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Topological optimization of a district heating network

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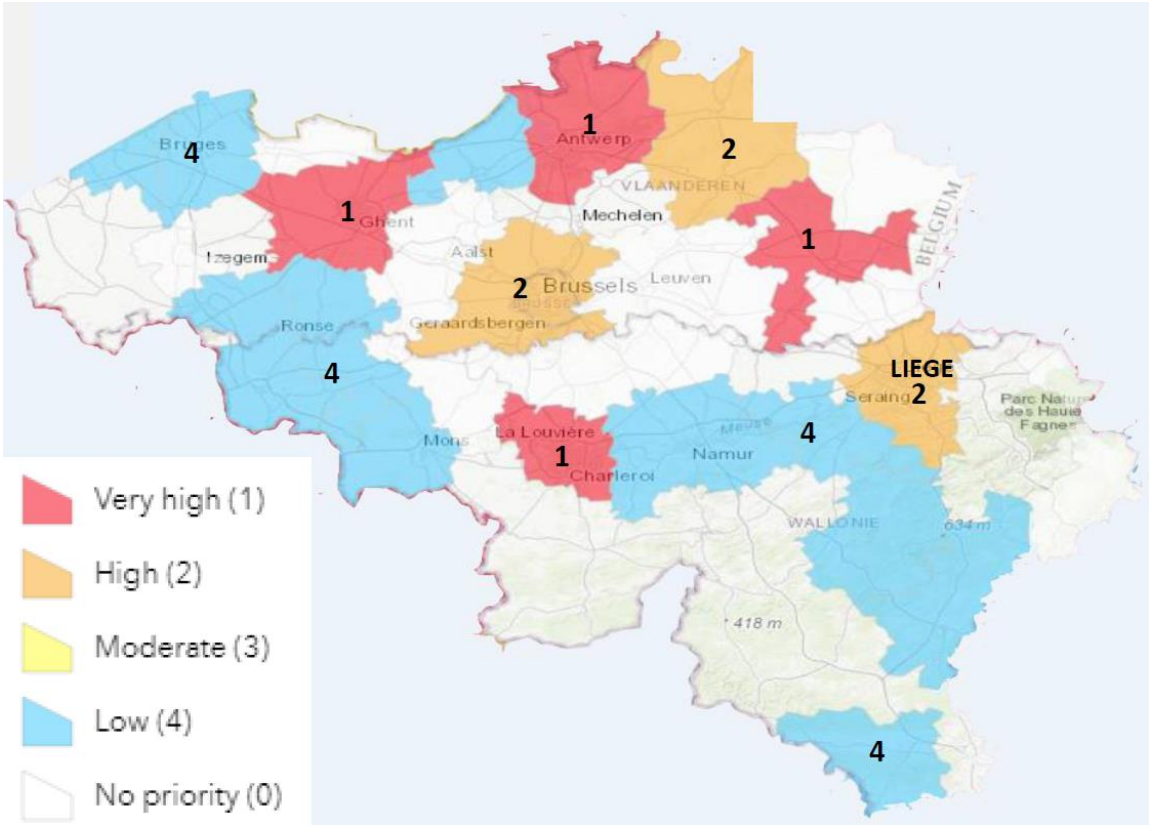
40% of the space heating demand could be covered by excess heat in Belgium



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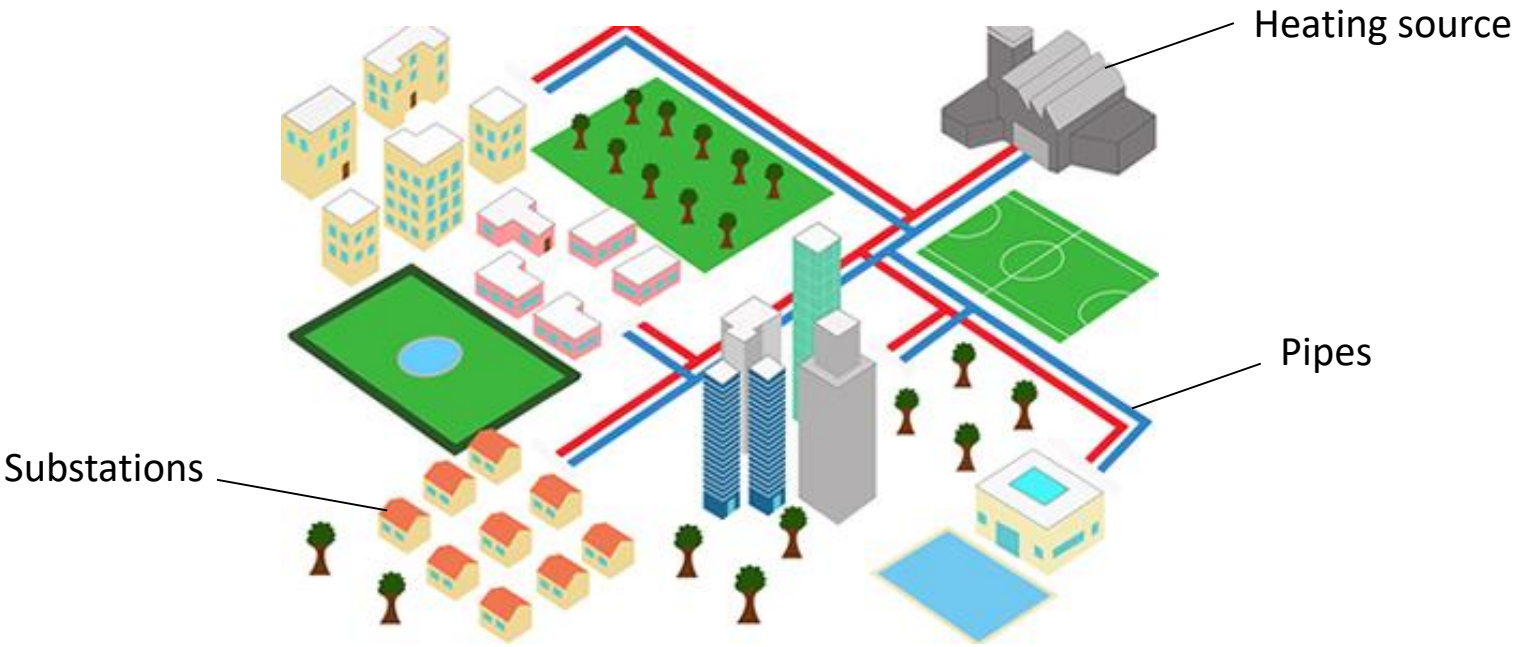
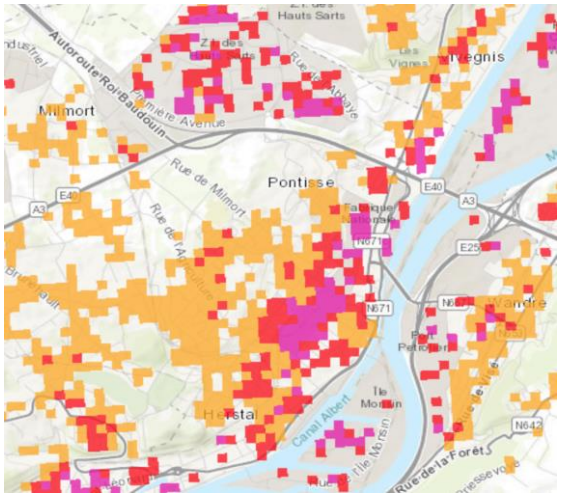
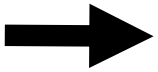
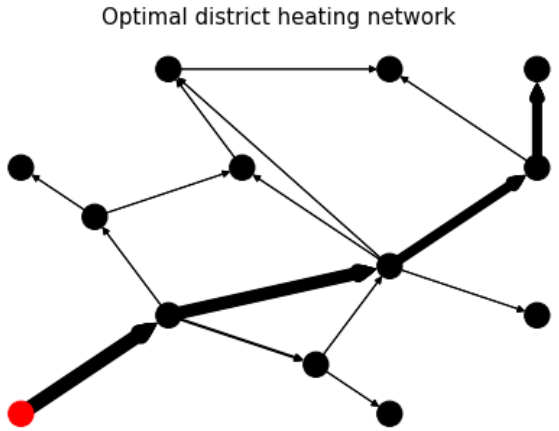
A solution to cover excess heat sources and to decrease GHG emissions is the use of district heating networks



There is a need for optimization models as decision tools for the optimal outline of district heating networks

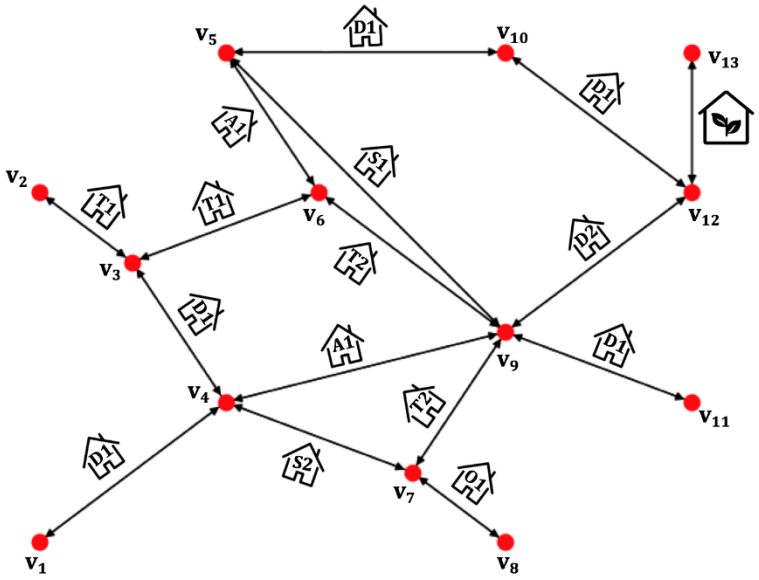


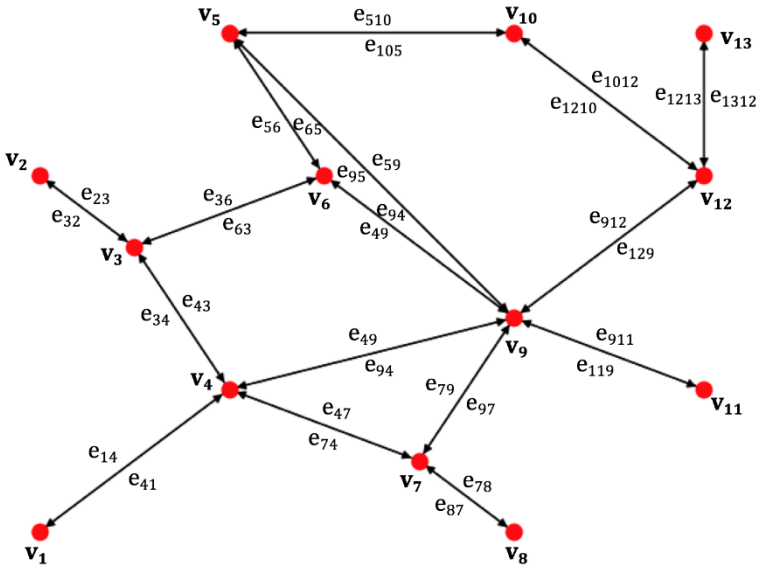




Authors	Objective function	Linear	Topology	Design	Multi-period
Apostolou (2018)	C_{TOT}	X	X	V	V
Bordin et al. (2016)	C_{TOT}	V	V	X	X
Dorfner (2016)	C_{TOT}	V	V	V	X
Mertz (2016)	C_{TOT}	X	V	V	X
Soderman (2007)	C_{TOT}	X	V	X	X
Weber (2008)	C_{TOT}	X	V	V	X
My model	C_{TOT}	V	V	V	V

A MILP with the minimization of the total costs as objective function using graph representation with vertices and edges





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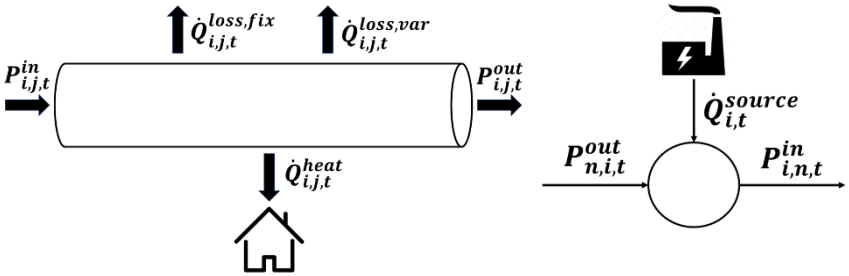
A **multi-period** mixed-integer linear programming model (MILP) including continuous and discrete variables is implemented

Continuous variables	**Discrete** variables
• $\dot{Q}_{i,t}^{source}$: Power production during timestep t @ plant i	• $x_{i,j}$: Construction of a pipe on edge ij
• $\dot{Q}_{i}^{source,installed}$: Power capacity to install @ node i	• y_i: Construction of a power plant @ node i
• $P_{i,j,t}^{in}$: Incoming power flow @ timestep t in edge ij from node i	• $u_{i,j,t}$: Use of the prospective pipe on edge ij @ timestep t
• $P_{i,j,t}^{out}$: Outcoming power flow @ timestep t in edge ij from node i	

These variables are submitted to some physical and technical constraints

1. Energy balance over edges and nodes



2. Maximum thermal capacity on edges $P^{max}_{i,j} \leq x_{i,j} \cdot \dot{Q}^{max,edge}_{i,j}$

3. Maximum thermal capacity at vertices $\dot{Q}^{source}_{i,t} \leq \dot{Q}^{max,source}_{i}$

4. Mandatory building of some pipes $x_{i,j} \geq m^{build}_{i,j}$

5. Possible location of heating sources $y_i \leq p^{location}_i$

6. Minimum power to install at each node $\dot{Q}^{source}_{i,t} \leq \dot{Q}^{source,installed}_{i}$

The objective function of the optimization problem is the minimization of the total cost of the system

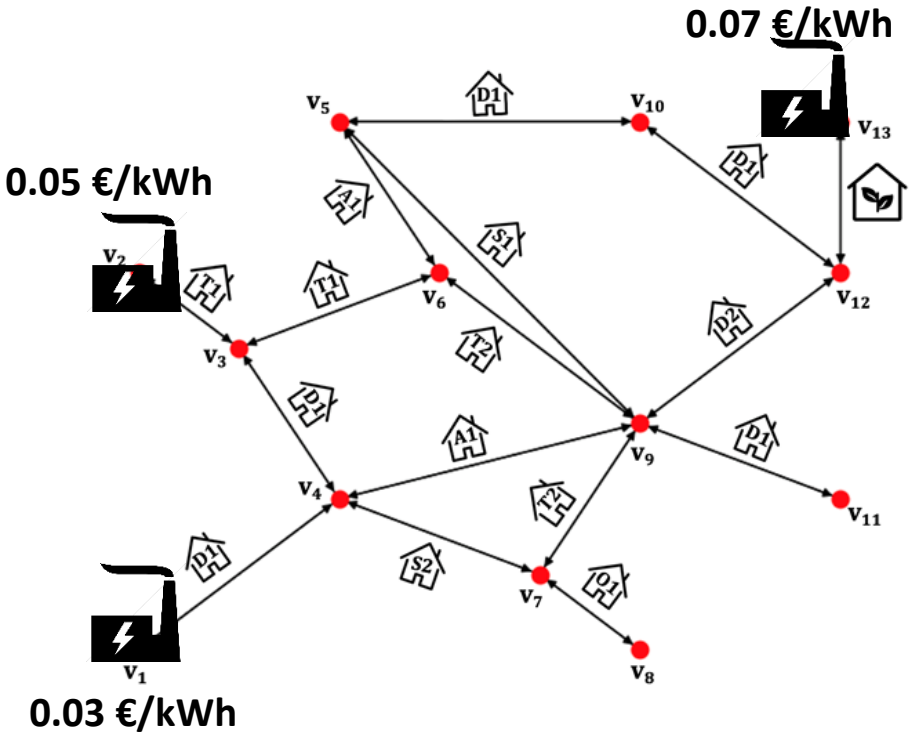
$$C_{TOT}$$

$$=$$

$$\underbrace{C_{heating\ plants} + C_{pipes} + C_{substations}}_{\text{CAPEX}}$$

$$+ \underbrace{C_{heat\ production} + C_{pumping\ power} - R_{heat}}_{\text{OPEX}}$$

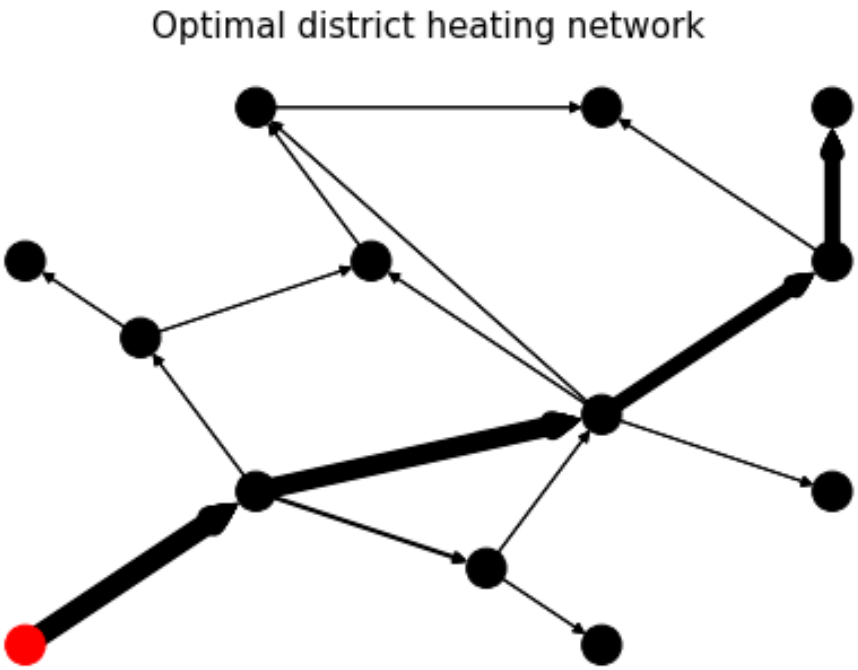
A case study with 16 streets and 3 potential heating sources is taken into account



Type	Description
A	Apartment
D	Detached
O	Office
S	Semi-detached
T	Terraced
G	Greenhouse

Class	Level of insulation
1	Well-insulated
2	Poorly insulated

Is it profitable to build a district heating network considering a heating revenue of 0.08 €/kWh for a project lifetime of 25 years? **YES**



- 25% of CO_2 emissions

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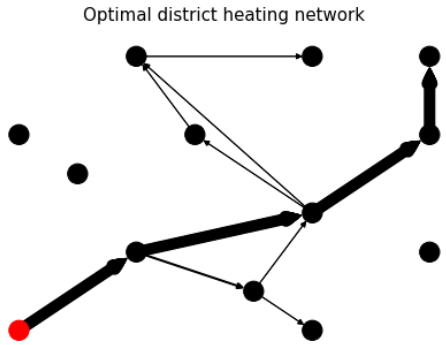
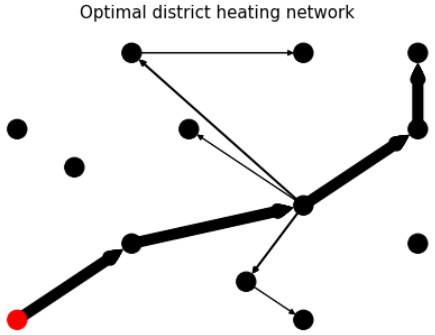
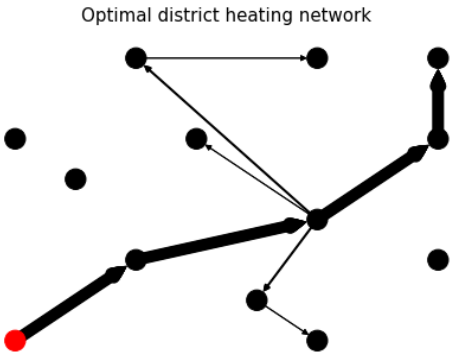
What happens if the heating revenue is decreased? Less streets are connected to the district heating network!



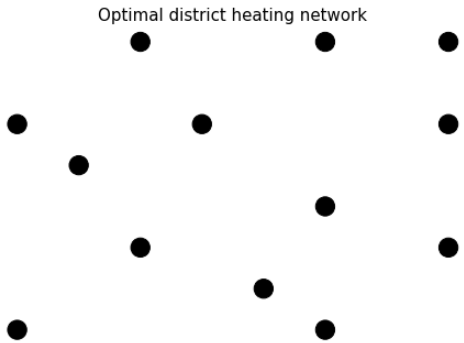
$r_{heat} = 0.07$€/kWh



$r_{heat} = 0.06$€/kWh

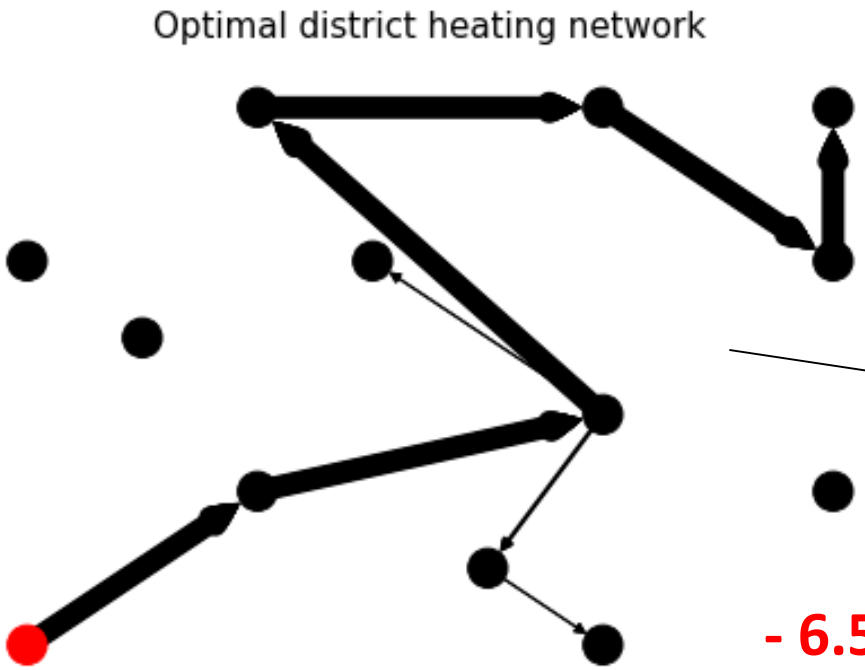


$r_{heat} = 0.05$€/kWh



$r_{heat} = 0.04$€/kWh

What happens if a pipe can not be built in a street? The network topology changes… and the revenues decrease



No more heat capacity on this edge

- 6.5% of total revenues

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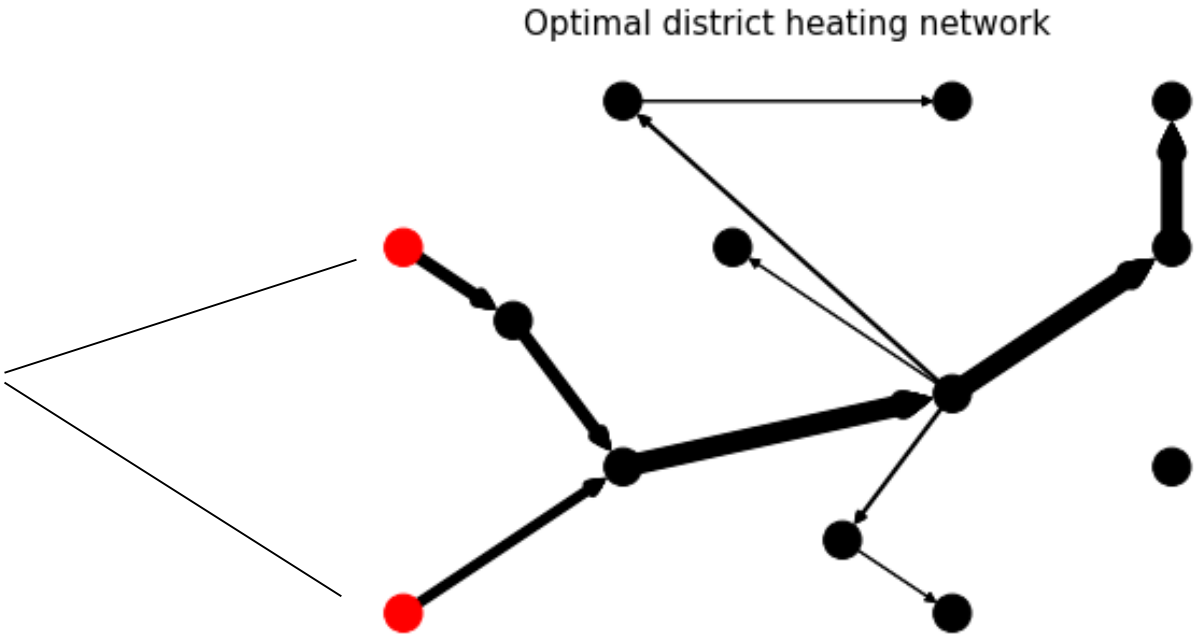
What happens if a unique heating source has not enough power capacity to feed the entire network? The network topology changes…

Use of 2 heating sources



- 14.5% of total revenues

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District heating networks can be more economically and environmentally profitable than decentralized heating production units!

Next steps:

- Include storage units into the networks
- Include electrification into heating sources potential
- Extend the model to larger case studies

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Thanks for your attention!

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