5th International Conference on Smart Energy Systems
Copenhagen, 10-11 September 2019
#SESAAU2019

Topological optimization of a district heating network

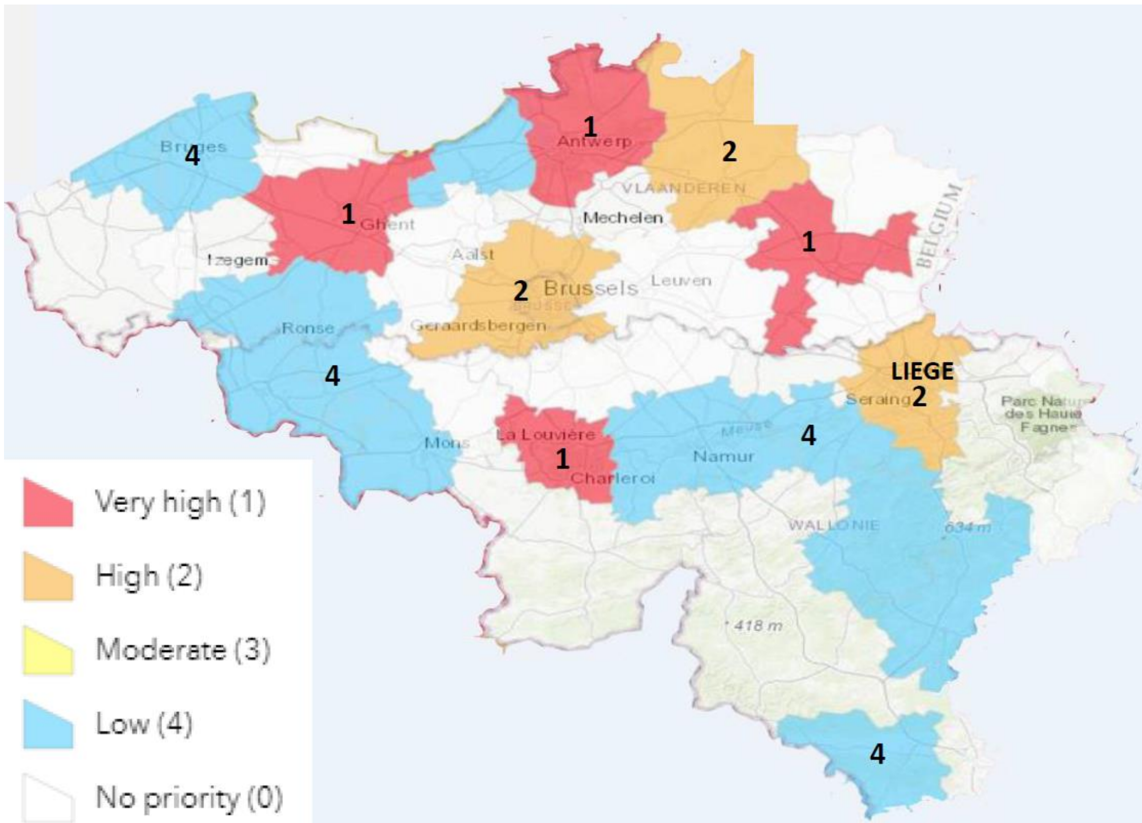
Thibaut Résimont
University of Liège (Thermodynamics laboratory)
thibaut.resimont@uliege.be

Powered by

Fonden Energi- & Miljødata
www.emdfonden.dk

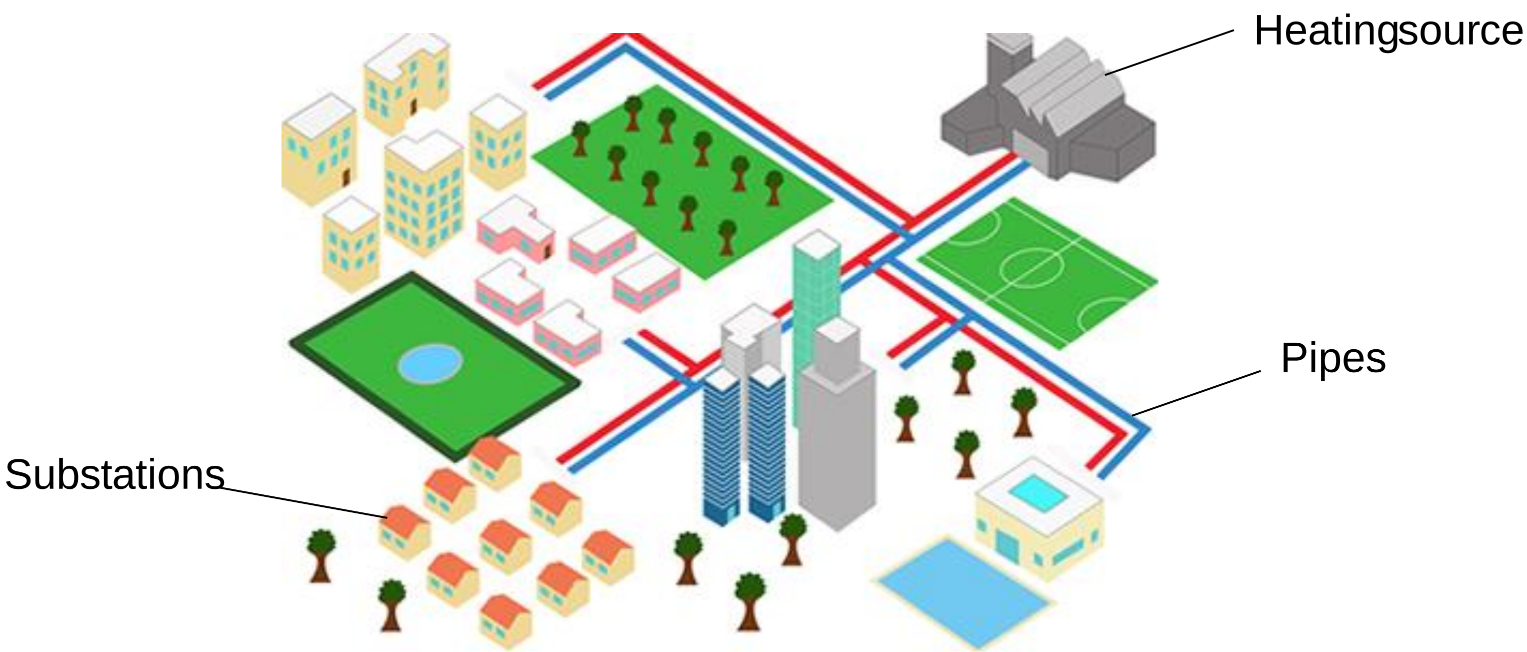
UN environment
DISTRICT ENERGY IN CITIES INITIATIVE
Innovation Fund Denmark
4DH

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



Powered by

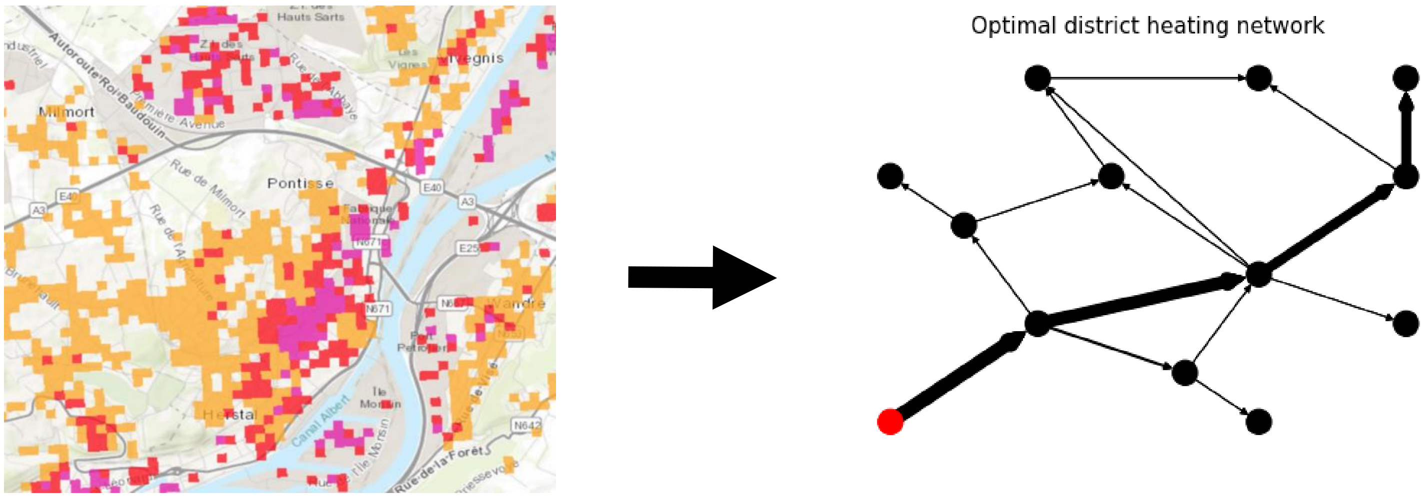
A solution to cover excess heat sources and to decrease GHG emissions is the use of district heating networks



Powered by

AALBORG UNIVERSITY DENMARK
reINVEST
sEEnergies
Fonden Energi- & Miljødata
www.emdfonden.dk
4DH
UN environment
DISTRICT ENERGY IN CITIES INITIATIVE
Innovation Fund Denmark

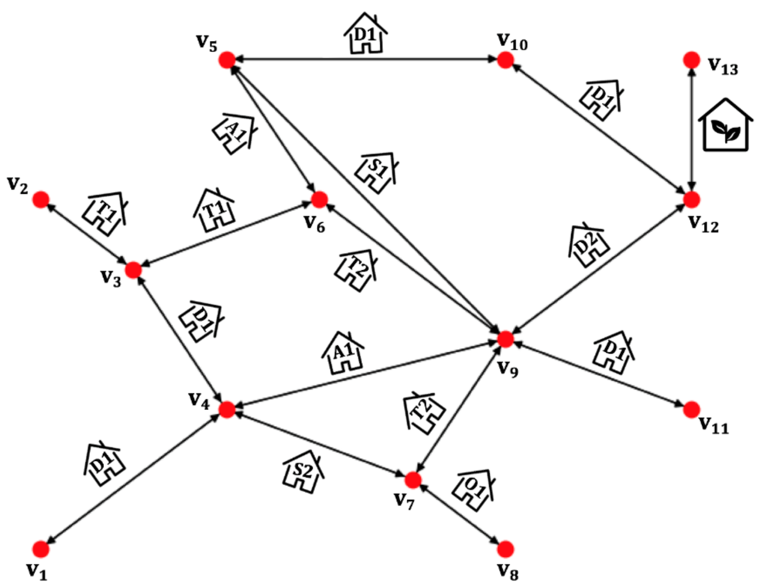
There is a need for optimization models as decision tools for the optimal outline of district heating networks

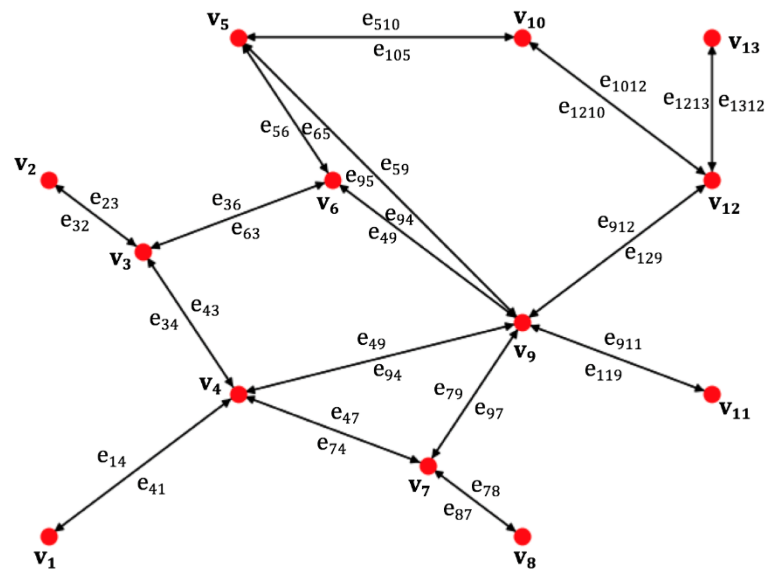


Powered by

Authors	Objective function	Linear	Topology	Design	Multi-period
Apostolou (2018)	C_{TOT}	X	X	V	V
Bordinet 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





Powered by

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

Continuous variables

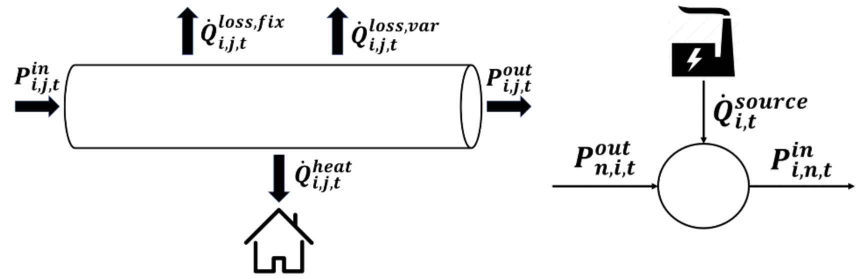
- $\dot{Q}_{i,t}^{source}$: Power production during timestep t @ plant i
- $\dot{Q}_{i}^{source,installed}$: Powercapacity to install @ node i
- $P_{i,j,t}^{in}$: Incomingpower flow @ timestep t in edge ij from node i
- $P_{i,j,t}^{out}$: Outcomingpower flow @ timestep t in edge ij from node i

Discrete variables

- $x_{i,j}$: Construction of a pipe on edgeij
- y_{i}: Construction of a power plant @ node i
- $u_{i,j,t}$: Use of the prospective pipe on edgeij @ timestep t

These variables are submitted to some physical and technical constraints

1. Energy balance over edges and nodes



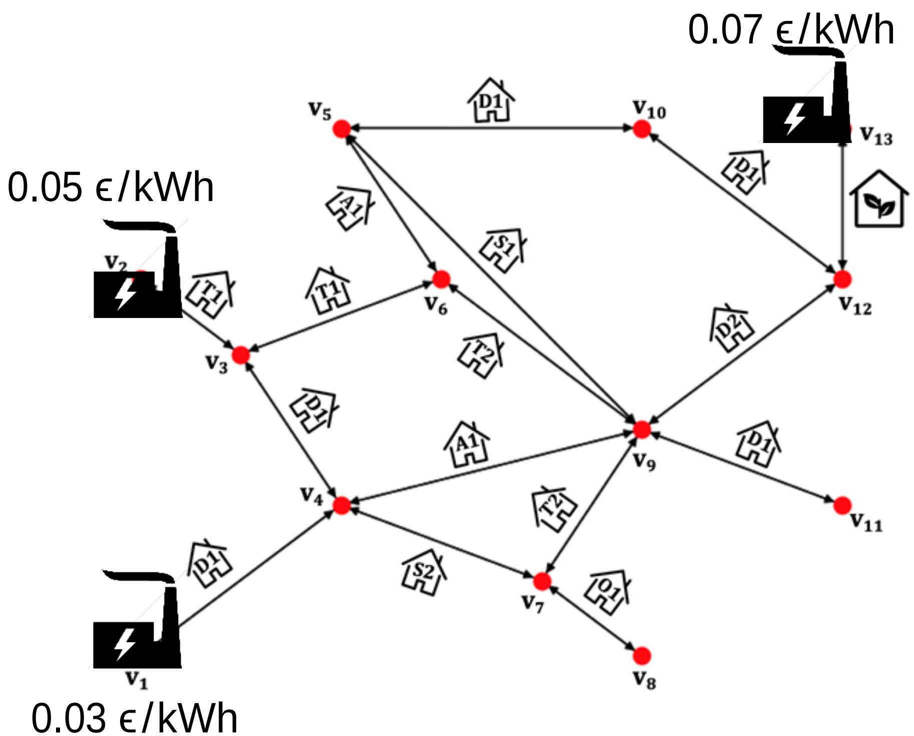
2. Maximum thermal capacity on edges $P^{max}_{i,j} \leq x_{i,j} \cdot \dot{Q}^{max,edge}_{i,j}$
3. Maximum thermal capacity at vertices $\dot{Q}^{source}_{i,t} \leq \dot{Q}^{max,source}_{i}$
4. Mandatory building of some pipes $x_{i,j} \geq m^{build}_{i,j}$
5. Possible location of heating sources $y_i \leq p^{location}_i$
6. Minimum power to install at each node $\dot{Q}^{source}_{i,t} \leq \dot{Q}^{source,installed}_{i}$

Powered by

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



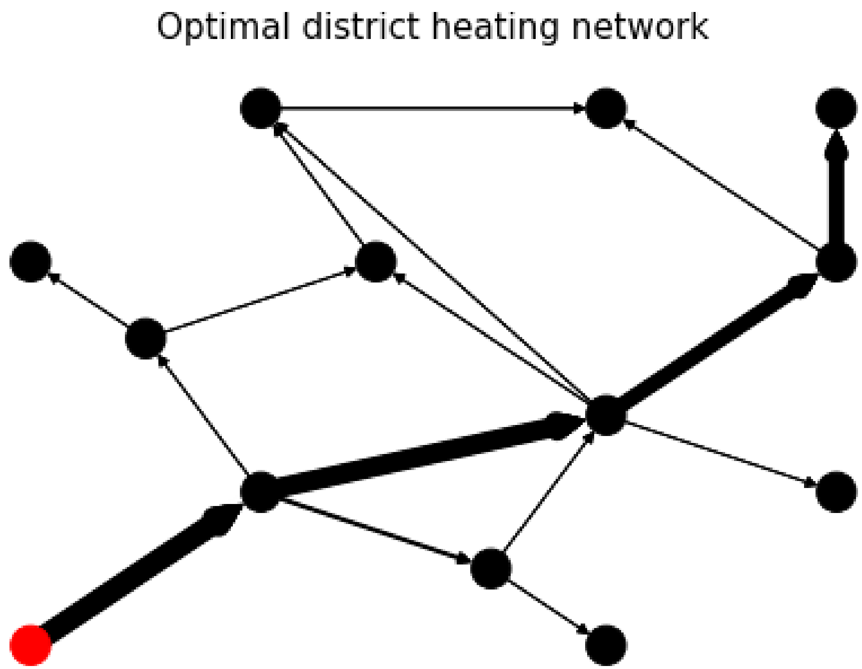
Type	Description
A	Apartment
D	Detached
O	Office
S	Semi-detached
T	Terraced
G	Greenhouse

Class	Level of insulation
1	Well-insulated
2	Poorly insulated

Powered by

AALBORG UNIVERSITY DENMARK
reINVEST
sEEnergies
Fonden Energi- & Miljødata www.emdfonden.dk
UN environment
DISTRICT ENERGY IN CITIES INITIATIVE
Innovation Fund Denmark
4DH

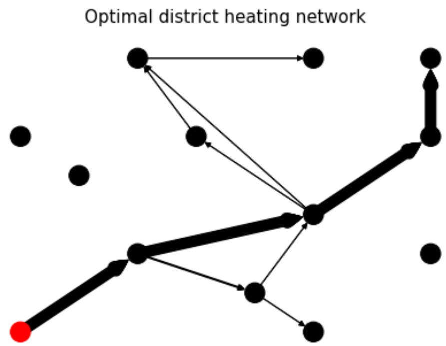
Is it profitable to build a district heating network considering a heating revenue of 0.08€/kWh for a project lifetime of 25 years? YES



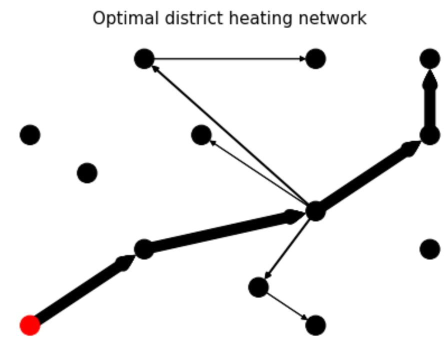
- 25% of CO_2 emissions

Powered by

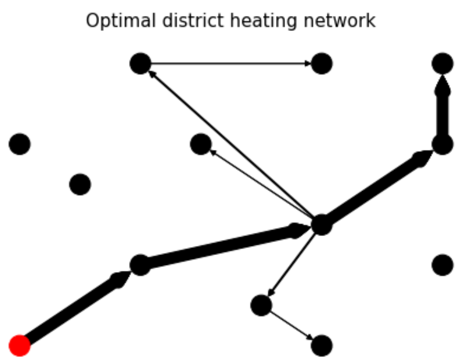
What happens if the heating revenue is decreased? Less streets are connected to the district heating network!



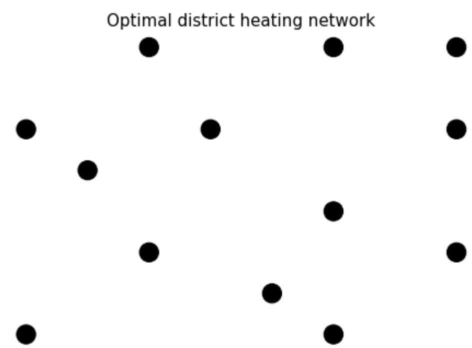
$r_{heat} = 0.07$ €κ⌉ ² K



$r_{heat} = 0.06$ €κ⌉ ² K



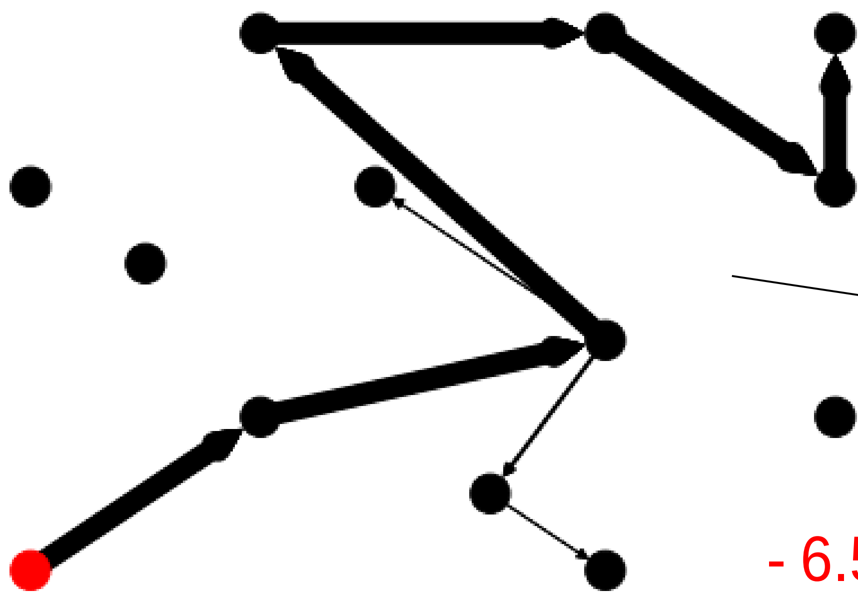
$r_{heat} = 0.05$ €κ⌉ ² K



$r_{heat} = 0.04$ €κ⌉ ² K

What happens if a pipe cannot be built in a street? The network topologyĞĸI·yƎŜăX I·yŘ ǘKŜ ǋŜǾŜyƌzŜă decrease

Optimal district heating network

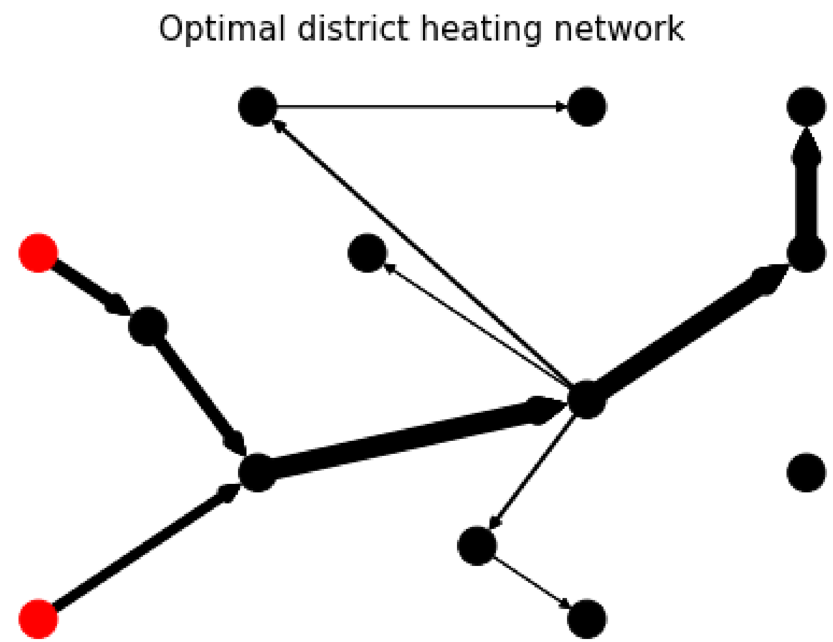


No more heat capacity on this edge

- 6.5% of total revenues

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

Use of 2 heating sources



- 14.5% of total revenues

Powered by

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

Thanks for your attention!

Thibaut Résimont
University of Liège Thermodynamics laboratory
thibaut.resimont@uliege.be

Powered by