Heat Production Optimization
Project Description

Case

HeatItOn is the utility in the city of *Heatington* which has to secure the heat delivery to approx. 1600 buildings through a single district heating network. They produce heat with a number of traditional heat-only boilers as well as units that combine the production of heat with the production / consumption of electricity (CHPs). They are planning the heat schedules manually but now they want to cost optimize their production. The goal of the project is to define heat schedules for all available production units with the lowest possible expenses and the highest profit on the electricity market.

About district heating

District heating is hot water from a power plant which is distributed to the buildings in a city through highly insulated pipes. In the buildings, the hot water is used for heating and for domestic hot water. The cooled water is then sent back to the plant, where it is reheated again. Figure 1 shows a small district heating grid with two heat producers.

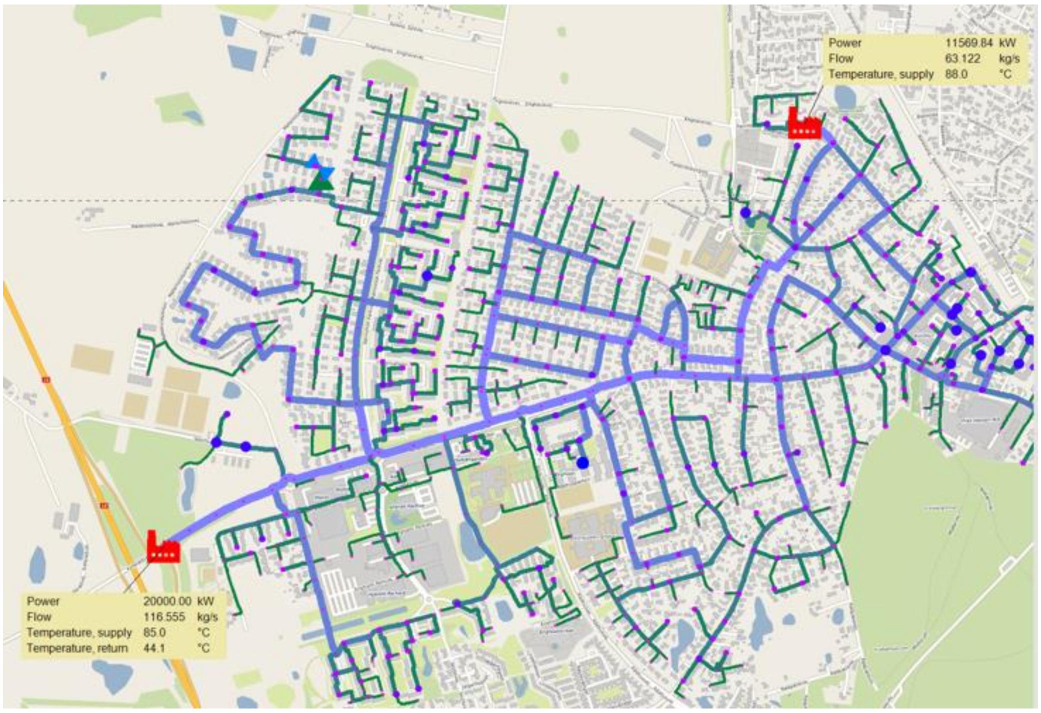

Figure 1: District heating grid with two heat producers

The majority of the heat comes from cogeneration plants that produce both electricity and heat. The heat can be produced in many different ways and with different types of fuel, such as waste, gas, coal, and biomass. In addition, the industry's surplus heat, solar and geothermal heat, and large heat pumps as well as electric boilers are also used. Figure 2 shows how heat production and electricity production / consumption is connected to the heat consumers.

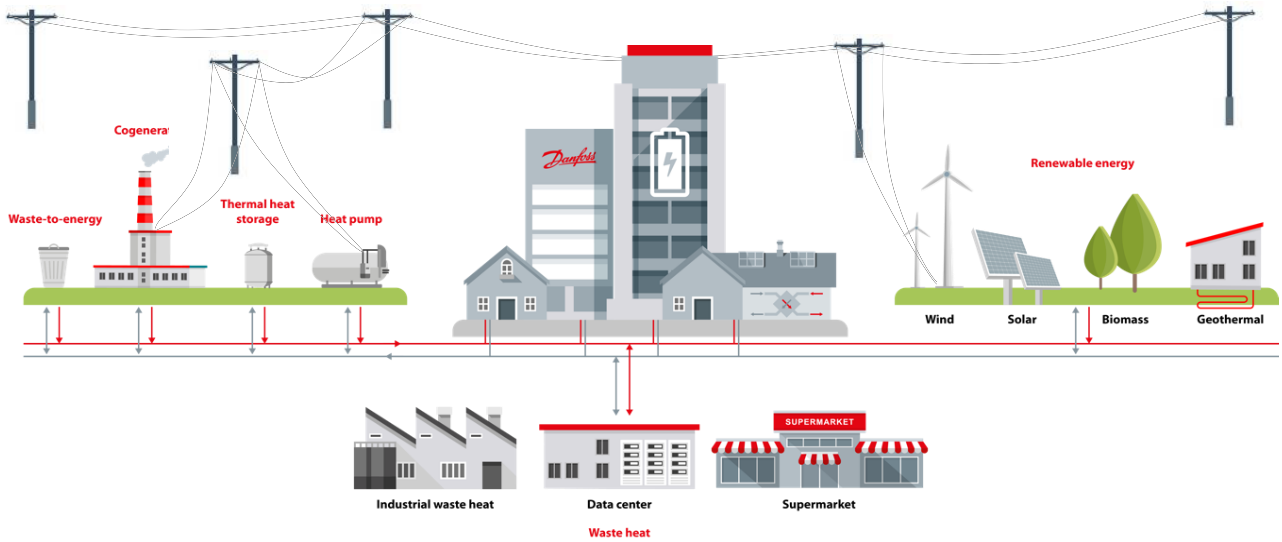

Figure 2: District heating production units

System overview

Figure 3 shows an overview of the optimization system. You are not constraint to use this design, but you should as a minimum develop the modules: Asset Manager, Source Data Manager and Result Data Manager. Further on you should implement either the Optimizer or the Data Visualization.

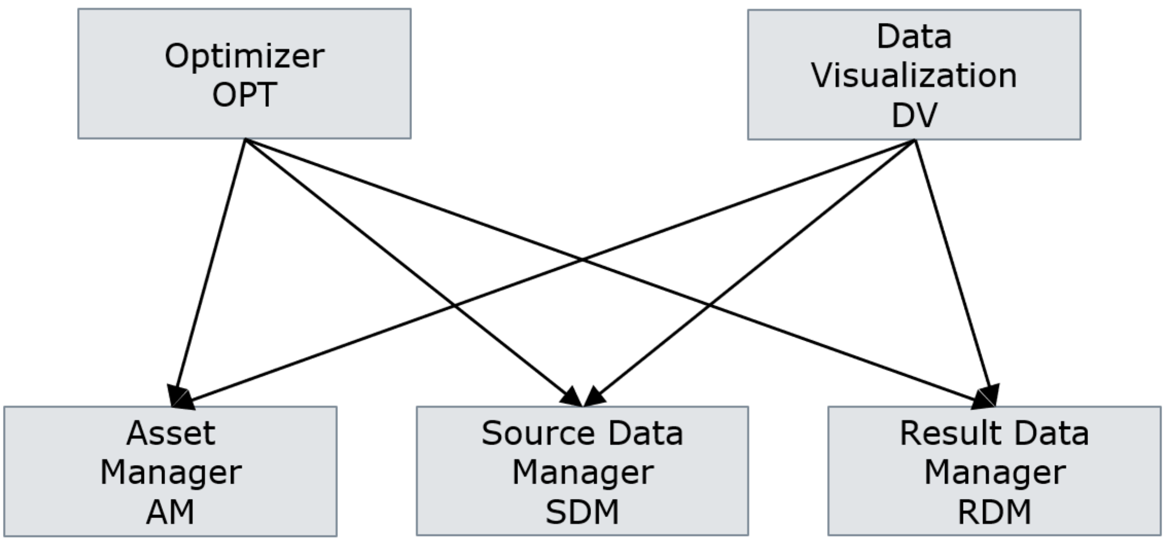

Figure 3: System overview diagram

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Asset Manager (AM)

The AM is a repository for static system information and is responsible for making this information available for other modules. The AM can hold its data in local files.

Through the AM, other modules can retrieve heating grid information such as name and a graphical representation of the grid.

The AM provides all configuration data for the production units such as name, possible operation points and a graphical representation of the units itself.

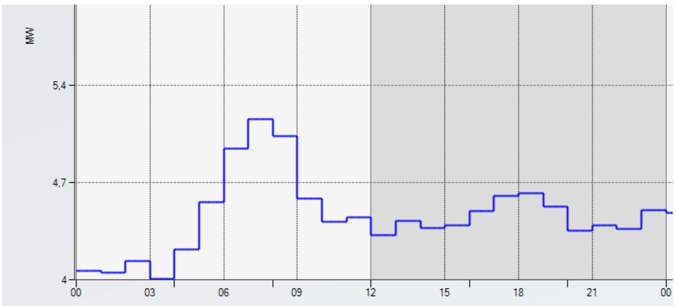
An operation point defines how a device can be operated. Parameters are produced heat, produced / consumed electricity, production costs, consumption of primary energy, produced CO_2 emissions. There is typically a minimum and a maximum operation point but, in this case, we assume that there is a maximum operation point for each unit which can be regulated to zero, meaning the device is switched off.

Source Data Manager (SDM)

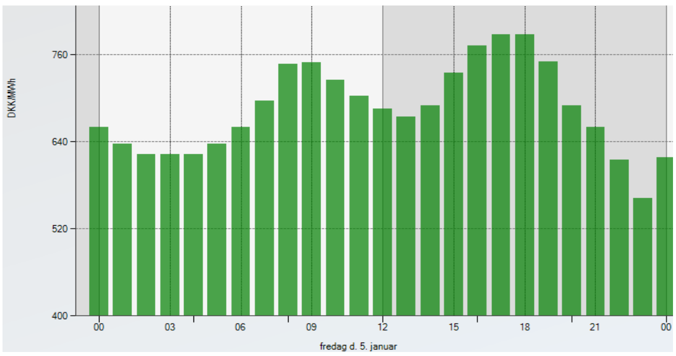
The SDM is a repository for dynamic system information. The SDM can hold its data in local CSV files.

The SDM provides time series for the heat demand and electricity prices.

The heat demand defines the required amount of heat in the heating grid which consists of the heat consumption from the final heat consumers and the heat loss in the heating grid. This is the amount of heat that has to be produced. The heat demand is expressed in MWh and is typically low during the night and has a high peak between 6 am and 9 am.



The electricity prices define how much a plant owner can get for 1 MWh produced electricity (gas motor, turbine). The same value has to be paid for 1 MWh consumed electricity (heat pump, electric boiler).



Both the heat demand and the electricity prices are given with a resolution of 1 hour.

Classified as Business

Result Data Manager (RDM)

The RDM is a repository for optimization results. The RDM can save result data in local CSV files.

Result data should be separated for each production unit and should contain important information such as produced amount of heat, produced / consumed electricity, production costs, consumption of primary energy and produced amount of CO_2.

Optimizer (OPT)

The OPT is the kernel module for the optimization of heat production.

The OPT considers all the available production units and calculates the best economical schedule of the heat production while securing heat availability to all buildings at any time. The schedules should be calculated for a given period, e.g. one week.

All units have a specific productions cost, expressed in € per MWh produced heat. All units are operating at their individual production cost. For heat only units there are no further expenses nor income. Electricity producing units can sell the produced electricity and have thereby an extra income depending on the electricity prices which can change from hour to hour. Electricity consuming units must buy the electricity and have thereby an extra expense, again depending on the electricity prices.

A good starting point for the optimization is to calculate net production costs. The net production costs for heat only boilers are the productions costs themselves. For electricity producing units, the net production costs are calculated as the production costs minus the value of the electricity that can be sold. For electricity consuming units, the net production costs are calculated as the production costs plus the value of the electricity that has to be purchased. For each unit, you can define a timeseries with net production costs for the entire optimization period. The timeseries has a time resolution of 1 hour and covers all the hours in the optimization period. The net production costs for heat only boilers are constant, however for electricity units they depend on the electricity price which is applied in the appropriate hour. Compare the net production costs of all units to build priorities.

Data Visualization (DV)

The DV is responsible for a graphical presentation of important source and result data.

Through the DV it will be possible to inspect the configuration of the heating grid and its productions units.

The DV will also present time series representations of the heat demand in the heating grid, heat production values, electricity production / consumption values, electricity prices, expenses and profit, consumption of primary energy and production of CO_2 emissions.

For a better understanding of the optimization results it would be a good idea also to visualize the net productions costs for all units, which are the heat production costs minus earnings from electricity sales / plus expenses for electricity purchase.

Scenarios

The implementation of the heat production optimization should be implemented in two scenarios. Implement first scenario 1 in the optimizer (OPT) and extend the optimization then to use electricity production / consumption in scenario 2.

Scenario 1

Scenario 1 consists of a single district heating network, a heat demand, one gas boiler and one oil boiler. The gas boiler will be cheapest, the oil boiler will operate at higher production costs and will be used in peak demand periods.

Both boilers operate at constant costs not dependent on the hour of operation. Schedule the cheapest boiler first and supplement with heat from the more expensive boiler if needed in regard to the heat demand.

Scenario 2

Scenario 2 consists of a single district heating network, a heat demand, one gas boiler, one oil boiler, one gas motor and one electric boiler. The gas motor produces electricity whereas the electric boiler consumes electricity. The gas motor is expected to run in high electricity price periods whereas the electric boiler should run when electricity prices are low.

The level of the electricity prices is the major reason for whether electricity producing / consuming units are economical good to use. Use the net production costs as described for the optimizer (OPT).

Danfoss Delivery

1. Graphical representation of the city area saved as JPG file.
2. Graphical representation of the heat production units saved as JPG files.
3. Configuration parameters for the heat production units, aka operation points, such as
    a. Heat production
    b. Electricity production / consumption
    c. Production costs
    d. Consumption of primary energy
    e. Production of CO_2 emissions

    All parameters are saved in TEXT files.
4. Heat demand and electricity prices for a 7-days winter period both with a resolution of 1 hour saved in a CSV file.
5. Heat demand and electricity prices for a 7-days summer period both with a resolution of 1 hour saved in a CSV file.

Deliveries from Danfoss will be delivered in separate documents.

Additional Exercises

If there is time left, you can try to extend your project with some of the following addition tasks.

1. If you have chosen to implement the Optimizer, also implement the Data Visualization.
2. If you have chosen to implement the Data Visualization, also implement the Optimizer.
3. Run scenario 2 with different configurations such as with or without the gas motor and compare the results in terms of revenue, CO_2 emissions etc.
4. Implement API´s for the communication between the modules.
5. Implement an API client to call the API from Energinet.dk to directly read electricity prices from their web server. The following links provide helpful information to get started. Unfortunately, not all pages are available in English.
    - https://www.energidataservice.dk/tso-electricity/Elspotprices
    - https://www.energidataservice.dk/guides/api-guides
    - https://energinet.dk/el/data-om-energisystemet/energi-data-service/