Improving the energy efficiency of geothermal energy utilisation by adjusting the user characteristic

User4GeoEnergy

Preliminary results presentation

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What is user characteristic?

A heating system is characterised by technical requirements:

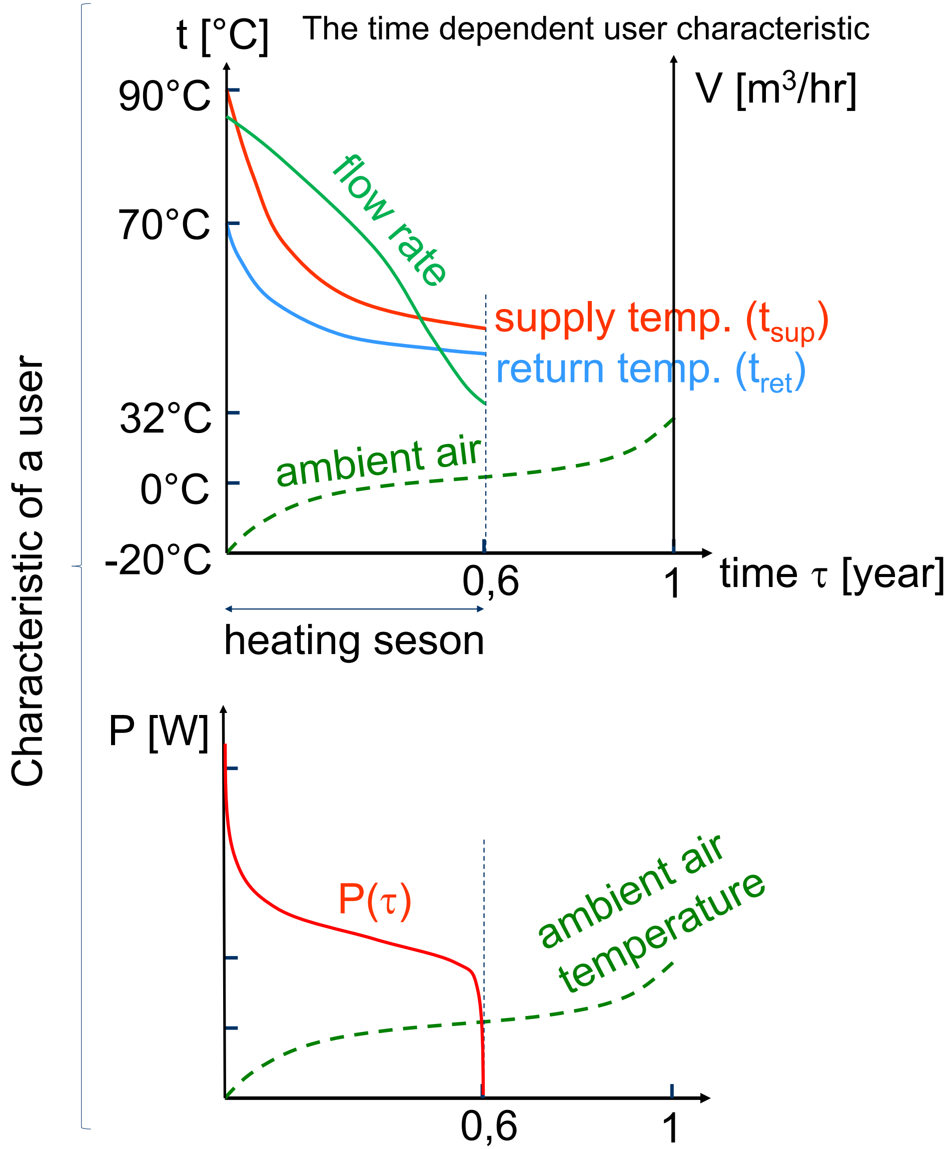
- supply temperature,
- return temperature
- the required flow of water.

Heat demand and the temperature of the return water depend mainly on the efficiency of the heating systems and weather conditions, but also the characteristics of the user(s) and the technology used.

The selection of appropriate parameters and management of the system is referred to as the control of power delivery. Suitable equipment and software control the work of an energy source.

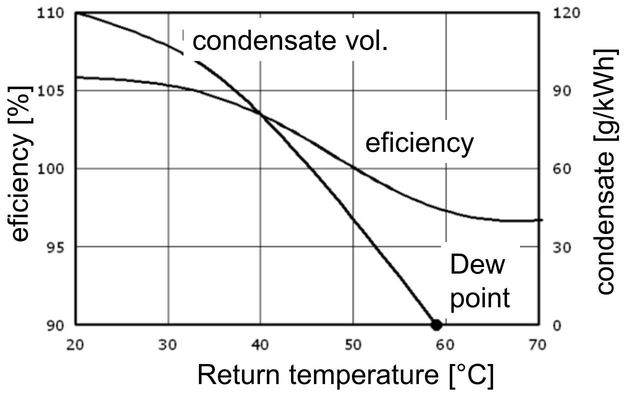
$$P(\tau) = V(\tau)\, c\, \rho\, [t_{sup}(\tau) - t_{ret}(\tau)]$$

$$Q\,[\,J\,] = \int_0^{1\,yr} P(\tau)\, d\tau$$



Why and how geothermal differs from fossil fuels?

$$P(\tau) = V(\tau)\, c\, \rho\, [t_{sup}(\tau) - t_{ret}(\tau)]$$



The **conventional source** specified installed power.

A decrease in the return temperature while keeping constant value of supply temperature results in a increase of power. If maximum power is already reached the supply temperature decrease.

Geothermal always gives a stable temperature t_{sup}, independently of the return temperature and the user characteristic.

You will not exceed the maximum power, you will always get constant water supply temperature → for geothermal t_{sup} = const.

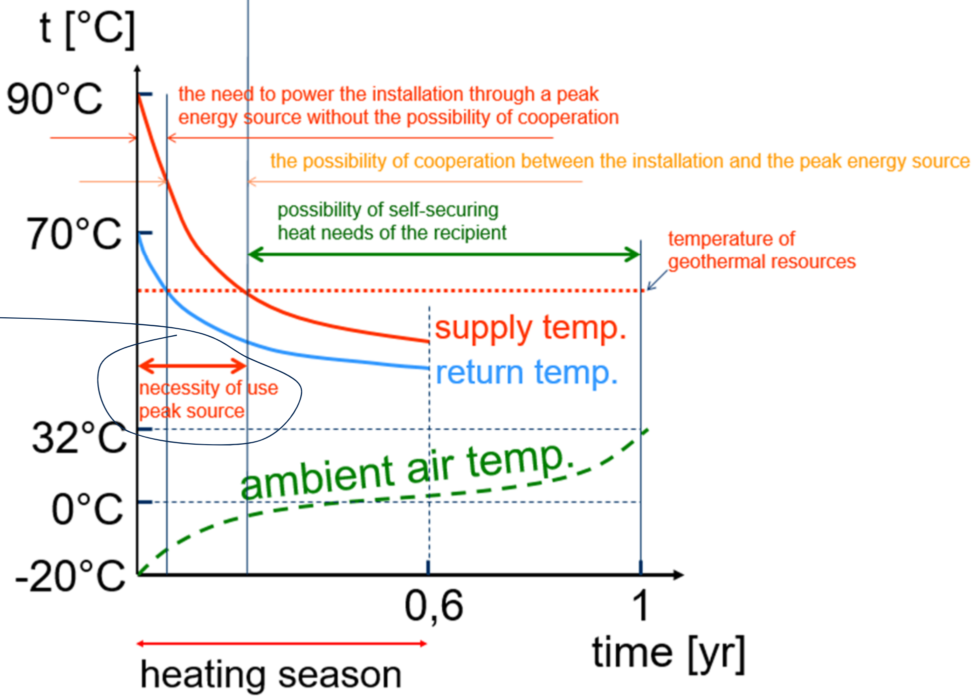
Obtained power depends on the return temperature – the lower value of t_{ret} the higher power P.

The lower return temperaturę t_{ret}, the lower geothermal water discharge V.

Power or temperature supplementing

Peak heating source

- The inability to reach the temperature required by the energy user (the installation that the user uses) results in the need to use additional, supporting heat sources (peaking sources).
- The peaking sources generate additional investment outlays and their use occurs when the supply temperature isn't high enough.



Emission factors of selected pollutants generated during the production of heat unit from [kg / GJ]

Polutant	Yellow Straw	Gray straw	Wood	Hard coal	Heating oil	Natural gas	Electricity (in Poland)
B(a)P	b.d.	b.d.	b.d.	0,001	$5{,}340\cdot10^{-8}$	0,000	$5{,}288\cdot10^{-5}$
Soot	b.d.	b.d	b.d.	0,514	0,000	0,000	0,005
Total dust	0,148	0,147	0,143	2,057	0,053	0,000	0,106
CO_2[14]	128,079	119,816[15]	123,81	105,714	48,954	60,475	290,851
CO	2,463	0,249	0,295	5,714	0,018	0,011	0,661
NO_2[16]	0,591	0,599	0,524	0,057	0,148	0,039	0,529
SO_2	0,128	0,129	0,095	0,731	0,113	0,000	1,798
polycyclic arom. HC	0,128	0,120	0,142	0,286	0,007	0,003	0,033
aliphatic HC				0,286	0,003	0,001	0,033

Simple facts

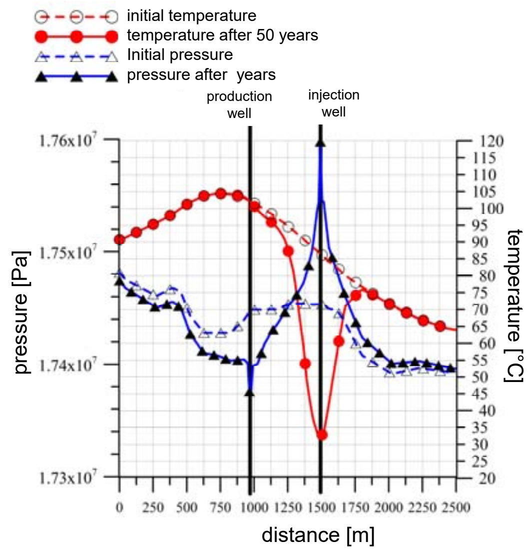
The Project background

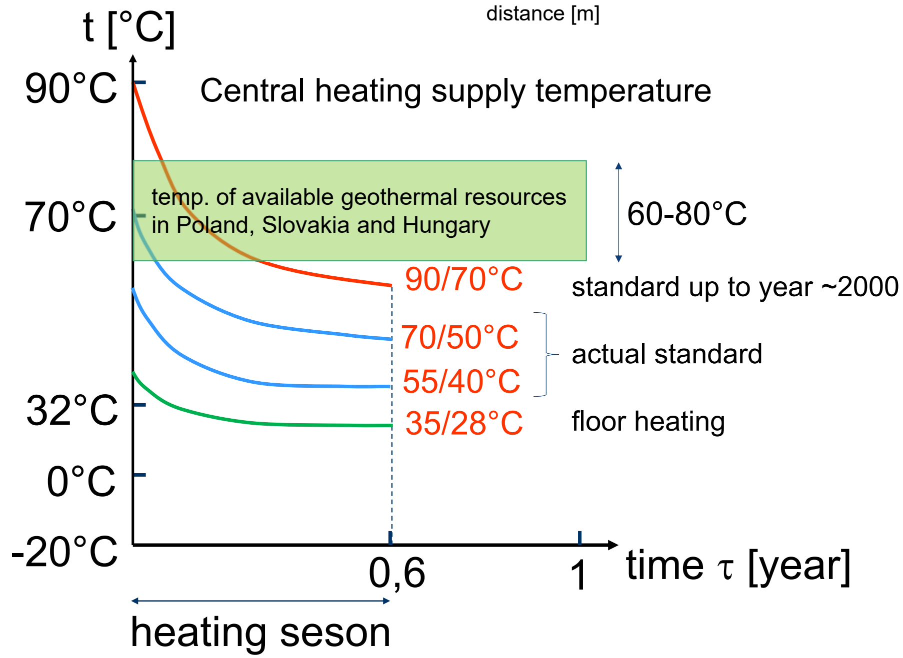
- **Geothermal energy is renewable – but it is not infinite nor free.** Overexploitation can deplete a reservoir while inefficient use of the water. The operation might be uneconomical.
- Still, **40-60°C thermal fluids are being discarded without further use in many geothermal systems**, even new ones.

We have widely used technology allows use even 35°C for space heating.

Why we do not use it?

- **it is easier to control a DHS while it is overheated** (each user have high enough temperature),
- if an operator needs to **reduce the supply temperature users have to be ready**. An DHS is „as good as the worst user".
- to get users ready **money have to be spent on extending the heating Surface or reduce power demand**. DH operators do not like to participate in it.
- Both sides: **DH operator and a user should know how much it cost** and **what kind of results are expected** (economic, ecological, energy-saving effect).





What we are going to do?

We are going to answer the question:
If retrofitting activities are profitable? Who should pay for them?

Local weather conditions
- ambient air temperature,
- wind speed,
- relevant humidity,
- solar radiation

Mathematical Modelling (WP5)
- users demand (characteristic vs weather conditions).
- district heating (heat and pressure losses, characteristic, power controlling),
- the energy source (technology, efficiency, power controlling),
- primary energy carriers.

Model database (WP 4)
Description of:
1. **current state of a system** (numerical model calibration), unitary price of primary energy carriers

2. **possible undertakings on a side of: energy users, district heating system, energy source**.
Information about available technology, which allows:
- changing characteristic of energy users,
- improve a district heating grid,
- modernise an energy source.

Results
- Primary energy carriers consumption,
- Power vs time for all sources used,
- Energy production by each source,
- Pollutants emission,
- Cost of energy production,
- Estimated financial expenditures for assumed retrofitting and modernisation,
- CAPEX, OPEX estimation,
- Results interpretation.

Methodology description

- The aim of the work is to develop and test on selected locations the methodology of mathematical modelling to improve the efficiency of geothermal energy use in district heating networks. The scope of modelling is to cover all elements of the system that are important for assessing the efficiency of geothermal energy use, from the energy source to the recipient:

  - energy source module. The energy source model will be focused on the use of geothermal energy, also taking into account the most commonly used peak support sources (heat pumps and peak load boilers),
  - distribution system module. It will take into account heat energy losses in the transmission, depending on the construction of the pipeline and the conditions of its laying,
  - energy user module, defining its characteristics in terms of parameters necessary to describe the cooperation of the energy consumer - heating network system,

- all modules will take into account the time variability of parameters relevant to the energy operation of the system. With particular emphasis on energy demand for heating and hot water preparation. For the description of weather conditions changing over time, it is planned to use meteorological data from the so-called typical meteorological year (TMY), with a resolution of one hour, taking into account the specific location of the installation,
- a model with lumped parameters will be used to model the effects of the work of the source-user system.

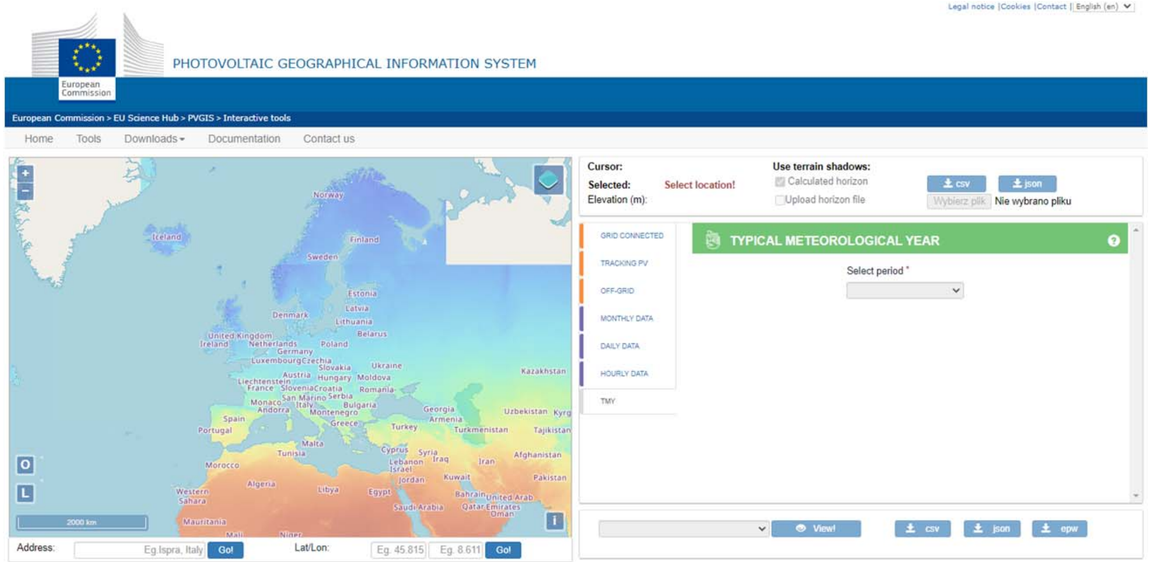
A certain logical sequence of actions was maintained, aiming at a quantitative description of the operating conditions of selected geothermal systems: from the **development of a conceptual model** of the system, through the **development of its mathematical model**, including its **calibration and testing**, to the possibility of **testing the effects of implementing modernization projects**.

(1) conceptual model of the system -► (2) mathematical model -► (3) calibration, testing -► (4) forecasting changes

Weather conditions

Based on the „Photovoltaic Geoghraphical Information System” https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#TMY

- Typical Meteorological Year (TMY) data,
- This option allows the user to download a data set containing a Typical Meteorological Year (TMY) of data. The data set contains hourly data of the following variables:
- Date and time,
- Global horizontal irradiance,
- Direct normal irradiance,
- Diffuse horizontal irradiance,
- Air pressure,
- Dry bulb temperature (2m temperature),
- Wind speed,
- Wind direction (degrees clockwise from north),
- Relative humidity,
- Long-wave downwelling infrared radiation,

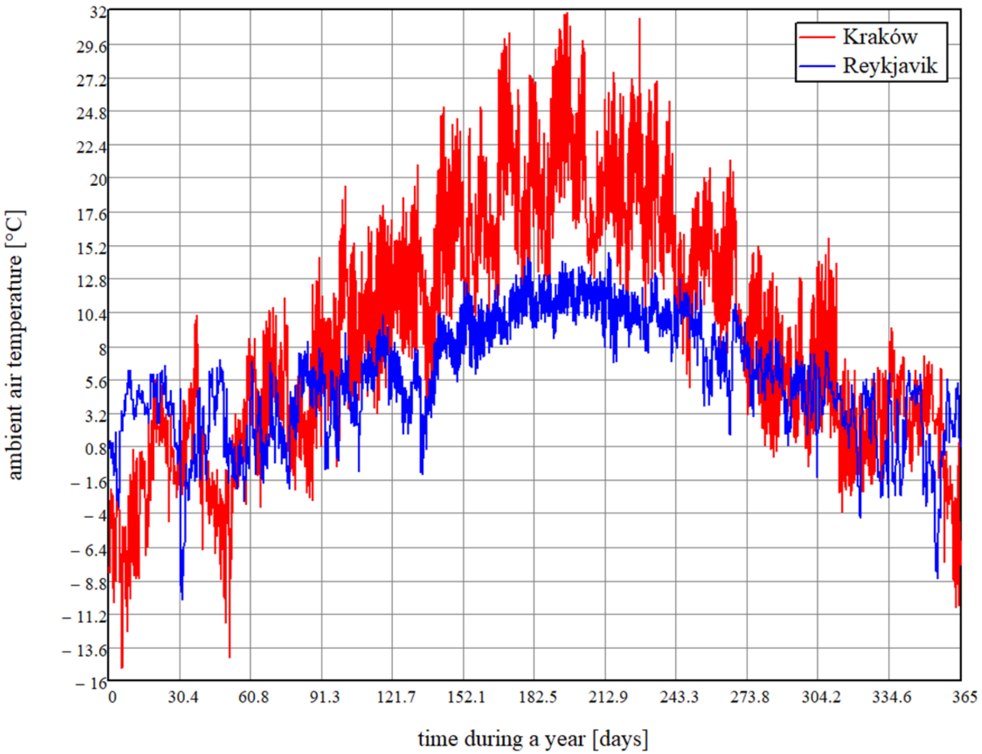


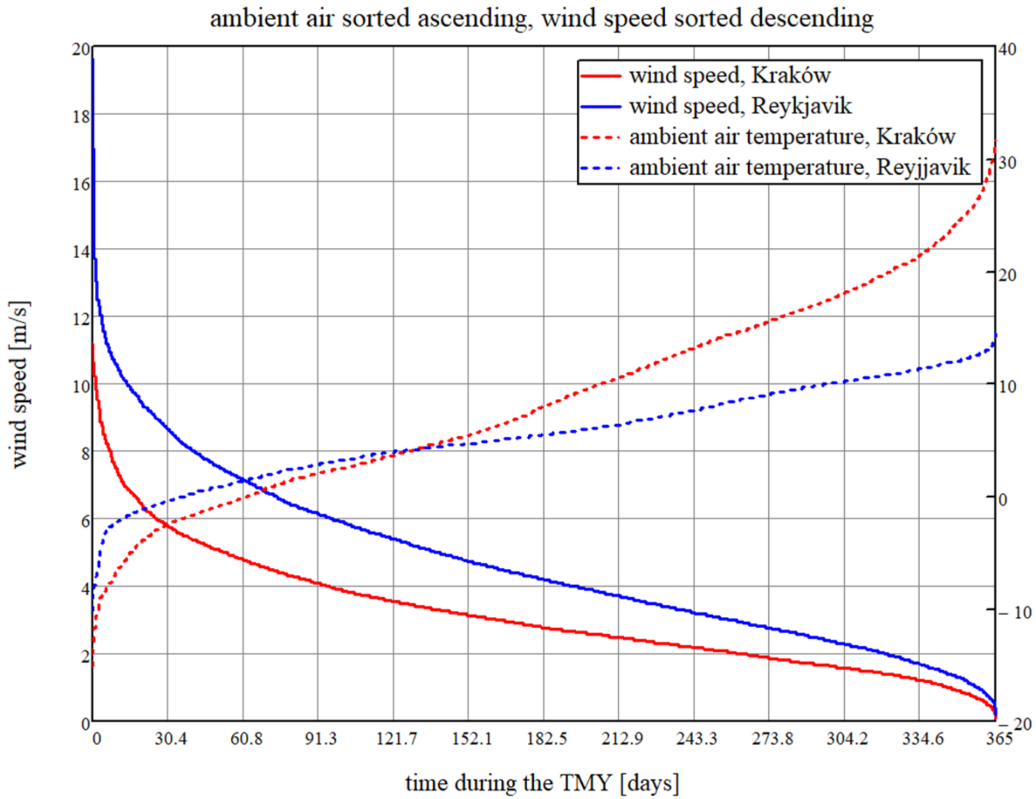
The data set has been produced by choosing for each month the most "typical" month out of 10 years of data. The variables used to select the typical month are global horizontal irradiance, air temperature, and relative humidity.

Weather conditions

Based on the „Photovoltaic Geoghraphical Information System**”** https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#TMY

- Comparison of ambient air temperature and wind speed in Kraków and Reykjavik (based on the TMY)





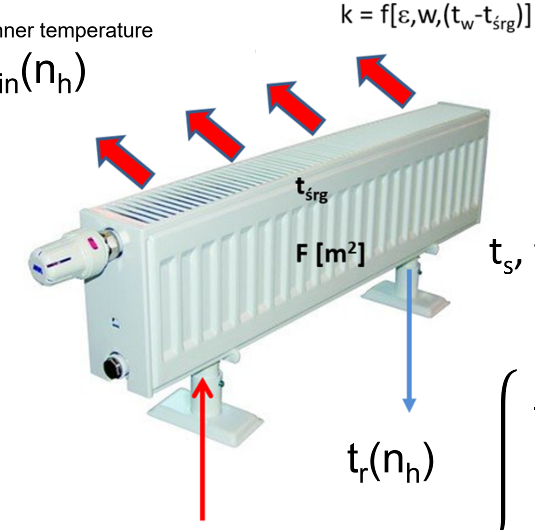
User characteristic

Ambient air temperature

$t_a(n_h)$

Inner temperature

$t_{in}(n_h)$



$t_r(n_h)$

$t_s(n_h)$

$V(n_h)$

Exponent **b** describe different heating systems (Recknagel i inni 2008):
~ 1.1 floor heating,
~ 1.2-1.3 plate radiators,
~ 1.25 pipes, pipes with finnes,
~ 1.3 radiators,
~ 1.25-1.45 convector heaters.

t_s, t_r – supply and return temperature:

$$\begin{cases} \dfrac{t_{in\_dsg}-t_{a\_dsg}}{t_{in}(n_h)-t_a(n_h)} = \dfrac{m_{dsg}}{m(n_h)}\dfrac{t_{s\_dsg}-t_{r\_dsg}}{t_s(n_h)-t_r(n_h)} \\ \dfrac{t_{in\_dsg}-t_{a\_dsg}}{t_{in}(n_h)-t_a(n_h)} = \left(\dfrac{\dfrac{t_{s\_dsg}-t_{r\_dsg}}{ln\left(\dfrac{t_{s\_dsg}-t_{in\_dsg}}{t_{r\_dsg}-t_{in\_dsg}}\right)}}{\dfrac{t_s(n_h)-t_r(n_h)}{ln\left(\dfrac{t_s(n_h)-t_{in}(n_h)}{t_r(n_h)-t_{in}(n_h)}\right)}}\right)^b \end{cases}$$

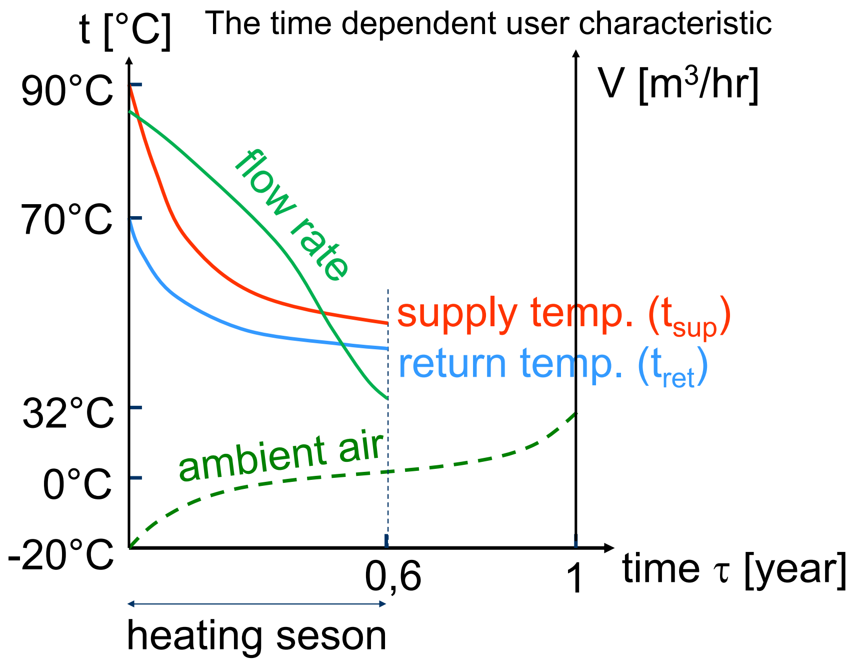
- subscript **dsg** is being linked to design conditions,

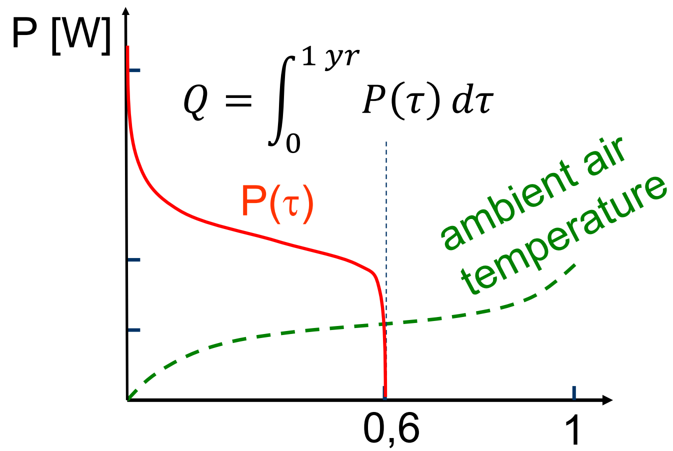
- $\mathbf{n_h}$ – time, hour of a year,

Flow of district heating water:

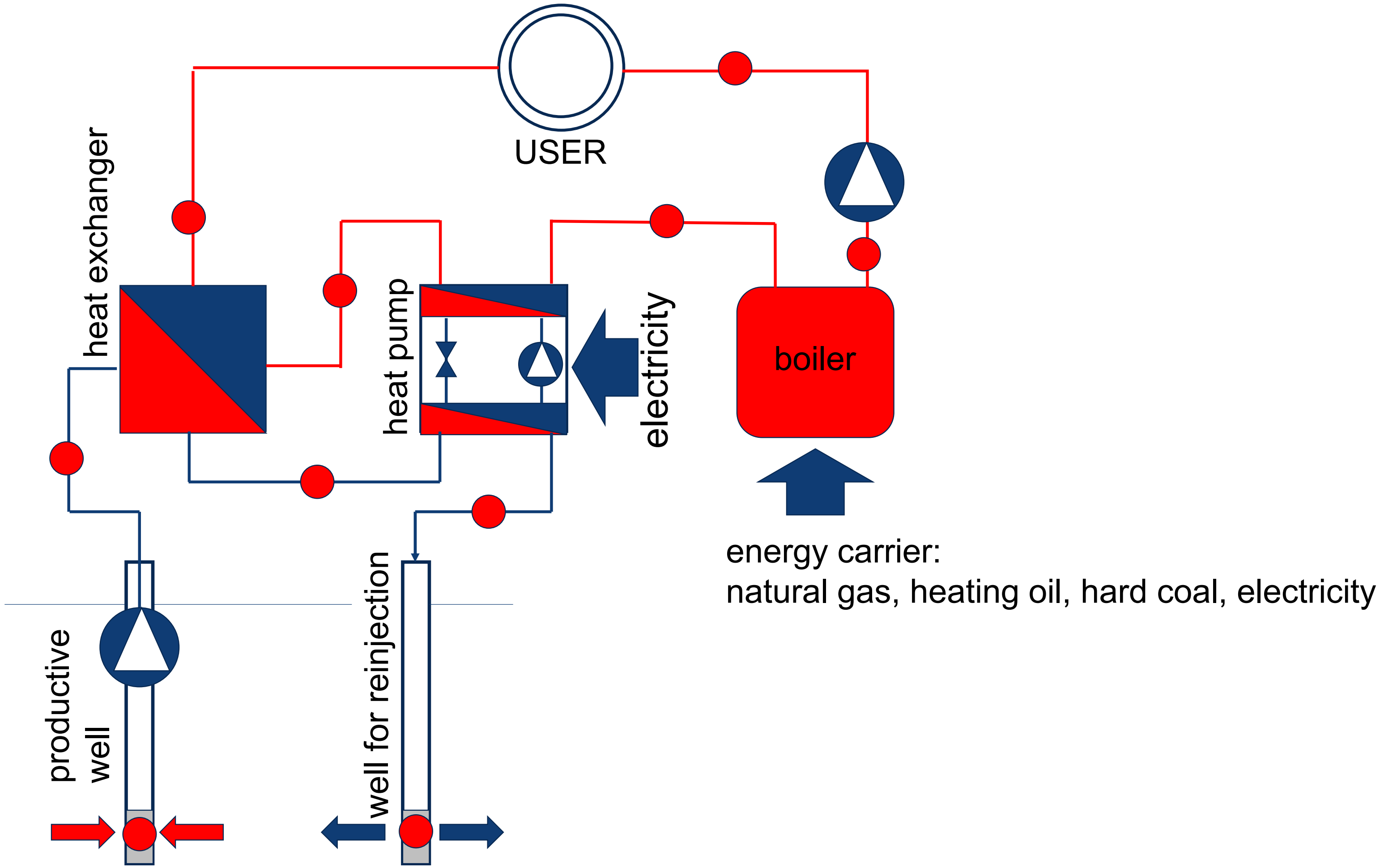
$$V(n_h) = V_{dsg}\left(\frac{t_{in}(n_h)-t_a(n_h)}{t_{in\_dsg}-t_{a\_dsg}}\right)^f$$

Characteristic of a user



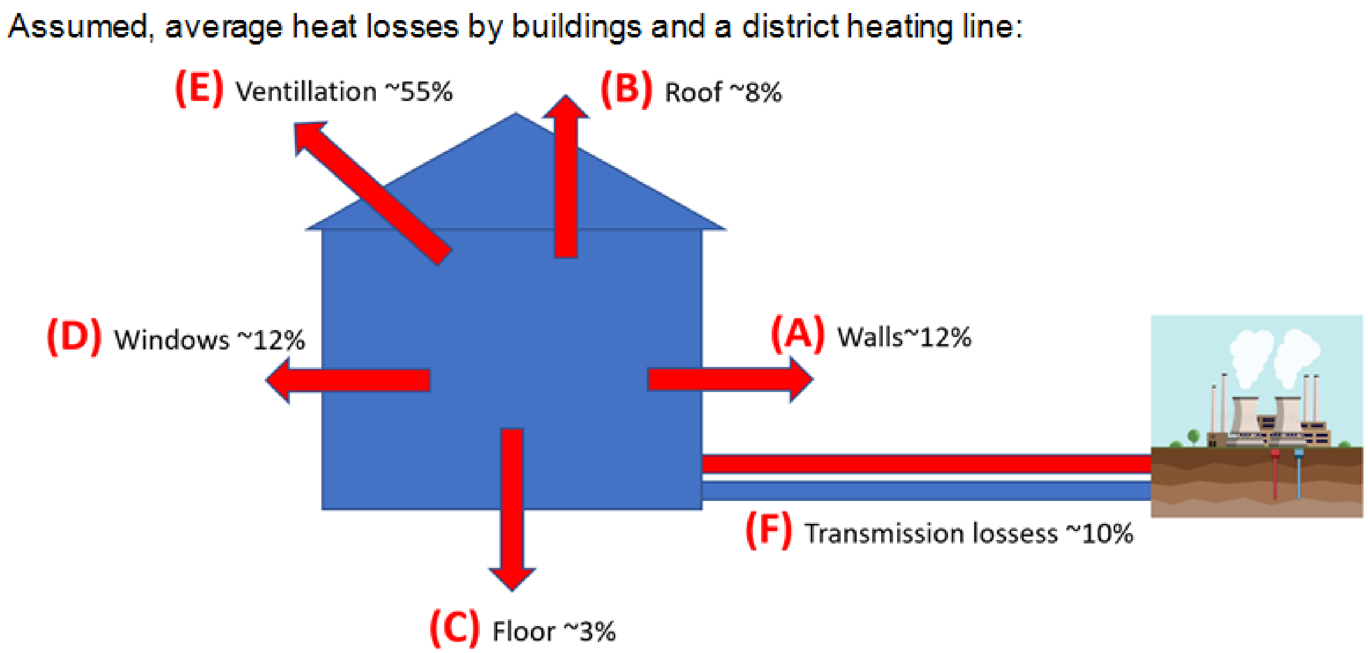


Heat source - U4GE calculator



Assumed share of heat losses at the state before retrofitting - U4GE calculator

(can be freely changed by a user, typical values are fixed)



Example of U4GE calculator, estimation of retrofitting activities financial expenditures

The case of Poland. Each country must be estimated separately.

External walls

$zł := 1$ $Euro := 4,7\ zł$

Typical values of heat exchange coefficient by: external walls, roof, floor on ground and windows (based on Polish standards)

NORMA	MAX WARTOŚĆ WSPÓŁCZYNNIKA PRZENIKANIA CIEPŁA U [W/m²K]			
	DLA ŚCIAN ZEWNĘTRZNYCH	DLA STROPODACHU	DLA PODDASZA	DLA OKIEN*
PN-57	1,16	0,87	1,16	-
PN-64	1,16	0,87	1,05	-
PN-74	1,16	0,70	0,94	-
PN-82	0,75	0,45	0,40	2,0-2,6
PN-91	0,55-0,70	0,30	0,30	2,0-2,6
Do 2008	0,30-0,50	0,30	0,30	2,0-2,6
*dla różnych stref klimatycznych				
Do 2017	0,25	0,2	0,25	1,3
Od 2017	0,23	0,18	0,25	1,1
Od 2021	0,20	0,15	0,25	0,9

$\Delta t := (20 - (-20))\ K$ ◄- 3th climatic zone PN-EN-12831

$U1 := 0,5\ \frac{W}{m^2\ K}$

$Uizo := \frac{1}{\frac{15\ cm}{0,045\ \frac{W}{m\ K}}} = 0,3\ \frac{W}{m^2\ K}$ ◄- insulation by styrofoam 15 cm thick

$U2 := \frac{1}{\frac{1}{U1} + \frac{1}{Uizo}} = 0,1875\ \frac{W}{m^2\ K}$

financial expenditures (https://allegro.pl/oferta/styropian-arsanit-fasadowy-classic-045-15-cm-13214113865):

v ---- assembling / cost of works

$WallExp := (250 + 31)\ \frac{zł}{m^2} = 281\ \frac{zł}{m^2}$

^ ---- cost of styrofoam

$P1 := U1 \cdot \Delta t = 20\ \frac{W}{m^2}$

$P2 := U2 \cdot \Delta t = 7,5\ \frac{W}{m^2}$

$\Delta P := P1 - P2 = 12,5\ \frac{W}{m^2}$

$RA_{Wall} := \frac{WallExp}{\Delta P} = 22480\ \frac{zł}{kW}$

$RA_{Wall} = 4782,98\ \frac{Euro}{kW}$

Expenditures related to the reduction of 1 kW of power losses by external walls ~4800 €/kW

Example of U4GE calculator

Estimation of retrofitting financial expenditures – in the case of Poland. Each country must be estimated separately.

Roof thermal insulation

$$U1 := 0,3 \frac{W}{m^2 K}$$

$$Uizo := \frac{1}{\dfrac{15\ cm}{0,045 \frac{W}{m\,K}}} = 0,3 \frac{W}{m^2 K}$$

$$U2 := \frac{1}{\dfrac{1}{U1} + \dfrac{1}{Uizo}} = 0,15 \frac{W}{m^2 K}$$

financial expenditures
(https://allegro.pl/oferta/styropian-arsanit-fasadowy-classic-045-15-cm-13214113865):

v ---- assembling / cost of works

$$RoofExp := (150 + 31) \frac{zł}{m^2} = 181 \frac{zł}{m^2}$$

^ ---- cost of styroform

$$P1 := U1 \cdot \Delta t = 12 \frac{W}{m^2}$$

$$P2 := U2 \cdot \Delta t = 6 \frac{W}{m^2}$$

$$\Delta P := P1 - P2 = 6 \frac{W}{m^2}$$

$$RA_{Wroof} := \frac{RoofExp}{\Delta P} = 30166,6667 \frac{zł}{kW}$$

$$RA_{Wroof} = 6418,44 \frac{Euro}{kW}$$

Typical values of heat exchange coefficient by: external walls, roof, floor on ground and windows (based on Polish standards)

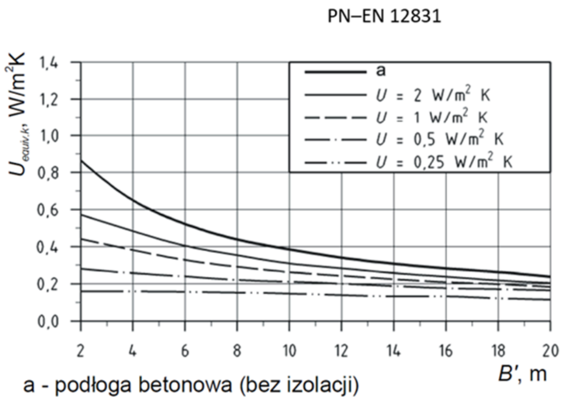
NORMA	MAX WARTOŚĆ WSPÓŁCZYNNIKA PRZENIKANIA CIEPŁA U [W/m²K]			
	DLA ŚCIAN ZEWNĘTRZNYCH	DLA STROPODACHU	DLA PODDASZA	DLA OKIEN*
PN-57	1,16	0,87	1,16	-
PN-64	1,16	0,87	1,05	-
PN-74	1,16	0,70	0,94	-
PN-82	0,75	0,45	0,40	2,0-2,6
PN-91	0,55-0,70	0,30	0,30	2,0-2,6
Do 2008	0,30-0,50	0,30	0,30	2,0-2,6
*dla różnych stref klimatycznych				
Do 2017	0,25	0,2	0,25	1,3
Od 2017	0,23	0,18	0,25	1,1
Od 2021	0,20	0,15	0,25	0,9

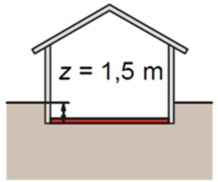
Expenditures related to the reduction of
1 kW of power losses by a roof ~6 400 €/kW

Example of U4GE calculator

Estimation of retrofitting financial expenditures – in the case of Poland. Each country must be estimated separately.

Floor on ground (based on methodology PN-EN-12831)





$$B := \frac{504\ \mathrm{m}^2}{0{,}5 \cdot \left(2 \cdot \left(20\ \mathrm{m} + \frac{504\ \mathrm{m}^2}{20\ \mathrm{m}}\right)\right)} = 11{,}1504\ \mathrm{m}$$

$$U1 := 0{,}5\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}} \qquad U1ef := 0{,}2\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}$$

$$Uizo := \frac{1}{\frac{15\ \mathrm{cm}}{0{,}045\ \frac{\mathrm{W}}{\mathrm{m\ K}}}} = 0{,}3\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}} \qquad Uizo := 0{,}18\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}$$

$$U2 := \frac{1}{\frac{1}{U1} + \frac{1}{Uizo}} = 0{,}1324\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}$$

$$U2ef := 0{,}1\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}$$

$$fg1 := 1{,}45 \qquad fg2 := \frac{20 - 7{,}6}{20 - (-20)} = 0{,}31 \qquad Gw := 1{,}0$$

$$H1 := fg1 \cdot fg2 \cdot Gw \cdot U1ef \cdot \Delta t = 3{,}596\ \frac{\mathrm{W}}{\mathrm{m}^2}$$

$$H2 := fg1 \cdot fg2 \cdot Gw \cdot U2ef \cdot \Delta t = 1{,}798\ \frac{\mathrm{W}}{\mathrm{m}^2}$$

$$\Delta P := H1 - H2 = 1{,}798\ \frac{\mathrm{W}}{\mathrm{m}^2}$$

v - work v - concrete 5 cm

$$FloorExp := (50 + 31 + 40)\ \frac{\mathrm{zł}}{\mathrm{m}^2} = 121\ \frac{\mathrm{zł}}{\mathrm{m}^2}$$

^ styrofoam+concret - materials

$$RA_{Floor} := \frac{FloorExp}{\Delta P} = 67296{,}9967\ \frac{\mathrm{zł}}{\mathrm{kW}}$$

$$RA_{Floor} = 14318{,}5099\ \frac{\mathrm{Euro}}{\mathrm{kW}}$$

Expenditures related to the reduction of 1 kW of power losses by a floor ~14 300 €/kW

Example of U4GE calculator

Estimation of retrofitting financial expenditures – in the case of Poland. Each country must be estimated separately.

Windows and external doors

Windows
https://e-alucon.pl/OKNO-PCV-150-x-150-1500-x-1500-RU-R-BIALE-p22065/?ref=ceneo.pl&utm_source=ceneo&utm_medium=referral&ceneo_cid=376d12a6-bff3-fe32-076f-2fee90fcff96

$U1 := 2{,}6\ \frac{W}{m^2\ K}$ $U2 := 1{,}1\ \frac{W}{m^2\ K}$ $\Delta P := (U1 - U2) \cdot \Delta t = 60\ \frac{W}{m^2}$

$$WindowsExp := \frac{1316\ zł}{1{,}5 \cdot 1{,}5\ m^2} = 584{,}8889\ \frac{zł}{m^2}$$

$$RA_{Windows} := \frac{WindowsExp}{\Delta P} = 9748{,}1481\ \frac{zł}{kW}$$

$$RA_{Windows} = 2074{,}07\ \frac{Euro}{kW}$$

Expenditures related to the reduction of
1 kW of power losses by a window ~2 100 €/kW

Example of U4GE calculator

Estimation of retrofitting financial expenditures – in the case of Poland. Each country must be estimated separately.

Ventilation including recuperation

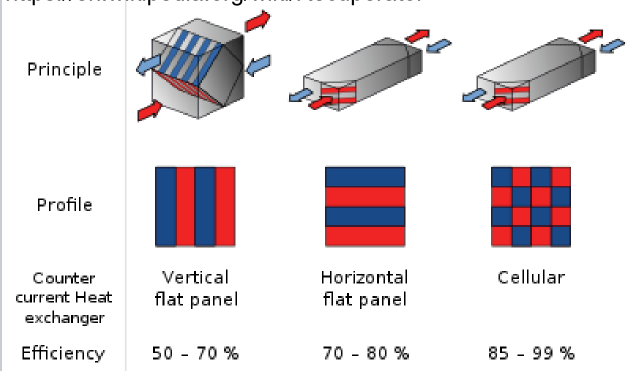
Ventilation

https://www.rekuperatory.pl/koszt-rekuperacji/

$$RA_{Went} := \frac{25 \cdot 10^{3}\ \text{zł}}{0,55 \cdot 12\ \text{kW}} = 3787,8788\ \frac{\text{zł}}{\text{kW}} \qquad RA_{Went} = 805,9317\ \frac{\text{Euro}}{\text{kW}}$$

^- heat recovery efficiency assumed 55%

https://en.wikipedia.org/wiki/Recuperator



Expenditures related to the reduction of
1 kW of power losses by ventilation including recuperation ~900 €/kW

Example of U4GE calculator

Estimation of retrofitting financial expenditures – in the case of Poland. Each country must be estimated separately.

Transmission heat losses by a district heating

Jednostkowe straty cieplne rurociągu preizolowanego [W/m]

Tabela 2

D_z	D_{ZP}	Temperatura rurociągu					
mm	*mm*	150°C	130°C	110°C	90°C	70°C	50°C
26,9	75	20,2	17,3	14,5	11,7	8,8	6,0
33,7	90	24,7	21,2	17,7	14,3	10,8	7,3
42,4	110	25,5	21,9	18,3	14,7	11,1	7,5
48,3	110	29,3	25,2	21,1	16,9	12,8	8,7
60,3	125	33,0	28,3	23,7	19,0	14,4	9,8
76,1	140	39,3	33,8	28,2	22,7	17,2	11,6
88,9	160	40,7	35,0	29,2	23,5	17,8	12,0
114,3	200	42,7	36,7	30,7	24,7	18,6	12,6
139,7	225	49,9	42,8	35,8	28,8	21,8	14,7
168,3	250	59,6	51,2	42,8	34,4	26,0	17,6
219,1	315	65,1	56,0	46,8	37,6	28,4	19,3
273,0	400	62,5	53,7	44,9	36,1	27,3	18,5
323,9	450	72,3	62,1	52,0	41,8	31,6	21,4
355,6	500	70,1	60,2	50,4	40,5	30,6	20,7
406,4	560	74,6	64,1	53,6	43,1	32,6	22,1
457,0	630	74,7	64,2	53,7	43,2	32,6	22,1
508,0	710	72,0	61,9	51,8	41,6	31,5	21,3
610,0	800	88,6	76,1	63,6	51,2	38,7	26,2

◀--- $q := 19 \frac{W}{m}$

Expenditures related to the reduction of 1 kW of power losses by pipes system (DH) ~44 000 €/kW

v- 2xDN125 + installation (work) expenditures equal to 1 m of a pipe

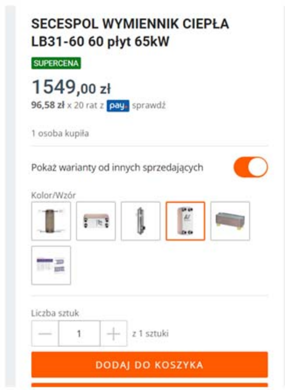
$$RA_{dh} := \frac{653 \frac{zł}{m} \cdot 3}{1,5 \cdot q - q} = 2,0621 \cdot 10^5 \frac{zł}{kW} \qquad RA_{dh} = 43874,5801 \frac{Euro}{kW}$$

^-- The assumption was that heat losses by 1 m of a pipe were 50% higher before retrofitting.

Example of U4GE calculator

Estimation of retrofitting financial expenditures – in the case of Poland. Each country must be estimated separately.

Plate heat exchangers – expenditures vs. temperature difference



Expenditures related to the installation of 1 kW of power vs temperature difference ~10 €/kW (Δt=21.6°C) ÷ 6.5 €/kW (Δt=59.4°C)

https://allegro.pl/oferta/secespol-wymiennik-ciepla-lb31-60-60-plyt-65kw-1334947

SECESPOL wymiennik ciepła LB31-60 - 60-65kW

0203-0066

SECESPOL = HEXONIC

$$\frac{1549\ \text{zł}}{62{,}5\ \text{kW}} = 5{,}27\ \frac{\text{Euro}}{\text{kW}}$$

The flow is directed into every other channel created by the heating panels.

LB31-60-1", 80/60-50/70°C - 65 kW, connections diameter GZ 1"

Example of U4GE calculator

Estimation of retrofitting financial expenditures – in the case of Poland. Each country must be estimated separately.

Radiators – expenditures vs. temperature difference

Based on PURMO – the radiator manufacturer

Moce cieplne grzejników płytowych zostały określone zgodnie z PN-EN 442 na podstawie pomiarów w laboratorium.
Jako parametry odniesienia zostały przyjęte temperatury 75/65/20 °C.

Moc cieplną grzejników dla innych parametrów można obliczyć z podanego poniżej wzoru:

$$\Phi = \Phi_n \left[\frac{\Delta t}{\Delta t_n} \right]^n$$

gdzie:
Φ - moc cieplna grzejnika [W]
Φ_n - moc cieplna grzejnika określona na podstawie pomiarów zgodnie z PN-EN 442 [W]
Δt - arytmetyczna lub logarytmiczna różnica temperatur [K]
Δt_n - arytmetyczna różnica temperatur 50 [K] obliczona dla temperatur odniesienia 75/65/20 °C
n - wykładnik potęgowy charakterystyczny dla danego typu grzejnika

Wskazówka

Jeśli warunek $c = \frac{t_p - t_i}{t_z - t_i} < 0{,}7$ jest spełniony,

to różnicę temperatur Δt należy obliczać według wzoru: $\Delta t_{logarytmiczna} = \frac{t_z - t_p}{\ln((t_z - t_i)/(t_p - t_i))}$

a jeśli jest on nie spełniony to Δt należy obliczać według wzoru: $\Delta t_{arytmetyczna} = \frac{t_z + t_p}{2} - t_i$

gdzie:
t_z - temperatura wody zasilającej grzejnik [°C]
t_p - temperatura wody powracającej z grzejnika [°C]
t_i - temperatura wewnątrz pomieszczenia [°C]

Cennik
POLSKA 02/2023

Ceny obowiązują od 01.02.2023

grzejniki płytowe

Expenditures related to the installation of 1 kW of power vs temperature difference ~5 200 €/kW (Δt=10°C) ÷ 156 €/kW (Δt=68°C)

Example of U4GE calculator

Estimation of retrofitting financial expenditures – in the case of Poland. Each country must be estimated separately.

Summary – retrofitting expenditures

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Currency	Euro/kW							Heating			Hot Water						
2	ExternalW	Roof	FloorOnGı	Windows	Ventilatio	Transmiss	HeatingSu	HotWater	tin[°C]	tout[°C]	Dtm[°C]	tin[°C]	tout[°C]	Dtm[°C]				
3	4800	6400	14300	2100	900	44000	5200	10	30	22	4,97	50	20	21,64	◄- unitary expenditures [Euro/kW]			
4							1690	9,75	35	28	11,14	55	30	30,83				
5							799,5	9,5	45	35	19,58	60	40	39,15				
6							458,9	9,25	55	45	29,72	70	30	36,41				
7							288,6	9	70	55	42,06	65	40	41,24				
8							234	8,84	75	65	49,83	70	40	43,28				
9							182	8	90	70	59,44	70	50	49,33				
10							156	6,5	110	70	68,05	80	60	59,44				

Estimation of Energy carriers – in the case of Poland. Each country must be estimated separately.

Energy carriers

Important information:
All prices for retrofitting activities are given as gross. They increase expenses by the value of VAT (in Poland 23%). This way, unexpected - additional costs were taken into account.

Example of U4GE calculator

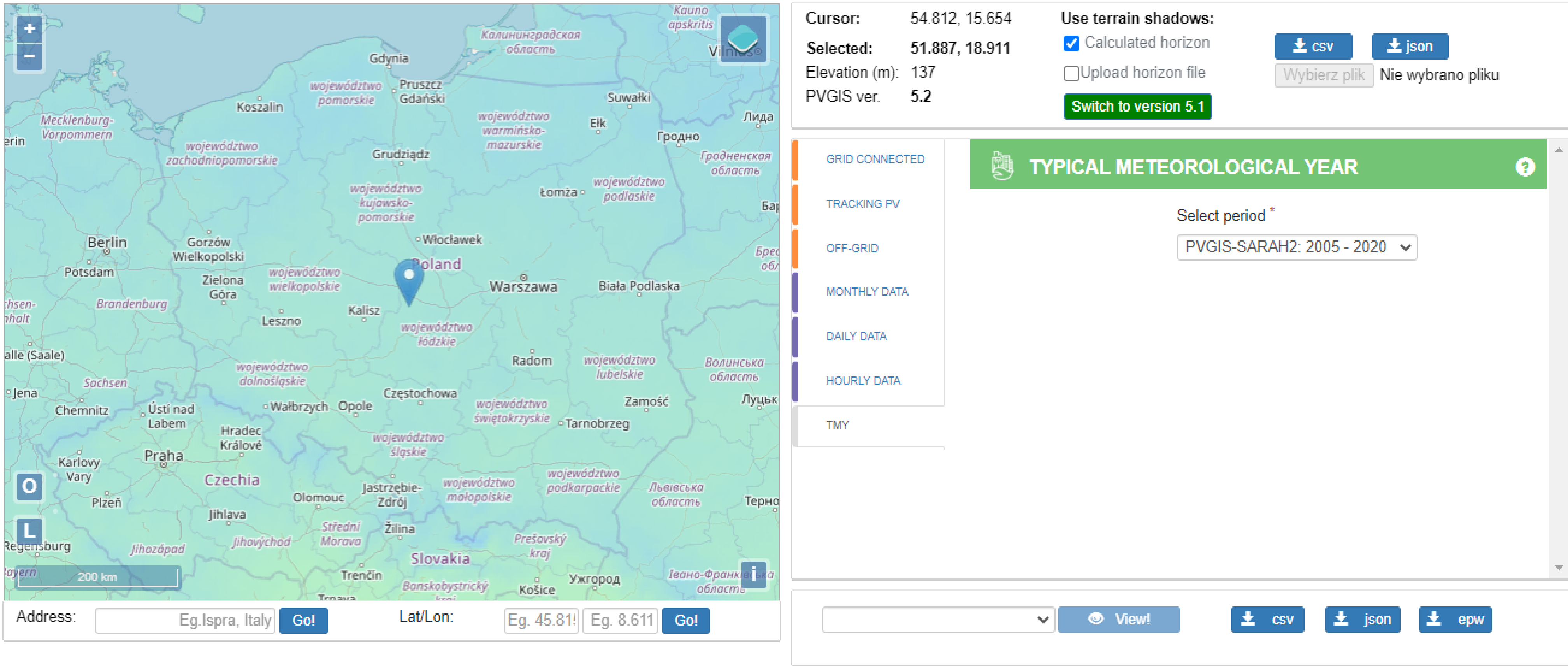
Estimation of energy carriers – in the case of Poland. Each country must be estimated separately.

Energy carriers

	A	B	C	D	E	F	G	H	K
1	Currency	Euro							
2	GasBoilerConventional	GasBoiler	OilBoiler	HardCoilB	ElectrictDi	HeatPumps			
3	191,4893617	234,0426	191,4894	170,2128	63,82979	382,9787		◀- unitary expenditures [Euro/kW]	
4	m3	m3	L	Mg	MWh	MWh		◀- measure unit	
5	35	35	34,86	2,50E+04	1	1		◀- lower calloric value of a fuel [MJ/unit] (in case of electricity use =1)	
6	0,9	0,96	0,9	0,8	0,99	4		◀- performance of utilisation HEAT/Chemical Energy [-]	
7	15	15	15	15	10	25		◀- lifetime for the equipment [years]	
8	0,744680851	0,744681	1,489362	744,6809	170,2128	170,2128		◀- price of energy carrier [Euro/unit]	
9									
10	57,65	57,65	72,48	96,37	196,67	196,67		◀- CO2 emission [kg/GJ]	in case of emission GJ=energu in fuel, excluding efficincy of a heat source
11	0,0004	0,0004	0,08	0,56	0,14	0,14		◀- SO2 emission [kg/GJ]	
12	0,04	0,04	0,07	0,17	0,14	0,14		◀- NOx emission [kg/GJ]	
13	0,0005	0,0005	0,002	4,8	0,0061	0,0061		◀- total dust emisssion [kg/GJ]	
14									
15	70							◀- payment for CO2 emission [Euro/Mg]	
16	0							◀- fee for geothermal water exploitation [Euro/m3]	

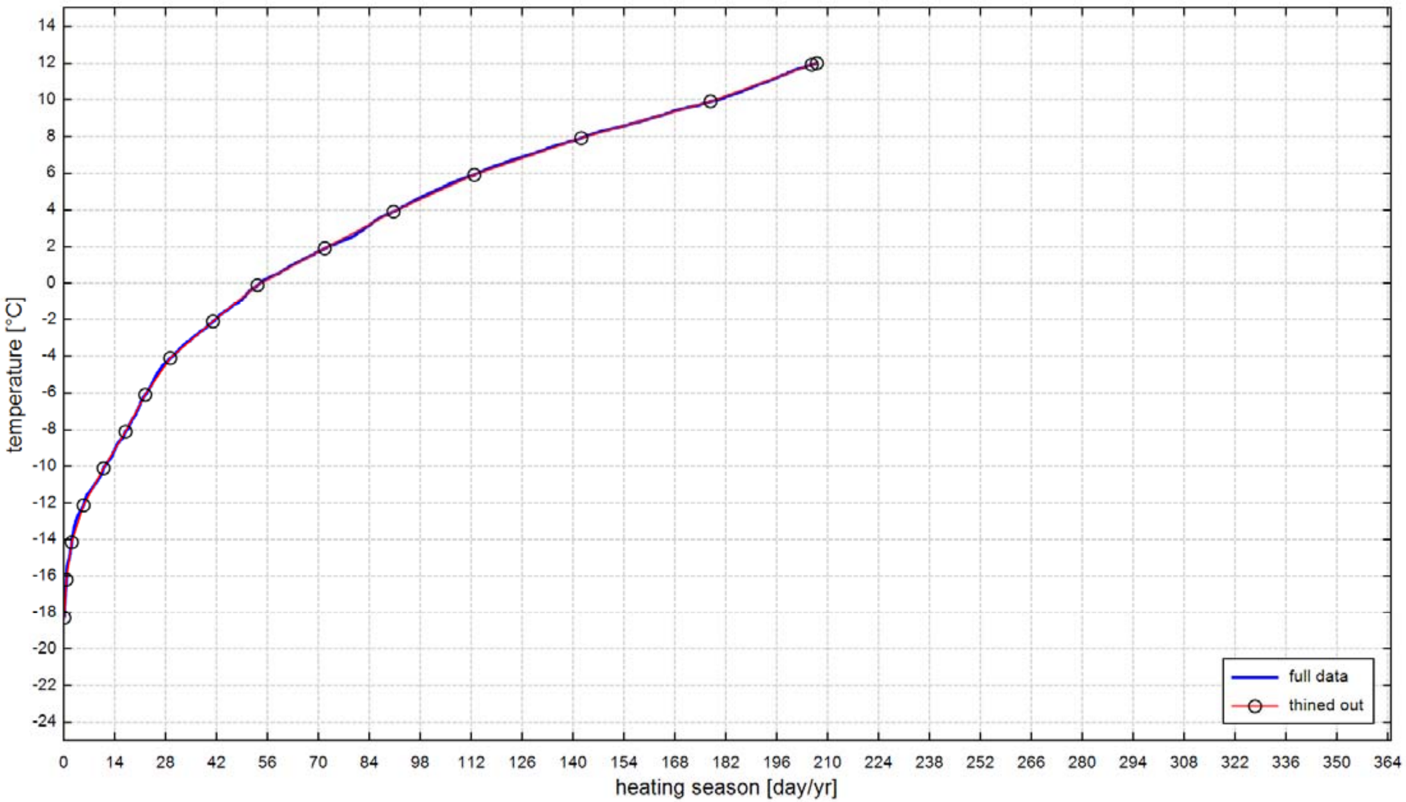
Example of U4GE calculator

Polish case study location: Poddębice



Example of U4GE calculator

Polish case study location: Poddębice



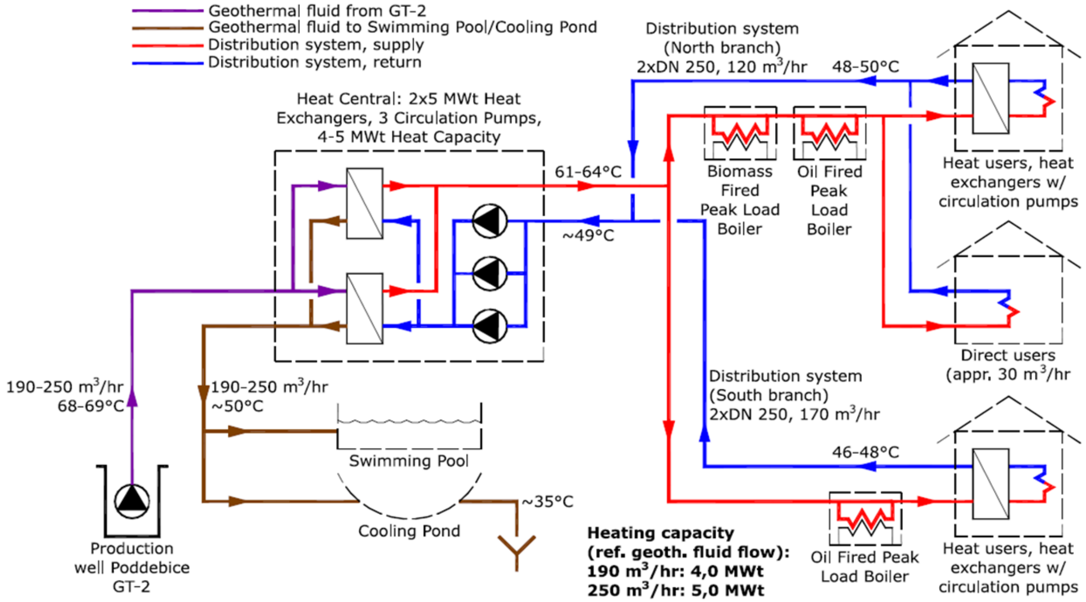
$$\begin{cases} \text{augment}\left(\dfrac{\text{col}(tsg;\,1)}{24};\,\text{col}(tsg;\,2)\right) \\ \text{augment}\left(\dfrac{\text{col}(tsg2;\,1)}{24};\,\text{col}(tsg2;\,2)\right) \end{cases}$$

Definition of a heating season (general suggestion for all locations – might be changed):

- ❑ The heating season begins if the average daily air temperature is 10°C or below for 3 days.
- ❑ The heating season ends if, for 3 consecutive days, the average daily temperature is higher than 10°C.

Example of U4GE calculator

Polish case study location: Poddębice



Water temperature at the wellhead ~68-70°C. The flow rate of geothermal fluid 190 m^3/h.

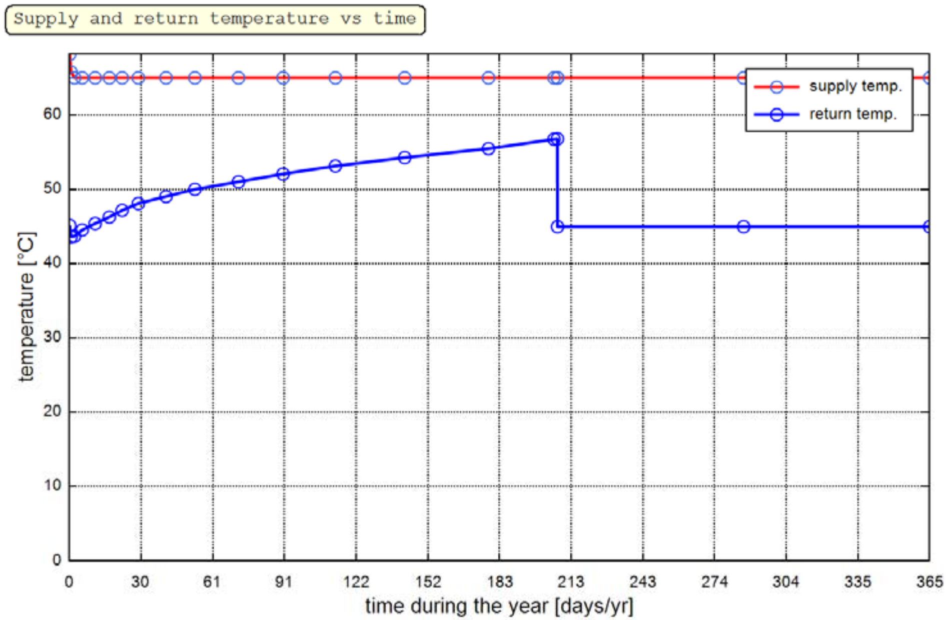
Design temperature of the district heating network 75/50°C, power demand (declared) ~9 MW (2017). Energy demand 63 TJ/yr (~700 GJ/yr oil boilers).

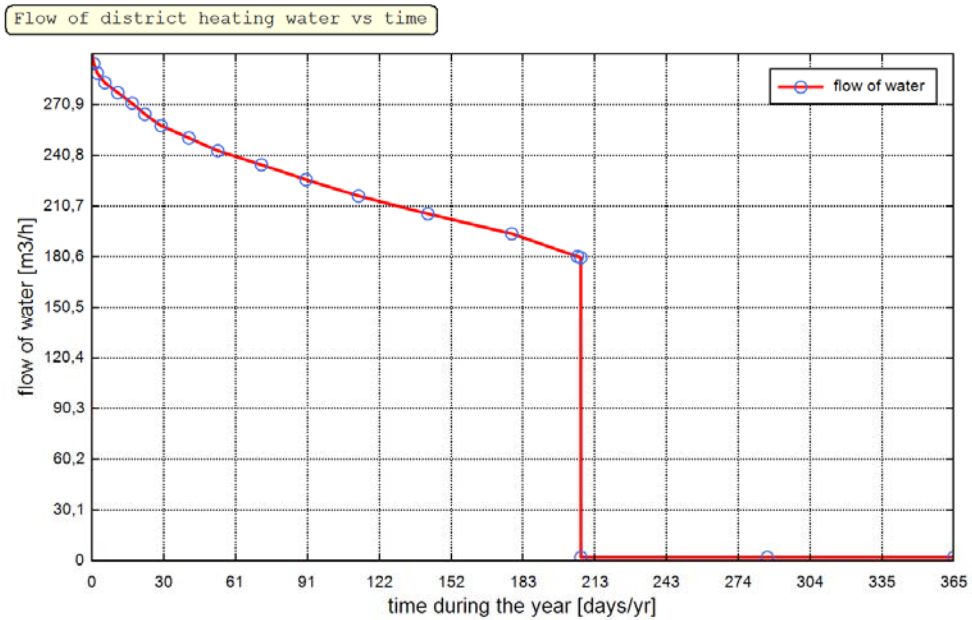
In 2022 the system was extended on ~7 MW, geothermal swiming pools + SPA.

Example of U4GE calculator

Polish case study location: Poddębice

User charcteristic 1 / 2 – before expansion

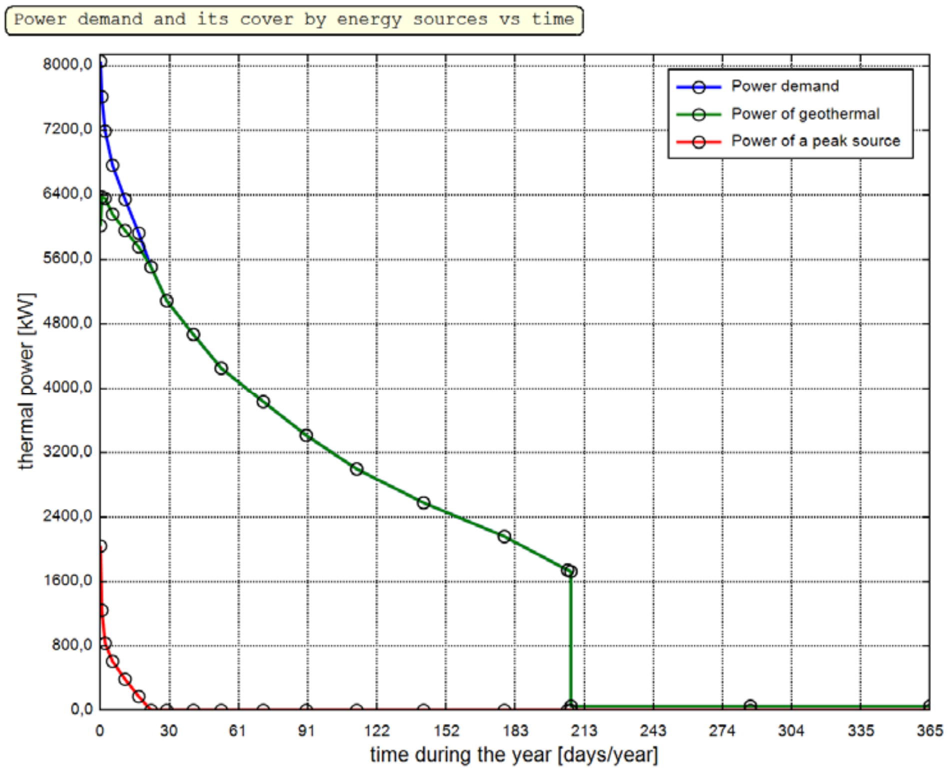


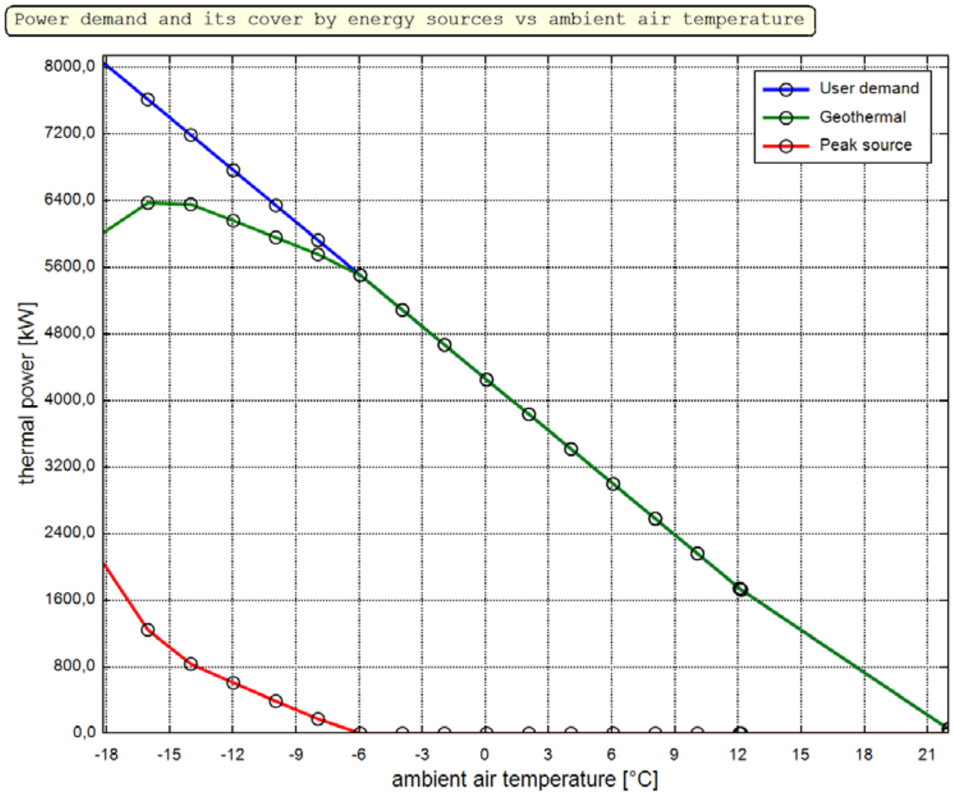


Example of U4GE calculator

Polish case study location: Poddębice

User charcteristic 2/2 – before expansion. Real power demand estimation on ~8 MW



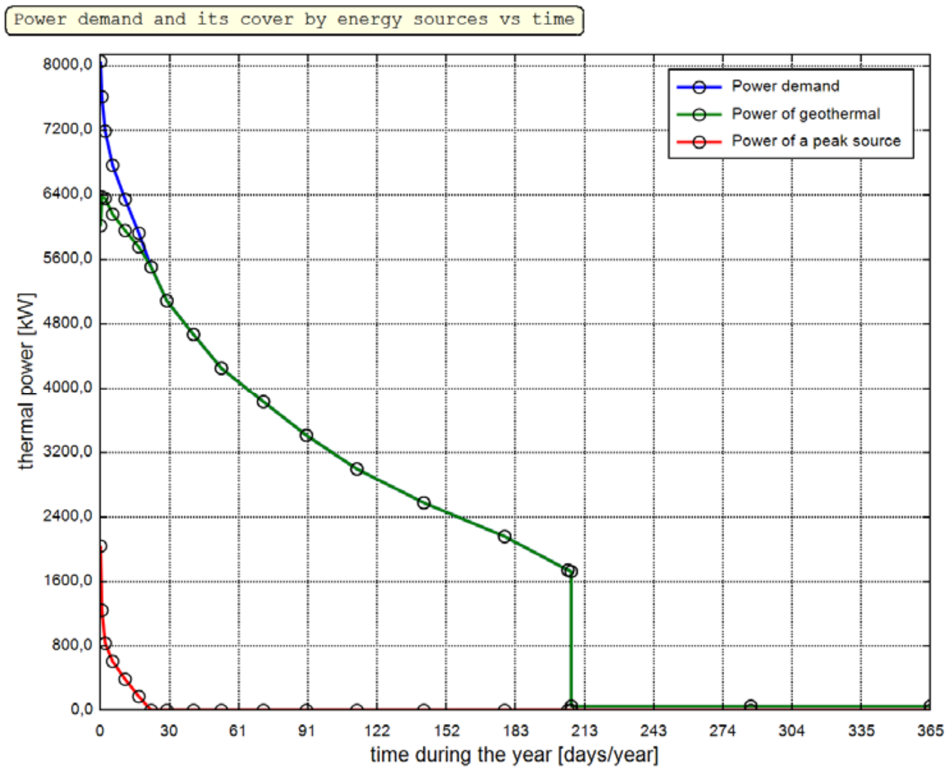


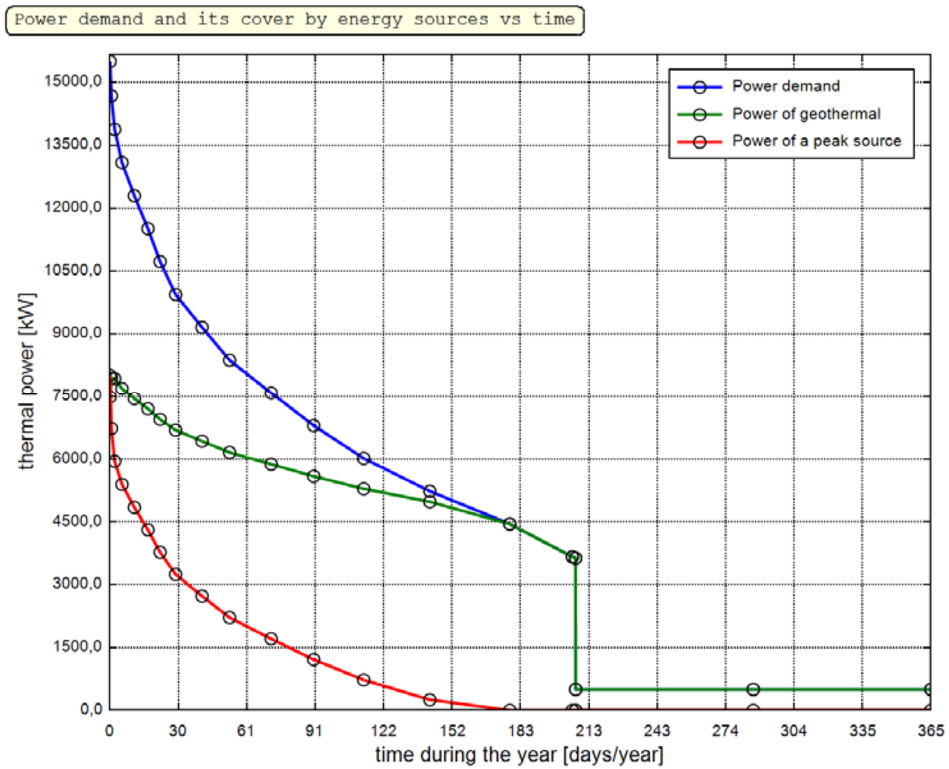
Example of U4GE calculator

Polish case study location: Poddębice

User charcteristic 2/2 – before and after expansion

Power demand BEFORE ~8 MW ► AFTER increase ~15 MW & increase of outflow of geothermal water from 200 to 250- m^3/h



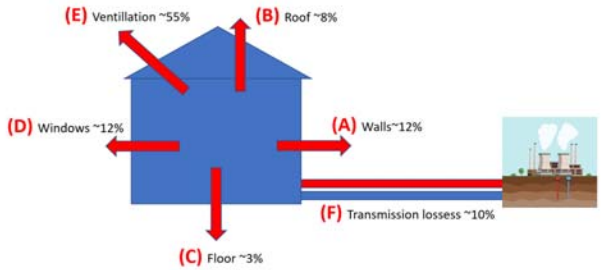


	Before expansion	After expansion
	Current state	Current state
Location: city and country	Poddębice PL	Poddębice PL
Geothermal resources: flow [m3/h] | temp.[°C]	200 | 73	250 | 73
Type of heat peak source	Heating oil	Heating oil
Status of heating system at users (radiators)	Central heating system exists, might be retroffited	Central heating system exists, might be retroffited
Status of hot water system at users	The hot tap water system exists, might be retroffited	The hot tap water system exists, might be retroffited
Status of heat peak source	Peak heat source exists	Peak heat source exists
Payment for emission of CO2 (status)	Payment for CO2 emission excluded	Payment for CO2 emission excluded
Design parameters for heating | wot water [°C]	68/45 | 65/45	68/45 | 65/45
User power demand: heating | hot water [kW] # total energy demand [GJ/yr]	8000 | 50 # 63517,9	15000 | 500 # 131906
Energy production: total; geothermal; peak source [GJ/yr]	63517,9 ; 62681,5 ; 836,3	131906 ; 105683,6 ; 26222,4
Share of sources in total energy production: geothermal; peak source [%]	98,68 ; 1,32	80,12 ; 19,88
Energy carrier used by a peak source [L/yr]	26656,91	835800,84
Emission of selected pollutants		
CO2 [ton/yr]	67,35	2111,78
SO2 [kg/yr]	74,34	2330,88
NOx [kg/yr]	65,05	2039,52
total dust [kg/yr]	1,86	58,27
Investment expenditures [k€]	0	0
Total cost | CAPEX | OPEX [k€/yr]	218,7 | 179 | 39,7	1634,1 | 389,3 | 1244,8

Increase of power and energy demand

Increase of heating oil consumption

Poddębice
Let's try encourage users to reduce power demand by retrofitting activities



(A) 15 ◄- (A) Reduction of heat losses by **EXTERNAL WALLS** on [%] in accordance to current state

(B) 0 ◄- (B) Reduction of heat losses by **ROOFS** on [%] in accordance to current state

(C) 0 ◄- (C) Reduction of heat losses by **FLOOR** on the ground on [%] in accordance to current state

(D) 0 ◄- (D) Reduction of heat losses by **WINDOWS** and external doors on [%] in accordance to current state

(E) 0 ◄- (E) Reduction of heat losses by **VENTILATION** (including recuperation, regeneration etc.) on [%] in accordance to current state

(F) 0 ◄- (F) Reduction of heat losses by **TRANSMIESSION LINES** (DH) on [%] in accordance to current state

(G) 0 ◄- (G) Extendents of **HEAT EXCHANGE SURFACE** on [%] accordance to current state

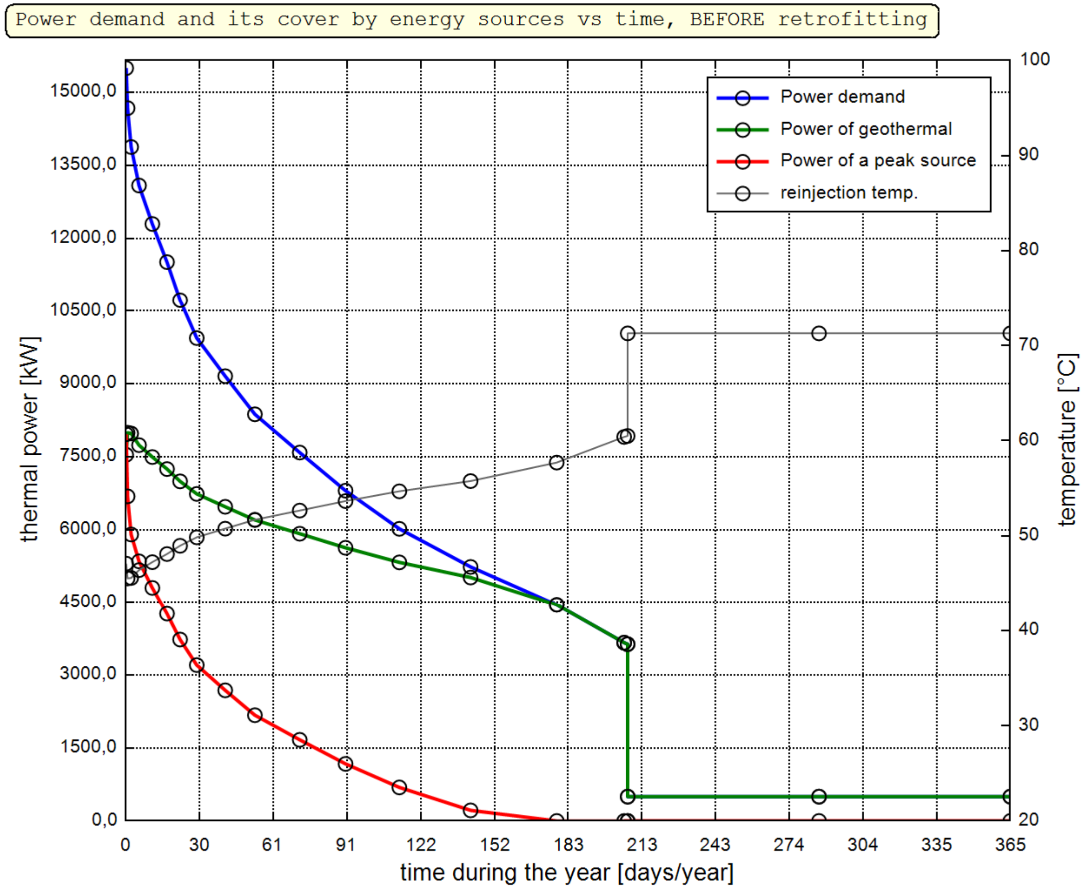
(H) 0 ◄- **(H) Hot tap water - extendents of heat exchange surface** on [%] accordance to current state

(I) 65 ◄- **(I) Reduction of hot tap water supply temperature** to the statted here value [°C] (current value is the max)

Example of U4GE calculator

Polish case study location: Poddębice

BEFORE retrofitting ► AFTER retrofitting



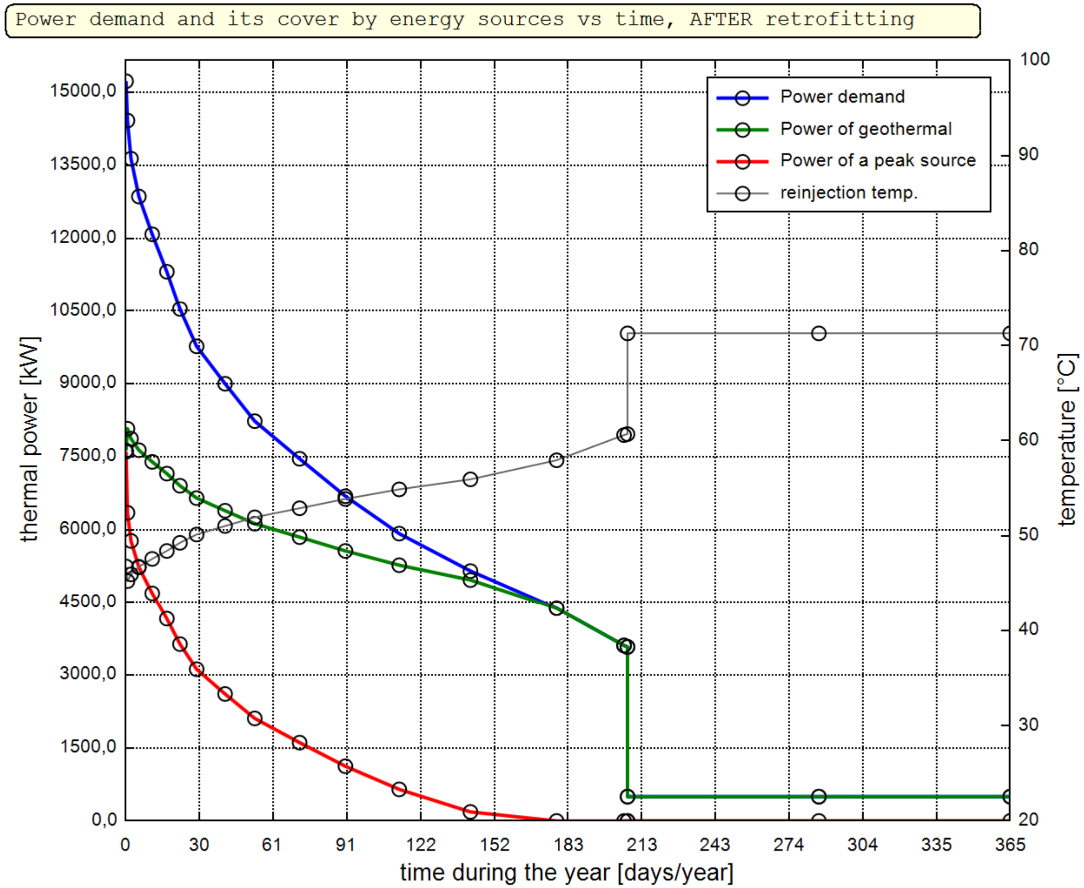
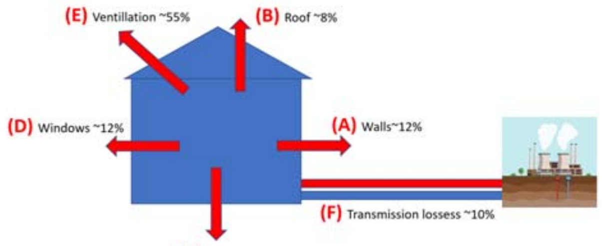


Table 1. List of the most important parameters and their values		
	Current state	After retrofitting
Location: city and country	Poddębice PL	Poddębice PL
Geothermal resources: flow [m3/h] | temp.[°C]	250 | 73	250 | 73
Type of heat peak source	Heating oil	Heating oil
Status of heating system at users (radiators)	Central heating system exists, might be retroffited	
Status of hot water system at users	The hot tap water system exists, might be retroffited	
Status of heat peak source	Peak heat source exists	Peak heat source exists
Payment for emission of CO2 (status)	Payment for CO2 emission excluded	Payment for CO2 emission excluded
Retrofitting results, reduction of power and energy demand		
(A) insulation of external walls [kW || GJ/yr ► % of energy]		270 || 2374,3 ► 15,00
(B) insulation of roofs [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(C) insulation of floors on ground [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(D) exchange of windows and external doors [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(E) ventilation inc. recuperation (if applied) [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(F) transmission losses [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(G) increase of heat exchange surface for heating (eg. radiatiors) [%]		0,00
(H) increase of heat exchange surface for hot water [%]		0,00
(I) reduction of supply temperature for hot water from ► to [°C]		65,00 ► 65,00
Status of a peak heat source after retrofitting		We are using the same peak heating source
Design parameters for heating | wot water [°C]	68/45 | 65/45	67,3/44,7 | 65/45
User power demand: heating | hot water [kW] # total energy demand [GJ/yr]	15000 | 500 # 131906	14730 | 500 # 129815,5
Energy production: total; geothermal; peak source [GJ/yr]	131906 ; 105683,6 ; 26222,4	129815,5 ; 104465 ; 25350,5
Share of sources in total energy production: geothermal; peak source [%]	80,12 ; 19,88	80,47 ; 19,53
Energy carrier used by a peak source [L/yr]	835800,84	808009,16
Emission of selected pollutants		
CO2 [ton/yr]	2111,78	2041,56
SO2 [kg/yr]	2330,88	2253,38
NOx [kg/yr]	2039,52	1971,7
total dust [kg/yr]	58,27	56,33
Investment expenditures [k€]	0	1296
Total cost | CAPEX | OPEX [k€/yr]	1401,3 | 389,3 | 1012	1432,5 | 454,1 | 978,4
Simple payback time for additional expenditures SPBT [yr]		38,5
Energy price reduction for final user [€/GJ]		0,26

Poddębice
Let's try encourage users to reduce power demand by retrofitting activities



(A) 15 ◄- (A) Reduction of heat losses by **EXTERNAL WALLS** on [%] in accordance to current state

(B) 0 ◄- (B) Reduction of heat losses by **ROOFS** on [%] in accordance to current state

(C) 0 ◄- (C) Reduction of heat losses by **FLOOR** on the ground on [%] in accordance to current state

(D) 0 ◄- (D) Reduction of heat losses by **WINDOWS** and external doors on [%] in accordance to current state

(E) 20 ◄- (E) Reduction of heat losses by **VENTILATION** (including recuperation, regeneration etc.) on [%] in accordance to current state

(F) 0 ◄- (F) Reduction of heat losses by **TRANSMIESSION LINES** (DH) on [%] in accordance to current state

(G) 0 ◄- (G) Extendents of **HEAT EXCHANGE SURFACE** on [%] accordance to current state

(H) 0 ◄- **(H) Hot tap water - extendents of heat exchange surface** on [%] accordance to current state

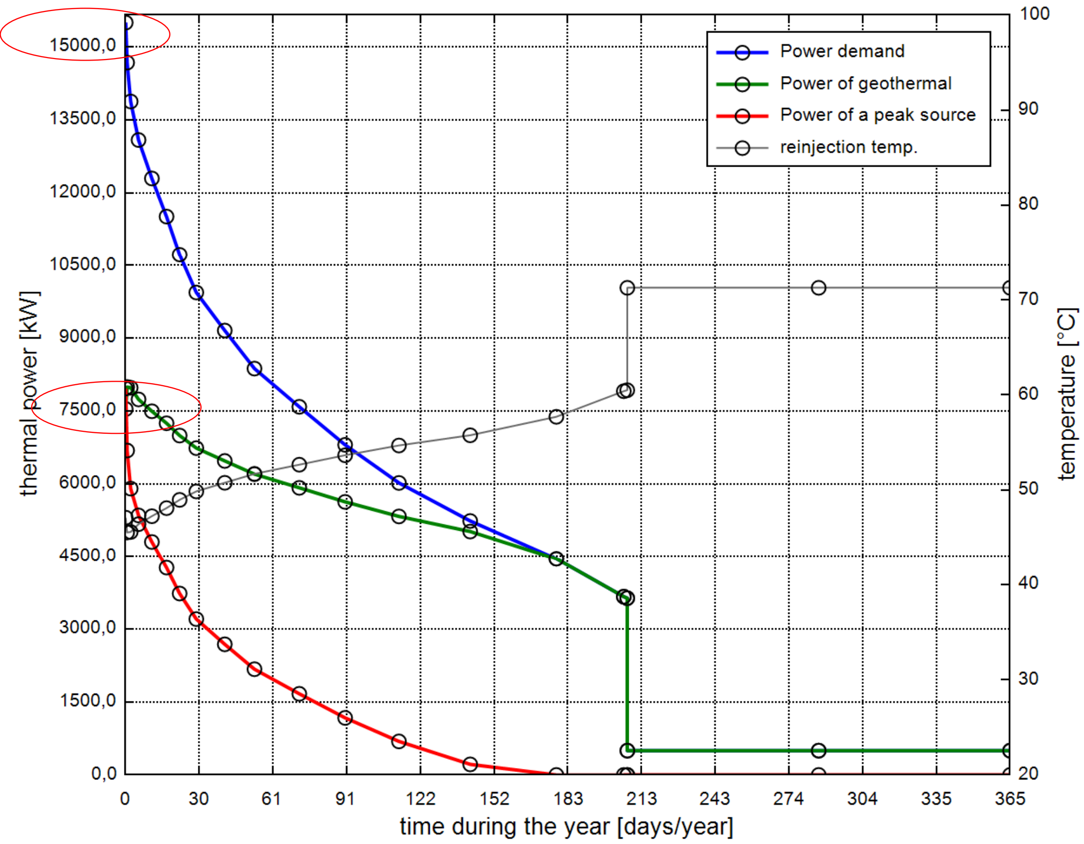
(I) 65 ◄- **(I) Reduction of hot tap water supply temperature** to the statted here value [°C] (current value is the max)

Example of U4GE calculator

Polish case study location: Poddębice

BEFORE retrofitting ► AFTER retrofitting

Power demand and its cover by energy sources vs time, BEFORE retrofitting



Power demand and its cover by energy sources vs time, AFTER retrofitting

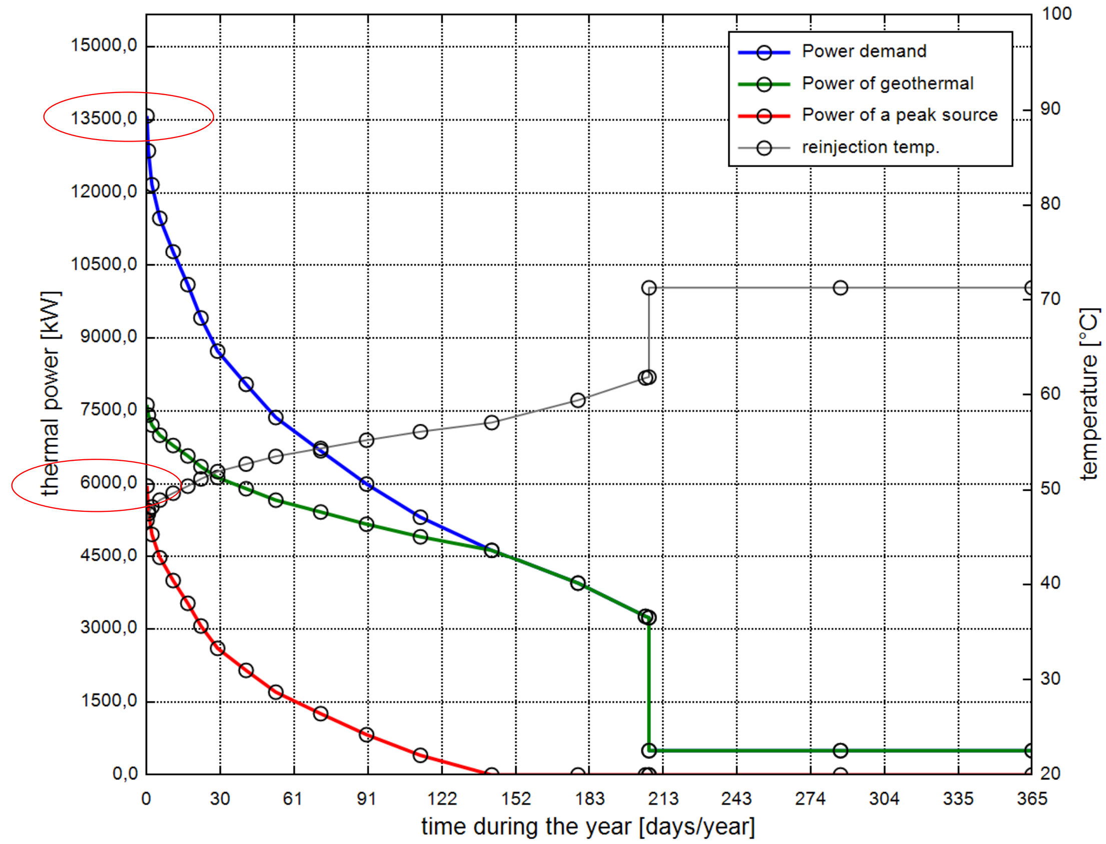
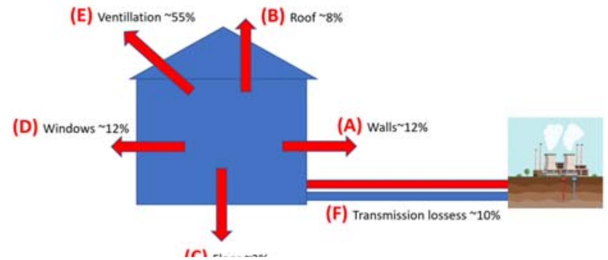


Table 1. List of the most important parameters and their values

	Current state	After retrofitting
Location: city and country	Poddębice PL	Poddębice PL
Geothermal resources: flow [m3/h] | temp.[°C]	250 | 73	250 | 73
Type of heat peak source	Heating oil	Heating oil
Status of heating system at users (radiators)	Central heating system exists, might be retroffited	
Status of hot water system at users	The hot tap water system exists, might be retroffited	
Status of heat peak source	Peak heat source exists	Peak heat source exists
Payment for emission of CO2 (status)	Payment for CO2 emission excluded	Payment for CO2 emission excluded
Retrofitting results, reduction of power and energy demand		
(A) insulation of external walls [kW || GJ/yr ► % of energy]		270 || 2374,3 ► 15,00
(B) insulation of roofs [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(C) insulation of floors on ground [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(D) exchange of windows and external doors [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(E) ventilation inc. recuperation (if applied) [kW || GJ/yr ► % of energy]		1650 || 14509,7 ► 20,00
(F) transmission losses [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(G) increase of heat exchange surface for heating (eg. radiators) [%]		0,00
(H) increase of heat exchange surface for hot water [%]		0,00
(I) reduction of supply temperature for hot water from ► to [°C]		65,00 ► 65,00
Status of a peak heat source after retrofitting		We are using the same peak heating source
Design parameters for heating | wot water [°C]	68/45 | 65/45	62,9/42,9 | 65/45
User power demand: heating | hot water [kW] # total energy demand [GJ/yr]	15000 | 500 # 131906	13080 | 500 # 117040,1
Energy production: total; geothermal; peak source [GJ/yr]	131906 ; 105683,6 ; 26222,4	117040,1 ; 96901,4 ; 20138,7
Share of sources in total energy production: geothermal; peak source [%]	80,12 ; 19,88	82,79 ; 17,21
Energy carrier used by a peak source [L/yr]	835800,84	641892,4
Emission of selected pollutants		
CO2 [ton/yr]	2111,78	1621,84
SO2 [kg/yr]	2330,88	1790,11
NOx [kg/yr]	2039,52	1566,35
total dust [kg/yr]	58,27	44,75
Investment expenditures [k€]	0	2781
Total cost | CAPEX | OPEX [k€/yr]	1401,3 | 389,3 | 1012	1305,6 | 528,4 | 777,2
Simple payback time for additional expenditures SPBT [yr]		11,8
Energy price reduction for final user [€/GJ]		2,01

Poddębice
Let's try encourage users to reduce power demand by retrofitting activities



(A) 15 ◄- **(A)** Reduction of heat losses by **EXTERNAL WALLS** on [%] in accordance to current state

(B) 0 ◄- **(B)** Reduction of heat losses by **ROOFS** on [%] in accordance to current state

(C) 0 ◄- **(C)** Reduction of heat losses by **FLOOR** on the ground on [%] in accordance to current state

(D) 15 ◄- **(D)** Reduction of heat losses by **WINDOWS** and external doors on [%] in accordance to current state

(E) 20 ◄- **(E)** Reduction of heat losses by **VENTILATION** (including recuperation, regeneration etc.) on [%] in accordance to current state

(F) 0 ◄- **(F)** Reduction of heat losses by **TRANSMIESSION LINES** (DH) on [%] in accordance to current state

(G) 30 ◄- **(G)** Extendents of **HEAT EXCHANGE SURFACE** on [%] accordance to current state

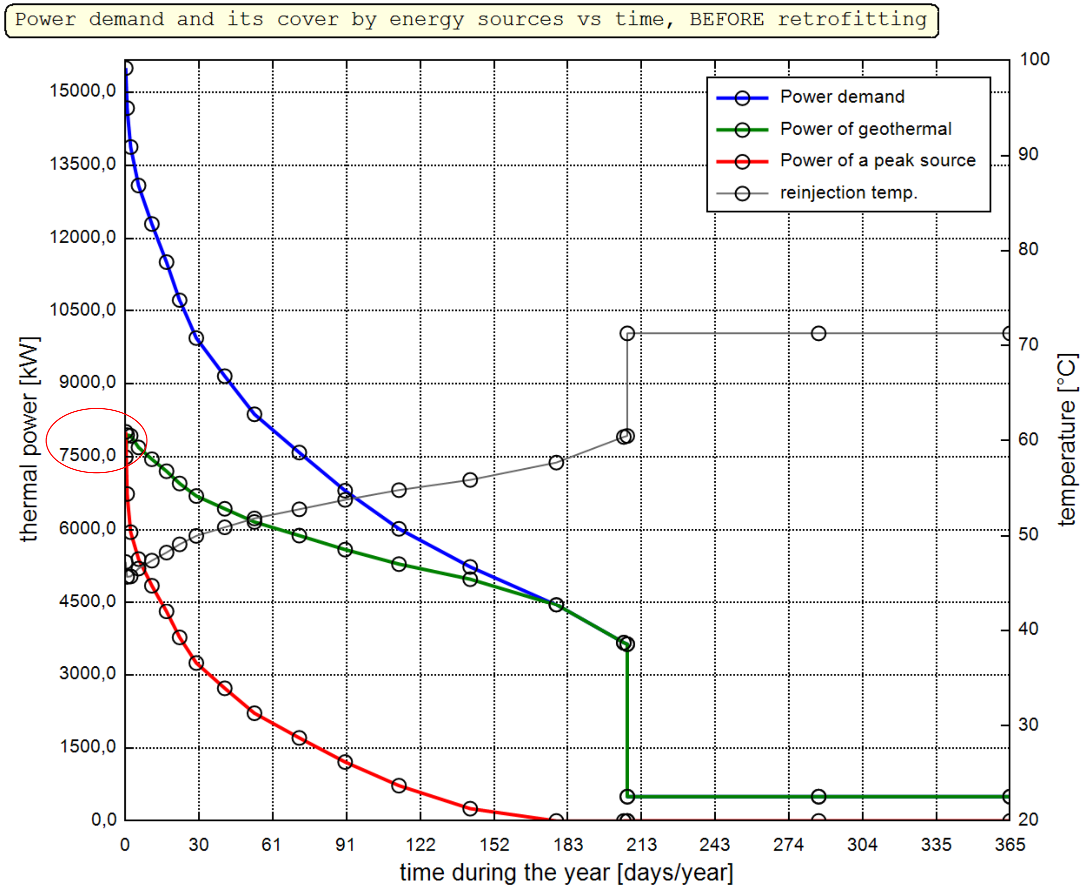
(H) 50 ◄- **(H) Hot tap water - extendents of heat exchange surface** on [%] accordance to current state

(I) 60 ◄- **(I) Reduction of hot tap water supply temperature** to the statted here value [°C] (current value is the max)

Example of U4GE calculator

Polish case study location: Poddębice

BEFORE retrofitting ► AFTER retrofitting



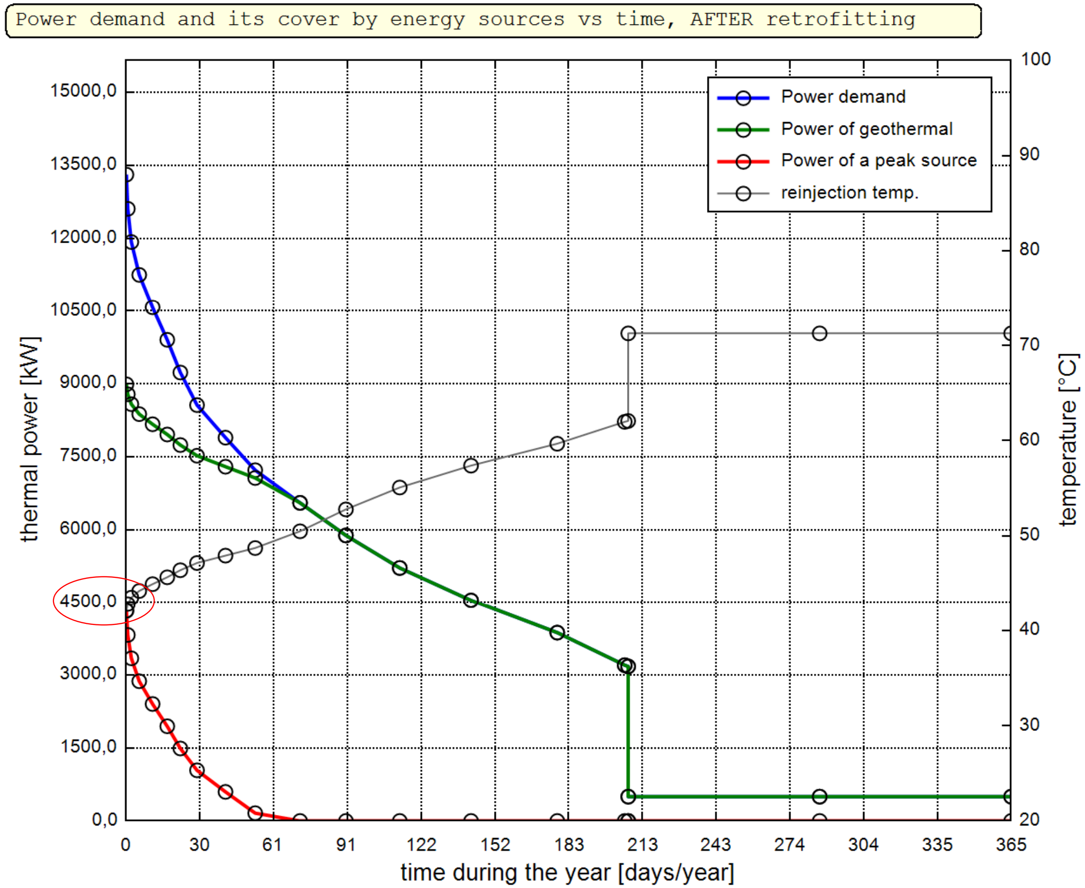
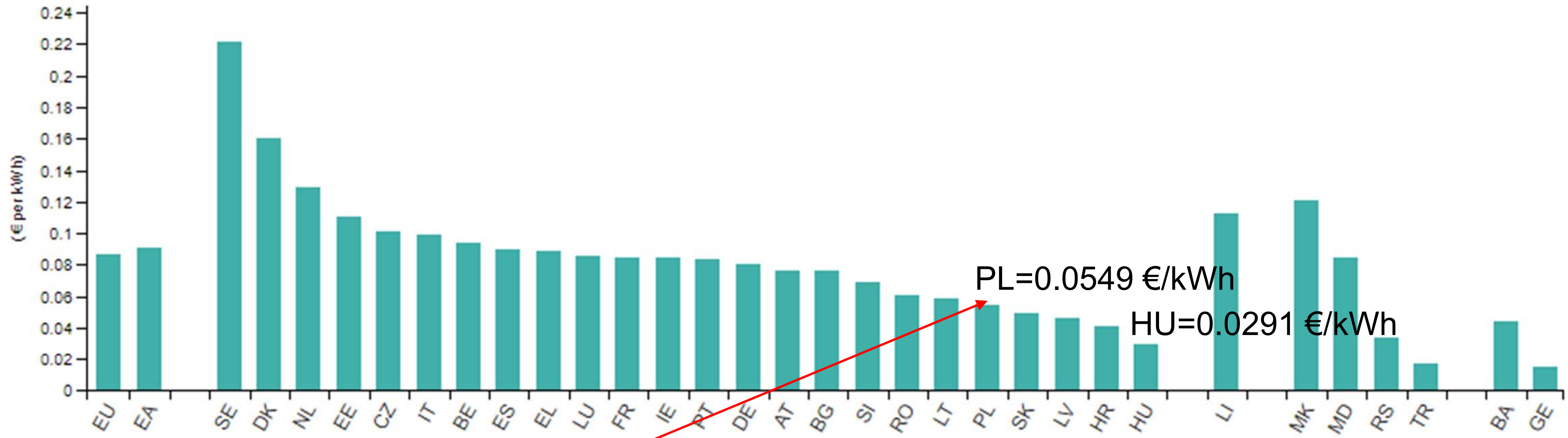


Table 1. List of the most important parameters and their values		
	Current state	After retrofitting
Location: city and country	Poddębice PL	Poddębice PL
Geothermal resources: flow [m3/h] | temp.[°C]	250 | 73	250 | 73
Type of heat peak source	Heating oil	Heating oil
Status of heating system at users (radiators)	Central heating system exists, might be retroffited	
Status of hot water system at users	The hot tap water system exists, might be retroffited	
Status of heat peak source	Peak heat source exists	Peak heat source exists
Payment for emission of CO2 (status)	Payment for CO2 emission excluded	Payment for CO2 emission excluded
Retrofitting results, reduction of power and energy demand		
(A) insulation of external walls [kW || GJ/yr ► % of energy]		270 || 2374,3 ► 15,00
(B) insulation of roofs [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(C) insulation of floors on ground [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(D) exchange of windows and external doors [kW || GJ/yr ► % of energy]		270 || 2374,3 ► 15,00
(E) ventilation inc. recuperation (if applied) [kW || GJ/yr ► % of energy]		1650 || 14509,7 ► 20,00
(F) transmission losses [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(G) increase of heat exchange surface for heating (eg. radiators) [%]		30,00
(H) increase of heat exchange surface for hot water [%]		50,00
(I) reduction of supply temperature for hot water from ► to [°C]		65,00 ► 60,00
Status of a peak heat source after retrofitting		We are using the same peak heating source
Design parameters for heating | wot water [°C]	68/45 | 65/45	56,9/37,2 | 60/30,6
User power demand: heating | hot water [kW] # total energy demand [GJ/yr]	15000 | 500 # 131906	12810 | 500 # 114949,6
Energy production: total; geothermal; peak source [GJ/yr]	131906 ; 105683,6 ; 26222,4	114949,6 ; 108111,2 ; 6838,4
Share of sources in total energy production: geothermal; peak source [%]	80,12 ; 19,88	94,05 ; 5,95
Energy carrier used by a peak source [L/yr]	835800,84	217964,37
Emission of selected pollutants		
CO2 [ton/yr]	2111,78	550,72
SO2 [kg/yr]	2330,88	607,86
NOx [kg/yr]	2039,52	531,88
total dust [kg/yr]	58,27	15,2
Investment expenditures [k€]	0	5071,1
Total cost | CAPEX | OPEX [k€/yr]	1401,3 | 389,3 | 1012	906,8 | 642,9 | 263,9
Simple payback time for additional expenditures SPBT [yr]		6,8
Energy price reduction for final user [€/GJ]		6,51

Let's look around - prices of natrural gas in Europe

Natural gas prices (including taxes) for household consumers, first half 2022



Prices of Energy carriers for business entities are much higher – that's only an example

Source: Eurostat (online data codes: nrg_pc_202)

eurostat

$$PriceNG\_PL := PricePL \cdot Qw = 0{,}6054\ \frac{€}{m^3}$$

$$PriceNG\_SK := PriceSK \cdot Qw = 0{,}5382\ \frac{€}{m^3}$$

$$PriceNG\_HU := PriceHU \cdot Qw = 0{,}3209\ \frac{€}{m^3}$$

How it fix to reaity? I pay about 3,5 zł/m3 including 23% VAT (Qw = 35,4 MJ/m3). Net price might be estimated then:

$$PricePL := \frac{3{,}5\ \frac{zł}{m^3}}{35{,}4\ \frac{MJ}{m^3} \cdot 1{,}23} = 0{,}0616\ \frac{€}{kW\ hr}$$

$$\Delta Price := \frac{PricePL - 0{,}0549\ \frac{€}{kW\ hr}}{0{,}0549\ \frac{€}{kW\ hr}} = 12{,}1\ \%$$

◄- it is 12% more

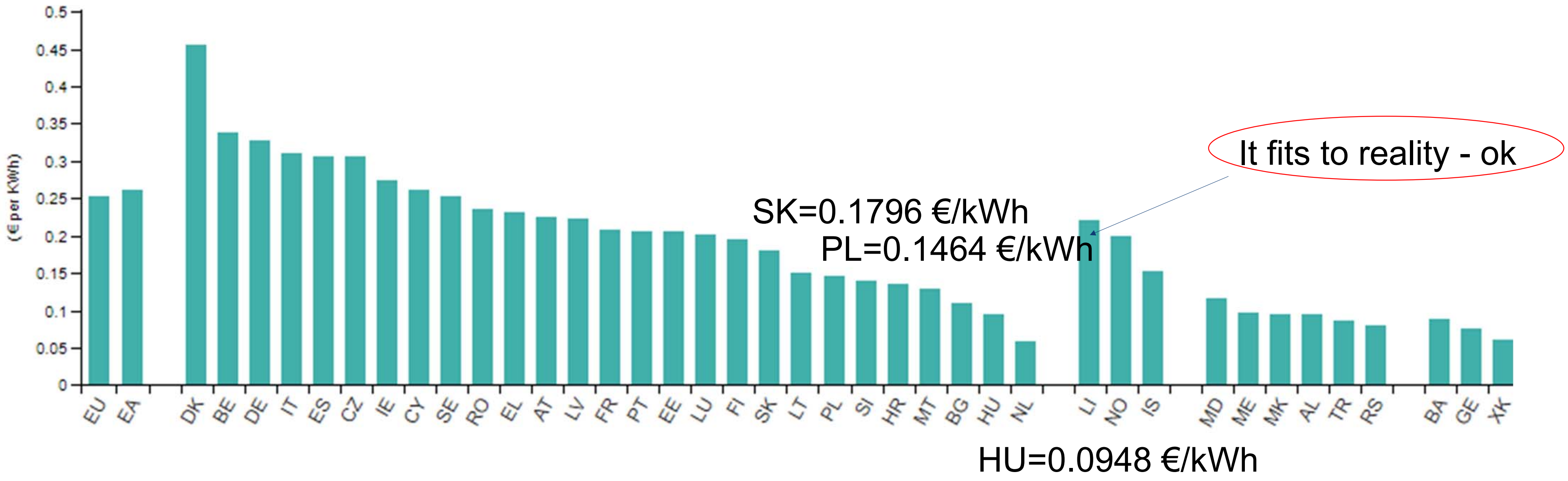
Let's include it to prices in case of SK and HU:

$$PriceSK := 0{,}0488\ \frac{€}{kW\ hr} \cdot (1 + \Delta Price) = 0{,}0547\ \frac{€}{kW\ hr}$$

$$PriceHU := 0{,}0291\ \frac{€}{kW\ hr} \cdot (1 + \Delta Price) = 0{,}0326\ \frac{€}{kW\ hr}$$

Prices of electricity in Europe

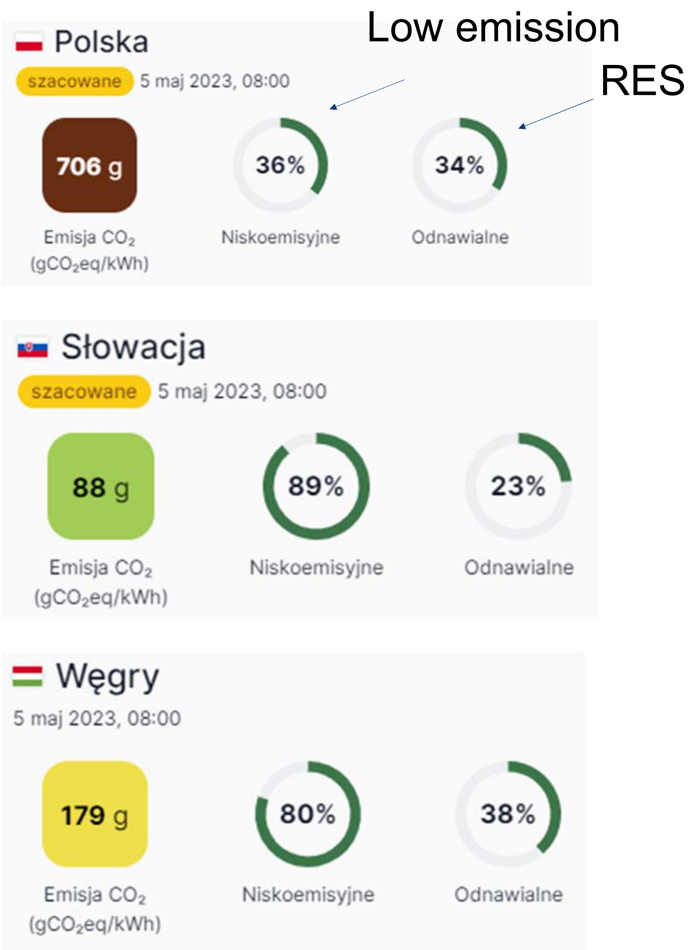
Electricity prices (including taxes) for household consumers, first half 2022



Kosovo (XK): This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo Declaration of Independence.

Source: Eurostat (online data codes: nrg_pc_204)

CO_2 emission (based on Electricity Maps: https://app.electricitymaps.com/zone/PL?nobrowsercheck=1&wind=true)



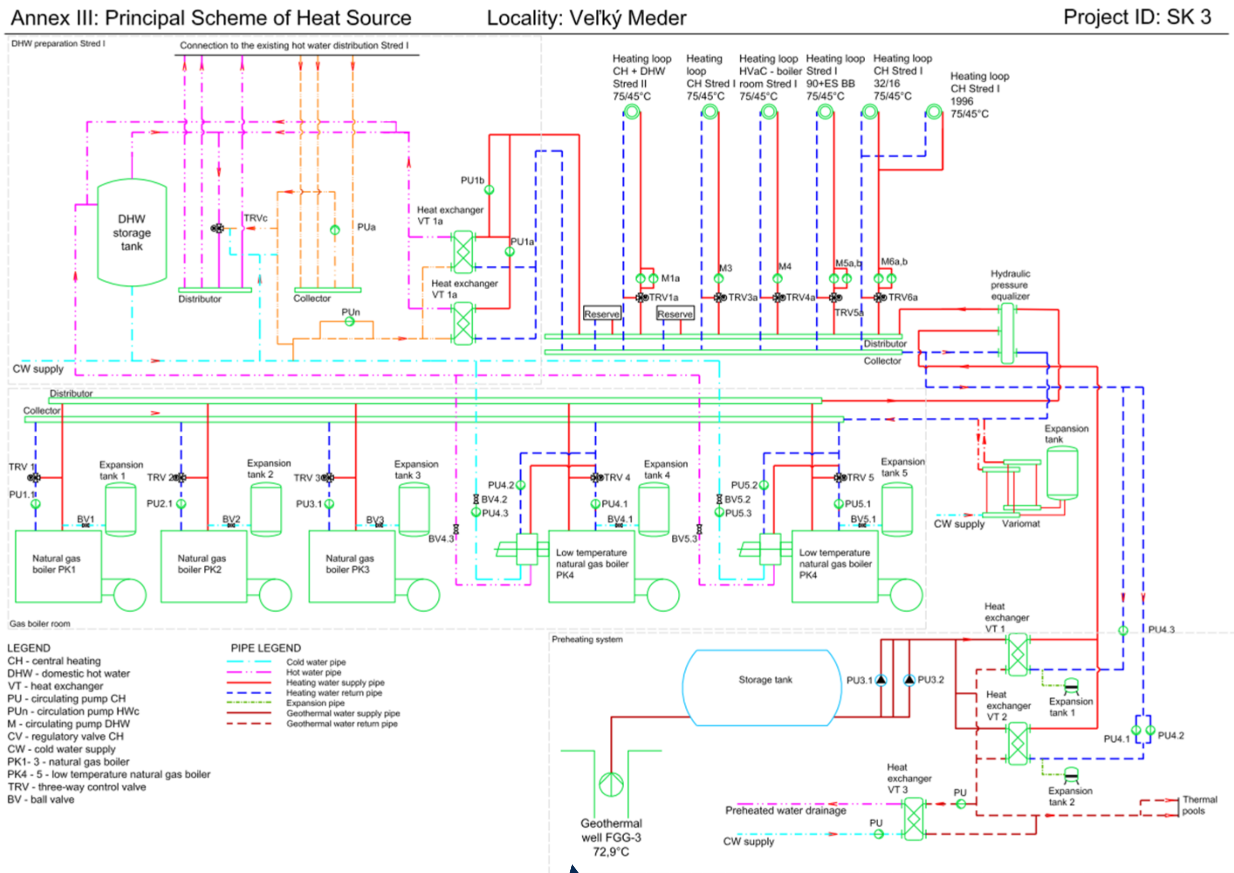
$$Eco2PL := 706 \frac{\mathrm{g}}{\mathrm{kW\ hr}} = 196{,}1111 \frac{\mathrm{kg}}{\mathrm{GJ}}$$

$$Eco2SK := 88 \frac{\mathrm{g}}{\mathrm{kW\ hr}} = 24{,}4444 \frac{\mathrm{kg}}{\mathrm{GJ}}$$

$$Eco2HU := 176 \frac{\mathrm{g}}{\mathrm{kW\ hr}} = 48{,}8889 \frac{\mathrm{kg}}{\mathrm{GJ}}$$

SLOVAKIA

Slovakia – Velky Meder today



Iceland Liechtenstein Norway grants | Norway grants

Improving the energy efficiency of geothermal energy utilisation by adjusting the user characteristics

User4GeoEnergy
Project Number: 2018-1-0502

Database — Dataset for particular project/locality — **Part 2** — **Locality ID.: SK 3**

Production Well 1

Well name:	VM-1	Maximal flow rate:	11,7 l/s
Well depth:	2 450 m	Maximal well head temperature:	96 °C
Production casing 1 diameter:	9 5/8 in	Well head pressure at maximal flow:	0,3 MPa
Production casing 2 diameter:	- in	Water level at static cond. (below surface):	0 m
Production liner diameter:	7 in	Water level at max. flow rate (below surface):	45,2 m
Outflow conditions:	Pumping	Mineralisation of geothermal water (TDS):	3,64 g/l
Depth of the pump:	120 m	Corrosive properties?	Yes
Electrical input of the pump:	22 kW	Scaling properties?	No
Well construction:	See Annex II	Dosing of inhibitor?	Yes

Water level depression resp. geothermal water temperature vs. flow rate dependence (if available): N/A

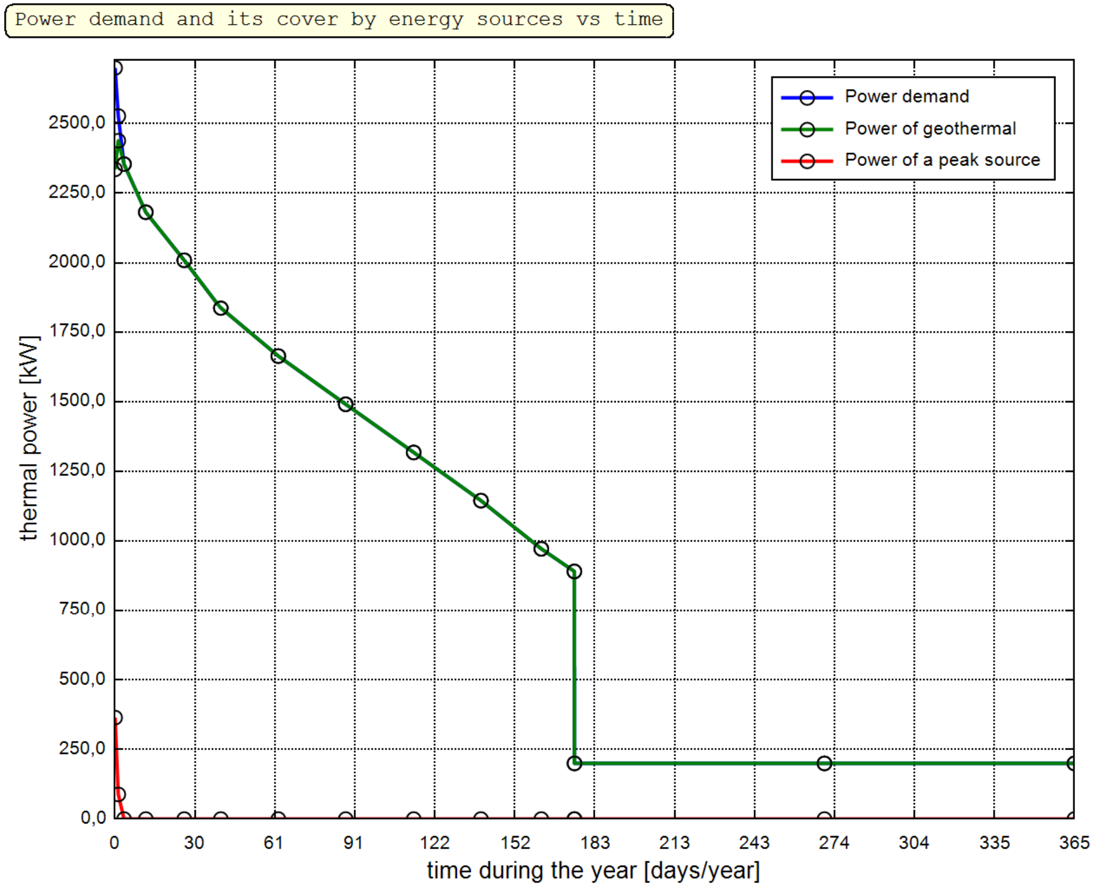
Power ~2500 kW, 75/45°C

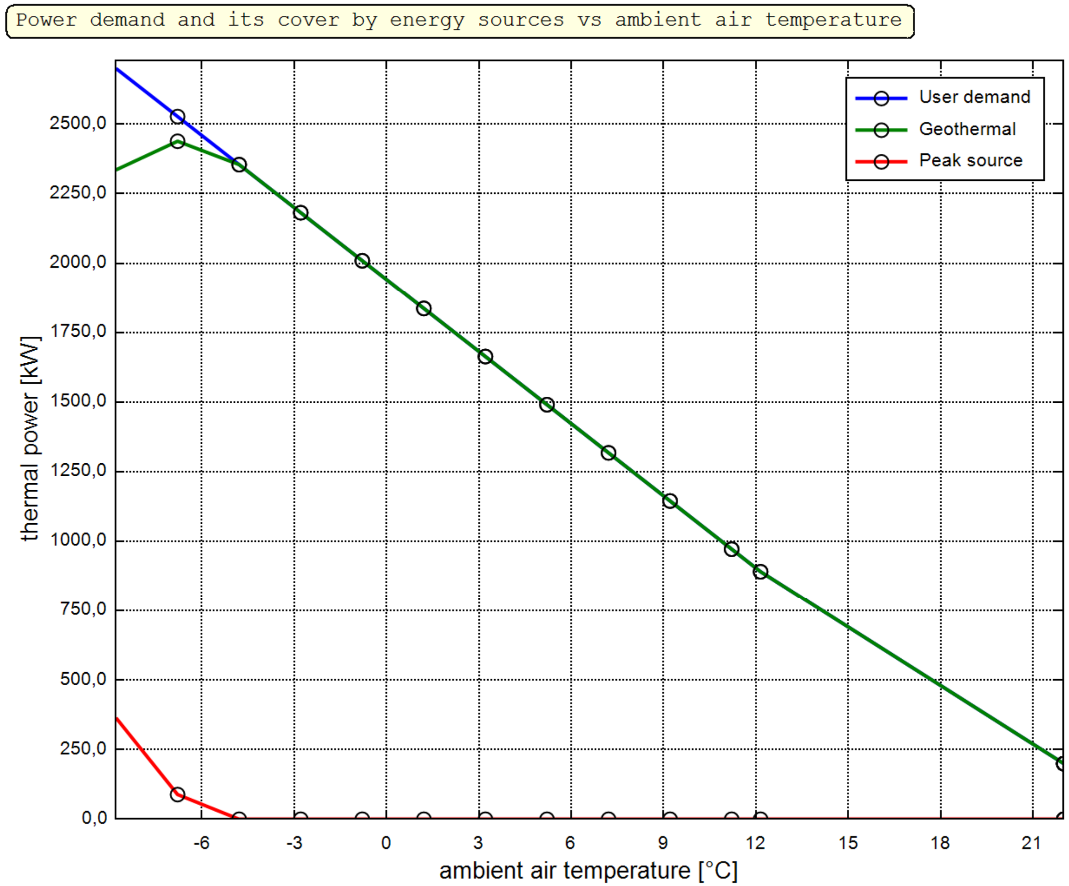
V_{geo} 11,7 l/s = 42 m^3/h, t_{geo} 96°C

$$42\ \frac{m^3}{hr} \cdot 4,19\ \frac{kJ}{L\ K} \cdot (96-45)\ K = 2,5\ MW$$

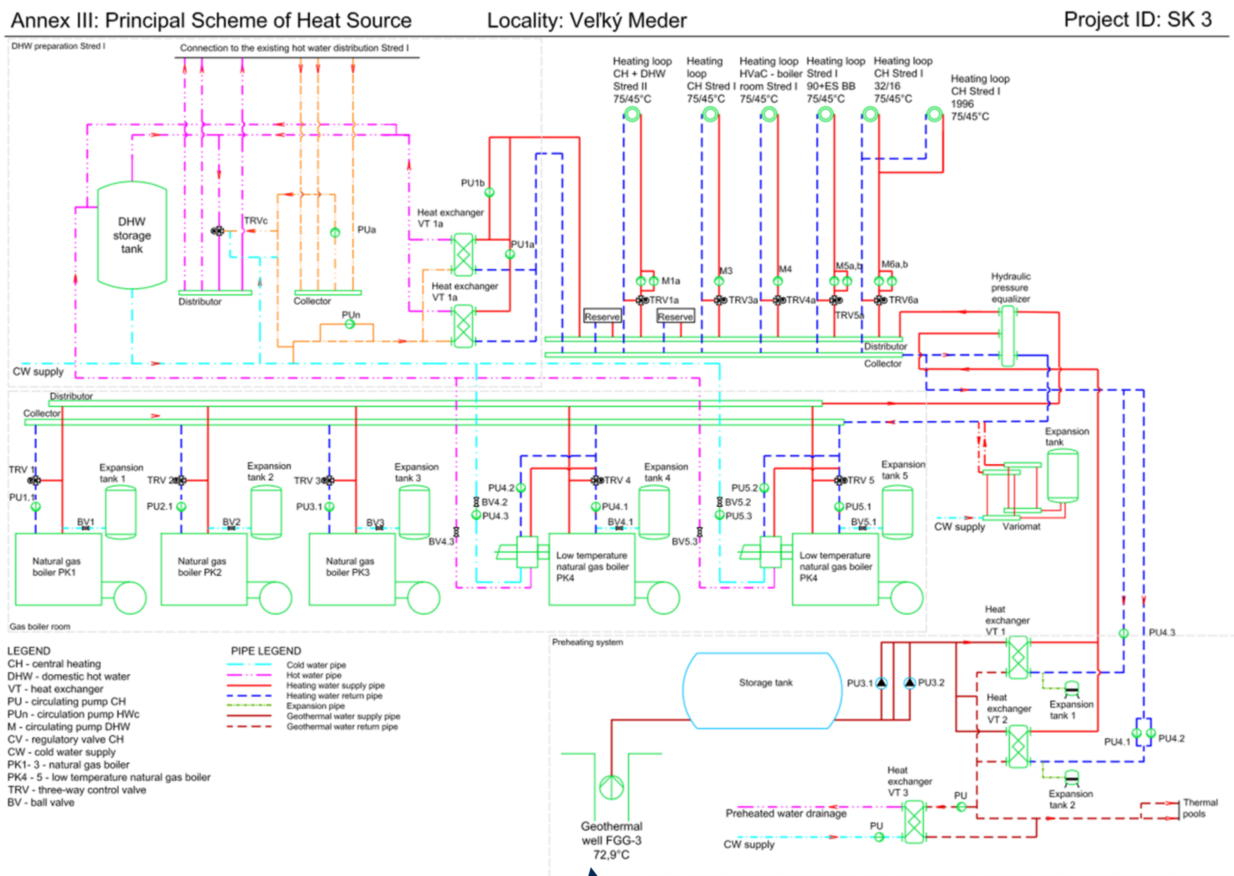
Geothermal covers 100% of power demand, there is nothing to improve

Slovakia – Velky Meder today





Slovakia – Velky Meder - future



Iceland Liechtenstein Norway grants — Norway grants

Improving the energy efficiency of geothermal energy utilisation by adjusting the user characteristics

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Production casing 1 diameter:	9 5/8 in	Well head pressure at maximal flow:	0,3 MPa
Production casing 2 diameter:	- in	Water level at static cond. (below surface):	0 m
Production liner diameter:	7 in	Water level at max. flow rate (below surface):	45,2 m
Outflow conditions:	Pumping	Mineralisation of geothermal water (TDS):	3,64 g/l
Depth of the pump:	120 m	Corrosive properties?	Yes
Electrical input of the pump:	22 kW	Scaling properties?	No
Well construction:	See Annex II	Dosing of inhibitor?	Yes

Water level depression resp. geothermal water temperature vs. flow rate dependence (if available): N/A

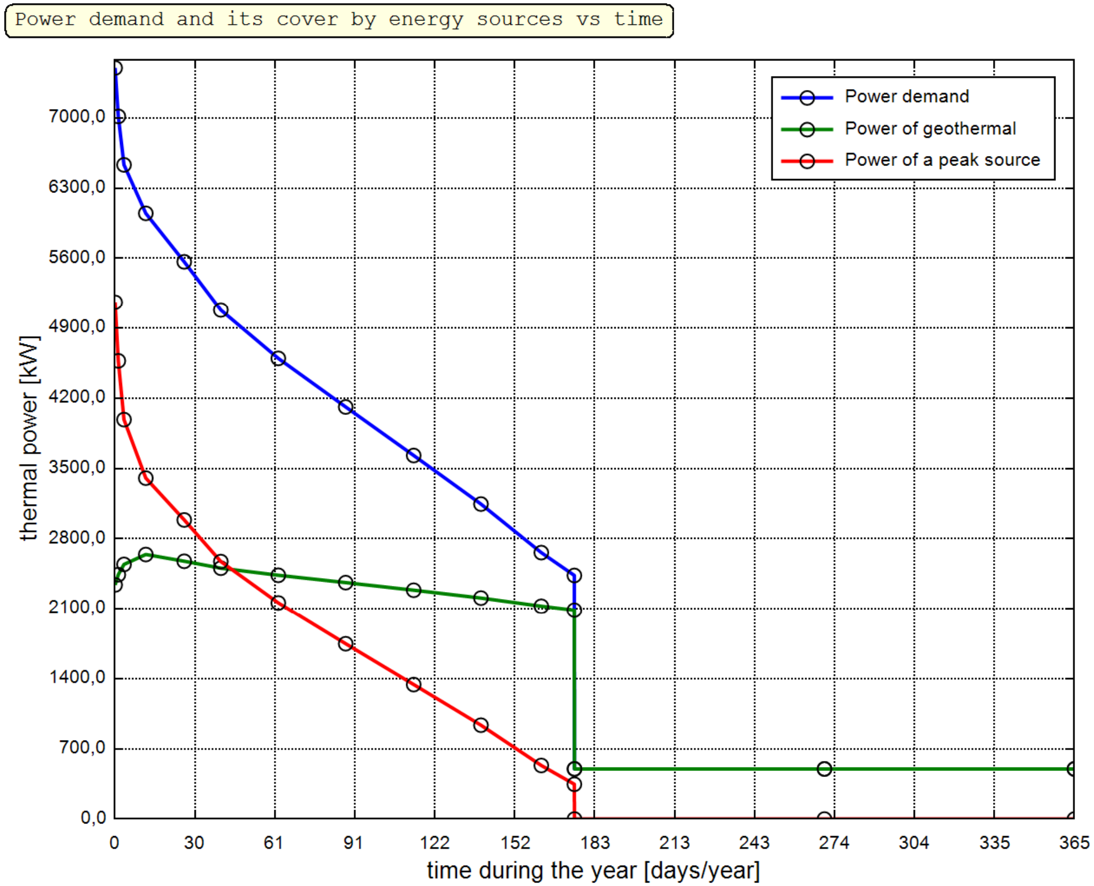
Power 7530 kW, 75/45°C

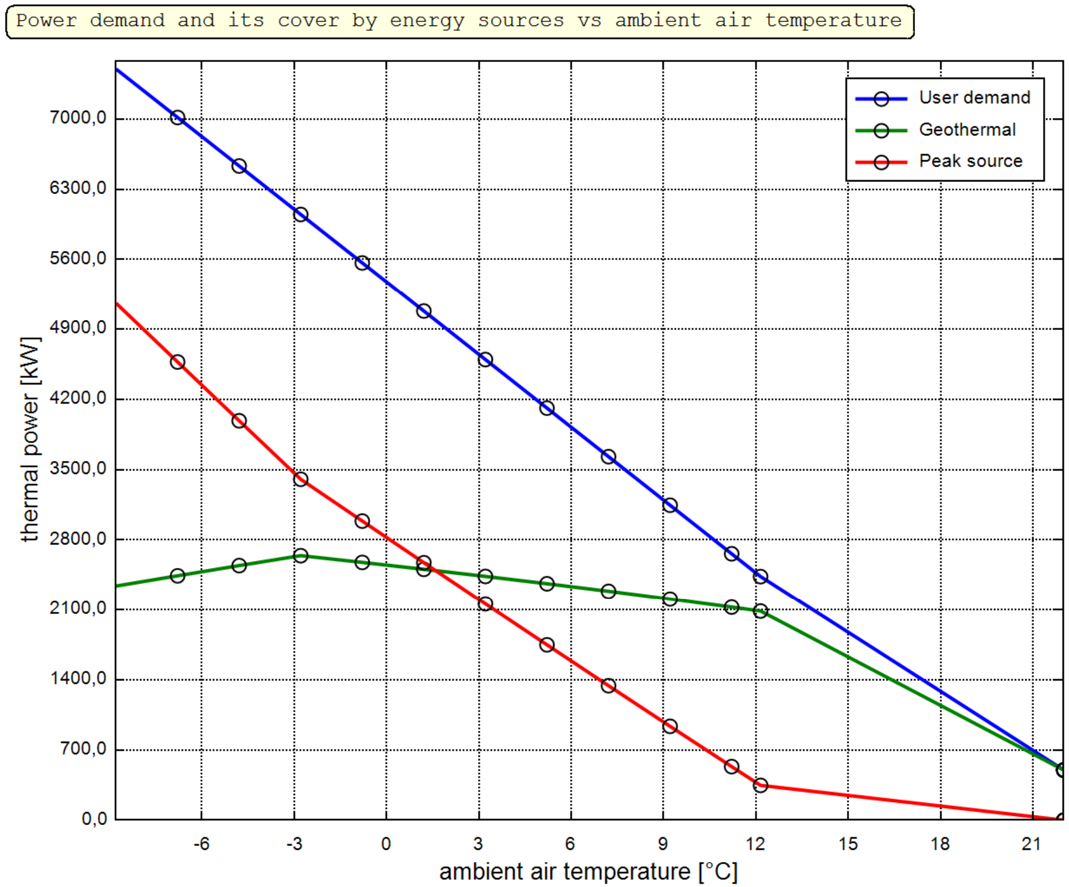
V_{geo} 11,7 l/s = 42 m^3/h, t_{geo} 96°C

The current design parameters of users are well fitted to the geothermal conditions. The required supply and return temperature is low compared to geothermal fluid temperature. That will be a challenge to improve something.

Slovakia – Velky Meder - future

Power ~7500 kW, 75/45°C
V_{geo} 11,7 l/s = 42 m^3/h, t_{geo} 96°C





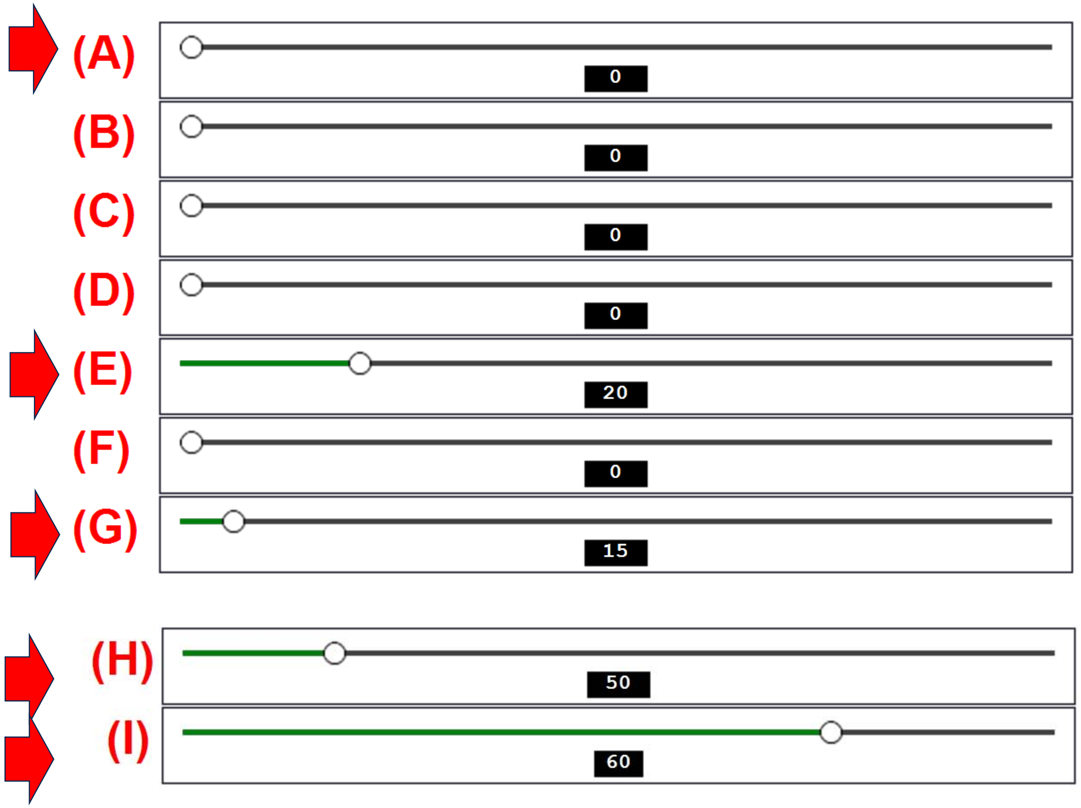
	A	B	C	D	E	F	G	H	J
1	Currency	Euro							
2	GasBoilerConventional	GasBoiler	OilBoiler	HardCoilB	ElectrictDi	HeatPumps			
3	229,787234	280,8511	229,7872	204,2553	76,59574	459,5745		◄- unitary expenditures [Euro/kW]	
4	m3	m3	L	Mg	MWh	MWh		◄- measure unit	
5	35	35	34,86	2,50E+04	1	1		◄- lower calloric value of a fuel [MJ/unit] (in case of electricity use =1)	
6	0,9	0,96	0,9	0,8	0,99	4		◄- performance of utilisation HEAT/Chemical Energy [-]	
7	15	15	15	15	10	25		◄- lifetime for the equipment [years]	
8	0,5382	0,5382	1,210863	605,4316	179,6	179,6		◄- price of energy carrier [Euro/unit]	
9									
10	57,65	57,65	72,48	96,37	24,44	24,44		◄- CO2 emission [kg/GJ]	in case of emission GJ=energu in fuel, excluding efficincy of a heat source
11	0,0004	0,0004	0,08	0,56	0	0		◄- SO2 emission [kg/GJ]	
12	0,04	0,04	0,07	0,17	0	0		◄- NOx emission [kg/GJ]	
13	0,0005	0,0005	0,002	4,8	0	0		◄- total dust emisssion [kg/GJ]	
14									
15	70							◄- payment for CO2 emission [Euro/Mg]	
16	0,027							◄- fee for geothermal water exploitation [Euro/m3]	

Slovakia:

- ► energy carrier prices based on Eurostat, modified,
- ► assumption that retrofitting activities are 20% more expensive than assumed in Poland

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Currency	Euro/kW							Heating			Hot Water			
2	ExternalW	Roof	FloorOnG	Windows	Ventilatio	Transmiss	HeatingSu	HotWater	tin[°C]	tout[°C]	Dtm[°C]	tin[°C]	tout[°C]	Dtm[°C]	
3	5760	7680	17160	2520	1080	52800	6240	12	30	22	4,97	50	20	21,64	◄- unitary expenditures [Euro/kW]
4							2028	11,7	35	28	11,14	55	30	30,83	
5							959,4	11,4	45	35	19,58	60	40	39,15	
6							550,68	11,1	55	45	29,72	70	30	36,41	
7							346,32	22,8	70	55	42,06	65	40	41,24	
8							280,8	10,608	75	65	49,83	70	40	43,28	
9							218,4	9,6	90	70	59,44	70	50	49,33	
10							187,2	7,8	110	70	68,05	80	60	59,44	

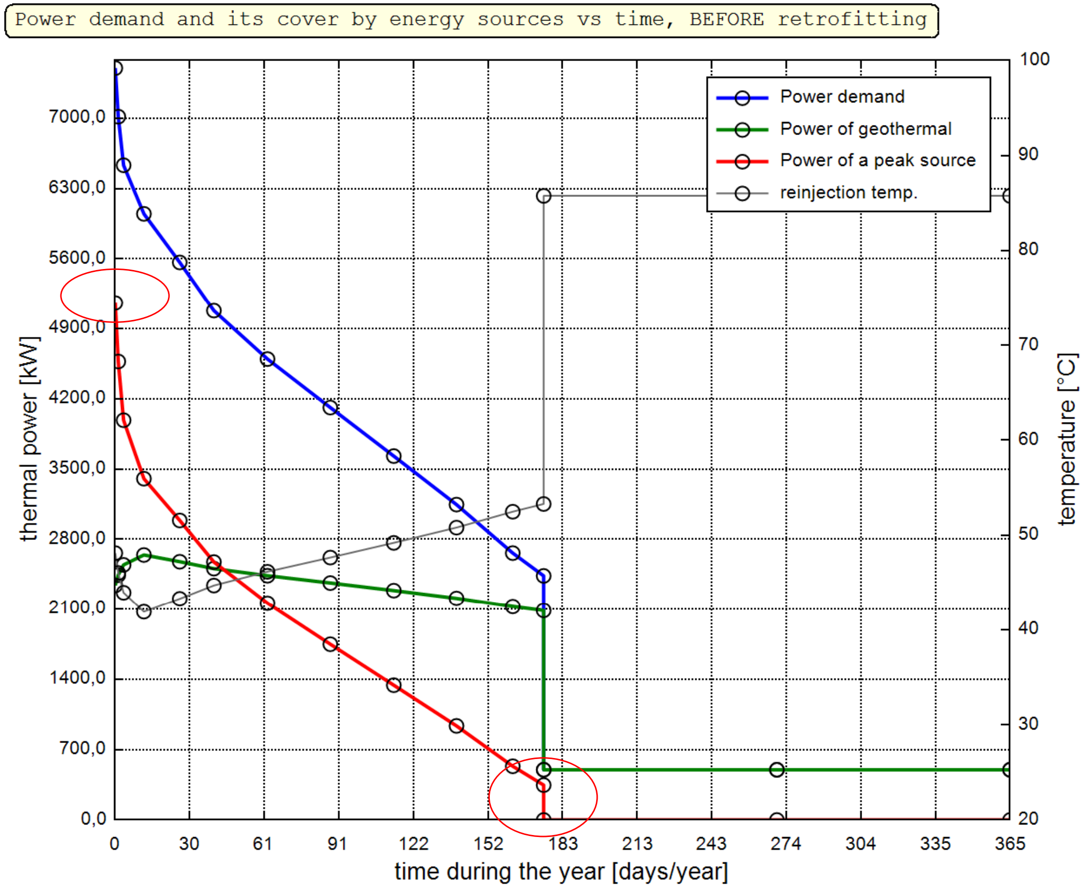
Slovakia – Velky Meder, implementation of selected retrofitting activities



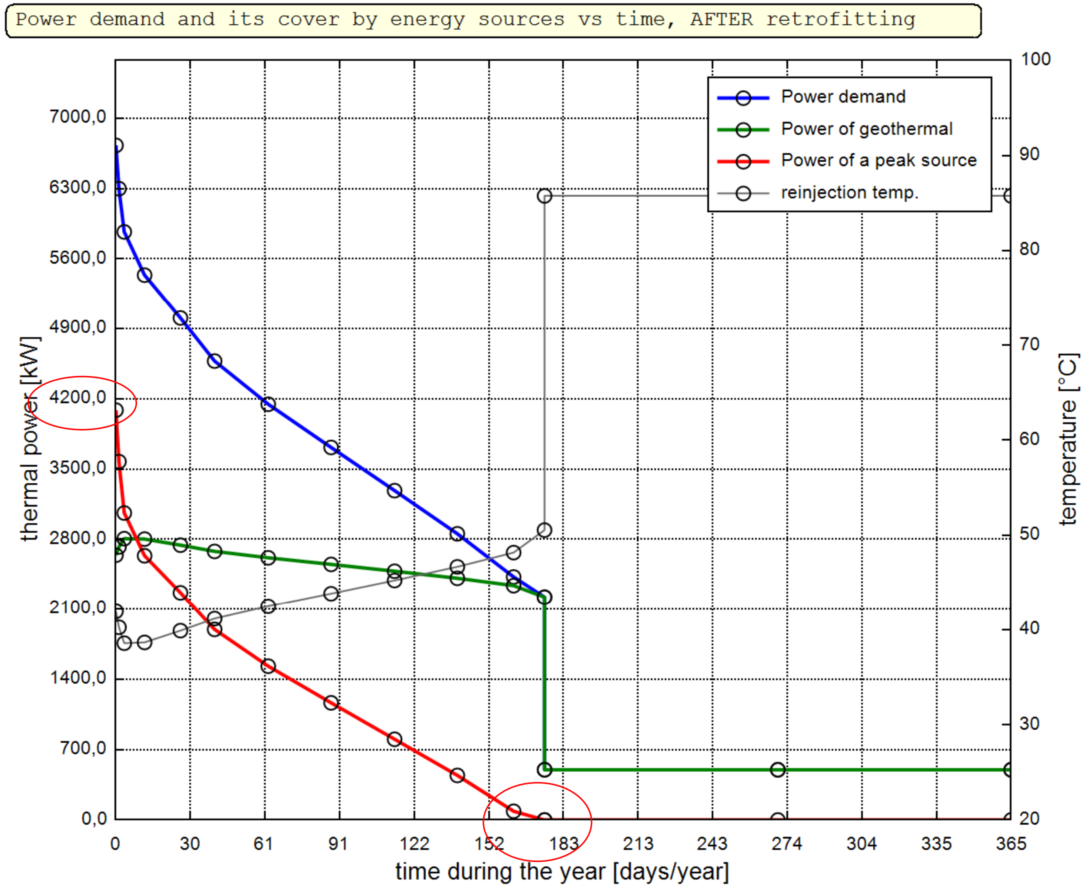
- ◄- (A) Reduction of heat losses by **EXTERNAL WALLS** on [%] in accordance to current state
- ◄- (B) Reduction of heat losses by **ROOFS** on [%] in accordance to current state
- ◄- (C) Reduction of heat losses by **FLOOR** on the ground on [%] in accordance to current state
- ◄- (D) Reduction of heat losses by **WINDOWS** and external doors on [%] in accordance to current state
- ◄- (E) Reduction of heat losses by **VENTILATION** (including recuperation, regeneration etc.) on [%] in accordance to current state
- ◄- (F) Reduction of heat losses by **TRANSMIESSION LINES** (DH) on [%] in accordance to current state
- ◄- (G) Extendents of **HEAT EXCHANGE SURFACE** on [%] accordance to current state
- ◄- **(H) Hot tap water - extendents of heat exchange surface** on [%] accordance to current state
- ◄- **(I) Reduction of hot tap water supply temperature** to the statted here value [°C] (current value is the max)

Slovakia – Velky Meder, implementation of the selected retrofitting activities

BEFORE



AFTER



Slovakia – Velky Meder

Table 1. List of the most important parameters and their values

	Current state	After retrofitting
Location: city and country	Velky Meder SK	Velky Meder SK
Geothermal resources: flow [m3/h] | temp.[°C]	42 | 96	42 | 96
Type of heat peak source	Gas boiler conventional	Gas boiler conventional
Status of heating system at users (radiators)	Central heating system exists, might be retroffited	
Status of hot water system at users	The hot tap water system exists, might be retroffited	
Status of heat peak source	Peak heat source exists	Peak heat source exists
Payment for emission of CO2 (status)	Payment for CO2 emission excluded	Payment for CO2 emission excluded
Retrofitting results, reduction of power and energy demand		
(A) insulation of external walls [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(B) insulation of roofs [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(C) insulation of floors on ground [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(D) exchange of windows and external doors [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(E) ventilation inc. recuperation (if applied) [kW || GJ/yr ► % of energy]		770 || 7915,5 ► 20,00
(F) transmission losses [kW || GJ/yr ► % of energy]		0 || 0 ► 0,00
(G) increase of heat exchange surface for heating (eg. radiatiors) [%]		15,00
(H) increase of heat exchange surface for hot water [%]		50,00
(I) reduction of supply temperature for hot water from ► to [°C]		65,00 ► 60,00
Status of a peak heat source after retrofitting		We are using the same peak heating source
Design parameters for heating | wot water [°C]	75/45 | 65/45	66,7/40 | 60/30,6
User power demand: heating | hot water [kW] # total energy demand [GJ/yr]	7000 | 500 # 71959	6230 | 500 # 65777,8
Energy production: total; geothermal; peak source [GJ/yr]	71959 ; 43900,2 ; 28058,8	65777,8 ; 46734,5 ; 19043,3
Share of sources in total energy production: geothermal; peak source [%]	61,01 ; 38,99	71,05 ; 28,95
Energy carrier used by a peak source [m3/yr]	890754,83	604548,04
Emission of selected pollutants		
CO2 [ton/yr]	1797,32	1219,83
SO2 [kg/yr]	12,47	8,46
NOx [kg/yr]	1247,06	846,37
total dust [kg/yr]	15,59	10,58
Investment expenditures [k€]	0	1267,5
Total cost | CAPEX | OPEX [k€/yr]	713,1 | 223,7 | 489,3	622,4 | 287,1 | 335,3
Simple payback time for additional expenditures SPBT [yr]		8,2
Energy price reduction for final user [€/GJ]		2,34

Slovakia Velky Meder – let's make thermal modernization procedures more realistic – step 2

We just double the sizes of hot tap water heat exchangers and slightly reduce supply temperature

(H) 100

◄- **(H) Hot tap water - extendents of heat exchange surface** on [%] accordance to current state

(I) 60

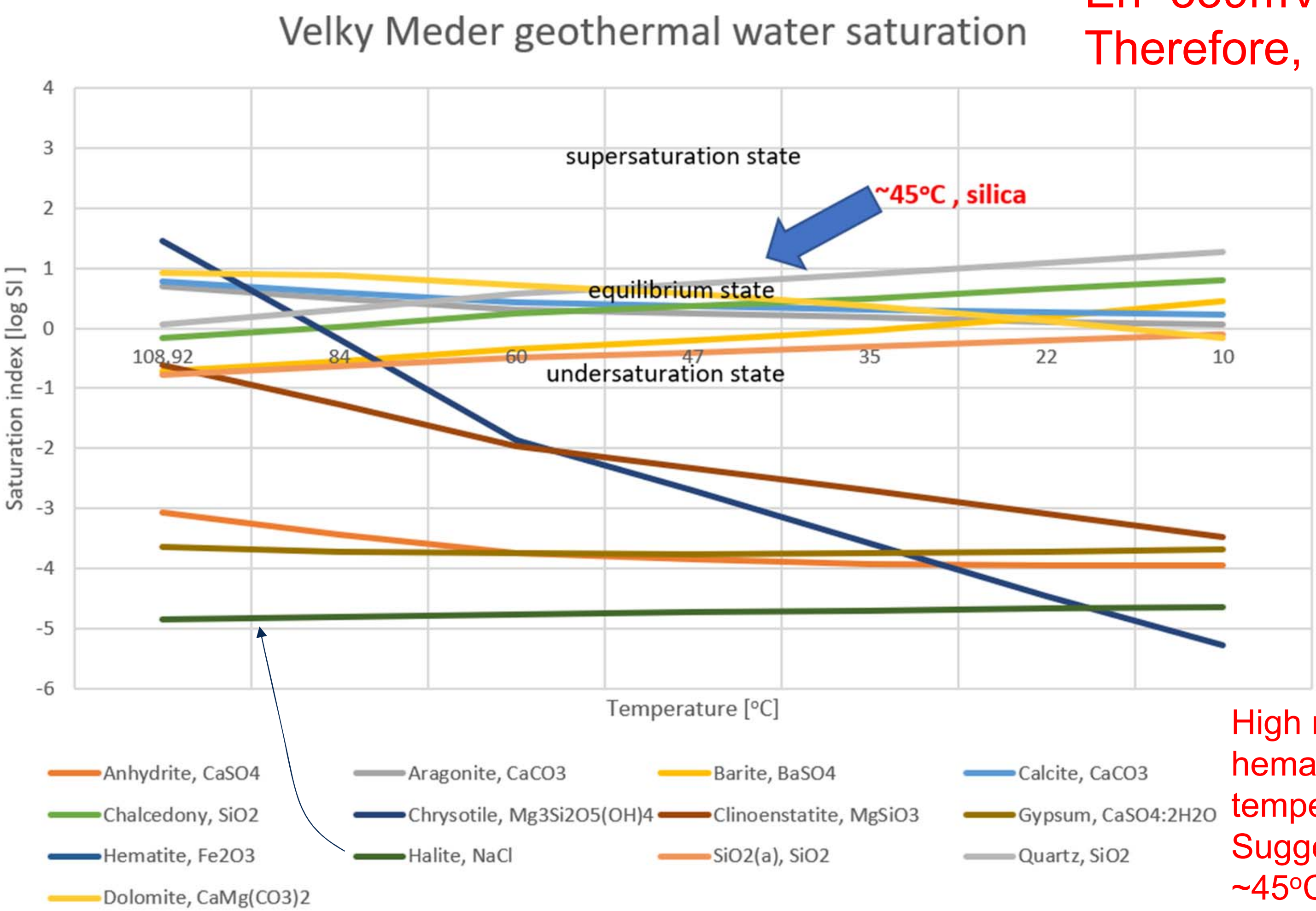
◄- **(I) Reduction of hot tap water supply temperature** to the statted here value [°C] (current value is the max)

Table 1. List of the most important parameters and their values

	Current state	After retrofitting
Location: city and country	Velky Meder SK	Velky Meder SK
Geothermal resources: flow [m3/h] | temp.[°C]	42 | 96	42 | 96
Type of heat peak source	Gas boiler conventional	Gas boiler conventional
Status of heating system at users (radiators)	Central heating system exists, might be retroffited	
Status of hot water system at users	The hot tap water system exists, might be retroffited	
Status of heat peak source	Peak heat source exists	Peak heat source exists
Payment for emission of CO2 (status)	Payment for CO2 emission excluded	Payment for CO2 emission excluded
Design parameters for heating | wot water [°C]	75/45 | 65/45	75/45 | 60/23,6
User power demand: heating | hot water [kW] # total energy demand [GJ/yr]	7000 | 500 # 71959	7000 | 500 # 71959
Energy production: total; geothermal; peak source [GJ/yr]	71959 ; 43900,2 ; 28058,8	71959 ; 47902,3 ; 24056,7
Share of sources in total energy production: geothermal; peak source [%]	61,01 ; 38,99	66,57 ; 33,43
Energy carrier used by a peak source [m3/yr]	890754,83	763703,73
Emission of selected pollutants		
CO2 [ton/yr]	1797,32	1540,96
SO2 [kg/yr]	12,47	10,69
NOx [kg/yr]	1247,06	1069,19
total dust [kg/yr]	15,59	13,36
Investment expenditures [k€]	0	5,2
Total cost | CAPEX | OPEX [k€/yr]	713,1 | 223,7 | 489,3	645 | 224 | 421
Simple payback time for additional expenditures SPBT [yr]		0,1
Energy price reduction for final user [€/GJ]		0,95

Velky Meder geothermal well,

Note: the water sample was aerated.
Eh=339mV
Therefore, test results may be unreliable.



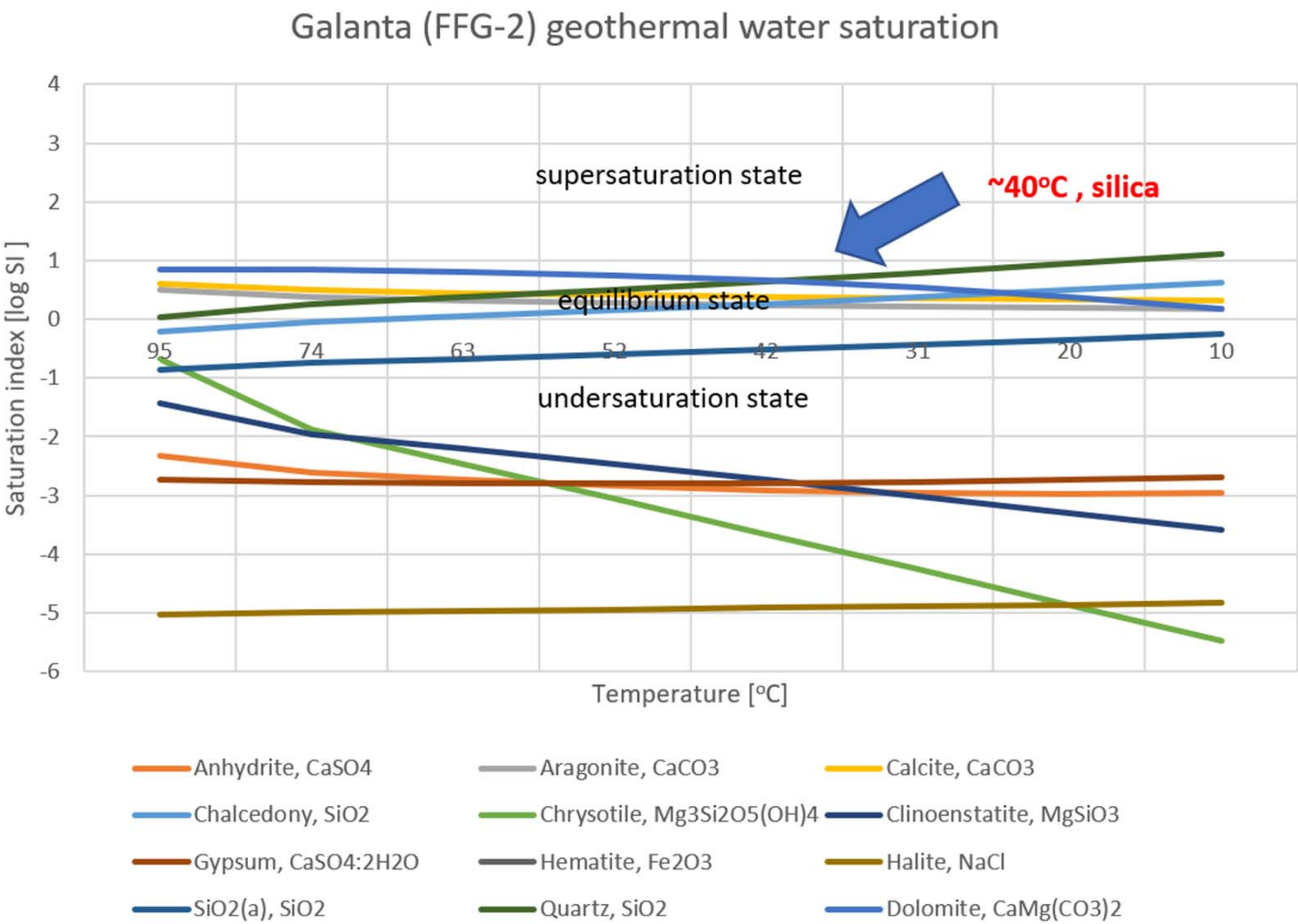
SI = 0 water is saturated/equilibrium state related to minerals

SI>0 water is supersaturated related to minerals

SI< 0 water is undersaturated related to minerals

High risk of precipitating iron minerals, such as hematite, pyrite, and magnetite in the whole temperature.
Suggestion do not cool water down below ~45°C, because of the possibility of silica scaling. We should use inhibitors.

Galanta FGG-2 geothermal well,



High risk to precipitate iron minerals, such as hematite, pyrite, and magnetite in the whole temperature.
Water cooling down ~40°C, because of the possibility of silica scaling.
We should use inhibitors.

SI = 0 water is saturated/equilibrium state related to minerals

SI>0 water is supersaturated related to minerals

SI< 0 water is undersaturated related to minerals

Note: the water sample was aerated, contain O_2.
Therefore, test results may be unreliable

Summary

The effects of retrofitting depends on:

- economic conditions (prices of energy carriers and thermal modernization treatments),
- atmospheric conditions (distribution and values of main parameters, including temperature),
- reservoir conditions (temperature, flow rate and composition of the geothermal fluid - precipitation of solid particles and corrosion).

The selection of appropriate retrofitting treatments is an optimization issue that depends on many factors.

Retrofitting activities have a strong impact on energy generation costs. They usually lower them.

Savings resulting from lower energy generation costs can finance treatment activities.

It is necessary to convince the user of energy that he/she **has an impact on the costs of energy generation**. The use of appropriate financial stimulators (feed in tariffs) may encourage the users to changes.

Thank you