

# An automated GIS-based planning and design tool for district heating: Scenarios for a Dutch city

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**AALBORG UNIVERSITY**  
DENMARK

4th International Conference on Smart Energy  
Systems and 4th Generation District Heating 2018  
#SES4DH2018

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# 4DH

**4th Generation District Heating  
Technologies and Systems**

# Comsof Heat – GIS based Automated Routing



**DH**  
District Heating  
Technologies and Systems

**INPUT: GIS and DESIGN RULES**

Calculation  
Input demand selection: Hot water demand and space heating demand with priority switching

Relative cost per nominal diameter per meter

Route type: Standard route (€/mm.m) € 8

Design constraint:  
 Design by flow velocity  
 Design by pressure gradient  
 Design by pressure number

Pressure number: P16

Temperature:  
 Supply temperature (°C): 90.0  
 Return temperature (°C): 60.0

Pressure:  
 Pressure margin (bar): 0.5  
 Min. pressure at heat exchanger (bar): 0.5



**OUTPUT: NETWORK, BOM and COSTS**

Unit	Material Cost	Labour Cost	Total	Calculated Cost	Unit
Service connection	€ 0.	€ 200.	€ 200.	5360.2	€ 1,812,043.39
Pipe and trench - DN20	€ 0.	€ 200.	€ 200.	137.0	€ 34,674.32
Pipe and trench - DN25	€ 0.	€ 330.	€ 330.	11.8	€ 3,760.23
Pipe and trench - DN40	€ 0.	€ 600.	€ 600.	21.6	€ 12,601.99
Demand	€ 0.	€ 0.	€ 0.	670.0	€ 0.
Extra activation cost per Home (heat exchanger - power 1 to 50kW)	€ 0.	€ 0.	€ 0.	291.0	€ 0.
Extra activation cost per Home (heat exchanger - Power > 50kW)	€ 0.	€ 0.	€ 0.	0.0	€ 0.
Distribution	€ 0.	€ 800.	€ 800.	40.4	€ 32,283.45
Pipe and trench - DN100	€ 0.	€ 180.	€ 180.	1868.5	€ 334,907.73
Pipe and trench - DN20	€ 0.	€ 200.	€ 200.	1059.2	€ 216,636.29
Pipe and trench - DN25	€ 0.	€ 250.	€ 250.	1054.8	€ 260,264.63
Pipe and trench - DN40	€ 0.	€ 300.	€ 300.	391.1	€ 116,847.18
Pipe and trench - DN50	€ 0.	€ 350.	€ 350.	619.4	€ 217,742.33
Pipe and trench - DN80	€ 0.	€ 400.	€ 400.	0.0	€ 0.
Substation	€ 0.	€ 0.	€ 0.	0.0	€ 0.
Pump	€ 0.	€ 0.	€ 0.	0.0	€ 0.
Transport	€ 0.	€ 0.	€ 0.	0.0	€ 0.
Pipe and trench - DN175	€ 0.	€ 0.	€ 0.	0.0	€ 0.

**Calculation Information**

Area Name	Area	Area	Area
Origin	167	167	167
Number of Homes	423	423	423
Household Density (Ht/ha)	423/167	2.53	2.53

**Cost Breakdown**

Network Cost	Home area	%
Service connection	€ 1,812,043.39	94%
Demand	€ 0.0	0%
Distribution	€ 1,217,246.46	61%
Transport	€ 1,208,246.69	23%
Total Cost	€ 3,388,791.37	100%

**Results**

Item	Value
Total Cost of Project	€ 3,388,791.37
Total Public branch length (m)	35,983.32
Deployment Cost per Home	€ 5,488.6



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# Comsof Heat - Features

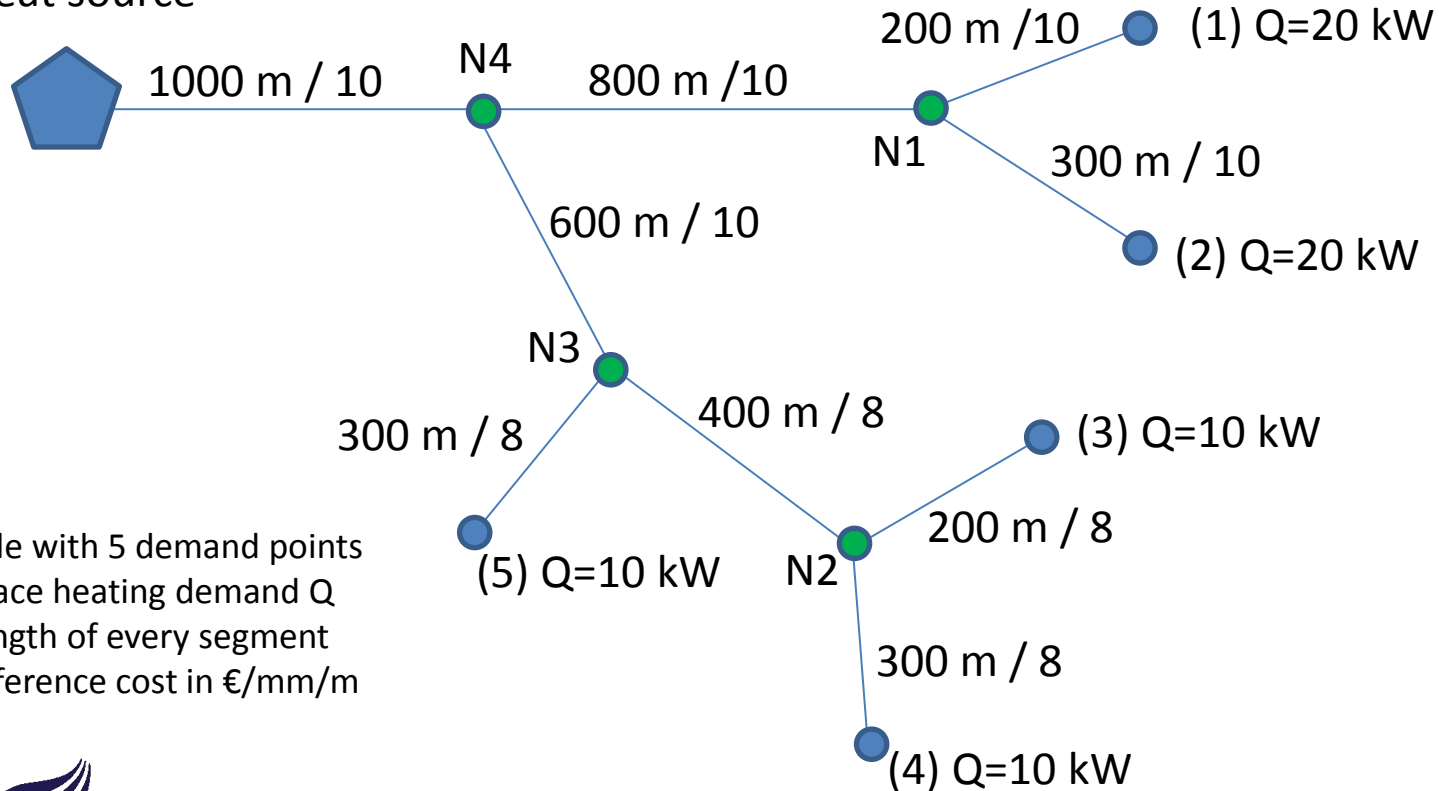


- Automatic routing & clustering
  - Cost optimized routing (graph theory) & clustering
  - Based on heuristics
  - Scalable up to multiple thousands of connections
  - Manual adjustments possible
- Dimensioning of transport network and distribution network
  - Cluster size dependant on chosen power 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

Heat source



Example with 5 demand points

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



# Comsof Heat – Design Principles



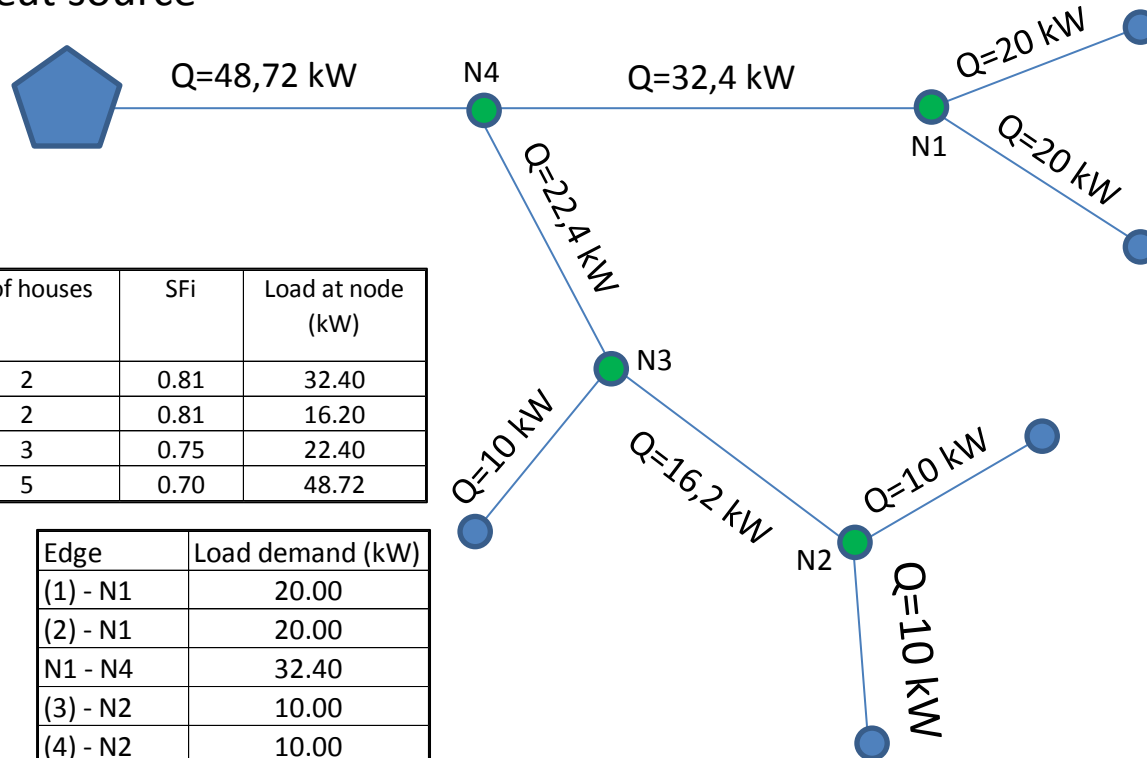
- Simultaneity for space heating:
  - $SF_{SHi} = 0,62 + (1-0,62)/Ni$
  - Where
    - $SF_{SHi}$  = simultaneity factor for space heating at node i
    - $Ni$  = number of houses at node i
- Space heating load:  $Q_{SHLi} = SF_{SHi} * Q_{CSHPLi}$ 
  - Where:
    - $Q_{SHLi}$  = space heat load at node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



# Comsof Heat – Design Principles

Heat source



	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



# Comsof Heat – Heat flow equation



Heat flow equation:

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

where,

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

$\underline{m}$  - mass flow rate (kg/s)

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

$\Delta T$  - temperature difference

Mass flow rate:

$$m = A_i \cdot \rho \cdot v$$

Where,

$A_i$  - internal area of pipe ( $m^2$ )

$\rho$  - 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. **Lookup table**

## 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



Max Heat transfer Q (kW)	Nominal diameter
5.0	DN15
10.9	DN20
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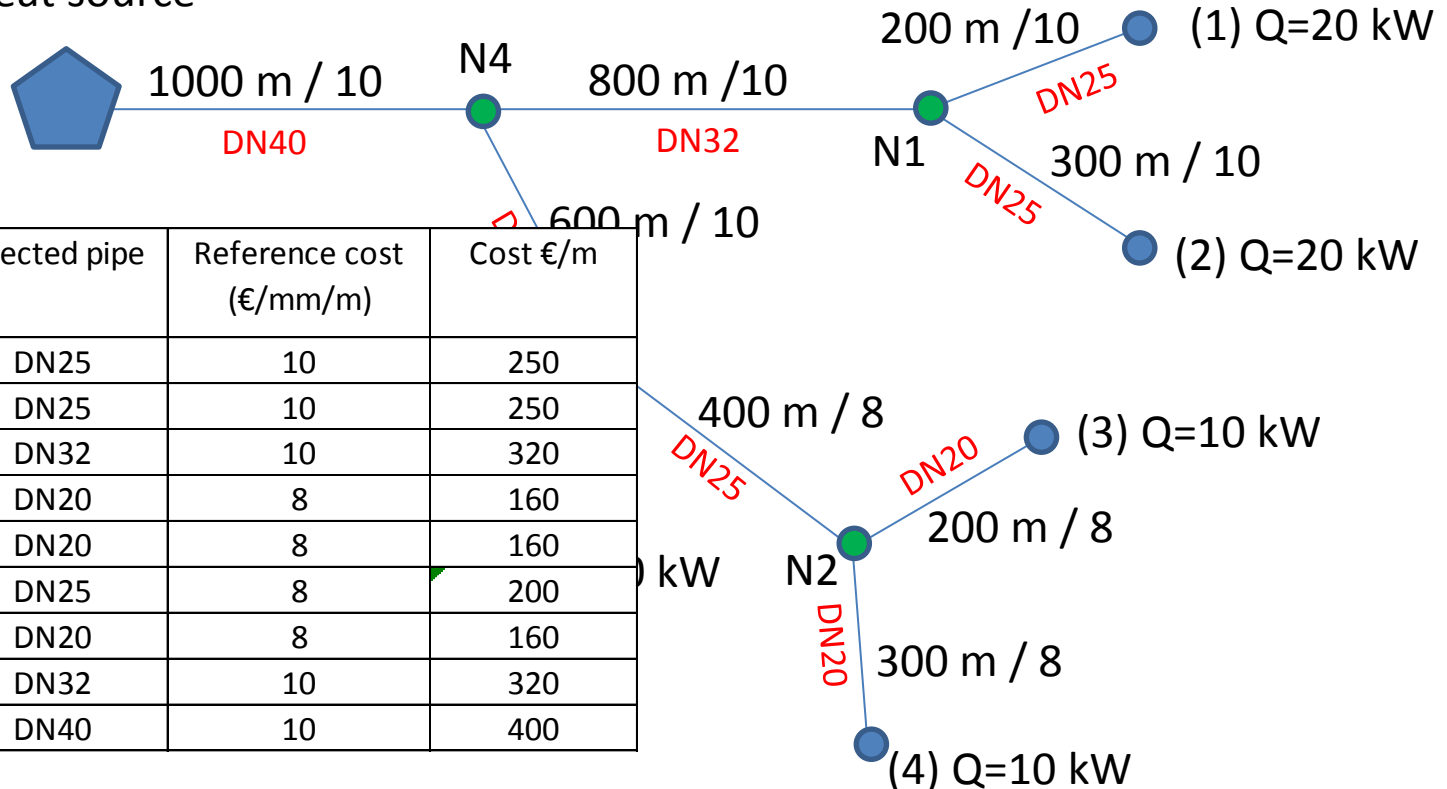
## Resulting network

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

Heat source



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



# 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
			<i>4100</i>			<i>1,181,000.00</i>



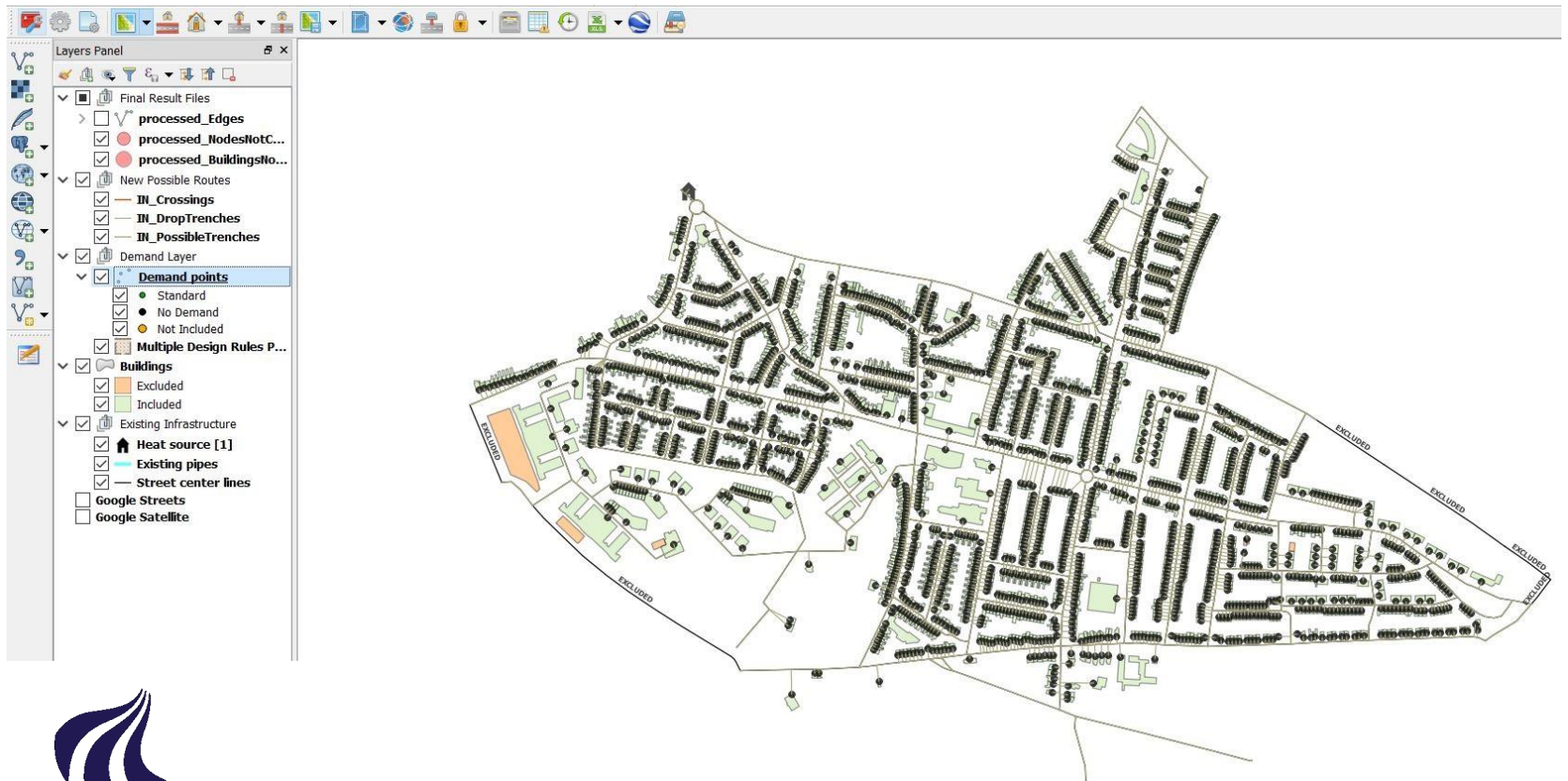


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# Case Study: Nijmegen - Hengstdal

More than 2300 buildings



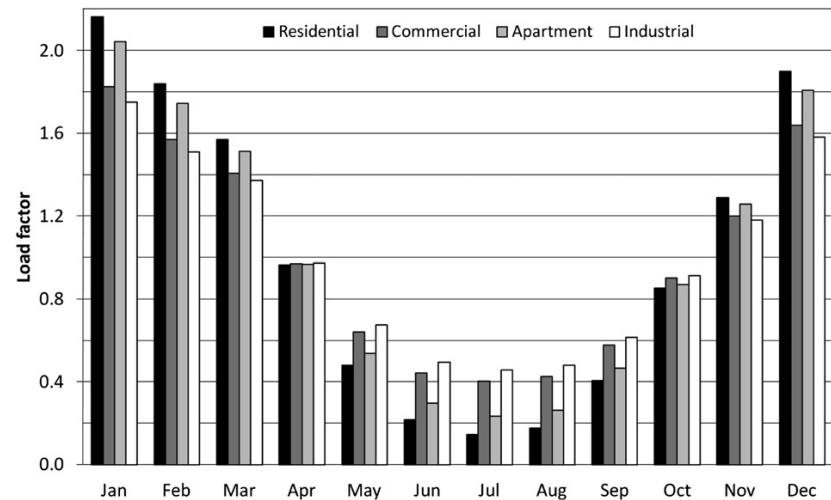
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# Network Design Parameters



- 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

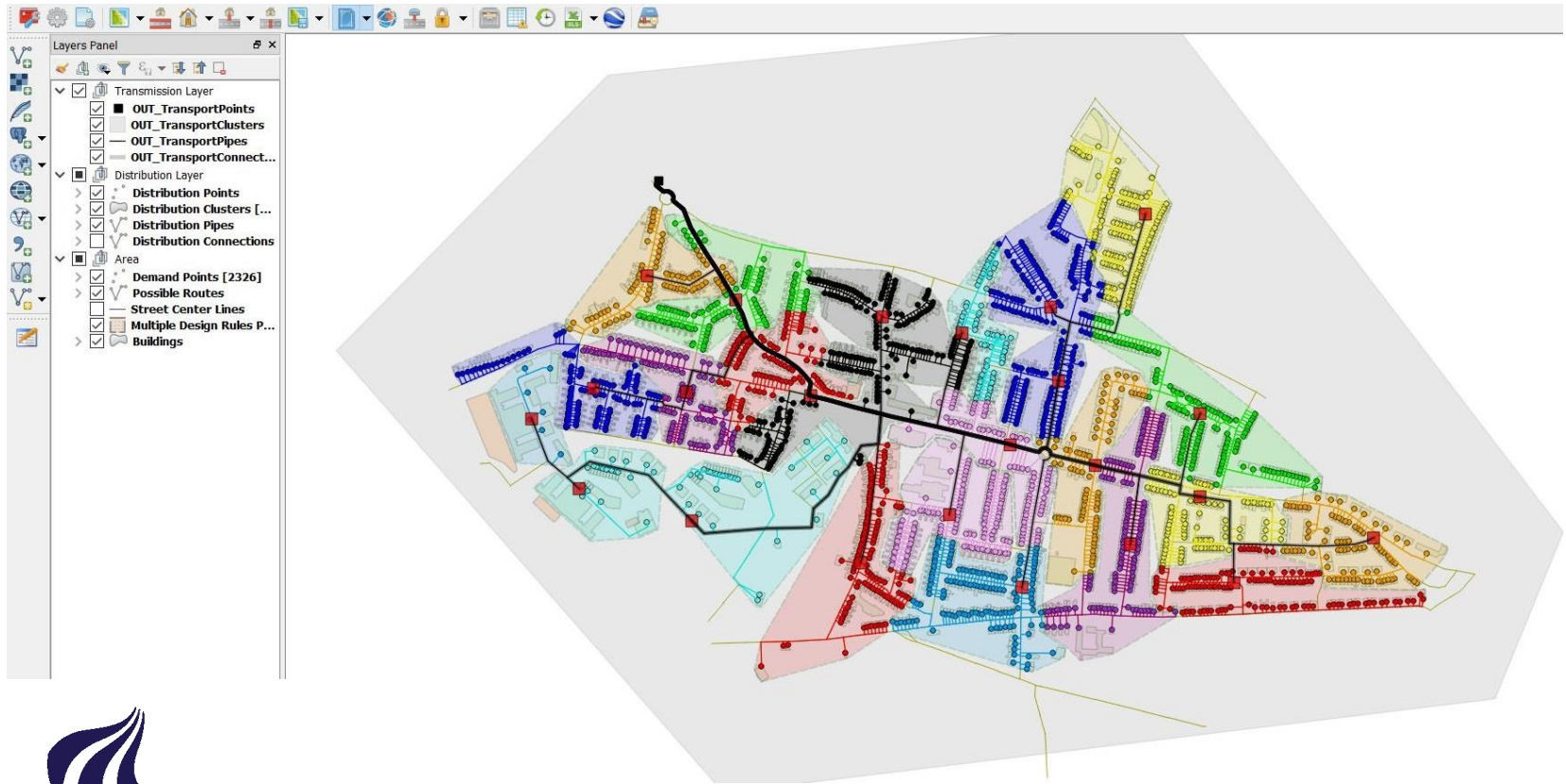


Monthly heat load factors

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.



# Designed Network with Transport and Distribution Layers



# Design Choice Scenarios

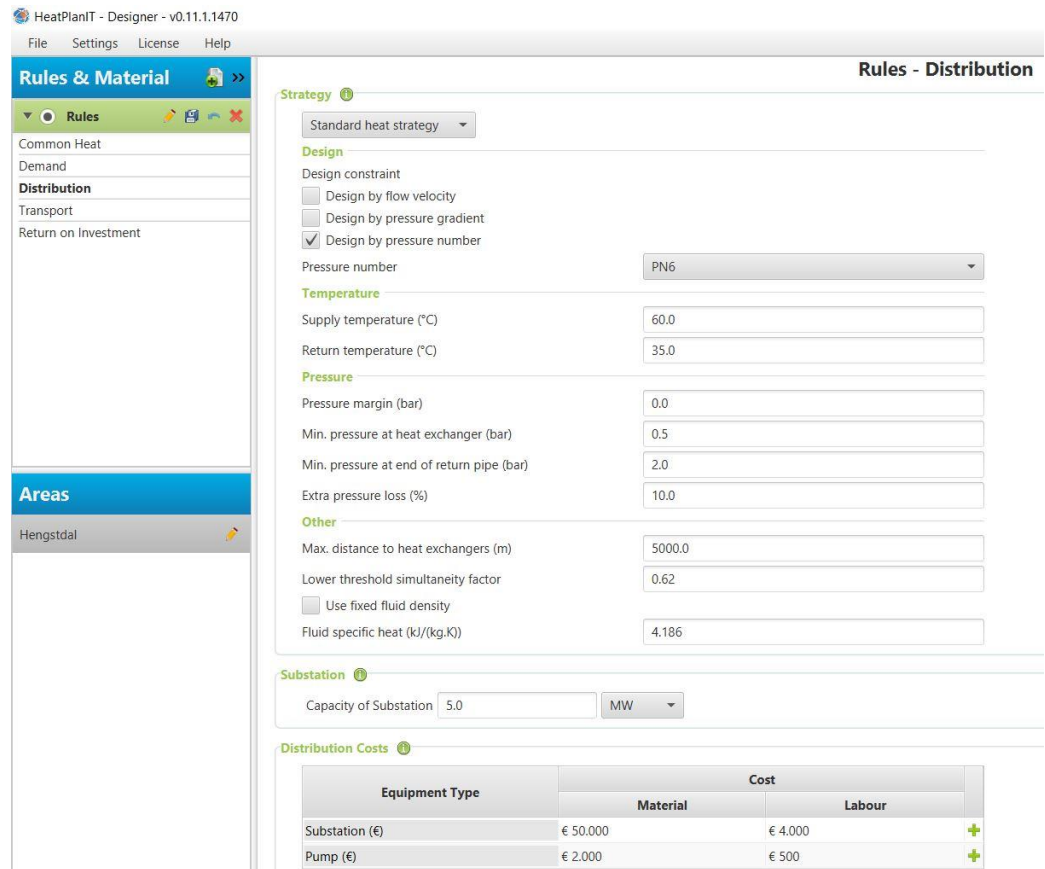
Design by flow velocity

Design by pressure number (Distribution and Transport pressure levels)

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

**Substation:**

- Substation size



HeatPlantIT - Designer - v0.11.1.1470

File Settings License Help

**Rules & Material**

Rules

- Common Heat
- Demand
- Distribution**
- Transport
- Return on Investment

Areas

Hengstdal

**Rules - Distribution**

Strategy

Standard heat strategy

**Design**

Design constraint

- Design by flow velocity
- Design by pressure gradient
- Design by pressure number

Pressure number: PN6

**Temperature**

Supply temperature (°C): 60.0

Return temperature (°C): 35.0

**Pressure**

Pressure margin (bar): 0.0

Min. pressure at heat exchanger (bar): 0.5

Min. pressure at end of return pipe (bar): 2.0

Extra pressure loss (%): 10.0

**Other**

Max. distance to heat exchangers (m): 5000.0

Lower threshold simultaneity factor: 0.62

- Use fixed fluid density

Fluid specific heat (kJ/(kg.K)): 4.186

**Substation**

Capacity of Substation: 5.0 MW

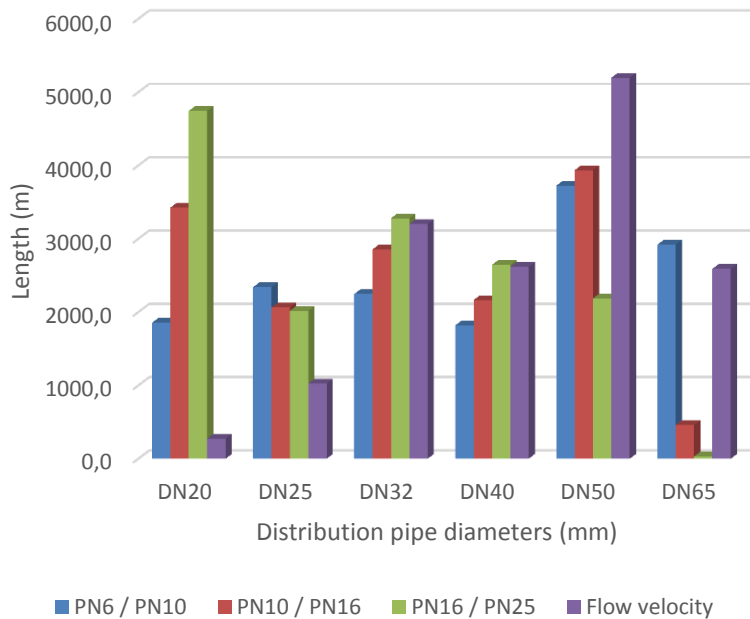
**Distribution Costs**

Equipment Type	Cost	
	Material	Labour
Substation (€)	€ 50.000	€ 4.000
Pump (€)	€ 2.000	€ 500

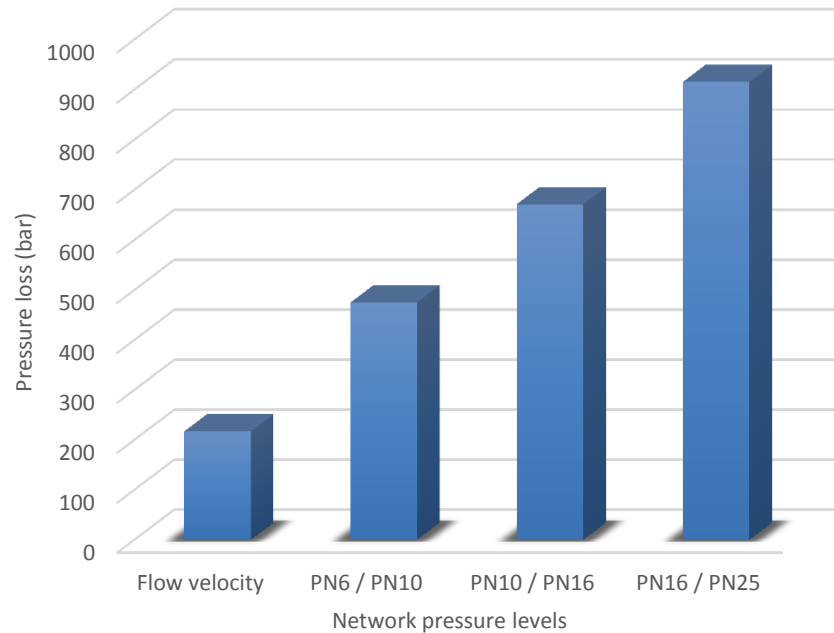


# Design Choice Scenarios

## Different pressure levels: Impact on pipe diameter



## Impact on pressure loss

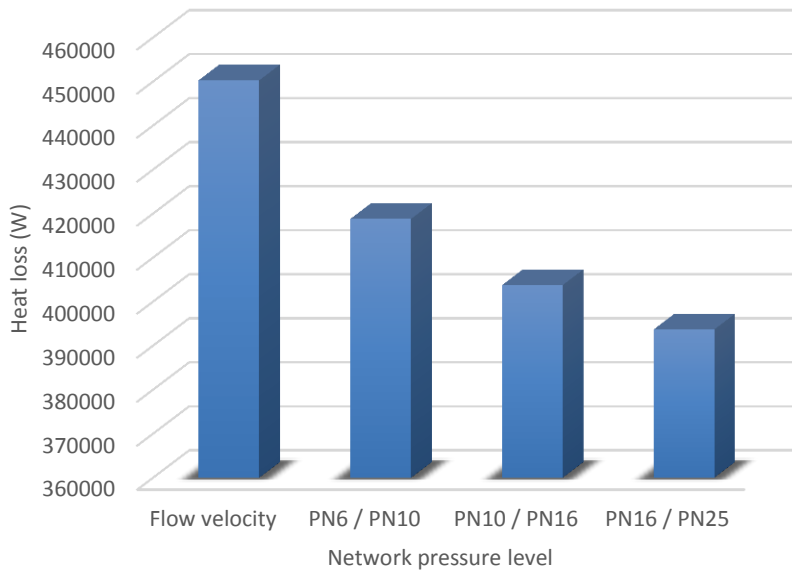




# Design Choice Scenarios



## Different pressure levels: Impact on heat loss

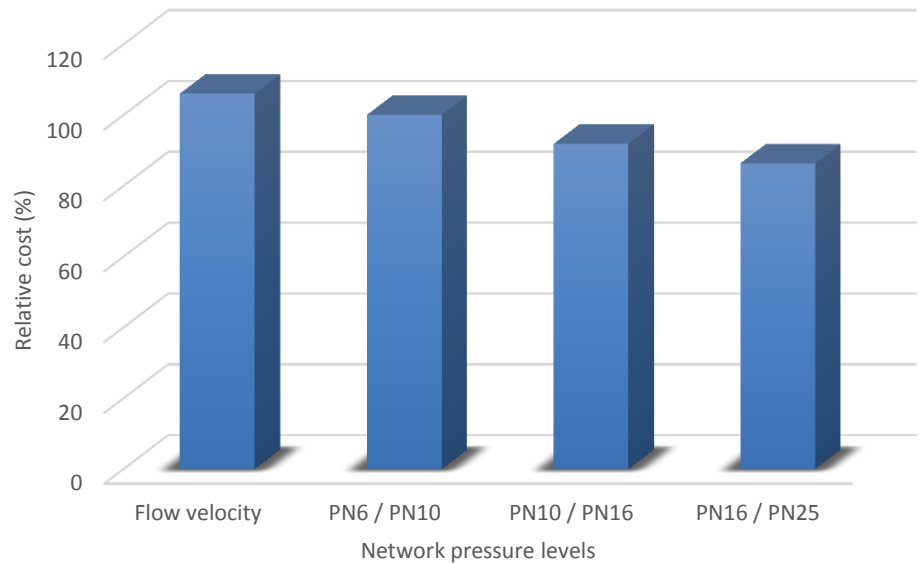


Reduction up to **13%**



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## Impact on cost



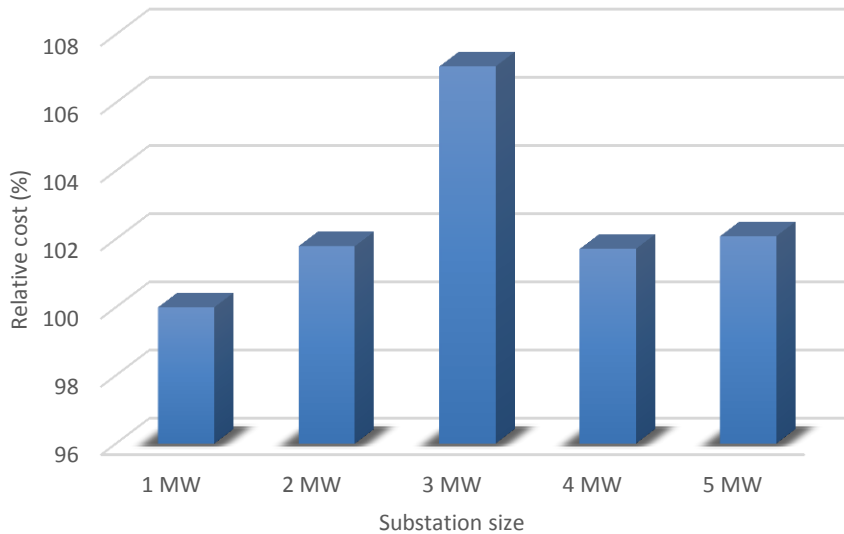
Reduction up to **18%**



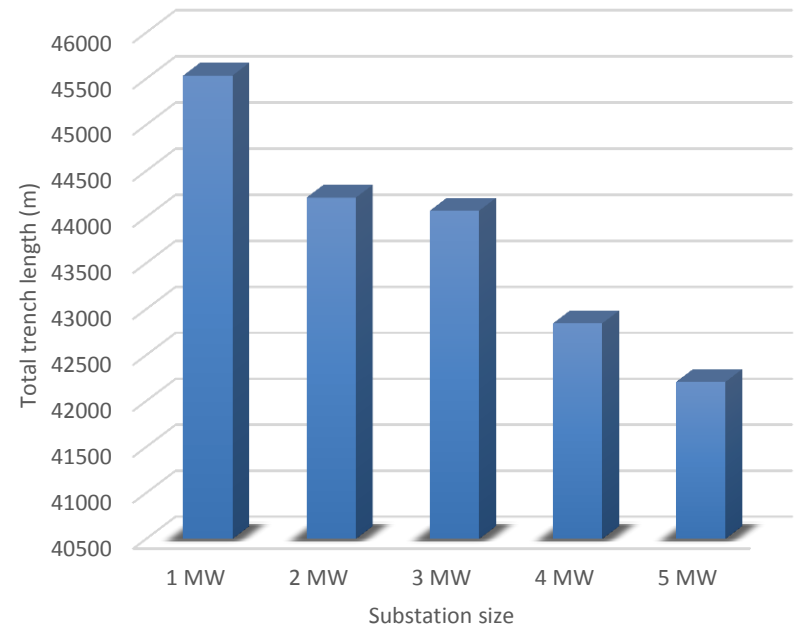
# Design Choice Scenarios



## Different substation sizes: Impact on cost



## Impact on total trench length



Reduction up to **8%**

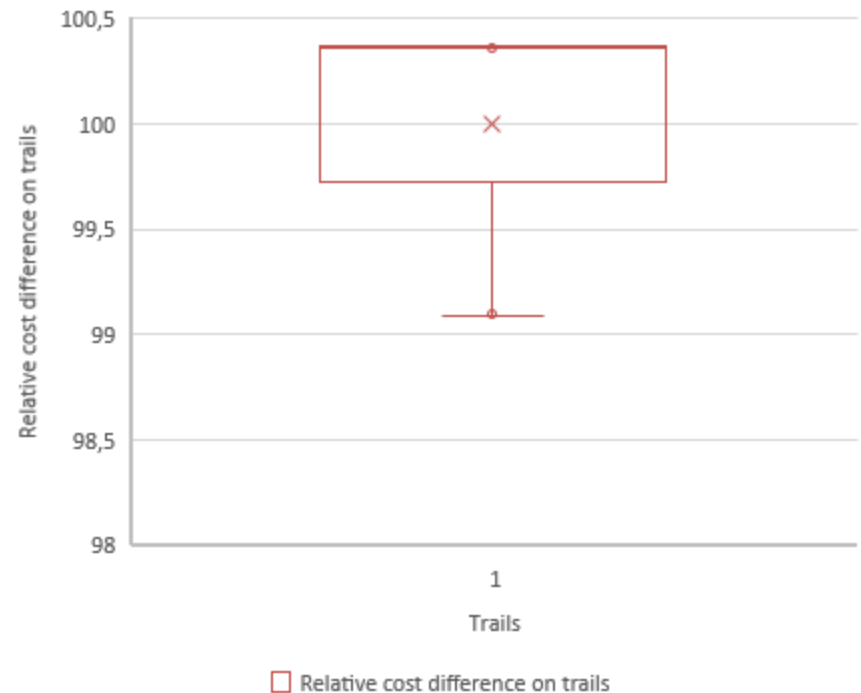


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# Repetition Scenarios – Coefficient of Variation

- 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

Primary Energy Supply & CO2 for Heating Buildings from 2010 to 2050  
EU CPI vs. HRE RE

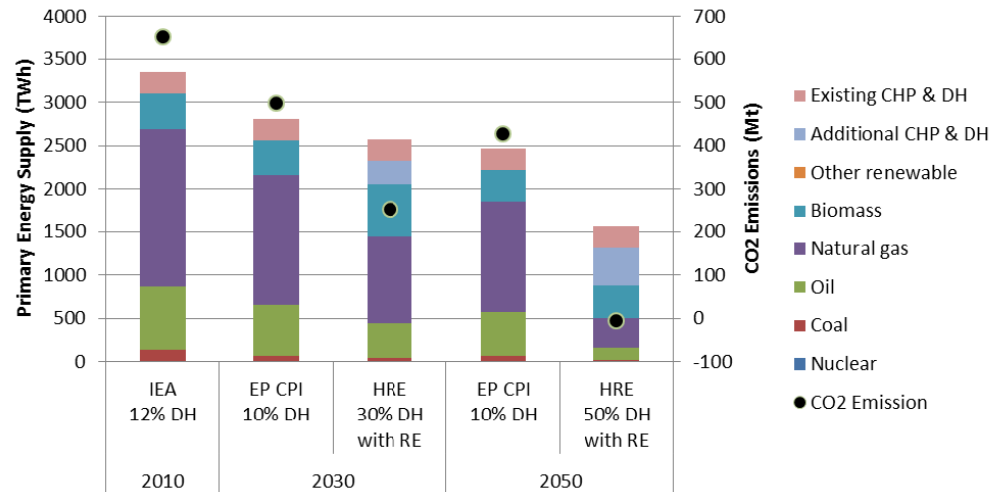


Figure 34: Primary energy supply and carbon dioxide emissions from hot water and the heating of buildings in the 2010, 2030, and 2050 EU27 energy system under a business-as-usual scenario and if district heating and CHP is expanded to 30% in 2030 and to 50% in 2050, in combination with the expansion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

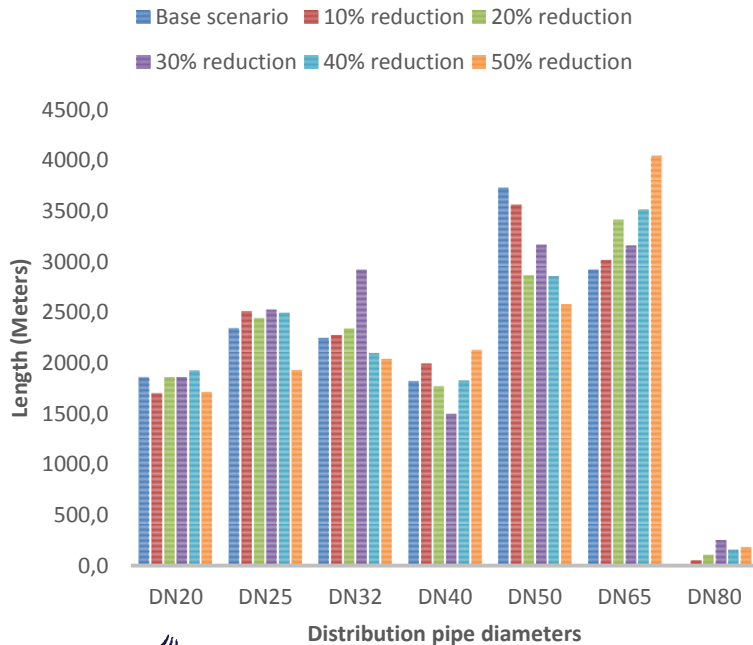
Source: HEAT Roadmap Europe 2050 – Study for the EU27



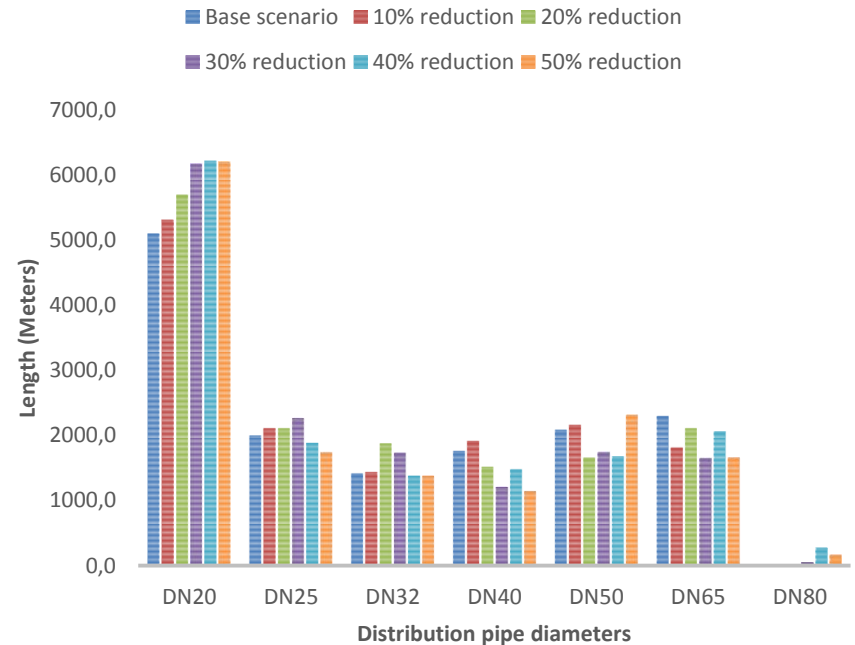
# Demand Reduction Scenarios



## Impact on pipe diameters: With hot water demand constant



## Without hot water demand



# Demand Reduction Scenarios

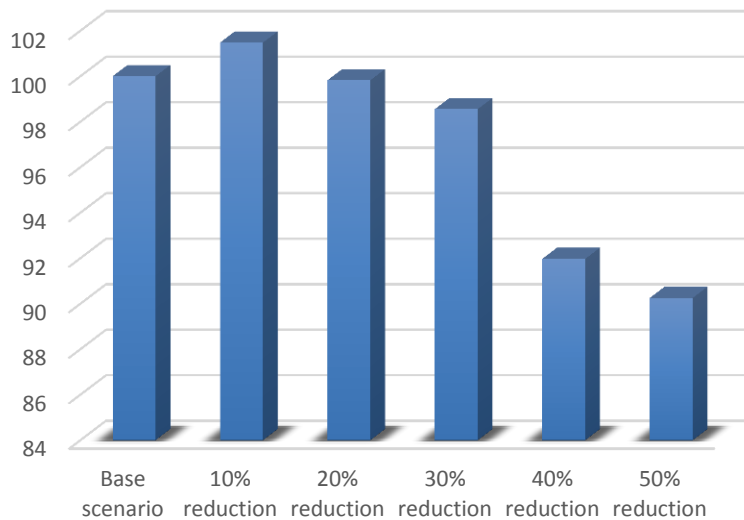


**Impact on network deployment cost:**

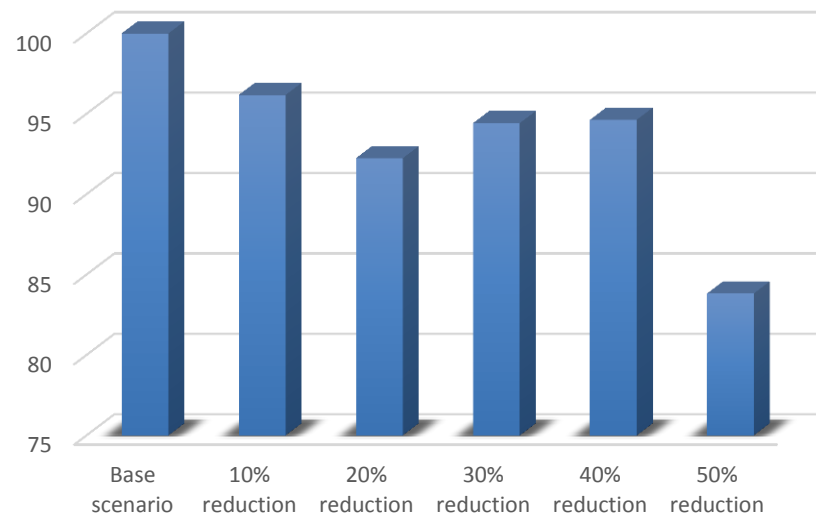
**With hot water demand constant**

**Without hot water demand**

**Total network cost**



**Total network cost**



**Reduction up to 9%**

**Reduction up to 16%**

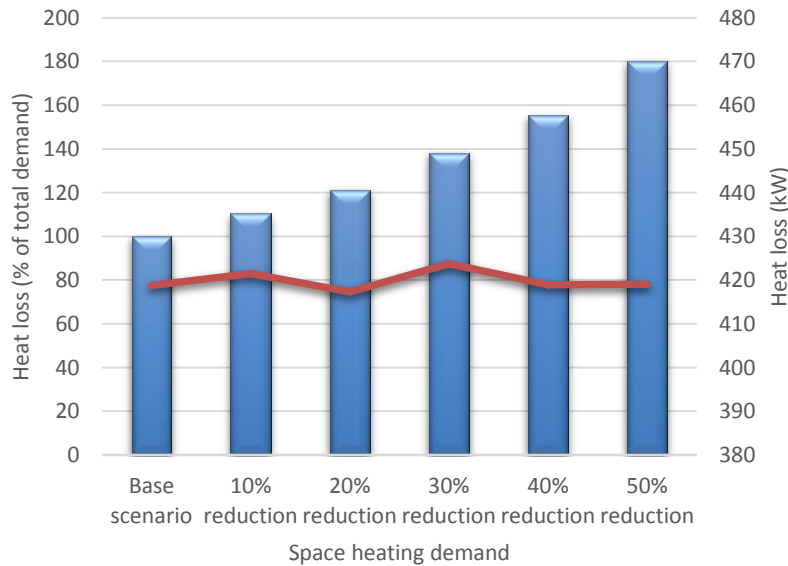
**Trench length dominates!**



# Demand Reduction Scenarios

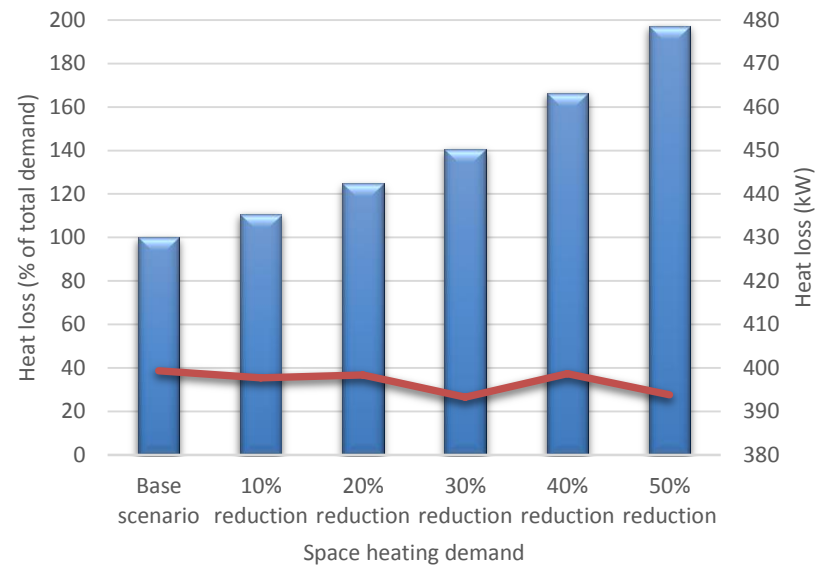
## Impact on heat loss:

### With hot water demand constant



Heat loss (% of total demand) Heat loss (kW)

### Without hot water demand



Heat loss (% of total demand) Heat loss (kW)



Increase up to **80%**

Reduce network supply temperature!

Increase up to **98%**

# 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

