4th International Conference on Smart Energy Systems and 4th Generation District Heating
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An automated GIS-based planning and design tool for district heating: Scenarios for a Dutch city

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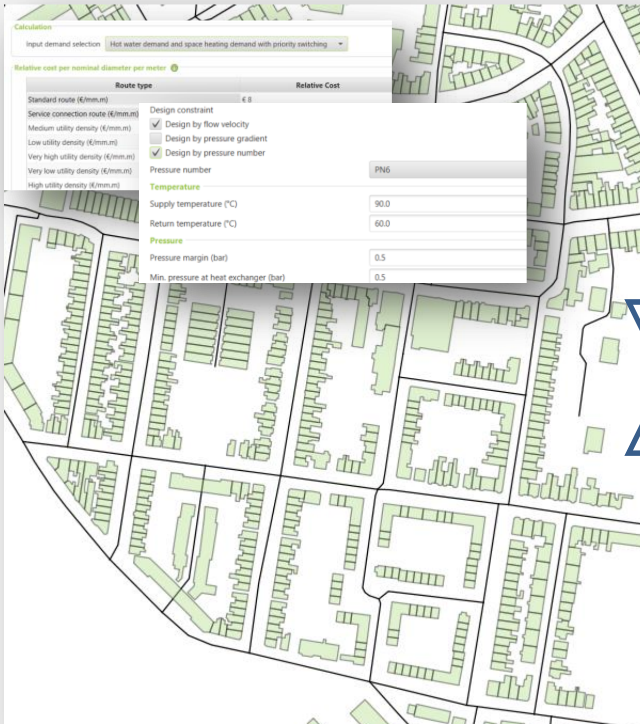
Comsof Heat – GIS based Automated Routing



INPUT: GIS and DESIGN RULES

OUTPUT: NETWORK, BOM and COSTS

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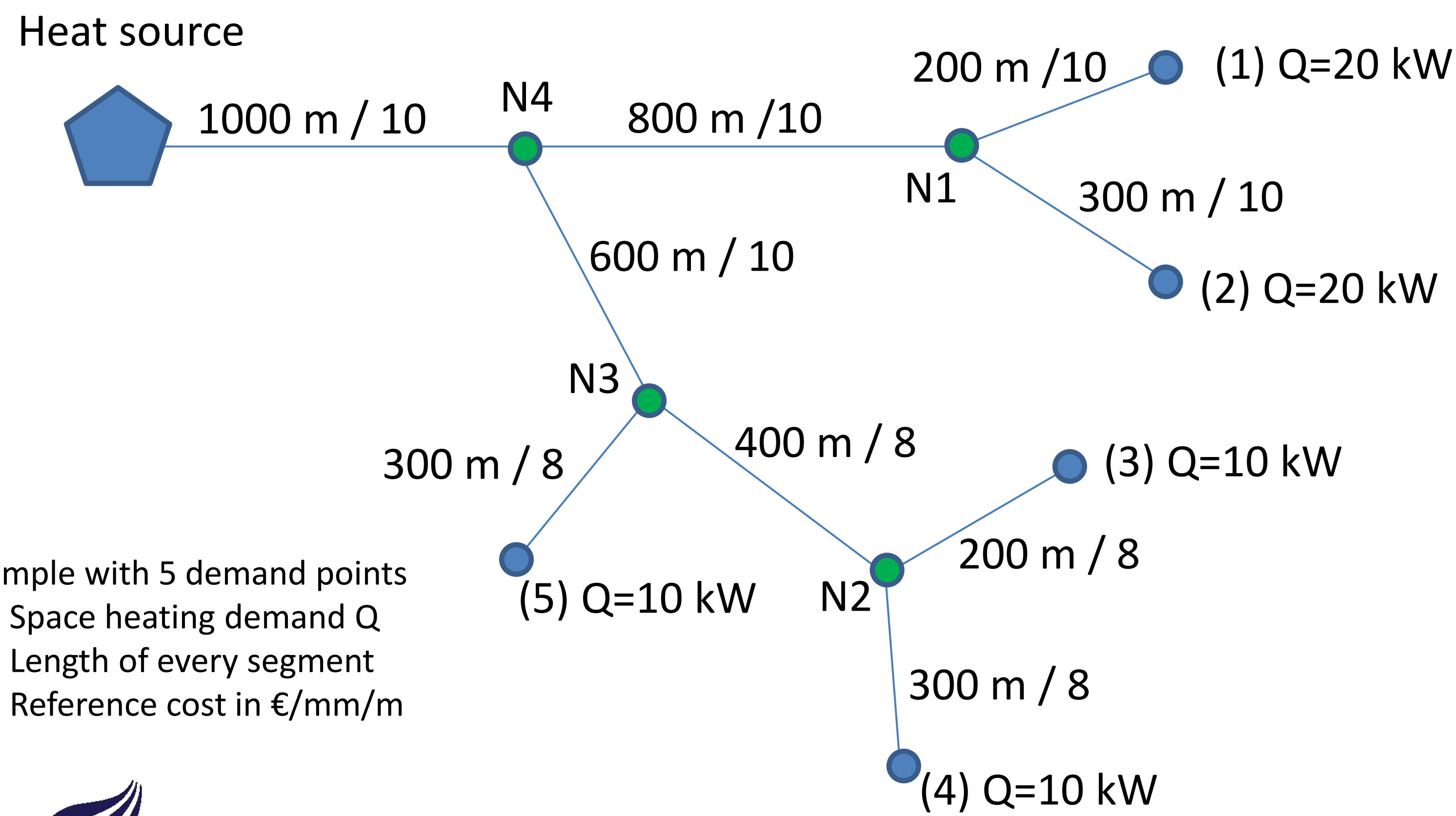
Comsof Heat - Features

- Automatic routing & clustering
  - Cost optimized routing (graph theory) & clustering
  - Based on heuristics
  - Scalable up to multiple thousands of connections
  - Manual adjustments possible
- Dimensioning of transport network and distribution network
  - Cluster size dependant on chosen power of substation
  - Dimension for 6, 10, 16, 25 bar
  - Calculation of heat losses (EN13941+A1 standard)
- Cost estimation of network deployment cost
- Investment analysis module (NPV, IRR, Payback time)
- Allows fast comparison of multiple scenarios in feasibility study phase

Comsof Heat – Design Principles



Example with 5 demand points

- Space heating demand Q
- Length of every segment
- Reference cost in €/mm/m

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Comsof Heat – Design Principles

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- Simultaneity for space heating:
  - SF_{SHi}= 0,62 + (1-0,62)/Ni
  - Where
    - SF_{SHi} = simultaneity factor for space heating at node i
    - Ni = number of houses at node I
- Space heating load: $Q_{SHLi} = SF_{SHi} * Q_{CSHPLi}$
  - Where:
    - Q_{SHLi} = space heat load at node i (Watt)
    - Q_{CSHPLi} = cumulative space heating **peak** load demand at node i (Watt)

Ni	SFi
1	1.000
2	0.810
3	0.747
4	0.715
5	0.696
6	0.683
7	0.674
8	0.668
9	0.662
10	0.658
11	0.655
12	0.652
13	0.649
14	0.647
…	…
800	0.620
…	…
1000	0.620

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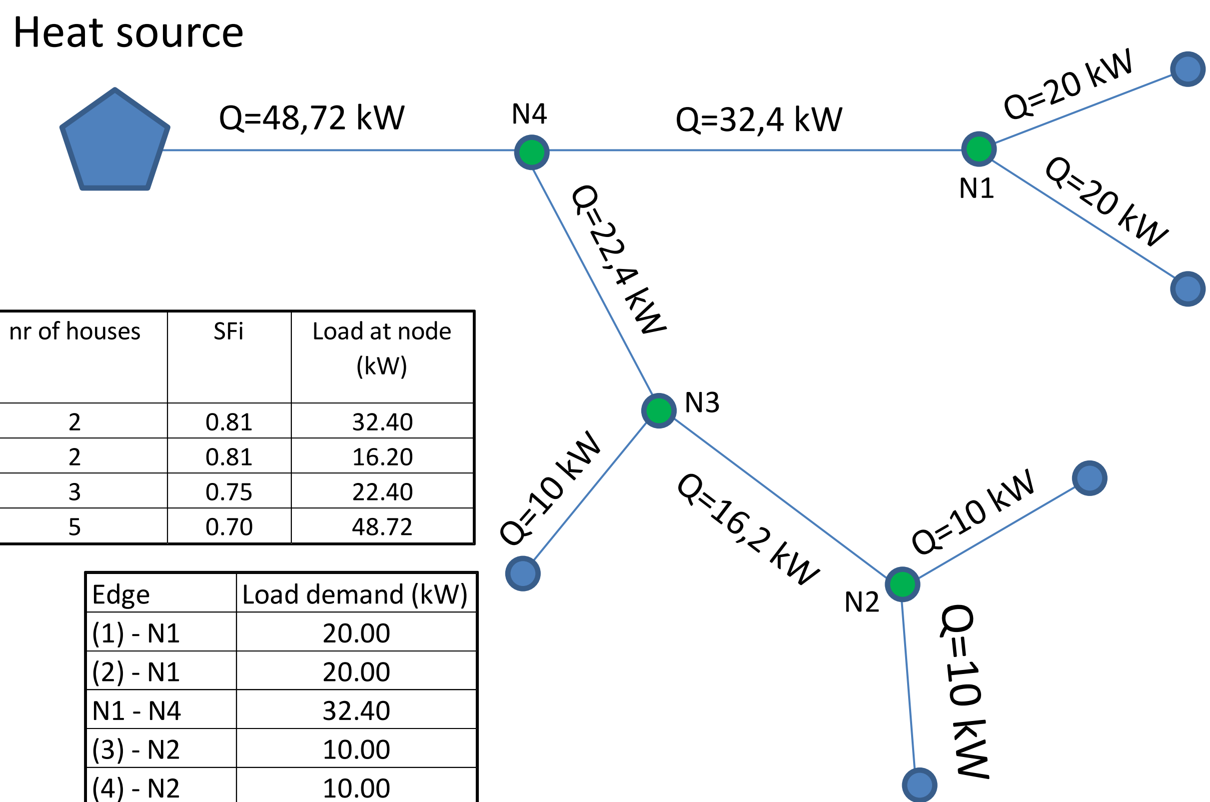
Comsof Heat – Design Principles



	Node	Cumulative peak load (kW)	nr of houses	SFi	Load at node (kW)
N1	1	40	2	0.81	32.40
N2	2	20	2	0.81	16.20
N3	3	30	3	0.75	22.40
N4	4	70	5	0.70	48.72

Edge	Load demand (kW)
(1) - N1	20.00
(2) - N1	20.00
N1 - N4	32.40
(3) - N2	10.00
(4) - N2	10.00
N2 - N3	16.20
(5) - N3	10.00
N3 - N4	22.40
N4 - Source	48.72

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Comsof Heat – Heat flow equation

Heat flow equation:

$$\underline{Q} = \underline{m} \times cp \times \Delta T$$

where,

$\underline{Q}$ - heat demand (W)

m - mass flow rate (kg/s)

cp - specific heat capacity (J/kg.K)

ΔT- temperature difference

Mass flow rate:

$$m = A_i.\rho.v$$

Where,

A_i - internal area of pipe (m^2)

ρ - density (kg/ m^3)

v – fluid velocity (m/s)

Comsof Heat – lookup table

- Calculate Q for all standard pipe diameters with given input parameters (from input rules):
  - Supply and return temperature
  - Surface roughness
  - Max allowed pressure loss

Max Heat transfer Q (kW)	Nominal diameter
5.0	DN15
10.9	DN20
21.2	DN25
41.6	DN32
62.3	DN40
118.3	DN50
236.3	DN65
364.5	DN80
737.5	DN100
1307.6	DN125
2180.2	DN150
4497.4	DN200
8189.9	DN250
12987.0	DN300
16790.3	DN350
23973.9	DN400
33042.5	DN450
44072.8	DN500
71846.1	DN600
107963.8	DN700
154196.4	DN800
209899.6	DN900
277612.8	DN1000
449961.6	DN1200

Comsof Heat – Pipe selection

- Select the pipe diameter that is big enough to transport the requested power in each edge of the network.

Network data

Edge	Load demand (kW)
(1) - N1	20.00
(2) - N1	20.00
N1 - N4	32.40
(3) - N2	10.00
(4) - N2	10.00
N2 - N3	16.20
(5) - N3	10.00
N3 - N4	22.40
N4 - Source	48.72

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Lookup table

Max Heat transfer Q (kW)	Nominal diameter
5.0	DN15
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107963.8	DN700
154196.4	DN800
209899.6	DN900
277612.8	DN1000
449961.6	DN1200

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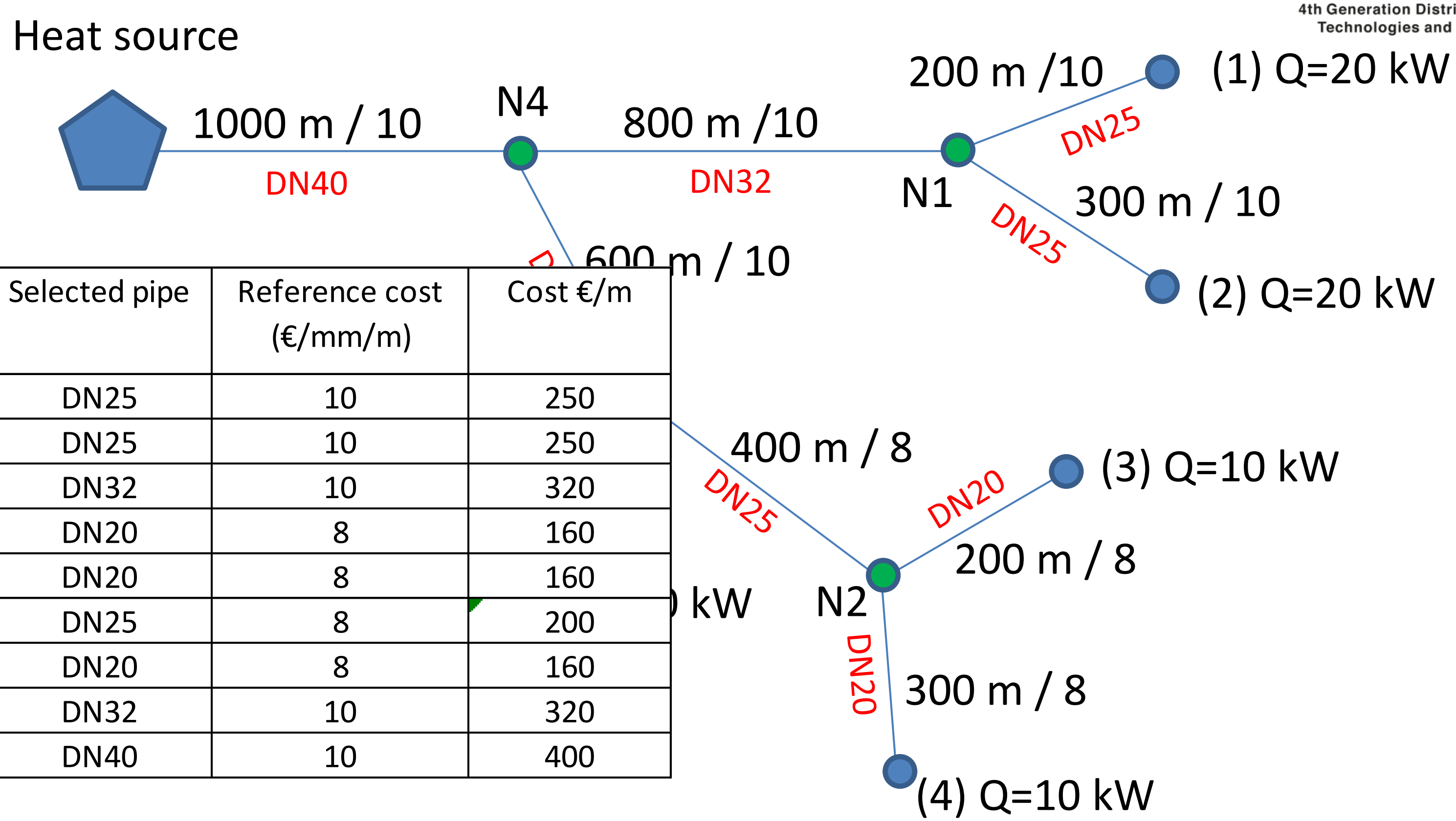
Resulting network

Edge	Load demand (kW)	Selected pipe
(1) - N1	20.00	DN25
(2) - N1	20.00	DN25
N1 - N4	32.40	DN32
(3) - N2	10.00	DN20
(4) - N2	10.00	DN20
N2 - N3	16.20	DN25
(5) - N3	10.00	DN20
N3 - N4	22.40	DN32
N4 - Source	48.72	DN40

Comsof Heat – Network Cost Estimation



Edge	Selected pipe	Reference cost (€/mm/m)	Cost €/m
(1) - N1	DN25	10	250
(2) - N1	DN25	10	250
N1 - N4	DN32	10	320
(3) -N2	DN20	8	160
(4) - N2	DN20	8	160
N2 - N3	DN25	8	200
(5) - N3	DN20	8	160
N3-N4	DN32	10	320
N4 - Source	DN40	10	400

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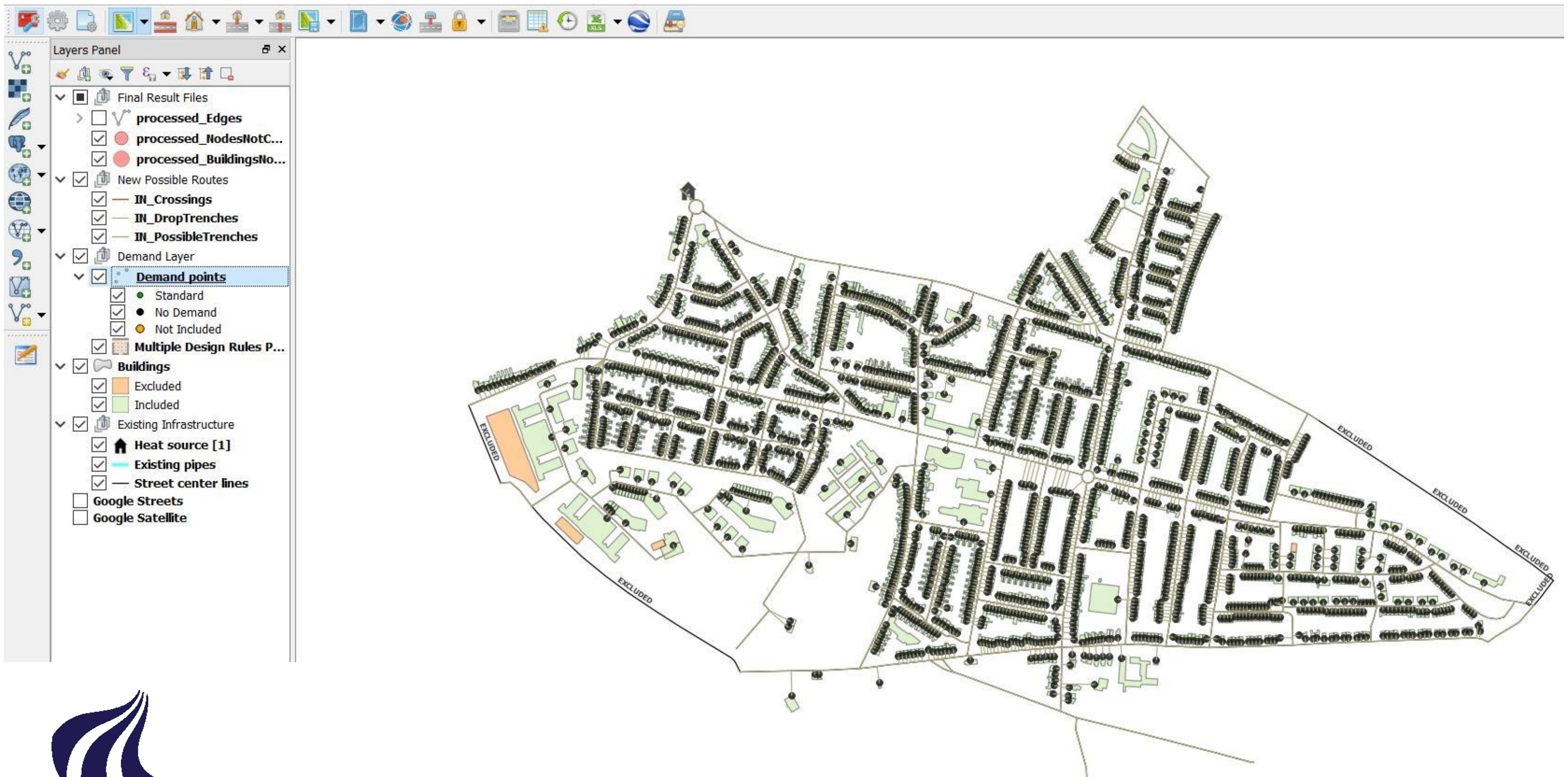
Comsof Heat – Network Cost Estimation

Edge	Load demand (kW)	Selected pipe	Length (m)	Reference cost (€/mm/m)	Cost €/m	Total cost (€)
(1) - N1	20.00	DN25	200	10	250	50,000.00
(2) - N1	20.00	DN25	300	10	250	75,000.00
N1 - N4	32.40	DN32	800	10	320	256,000.00
(3) -N2	10.00	DN20	200	8	160	32,000.00
(4) - N2	10.00	DN20	300	8	160	48,000.00
N2 - N3	16.20	DN25	400	8	200	80,000.00
(5) - N3	10.00	DN20	300	8	160	48,000.00
N3-N4	22.40	DN32	600	10	320	192,000.00
N4 - Source	48.72	DN40	1000	10	400	400,000.00
			4100			*1,181,000.00*

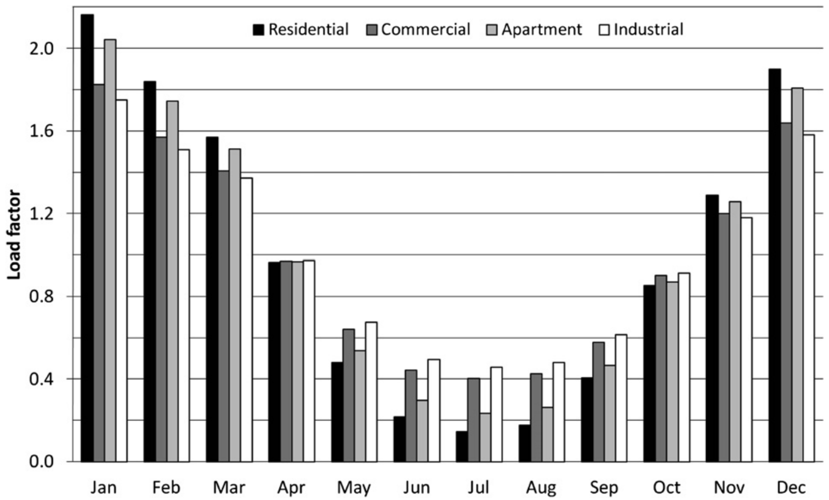
Case Study: Nijmegen - Hengstdal

More than 2300 buildings



Network Design Parameters

- Heat demand estimation from yearly **gas consumption data**
- DH network designed for **peak load**
- Network operating temperature levels:
  - Transport network - 65 degC and 40 degC
  - Distribution network – 60 degC and 35 degC



Monthly heat load factors

Source: Dalla Rosa, A., et al. "District heating (DH) network design and operation toward a system-wide methodology for optimizing renewable energy solutions (SMORES) in Canada: A case study." *Energy* 45.1 (2012): 960-974.

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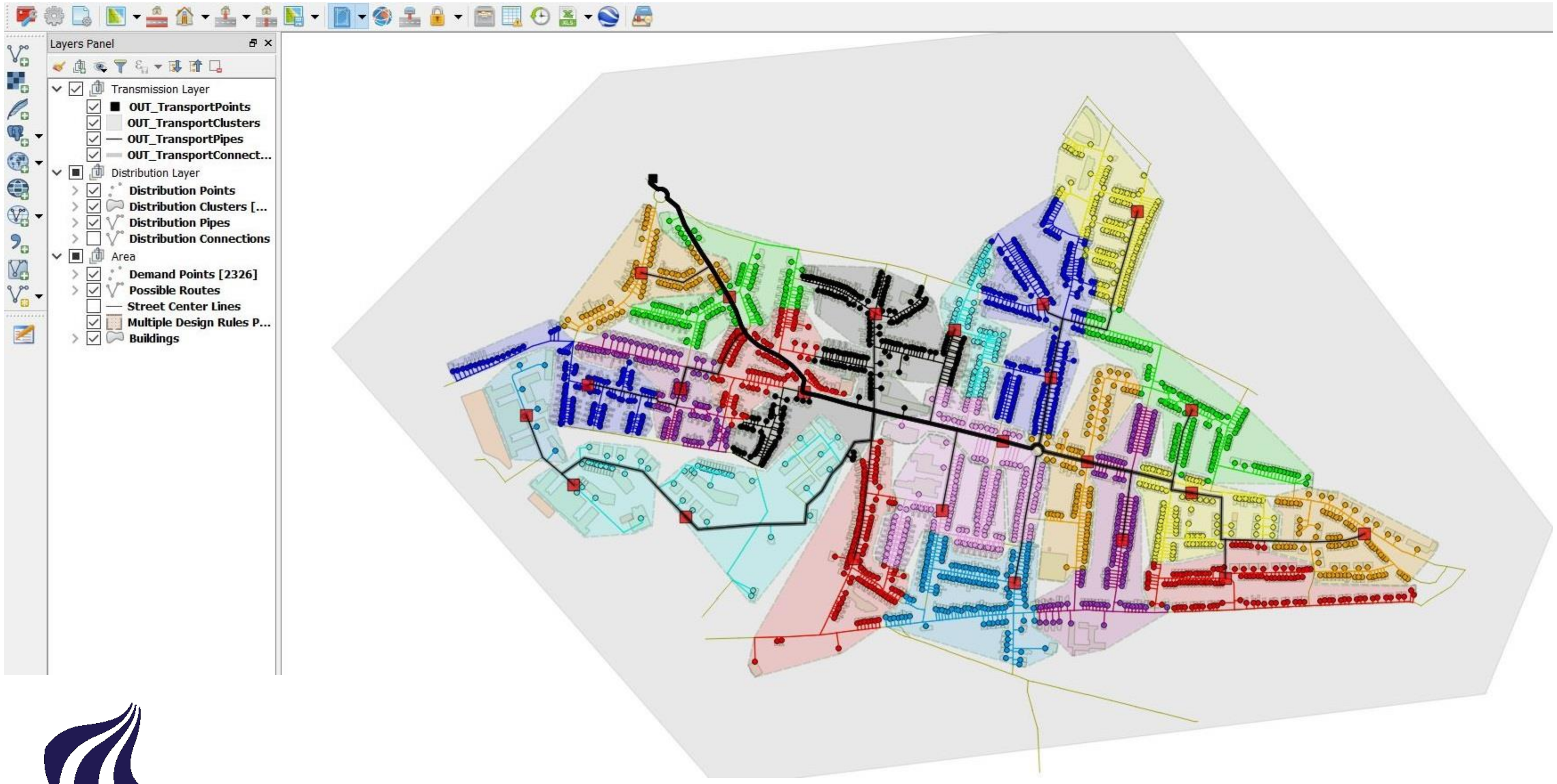
Designed Network with Transport and Distribution Layers



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Design Choice Scenarios

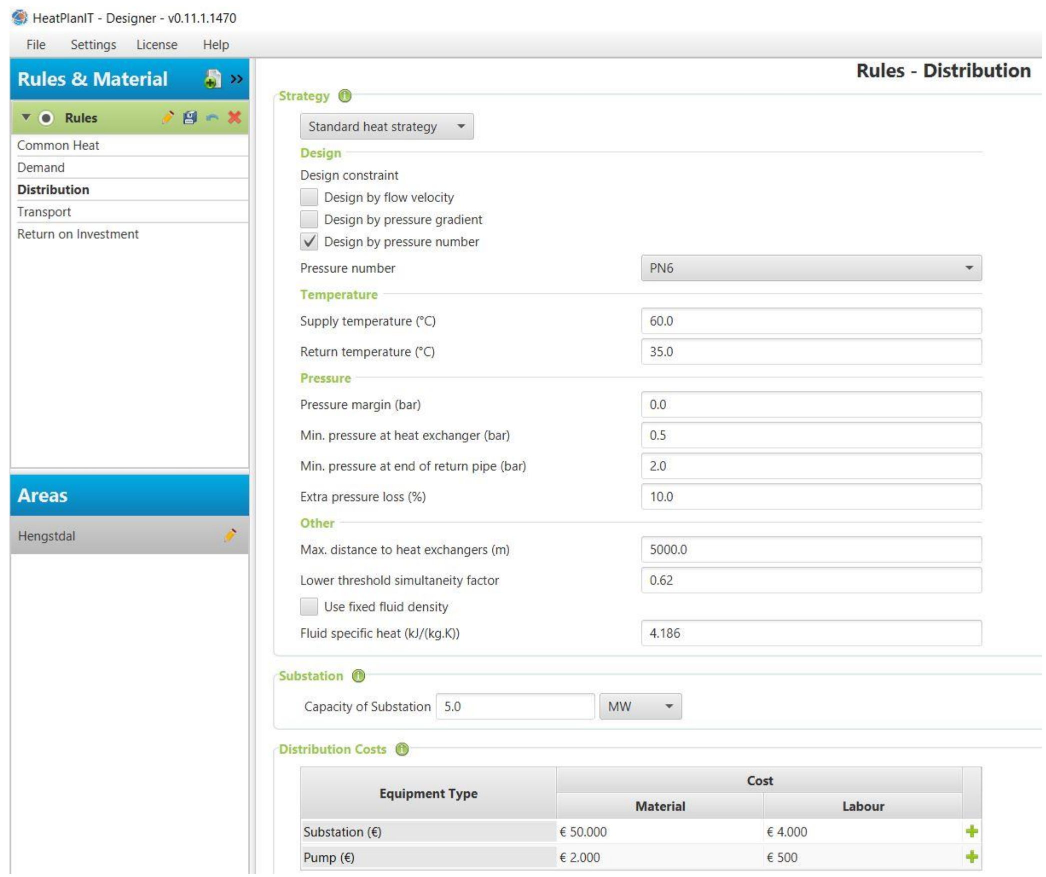
Design by flow velocity

Design by pressure number (Distribution and Transport pressure levels)

- PN6 and PN10
- PN10 and PN16
- PN16 and PN25

Substation:

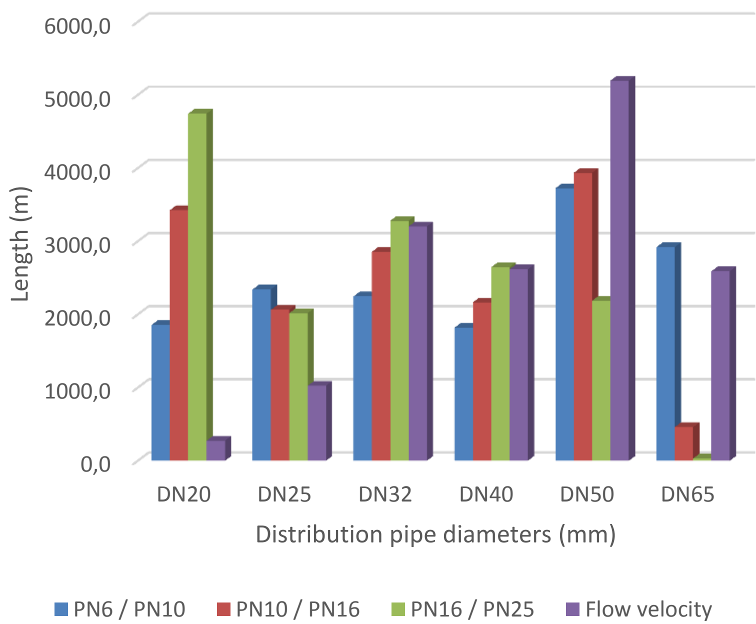
- Substation size



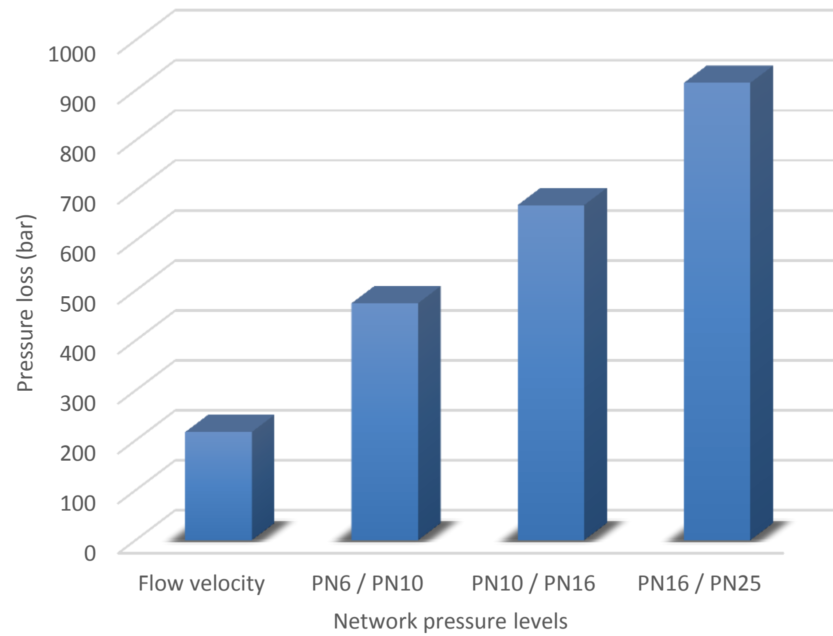
Design Choice Scenarios

Different pressure levels:

Impact on pipe diameter



Impact on pressure loss



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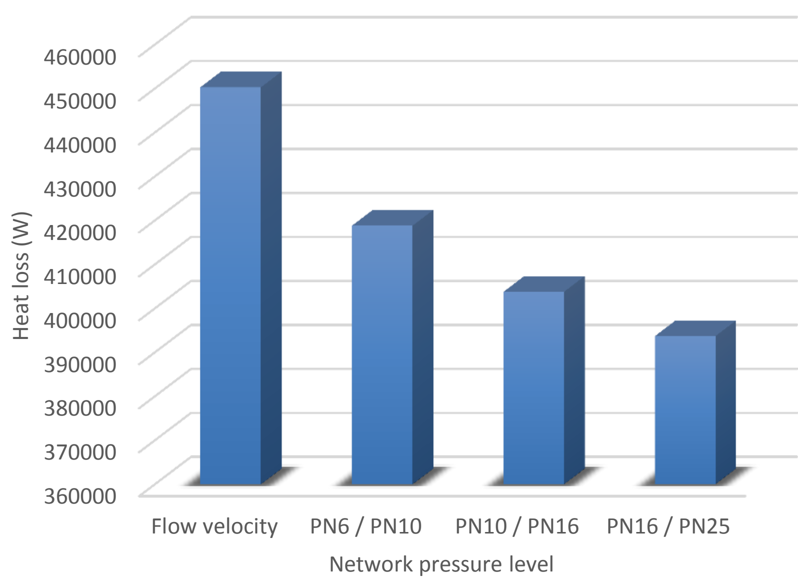
Design Choice Scenarios

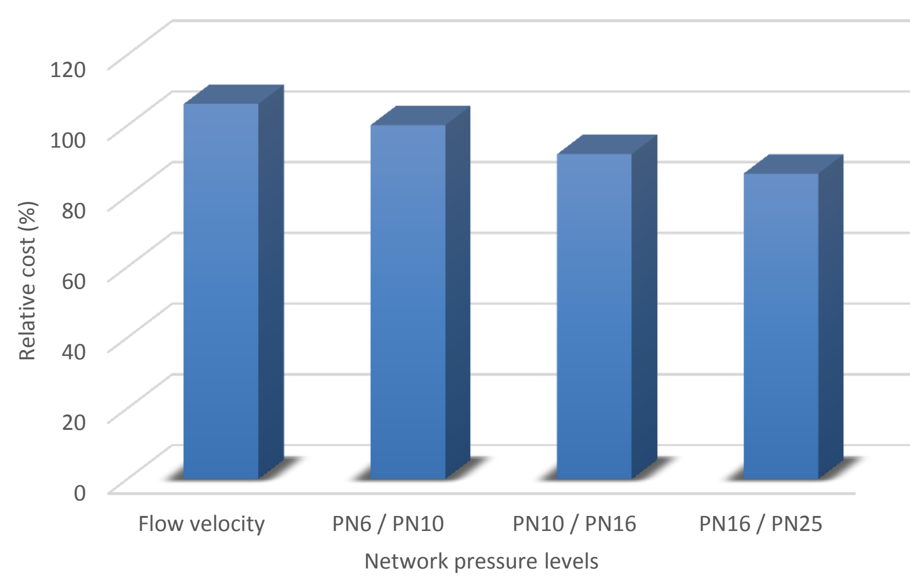
Different pressure levels:

Impact on heat loss



Reduction up to **13%**

Impact on cost



Reduction up to **18%**

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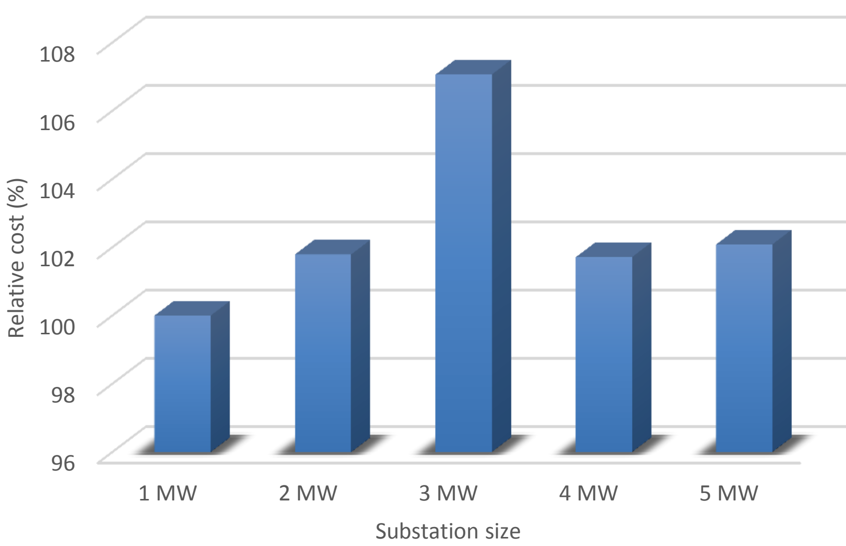
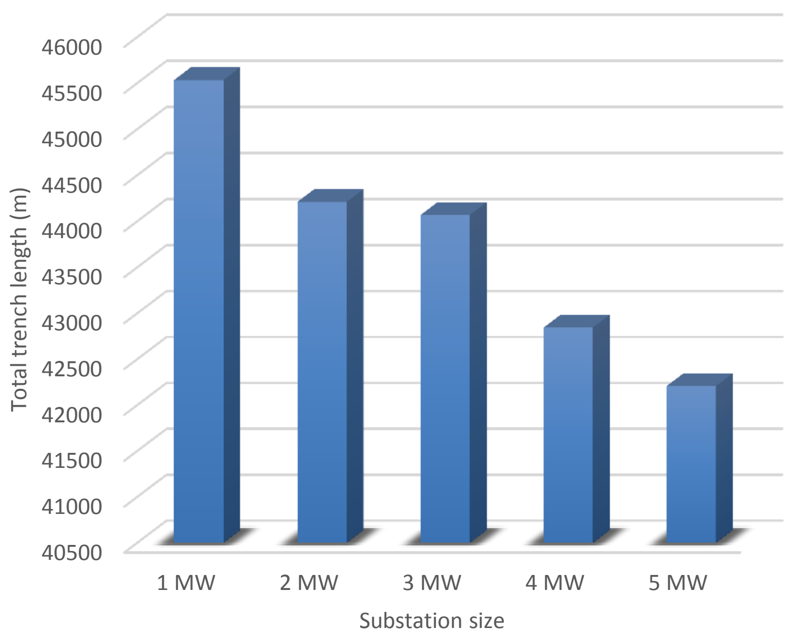
Design Choice Scenarios

Different substation sizes:

Impact on cost



Impact on total trench length



Reduction up to **8%**

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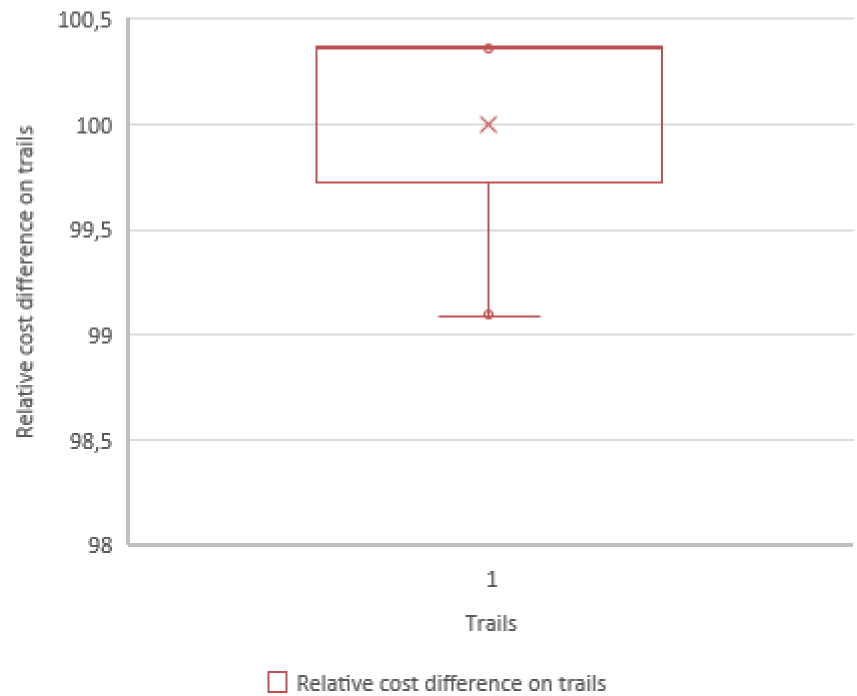
Repetition Scenarios – Coefficient of Variation

- Number of trials – **7**
- Coefficient of variation (CoV) is **0.6%**
- Calculated with relative difference in cost



Demand Reduction Scenarios

Reduction in space heating demand and keeping **hot water demand constant**

Reduction in space heating demand and having **separate electric boilers for hot water demand**

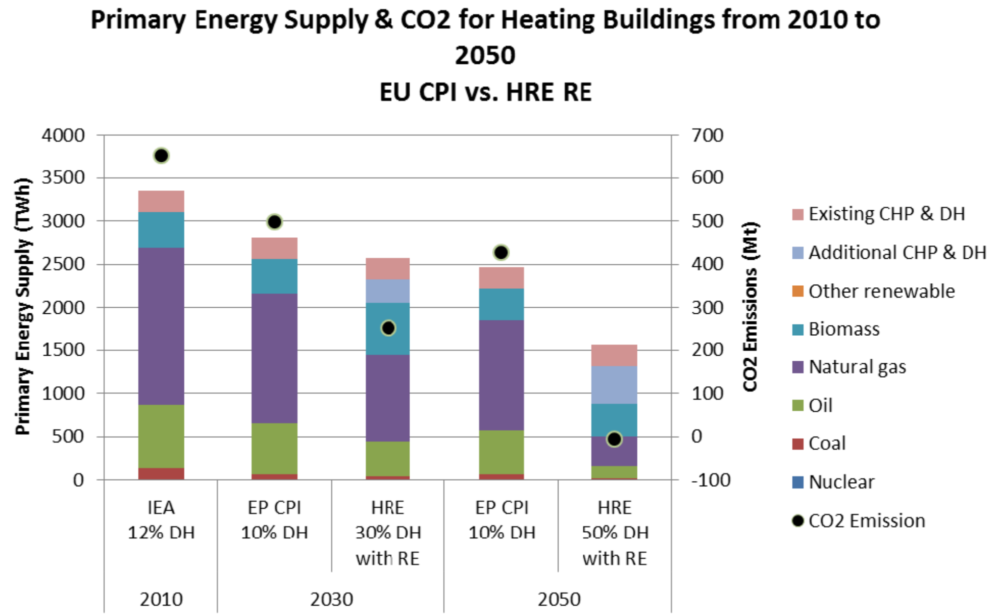


Figure 34: Primary energy supply and carbon dioxide emissions from hot water and the heating of buildings in the 2010, 2030, and 2050 EU27 energy system under a business-as-usual scenario and if district heating and CHP is expanded to 30% in 2030 and to 50% in 2050, in combination with the expansion of industrial waste heat, waste incineration, geothermal, and solar thermal heat for district heating.

Source: HEAT Roadmap Europe 2050 – Study for the EU27

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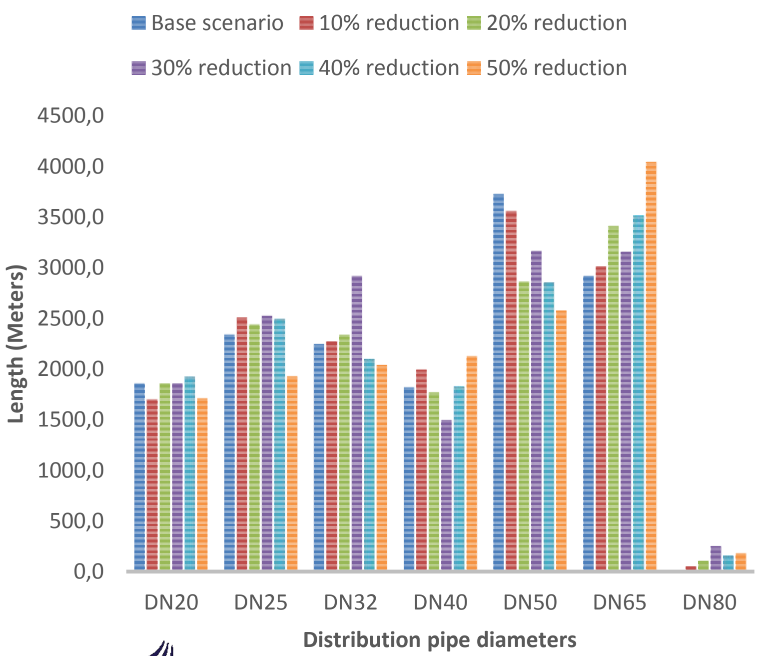
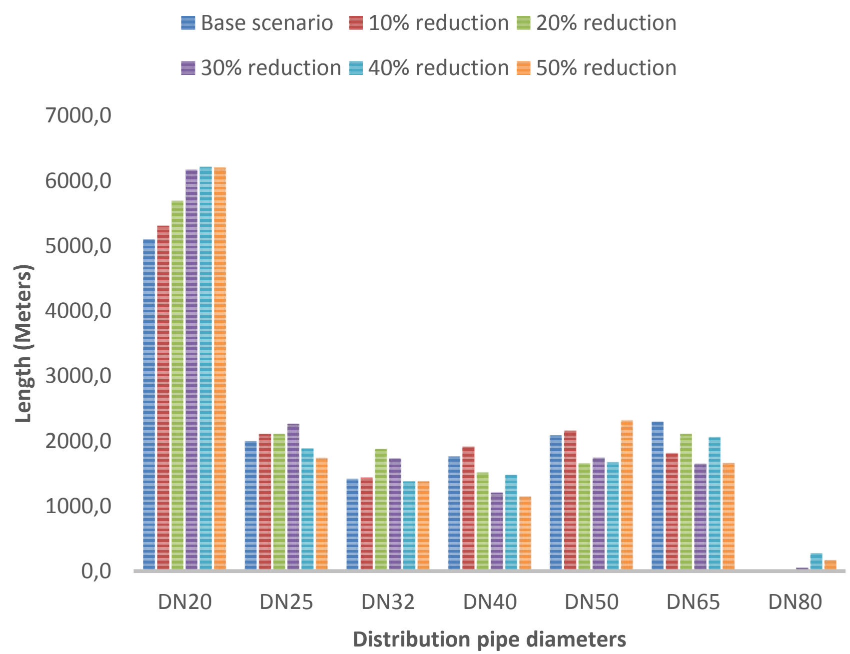
Demand Reduction Scenarios

Impact on pipe diameters:

With hot water demand constant



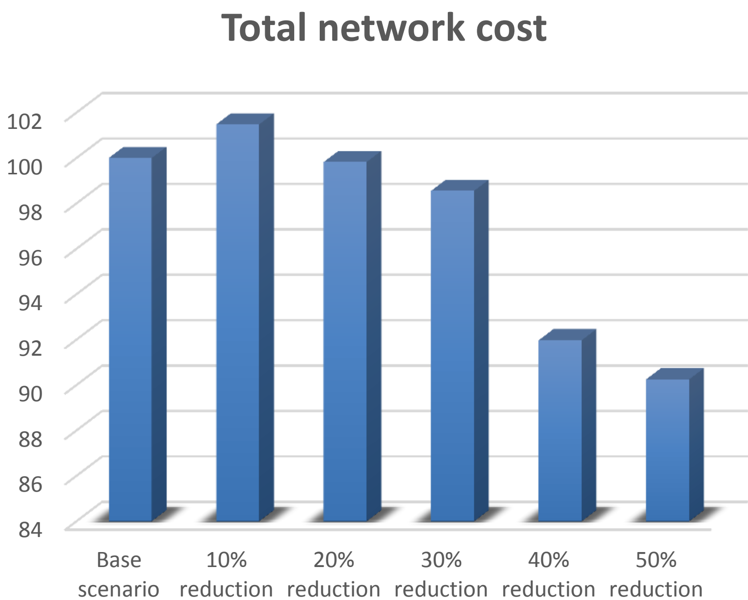
Without hot water demand



Demand Reduction Scenarios

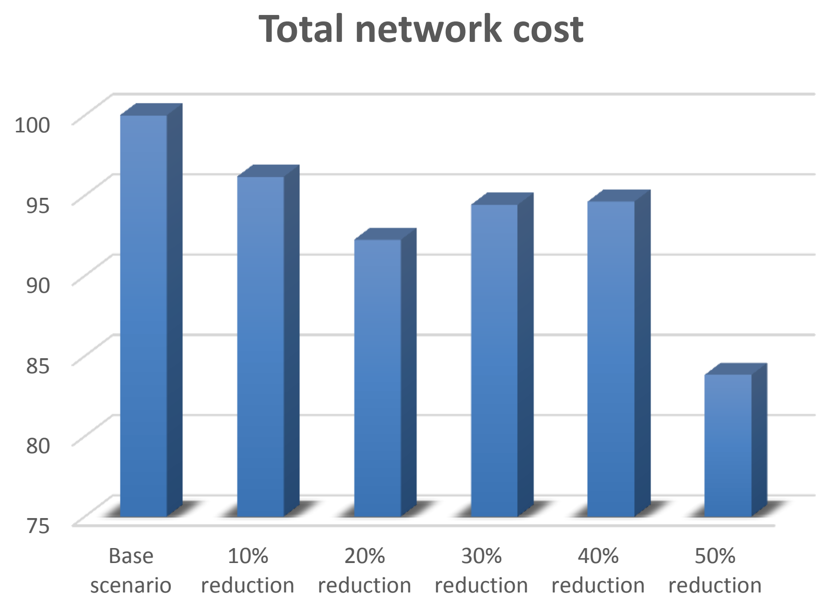
Impact on network deployment cost:

With hot water demand constant



Reduction up to **9%**

Without hot water demand



Reduction up to **16%**

Trench length dominates!

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Demand Reduction Scenarios

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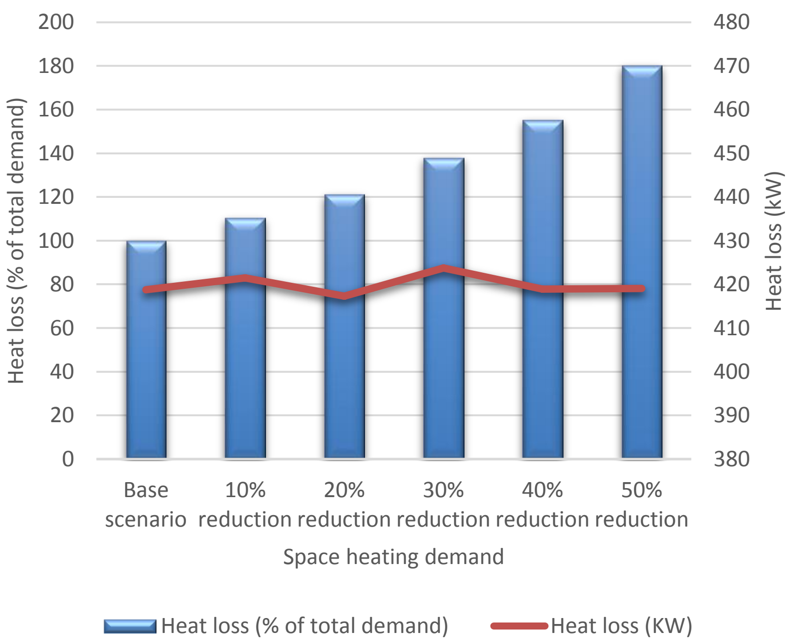
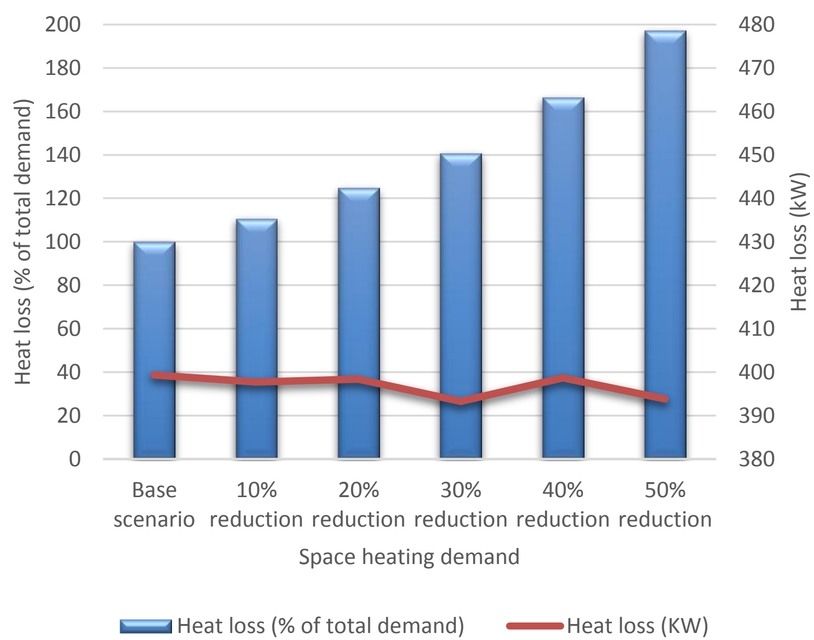
Impact on heat loss:

With hot water demand constant



Increase up to **80%**

Without hot water demand



Increase up to **98%**

Reduce network supply temperature!

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Summary

Comsof Heat reduces the calculation time significantly

Network pressure levels and substation size:

- Impact on cost, heat and pressure loss

Reduction in heat demand:

- doesn’t lead to corresponding reduction in network deployment cost
- Increase heat loss substantially

Action:

- Integration of localised / decentralized energy production and storage inside networks