Energy Efficiency (EE) and verification of EE measures

Programme title: Green Finance Facility to Improve Air Quality and Combat Climate Change in North Macedonia

Short title: North Macedonia Green Finance Facility (NMGFF)

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About Energy Efficiency

- Energy efficiency is one of the key pillars for meeting climate objectives – on a par with increasing the use of renewable energy.
- Often energy efficiency is underestimated in existing planning and investment programmes
- Cost-efficient energy efficiency measures should be taken into account when shaping energy policies and making relevant investment decisions
- Improving energy efficiency ensures that:
  - Only the energy really needed is produced
  - Investments in stranded assets are avoided
  - Demand for energy is reduced and managed in a cost-effective way

About Energy Efficiency

- Energy supply, as well as demand, needs to be more efficient, in particular by means of cost-effective end-use energy savings demand response initiatives and more efficient conversion, transmission, and distribution of energy whilst still achieving the objectives of the decisions.
- National policies should encourage actions in energy efficiency and energy demand management on an equal footing with alternative actions to respond to a specific need or objective, in particular when energy supply or energy infrastructure investments are at stake – whether public or private.
- Proper assessment of energy efficient solutions in cost-benefit analysis and impact assessments, taking a broader societal perspective. This requires proper cost-benefit analysis methodologies adapted to different contexts and sectors.

EE first

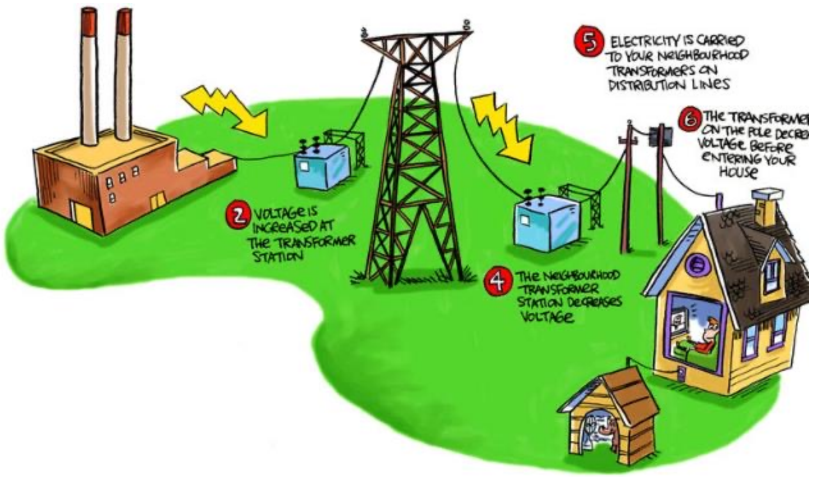
- **2006** Directive on end-use efficiency and energy services
- **2010** EU 2020 strategy: 20% EE target
- **2012** EED entered into force
- **2014** First NEEAP’s by Member States
- **2016** focussed EED review: 32.5% target & Art 7, 9, 11
- **2019** Green Deal with increased climate target
- **2019** First NECP’s by Member States
- **2020** Review and revision of EED regarding increased targets

Electricity and the power system

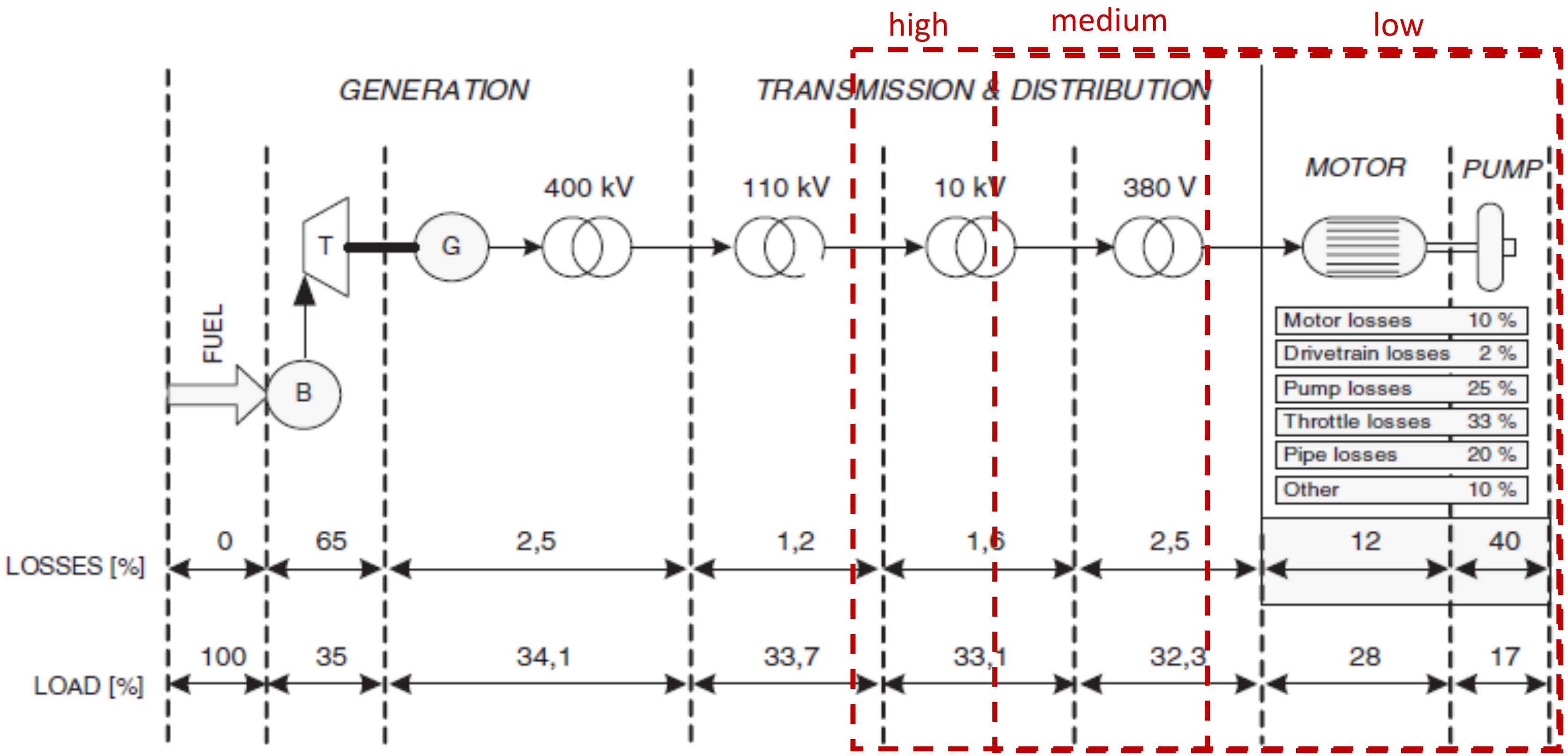
- The most widespread and most accessible form of energy
- Technically, the most convenient and cleanest form of energy
- The simplest form of energy for transformation and transport
- Simultaneity of production and consumption and (still) limited ability to store – main shortcoming!
- Production -> Transmission -> Distribution -> Consumption
- η=0,35-0,4 η=0,95-0,98 η=0,90-0,95 η=0,05-0,95

$$E_{prim} = E_{el} \times f_p$$

<u>1 kWh (el) = 3 kWh (prim)</u>

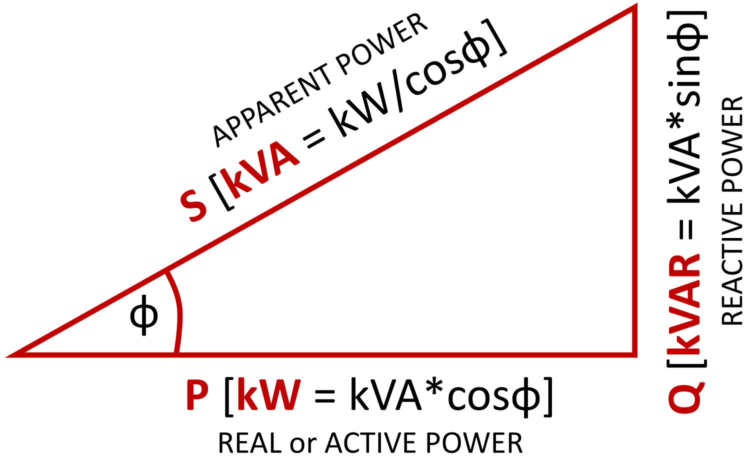


Power system and low-voltage grid



Basic terms

- Active and reactive power
- Power factor
- Load diagram
- Peak demand
- Power and energy
- Load factor



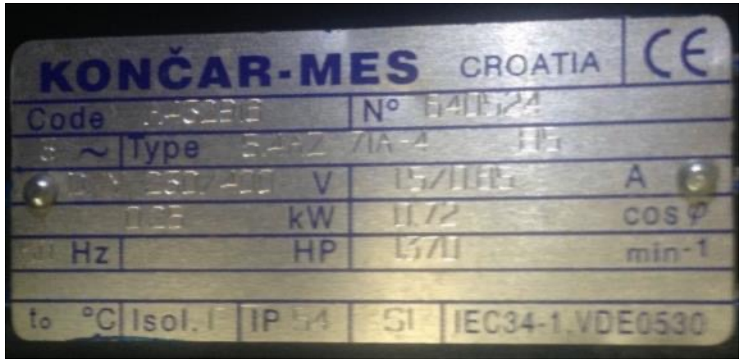
$S^2 = P^2 + Q^2$

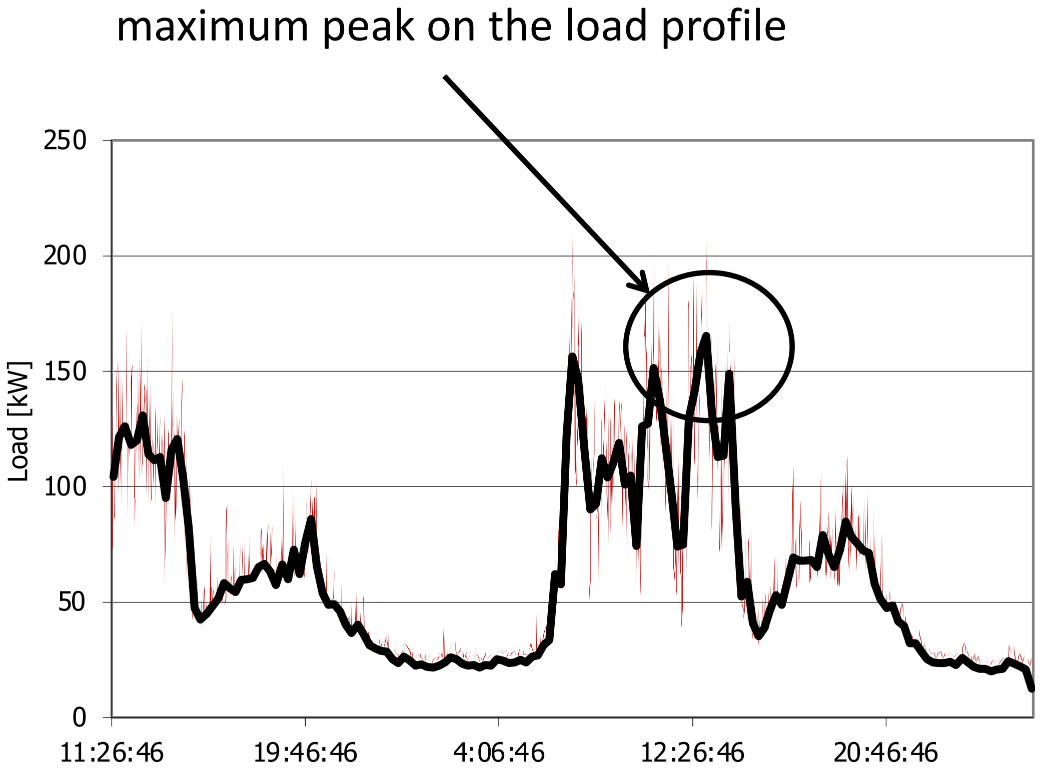
$P = \sqrt{3}\, V_L\, I_L \cos\phi$ (3-phase load)

$P = V_L\, I_L \cos\phi$ (1-phase load)

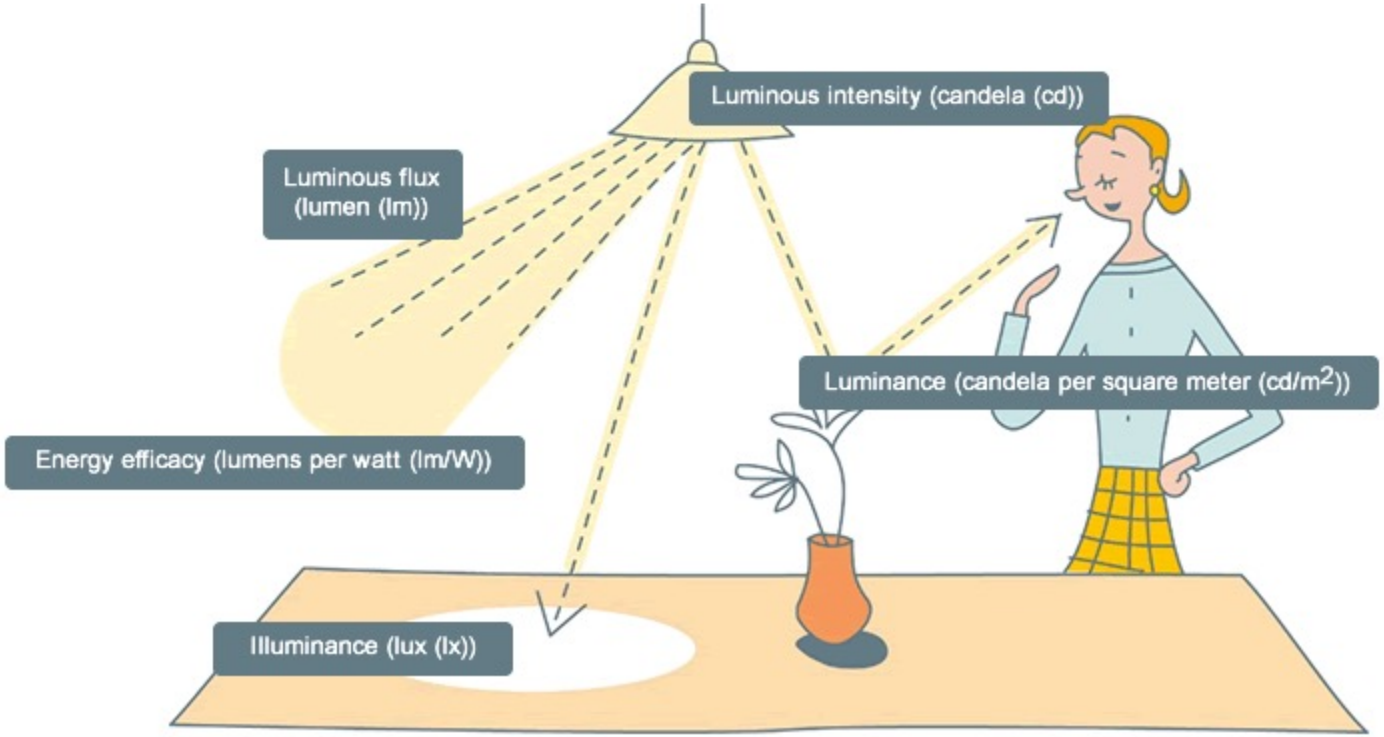
$Q = V_L\, I_L \sin\phi$

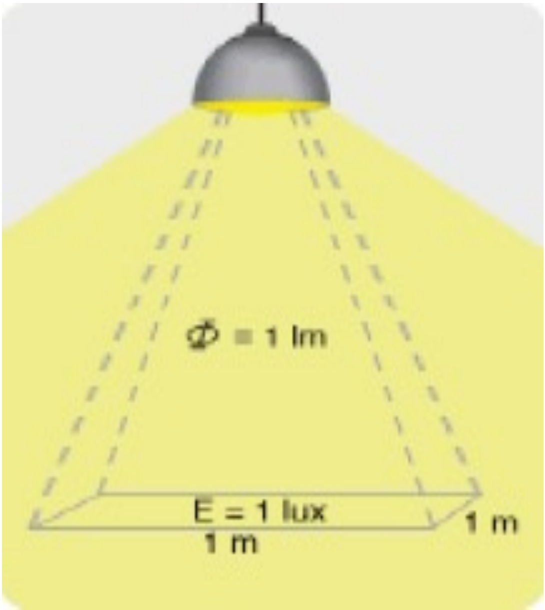
$$PF = \frac{P}{S} = \cos\varphi$$





Lighting terminology





Source: https://panasonic.net/ecosolutions/lighting/technology/knowledge/02/

Lighting - typology

- Thermal – bodies that emit electromagnetic radiation because of their increased temperature
  - Incandescent
  - Halogen
- Gas-discharge – gas emits electromagnetic radiation when a stream of electrons travels through it
  - Low pressure – fluorescent
  - High pressure – mercury and sodium
- Solid-state – light is created inside solid-state materials
  - LED
  - OLED

Incandescent light bulbs

- luminous efficacy: 8-15 lm/W
- lifetime: 1.000 h
- colour temperature: 2600-2800 K

Halogen lamps

- luminous efficacy: up to 25 lm/W
- lifetime: 4.000 h
- colour temperature: 2800 K

High pressure discharge lamps

- luminous efficacy: up to 180 lm/W
- lifetime: 20.000 h
- colour temperature: 2000-5500 K

Fluorescent lamps (tubes or CFLs)

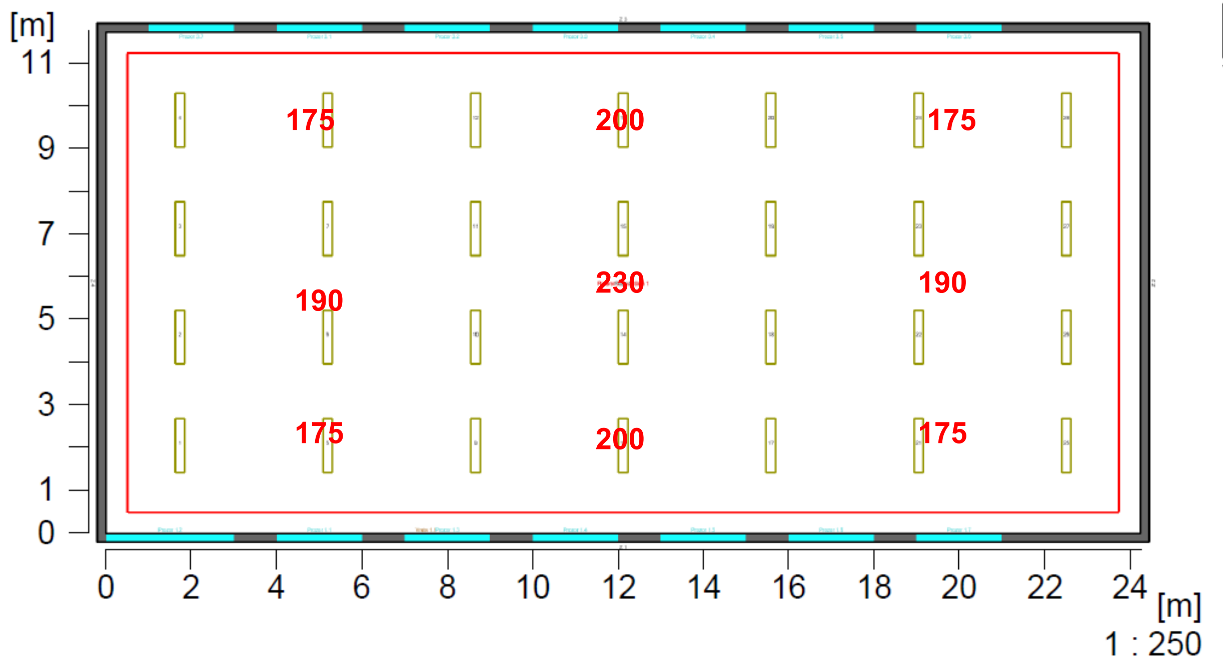
- luminous efficacy: 70-130 lm/W
- lifetime: 6.000-15.000 h
- colour temperature: 2700 – 6000 K

LED

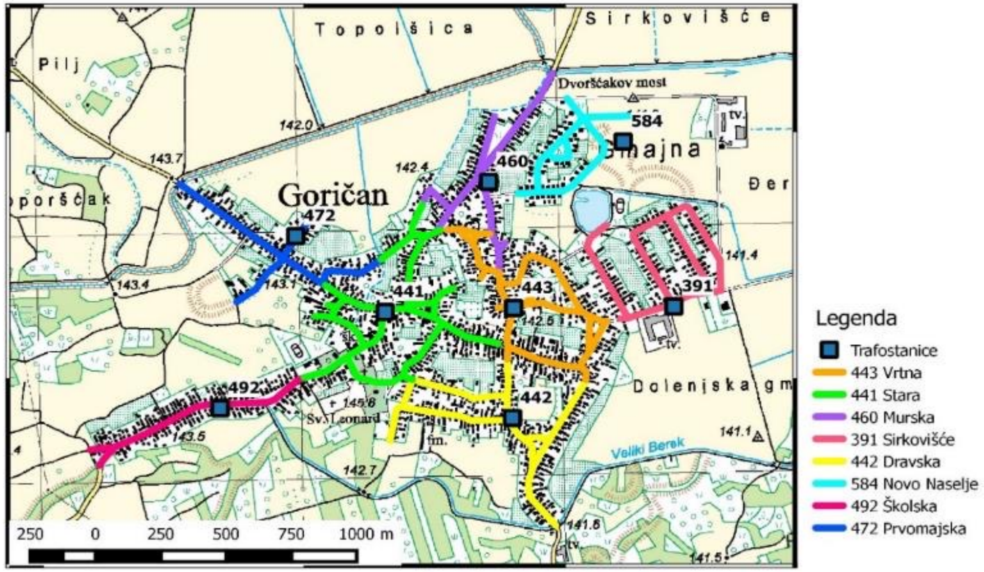
- luminous efficacy: 60-90 lm/W
- lifetime: 40.000-80.000 h
- colour temperature: 2000 - 6500 K

Lighting in buildings

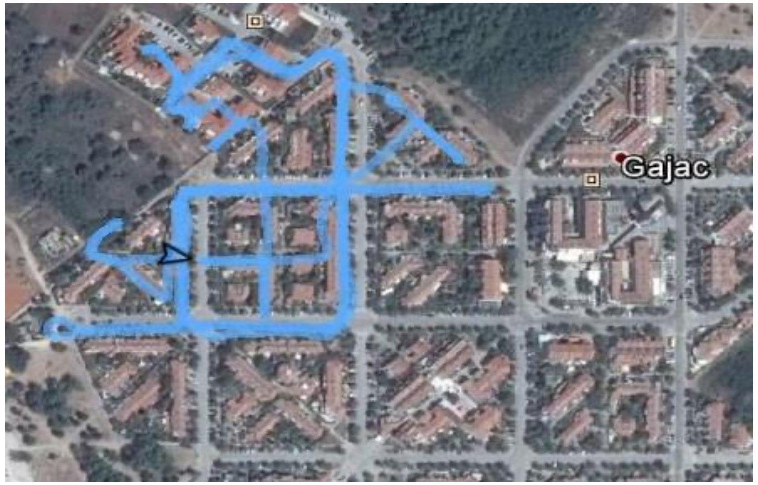
Room	Number of luminaires	Type of luminaire	Measured illuminance [lx]
Kitchen	9	FC 4x18	100
	44	FC 2x36	400
	3	FC 3x36	350
Hall	35	FCE 4x14	700
Room 101	4	FC 4x18	829
	3	HAL 35	
Room 101 A	6	FC 4x18	412
	3	HAL 35	
	1	ŽN 60	
Room 102	2	ŽN 60	596
	6	FC 4x18	
Room 103	6	FC 4x18	505
Room 104	4	FC 3x36	698
Room 105	4	FC 3x36	500



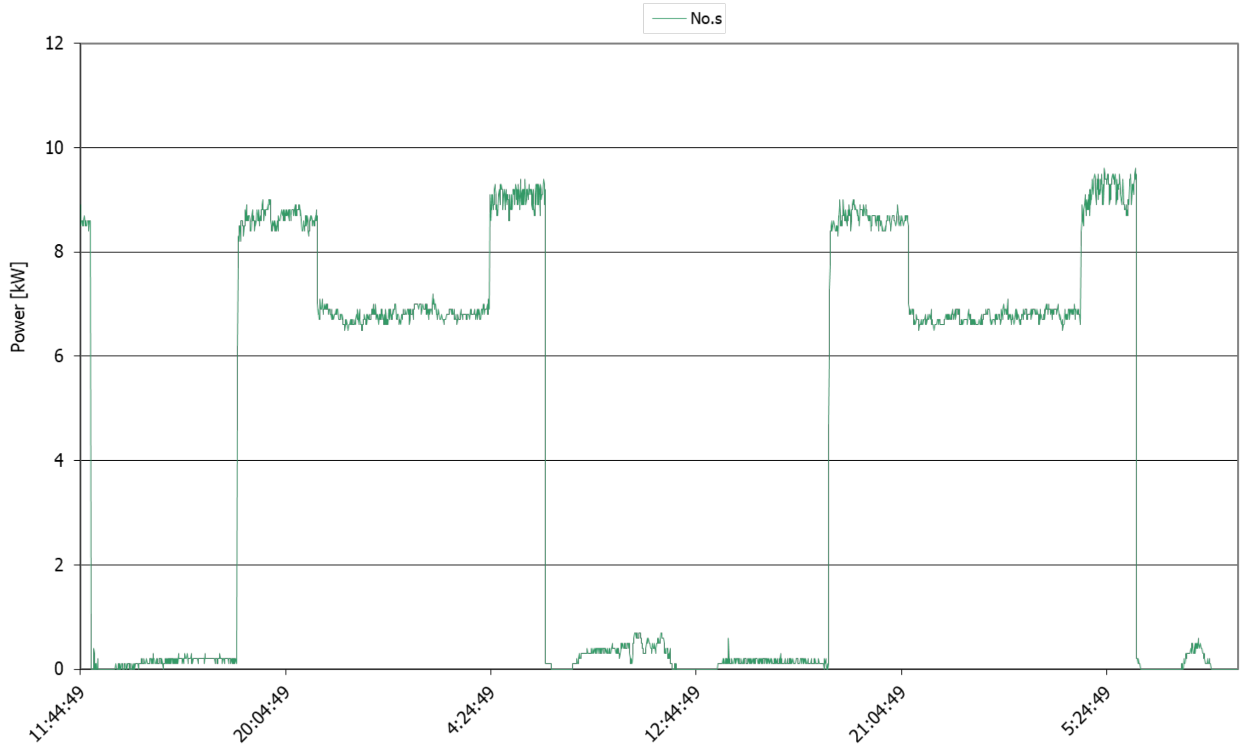
Outdoor lighting

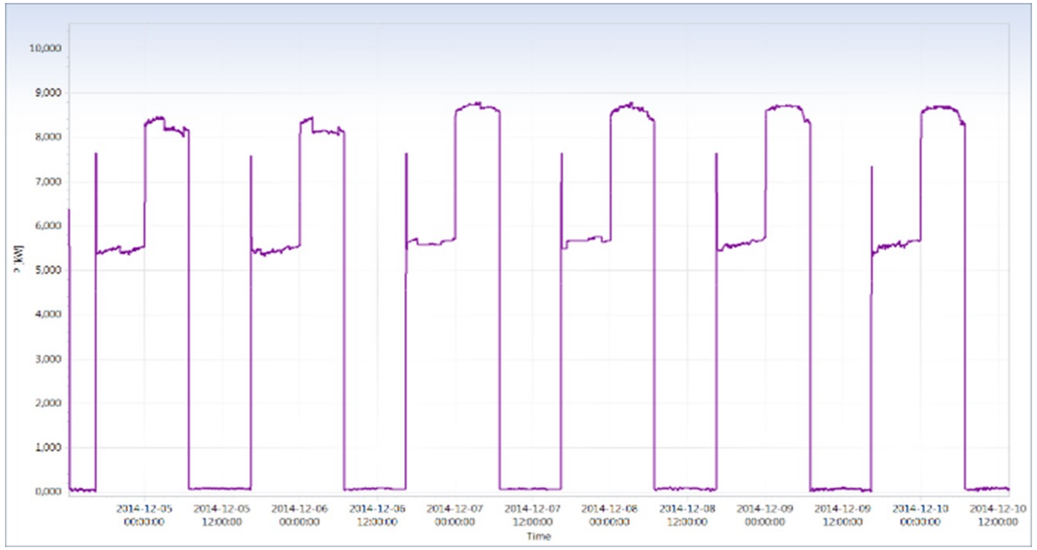


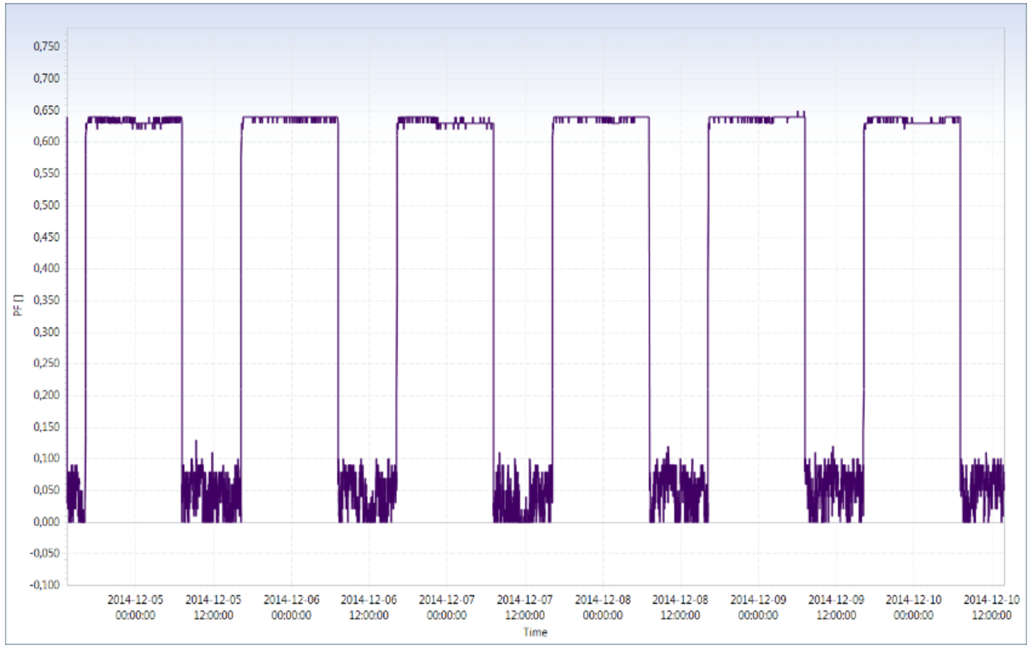
- Create a list of all lighting places by:
  - Location (switch cabinet)
  - Type of light (light source + luminaire)
  - Colum type
  - Operation / Number of working hours
- Measurement of consumption parameters of electricity (where it makes sense - mostly on more than 30 lamps or 3 kW of installed power) 2-5 days:
  - Total installed power and power per phase (15 min and 5/30 s triggering)
  - Voltage per phase
  - PF



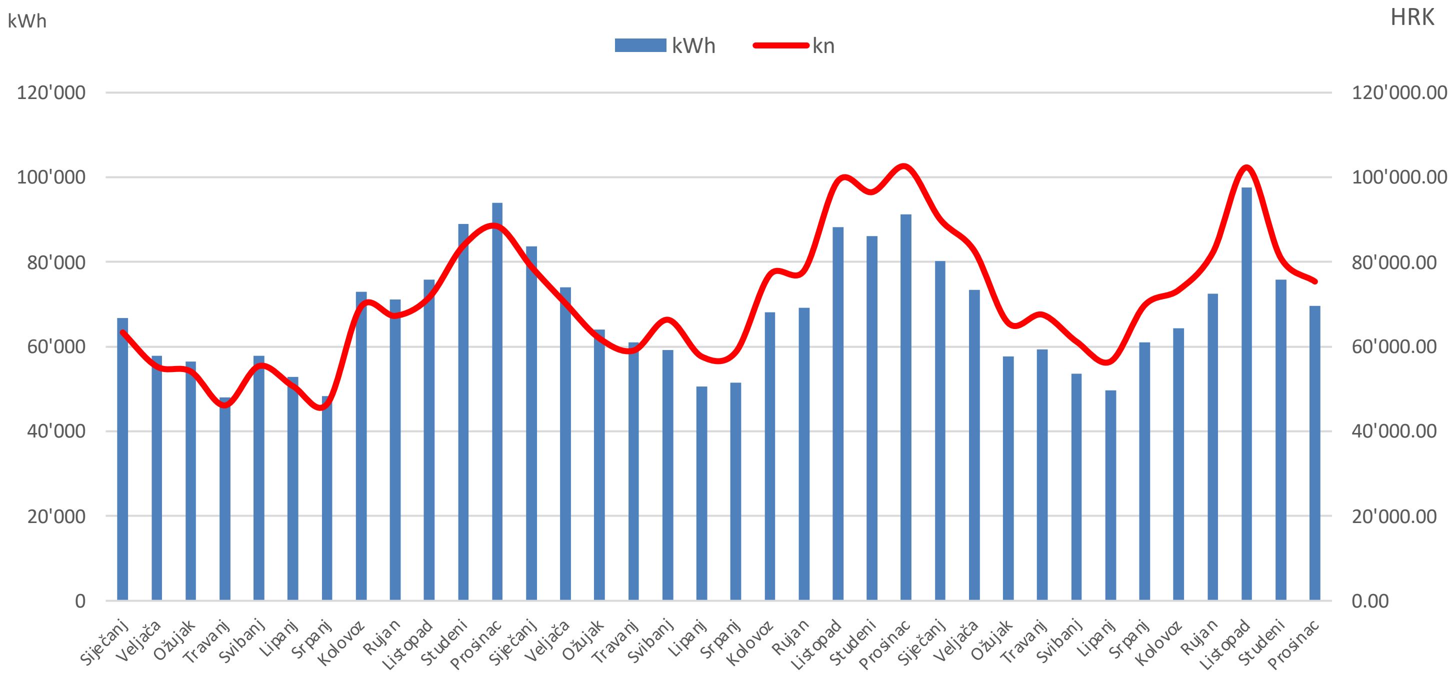
Outdoor lighting

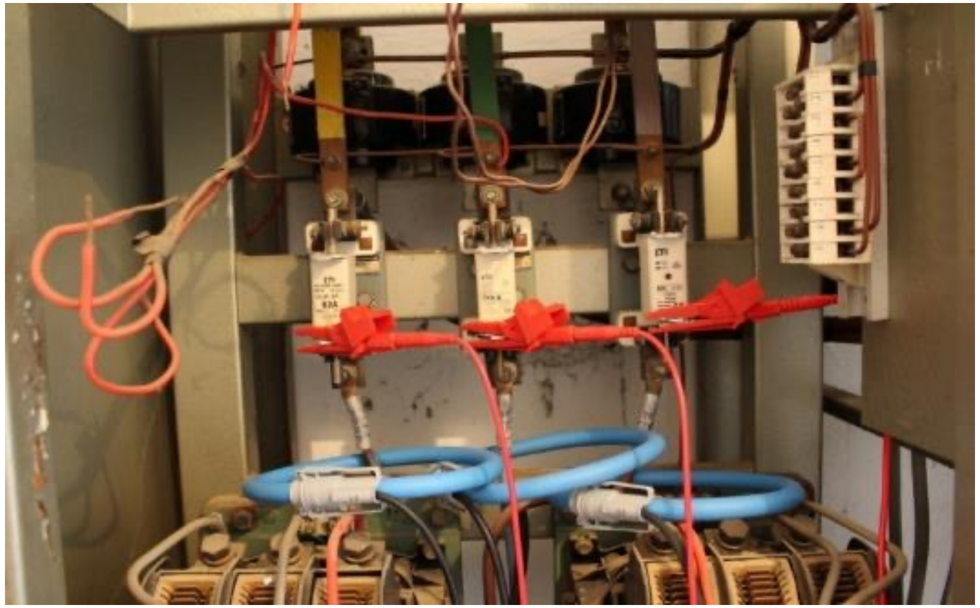


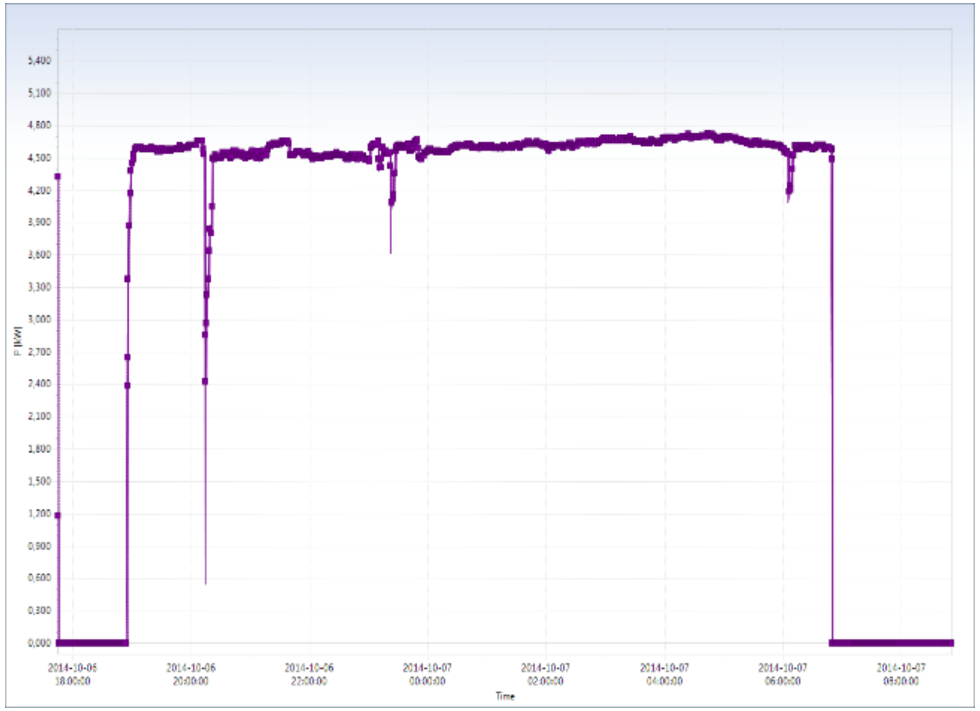




Outdoor lighting

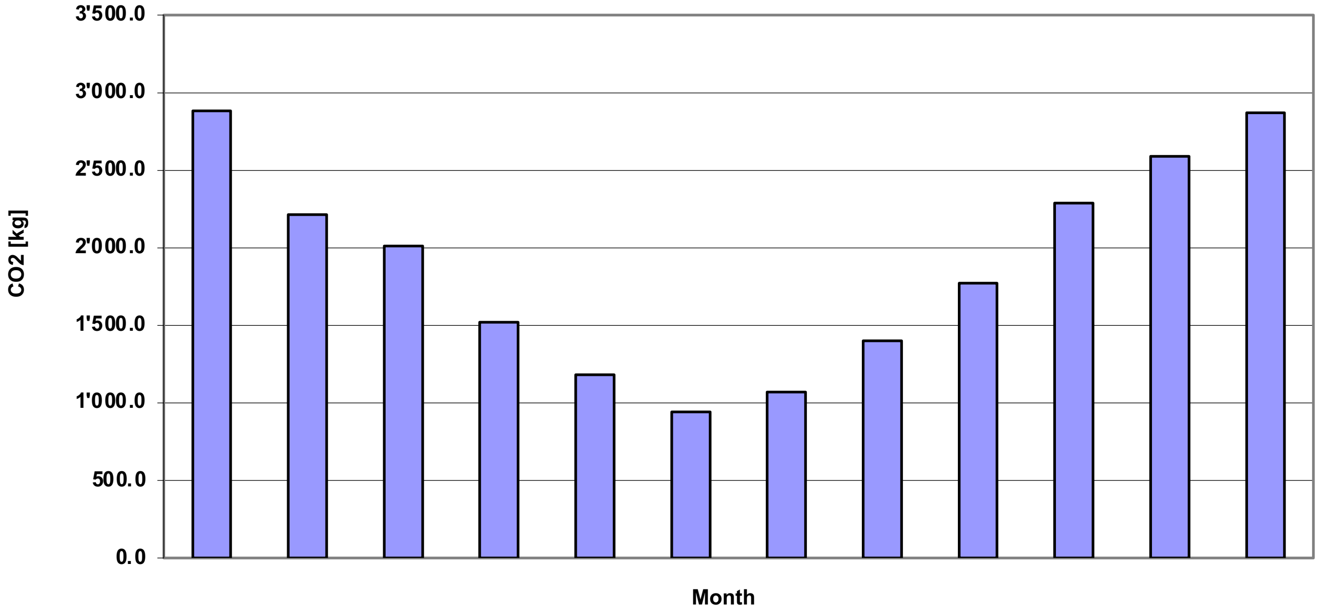






Outdoor lighting

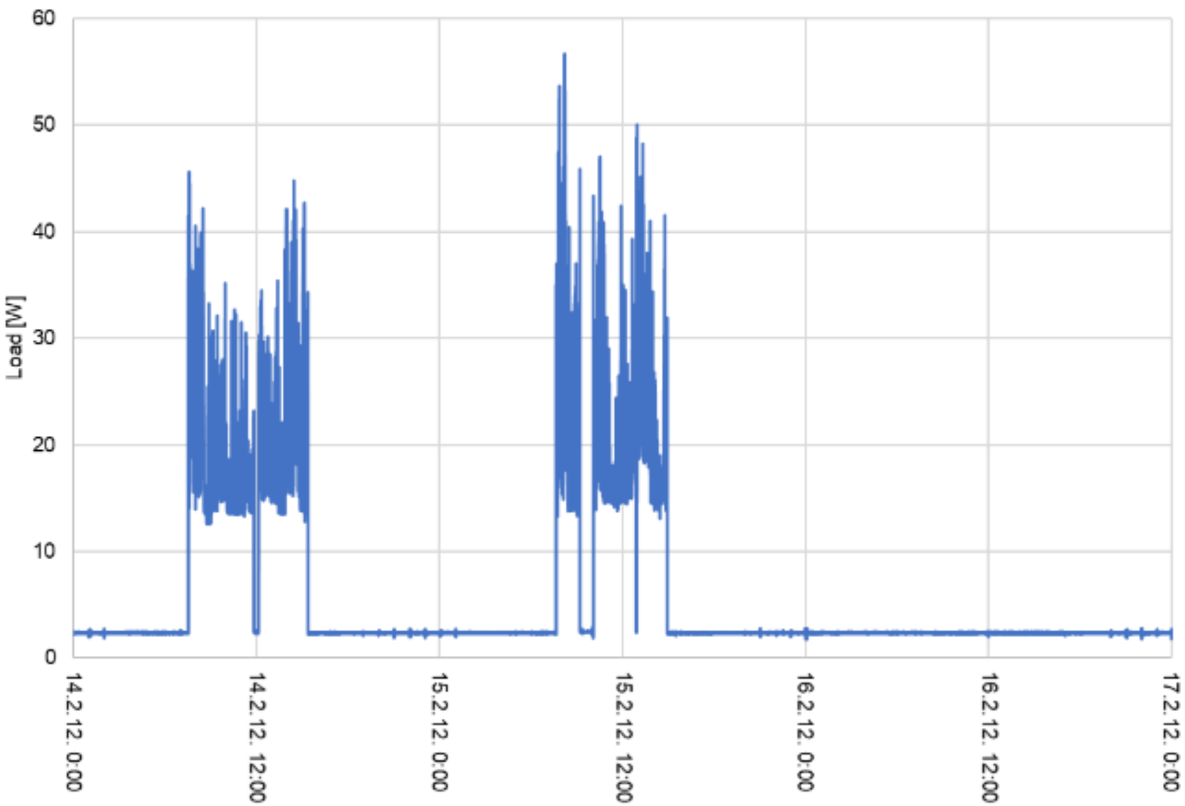
- CO_2 emission calculation:



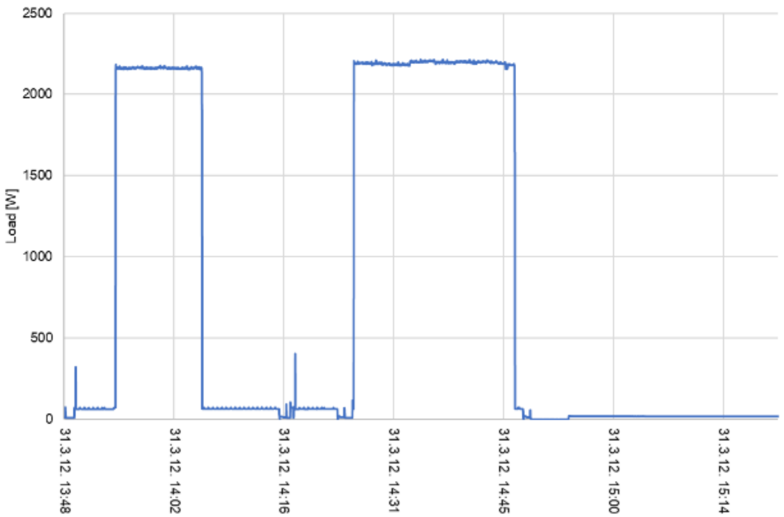
- $EM_{el} = E_{el} \times EF_{se}$ [kg/a]
  - E_{el} baseline yearly electricity consumption in kWh,
  - EF_{se} coefficient that relates to emissions of CO_2 needed to produce and transport 1 kWh of electricity to end consumer (state normalized)

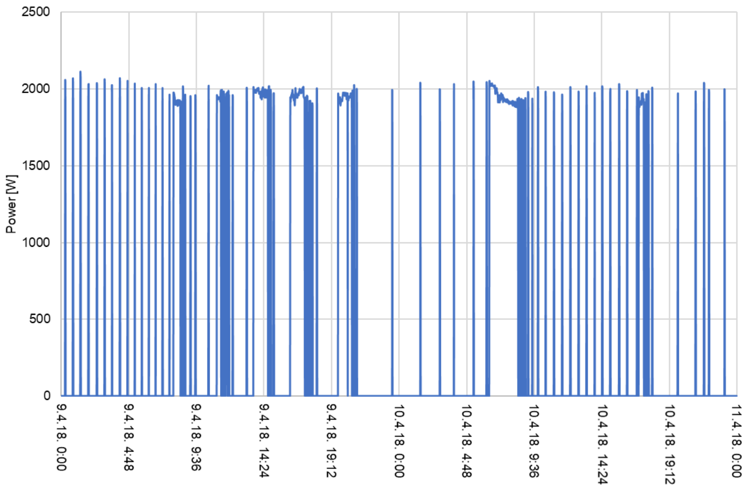
Appliances

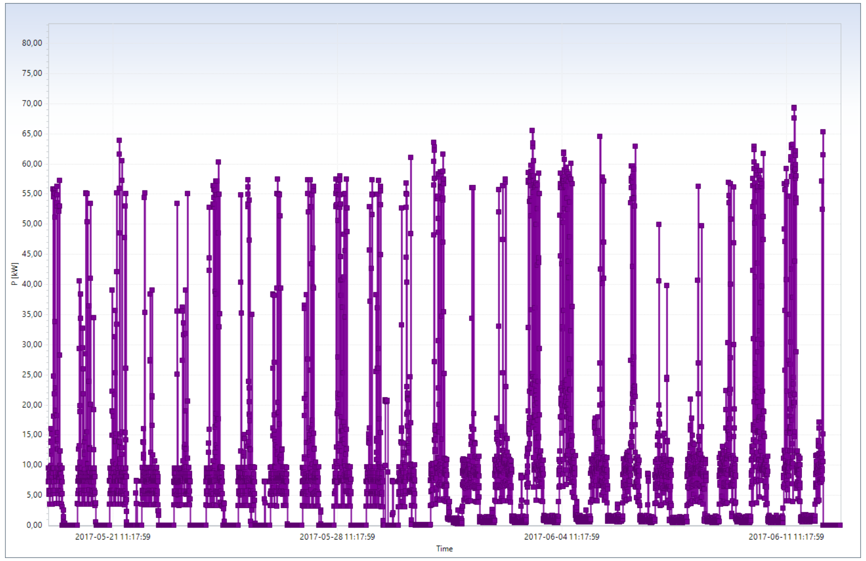
- Office equipment
- Kitchen equipment
- Electric motors
- Heaters
- Laundry equipment
- Other



Appliances


Load [W]
2500
2000
1500
1000
500
0
31.3.12. 13:48
31.3.12. 14:02
31.3.12. 14:16
31.3.12. 14:31
31.3.12. 14:45
31.3.12. 15:00
31.3.12. 15:14


Power [W]
2500
2000
1500
1000
500
0
9.4.18. 0:00
9.4.18. 4:48
9.4.18. 9:36
9.4.18. 14:24
9.4.18. 19:12
10.4.18. 0:00
10.4.18. 4:48
10.4.18. 9:36
10.4.18. 14:24
10.4.18. 19:12
11.4.18. 0:00


P [kW]
80,00
75,00
70,00
65,00
60,00
55,00
50,00
45,00
40,00
35,00
30,00
25,00
20,00
15,00
10,00
5,00
0,00
2017-05-21 11:17:59
2017-05-28 11:17:59
2017-06-04 11:17:59
2017-06-11 11:17:59
Time

Example

It is necessary to determine the annual energy consumption of the computer with the display in the office space. The office space, and therefore the computer, is used 8 hours, 5 days a week, except for vacations. During working hours, the computer runs in standby mode for an average of 1 hour. At other times, the computer is turned off but is connected to the network. Operating hours:

$$t_{on} = 52\ weeks \times 5 \frac{day}{week} \times 7 \frac{hour}{day} - 25\ days\ of\ vacation \times 7 \frac{hour}{day} = 1.645\ h$$

$$t_{s-b} = 52\ weeks \times 5 \frac{day}{week} \times 1 \frac{hour}{day} - 25 days\ of\ vacation \times 1 \frac{hour}{day} = 235\ h$$

$$t_{off} = 8.760 - t_{on} - t_{s-b} = 6.880\ h$$

Example

The computer with a screen at the location has a nominal installed power of 200 W. Measurements have shown that the average load is 120 W in a typical operation. The screen shuts off on standby, and the average power is 52 W. In moments when the computer and the screen are off, the losses of 3 W are measured. The total energy consumed is:

$$E = \frac{P_{on} \times t_{on} + P_{s-b} \times t_{\mathrm{s-b}} + P_{off} \times t_{off}}{1000} = \frac{120 \times 1645 + 52 \times 235 + 3 \times 6880}{1000} = 230\ kWh$$

Adjusted operation hours: $t = \frac{E}{P_{nominal}} = \frac{230}{0{,}2} = 1.150\ h$

Smart metering

$$FES_{Oi} = E\ x\ r_{EL} + (G_{PP} + G_{ELLU} + G_{UNP} + G_{TE})\ x\ r_G$$

FES_{Oi}	*[kWh/god]*	Annual savings
E	*[kWh/god]*	Annual electricity consumption (before smart metering installation
r_{EL}	-	Electricity savings factor (referent value)
G_{PP}	*[kWh/god]*	Annual natural gas consumption
G_{ELLU}	*[kWh/god]*	Annual oil consumption
G_{UNP}	*[kWh/god]*	Annual liquefied petroleum gas consumption
G_{TE}	*[kWh/god]*	Annual heat consumption
r_G	-	Fuel savings factor (referent value)

Smart metering

$$E_{CO2O} = \frac{E\ x\ r_{EL}\ x\ e_{EL} + (G_{PP}\ x\ e_{PP} + G_{ELLU}\ x\ e_{ELLU} + G_{UNP}\ x\ e_{UNP} + G_{TE}\ x\ e_{TE})\ x\ r_G}{1000}$$

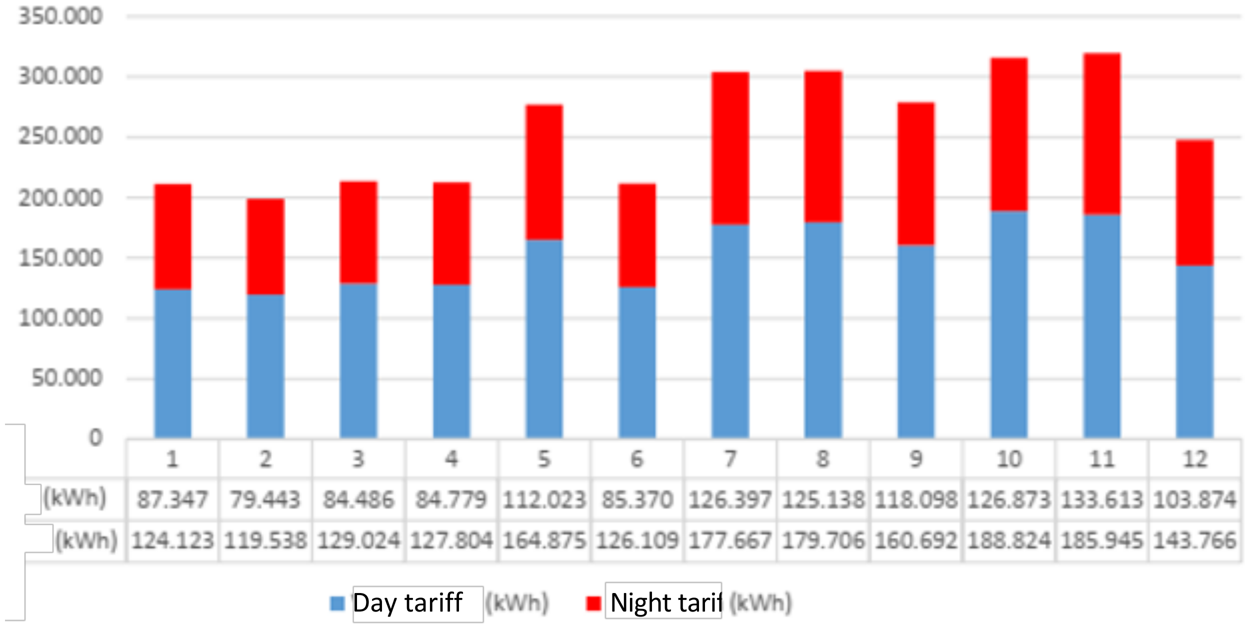
E_{CO2o}	[tCO_2 / god.]	Annual emission reduction
e_{EL}	[$kgCO_2$ / kWh]	Electricity emission factor 0,159
e_{PP}	[$kgCO_2$ / kWh]	Natural gas emission factor 0,214
		Oil emission factor 0,300
e_{ELLU}	[$kgCO_2$ / kWh]	Liquefied petroleum gas emission factor 0,255
e_{UNP}	[$kgCO_2$ / kWh]	
e_{TE}	[$kgCO_2$ / kWh]	Heat emission factor 0,326

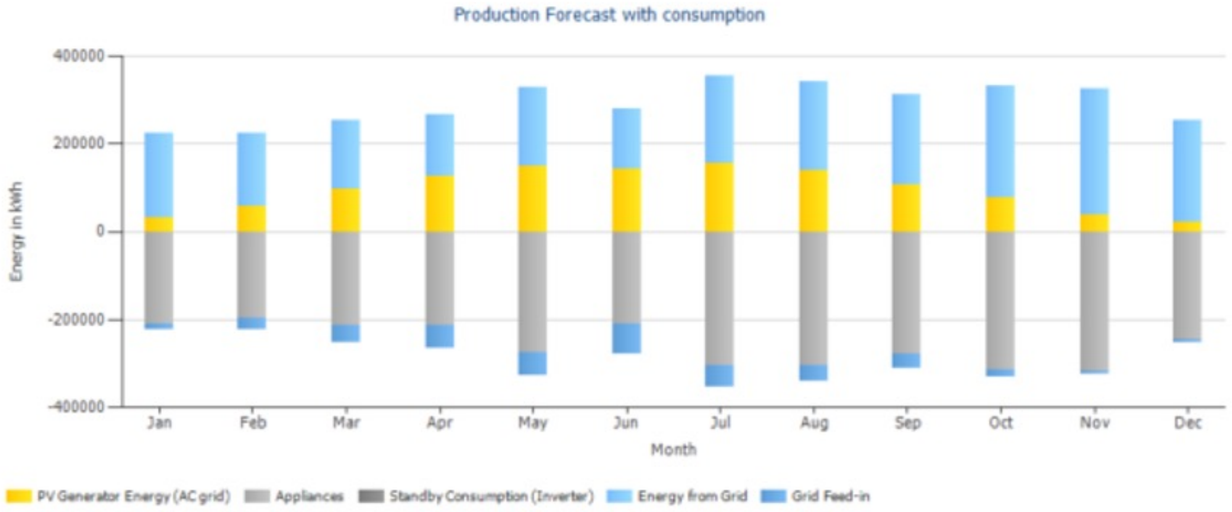
Solar photovoltaic (PV)

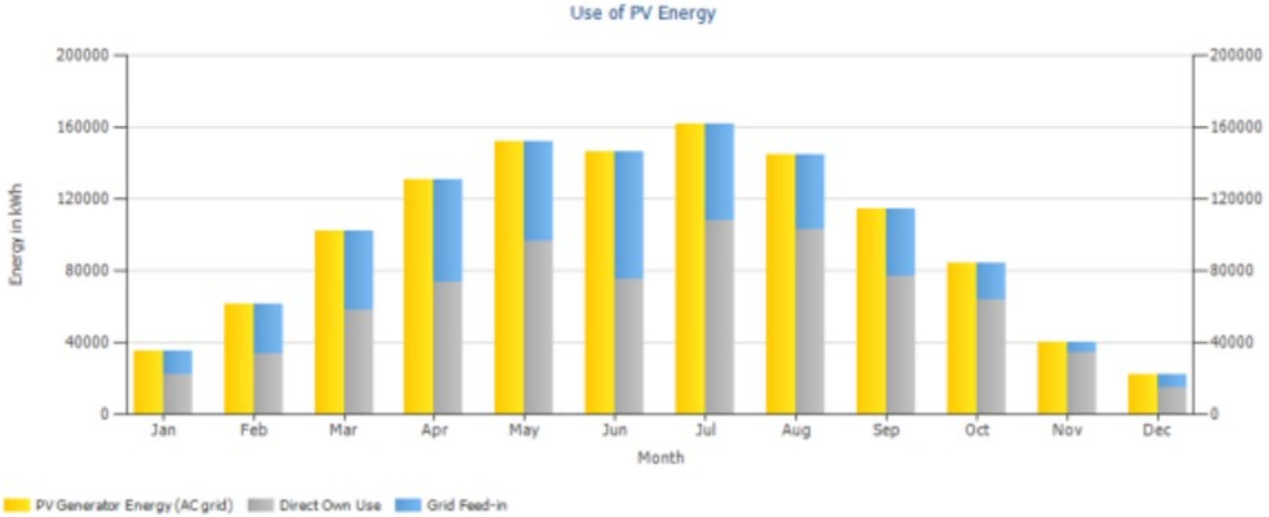
$$FES = P_{PV} * h * PR * (1 - ee_{net})$$

FES [kWh/god.]	• Annual savings
P_{PV} *[kW]*	• Installed peak power of PV plant
h [h/god.]	• Working hours on peak power
ee_{net} *[-]*	• Share of electricity transferred to the distribution grid
PR [-]	• Performance Ratio (metered electricity vs. electricity generated by PV modules)

Solar photovoltaic (PV) - example







Solar photovoltaic (PV) - example

- (A1) 1.193.365 kWh
- 760.298 kWh self-consumption
- 433.067 kWh grid
- Ratio 63,71% (eenet = 0,3629)
- (A2) PR = 0.7 (referent value)
- (A3) PPV = 1,034.88 kW (peak power)
- (A1)/(A2×A3) h = 1,647.35 h/y

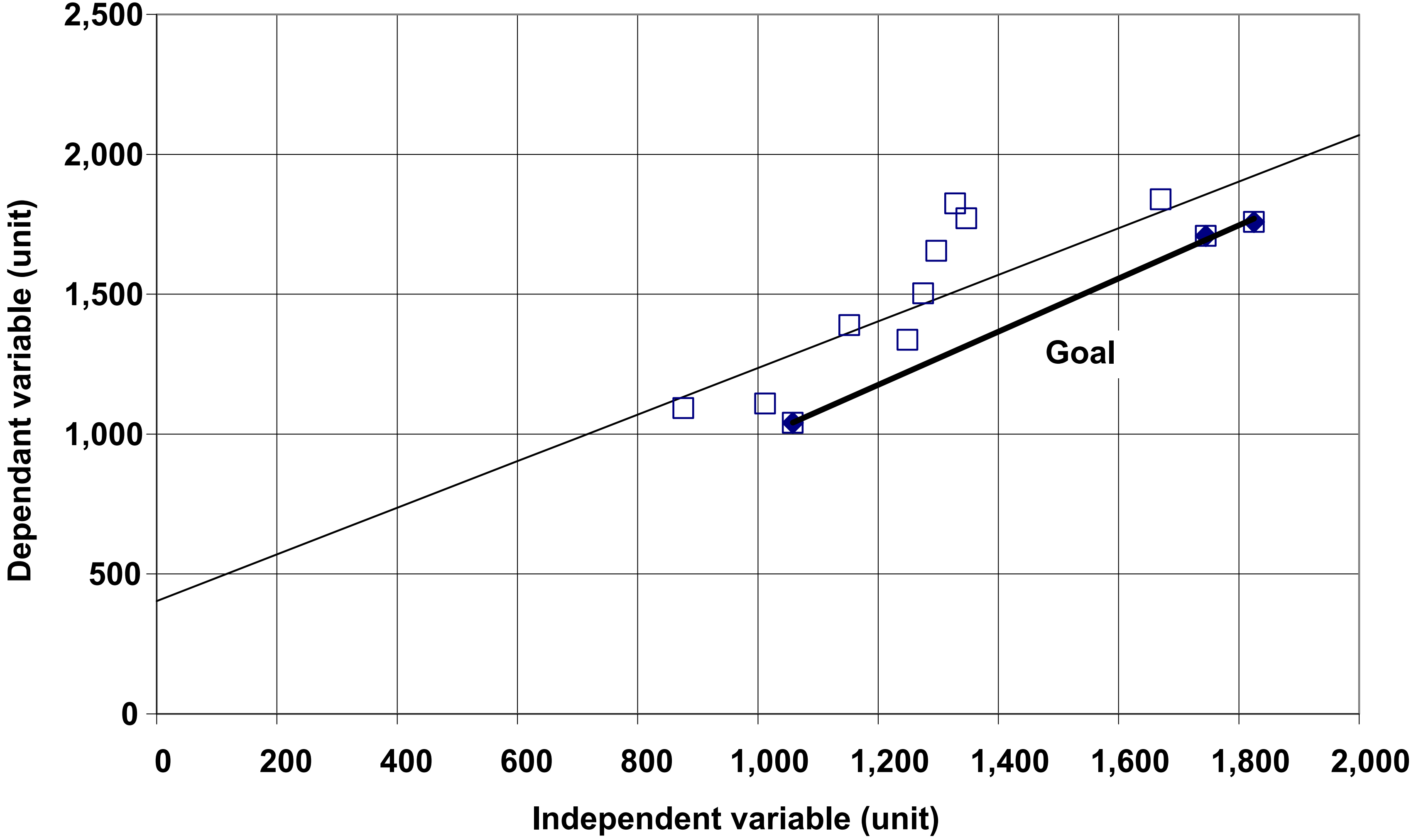
- FES = 760,298.00 kWh/y
- e = 0,159 kgCO2/kWh
- ECO2 = 120,89 t/y

$$FES = P_{PV} * h * PR * (1 - ee_{net})$$

$$E_{CO_2} = FES \cdot \frac{e}{1000}$$

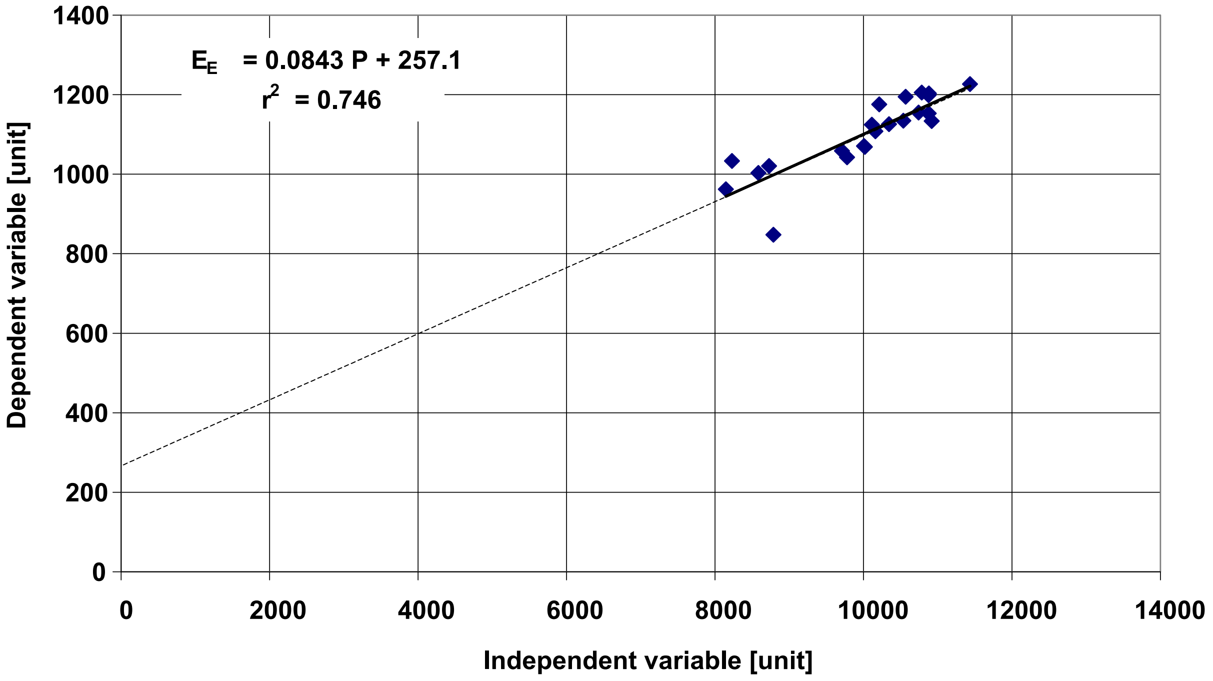
E_{CO2}	[tCO_2 / god.]
FES	[kWh/ god.]
e	[$kgCO_2$ / kWh]

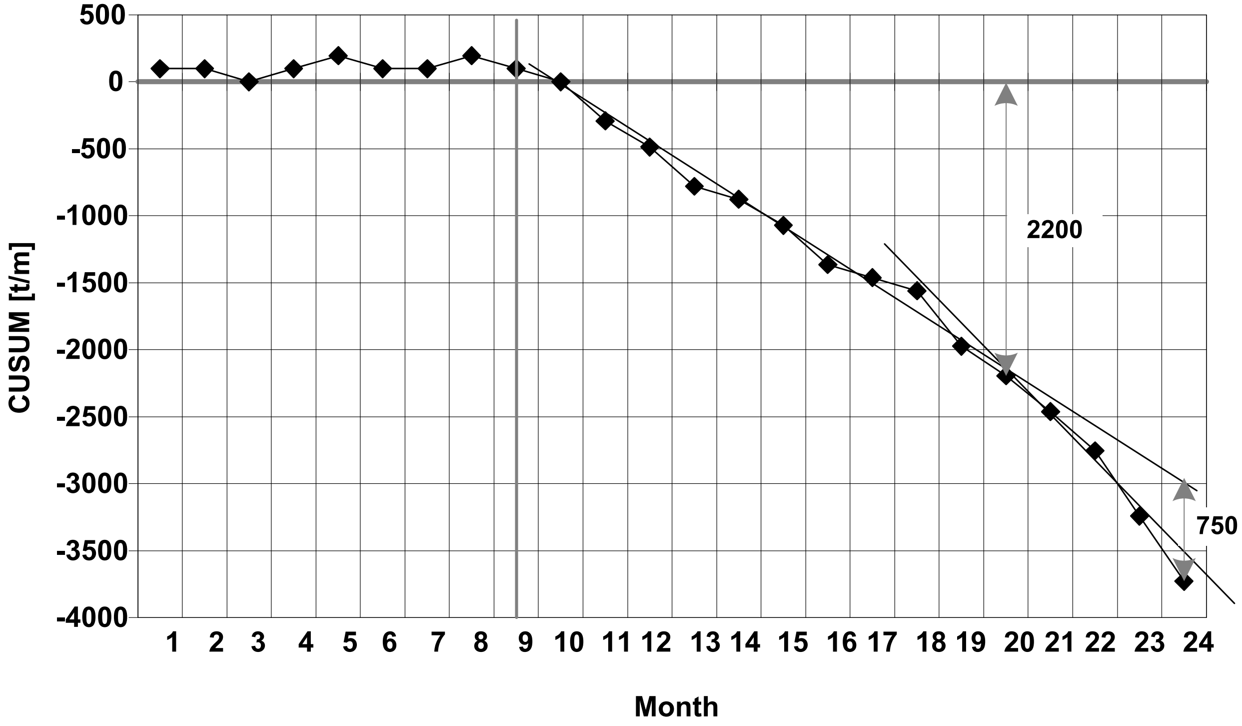
Targets



2,500
2,000
1,500
1,000
500
0
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Dependant variable (unit)
Independent variable (unit)
Goal

ET curves and CUSUM





Discussion

Thank you!

Matija Vajdić