Iceland Liechtenstein Norway grants

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

WP5 Methodology development and testing

Leszek Pająk

MEERI PAS

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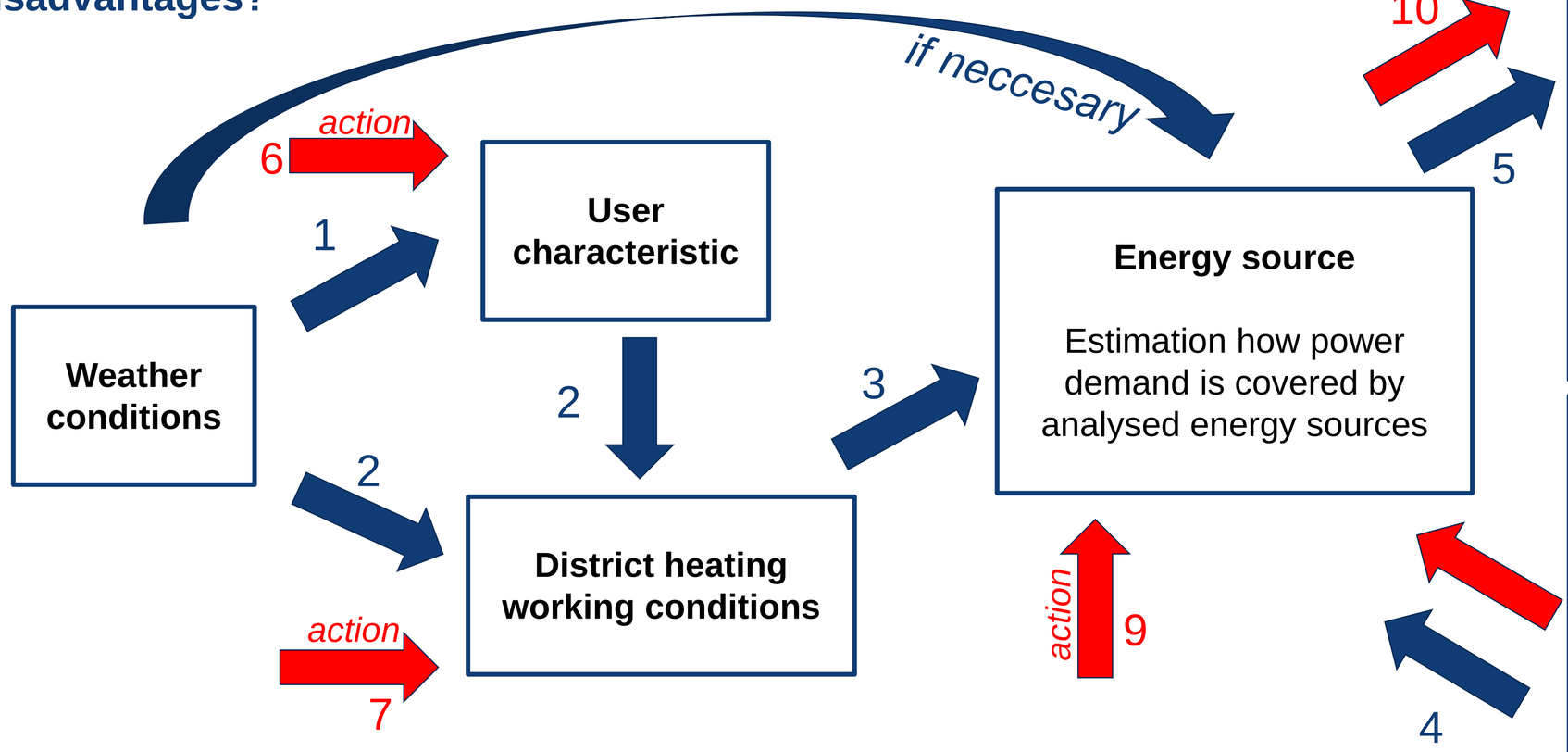
Description of the WP 5

- The purpose of the work package is **to design, create and test the core service of the project: the mathematical model based methodology**. This methodology will rely on the mathematical model of the entire heating system: from the source to the user. The model will be based on two coupled modules:
- The module **ENERGY SOURCE AND DISTRIBUTION** defining the heat source (geothermally based, supported by the peak-load boiler) and heat transmission system,
- The module **USER**, defining the characteristics of the heat end user, who is supplied with the energy from the district heating network.
- Both modules are time-discretized, as the heat demand and the process of heat distribution (including heat losses to the surroundings) are weather dependent. Therefore, **hourly data of a typical meteorological year will be used for each location**.
- The model will be developed as a **lumped parameters model** – using a finite number of nodes describing the operating conditions of the system. The conceptual model of the system will be used to determine the location and number of calculation nodes. Knowing the location of the nodes and values of independent variables at these nodes, sought values of the entire energy system can be determined *dynamically in time.*
- **The activities provided for in WP5 have preserved logical continuity**: from the development of the conceptual model, through the development of the mathematical model, its calibration and testing, finishing with improving the methodology. The activities and the output delivered in this work package will lay a foundation for the WP6 activities, among others for the online analysis tool development to reach bigger audience.
- **The target group of the WP5 are designers and operators** of geothermal district heating systems as well as **the environment**, which will benefit from the lower stress on the geothermal reservoir and decreased combustion of conventional fuels in localities which adapt the developed methodology. Therefore, this work package with its output will directly address the outcome “Adverse effects of human activities on the environment reduced”.

How we are going to work?

Our target in WP 5 is to develop a model which is able to answer the question: (1) is it worth to improve an energy user characteristic? (2) what kind of expectations are realistic? (3) what are the advantages and disadvantages?



Data processing

- Energy production by each energy source
- Primary energy carrier consumption, including pumping, and geothermal water exploitation and reinjection
- Pollutants emission
- Financial expenditure estimation CAPEX
- Operating cost estimation OPEX
- Estimation of economical factors
- Estimation of techno-economical factors
- Estimation of techno-ecological factors
- Estimation of eco-economical factors

Data interpretation step 1

Data interpretation step 2 (action → result)

Database

1. Information about operating installations (useful during the model calibration process)

2. Primary energy carriers price

3. Financial expenditures related to:
   - modernisation, retrofitting of DH
   - modernisation, retrofitting of users installations or building itself

4. Data useful during output interpretation

1st step – model calibration or state of the art

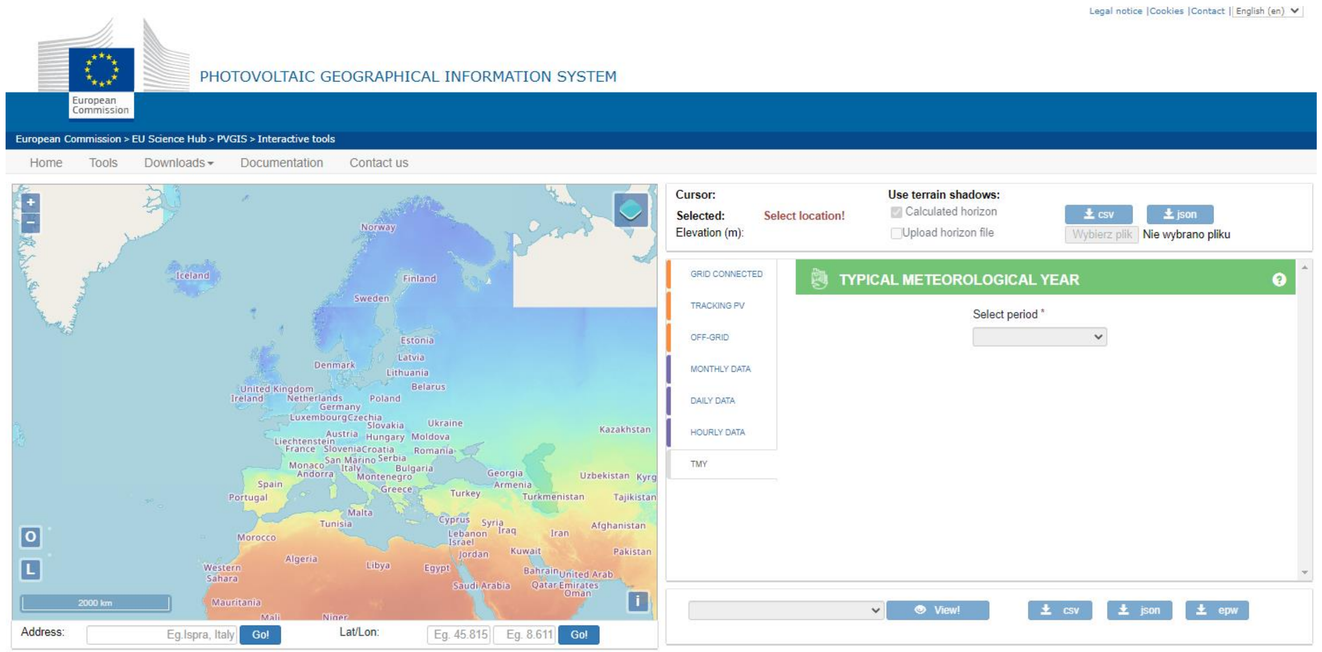
2nd step – assessment of the effects of the proposed changes in the system

action = improvement

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,

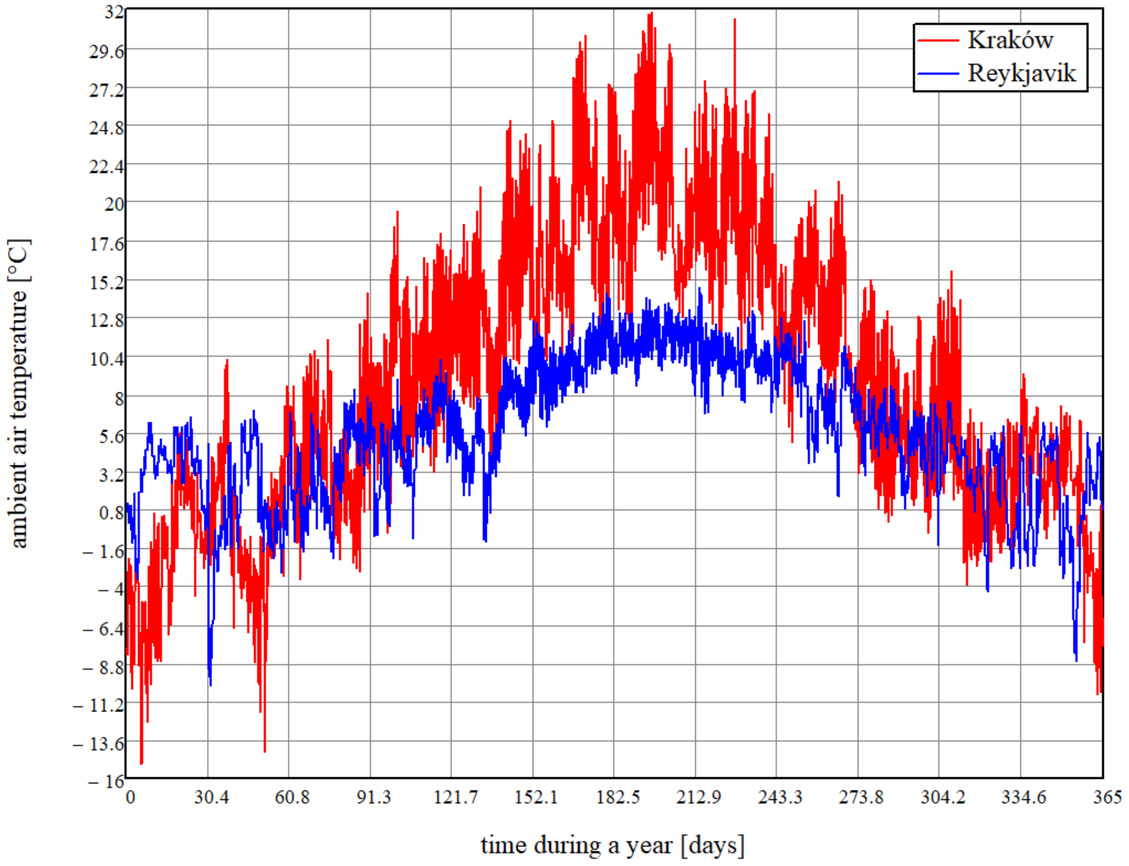


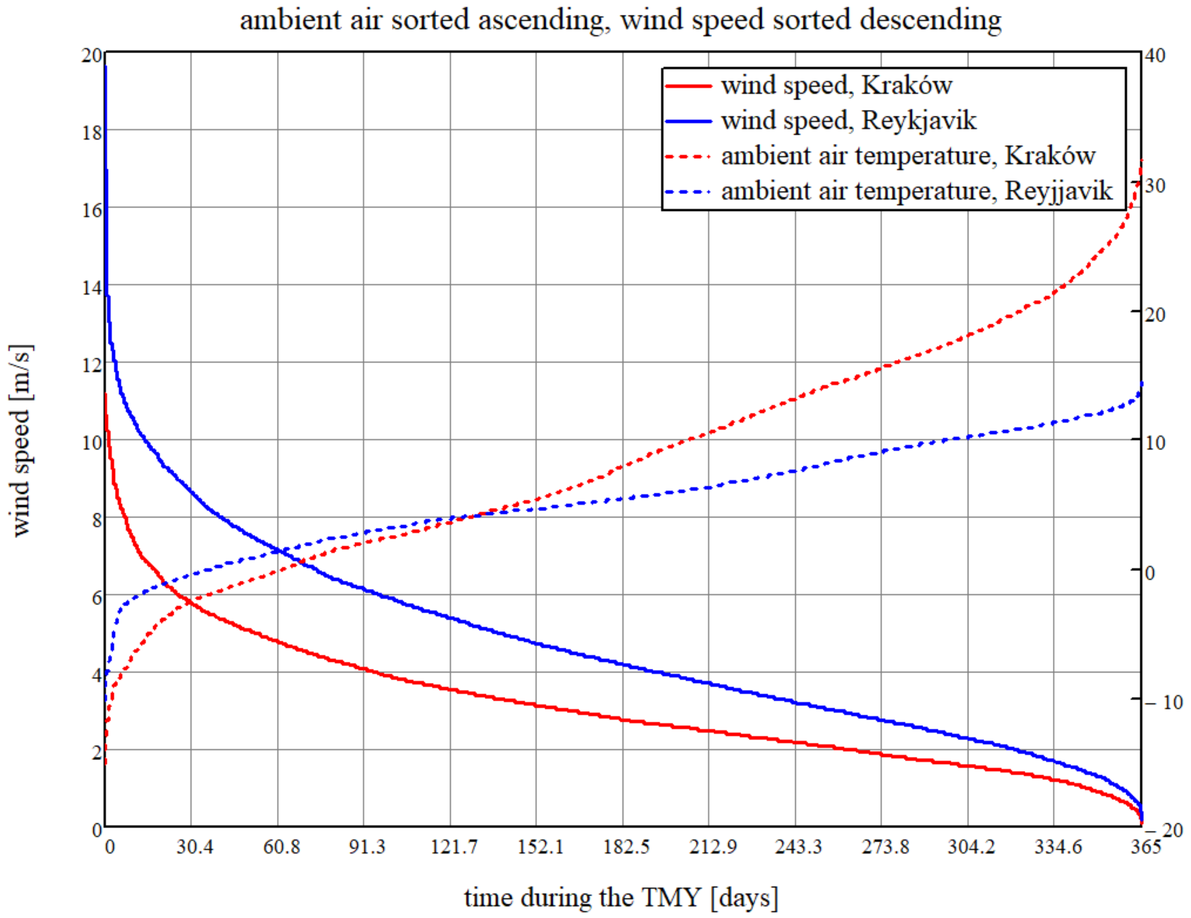
The data set has been produced by choosing for each month the most "typical" month out of 10 years of data. The variables used to select the typical month are global horizontal irradiance, air temperature, and relative humidity.

Weather conditions

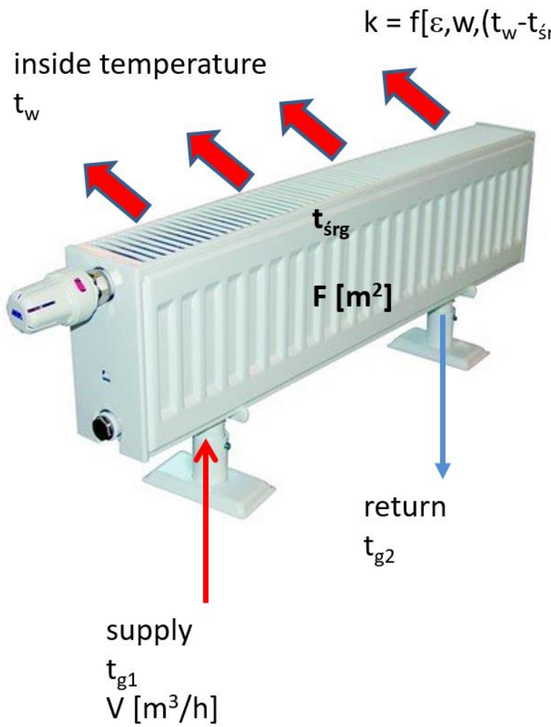
Based on the „Photovoltaic Geoghraphical Information System**”** https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#TMY

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





User characteristic



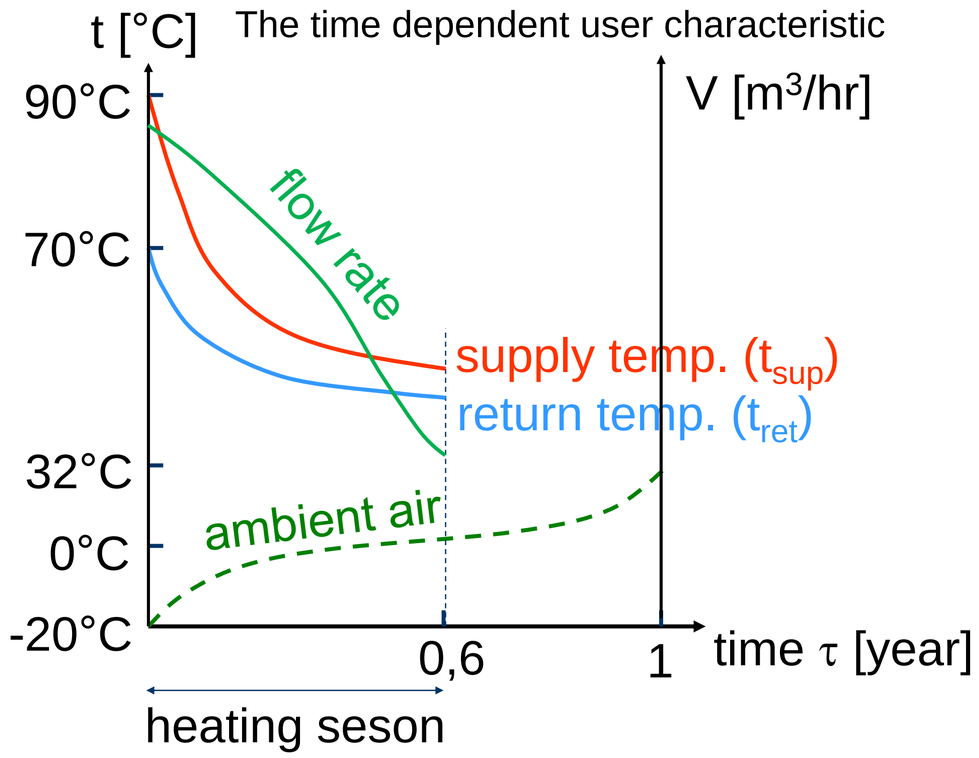
„force" for heat exchange $\Delta t_{śg}=t_{śg}-t_w$

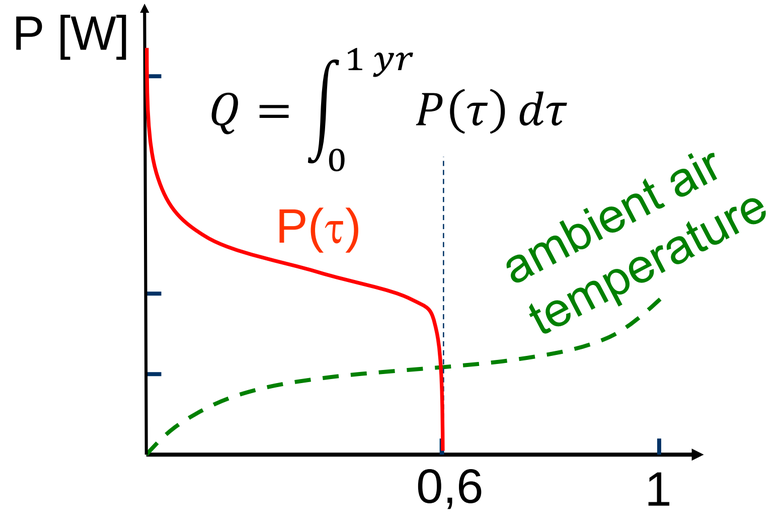
$$\begin{cases} P = k\,F\left(t_{śrg} - t_w\right) \\ P = V\,\rho\,c\left(t_{g1} - t_{g2}\right) \end{cases}$$

$$\Delta t_{śg} := \frac{\left(t_{g1} - t_w\right) - \left(t_{g2} - t_w\right)}{\ln\left(\frac{t_{g1} - t_w}{t_{g2} - t_w}\right)}$$

$$V := V_{max} \cdot \left(\frac{t_w - t_z}{t_w - t_{z_min}}\right)^{0,33}$$

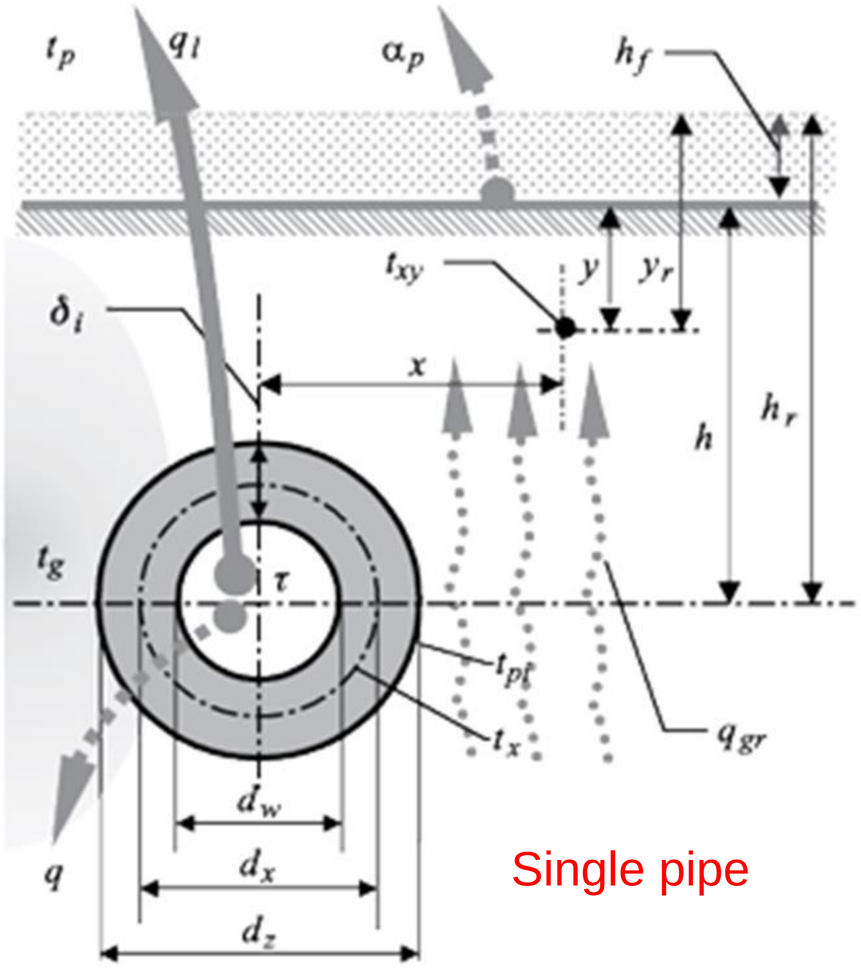
Characteristic of a user



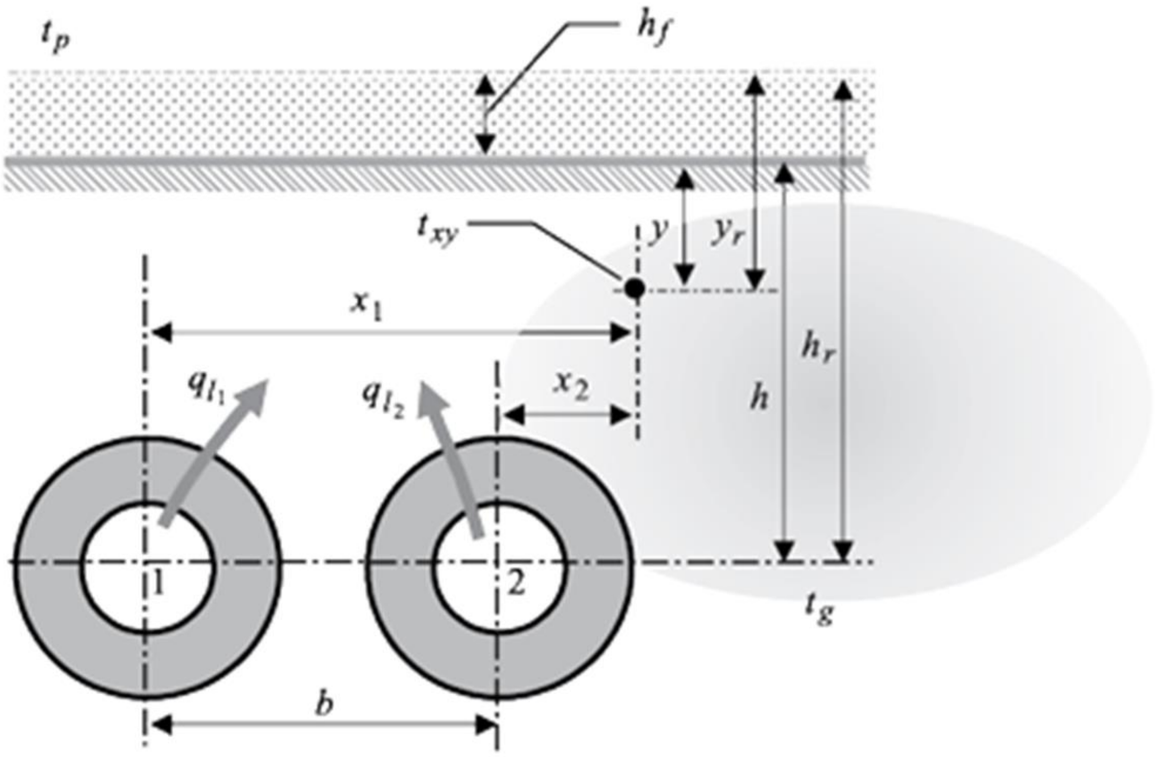


District heating grid characteristic

District heating working conditions:
- heat losses,
- pressure losses,
- power management.



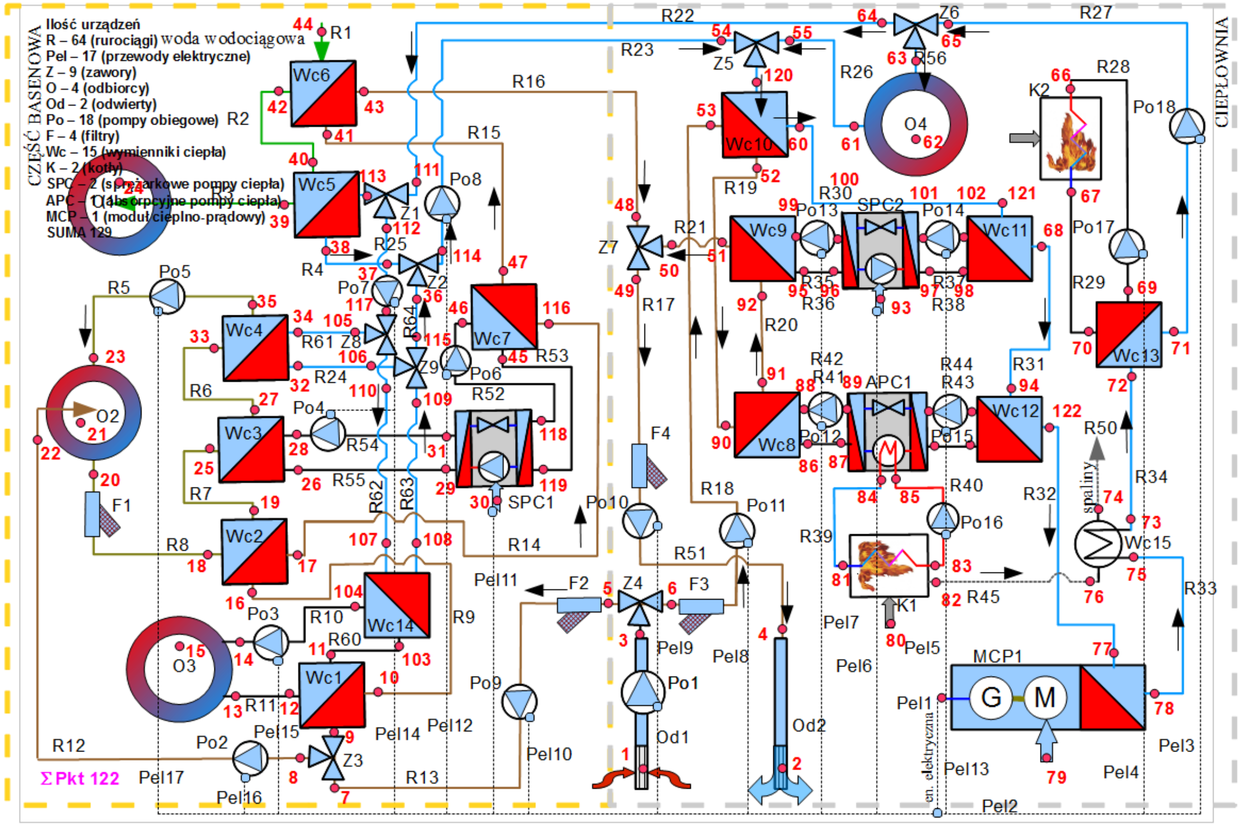
Single pipe



Duble pipe

Energy source

Method used: the lumped parameters model

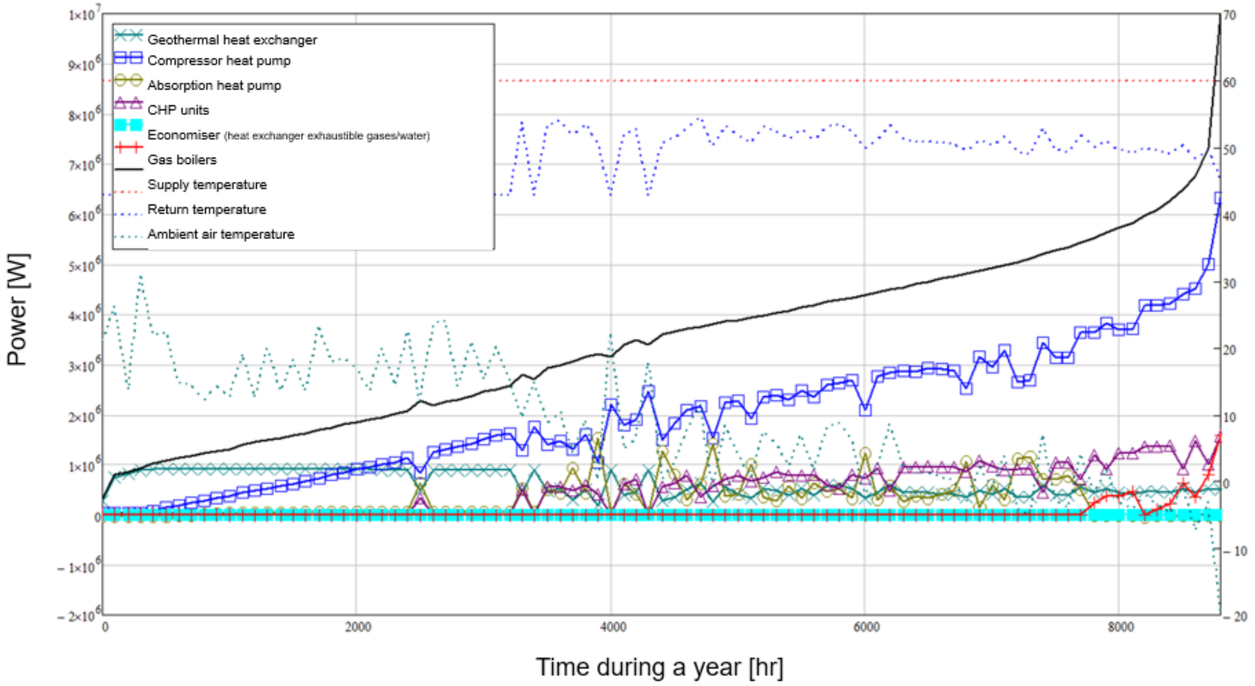


Each node of the system is described by:

- temperature (calculated in each time step),
- pressure (calculated in each time step),
- flow of water (geothermal or DH fluid, calculated in each time step).

Each device in the system is described by:

- efficiency (constant or as a function),
- installed power (constant for considered unit),
- limitations (max temp., max flow, max. power, etc.).



Energy production for each energy source is calculated $Q[J] = \int_0^{1\,yr} P(\tau)\,d\tau$

Thank you