Showcasing the potential of adjoint-based topology methods to optimize District Heating Network design on district level

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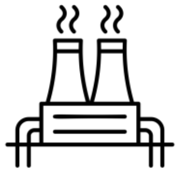
Simulation model

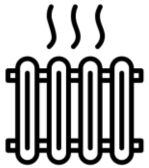
$q\ \ p\ \ T$ Steady state

Thermal/hydraulic pipe network model

Hydraulic Friction & Heat losses



Heat supply at constant temperature



Characteristic radiator equation & Bypass

Optimization problem

Design variables

- Pipe diameter
- Valve settings
- Heat Inflow

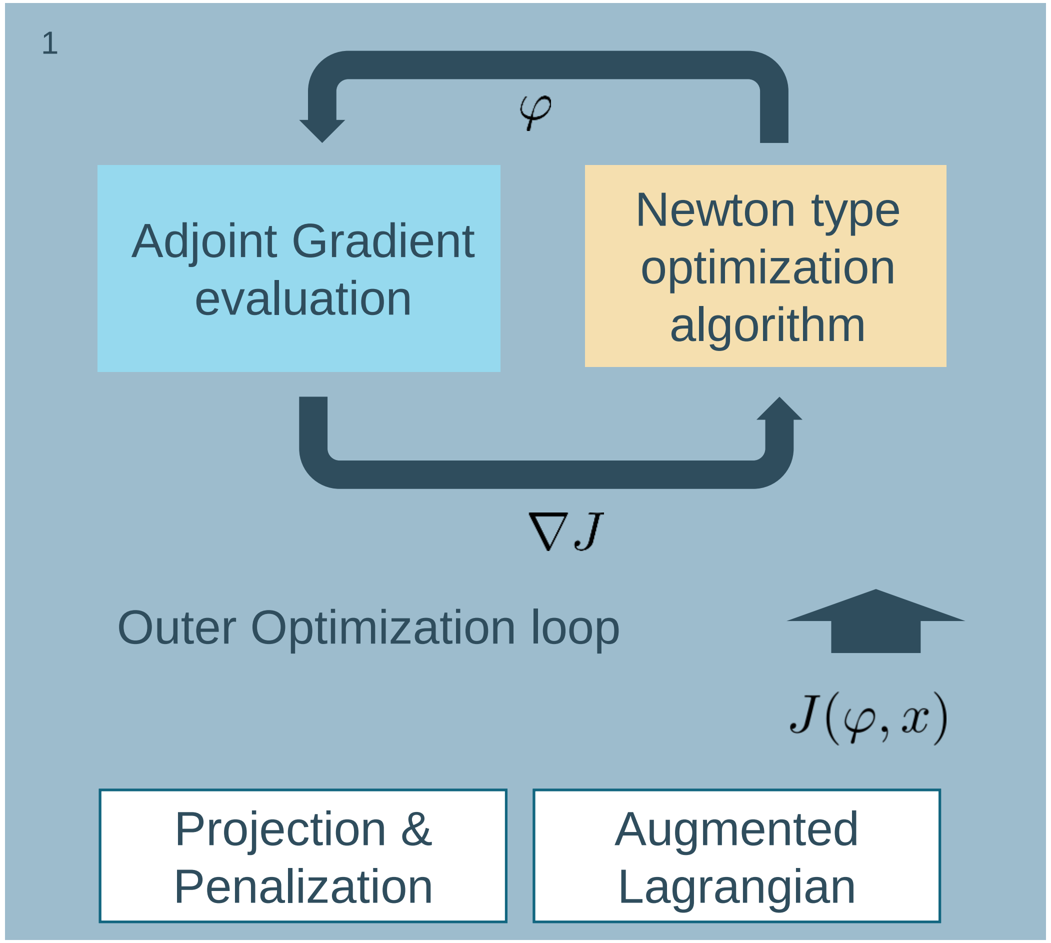
Cost functions

- Piping
- Pumping
- Heat capacity
- Heat production
- Revenue

Design constraints

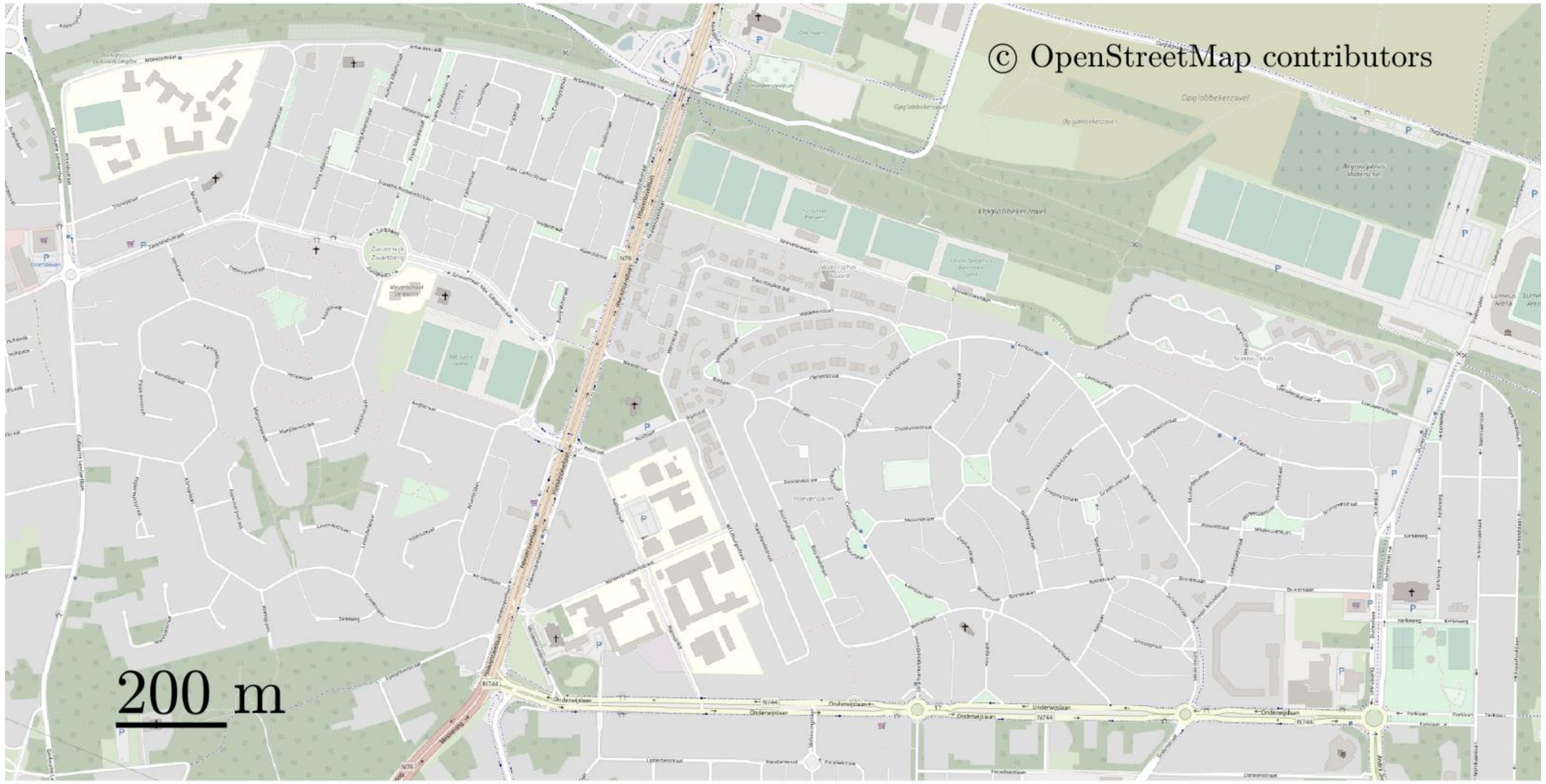
- Thermal Comfort
- Pressure limit

Methodology



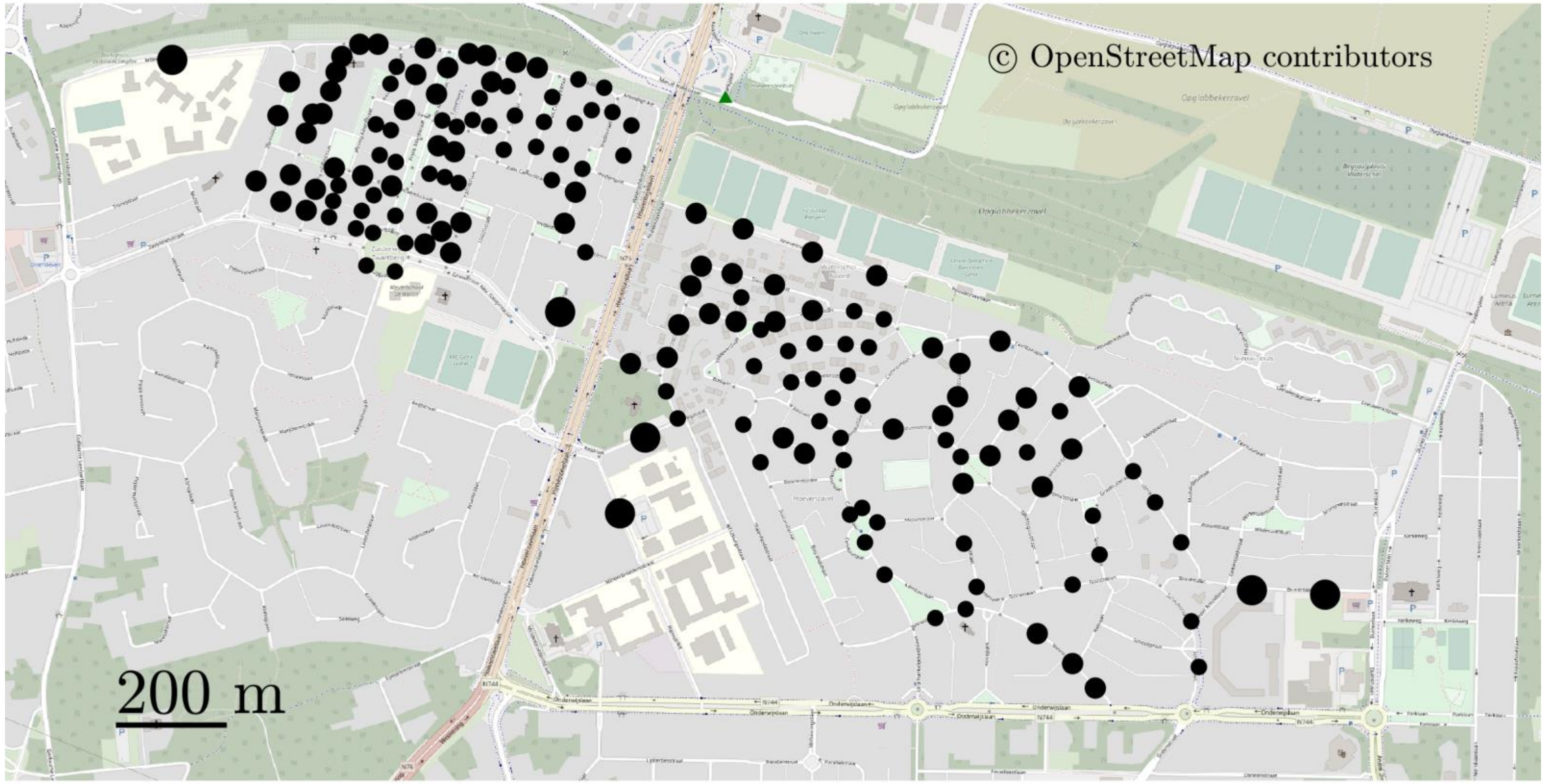
[1] Blommaert 2020 (arXiv:2008.08328)

Case study



$$T_{\text{outside}} = -8°$$

Case study - Heat demand



Heat demand

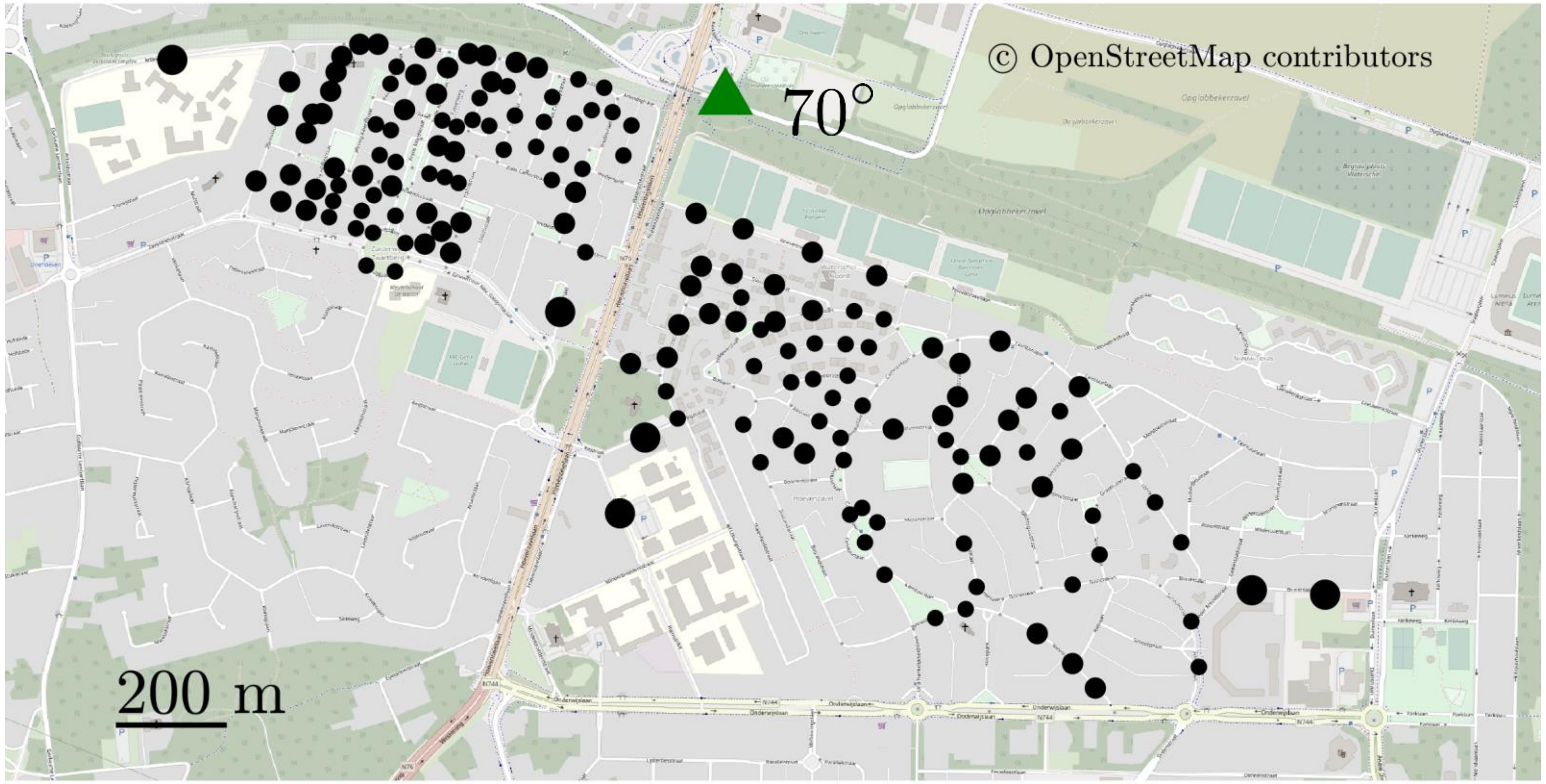
- 15 kW
- 25 kW
- 50 kW

Nominal temperature

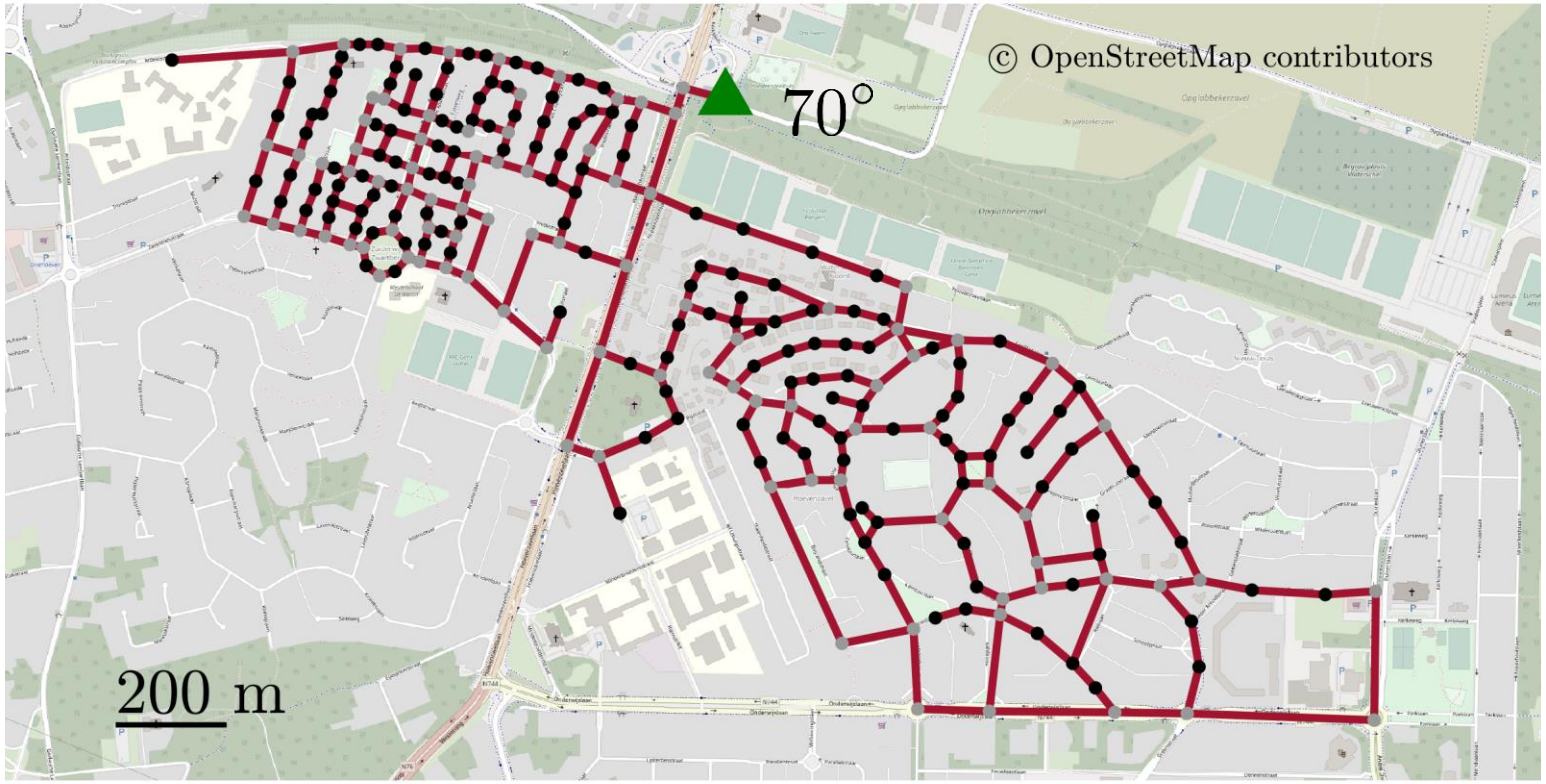
- 55°

$$\|Q - Q_{\mathrm{d}}\| \leq 5\%$$

Case study - Producer



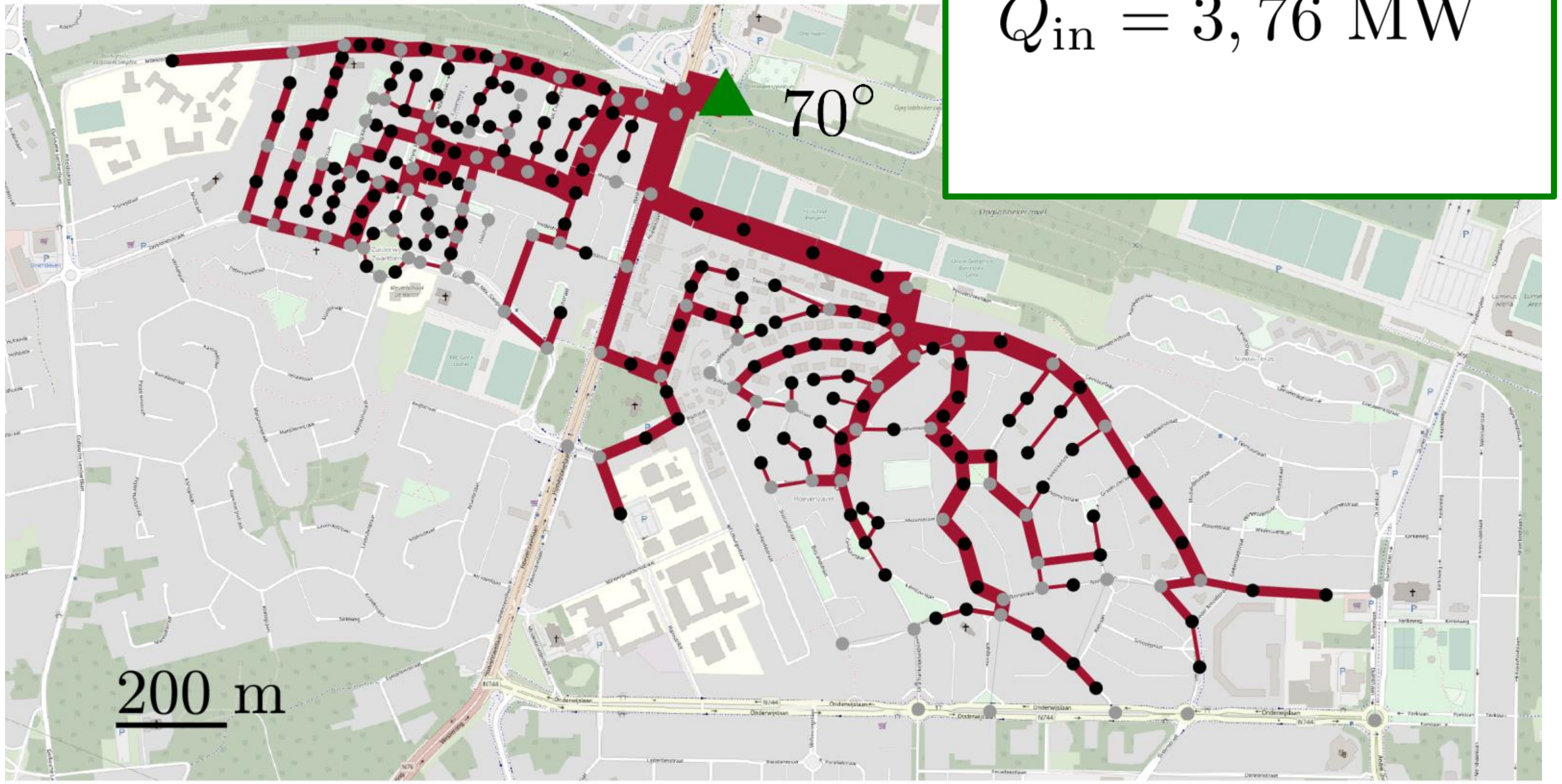
Case study - Potential routes



$$0\ \text{cm} \leq D \leq 40\ \text{cm}$$

$$\|\Delta p\|_\infty \leq 10\ \text{bar}$$

Case study - One heat source

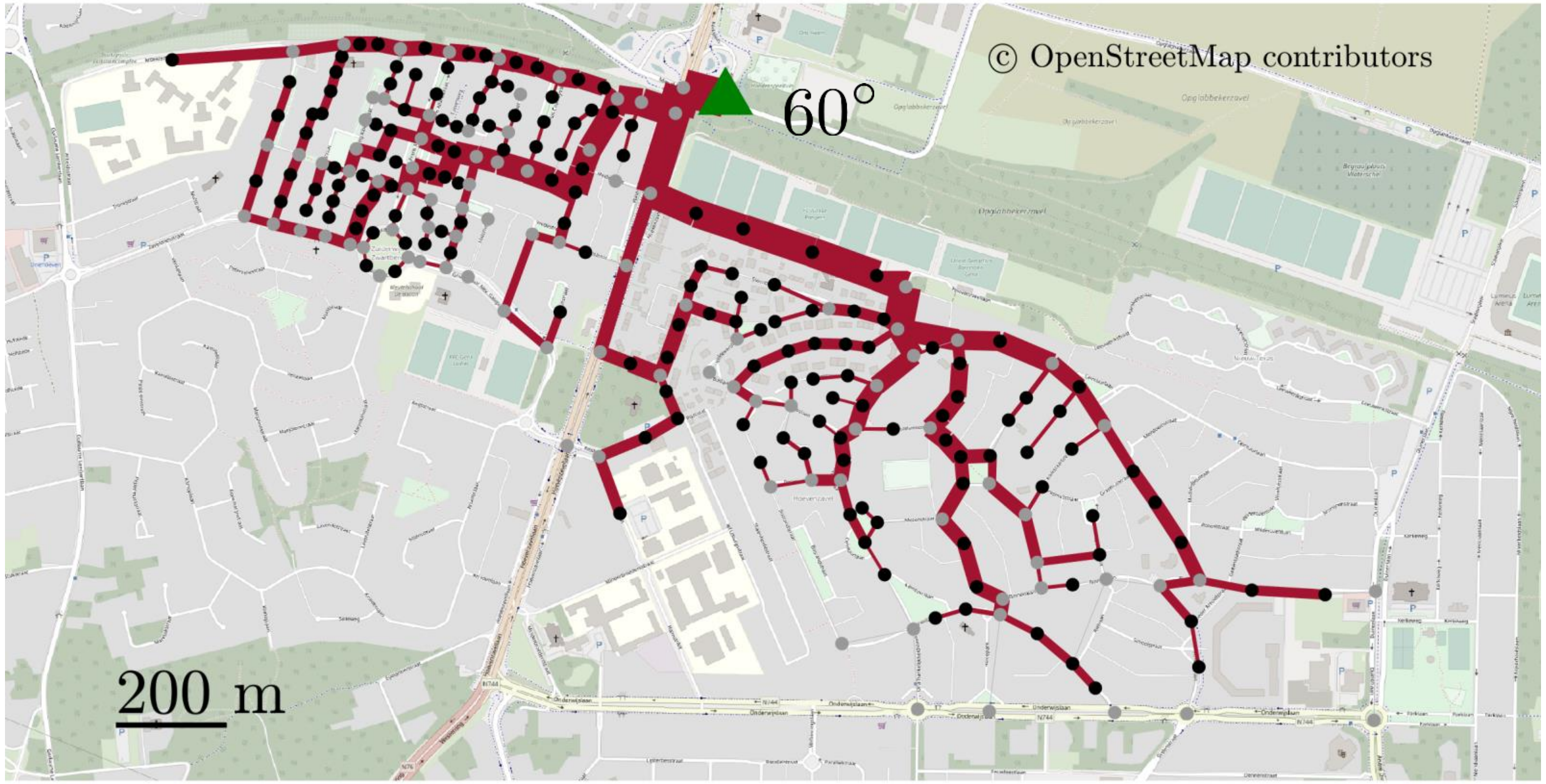


$$Q_{\text{in}} = 3,76\ \text{MW}$$

$$\text{NPV} = 8,42\ \text{M€}$$

$$c_{\min} = 6,31\ \text{ct/kWh}$$

Case study - Lower temperature level

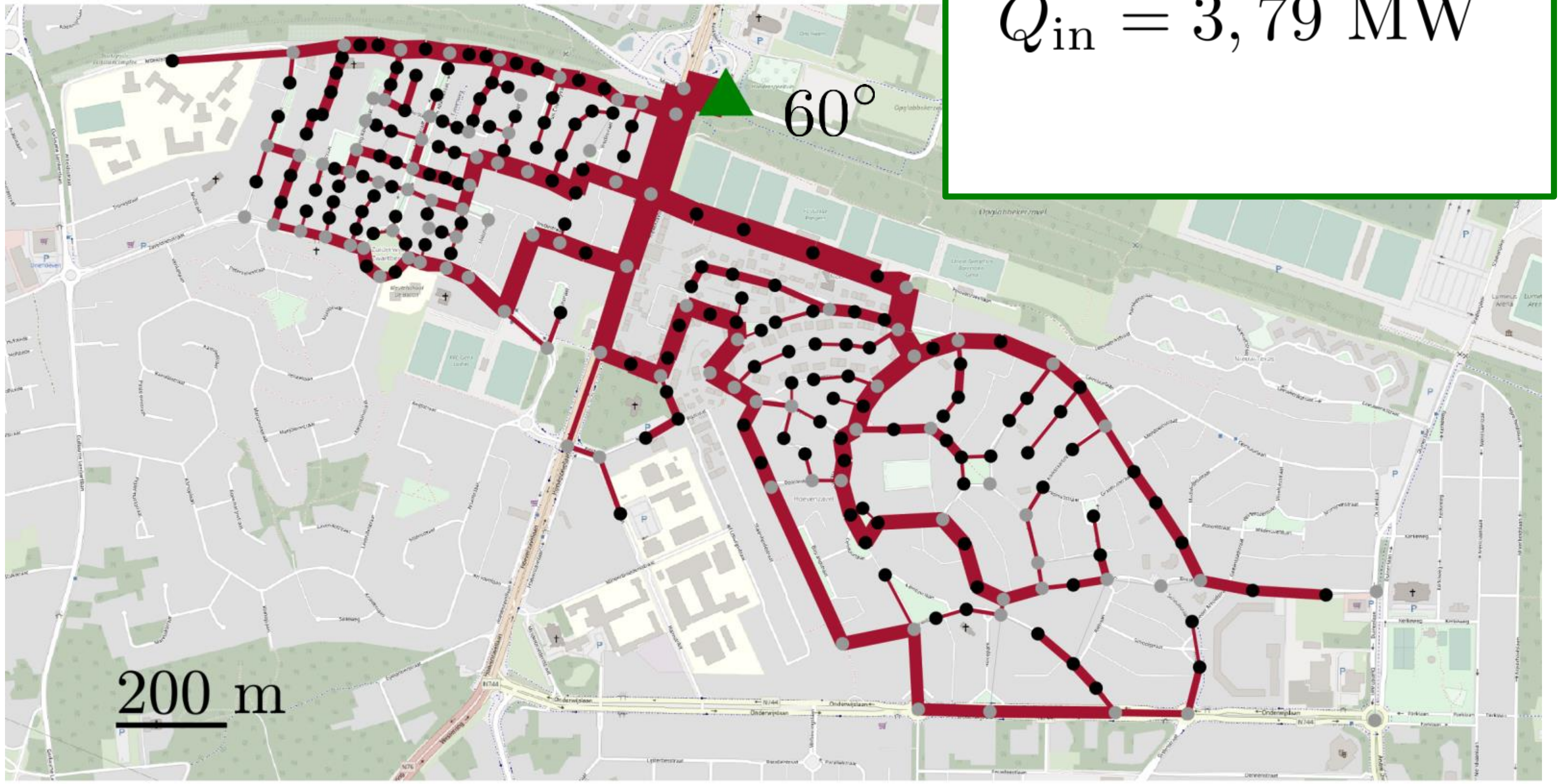


Solving control problem on fixed topology

$$\frac{q_{60^\circ}}{q_{70^\circ}} \approx 1.31$$

$$\|\Delta p\|_\infty = 17,4 \text{ bar}$$

Case study - Lower temperature level

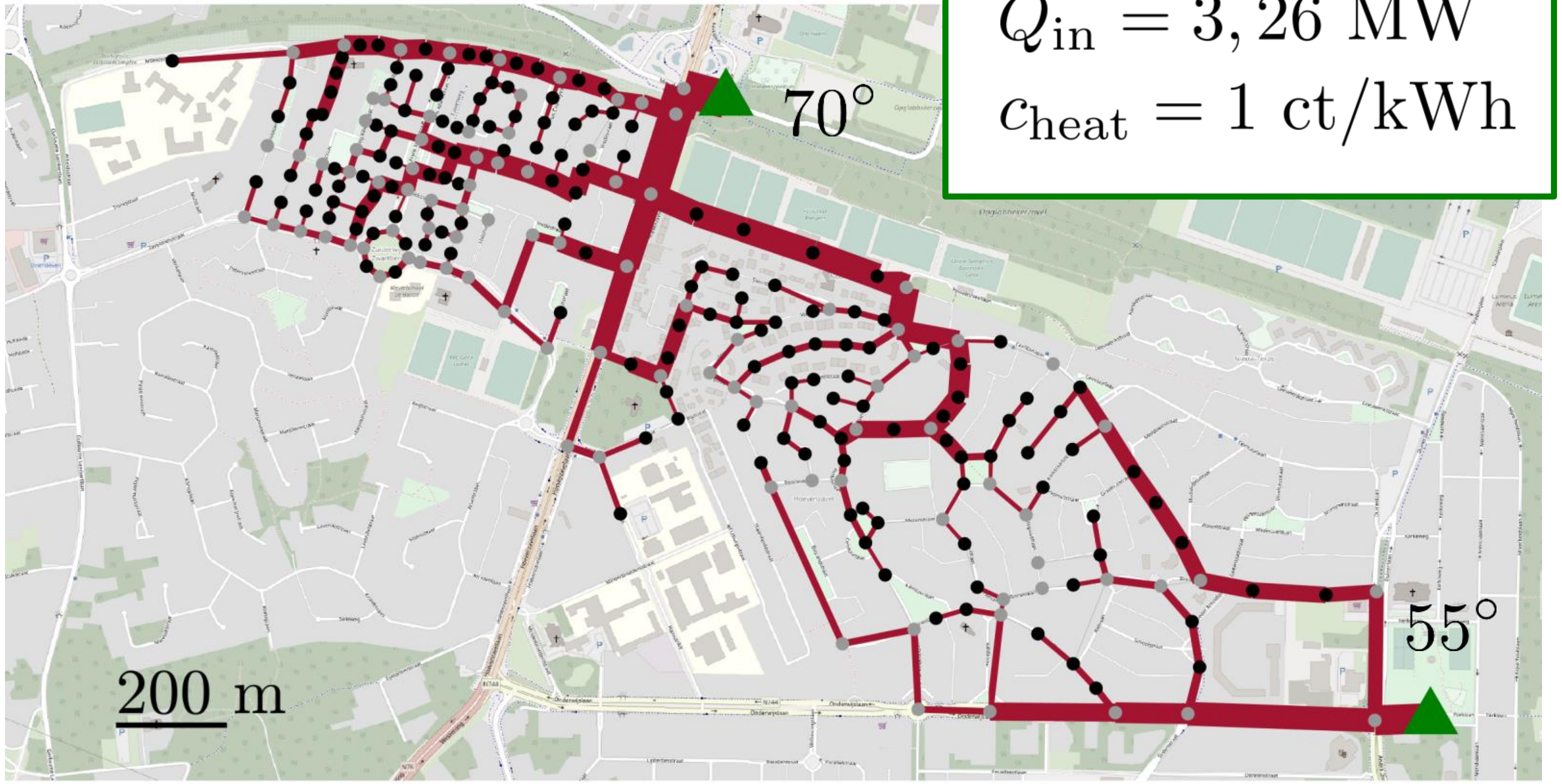


$$Q_{\text{in}} = 3,79 \text{ MW}$$

$$\text{NPV} = 6,73 \text{ M€}$$

$$c_{\min} = 6,65 \text{ ct/kWh}$$

Case study - Additional waste heat

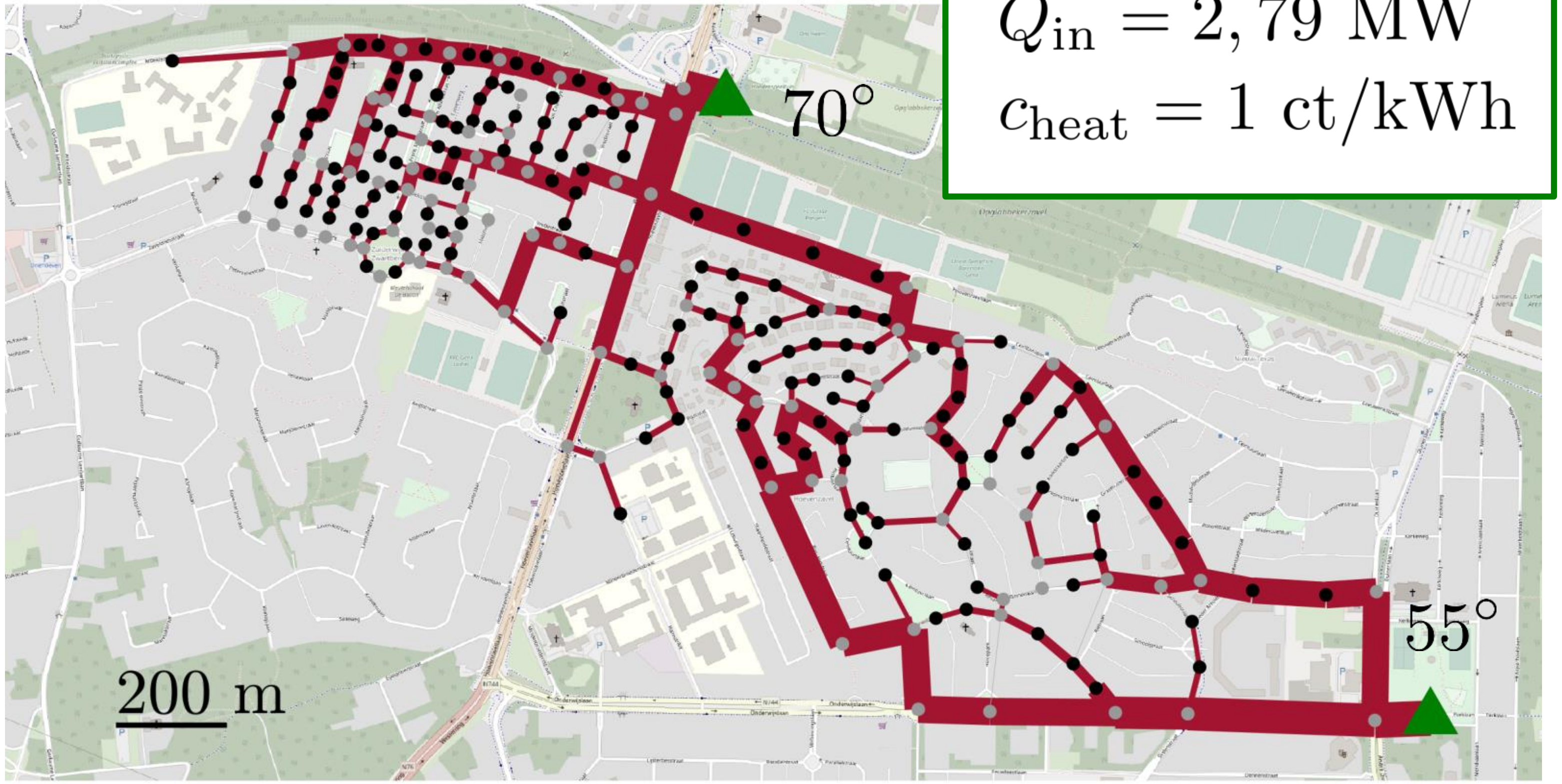


$Q_{\text{in}} = 3,26$ MW
$c_{\text{heat}} = 1$ ct/kWh

NPV = 8,86 M€
$c_{\text{min}} = 6,2$ ct/kWh

$Q_{\text{in}} = 0,5$ MW
$c_{\text{heat}} = 1$ ct/kWh

Case study - Heat pricing



$Q_{\text{in}} = 2,79\ \text{MW}$
$c_{\text{heat}} = 1\ \text{ct/kWh}$

$\text{NPV} = 10,36\ \text{M€}$

$c_{\min} = 5,92\ \text{ct/kWh}$

$Q_{\text{in}} = 1\ \text{MW}$
$c_{\text{heat}} = 0,5\ \text{ct/kWh}$

Conclusion

Adjoint gradients & projection / penalization methods offer a powerful and scalable tool for DHN design

Non-linear transport models and operational details impact both network design and topology

Discrete DHN topology for case study (160 consumers & 632 design variables) was achieved in ~ 20min

Energy Ville

KU LEUVEN

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Sources

Reference

Blommaert, Maarten, Yannick Wack, and Martine Baelmans. "An Adjoint Optimization Approach to Network Topology and Discrete Pipe Size Design for District Heating Networks." arXiv preprint arXiv:2008.08328 (2020).

Icons

“pipe” created by Angelo Troiano from Noun Project

“Geothermal Energy” created by Vectors Point from Noun Project

“Radiator” created by Nikita Kozin from Noun Project

“diameter” created by Magicon from Noun Project

“valve” created by Made from Noun Project

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