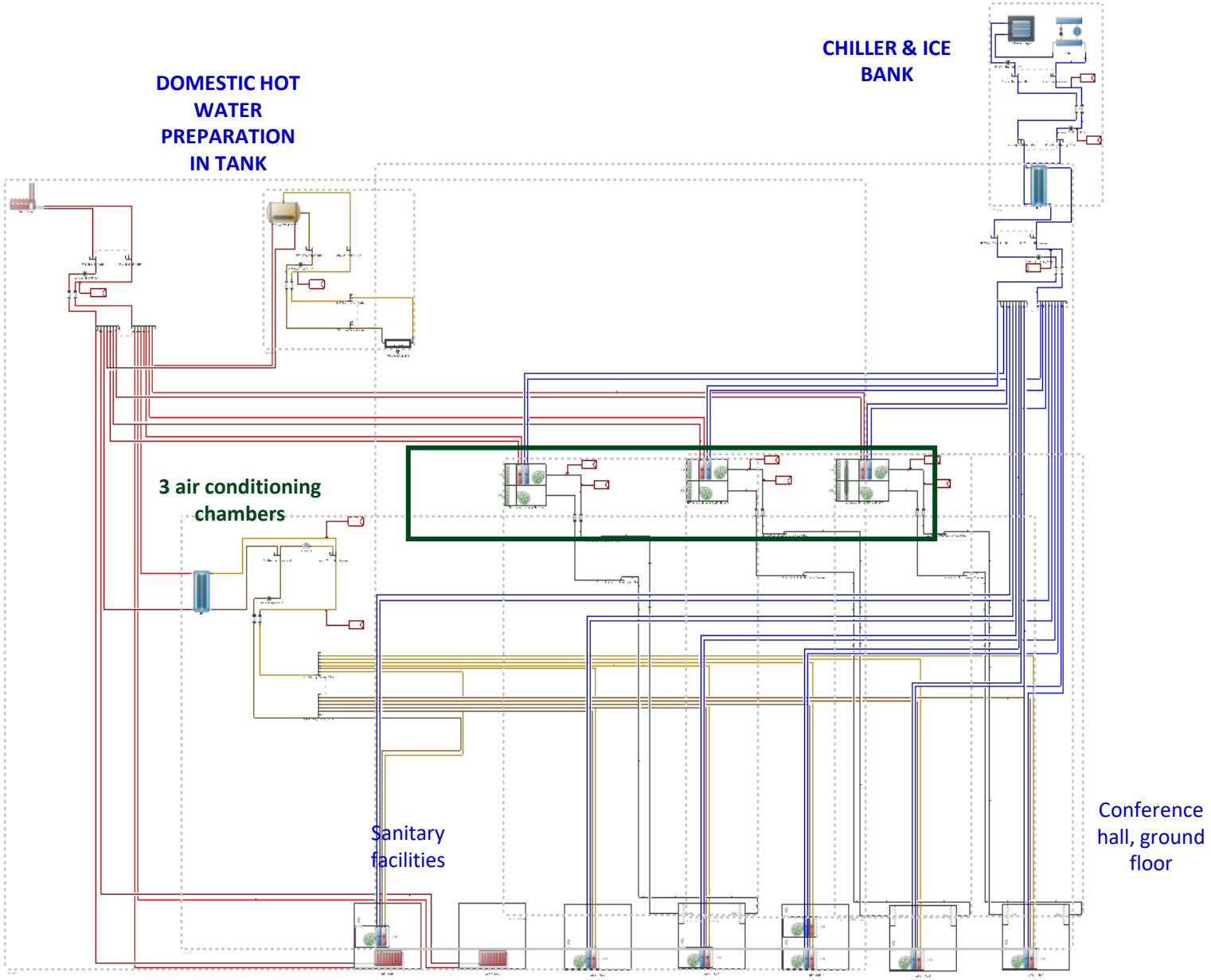
# Building model

- Model all construction materials and elements from existing project documentation, energy audit report or onsite examination



# HVAC System

- Model existing HVAC system of 250 kW district heating, 76,9 kW chiller & ice bank, 3 air conditioning chambers supplying fan coils and water radiators

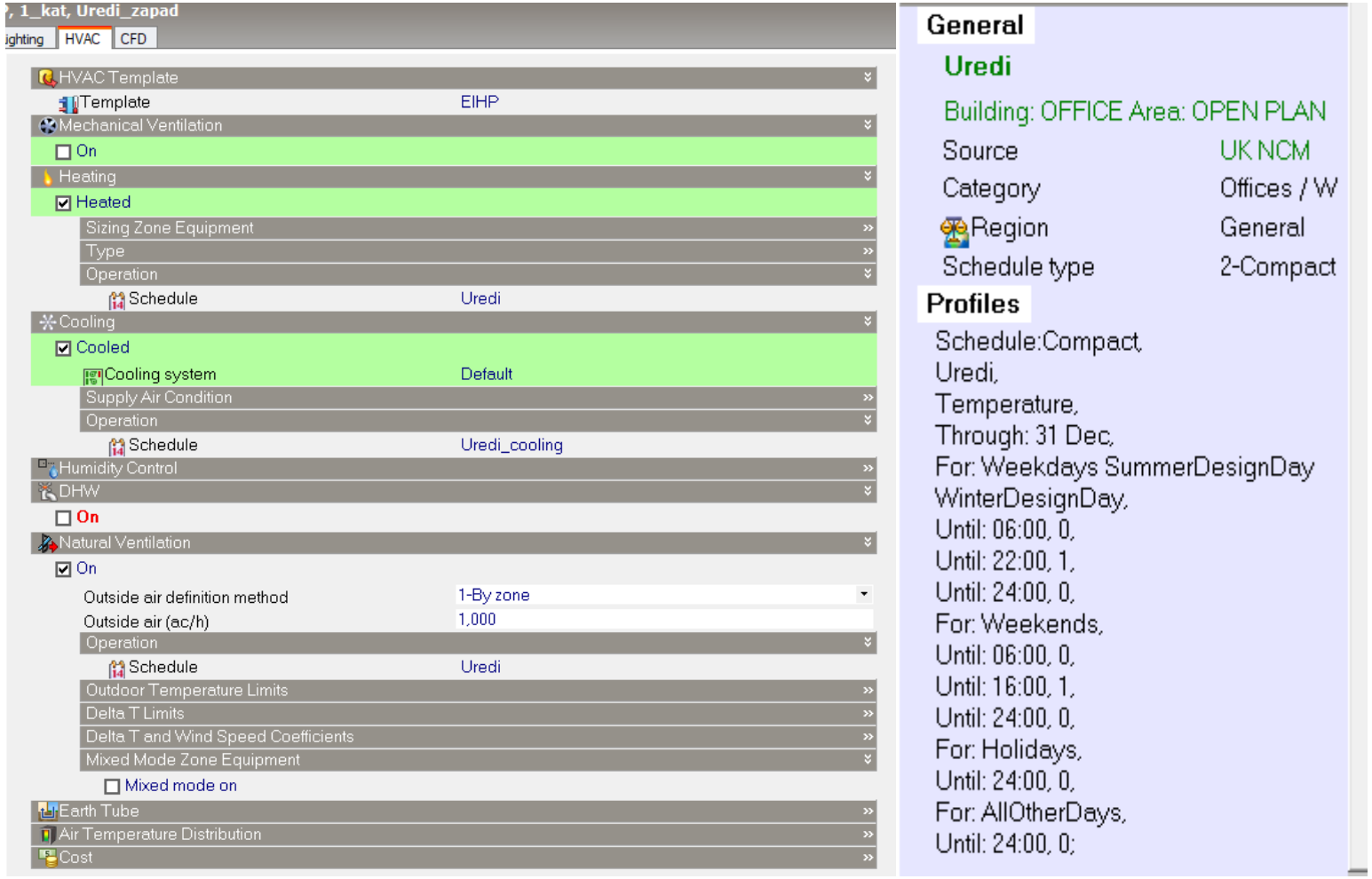



DesignBuilder

*Graphic visualization in DesignBuilder of existing HVAC system at EIHP office building*

# HVAC System

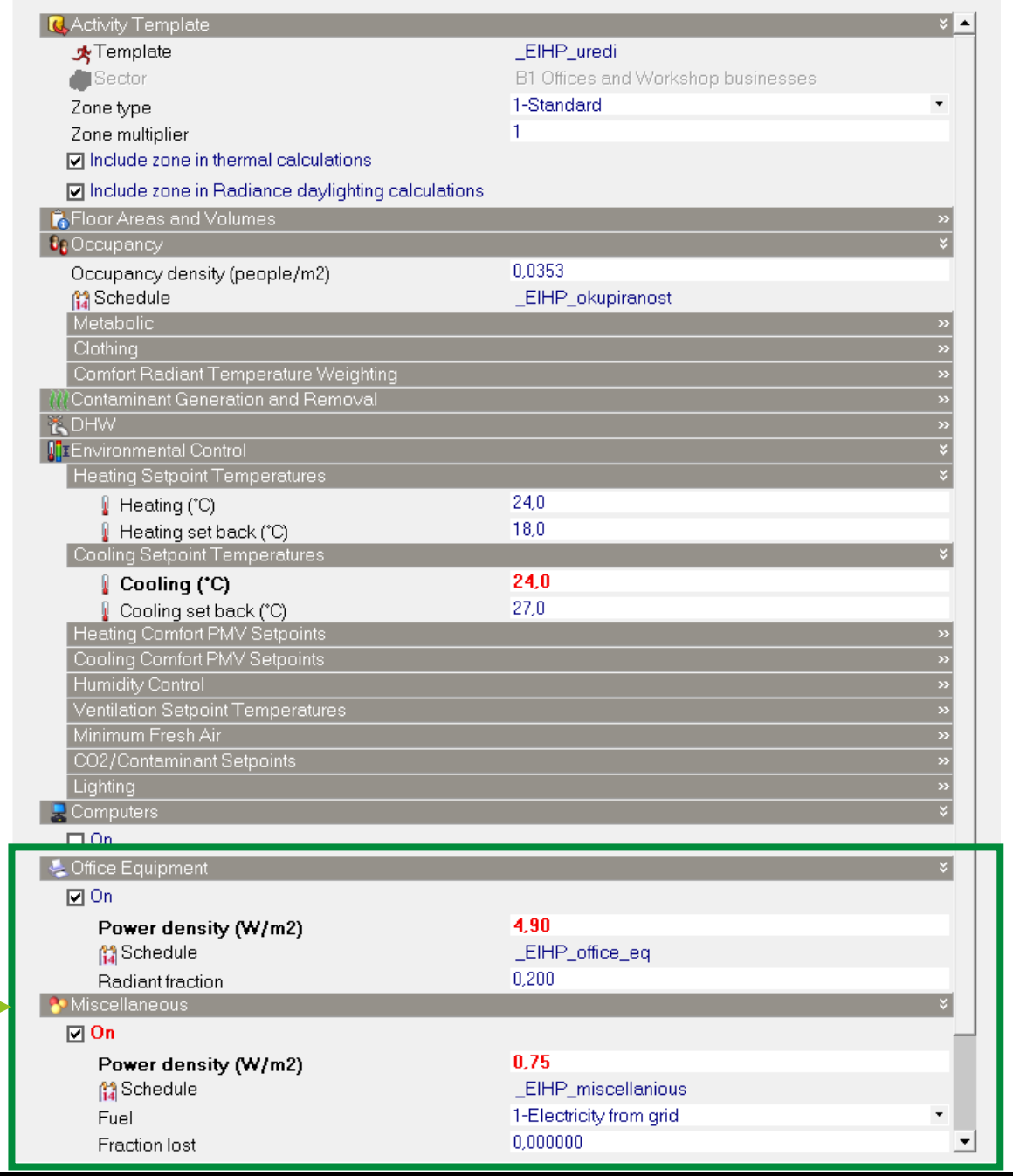
- Entry of heating & cooling operation schedules in HVAC tab for each zone



# Activity tab

- Entry of occupancy schedules, heating and cooling setpoints and electricity consumption of equipment for each zone

Electricity consumption of equipment



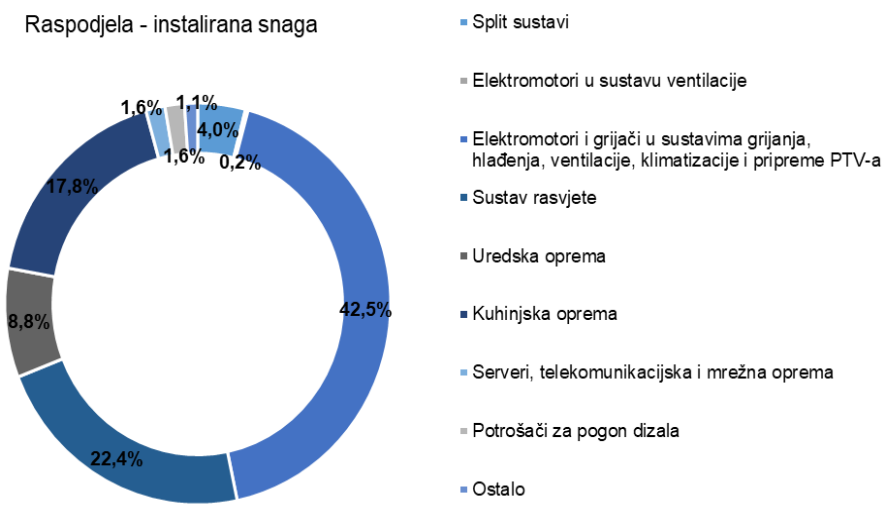
# Electricity consumption model

- Entry and creation of a model for an existing building
  - Getting data from the energy audit, talking with users about how to use the building and the system
- Entry and creation of a model for a new building
  - Getting data from project documentation and use of average usage schedules

# Electricity consumption model

- Systems and groups of electrical consumers:
  - Lighting system
  - Computers
  - Office equipment
  - Kitchen appliances
  - Specific process in building (in case of production)
  - Other equipment

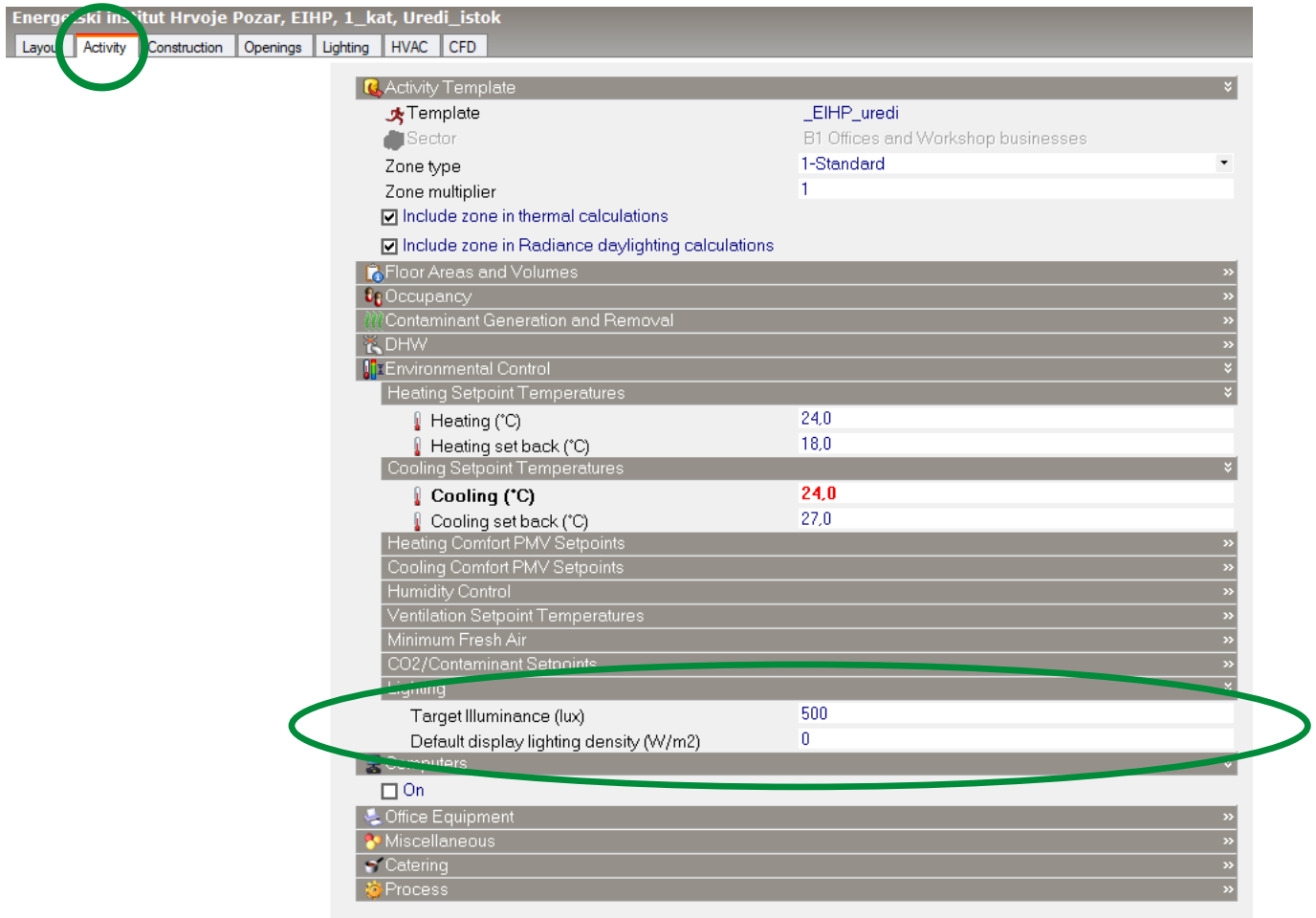
| Tip potrošača | Broj | Instalirana snaga [kW] |
|---|---|---|
| Uredska oprema | 213 | 19,47 |
| Kuhinjska oprema | 16 | 39,43 |
| Serveri, telekomunikacijska i mrežna oprema | 33 | 3,56 |
| Potrošači za pogon dizala | 1 | 3,60 |
| Ostalo | 15 | 2,44 |
| **Ukupno** | **278** | **68,50** |



# Electricity consumption model

- For each system is determined:
  - Installed power of equipment
  - Equipment usage schedule
  - Zoning of equipment
  - Other specific parameters

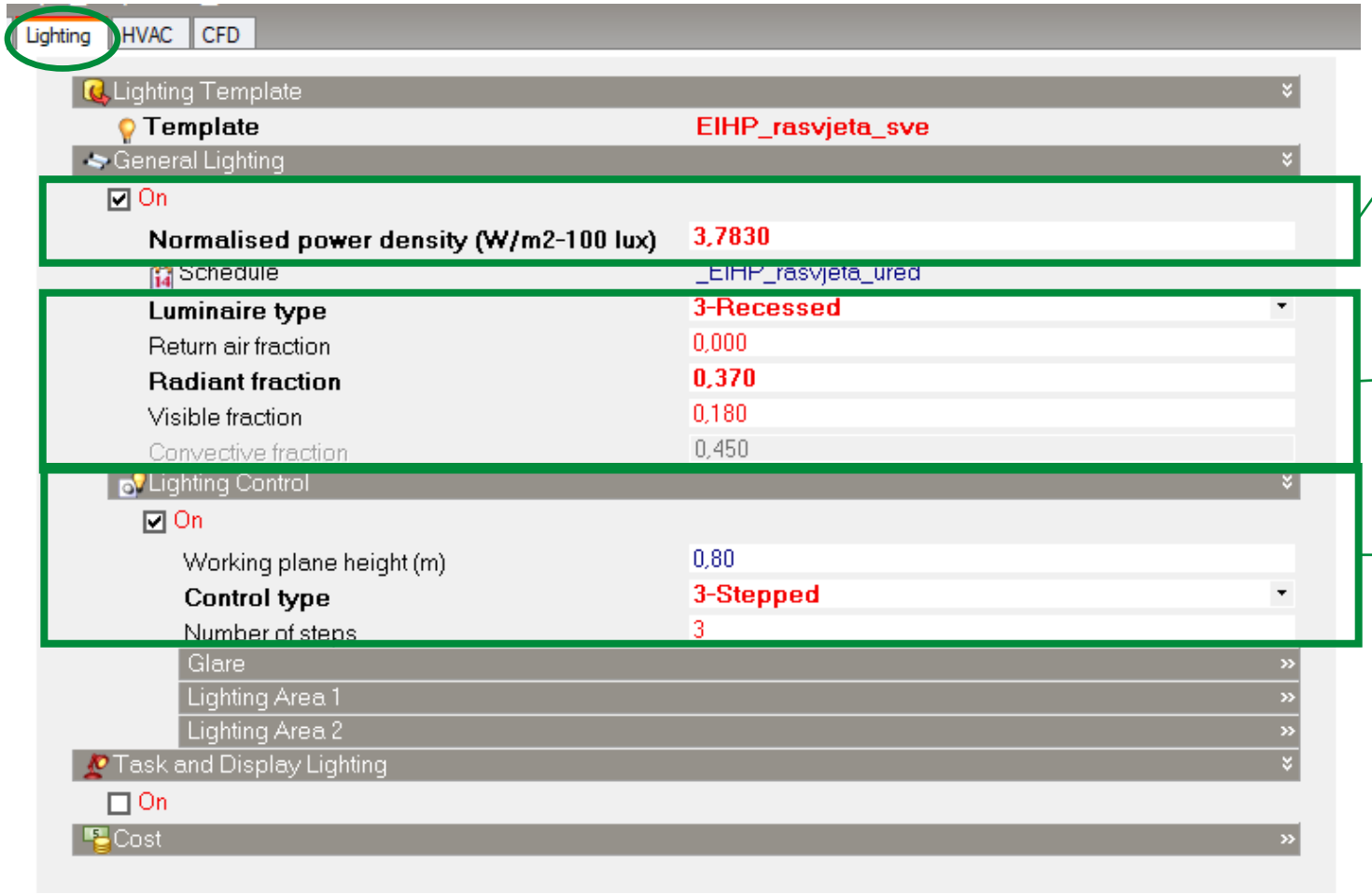
# Lighting system




Defining of Target Illuminance (lux) in Activity tab

# Lighting system

Entry of lighting system parameters:




8.301,4 W/438.88 $m^2$ = 18,915 W/$m^2$

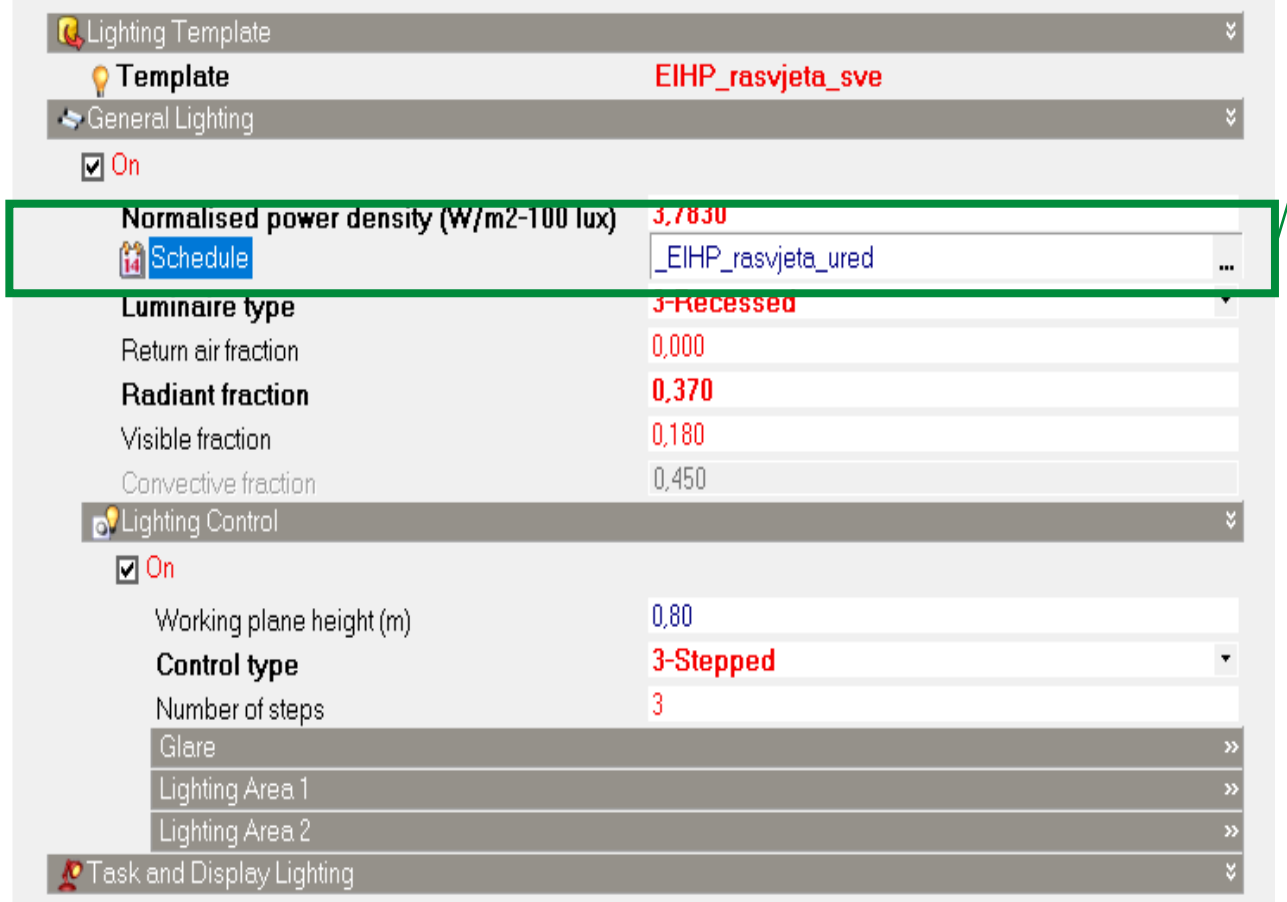
Illuminance = 500 lux
18,915/5 = 3,7830 W/($m^2$ 100 lux)

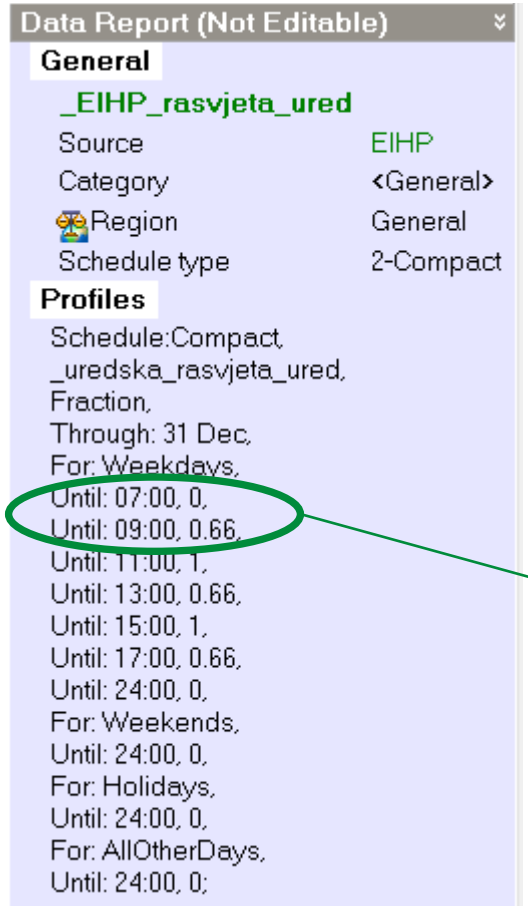
the way the lamp is mounted affects the internal gains

Lighting management – stepped
3 steps

# Lighting system

Usage Schedule
- Hourly distribution – percentage of lighting which is used

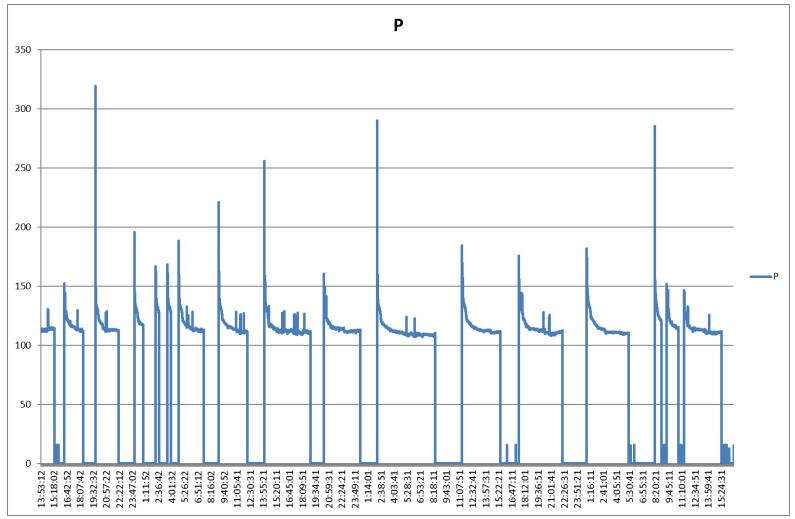


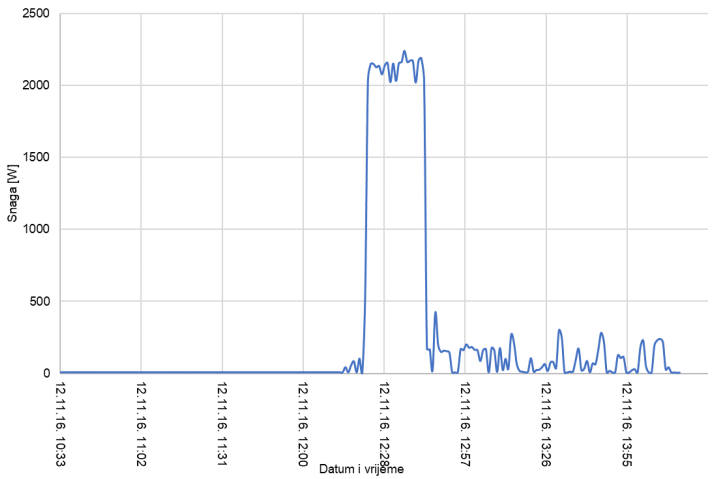

For example between 7 and 9 o'clock, 66 % of installed lighting power is being used

# Equipment

- Depending on individual consumers and usage, different hourly loads
  - Example 1– Refrigerator, has relatively the same hourly consumption

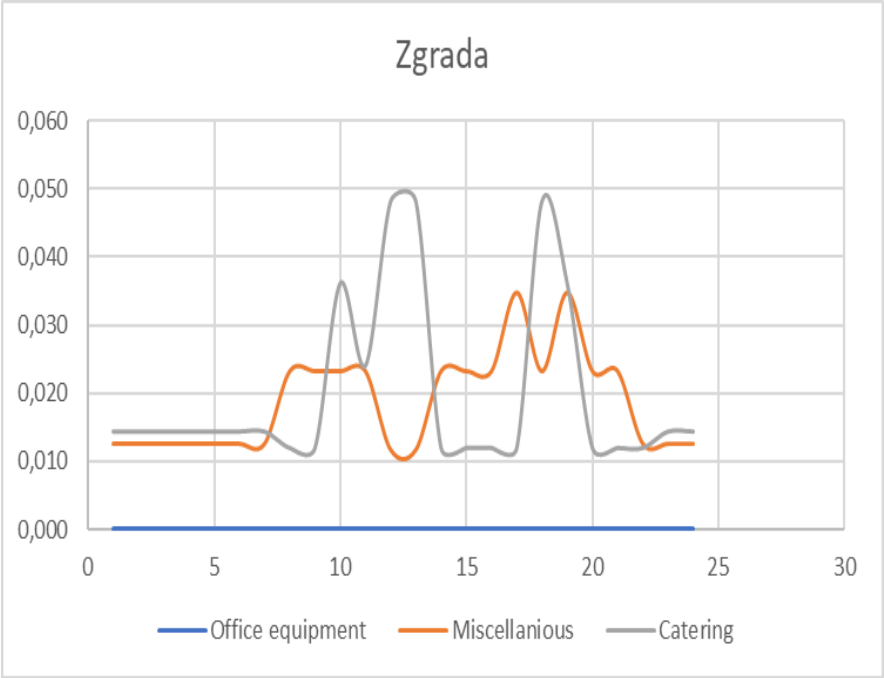



  - Example 2– Washing machine, hourly consumption varies significantly



# Equipment

- Elaboration of the model for a typical day at the hourly level of operation of individual devices with a certain probability - marked uncertainty without measurement



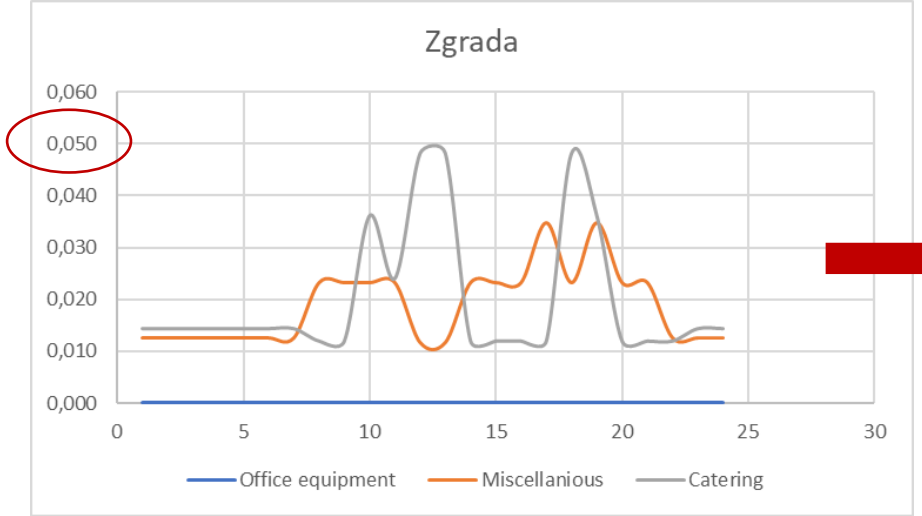

- For example, the oven is not turned on every day, and at the same hour - the probability of a coincidence in every day and every hour

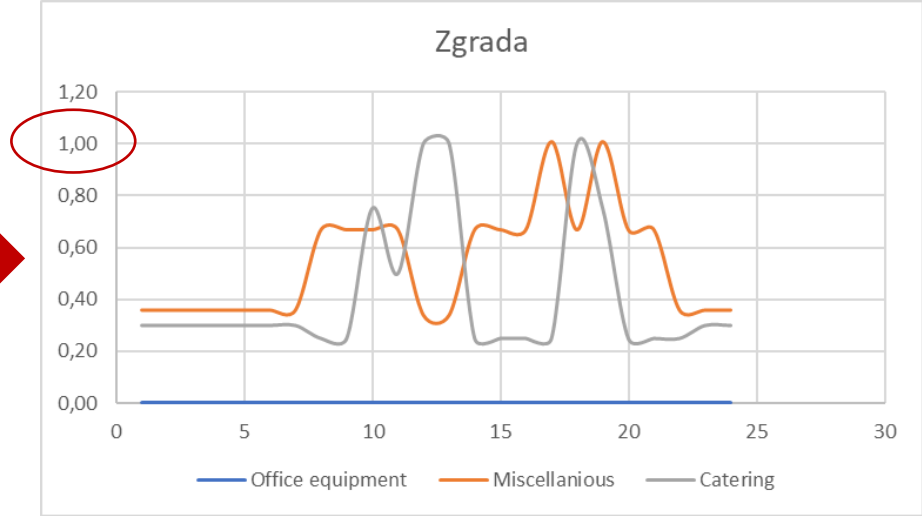
- Complex evaluation of the interaction of various devices - the most accurate data 15 min curve of real consumption from the meter

# Equipment

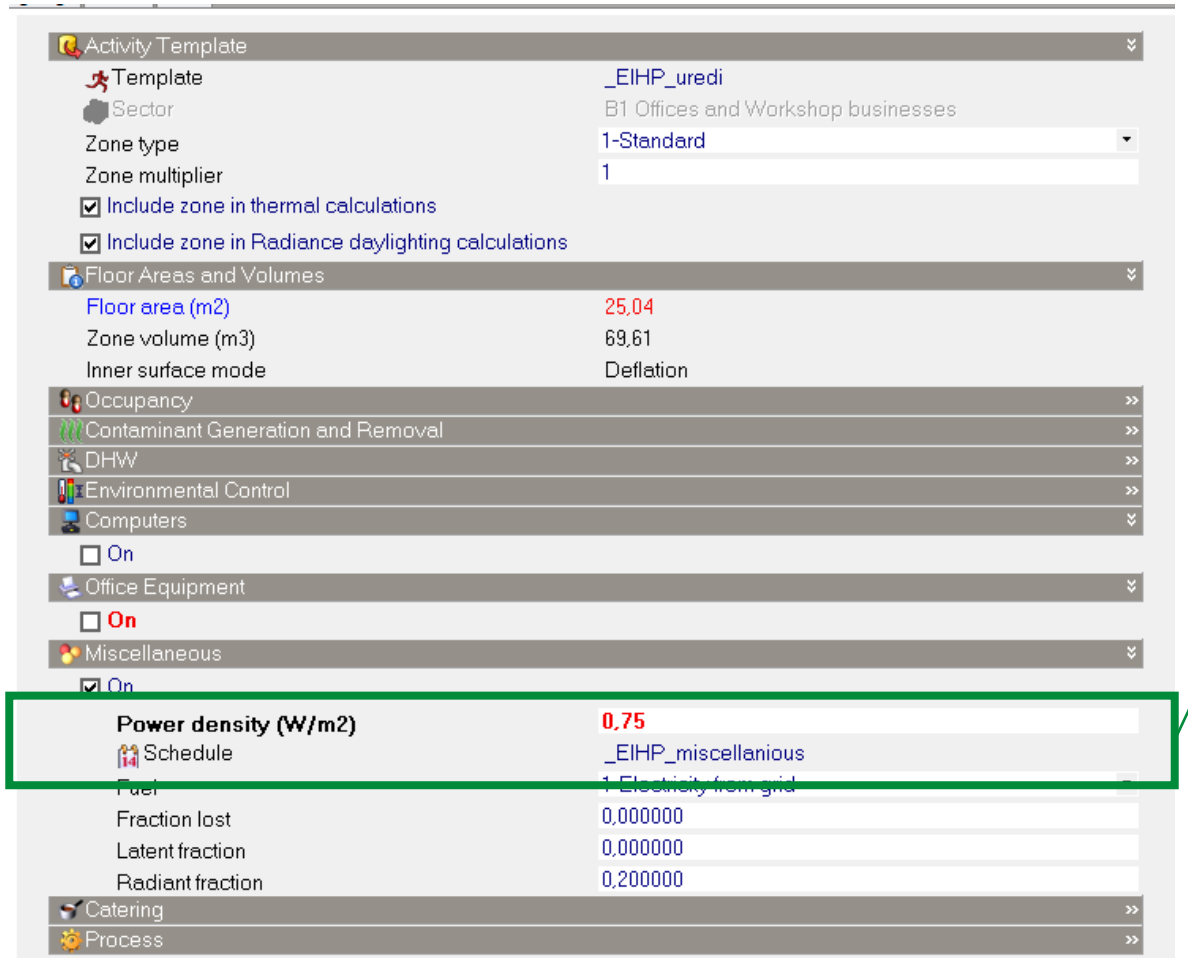
- Entry of normalized power divided with floor area:
  - Normalized power is determined according to the maximum consumption in one hour
  - Be careful with zoning
  - Schedule is determined according to the maximum

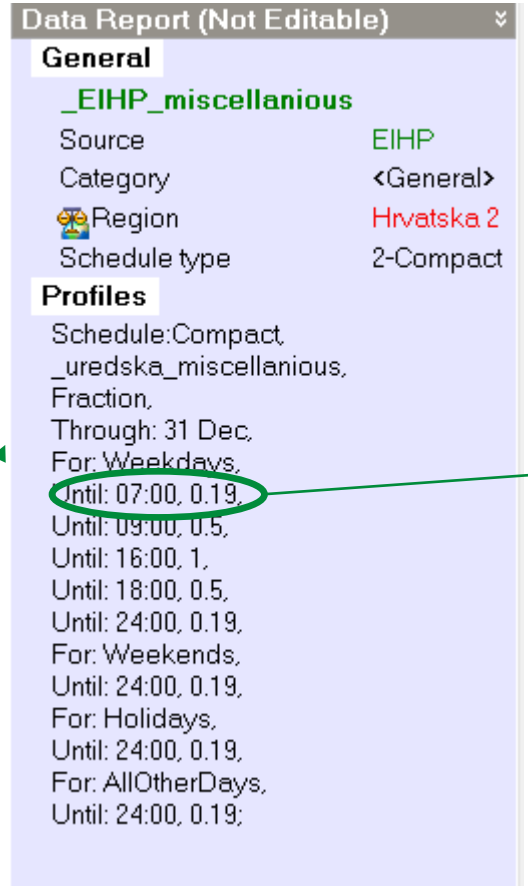
60 W/m$^2$ – real power → 60*0,05= **3 W/m$^2$** – normalized power



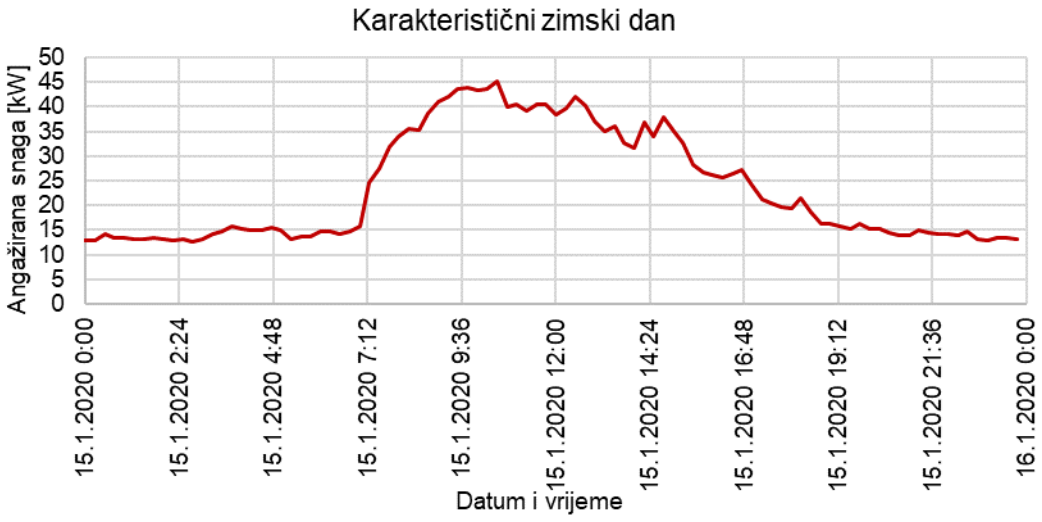
# Equipment

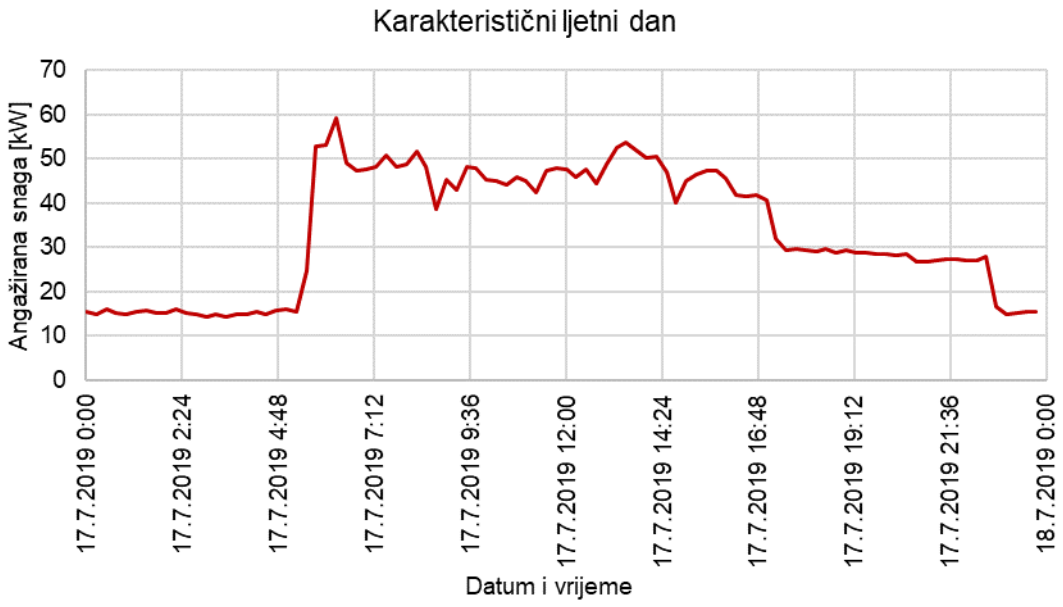


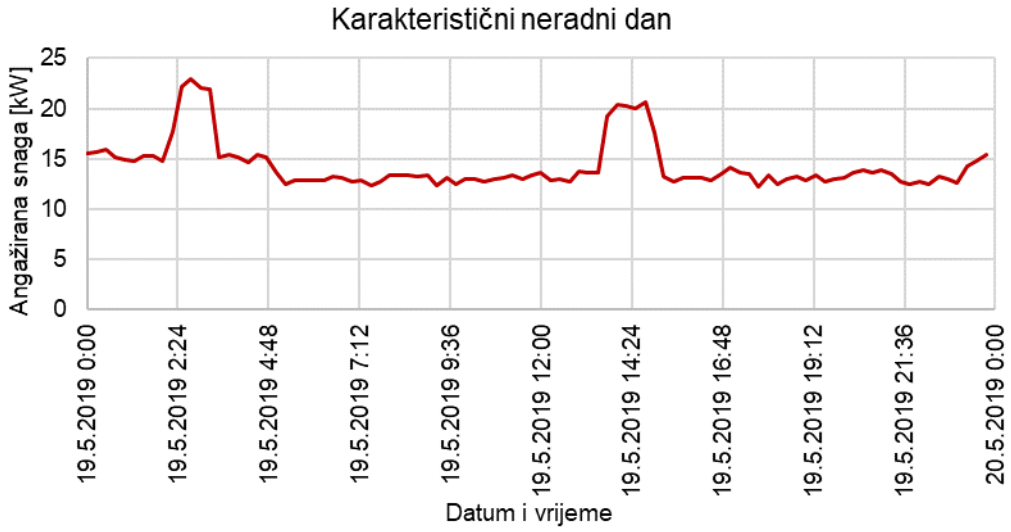



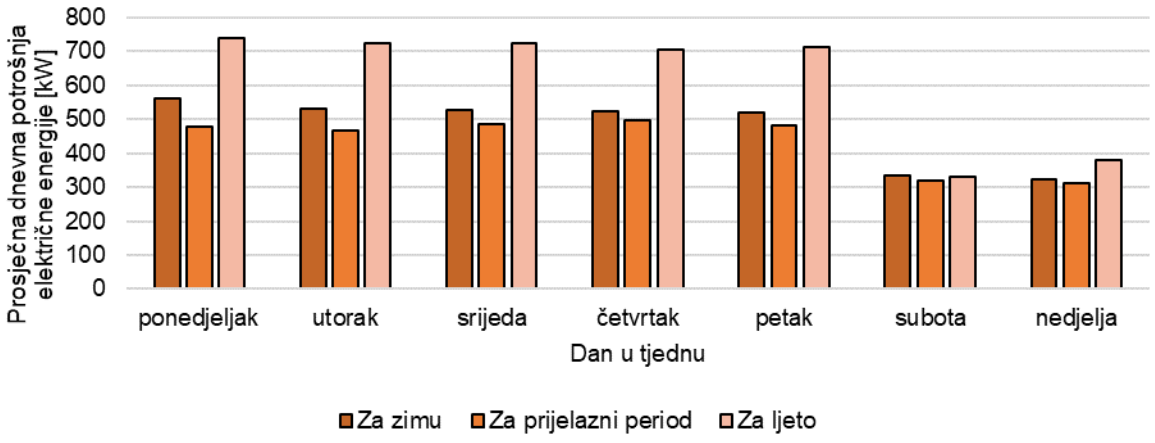

Usage schedule introduces the greatest uncertainty into the calculation - model calibration

# Measurments



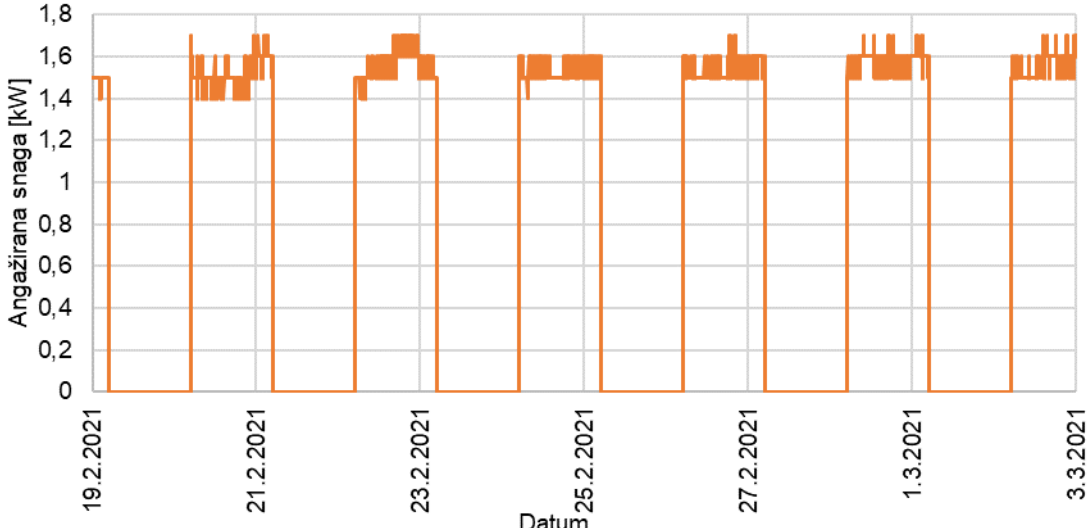



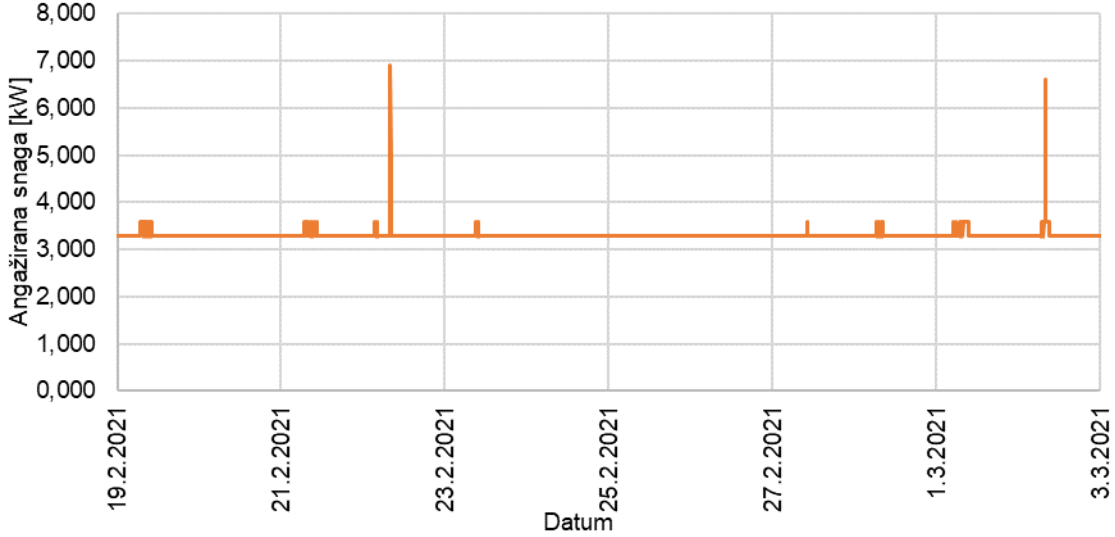



# Measurments

Measurement of electric motor consumption for driving pumps in the heating system

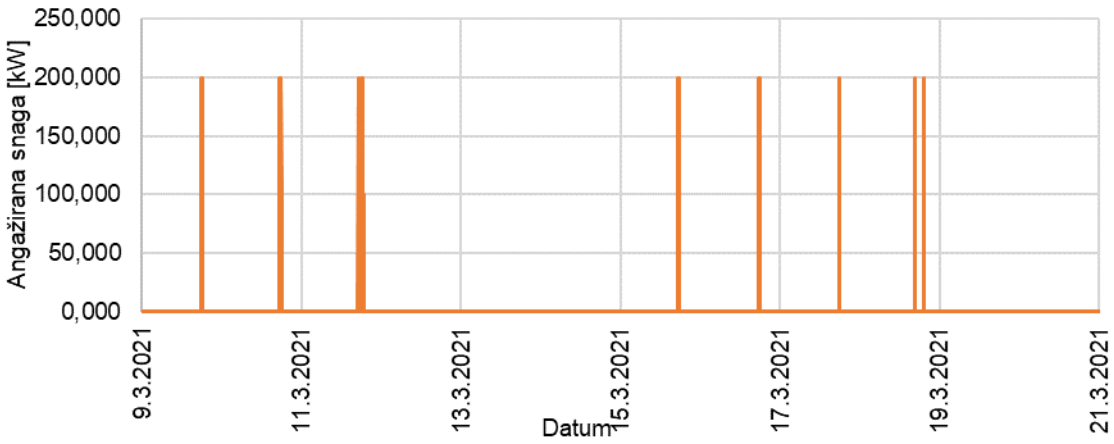
| | |
|---|---|
| Instalirana snaga mjerenog sustava [kW] | 7,5 |
| Prosječna izmjerena snaga [kW] | 3,3 |
| Radno vrijeme sustava | od 0:00 do 24:00 |
| Pretpostavljeni godišnji broj sati rada [h] | 4.368 |
| Godišnja potrošnja električne energije [kWh] | 14.480 |



# Measurments

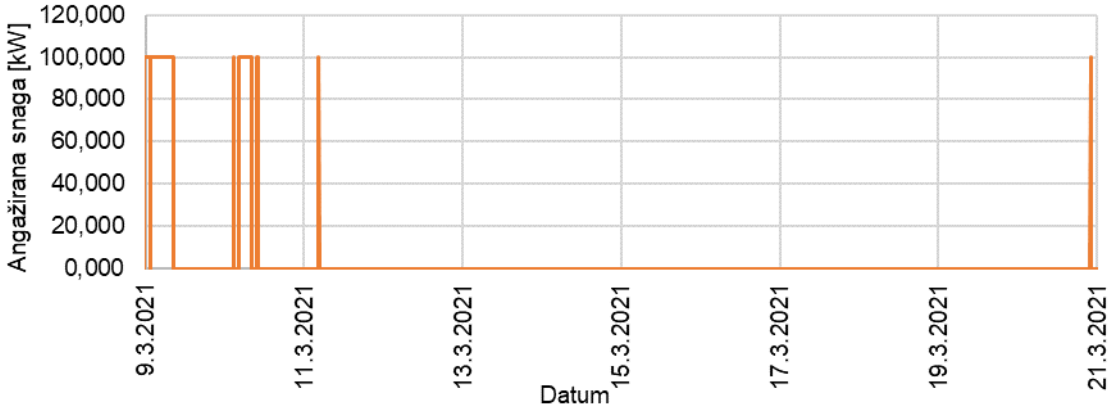
Measurement of lighting system in hallway




| | |
|---|---|
| Instalirana snaga mjerenog sustava [W] | 180 |
| Udio vremena kada se koristila rasvjeta [%] | 1,1 |
| Broj sati korištenja u godini [h] | 96 |

# Measurments

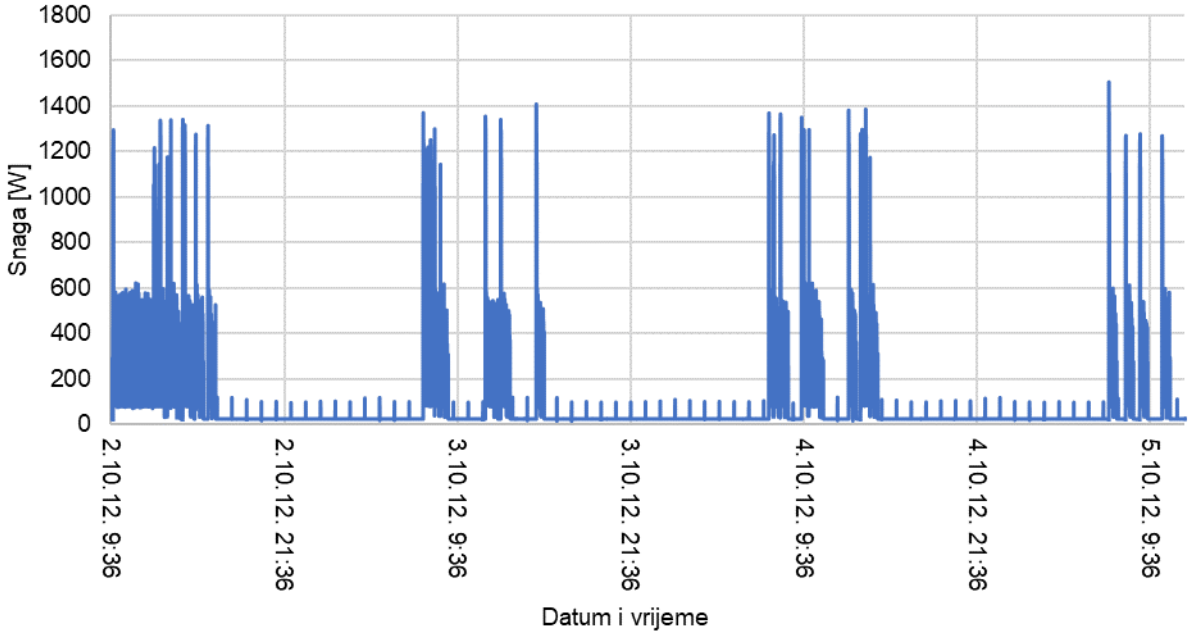
Measurement of electric motor consumption in fan coils




| | |
|---|---|
| Instalirana snaga mjerenog sustava [W] | 174 |
| Udio vremena kada su se koristili ventilokonvektori [%] | 15 |
| Broj sati korištenja u godini [h] | 1.087 |

# Measurments

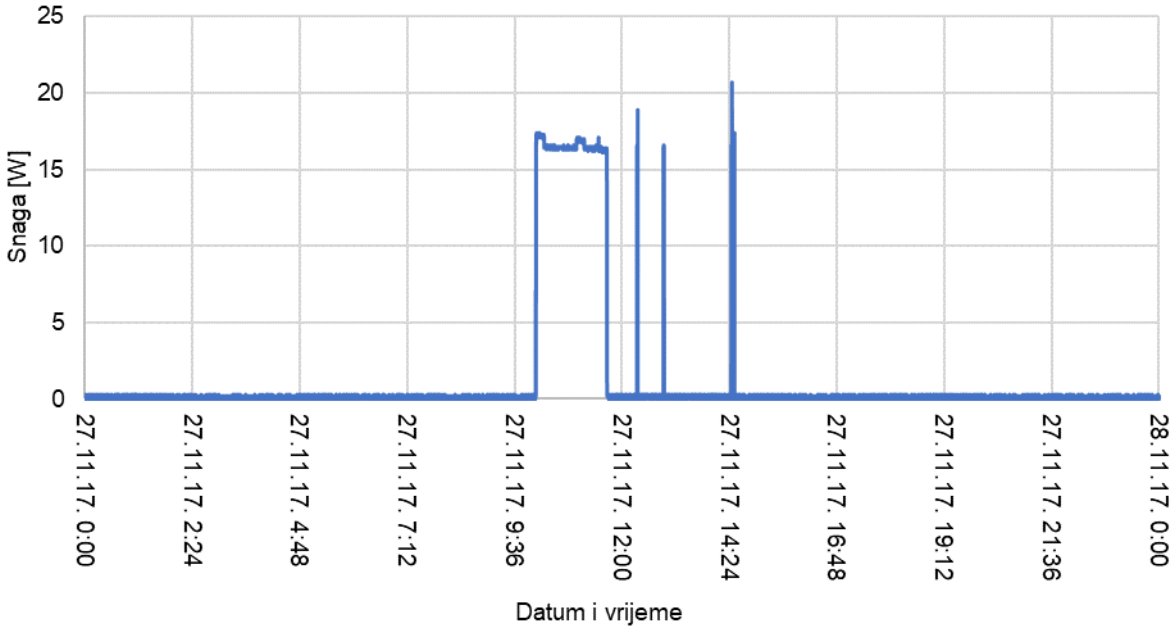
Measurement on a Minolta Di470 photocopier




| | |
|---|---|
| Maksimalna snaga [W] | 1.490 |
| Minimalna snaga [W] | 14 |
| Nazivna snaga [W] | 1.430 |
| Preračunati udio vremena kada se uređaj koristi na nazivnoj snazi [%] | 5 |
| Udio rada u višem tarifnom razdoblju [%] | 75 |

# Measurments

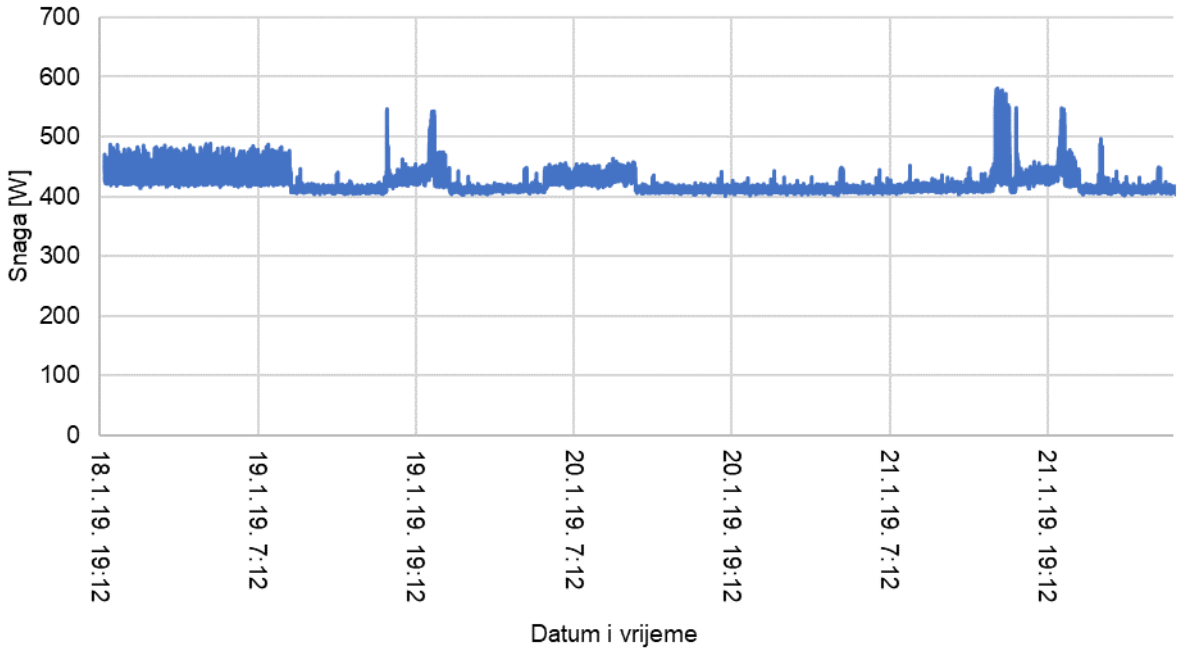
Measurement of the DELL P2414H electronic screen




| | |
|---|---|
| Maksimalna snaga [W] | 20,7 |
| Minimalna snaga [W] | 0 |
| Nazivna snaga [W] | 28 |
| Preračunati udio vremena kada se uređaj koristi na nazivnoj snazi [%] | 17 |
| Udio rada u višem tarifnom razdoblju [%] | 95 |

# Measurments

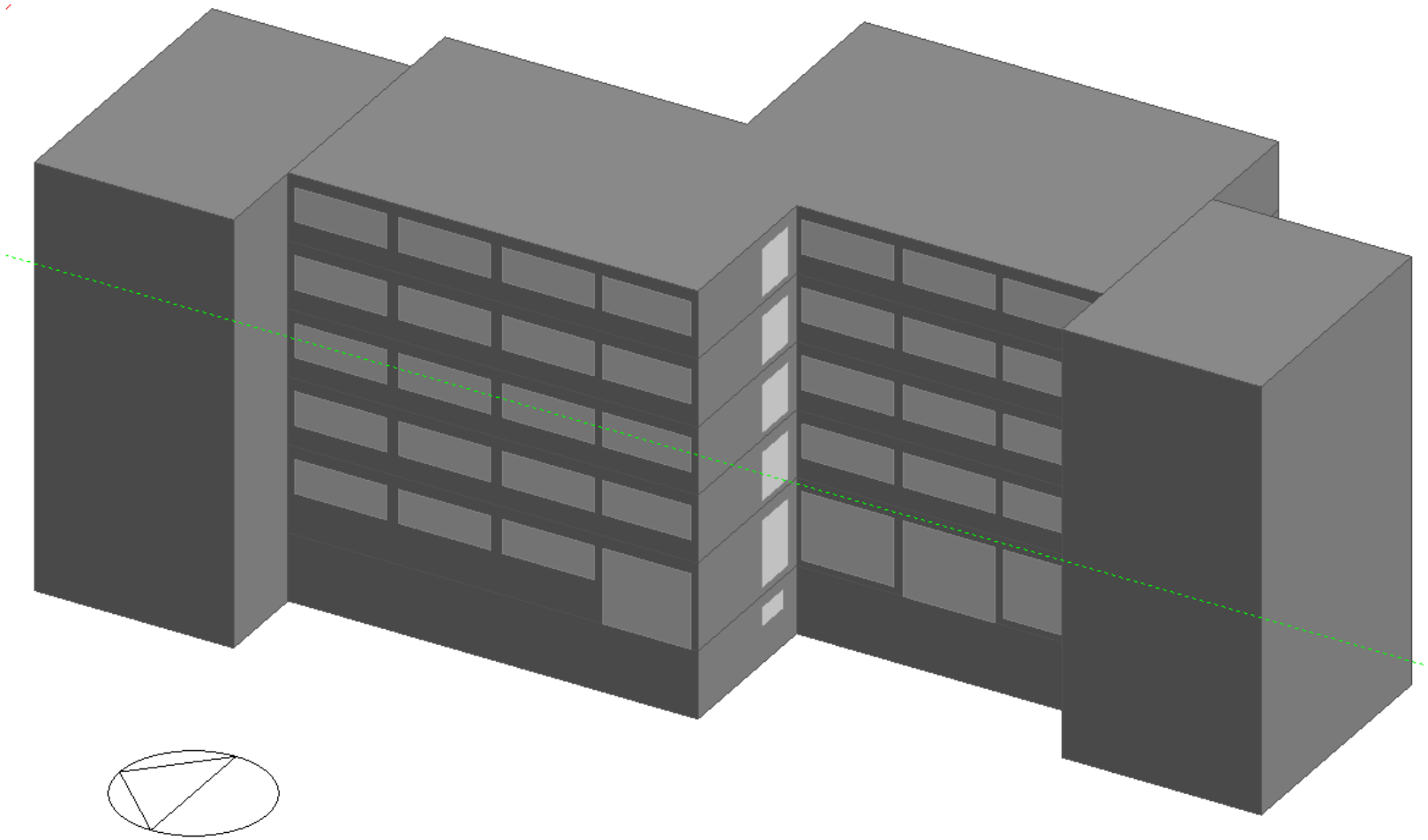
Measurement of 4 servers on site




| | |
|---|---|
| Maksimalna snaga [W] | 581 |
| Minimalna snaga [W] | 401 |
| Nazivna snaga [W] | 1.600 |
| Preračunati udio vremena kada se uređaj koristi na nazivnoj snazi [%] | 27 |
| Udio rada u višem tarifnom razdoblju [%] | 56 |

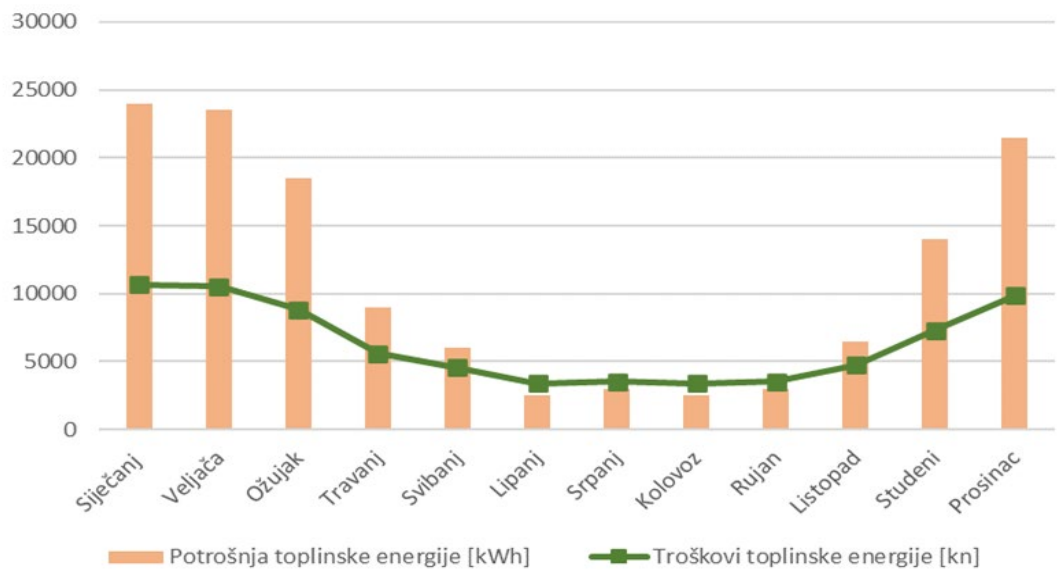
# Calibration process

- 3 possible ways of calibrating model dependent on data availability:
  - Annual model
  - Monthly model
  - Hourly & subhourly model

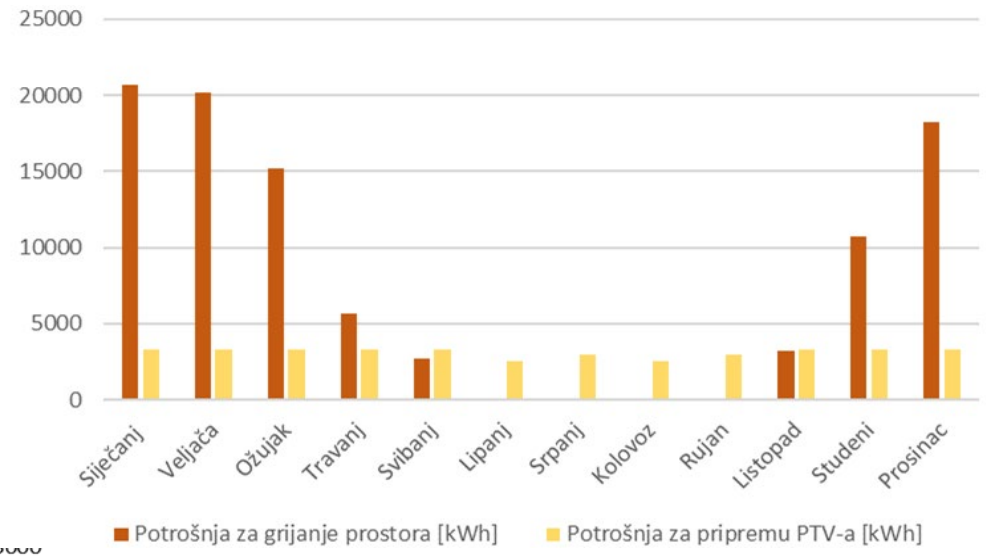


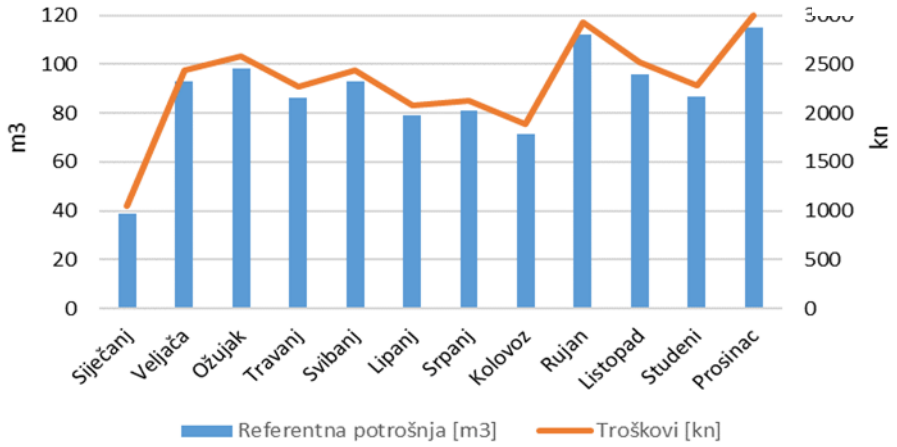
# Energy bills

*Reference values related to annual heating energy and cost*




Distribution of heating energy and energy for preparation of DHW



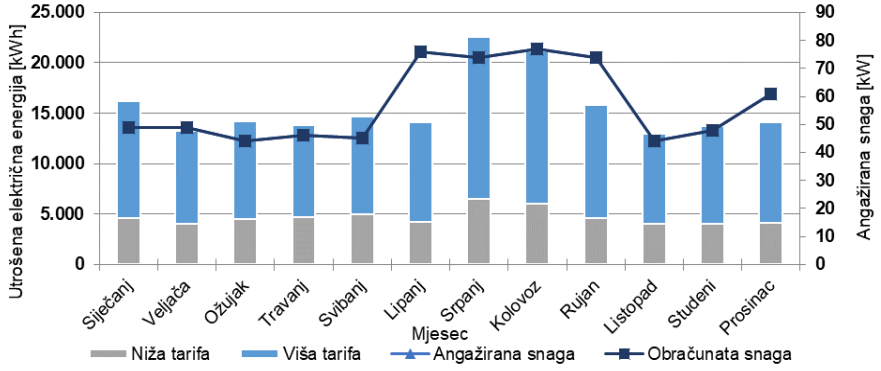

Annual consumption and cost of water

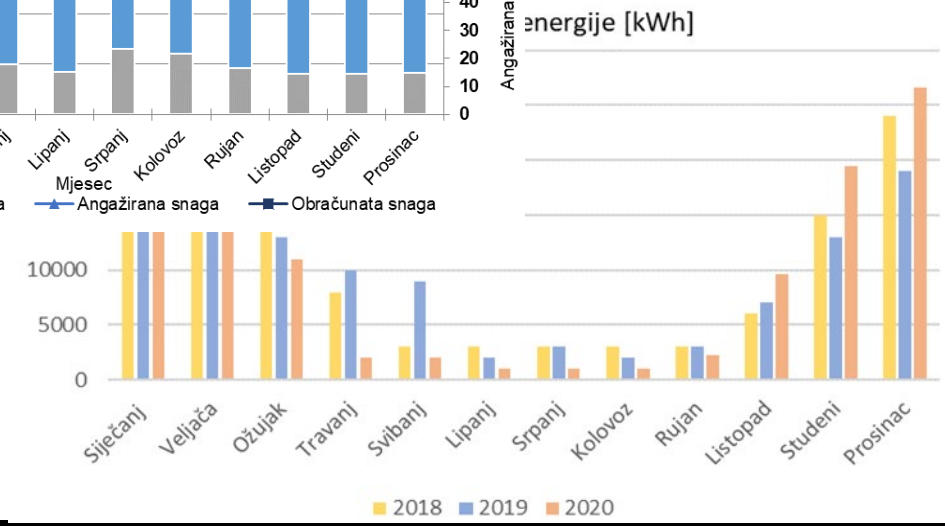
# Energy bills and energy audit

*Reference values related to energy and water consumption for the building (2019)*

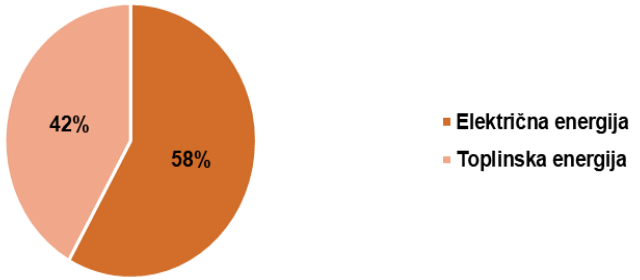
| Energenti i voda | Jedinica | Referentne vrijednosti | | |
|---|---|---|---|---|
| | | Godišnja potrošnja | Godišnja potrošnja energije | Godišnja emisija $CO_2$ |
| | | [jedinica/god.] | [kWh/god.] | [tona/god.] |
| Električna energija | kWh | 186.539,00 | 186.539,00 | 43,837 |
| Toplinska energija | kWh | 134.000,00 | 134.000,00 | 46,364 |
| Voda | $m^3$ | 1.051,50 | - | 0,236 |
| **Ukupno** | | | **320.539,00** | **90,437** |

*Total reference consumption of electricity in higher and lower tariffs and engaged power by month from January to December*

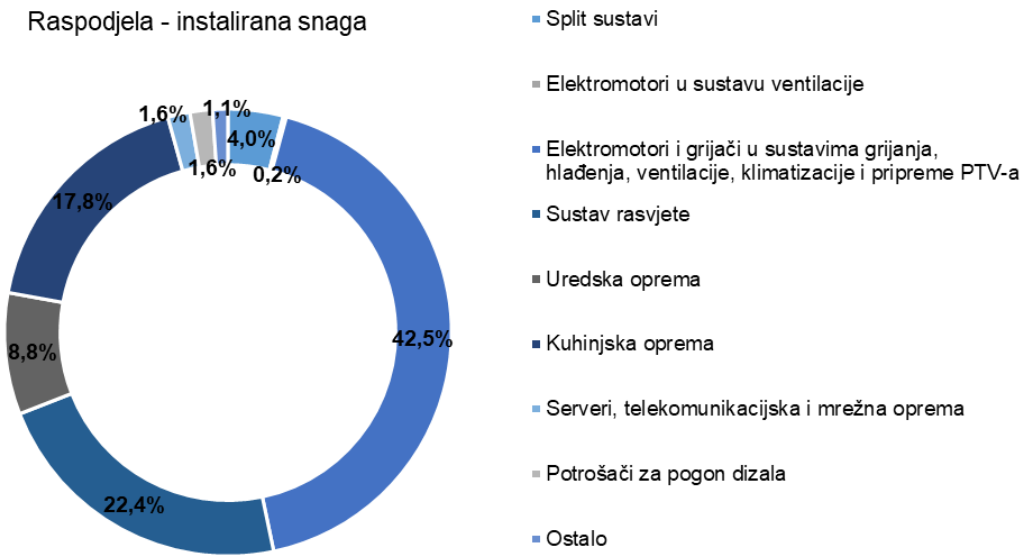



Shares of individual forms in reference energy consumption

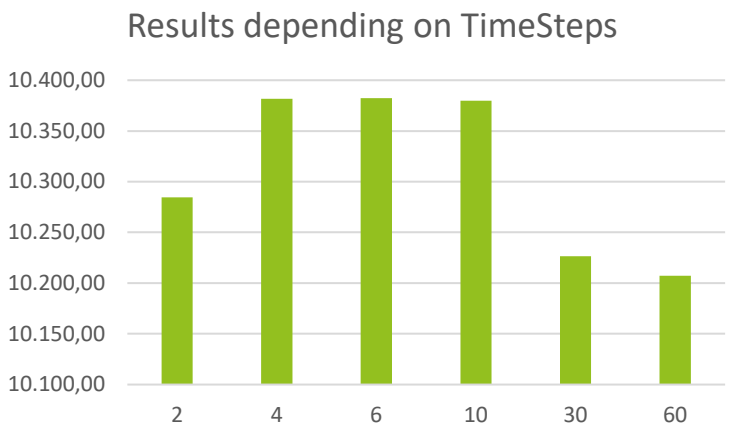


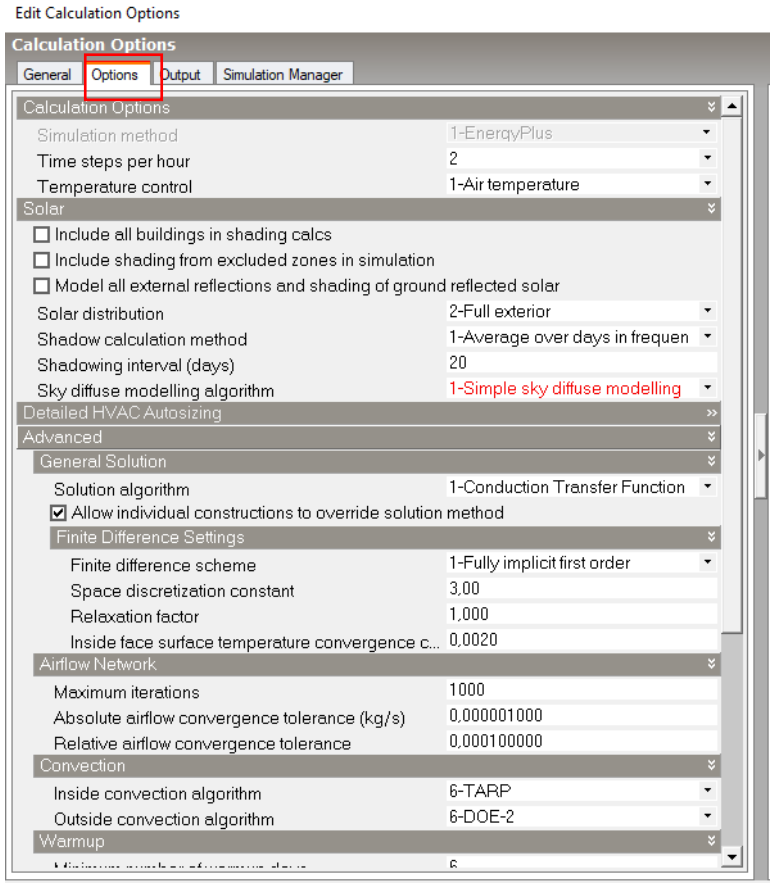

Distribution of main groups of consumers according to installed power



# Time Step Factor

| Time steps per hour | Run simulation Time | Total Energy [kWh] | 10284,5 |
|---|---|---|---|
| 2 | 0:00:24 | 10.284,53 | -0,000292% |
| 4 | 0:00:34 | 10.381,63 | -0,944431% |
| 6 | 0:00:46 | 10.382,20 | -0,949973% |
| 10 | 0:01:08 | 10.379,82 | -0,926832% |
| 30 | 0:02:44 | 10.226,57 | 0,563275% |
| 60 | 0:04:37 | 10.207,12 | 0,752394% |



# Final Calibration Results

**Site and Source Energy**

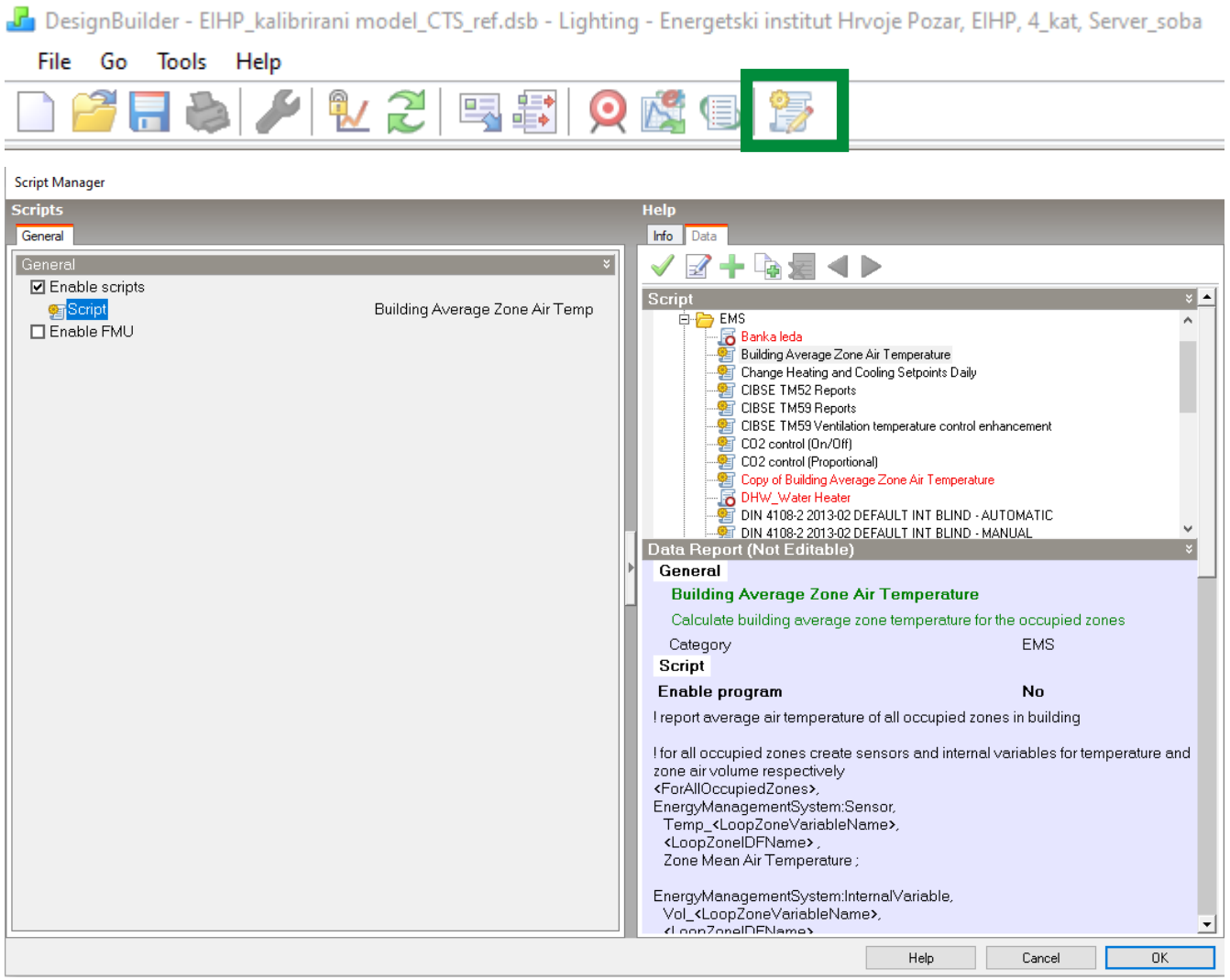
| | Total Energy [kWh] | Energy Per Total Building Area [kWh/m2] | Energy Per Conditioned Building Area [kWh/m2] |
|---|---|---|---|
| Total Site Energy | 288684.49 | 120.62 | 137.46 |
| Net Site Energy | 288684.49 | 120.62 | 137.46 |

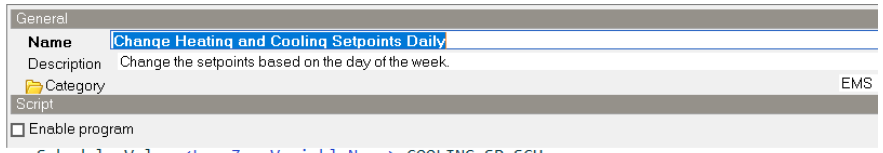
**End Uses**

| | Electricity [kWh] | Natural Gas [kWh] | Additional Fuel [kWh] | District Cooling [kWh] | District Heating [kWh] | Water [m3] |
|---|---|---|---|---|---|---|
| Heating | 0.00 | 0.00 | 0.00 | 0.00 | 130235.82 | 0.00 |
| Cooling | 31478.37 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Lighting | 38702.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Lighting | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Equipment | 53401.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Equipment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fans | 17217.96 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pumps | 17638.81 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Rejection | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Humidification | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Recovery | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water Systems | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 365.77 |
| Refrigeration | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Generators | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | | | |
| Total End Uses | 158448.68 | 0.00 | 0.00 | 0.00 | 130235.82 | 365.77 |

| Energenti i voda | Jedinica | Referentne vrijednosti | | |
|---|---|---|---|---|
| | | Godišnja potrošnja | Godišnja potrošnja energije | Godišnja emisija $CO_2$ |
| | | [jedinica/god.] | [kWh/god.] | [tona/god.] |
| Električna energija | kWh | 186.539,00 | 186.539,00 | 43,837 |
| Toplinska energija | kWh | 134.000,00 | 134.000,00 | 46,364 |
| Voda | $m^3$ | 1.051,50 | - | 0,236 |
| **Ukupno** | | | **320.539,00** | **90,437** |

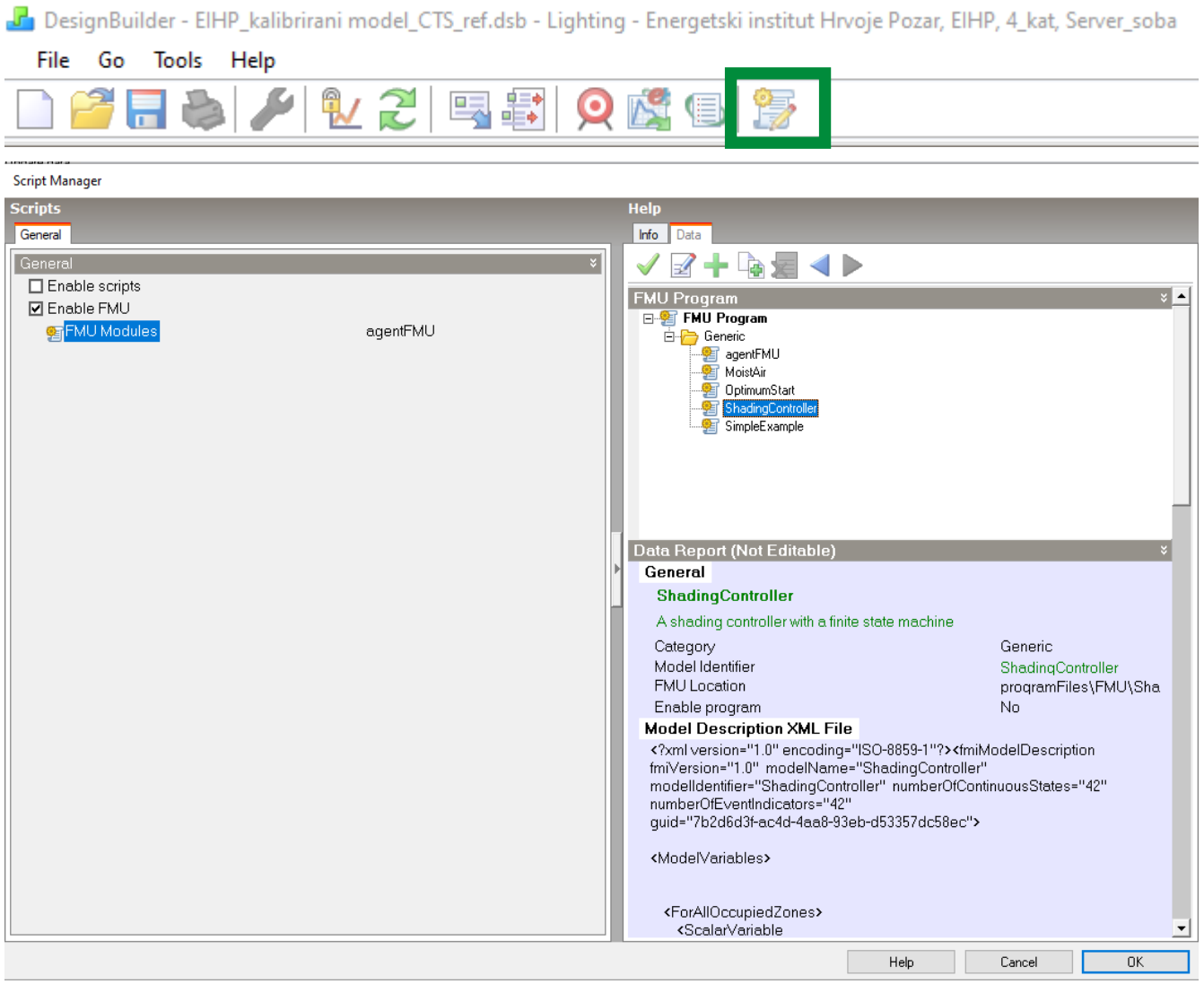
# EMS & FMU Scripts




```
   Schedule_Value_<LoopZoneVariableName>_COOLING_SP_SCH,
   <LoopZoneIDFName> COOLING SP SCH,
   Schedule:Compact,
   Schedule Value;

EnergyManagementSystem:Actuator,
   Schedule_Value_<LoopZoneVariableName>_HEATING_SETPOINT_SCHEDULE,
   <LoopZoneIDFName> HEATING SETPOINT SCHEDULE,
   Schedule:Compact,
   Schedule Value;
<LoopNextZone>

EnergyManagementSystem:ProgramCallingManager,
    My_Setpoint_Schedule_Calculator_Example,
    BeginTimestepBeforePredictor,
    MyComputedCoolingSetpointProg,
    MyComputedHeatingSetpointProg;

EnergyManagementSystem:Program,
    MyComputedCoolingSetpointProg,
    IF DayOfWeek < 6 && Holiday == 0,
<ForAllOccupiedZones>
       Set Schedule_Value_<LoopZoneVariableName>_COOLING_SP_SCH = 26.0,
<LoopNextZone>
    Else,
<ForAllOccupiedZones>
       Set Schedule_Value_<LoopZoneVariableName>_COOLING_SP_SCH = 100.0,
<LoopNextZone>
    Endif;

EnergyManagementSystem:Program,
    MyComputedHeatingSetpointProg,
    IF DayOfWeek < 6 && Holiday == 0,
<ForAllOccupiedZones>
       Set Schedule_Value_<LoopZoneVariableName>_HEATING_SETPOINT_SCHEDULE = 21.0,
<LoopNextZone>
    Else,
<ForAllOccupiedZones>
       Set Schedule_Value_<LoopZoneVariableName>_HEATING_SETPOINT_SCHEDULE = 15.0,
```

# EMS & FMU Scripts




- FMU – Functional Mock-up Unit - representation of a dynamic system based on a tool independent standard interface called Functional Mockup Interface (FMI)
- enables the exchange of models from a very diverse range of **domains** and **applications**
- used to perform co-simulation and real time simulations by coupling systems
- Example: EnergyPlus & Modellica + real measured data

TIMEPAC The new EPC for Europe

# If you would like more information, please visit www.timepac.eu or contact us at

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Thanks for your attention!



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