



District heating network optimization with EA-SAS Heating

Information about network:

The District Heating (DH) network of Šakiai city first started operation in 1963 – 1964. The first heat sources were 7 coal burning boilers, which were later replaced with the 8 liquid fuel burning boilers. At first this was enough to heat current commercial users as well as some blocks of flats. Some years later due to the city spreading north another boiler house was built. 6 liquid fuel boilers were built and some boilers of the same type were added to heat a planned nearby hospital. So, using two boilers house the whole city had heat. These liquid fuel boilers were changed to burning gas. Finally to modernize heat production biomass boilers were installed to change the fossil fuel burning ones, this change led to lower cost of heating for consumers.

Lastly, it was decided to use new innovative solutions to try and optimize heat production to increase sustainability and reduce carbon footprint. For this task Energy Advice solution EA-SAS Heating was chosen.

Facts:

Number of consumers: 105

Length of network: 16,453 km

Distribution network age: 58

Age of facilities: biomass boiler 7 years; gas 2007-2008.

Two boiler houses.

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Introduction

District Heating network operators face energy transition issues. CO2 emission limitation force District Heating companies to increase of operation effectiveness, heat generation from renewable energy sources and waste energy integration. Finally, evolution of DH companies should be sustainable due to high Return of Investment rate. The limitation factor is current unsatisfactory performance indicators of DH network, such as energy transmission efficiency, OPEX for maintenance. Current article yield case study of DH company, which have installed EA-SAS Heating solution and since 2019 operates DH network in optimum.

Former situation

DH network operator control supply temperature according to environmental temperature. Minimum Supply Temperature from boiler house (further Supply Temperature) in the years before 2019 was 70°C. Average Return to Boiler house temperature (further Return Temperature) during Hot period was 50°C. The Hot and Cold periods means periods, there building heating is off and on. Heat production, Consumption and efficiency monthly data is described in Table 1.

Table 1. Heat production

2018	1	2	3	4	5	6	7	8	9	10	11	12
Produced, MWh	3768	3968	3623	1132	639	506	381	505	557	1650	2692	3664
Consumption, MWh	3259	3438	3144	893	372	319	257	305	360	1326	2383	3087
Efficiency	86%	87%	87%	79%	58%	63%	67%	60%	65%	80%	89%	84%



Digital Twin tools

During the Project, the EA-SAS Heating Cloud solution, powered by Energy Advice, was installed for real time Digital Twin. The EA-SAS Heating is used for data collection from Boiler House and Consumers. The real time data analytics math was produced by Energy Advice team and implemented using Python scripts, which are running in EA-SAS Heating.

GIS data was collected and Thermal - Hydraulic model was developed using EA-PSM Hydraulic software [1], powered by Energy Advice. EA-PSM Hydraulic software could be used as standalone application, also as have full integration with EA-PSM Heating as backend application.

EA-PSM software has GIS powered by ESRI Technology.

Project process

Heating network model was created using EA-PSM GIS feature. It is possible to import already prepared GIS map data in GDB or MDB format or create the GIS data in EA-PSM. During the project, Thermal – Hydraulic model was created from scratch and required element information collected from Customer provided data.

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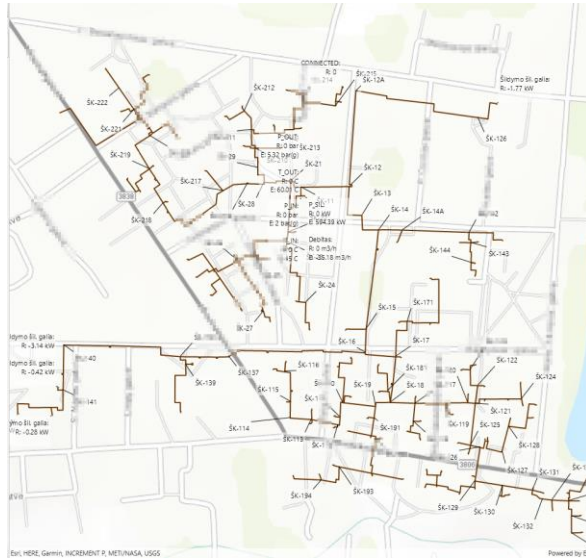


Figure 1 GIS of city (EA-PSM hydraulic view)

EA-PSM Data Model collects all possible data about the network: pipe diameter, pipe length, insulation type, pipe height, pump characteristics (these can be selected from already integrated library or modelled by user), heat source characteristic, Heat substation characteristics.

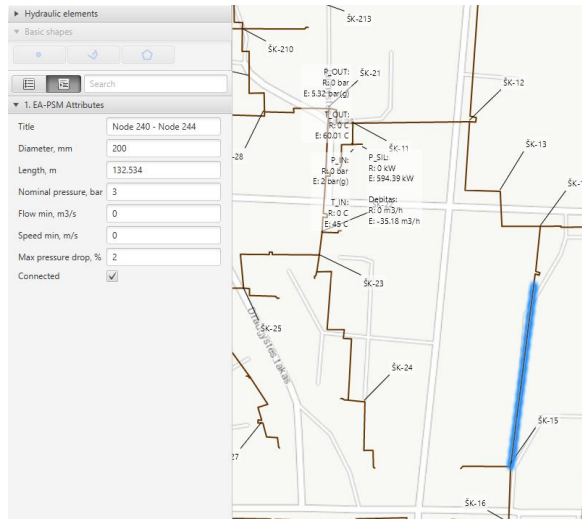
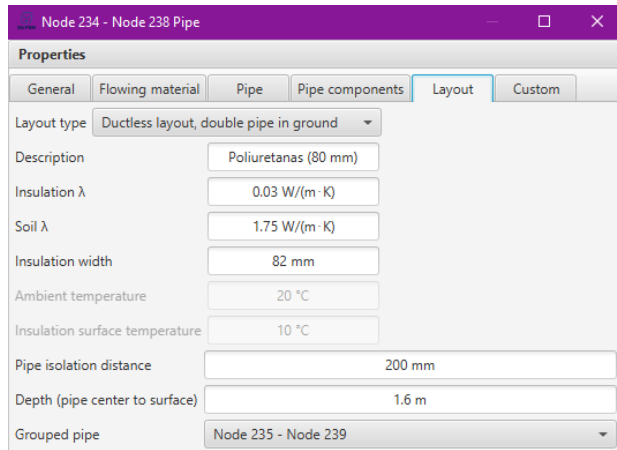


Figure 2 Selected pipe and most important information (EA-PSM hydraulic view)

Selected pipe can be further analyzed to set flowing liquid, its parameters, set isolation, its parameters and pipe placement. These parameters affect final calculation result, so it is needed to correctly set them.



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Figure 3 Pipe layout property window (EA-PSM hydraulic view)

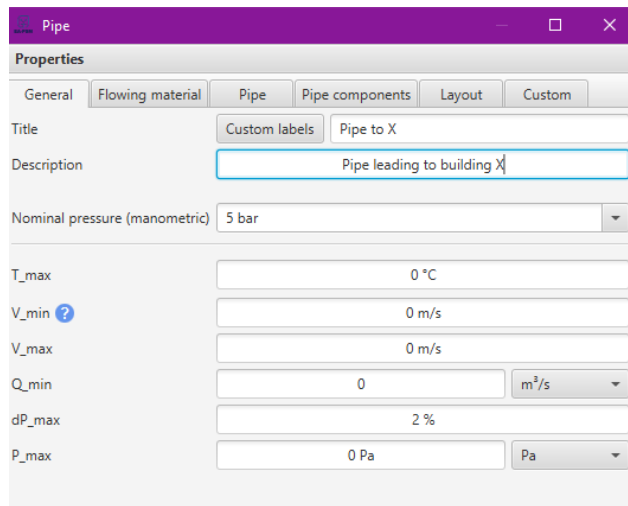
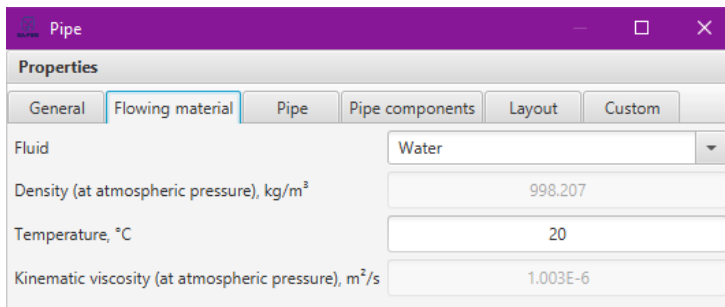
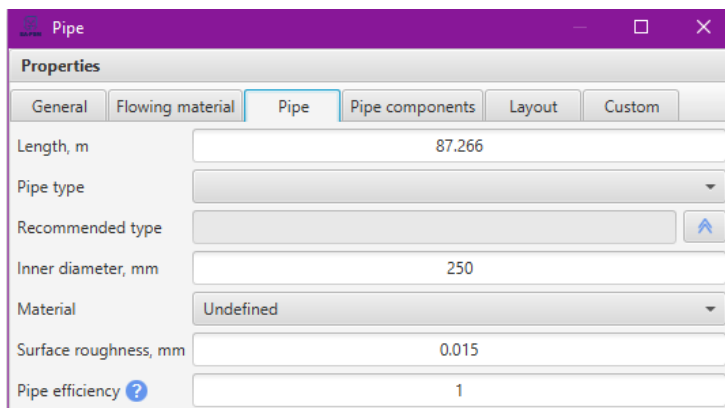


Figure 4 General pipe properties (EA-PSM hydraulic view)



Properties					
General	Flowing material	Pipe	Pipe components	Layout	Custom
Fluid	Water				
Density (at atmospheric pressure), kg/m ³	998.207				
Temperature, °C	20				
Kinematic viscosity (at atmospheric pressure), m ² /s	1.003E-6				

Figure 5 Pipe flowing material properties (EA-PSM hydraulic view)



Properties					
General	Flowing material	Pipe	Pipe components	Layout	Custom
Length, m	87.266				
Pipe type	[Dropdown]				
Recommended type	[Dropdown] [Up Arrow]				
Inner diameter, mm	250				
Material	Undefined				
Surface roughness, mm	0.015				
Pipe efficiency ?	1				

Figure 6 Pipe geometrical properties (EA-PSM hydraulic view)

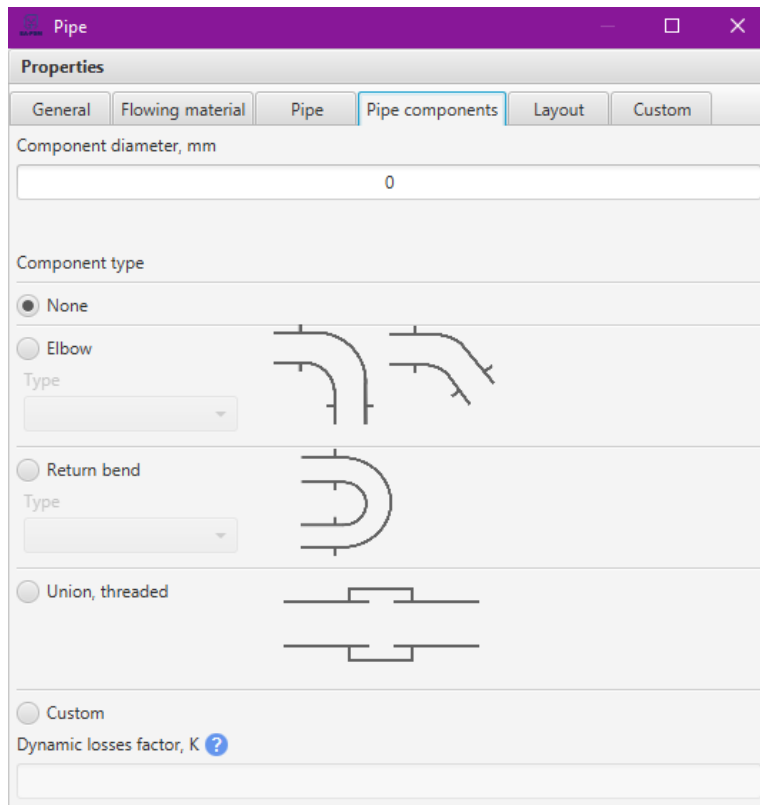


Figure 7 Setting different kind of pipe components (EA-PSM hydraulic view)

Pump models are selected from a library and can be configured according to specific cases or modelled completely. This allows to use most exact characteristics for modelling pressure, network flow volume and pump electrical efficiency.

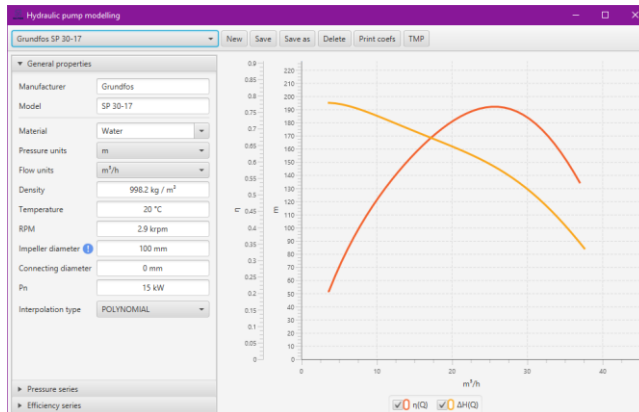


Figure 8 Pump characteristics (EA-PSM hydraulic view)

Also, by creating a Digital Twin of the heating network it is possible find the most optimal pump for each network working mode. Detailed explanation of process is explained in [2]

Heat energy Consumer model

Heat and hot water consumers are modelled according to collected historic data for consumption. Collected monthly data is put through algorithms in order to create forecast of accounting for each hour metrological data. This data can be improved by implementing smart readers into model. Using smart meters that are connected to internet it is possible for them to send data in real time to model. Also, if smart readers transmit data in 1-10 minute intervals, this data can be used to see physical effects of controlling supply temperature, like thermal movement, stresses in pipe and similar information, this allows to not only optimize supply temperature, but also provide feedback on network and user integrity.

These smart meters are also configured to be shown in one map. This gives user ability to use one map to see all metering devices from different providers in one place. This map is configured and accessed through web application.



Figure 9 Example of smart meters on map (EA-SAS Heating view)

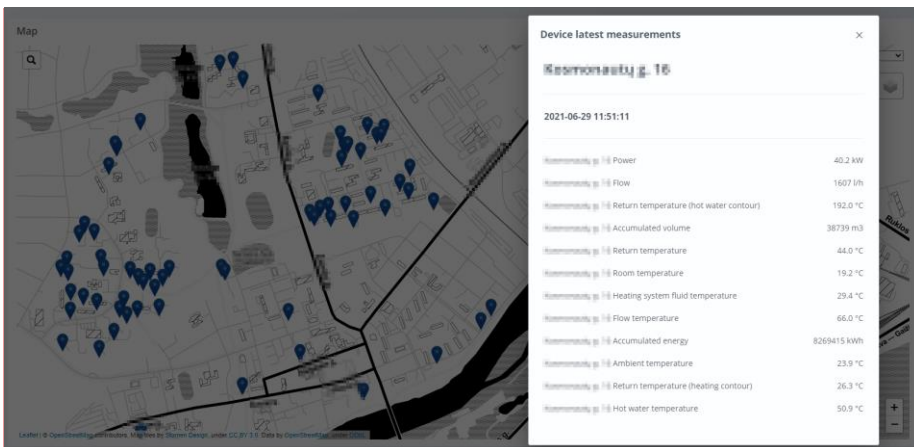


Figure 10 Smart meter readings (EA-SAS Heating view)

Map element is easily configurable so adding new meters is streamlined. All meters can be configured to show wanted values at any moment in time.

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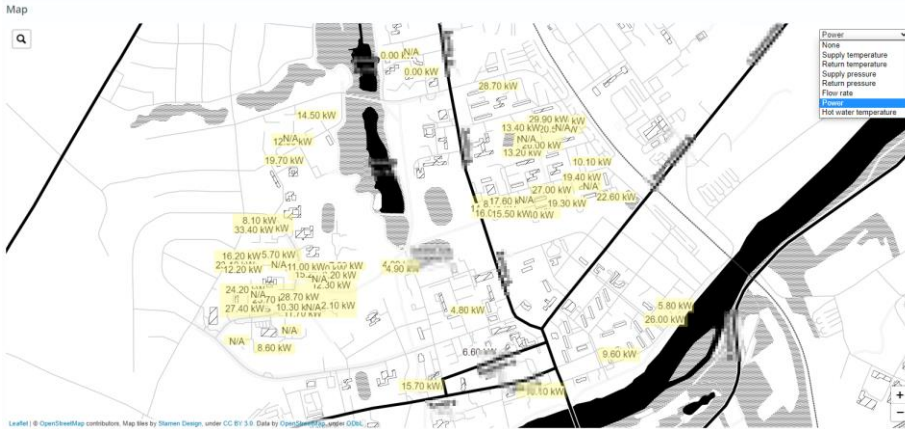


Figure 11 Smart meter metering data presentation on map (EA-SAS Heating view)

Graph below shows forecast of consumer heat demand. The same principal is used for hot water demand.

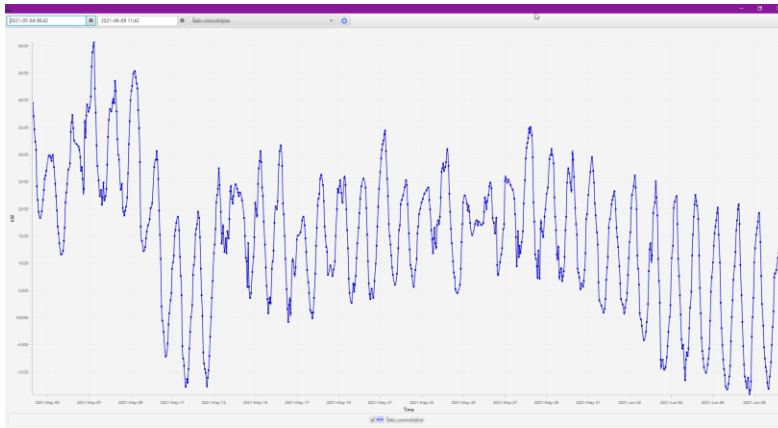


Figure 12 Heat demand forecast (EA-PSM Hydraulic view)

These values are calculated for each hour of the day, then used in calculations to determine what is the total heat demand for consumers at any given time of day.

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The Digital Twin model takes the total heat demand of consumers, adds the heat losses caused from pipes to generate the total amount of heat needed to generate at any operating moment. This allows for users of EA-PSM Heating to do automatic calculations for heat generation optimization.

Thermal calculations

Hydraulic calculations

The first step in validating a Digital Twin model of the city is to test hydraulic flow calculations. These are done in EA-PSM using Newton – Raphson method, one can read more about it in [3] and [4]. After these calculations succeed next steps are thermal calculations.

Losses in pipes

By using pipe length, diameter, isolations and other parameters heat losses in pipes are calculated. Information and validation of calculations is provided in [4].

Optimization Strategy

Optimization strategy refer to full description of Thermal Hydraulic model of District heating network. Basic energy balance equation:

$$Q_{production} = Q_{Losses} + Q_{consumption} \quad (1)$$

Losses in pipe are described as:

$$Q_{Losses} = \lambda_{supply_pipe} \cdot (T_{supply} - T_{enviromental}) \cdot t + \lambda_{return_pipe} \cdot (T_{return} - T_{enviromental}) \cdot t \quad (2)$$

where λ –pipe to environment heat losses coefficient, kW/K, t – time, hours.

Consumer behavior is described by two model from building perspective and network perspective:

$$Q_{consumption} = \lambda_{building} \cdot (T_{inside} - T_{envirom}) \cdot t \quad (3)$$

$$Q_{consumption} = c \cdot \rho \cdot V \cdot (T_{supply} - T_{return}) \cdot \eta_{heat_exchanger} \cdot t \quad (4)$$

Minimization of grid losses by solving equations (1) – (4), including grid topology, yields requirement of maximum fluid flow.

Usually, Consumer Heat Substations have heat exchanger with control valve and automation (PLC). The PLC control building side supply temperature and guaranty required temperature by flow control through heat exchanger. So, fluid flow rate from Grid side depends on Heat demand and supply temperature. Higher supply temperature leads to lower flow rate and vice versa. Finally, lower supply temperature leads to higher flow rate and higher flow rate leads to lower thermal losses in pipe.

By joining these calculations and the forecast demand from consumer data final calculations are completed and visualized in EA-PSM GIS platform. This allows to quickly bring up most important network parameters in user friendly way. Below are examples of different calculation results in one network

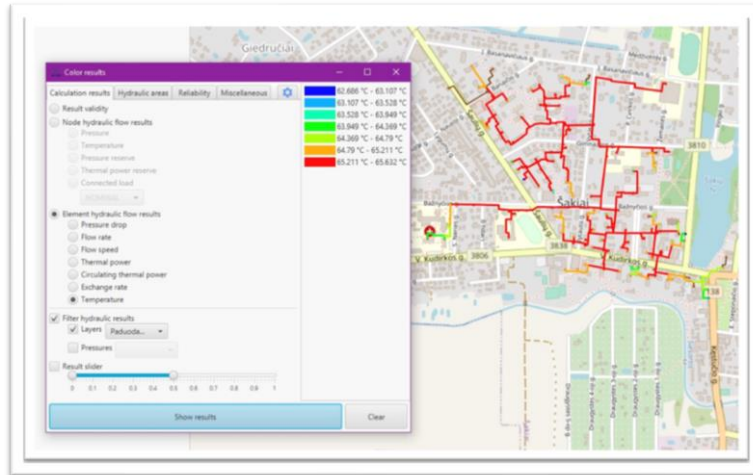


Figure 13 Thermal calculation temperature results in network (EA-PSM Hydraulic view)

Project results

Energy savings due to optimization are described using KPI. Grid operation is affected by environmental temperature, consumer behavior, pipe insulation maintenance, consumer building maintenance, etc. For example, due to consumer behavior, building infiltration could change, which leads to higher or lower thermal consumption, which leads to higher or lower grid losses.

The KPI is calculated to eliminate environmental temperature effect:

$$\text{Consumption coef} = \frac{Q}{(T_{ref} - T_{environmental}) \cdot \text{hours}}, \text{ kW/K} \quad (5)$$

Where $T_{ref} = 22^{\circ}\text{C}$ Consumer building inside temperature.

The same approach is used for Production side KPI:

$$\text{Production coef} = \frac{Q}{(T_{ref} - T_{environmental}) \cdot \text{hours}}, \text{ kW/K} \quad (6)$$

Grid losses coefficient:

$$\text{Grid coef} = \text{Production coef} - \text{Consumption coef}, \text{ kW/K} \quad (7)$$



Project results are presented in Table 2.

Table 2. Project results

Year	Degree Hours	Production coef, kW/K	Consumption coef, kW/K	Grid coef, kW/K	Production, MWh	Consumption, MWh	Grid Losses, MWh	Energy Savings (from Grid losses)	Energy Savings (from Production)
2018	119664	2095,11	1624,99	470,12	23091,04	19148,98	3942,06	Reference	
2019	106116	2534,63	1781,08	753,55	17698,53	14380,76	3317,77	16%	3%
2020	108973	1871,17	1502,50	368,68	16236,70	13586,72	2649,98	33%	6%

From Table 2 could be seen, that heat demand reduced from 1624 kW/K in 2018 up to 1502 kW/k in 2020. On other hand, heat consumption increased up to 1781 kW/k in year 2019. However, heat consumption increase in 2019 by 157 kW/K, led to production increase by 439 kW/k. The Optimum grid operation was launched on September of 2019, so grid operation was stabilized and Grid Losses reduced up to 3317 MWh in 2019.

Finally, demand reduction in 2020 and optimum operation allowed decrease production, and Grid Coef up to 368 kW/k, Grid Losses reached only 2649 MWh.

EA-SAS Heating benefit was calculated comparing 2019 and 2020 with reference year 2018. During the last three month in 2019 Grid Losses was reduced by 625 MWh (16% from Grid Losses in Reference year). During the 2020, Grid Losses was reduced by 1293 MWh (33% from Grid Losses in Reference year).



Bibliography

- [1] EnergyAdvice, „EA-PSM manual,“ 2018. [Tinkle]. Available: https://easas.energyadvice.lt/EAPSM2018_HYDRAULIC_WEB_MANUAL_EN/.
- [2] V. Siozinyis ir M. Jonaitis, „Combined Electricity and Hydraulic Analysis of Cascade Heating Supply Infrastructure with EA-PSM“.
- [3] UAB Energy Advice, „EA-PSM Hydraulic load flow validation case“.
- [4] UAB Energy Advice, „Hydraulic Calculations“.
- [5] UAB Energy Advice, „EA-PSM Hydraulic 2019 thermal pipe losses,“ 2019.

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