PRO 2: Optimization of District Heating Production Planning

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Introduction

District Heating (DH) is the most common technology used to warm up houses in Sweden. Stockholm has had district heating since the 1950s, with a network that grew through local systems that later became interconnected.

Different utilities cooperate in the same DH network. Stockholm Exergi is the largest actor with about 8 TWh of heat produced annually, while Söderenergi, Norrenergi, and EOn supply the remaining 4 TWh.

The optimization and production planning of such a system is quite complex since it is carried out by different actors and is affected by several factors.

In this project, we will start by modeling a DH network that resembles the one in Stockholm. Centralized heating plants will include technologies such as CHP, HOB, and Heat Pumps.

The optimal production planning has to be defined for different days of the year in different Scenarios. Factors that can affect the production planning such as load variations, variable electricity tariffs, network limitations, additional customers, and demand side management in existing substations will be investigated.

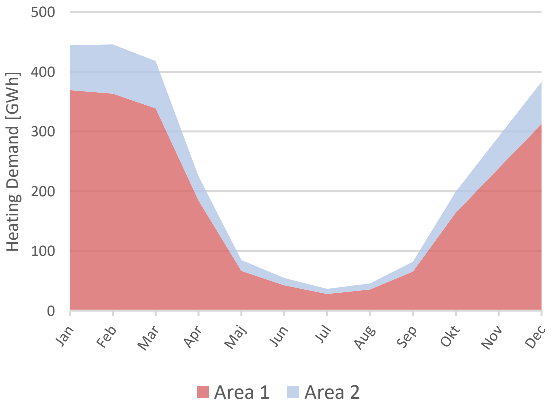
Step 1: Base Case Scenario

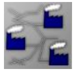
The first step consists of modeling a DH network that supplies two areas with different demands.

All the information about heating loads, fuel technologies, and prices are provided in the Excel file “PRO2_Inputs.xlsx”.

All the parameters that are not provided can be calculated.

Main Parameters per Area			
	AREA 1	AREA 2	
P_{th} [MW_{th}]	800	200	* Thermal power supplied to the customers
α-value	0.4	0.6	* Ratio between electrical power and heating power
η_{boiler}	0.85	0.9	* Ratio between thermal power in steam and thermal power in fuel
$\eta_{condenser}$	0.75	0.8	* Ratio between thermal power supplied and thermal power in steam after the expansion
COP Heat Pumps	3.5	3.5	* Ratio between thermal power delivered and electrical power needed to run the compressor



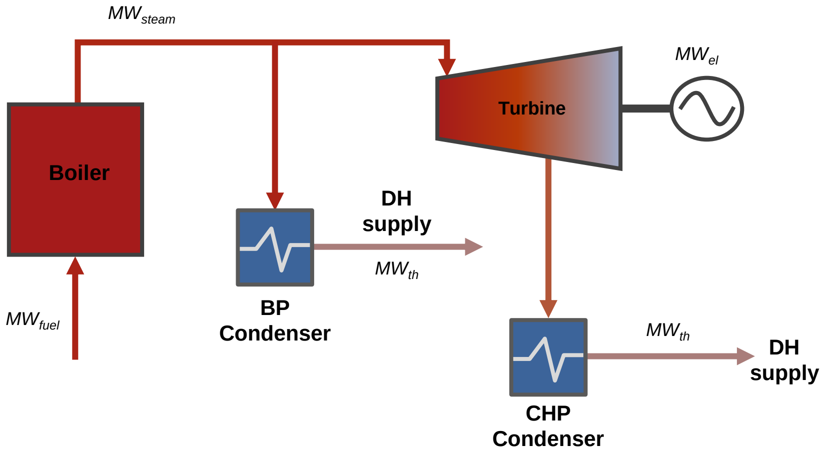
Hint:
- *separate the different areas using “District Heating Grid Containers” in BoFiT* 
- *use the component “Limiter Heat” to limit the heat transfer in the connection between Area 1 and Area 2* 

Step 1: Base Case Scenario

The following table is provided to guide you to use the correct power flows in the model.

Remember that BoFiT only cares about MW and Euro. For simplicity, we will consider even the steam flow [kg/s] after the boiler as power flow [MW_{steam}].

Power Flow in the System at Max Capacity				
Fuel	MW_{fuel}	MW_{steam}	MW_{el}	MW_{th}
Waste				400.0
Wood Chips				320.0
Electricity A1				80.0
Bio Oil A1*				50.0
Electricity A2				20.0
Bio Pellets				100.0
Bio Oil				80.0



**The bio oil boiler in area 1 is used as a back up in case that the available capacity is not enough to cover the demand (keep it off if not necessary)*

Step 1: Base Case Scenario

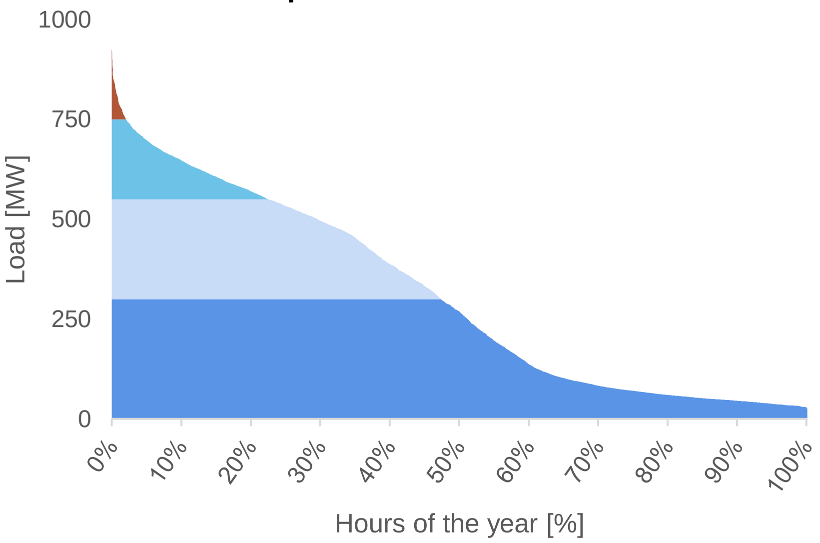
Once the model has been set up, the annual optimization (on the current year) can be performed. Relevant results to be shown include the Load Duration Curve (Dispatch Order) for the year, heat production by source, electricity production by source, operation costs, and revenues for the selected days.

The 4 selected days to compare are:

- Day containing the hour with ´higher demand
- Day containing the hour with lower
- Day when the electricity price is higher
- Day when the electricity price is lower

If there are multiple days with the same values just select the one that you prefer. You will have to show results for the same 4 days for each scenario you are going to model.

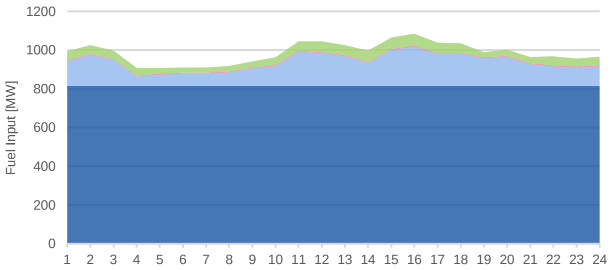
Example of Load Duration Curve



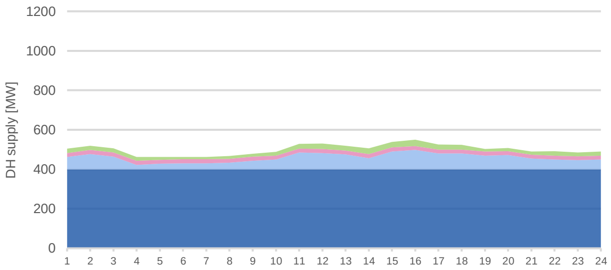
Step 1: Base Case Scenario

Here are some examples of how the results could look like:

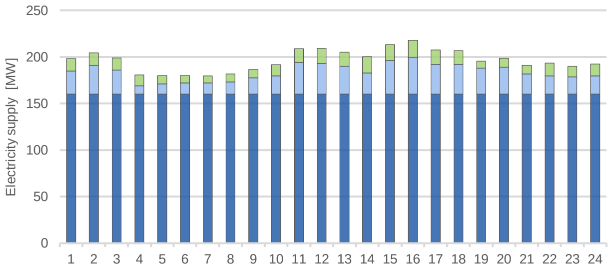
Fuel input to boiler



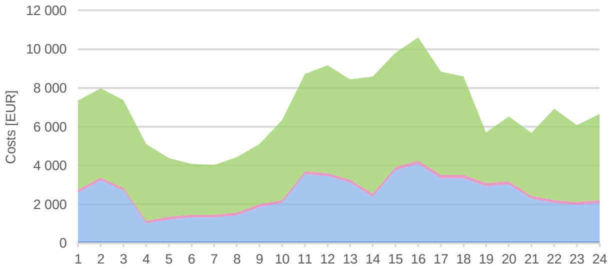
DH supply by fuel



Electricity production by fuel



Fuel cost



Step 1: Summary

Important questions that should be answered are:

- How is the dispatch order? (Show it in a load duration curve chart)
- How does the production change in the selected days?
- How does the electricity generation change in the different days?
- Is it always profitable to produce electricity? Why?
- How much should the DH price be to reach the break even point?
- How much are the annual revenues using the DH prices provided?

Always try to present what **you** think is relevant and be prepared to answer questions!

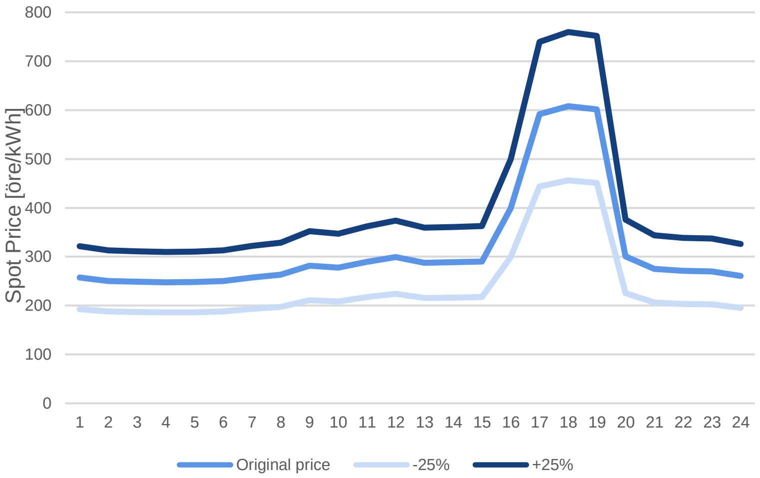
Step 2.1: Variable Electricity Prices

Electricity price has a relevant role in the production planning of a DH company. In the Base Case model electricity is both purchased to run the Heat Pumps and produced in the CHP plants.
Electricity price can be much more volatile than other fuels price as it has been demonstrated in the last years in which the spot price has significantly increased.

Perform a sensitivity analysis on the electricity price by increasing and decreasing the spot price by **25%**.

All the other costs used to calculate the retail price remain constant.

How will variable electricity prices affect the production planning of the system?



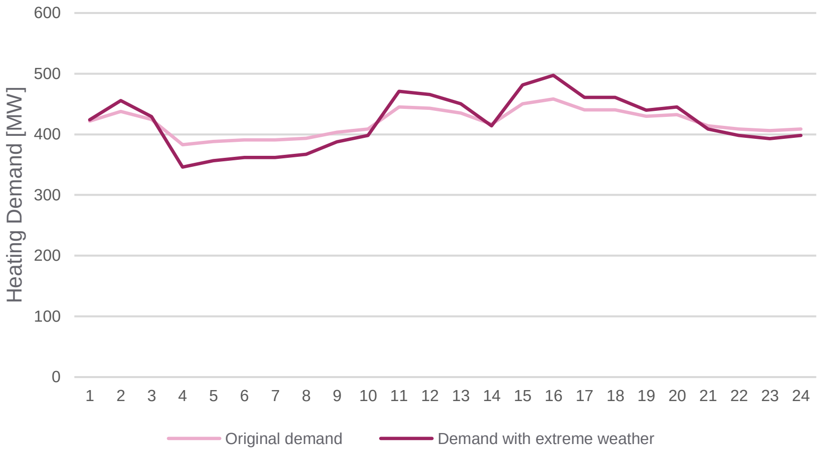
Step 2.2: Extreme Weather Conditions

In case of extreme weather conditions, such as very cold winter days and very warm summer days the heating demand can change significantly.

It is important to test different weather forecasts to be prepared to readapt the DH production planning in case of extreme weather conditions.

Use the new heating demands, in which a volatility function has been applied, for both areas.

How will extreme weather conditions affect the production planning of the system?



Step 2: Summary

Important questions that should be answered are:

- How is the electricity price affecting the production planning? (2.1)
- How could extreme weather conditions affect the production planning? (2.2)
- How are the costs and revenues changing compared to the base case?

Always try to present what **you** think is relevant and be prepared to answer questions!

Step 3.1: Thermal Energy Storage

Thermal energy storage represents an interesting solution to decouple the production from the heating demand. In this way, cheaper fuel can be used to produce extra heat that can be stored and used in peak hours.

In this scenario, a new area is getting connected to the DH network, and the existing capacity is not enough to cover the new demand. A first solution can be installing additional heat generation capacity. A second solution is to install a heat accumulator that can be charged when the demand is low and discharged to cover the peak demand.

In your model:

- Add Area 3 to the network and connect it to both Area 1 and Area 2 without limitations.
- CASE 1:
  - Include a bio-oil HOB in Area 3 (use same efficiencies of area 2). What is the minimum capacity needed to cover the new demand?
  - How will the production change? How will the costs and revenues change?
- CASE 2:
  - Include a heat accumulator. In which area is better to install it? What is the minimum storage capacity needed to cover the demand without adding extra heating capacity to the network?
  - How will the production planning change? Compare it to the previous case

Step 3.2: Demand Side Management

Demand Side Management is a useful tool to shave demand's peak and reduce production costs.

In this scenario, a new area is added to the network. Instead of adding extra capacity or a heat accumulator, a demand side management strategy has to be implemented to reduce the peak demand and supply the whole network.

In your model:

- Add Area 3 to the network and connect it to both Area 1 and Area 2 without limitations.
- CASE1:
  - Implement a strategy that reduces the 3 hours with the highest peak in every day of the winter season (Jan-Mar; Nov-Dec).
  - How much should the peak loads be reduced in percentage to guarantee the DH supply to the entire network?
  - How much are the annual savings in terms of production costs?
- CASE 2:
  - Improve the strategy in a way that the same amount of energy cut in the peak hours can be recharged in the 6 hours with the lowest demand, on the same day.
  - How much should the peak loads be reduced in percentage to guarantee the DH supply to the entire network?
  - How much are the annual savings?

Step 3.3: New DH Company Connected

DH supply is a business in which usually different companies participate. In this scenario a new DH production company wants to connect to the existing network. You, as main supplier and network owner, want to understand how to integrate the new generation to the production planning and what kind of incentives give to the new company.

In your model:

- Add a new Area 3 with the generation capacity specified in the excel file (only generation not demand) and connect it to both Area 1 and Area 2 without limitations.
- How is the production planning changing?
- How much should you pay the new company to achieve same revenues as the base case?
- Is there any possibility to achieve better revenues?

Step 3: Summary

Important questions that should be answered are:

- How does the system change? Which new component have been implemented?
- How is the new dispatch order? (Show it in a load duration curve chart)
- How does the production change compared to the base case?
- How does the electricity generation change compared to the base case?
- Is it always profitable to produce electricity? Why?
- How much are the new revenues?
- How is the price of DH changing in order to achieve same revenues of the base case?

Always try to present what **you** think is relevant and be prepared to answer questions!

Steps for the Groups

GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6
1	1	1	1	1	1
2.1	2.2	2.1	2.2	2.1	2.2
3.1	3.2	3.3	3.1	3.2	3.3

GROUP 7	GROUP 8	GROUP 9	GROUP 10	GROUP 11	GROUP 12
1	1	1	1	1	1
2.1	2.2	2.1	2.2	2.1	2.2
3.1	3.2	3.3	3.1	3.2	3.3

Grading Matrix

	E (Step 1)	C (Step 2)	A (Step 3)
ILO 3: MODEL	**<u>Base case model</u>** Develop a base case model in BoFiT following the project instructions. • Present the process of builidng the model • Tell us about the main components • Show knowledge and understanding about what you have modeled.	**<u>Sesnitivity analysis</u>** Implement the new inputs in the model and optimize the new scenarios. • Show understanding about how the inputs changed and what could be the expected outcomes.	**<u>Alternative model</u>** Develop an alternative model in BoFiT following the project instructions. • Present the process of builidng the model • Tell us about the main components • Show knowledge and understanding about what you have modeled.
ILO 4: EVALUATE	**<u>Results for selected days</u>** Generate time series results for the selected days and present them in tables and charts. • Present the load duration curve for the entire year • Present the daily production by fuel for the selected days • Present economic results e.g. revenues and fuel costs	**<u>Results for selected days</u>** Here we expect to see similar results as for the base case scenario (step 1). • Present the load duration curve for the entire year • Present the daily production by fuel for the selected days • Present economic results e.g. revenues and fuel costs	**<u>Results for selected days</u>** Here we expect to see similar results as for the previous two scenarios (step 1 and 2). • Present the load duration curve for the entire year • Present the daily production by fuel for the selected days • Present economic results e.g. revenues and fuel costs
ILO 5: ANALYZE	**<u>Compare different results</u>** Make a comparison between the different days presented in the previous point. Discuss the outcomes and explain the causes of the main differences.	**<u>Compare different results</u>** Make a comparison between this scenario and the base case. How does the production change? How do the revenues change?	**<u>Compare different results</u>** Make a comparison between this scenario and the base case. How does the production change? How do the revenues change?

Q&A Sessions

We will have 4 Q&A sessions in the computer rooms in the M building:

- 15th November 8:00 – 10:00
- 22nd November 8:00 – 10:00
- 29th November 8:00 – 10:00
- 6th December 8:00 – 10:00

The idea is that you sit in groups working at your project and we will be there to help you.

You can access the computer rooms in the M building and work on your projects whenever you want! But in these days we will also be there.

See you there and good luck!