IEA Bioenergy Task 32 - Biomass Combustion and Co-firing:

District Heating in selected IEA Countries

and

Sensitivity of System Design on Heat Distribution Costs

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IEA Networking Event Switzerland, Forum Fribourg
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District Heating in selected IEA Countries

and

Sensitivity of System Design on Heat Distribution Costs

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1. Theory

Sensitivity of System Design on Heat Distribution Costs

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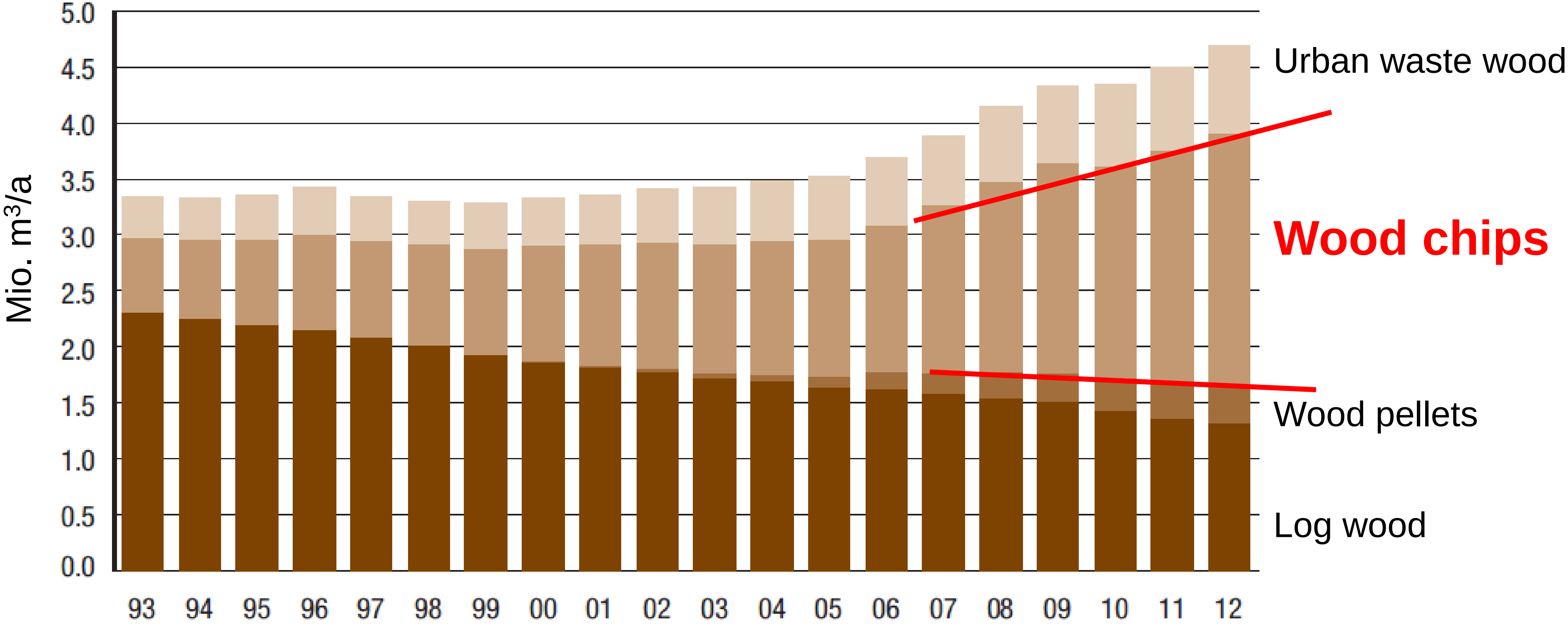
Wood Energy in Switzerland



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Jahrbuch Wald und Holz 2013, BAFU

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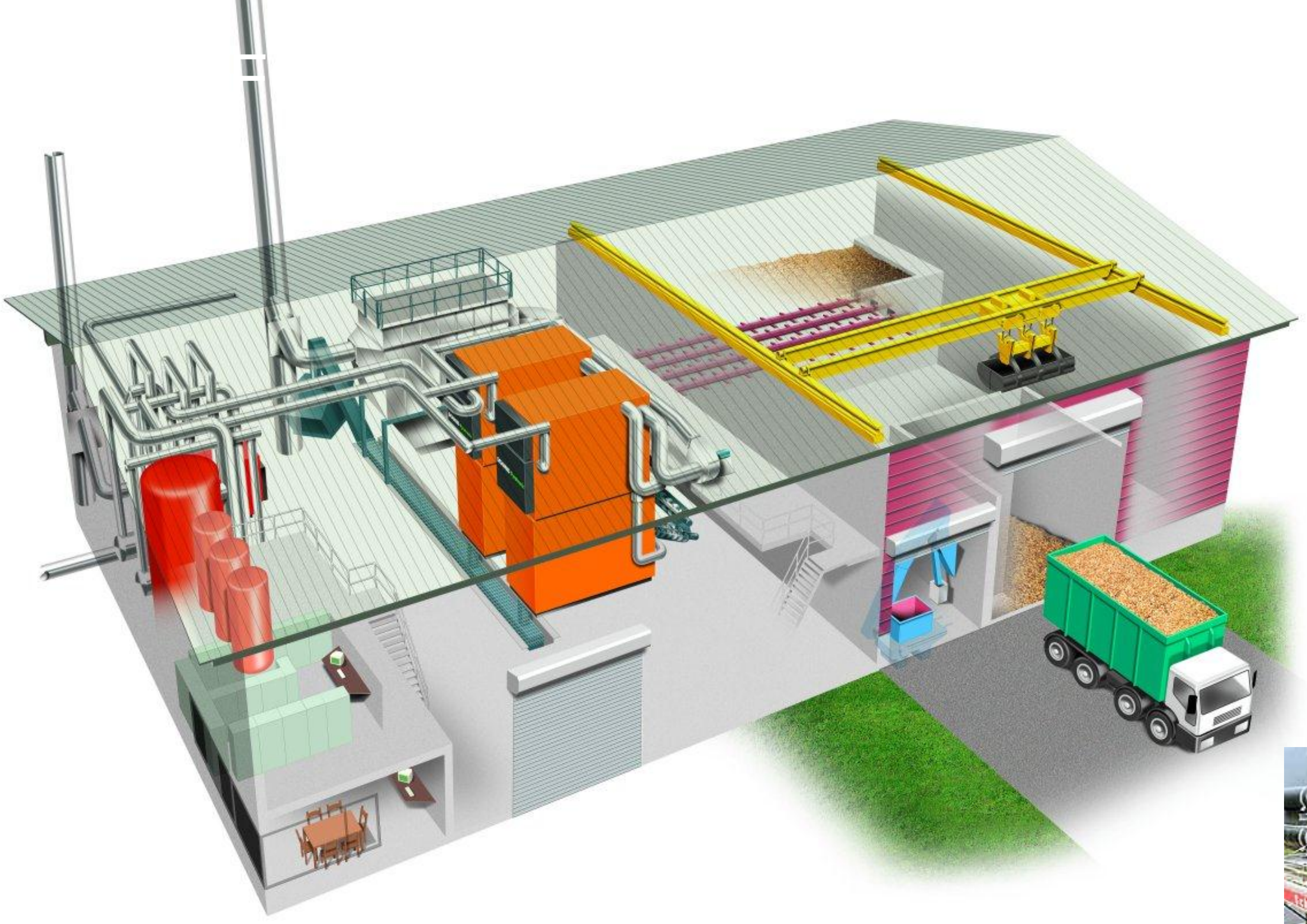

6.4 MW, AVARI Wilderswil (BE), Schmid AG

www.beo-news.ch/Sept2000/avari14.htm

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Motivation

+

District Heating (DH) offers attractive opportunities to use **biomass** and other renewable energies to subsidise decentralised fossil heatings.

–

Disadvantage

DH causes additional costs and energy losses.

Aim

Design guidelines for the plant planning

which enable minimum heat distribution costs

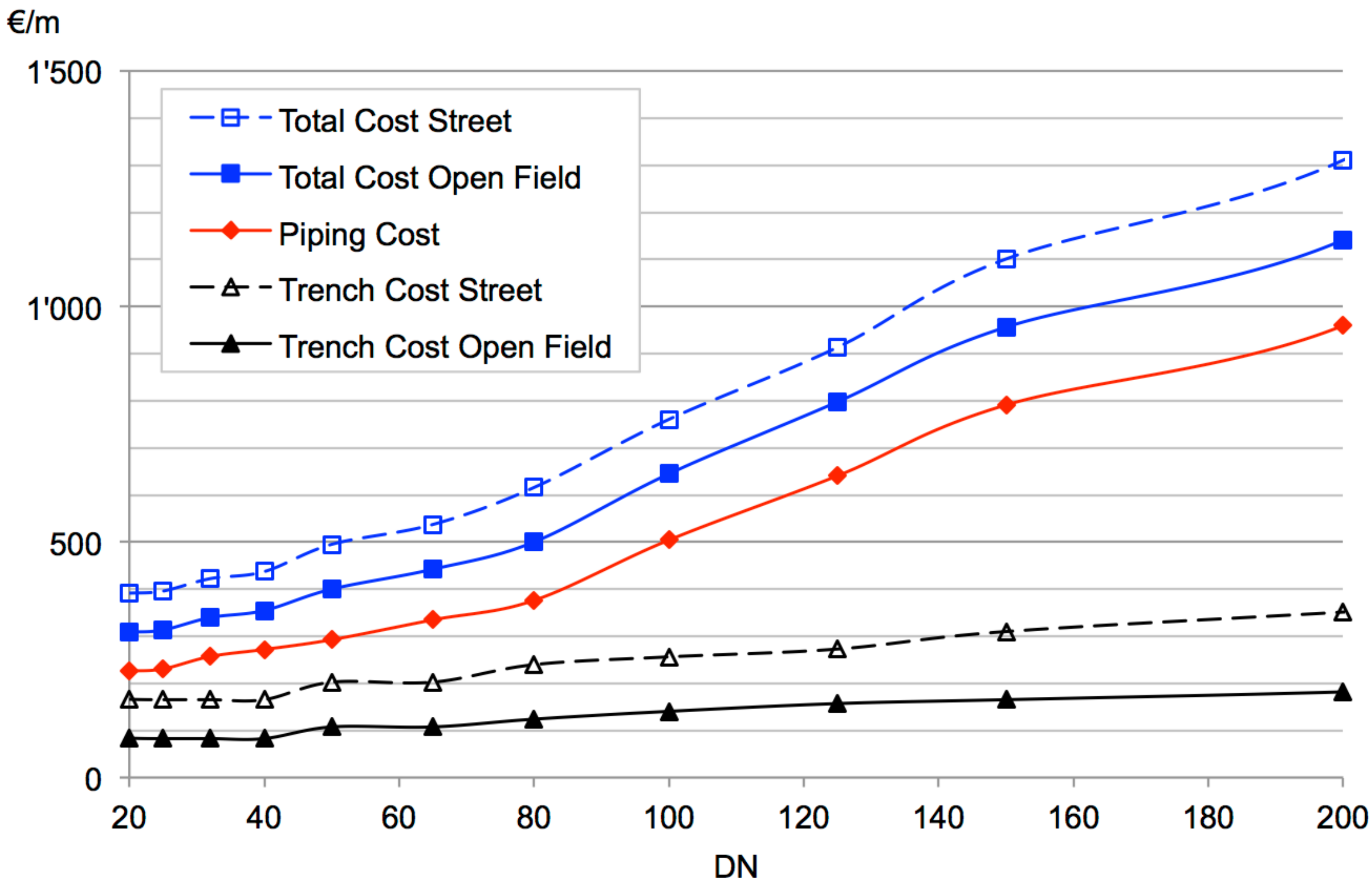
Method

The study investigates the influence of design parameters on the heat distribution costs by the **annuity method**:

1. **Capital costs**

2. **Operational costs** for
   a) fuel to cover the heat losses
   b) electricity for the pumping

Assumptions: 1. Investment costs –> Capex



Data source 2012: 1) Brugg Pipesystems, 2) Isoplus, 3) Logstor, 4) Jenni, 5) Ködel.

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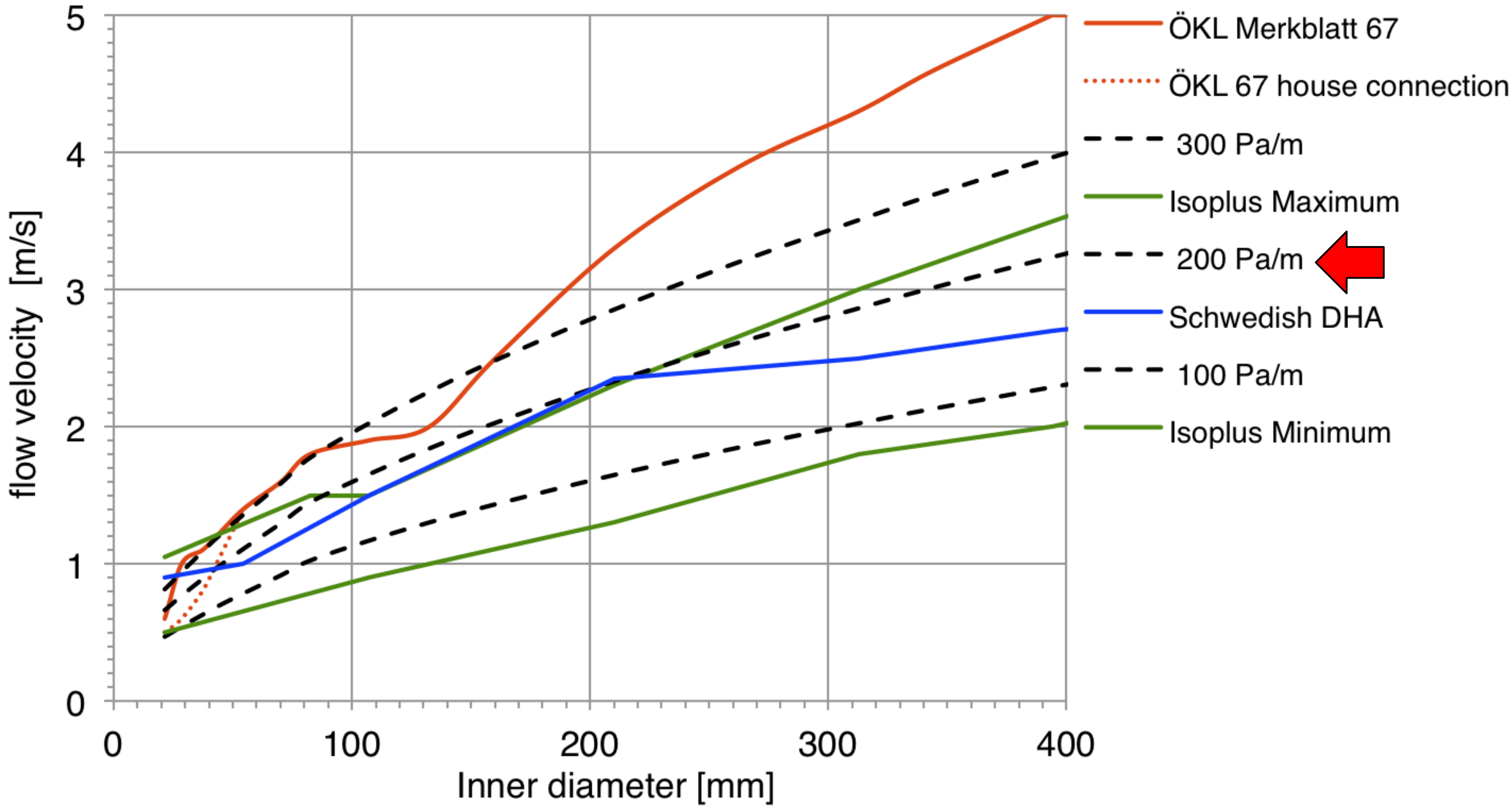
Nussbaumer, T.; Thalmann, S.: Sensitivity of System Design on Heat Distribution Costs in District Heating, Zürich 2014, ISBN 3-908705-27-4, www.ieabioenergytask32.com

Assumptions: 2. Pumping Work –> Opex

Maximum flow velocity to avoid cavitation pitting



Swedish & Isoplus: Frederiksen, S.; Werner, S.: District Heating and Cooling, Lund 2013, ISBN 978-91-44-08530-2
ÖKL Merkblatt 67: ÖKL Merkblatt 67, 2nd edition, ÖKL, Vienna 2009
100/200/300 Pa/m: Nussbaumer, T.; Thalmann, S.: Sensitivity of System Design on Heat Distribution Costs in District Heating, Zürich 2014, ISBN 3-908705-27-4, www.ieabioenergytask32.com

Input parameters

Input parameters	Symbol	Unit			***Reference***		
Connection load*	$\dot{Q}$	MW	-	0.5	***1***	2	-
Pipeline length	L	m	-	500	***1000***	2000	-
Full-load hours	τ	h/a	-	1000	***2000***	4000	-

Definition:

Linear heat density = distributed heat* per year and meter of pipeline

pipeline length = trench length

Reference case:

$$LHD^* = \frac{1\,\text{MW} \cdot 2000\,\frac{\text{h}}{\text{a}}}{1000\,\text{m}} = \mathbf{2.0}\,\frac{\text{MWh}_{\text{pipeline}}}{\text{a} \cdot \text{m}} \overset{\text{for 10\% losses}}{=} \mathbf{1.8}\,\frac{\text{MWh}_{\text{consumer}}}{\text{a} \cdot \text{m}}$$

*here: LHD = pipeline input / length of pipeline

QM: LHD = consumer input / length of pipeline = $LHD^{x}\big|_{\text{pipeline}}$

(consumer input = pipeline output)

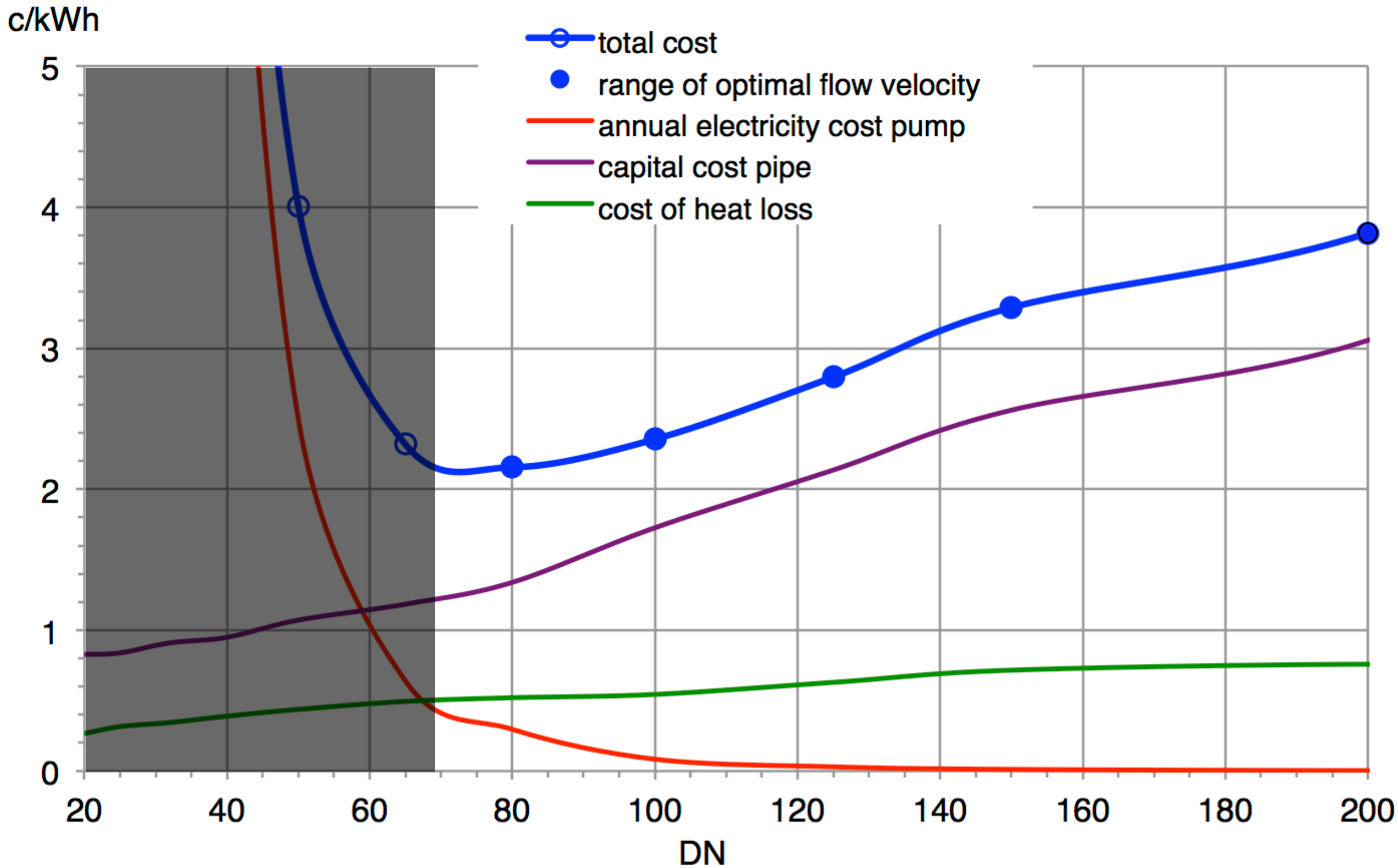
Input parameters

Input parameters	Symbol	Unit	***Reference***				
Connection load*	$\dot{Q}$	MW	-	0.5	***1***	2	-
Pipeline length	L	m	-	500	***1000***	2000	-
Full-load hours	τ	h/a	-	1000	***2000***	4000	-

Input parameters

Input parameters	Symbol	Unit	*Reference*				
Connection load*	$\dot{Q}$	MW	-	0.5	***1***	2	-
Pipeline length	L	m	-	500	***1000***	2000	-
Full-load hours	τ	h/a	-	1000	***2000***	4000	-
Network operation hours	τ_N	h/a	-	2000	***8760***	4000	-
Network supply temp.	T_S	°C	40	60	***80***	100	-
Temperature difference	ΔT	K	-	15	***30***	45	60
Insulation Class	Series	-	-	1	***2***	3	-
Electricity price	p_e	c/kWh	-	8.25	***16.5***	33	-
Fuel price	p_F	c/kWh	0	2.5	***4***	10	-
Calculation duration	n	a	-	-	***30***	-	-
Capital interest rate	i	% / a	-	0	***3.0***	6.0	-
Annuity factor	a	% / a	-	3.33	***5.10***	7.26	-

Results: Contribution of Cost Factors



A **1 MW network** with an annuity of 5.1 % p.a. (3.0 % p.a. for 30 years) reveals:

- the **heat distribution costs achieve a minimum for the smallest allowable pipe diameter**
- the costs are 2.16 c/kWh in the worst-case of one consumer and **1.99 c/kWh** for distributed consumers
- the costs consist of **62% capital costs** 25% fuel costs at a fuel price of 4.0 c/kWh, and 13% electricity costs at electricity for 16.5 c/kWh

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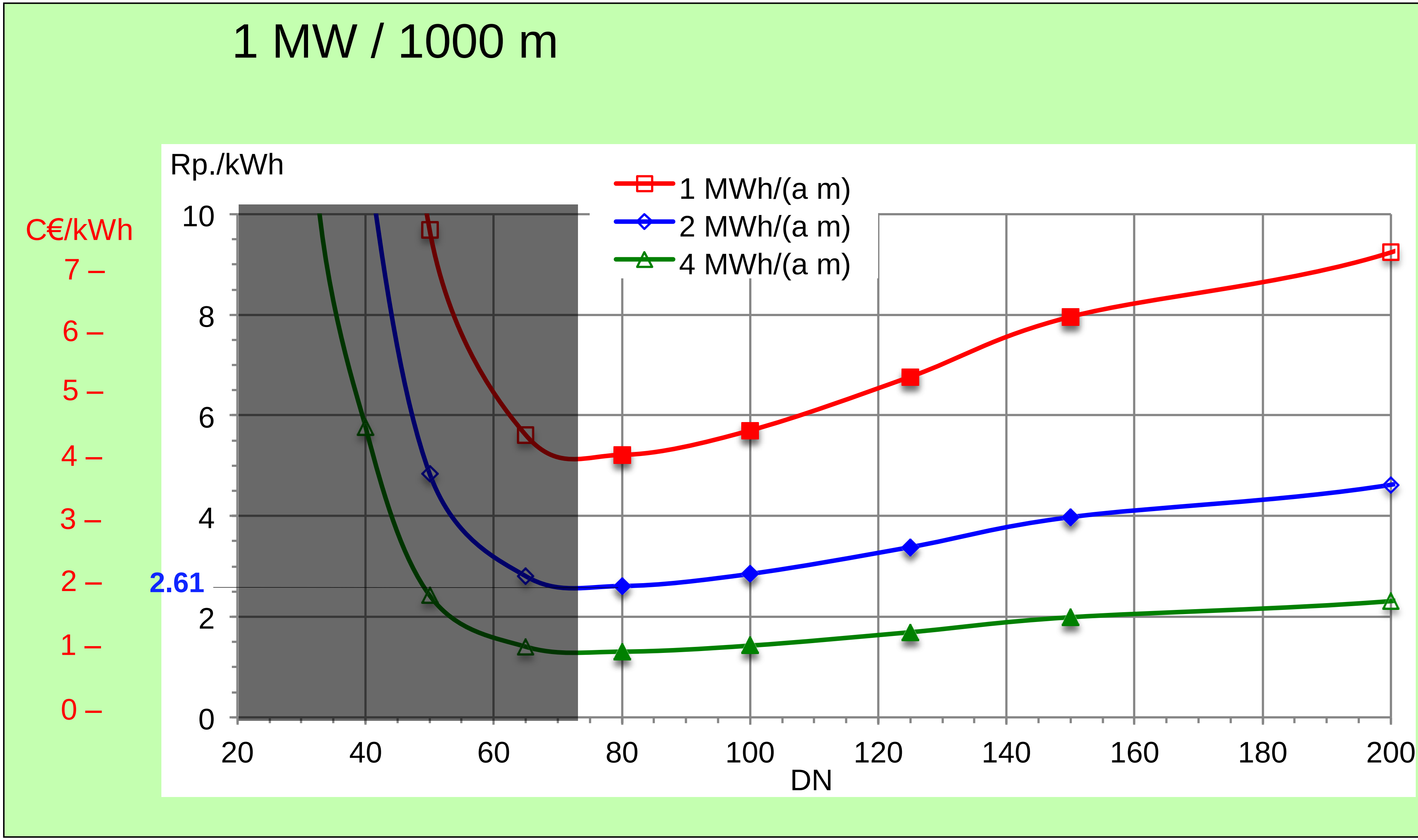
Results: Influence of Linear Heat Density



- **minimum cost for the smallest allowable pipe diameter**
- 2.16 c/kWh for one consumer and **1.99 c/kWh** for distributed consumers
- **62% capital costs,** 25% fuel costs, and 13% electricity costs

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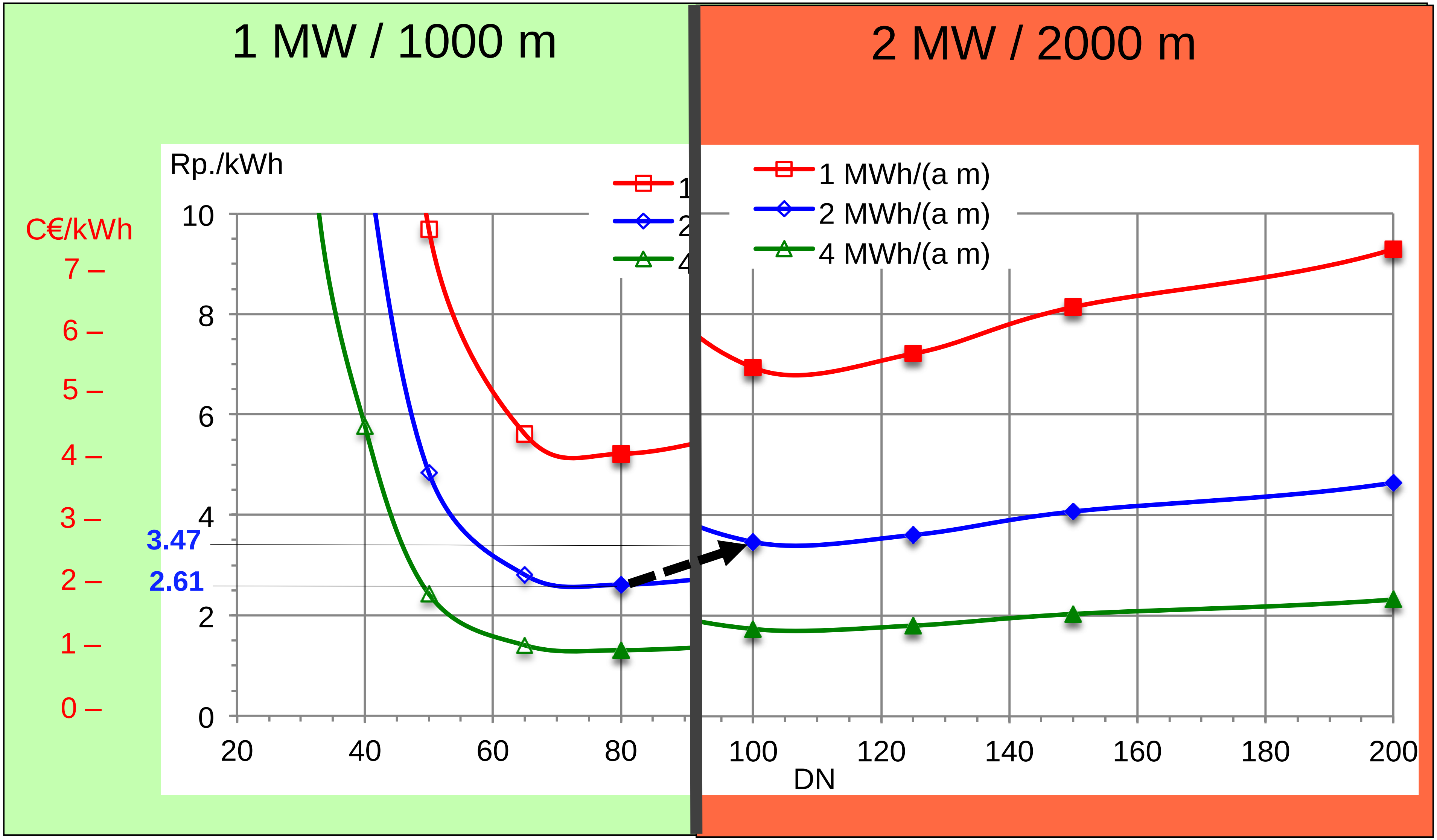
Influence of Size for a linear Network Extension

= Influence of Pipeline Length at constant linear heat density



Diseconomies-of-scale

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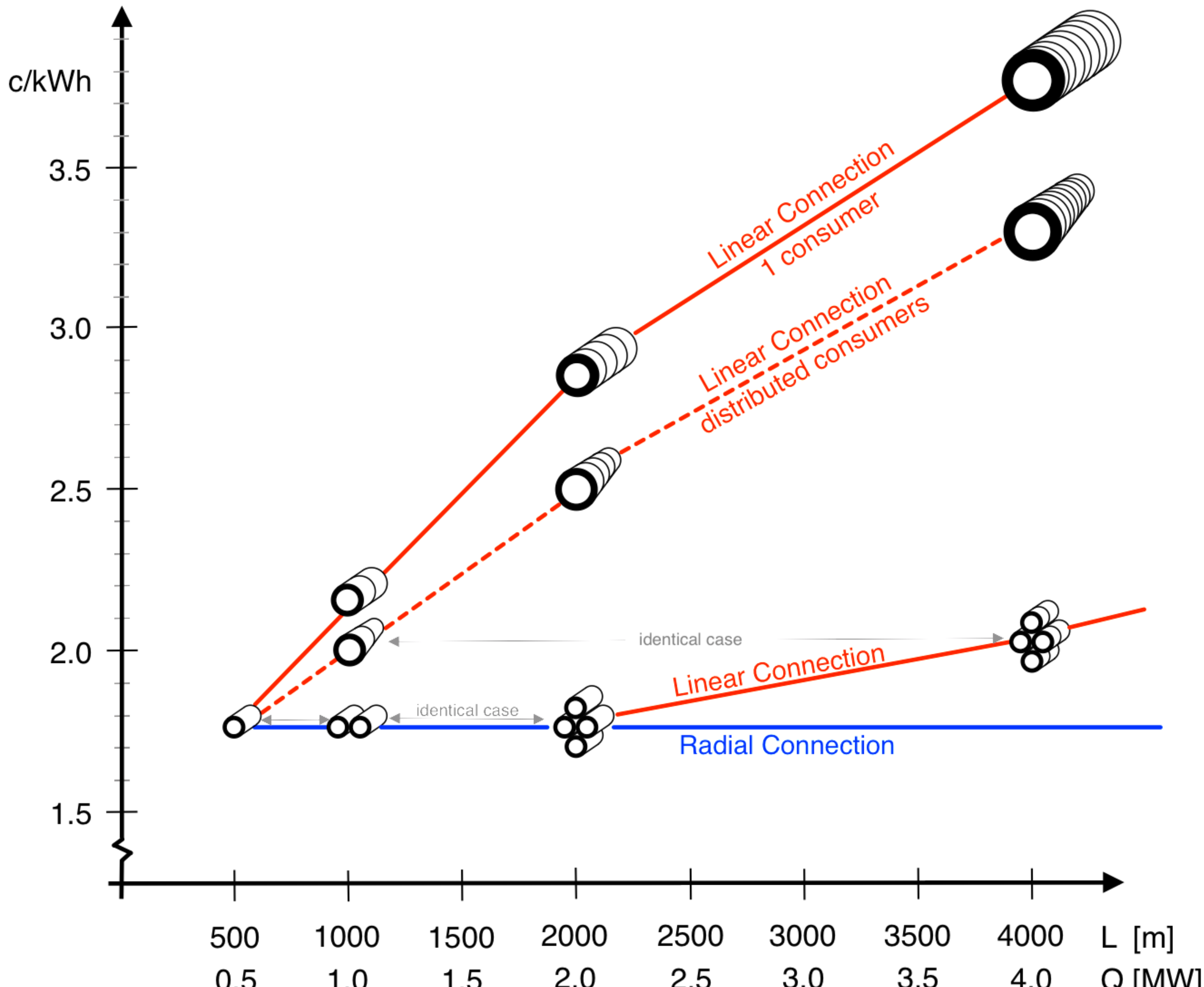
Comparison of linear and radial Network Extension



Conclusions: 1. Cost Optimisation

1. The **capital costs** dominate the heat distribution costs.

2. Since capital costs increase with pipe diameter while pumping costs remain moderate, a design for **smallest feasible pipe diameters** is crucial.

3. For the model network, **oversizing** by
   +1 nominal diameter results in **9%** higher costs,
   +2 nominal diameters cause **30%** higher costs.

4. Besides the pipe diameter, the low return temperatures are essential to exhaust the **maximum temperature difference** in the network.

Conclusions 2: Size Influence

1. At *constant linear heat density* and for *identical network structure*, district heating is related to **<u>dis</u>economies of scale** due to the need of larger pipe diameters for increased connection load.

2. Consequently,

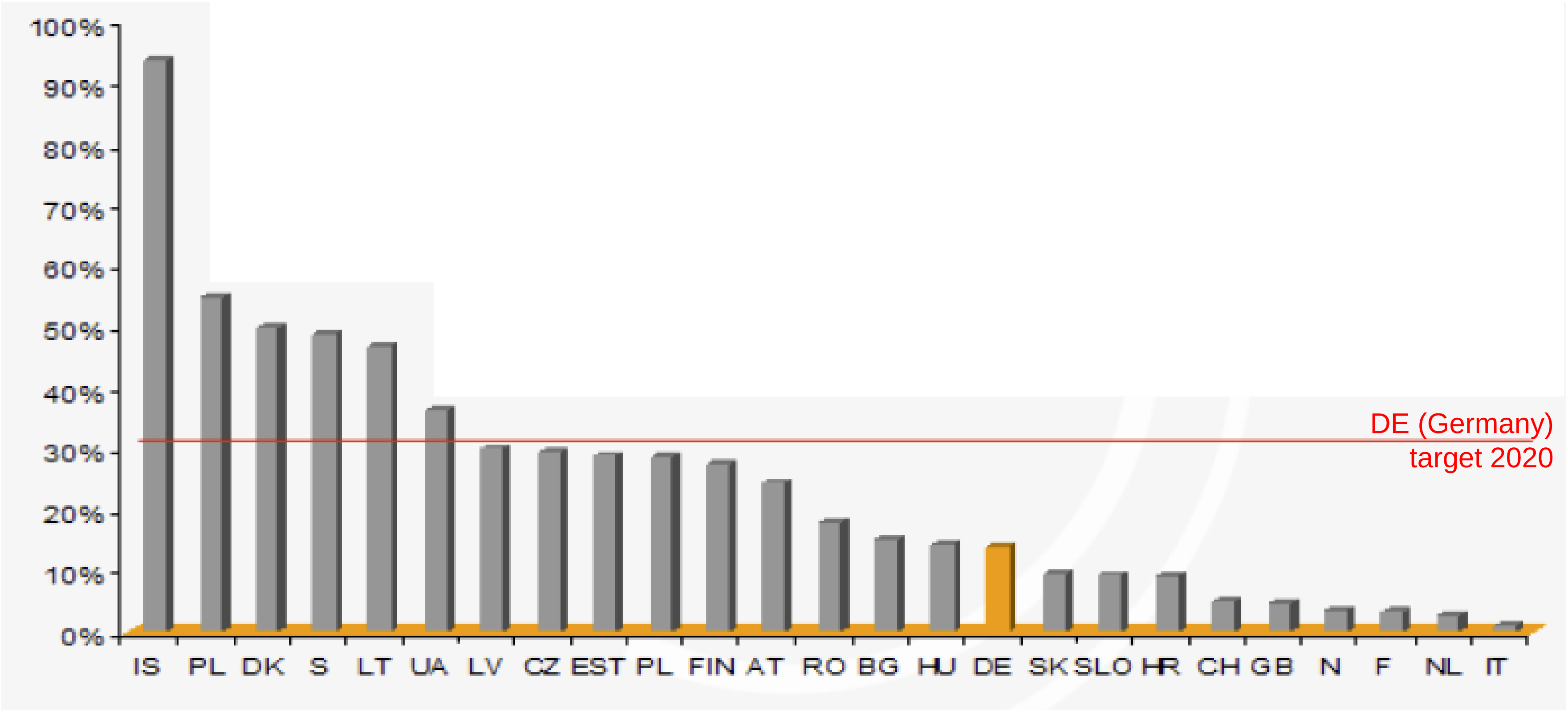
   – **network expansion by densification is favourable**

   – an **increase in network size at identical network structure and constant linear heat density is unfavourable**

2. Survey

District Heating in selected IEA Countries

Motivation: District heating assists the use of biomass for energy



Relative share of residential buildings heated by district heating in Europe by 2010.

AGFW-Hauptbericht 2010, Frankfurt am Main 2011

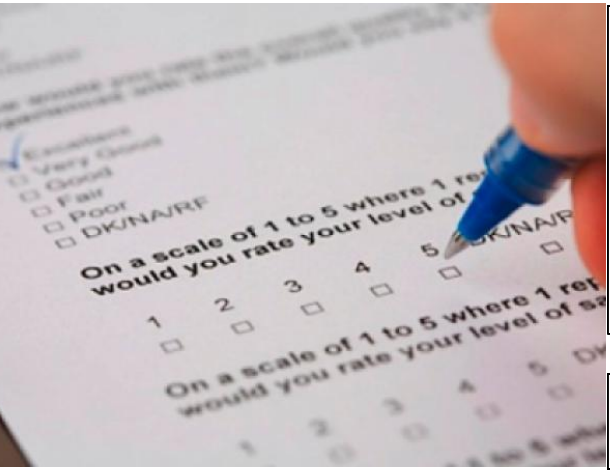
Aim

1. **Survey** on efficiency and cost of district heating

2. Analyse **influences** of key parameters, i.e.:
   – the **linear heat density (LHD)**
   – the connection load
   – and other parameters

3. Derive **recommendations** for efficient design

Method

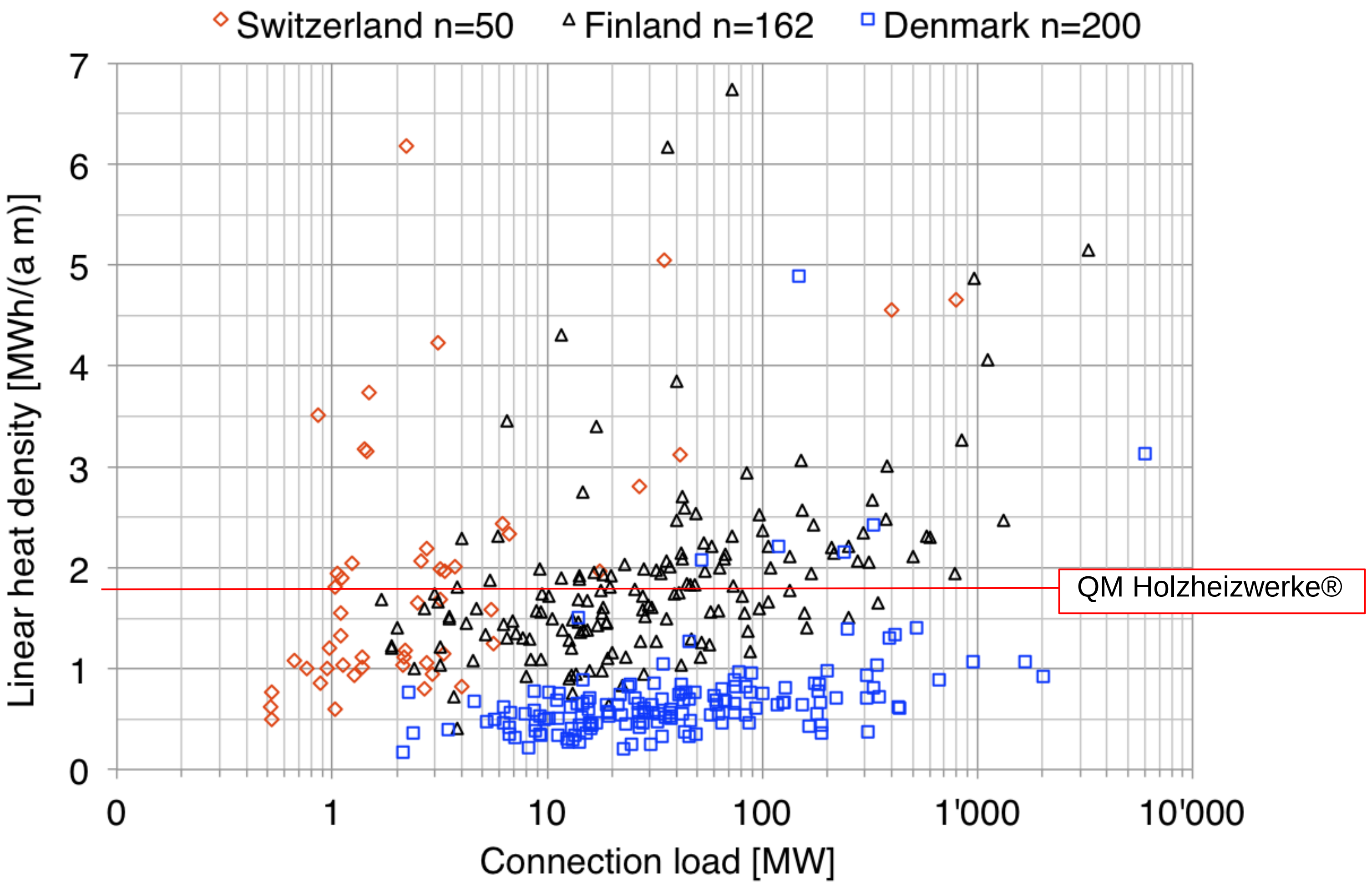


1. **Questionnaire** for data collection
   – IEA Bioenergy Task 32
   – IEA Implementing Agreement on District Heating and Cooling (IEA-DHC)

2. **Internet survey**

Result: **Data from > 800 systems** from
– Austria
– Denmark
– Finland
– Germany
– Switzerland

Results: 1. Connection Load & Linear Heat Density



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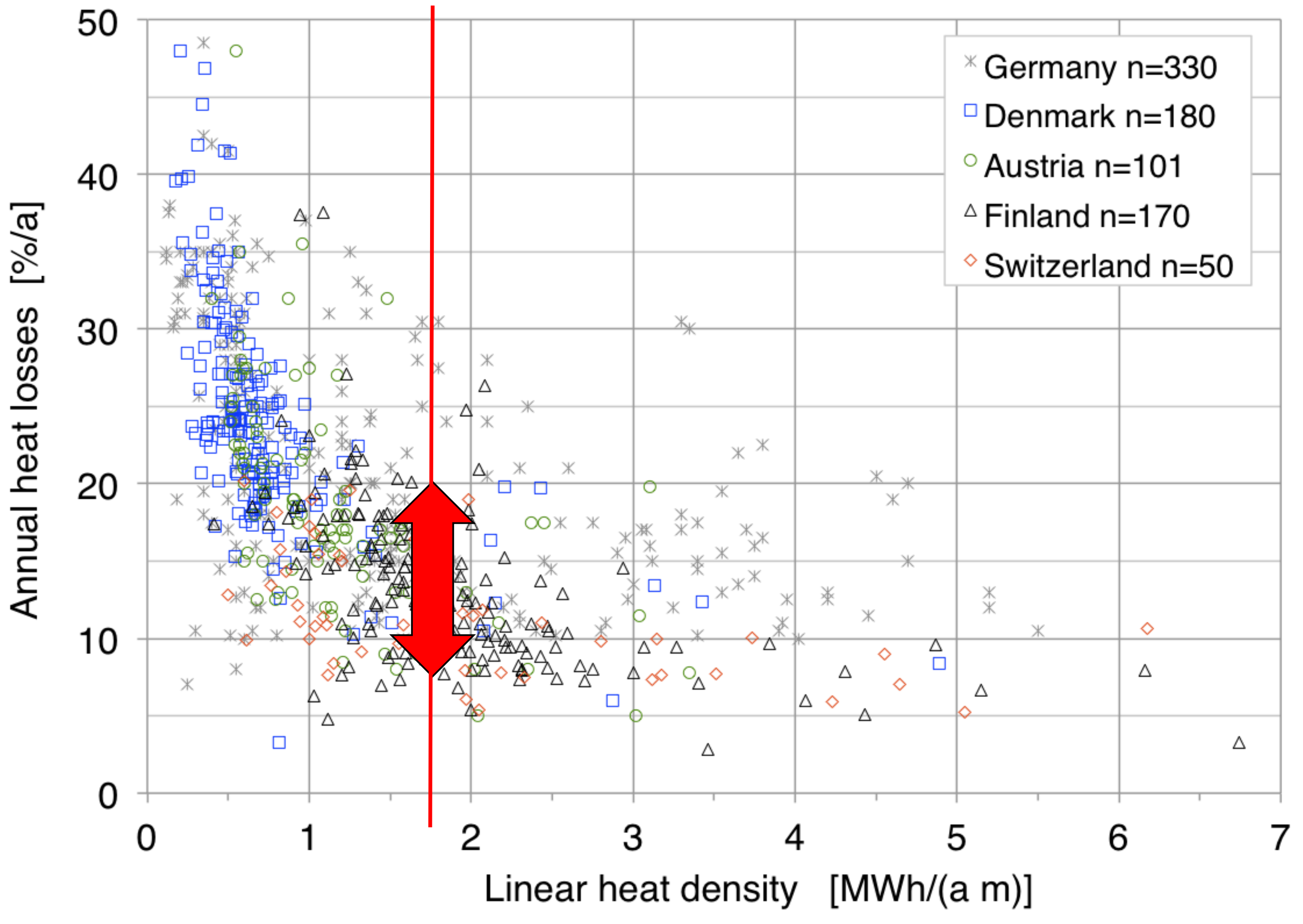
The linear heat density covers a range from < 0.5 to > 5 MWh/(a m) thus more than a factor of 10. Compared to 1.8 MWh/(a m) proposed by QM Holzheizwerke®

LHD in Finland and Switzerland > 1 MWh/(a m), while Denmark < 0.5 to 1 MWh/(a m).

Results: 2. Linear Heat Density & Heat Losses



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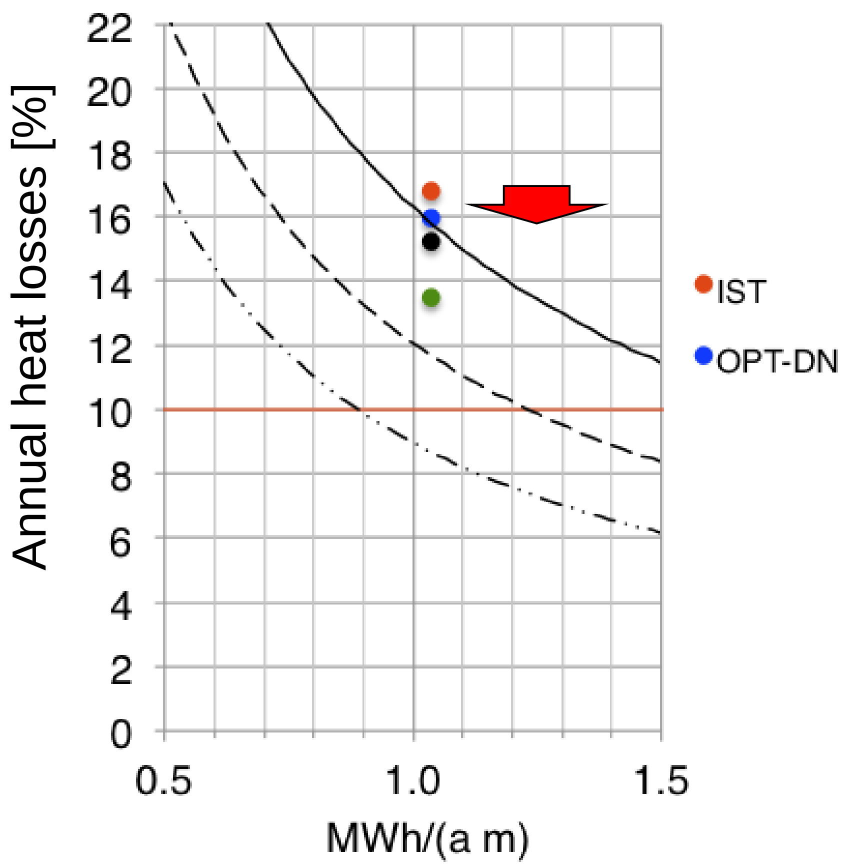
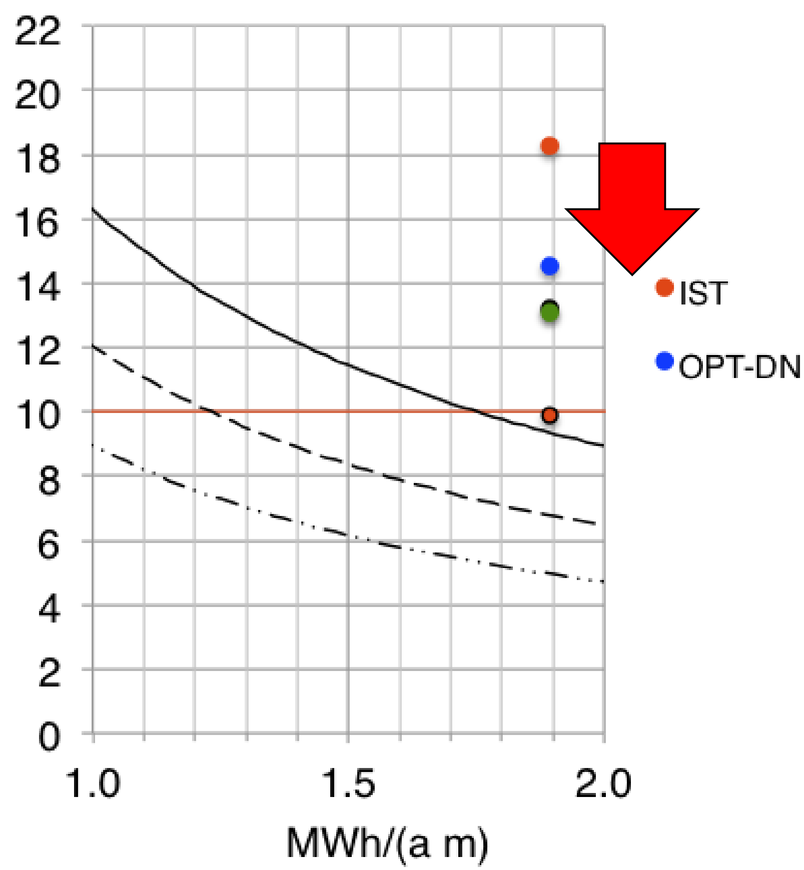
The evaluation reveals a strong dependence of the heat losses on the linear heat density. For the minimum value of 1.8 MWh/(a m) as proposed by QM Holzheizwerke®, typical heat losses of 13 % are achieved compared to the target value of QM of 10 %

Optimisation Potential by Pipe Diameter

DH with almost optimal design



DH with oversized pipe diameter



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For most investigated systems (80% of examples), pipe diameters are oversized by one or more dimensions, thus leading to significantly increased capital cost and heat distribution losses

Conclusions

1. The **linear heat density** is confirmed as an important quality parameter.

2. However, the survey shows that the heat losses cover a range of more than a **factor 3** at a constant linear heat density. This shows, that **additional parameters** strongly influence the losses, namely:

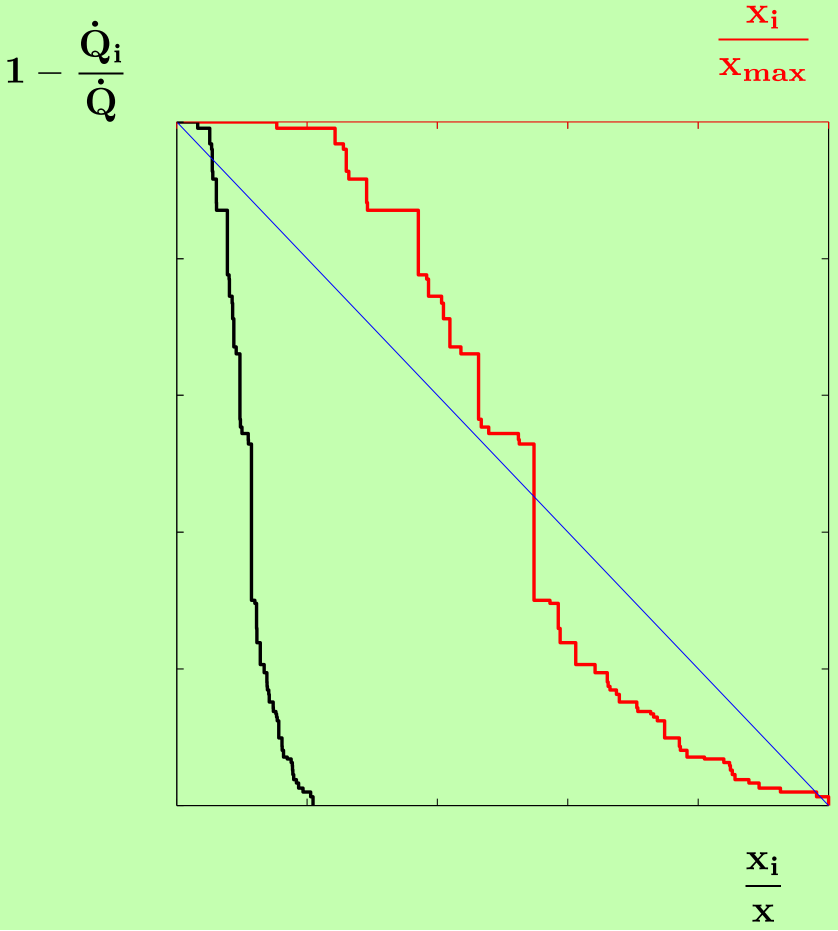
3. The **pipe diameter is a key parameter**.

4. The **network layout**, the **temperature** spread, and the **full-load hours**.

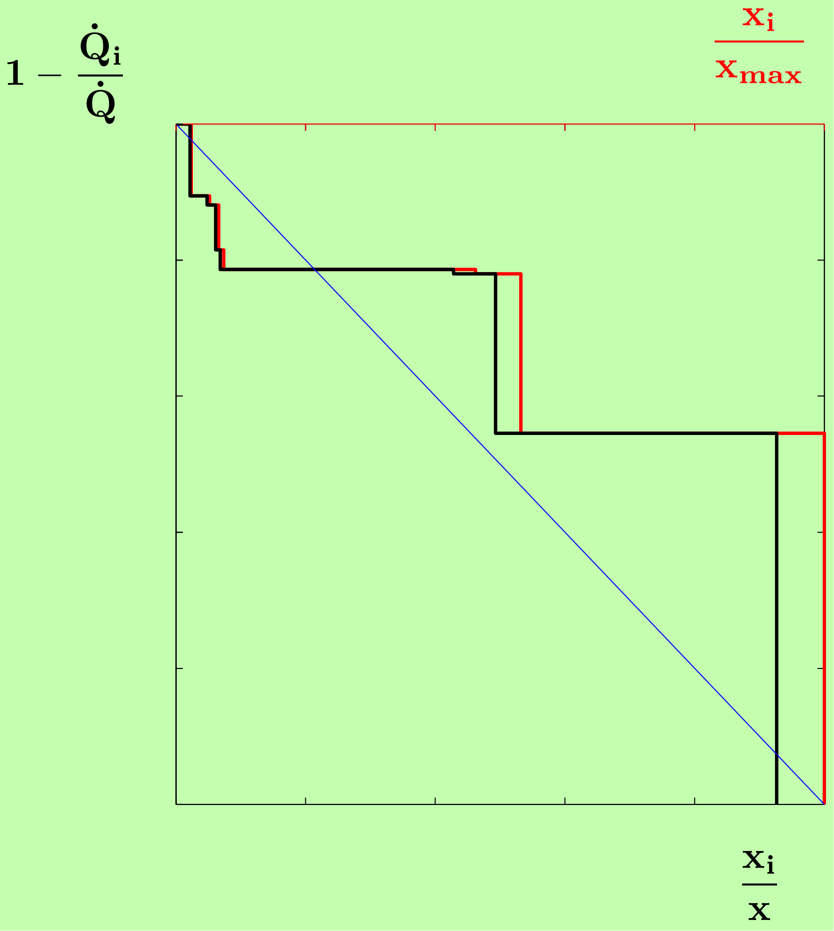
5. An analysis of DH examples reveals **80 % oversized line sections**.
   This refers to a **potential to reduce losses up to 20 % and costs up to 30 %**.

Outlook: Tool to evaluate the Network Structure

ideal distribution



unfavourable distribution



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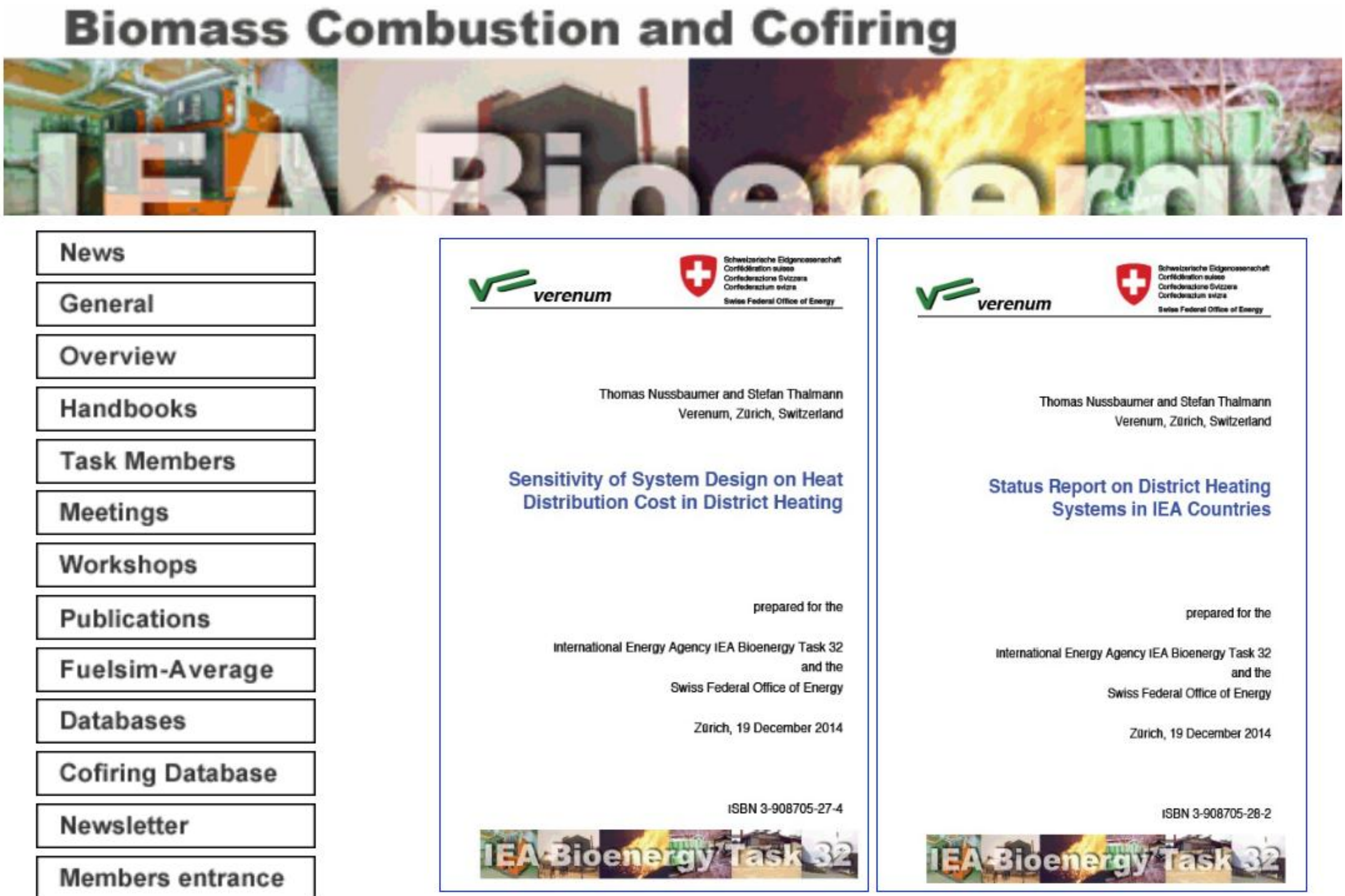
www.ieabioenergytask32.com



Acknowledments

Swiss Federal Office for Energy (SFOE)

International Energy Agency Bioenergy Task 32

Plant owners of district heating systems in SWI

IEA IA on District Heating and Cooling

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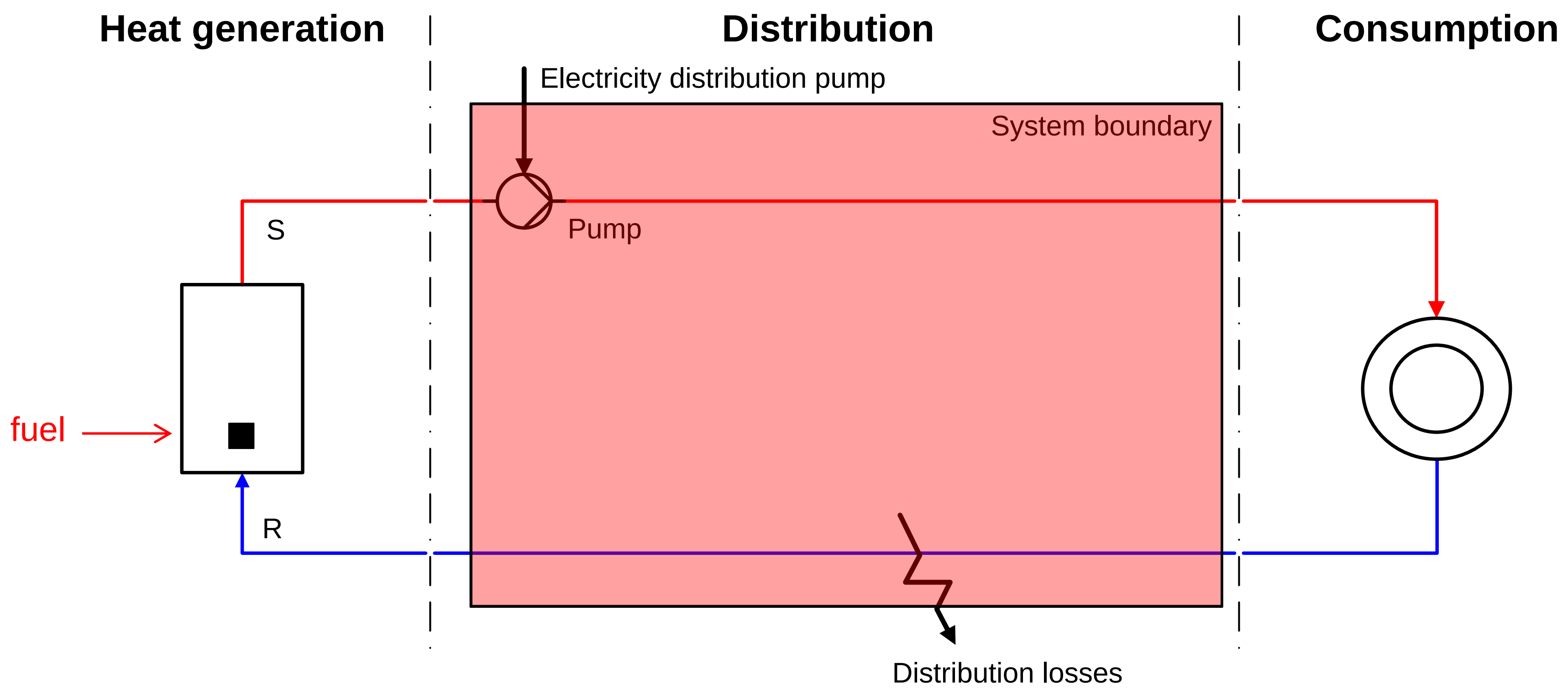
The end

System Definition



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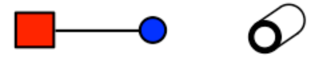
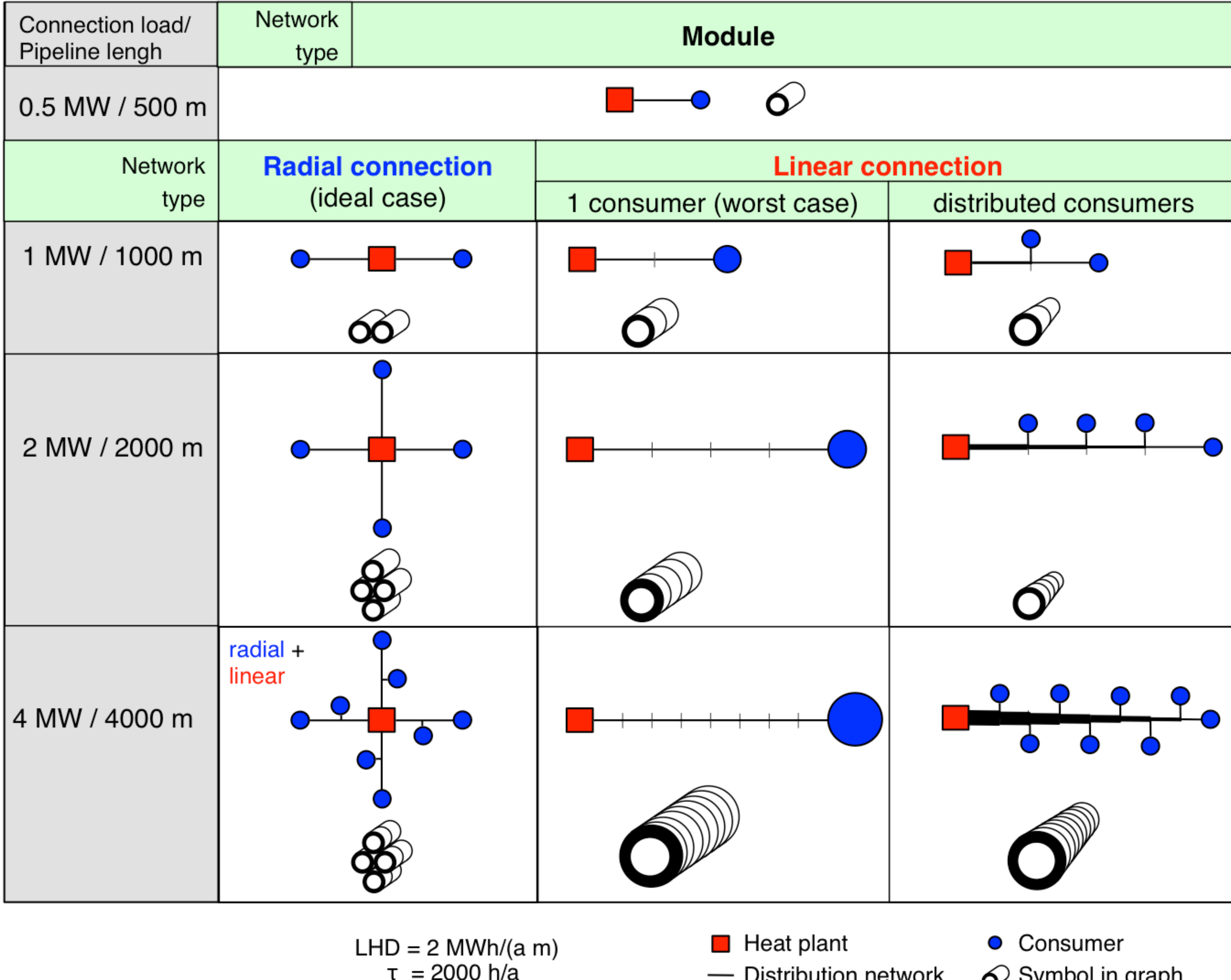
Connection load/ Pipeline lengh	Network type	Module
0.5 MW / 500 m		

LHD = 2 MWh/(a m)
τ = 2000 h/a

Heat plant
Consumer
Distribution network
Symbol in graph



Connection load/ Pipeline lengh
Network type
Module
0.5 MW / 500 m
Network type
Radial connection (ideal case)
Linear connection
1 consumer (worst case)
distributed consumers
1 MW / 1000 m
2 MW / 2000 m
4 MW / 4000 m
radial + linear
LHD = 2 MWh/(a m)
τ = 2000 h/a
Heat plant
Distribution network
Consumer
Symbol in graph