

TOOLS AND SOFTWARE - DISTRICT MODELLING – ENERGYPRO

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energyPRO

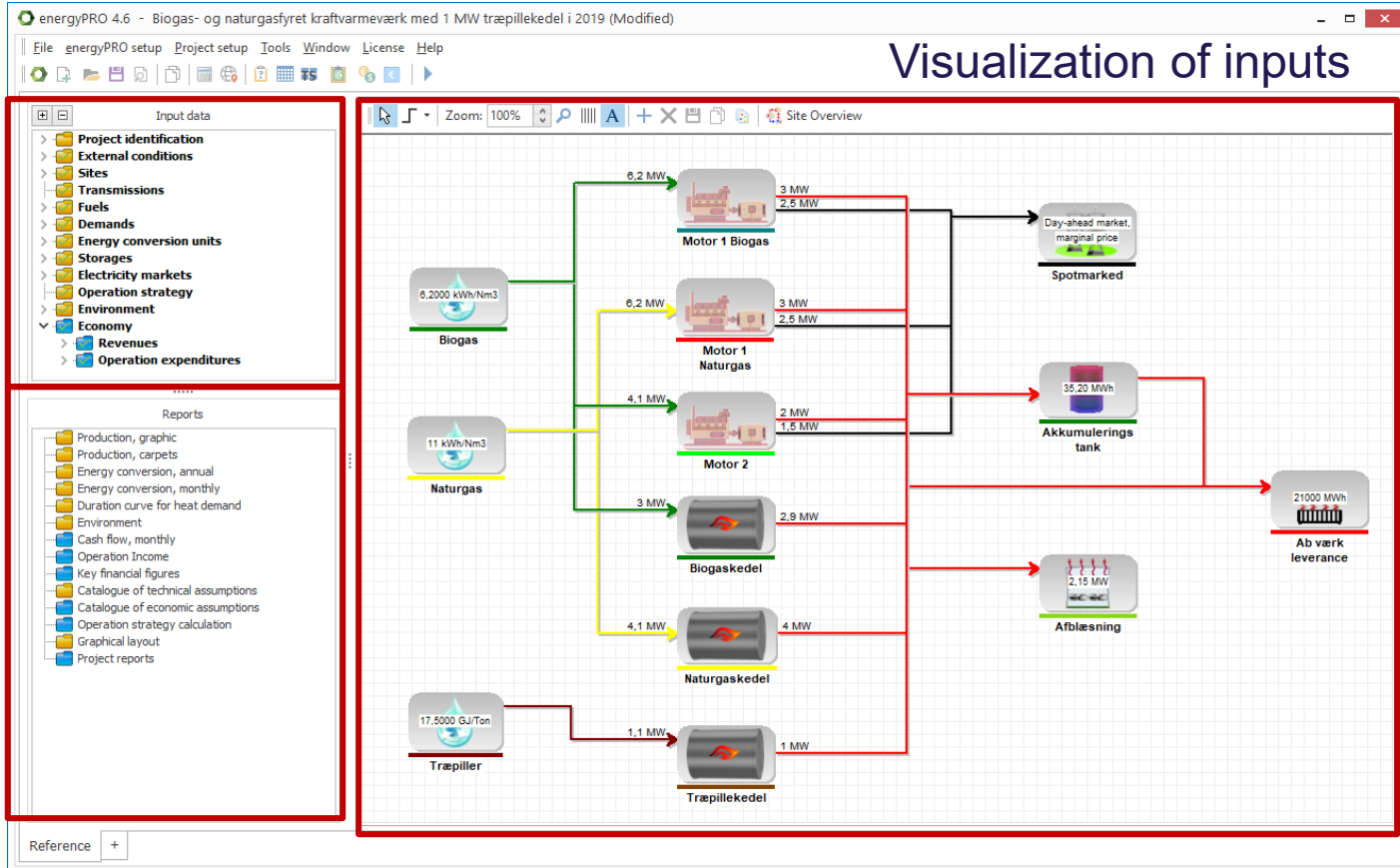
- Commercial tool developed and maintained by EMD International A/S. (www.emd.dk)
- A deterministic energy balancing tool for combined techno-economic simulation and analysis of energy projects.
- Conversion units are operated based on a priority list (least-cost or user-defined).
- Simulations can be done down to 10 minutes steps over any given timespan.
- energyPRO can e.g. be used for:
 - Simulating the operation of an energy plant
 - Making detailed investment analyses
 - Modelling industrial cogeneration and trigeneration
 - Simulating energy plants participating on different electricity markets
 - Analysing the interaction between separate energy plants
- Primarily used for simulation of district heating plants. (not the grids, though)



energyPRO UI

Visualization of inputs

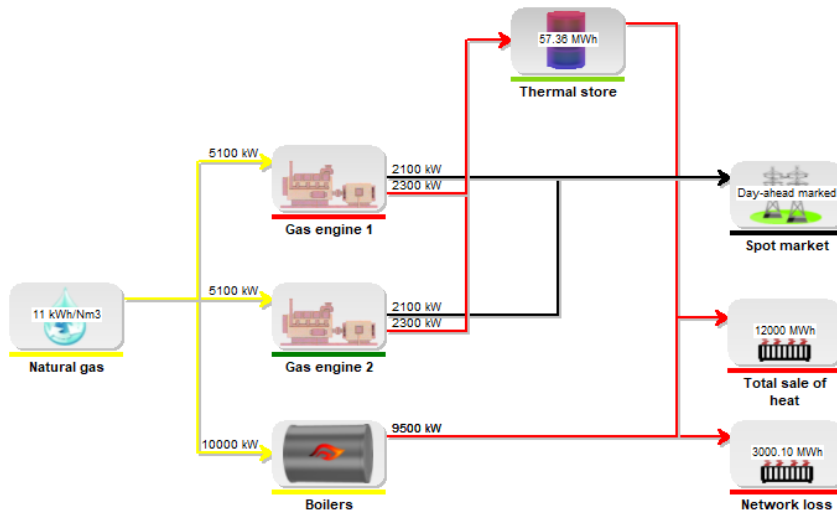
Inputs



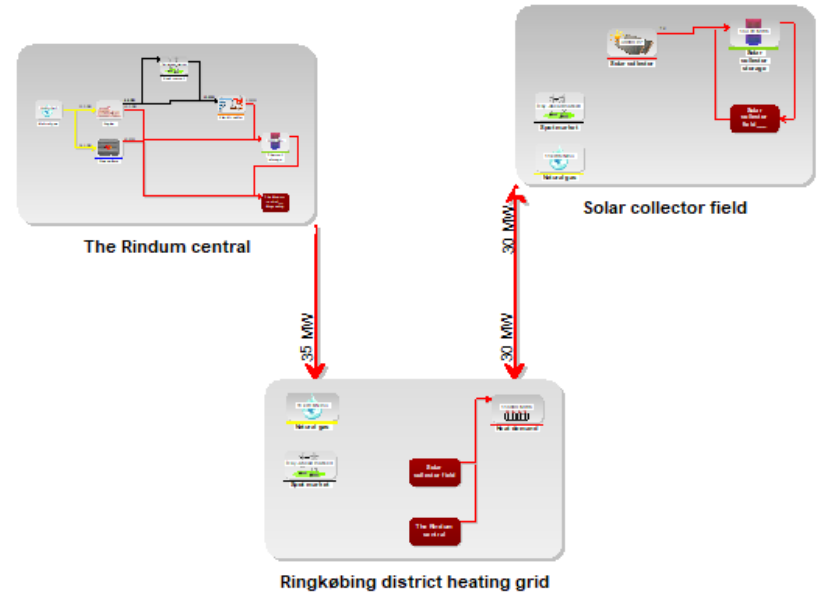
Outputs

Examples of district heating plant models

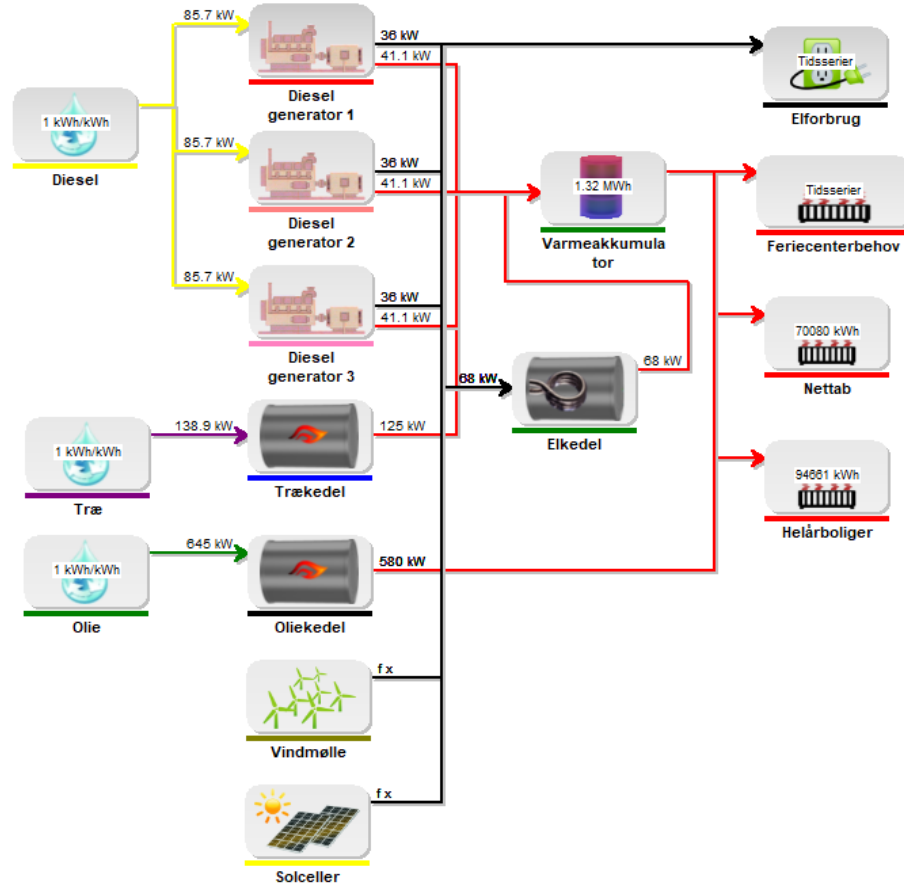
Simple one site plant



District heating system with plants in several sites



Also possible to simulate island energy systems

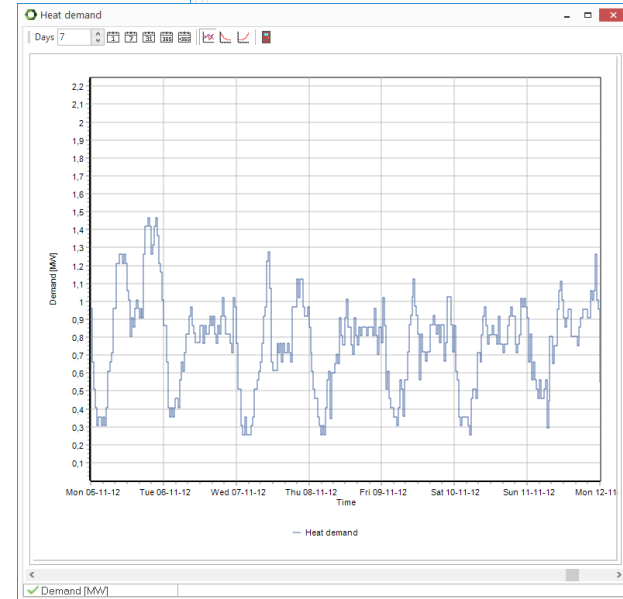


Energy demands in energyPRO

- Heat
 - Electricity
 - Process heat
 - Cooling
 - (Fuel)
-
- energyPRO aims to meet all energy demands in a given model by utilizing energy conversion units, storages, and electricity markets.
 - Also possible to produce electricity for sale on electricity markets.



The screenshot shows the 'Total sale of heat' configuration window. The window title is 'Total sale of heat'. The 'Name' field is 'Total sale of heat' and the 'Heat demand' field is 'Heat demand'. The 'Development of Demand in Planning Period' section has 'Demand in Specified year' set to 'Fixed' with a value of '12000,0' MWh. The 'Demand depends on external conditions' section is checked, with a 'Dependent fraction' of '75,0 %' and a 'Restricted season for dependent demand (dd-mm)' of '01-09' to '31-05'. The 'Formula for dependency' section is set to 'Depends linear on ambient temperatures' with a 'Reference temperature' of '17,0 °C' and a 'Symbol for ambient temperatures' of 'T'. The formula is $0,1637 \cdot \text{Max}(17,0 - T, 0) + 0,3425$. The 'Fixed profile of demand' section is set to 'Daily' with a table showing two time periods: 06:00 to 19:00 with a ratio of 10,0, and 19:00 to 06:00 with a ratio of 8,0. The window has 'Add line', 'Delete line', and 'As graphics' buttons.



Energy conversion units in energyPRO

- Power plants
- CHP plants
- Fuel boilers
- Electric boilers
- Electric-driven heat pumps and chillers
- Absorption heat pumps and chillers
- Electrolysers and other fuel producing units
- Wind turbines
- PV
- Solar thermal
- Etc.

Name: Wind farm

Calculation type

- Annual production calculated
- Fixed annual production

Non availability periods

Wind speed specification

Time series: Wind_54.07N_9.0

Measure height: 50 m

Hub height: 67 m

Hellmann exponent: 0.15

Advanced (scale power curve)

Percentage

Absolute (Max)

Max. power in original power α : 2,000 kW

Max. power in modified power α : 6,000 kW

Wind speed	Power [kW]	Power
3.00	0.00	0.00
4.00	66.30	198.90
5.00	152.00	456.00
6.00	280.00	840.00
7.00	457.00	1,371.00
8.00	690.00	2,070.00
9.00	978.00	2,934.00

Add line Delete line

Power curves

Operation	Fuel input	Elec. consur	Heat Consur	Proc. Heat C	Fuel output	Heat	Process Hea	Elec. power	Cooling
Performance	MW	MW	MW	MW	MW	MW	MW	MW	MW
Max.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Add line Delete line Enable formulas in power curve

Energy storage systems in energyPRO

- Thermal
 - Cooling
 - Fuel
 - Battery
 - Stand-alone
 - Part of electric vehicle
- Pumped hydro station

Thermal store

Name: Thermal store

Thermal store Non availability periods

Volume [V]
1000,0 m³

Temperature in the top [Tt] °C
90,00

Temperature in the bottom [Tb] °C
RT()

Utilization
90,0 %

Storage capacity :
57,36 MWh as of Tue 1. January 2019

Minimum storage content in % of storage capacity
0,0 % 0,00 MWh

Storage Loss

Storage Height [h] 14,20 m Insulation Thickness [s] 300,00 mm Thermal Conductivity [Lambda] 0,0370 W/(m°C)

Ambient Temperature [Ta] <Constant> 20,00 °C

Formula for loss at full store User Defined
$$\frac{(\lambda \cdot 1000 / s) \cdot \pi \cdot \sqrt{V / (h \cdot \pi)}}{(2 \cdot h + \sqrt{V / (h \cdot \pi)})} \cdot (Tt - Ta) / 10^6$$
 MW

Formula for loss at empty store
$$\frac{(\lambda \cdot 1000 / s) \cdot \pi \cdot \sqrt{V / (h \cdot \pi)}}{(2 \cdot h + \sqrt{V / (h \cdot \pi)})} \cdot (Tb - Ta) / 10^6$$
 MW

OK Cancel

New E Cars

Name: New E Cars

Storage and charging **Charging Restrictions**

Power and capacity units MW/MWh

Battery and Demand

Capacity 0 MWh Non availability periods

Driving demand as time series:

Charging / Discharging

	Capacity	Efficiency
Charging Power	0,0 MW	85,0 %
Discharging Power	0,0 MW	85,0 %

Comments:

OK Cancel

Fuels in energyPRO

- Customizable.
- Possible to add restrictions to available amounts and to add fuel storage.
- Also possible to require the fuel to first be produced by other units in the model.
- Emissions for fuel usage can be added.

Biogas

Name: Biogas

Unit: Nm3 Heat value: 6,200 kWh/Nm3

Advanced

Restrictions and storage Fuel storage, max utilizable content: 0 Nm3

Offered fuel as time series

#	Date	[MW]
1	01-01-2017 00:00:00	4,5000
2	01-01-2018 00:00:00	4,5000

Unit: MW

Buttons: Copy all, Copy selected, Paste, Delete all, Delete selected

Buttons: Add line, Delete line

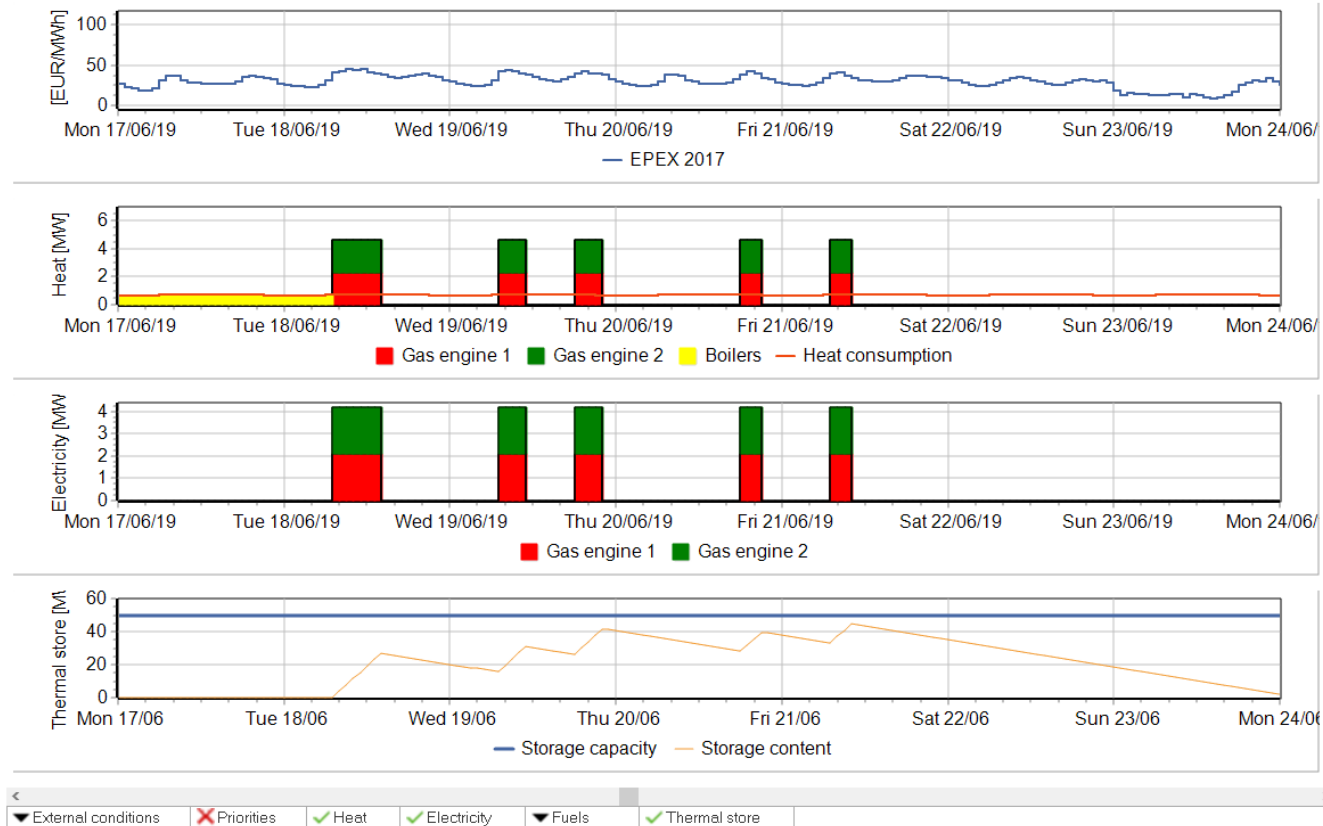
Move timeseries on:
 Weekly basis
 Date basis

Comments:

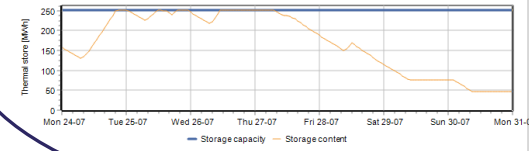
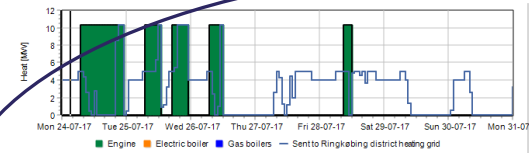
Buttons: OK, Cancel



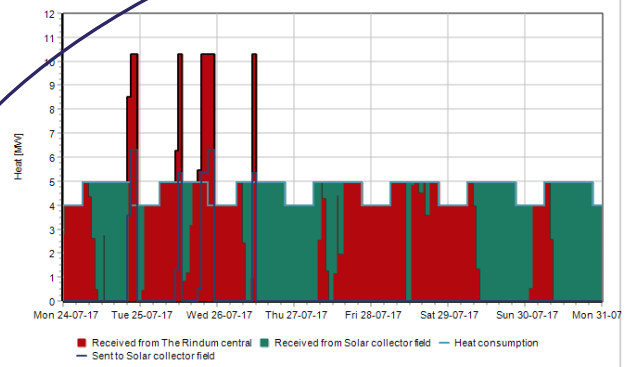
Example of one week of operation – One site district heating plant with CHP units, thermal storage system, and a fuel boiler



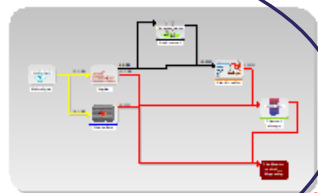
Example of one week of operation – District heating system with several sites



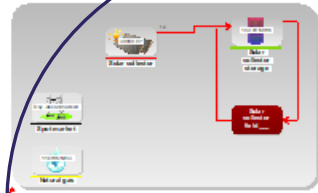
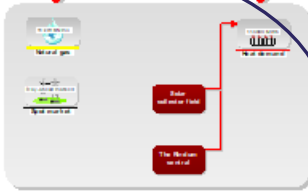
External conditions Priorities Heat Electricity Fuels Thermal store



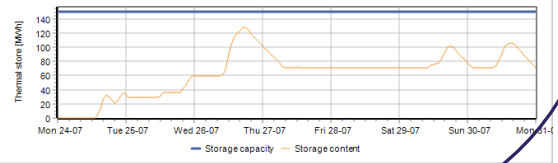
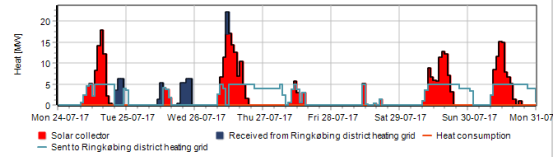
External conditions Heat Fuels



35 MW



30 MW



External conditions Priorities Heat Fuels Thermal store



Possible to change input files and run input files in energyPRO with XML files (Requires INTERFACE module)

Command line: ...\\energyPRO.exe /XMLMod input.xml

Simple example where the XML file is used to get energyPRO to print Operation income of a energyPRO model to a CSV file:

```
<?xml version="1.0"?>
- <XMLtoEnergyPRO>
  - <Head>
    <energyPRODataFile>c:\\Interface\\Vestdansk 5MW-kraftvarmeværk på markedsvilkår i 2013.epp</energyPRODataFile>
  </Head>
  <InputDataElements> </InputDataElements>
  - <OutputDataElements>
    <ReportBaseID>10030</ReportBaseID>
    <ReportDelimiter>;</ReportDelimiter>
    <ReportFileName>c:\\Interface\\Resultat af ordinær drift.csv</ReportFileName>
    <ReportFile>csv</ReportFile>
  </OutputDataElements>
</XMLtoEnergyPRO>
```



A few examples of published research where energyPRO has been used

- Sorknæs P, Lund H, Andersen AN. Future power market and sustainable energy solutions – The treatment of uncertainties in the daily operation of combined heat and power plants. *Appl Energy* 2015;144:129–38. doi:10.1016/j.apenergy.2015.02.041.
- Sorknæs P, Lund H, Andersen AN, Ritter P. Small-scale combined heat and power as a balancing reserve for wind – The case of participation in the German secondary control reserve. *Int J Sustain Energy Plan Manag* 2015;4:31–42. doi:10.5278/ijsep.2014.4.4.
- Østergaard PA, Andersen AN. Booster heat pumps and central heat pumps in district heating. *Appl Energy* 2016;184:1374–88. doi:10.1016/J.APENERGY.2016.02.144.
- Andersen AN, Østergaard PA. Analytic versus solver-based calculated daily operations of district energy plants. *Energy* 2019. doi:10.1016/j.energy.2019.03.096.
- Andersen AN, Østergaard PA. A method for assessing support schemes promoting flexibility at district energy plants. *Appl Energy* 2018. doi:10.1016/j.apenergy.2018.05.053.
- Østergaard PA, Jantzen J, Marczinkowski HM, Kristensen M. Business and socioeconomic assessment of introducing heat pumps with heat storage in small-scale district heating systems. *Renew Energy* 2019. doi:10.1016/j.renene.2019.02.140.
- Kiss VM. Modelling the energy system of Pécs - The first step towards a sustainable city. *Energy* 2015. doi:10.1016/j.energy.2014.11.079.
- Ben Amer-Allam S, Münster M, Petrović S. Scenarios for sustainable heat supply and heat savings in municipalities - The case of Helsingør, Denmark. *Energy* 2017. doi:10.1016/j.energy.2017.06.091.
- Rämä M, Wahlroos M. Introduction of new decentralised renewable heat supply in an existing district heating system. *Energy* 2018. doi:10.1016/j.energy.2018.03.105.
- Büchele R, Kranzl L, Hummel M. Integrated strategic heating and cooling planning on regional level for the case of Brasov. *Energy* 2019. doi:10.1016/j.energy.2019.01.030.
- Kontu K, Rinne S, Junnila S. Introducing modern heat pumps to existing district heating systems – Global lessons from viable decarbonizing of district heating in Finland. *Energy* 2019. doi:10.1016/j.energy.2018.10.077.
- Wahlroos M, Pärssinen M, Manner J, Syri S. Utilizing data center waste heat in district heating – Impacts on energy efficiency and prospects for low-temperature district heating networks. *Energy* 2017. doi:10.1016/j.energy.2017.08.078.



QUESTIONS?



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