Heat Grid –
District Heating with Biomass in Switzerland and in IEA Countries

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Bioenergy Grid Integration 19 October 2017, Baden

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Sustainable Biomass Potential in Switzerland

		Sustainable Potential PJ/a	Used PJ/a	**Unused** PJ/a (% CH)
1	Wood	50	36	14 (+ 40%)
2	Non-Wood	47	12	34 (+300%)
1+2	**Biomass** (w/o MSW)	97	48	46 **(+100%)**
	Total in SWI	8.8%	4.4%	4.4% (+100%)
	DH (mainly MSW)		18 PJ /a 2.2%	


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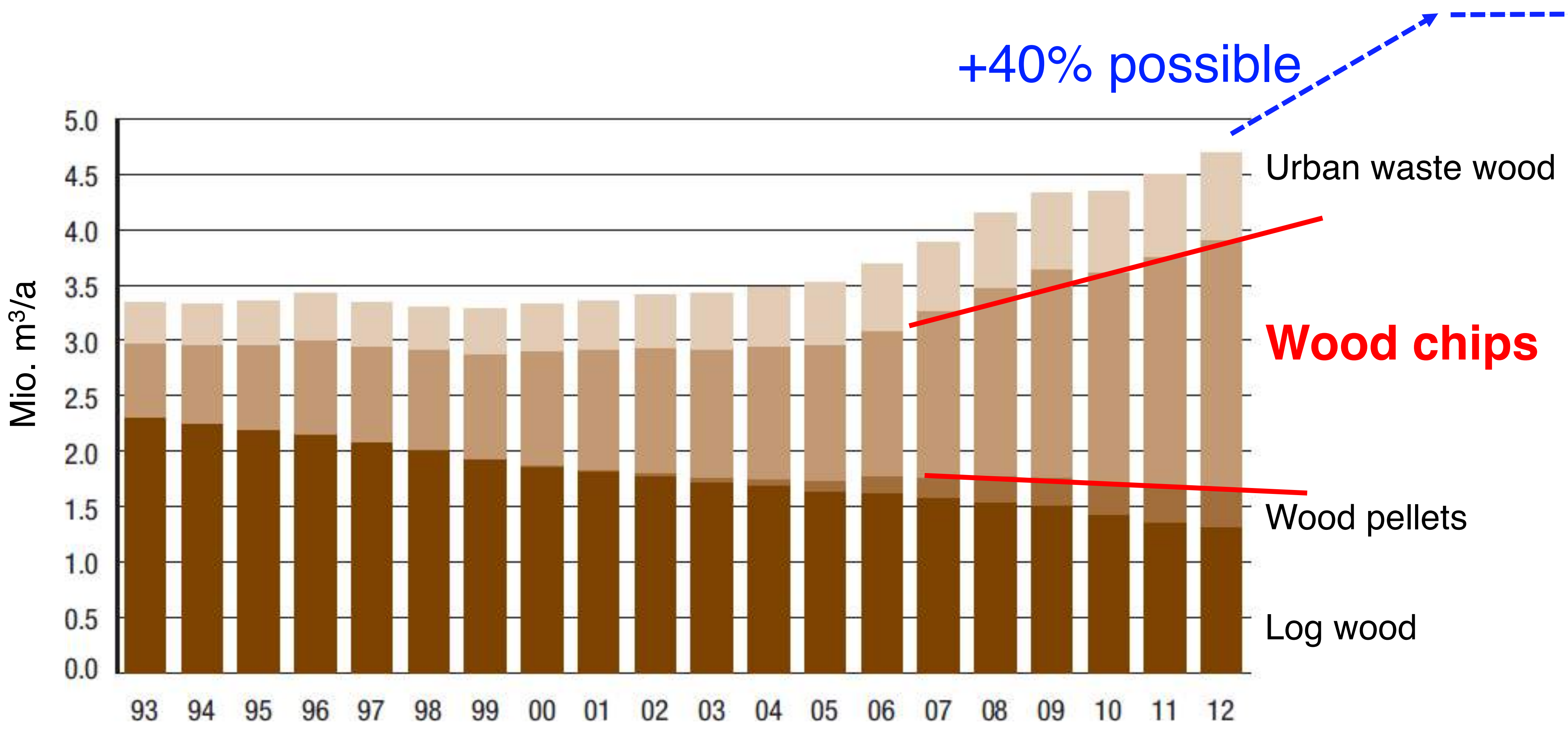
Biomassenpotenziale der Schweiz für die energetische Nutzung

Ergebnisse des Schweizerischen Energiekompetenzzentrums SCCER BIOSWEET

Oliver Thees, Vanessa Burg, Matthias Erni, Gillianne Bowman, Renato Lemm

Eidg. Forschungsanstalt für Wald, Schnee und Landschaft WSL
CH-8903 Birmensdorf

Wood Energy in Switzerland



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[Jahrbuch Wald und Holz 2013, BAFU]

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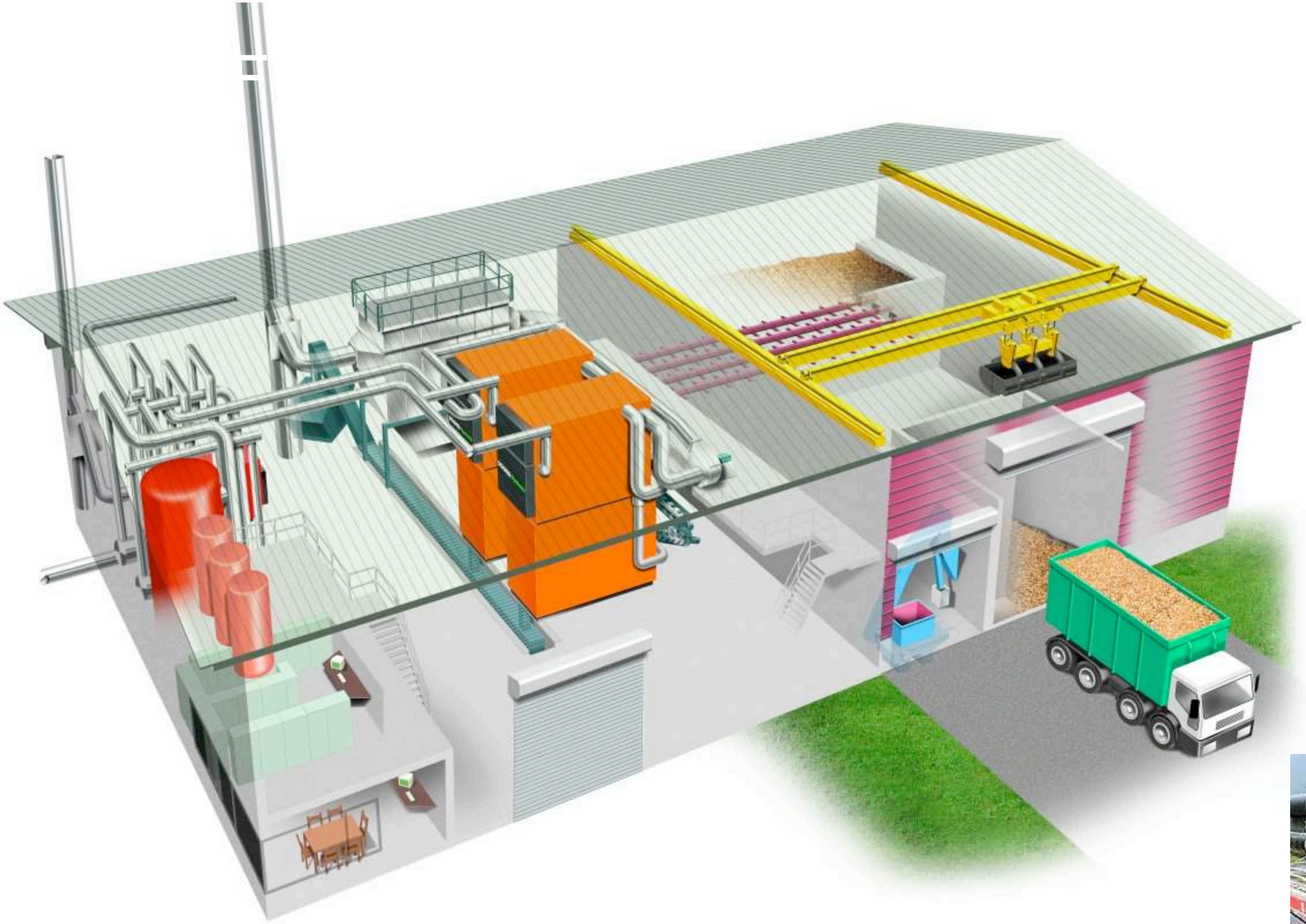

6.4 MW, AVARI Wilderswil (BE), Schmid AG

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

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Motivation for District Heating (DH)

+

DH enables to use **biomass** as renewable energy

- to subsidise decentralised fossil heatings
- with low (air) pollution and high comfort

–

DH causes additional costs and energy losses

Content

1 Design	1 Network design 2 Integration of energy storage
2 Optimisation	1 of heat consumers 2 of existing networks
3 IEA Survey	District Heating in IEA Countries

1 Design

1 Network design for cost optimisation

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Swiss Federal Office of Energy

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Sensitivity of System Design on Heat Distribution Cost in District Heating

prepared for the

International Energy Agency IEA Bioenergy Task 32
and the
Swiss Federal Office of Energy

Zürich, 19 December 2014

ISBN 3-908705-27-4

IEA Bioenergy Task 32

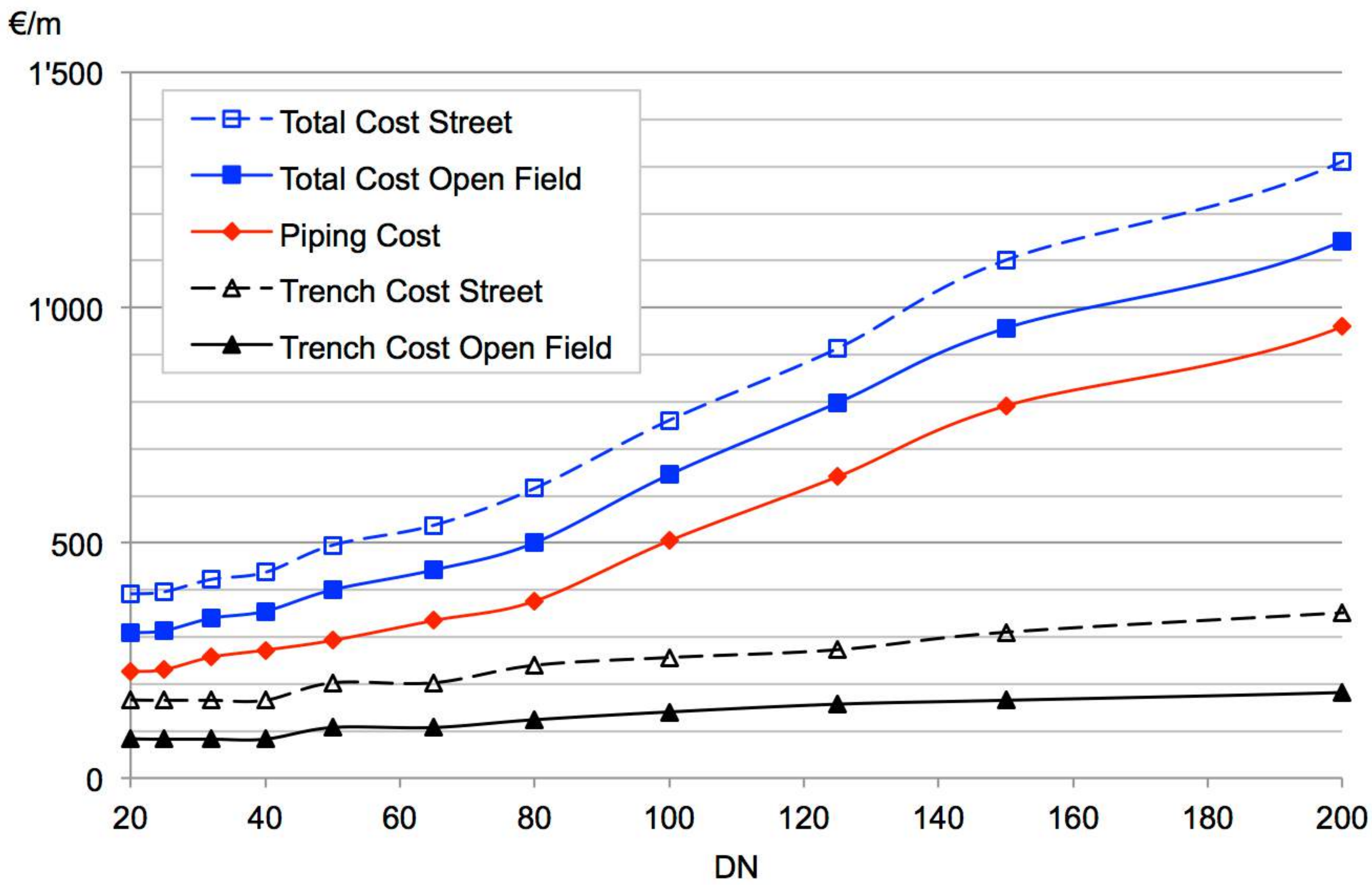
Method: Capex + Opex

a) Reference for 1 MW / 1000 m with 2000 h/a = 2 MWh/a m

Linear Heat Density

b) Variation of main parameters

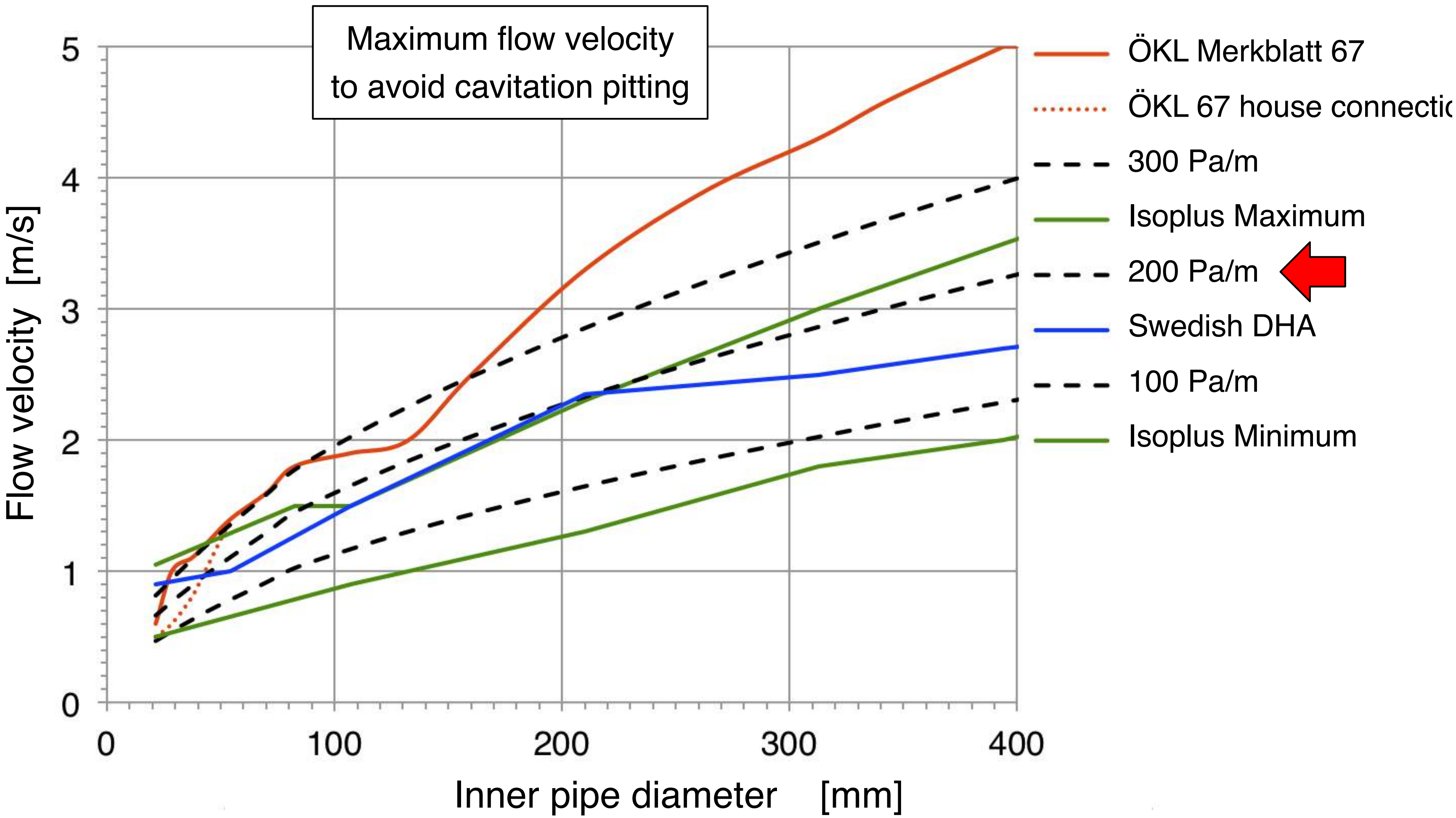
Basis 1: Capex based on Investment cost



[T. Nussbaumer, & S. Thalmann, *Energy* 101 (2016) 496–505]

Data from: Brugg, Isoplus, Logstor, Jenni, Ködel

Basis 2: Opex due to pumping + fuel to cover heat losses



[T. Nussbaumer, & S. Thalmann, *Energy* 101 (2016) 496–505]

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

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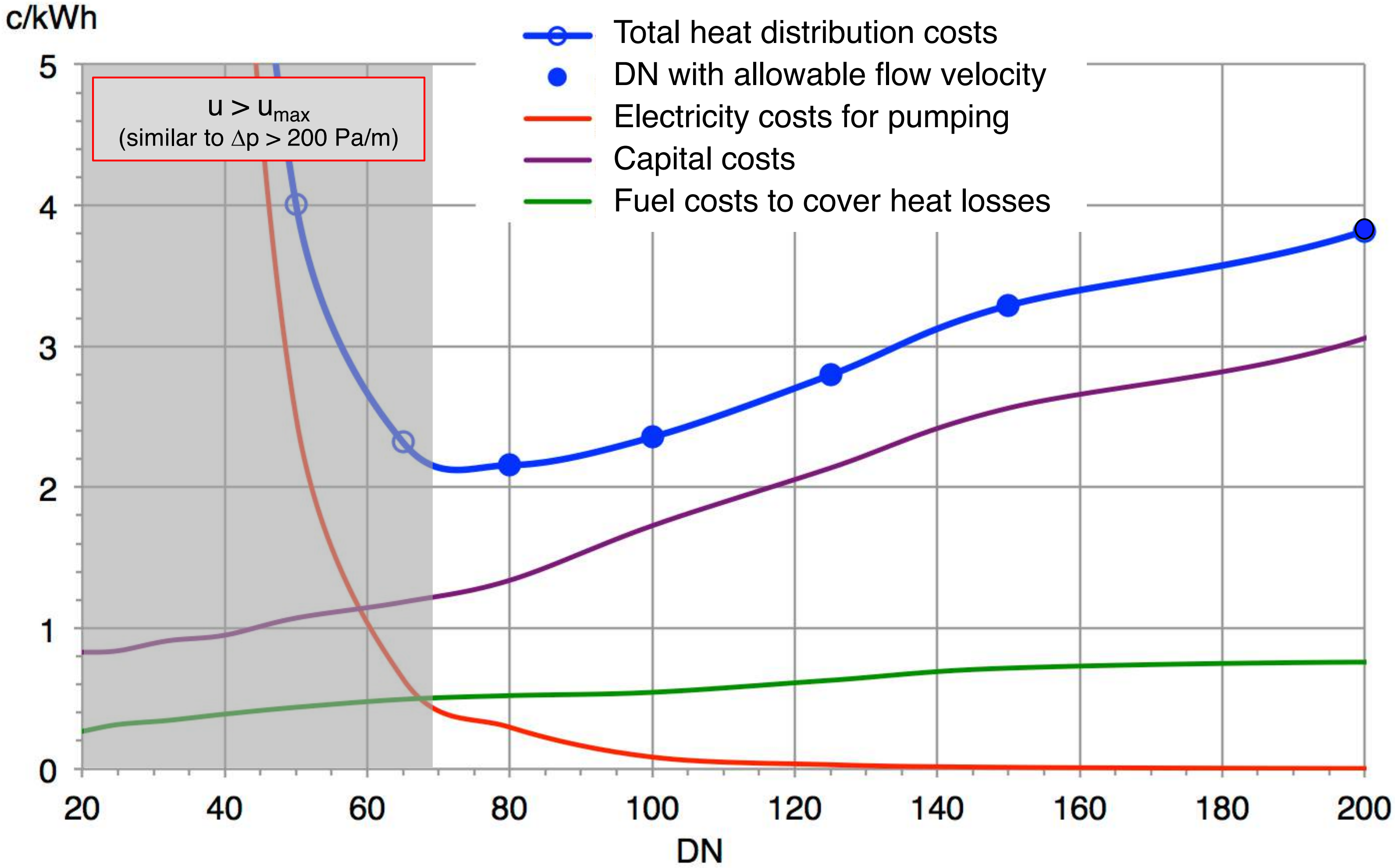
Results: Contribution of Cost Factors

for 1 MW / 1000 m with 2000 h/a = 2 MWh/a m



[T. Nussbaumer, & S. Thalmann, *Energy* 101 (2016) 496–505]

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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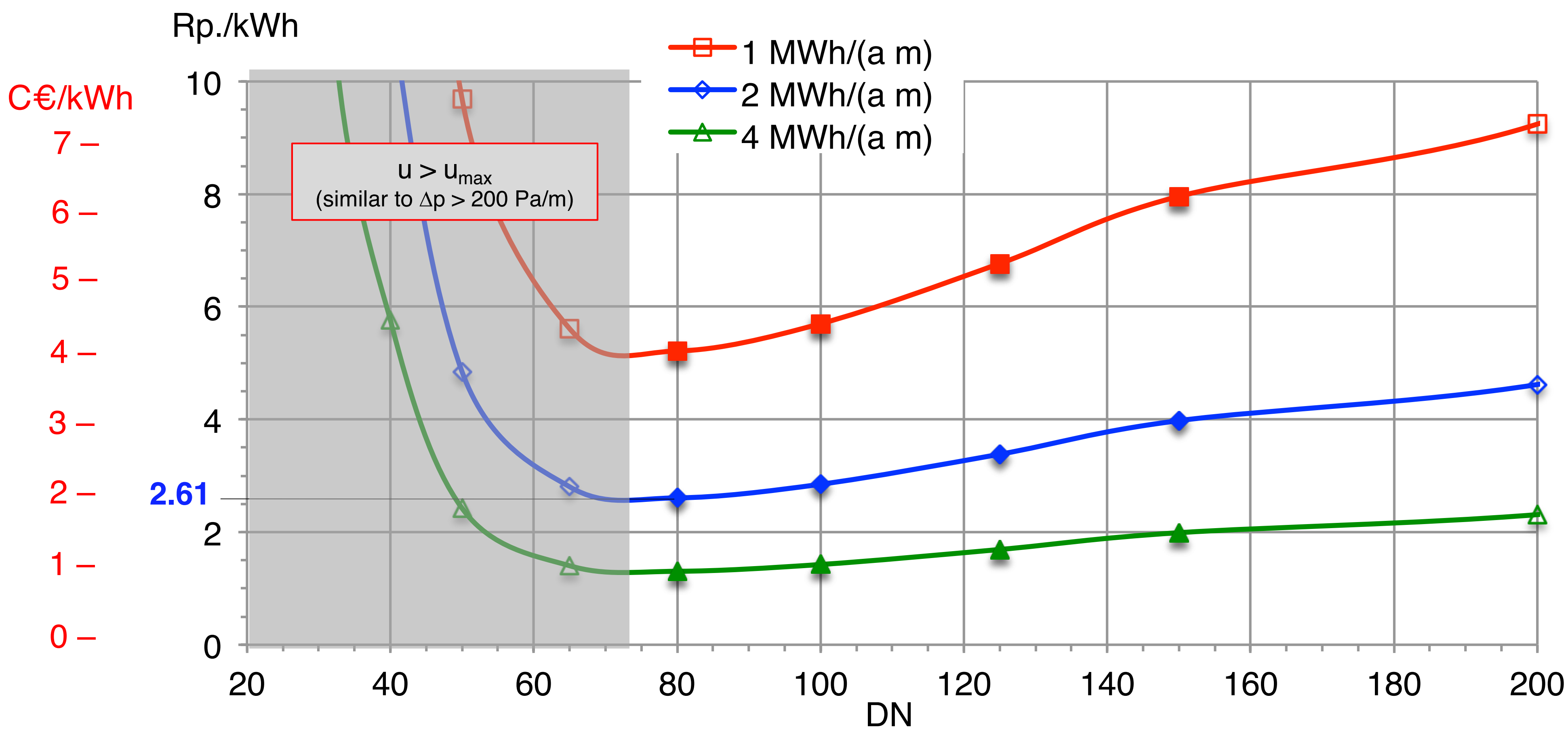
Results: Influence of Linear Heat Density

for 1 MW / 1000 m with 1000 / 2000 / 4000 h/a



- **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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Conclusions on Design for Cost Optimisation

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

2. Since
   - capital costs increase with pipe diameter
   - while pumping costs remain moderate,

   the **smallest feasible pipe diameter** achieves minimum possible heat distribution cost

1 Design

2 Integration of thermal energy storage

Motivation of heat storage

1. Continuous operation of biomass boilers reduces start-ups

2. Heat storage increases flexibility for CHP and power production

3. Heat storage to cover peaks enables to reduce the boiler capacity
   –> investigated in a study at Lucerne Uni oAS by [Schelker 2017]

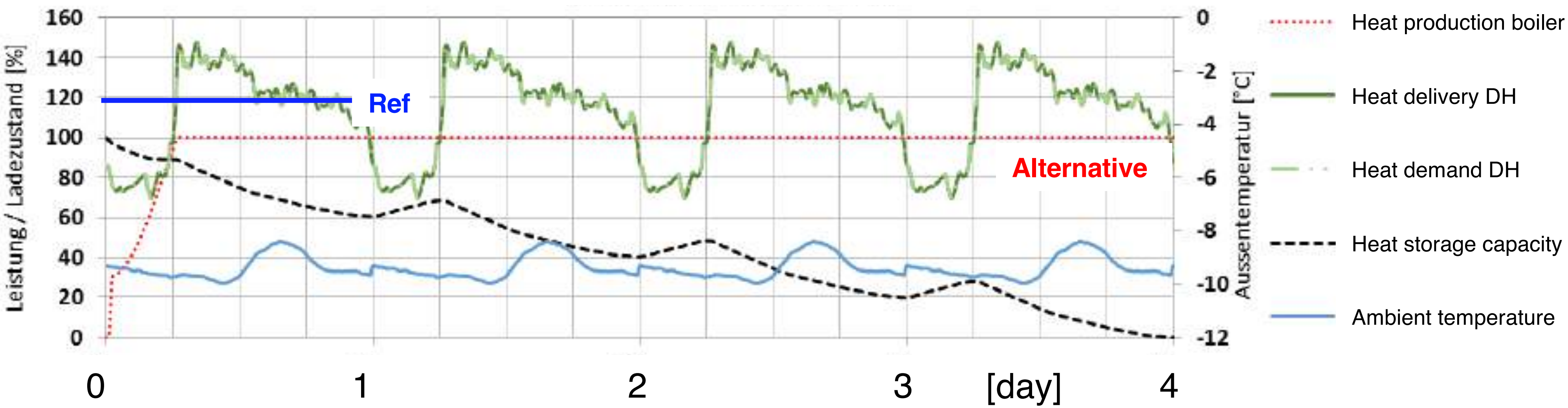
Method

Simulation of heat storage state during “cold period” in Swiss midlands

Reference: One biomass boiler for 24 h at -15° (or one and fossil backup)

Alternative: One biomass boiler for -10° **plus** heat storage for 8 days

(Swiss midlands exhibit one period in 40 years of 15 days with -15°)



example for a
storage capacity resulting in
4 days security of supply

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[D. Schelker: Optimale Speichergrösse, Master Thesis in Bioenergy, advisor T. Nussbaumer, HSLU 2017]

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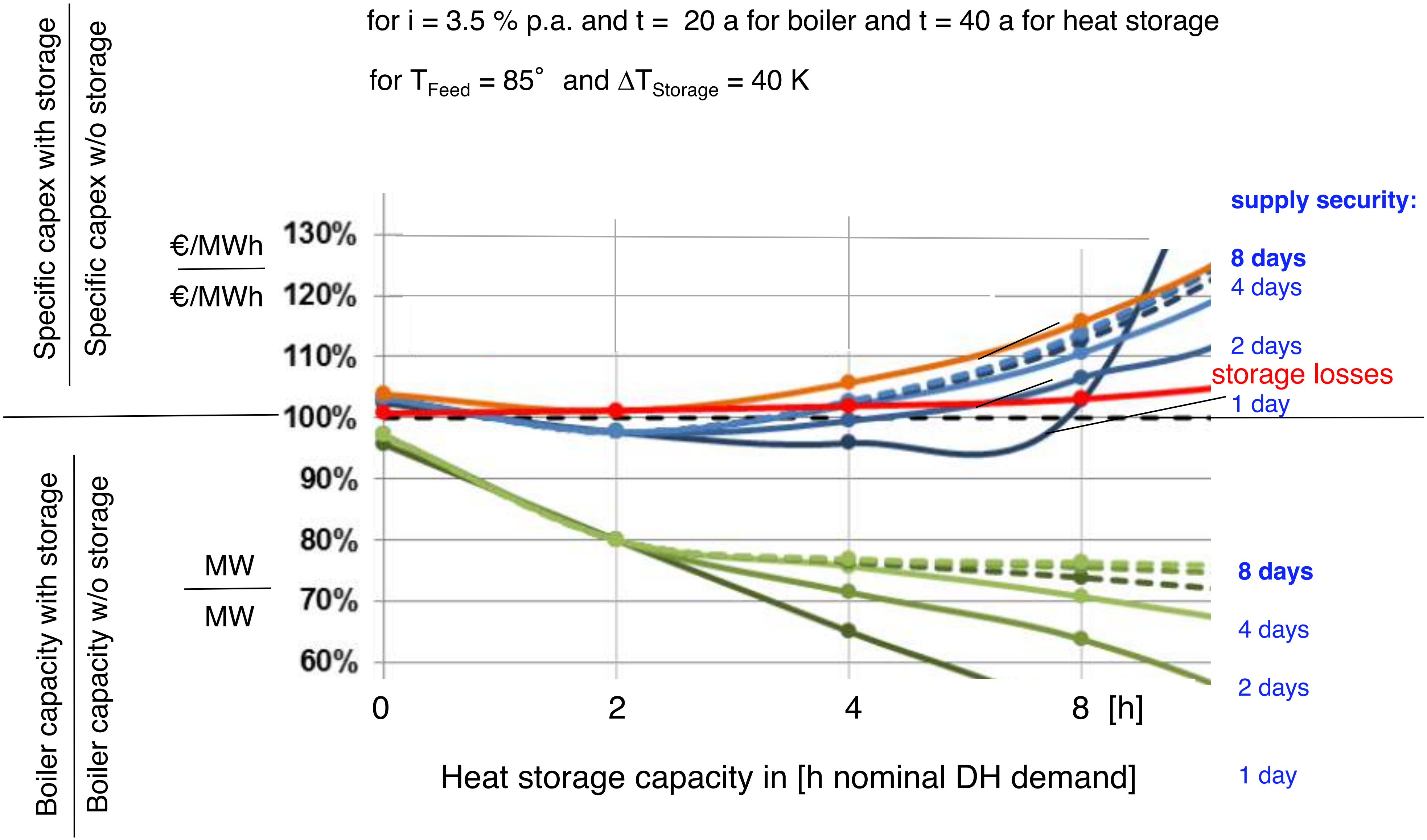
Result: Capex and boiler capacity as function of storage capacity

for i = 3.5 % p.a. and t = 20 a for boiler and t = 40 a for heat storage

for T_{Feed} = 85° and $\Delta T_{Storage}$ = 40 K



Conclusion on Heat Storage Design for Peak Load

Heat storage to cover peaks enables a cost minimum

in the example at 2 to 3 h capacity
which reduces the boiler capacity by 20% and
the total capex by 2.5 %

w/o taking into account other advantages

2 Optimisation

1 Optimisation of heat consumers

Background

During **night**, the heat consumption is reduced causing disadvantages for DH:

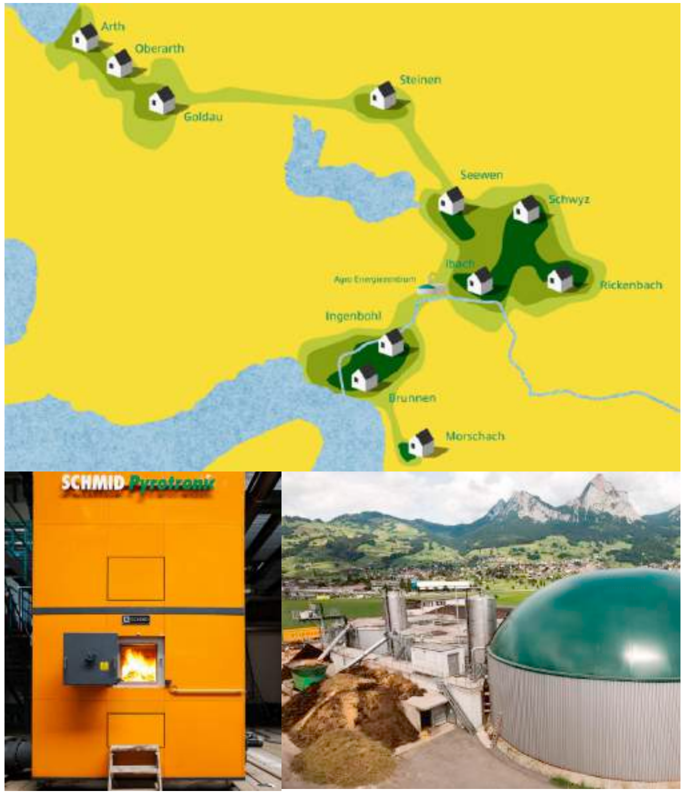
1. **Peak load** with rapid increase of heat demand can increase emissions and use of fossil auxiliary boiler

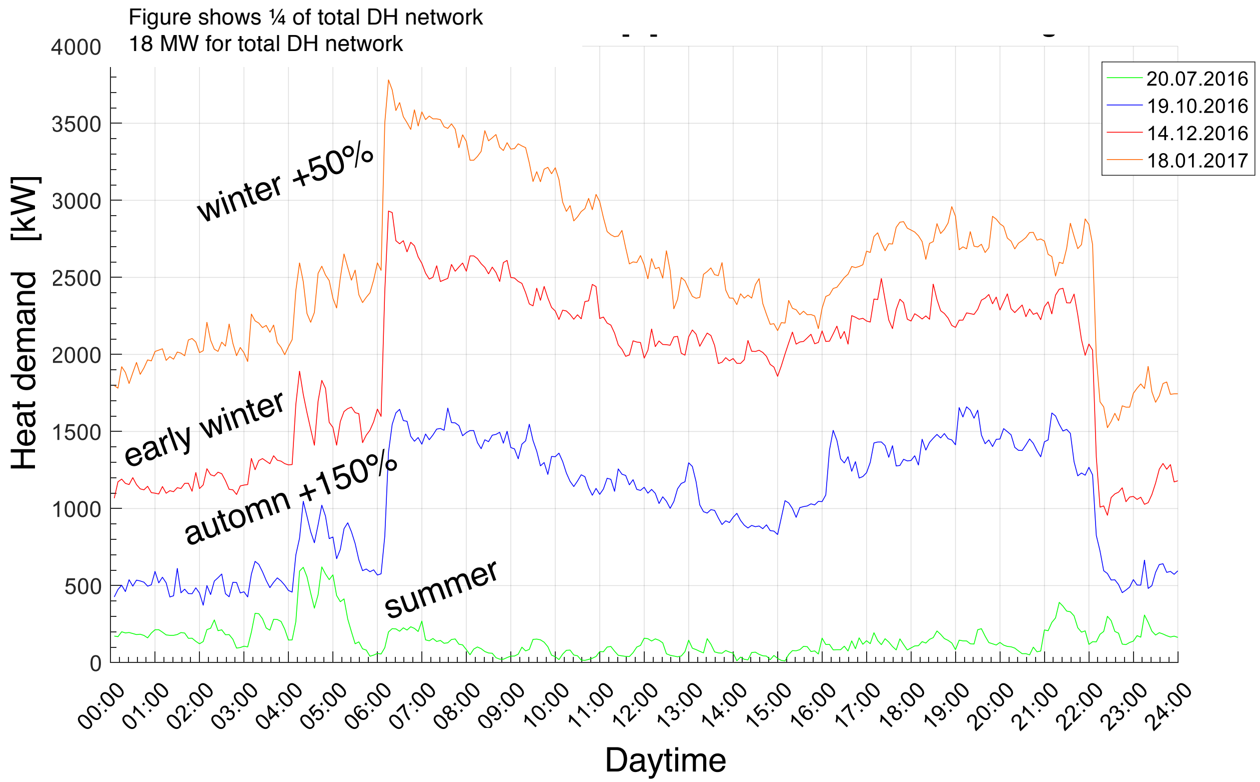
2. Compared to a constant demand, the connection load is reduced

3. Non ideal power production for CHP

Method

1. The demand of a DH is described in a 5 minutes resolution based on data from 800 consumers of AGRO Energie Schwyz with 17 MW and 80 km.

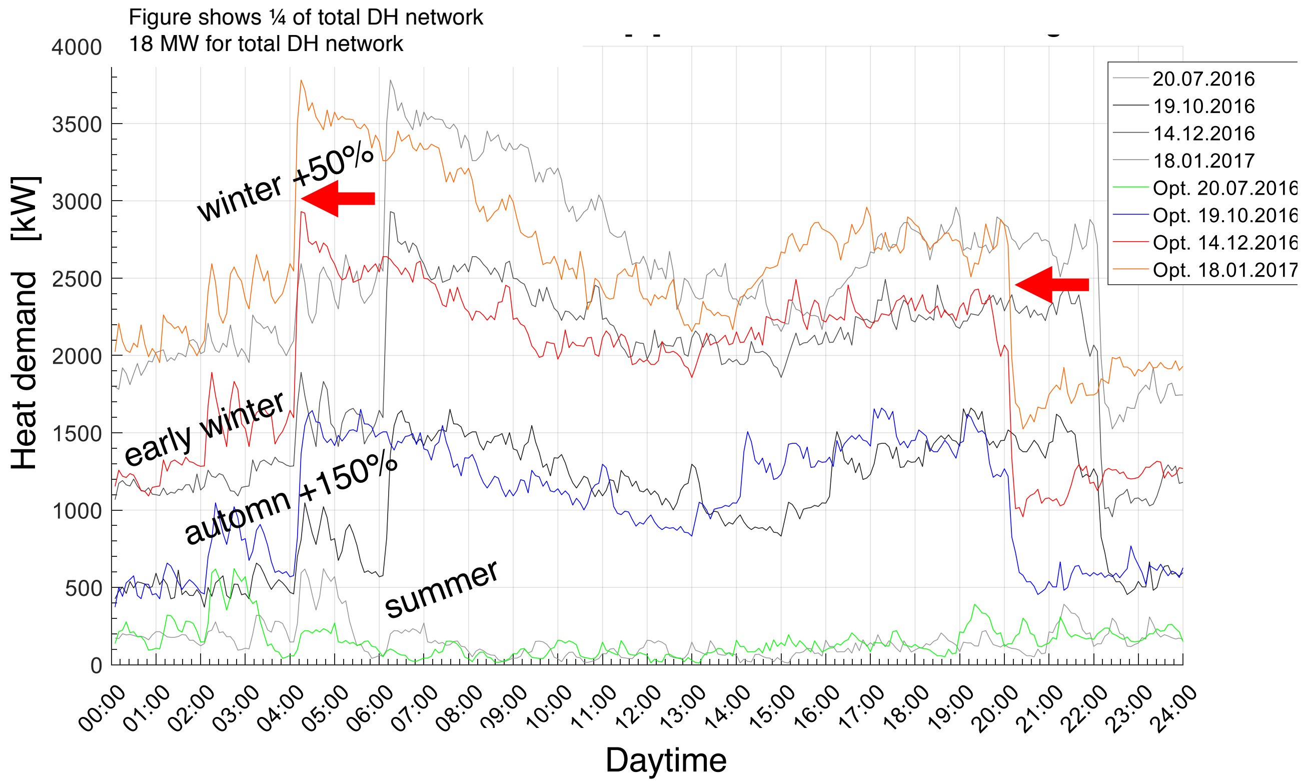




Method

2. A simulation in Matlab is performed to investigate the effect of

    1. a shift of 2 h for consumers with floor heating (35%)



[F. Hemmerlein: Optimierung der Laststpitzen (bei AGRO Schwyz), Bachelor Thesis in Bioenergy, advisor T. Nussbaumer, HSLU 2017]

1. ...

Method

2. A simulation in Matlab is performed to investigate

    1. a shift of 2 h for houses with floor heating (35%)

    2. an additional lock of floor heating during the 40 minutes peak

    and other measures

Results

1. A **shift** of 2 h for all floor heating reduces the peak, and the additional **lock** during the 40 min. peak even more.

   Both measures allow to reduce the heat production capacity or to increase the connection load by app. **10%.**

2. The potential enables

   a) low marginal costs for additional consumers and therefor

   b) an additional profit of 200 k€/a corresponding to 1.5% of the heat distribution costs

2 Optimisation

2 Optimisation of existing networks

Background

1. Heat distribution capacity is proportional to ΔT_{DH} = T_{feed}–T_{return}

$$\boxed{\dot{Q} = \dot{m}\, c_P\, \Delta T = \dot{V}\, \rho\, c_P\, \Delta T}$$

2. T_{return} is influenced by the consumers:
   - heat exchange in the substations
   - secondary heat distribution

3. Mal-operated consumers increase T_{return} thus
   – increase opex by increased pumping demand and heat losses
   – reducing the DH capacity, hence the connection load

Method

1. Data acquisition from each consumer during a heating period of delivered
   - heat in kWh (standard for accounting)

     and
   - volume in m^3 (often not documented)

2. Calculation of effect of each consumer
   a) Δ**m** = additional mass flow = (mass flow – mass flow at ΔT_{ref})
   b) ΔT_{DH}

3. Ranking to identify consumer(s) with negative effect

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Based on: [H. Zinko et al: Improvement of operational temperature differences in district heating sys-tems, International Energy Agency – Implementing Agreement on District Heating and Cooling, IEA DHC/CHP, Annex VII 8DHC-05.03, Paris 2005]

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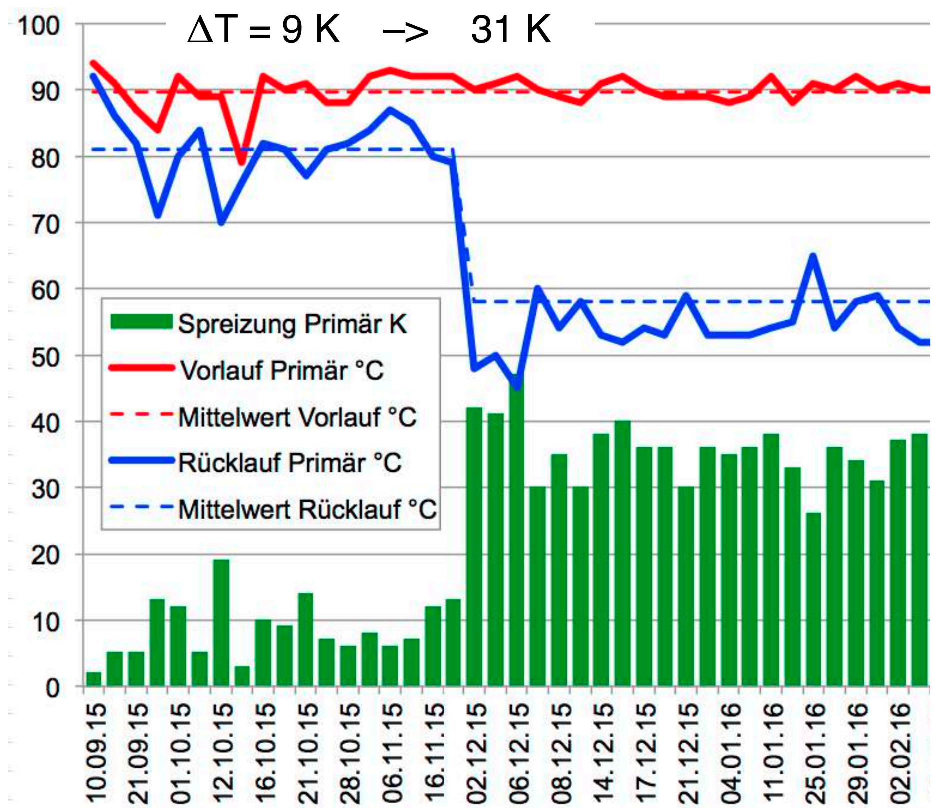
Results from three DH networks

DH1 = ok (all consumers with **Δm close to 0** (ΔT > 30 K as target)

DH2 & 3 = Optimisation potential due to consumer(s) with **Δm >> 0**



[T. Nussbaumer & S. Thalmann: HK Gebäudetechnik 2 2017, 36–41]
or www.holzenergie-symposium.ch proc. 2016

Results

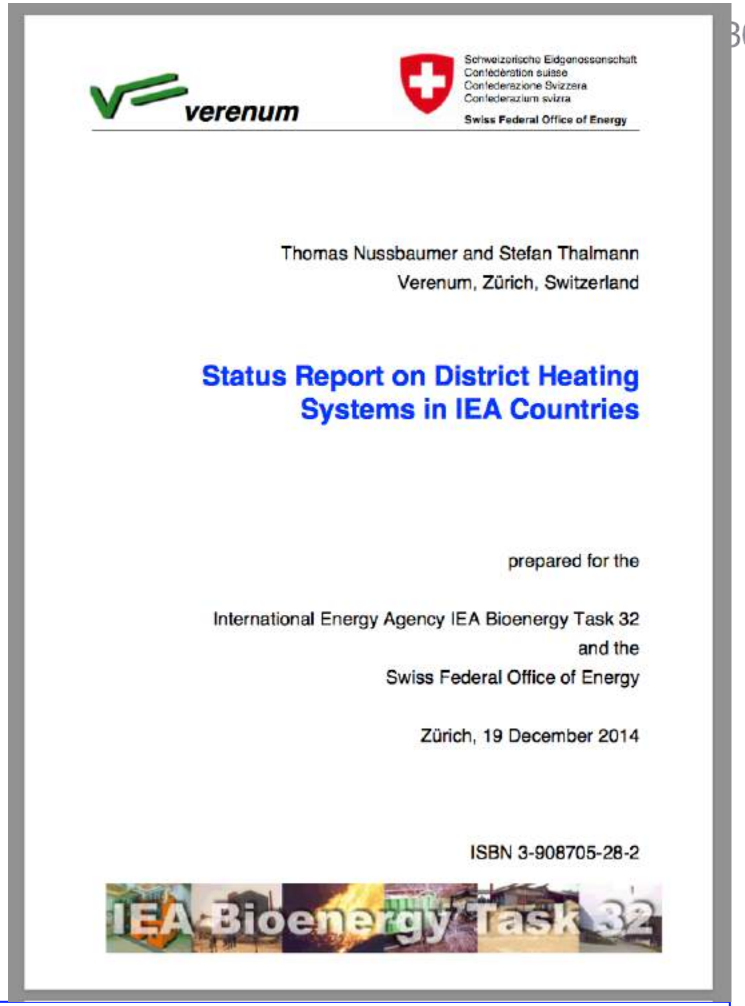
–> Identification of malfunction by inspection

–> Measures, e.g. replacement of control valve

Improvement: **ΔT_{DH} = 1.2 K** and **1.5 K**

based on 30 K = **4% and 5%** reduction of mass flow or increase of connection load

ROI for prio 1 measures: 2 – 4 years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Swiss Federal Office of Energy

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Status Report on District Heating Systems in IEA Countries

prepared for the

International Energy Agency IEA Bioenergy Task 32
and the
Swiss Federal Office of Energy

Zürich, 19 December 2014

ISBN 3-908705-28-2

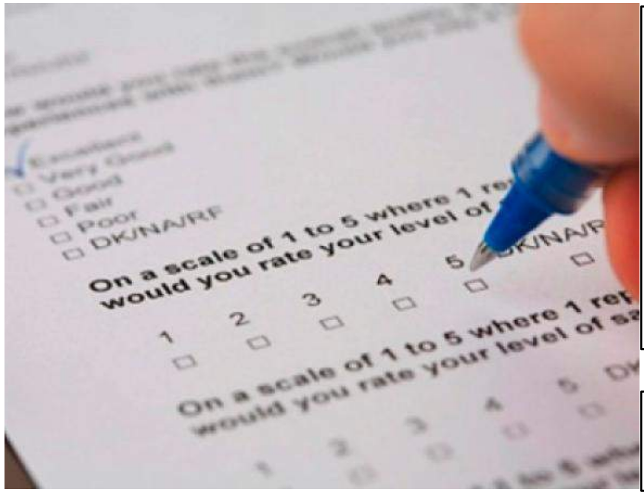
IEA Bioenergy Task 32

3 IEA Survey

District Heating in Task 32 Countries

Survey on efficiency and cost to analyse **influences** of key parameters

Method

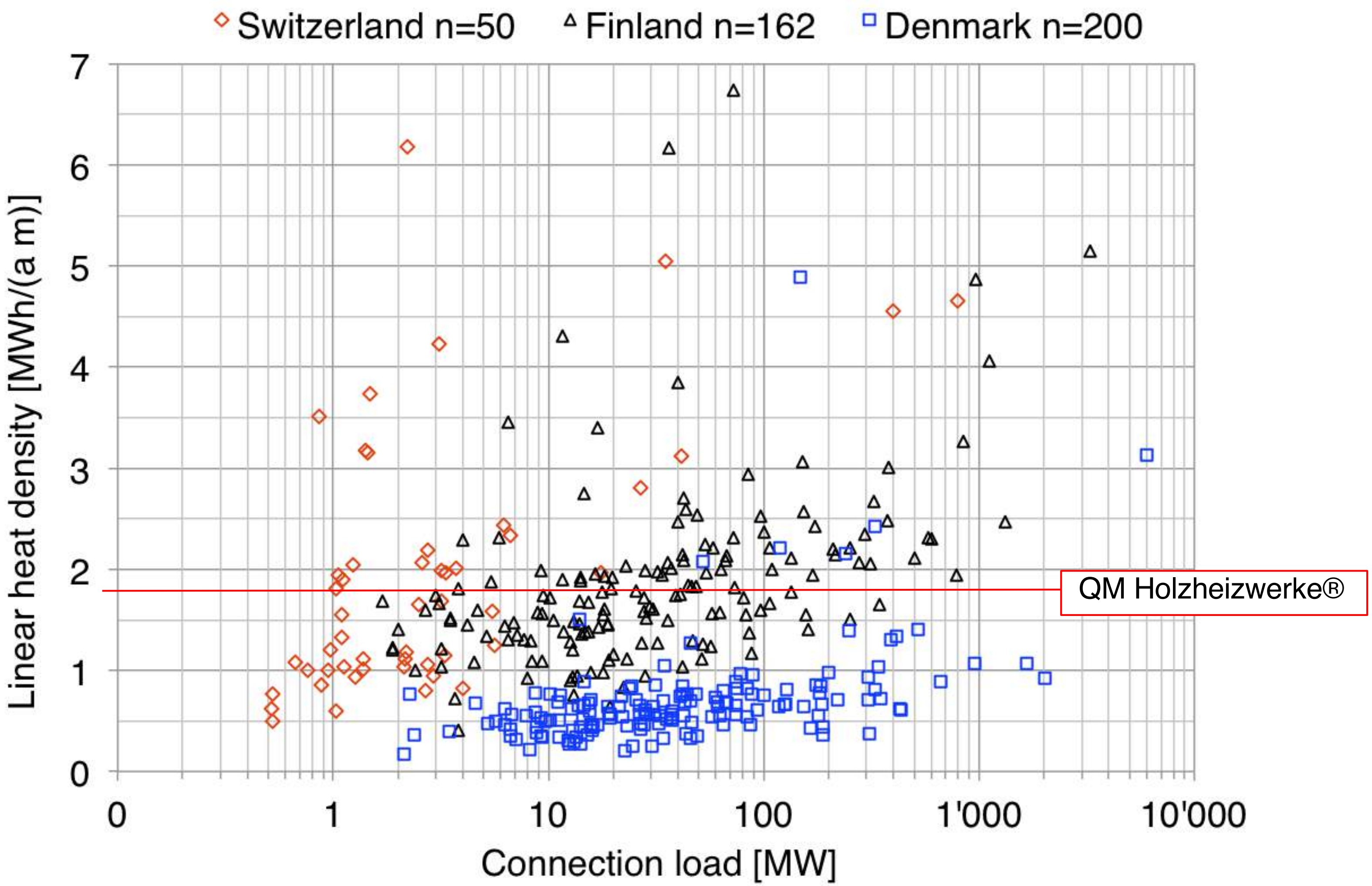


1. **Questionnaire** for data collection
   - IEA Bioenergy Task 32
   - IEA Implementing Agreement on District Heating and Cooling (IEA-DHC)

2. **Internet survey**

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

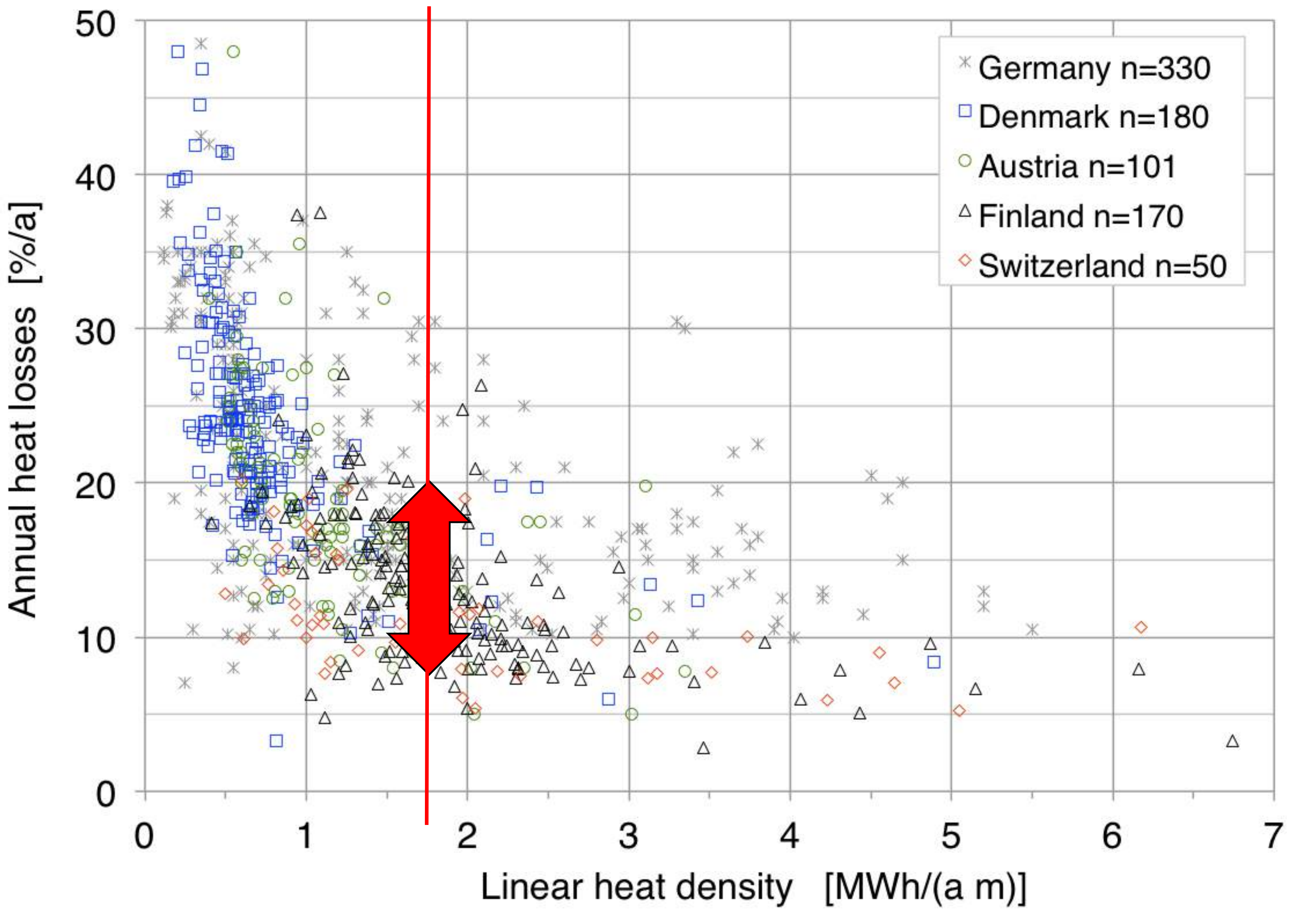
Results: Linear Heat Density = f(Connection Load)



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: Heat Losses = f(Linear Heat Density)



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 %

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[T. Nussbaumer & S. Thalmann, 23rd European Biomass Conference and Exhibition, Vienna, 1–4 June 2015, ICV.4.50]

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Conclusions

– The **linear heat density** is a crucial parameter.

– The range of the heat losses of more than a **factor of 3** at constant linear heat density shows that **other parameters** also strongly influence losses and cost:

a) The **pipe diameter**[1)2)] ([2)] 80 % oversized line sections wize losses +20 % and costs +30 %)

b) The **temperature spread**[1)]

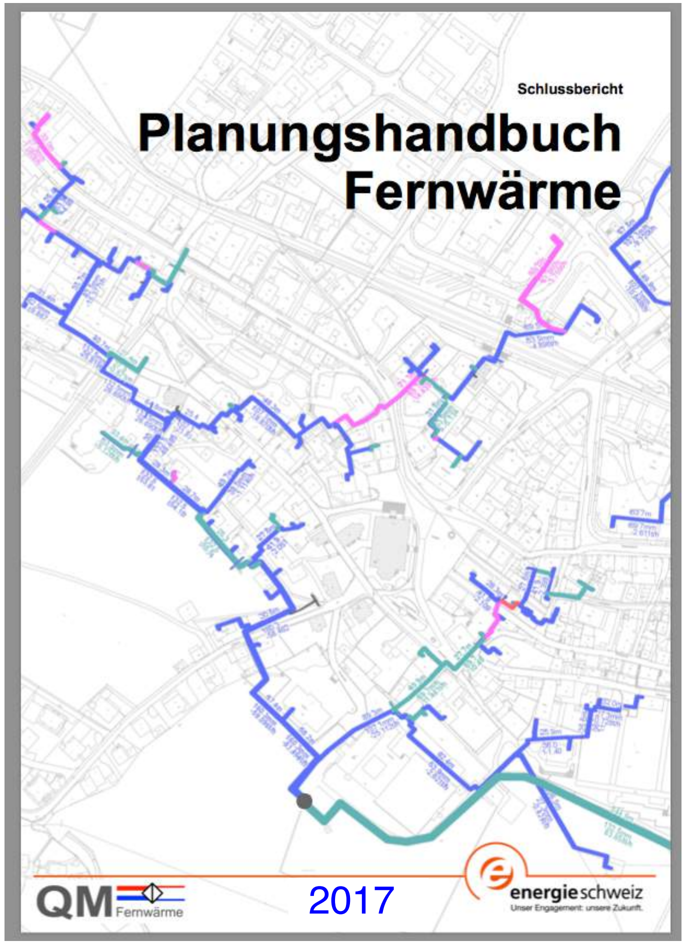
c) The **network layout**[1)]

1) [T. Nussbaumer, T. & S. Thalmann, *Energy* 101 (2016) 496–505]

2) [S. Thalmann, A. Jenni, T. Nussbaumer: Ist-Analyse von Fernwärmenetzen, 13. Holzenergie-Symposium, ETH Zürich 12.9.2014, Verenum Zürich 2014, ISBN 3-908705-25-8, 235–259, www.holzenergie-symposium.ch]

Outlook

1. To exhaust the potential of District Heating, plant planning and operation are crucial



2. Experiences are available and need to be implemented by training and eduction, e.g. „Handbook on District Heating Planning“ available at www.qmfernwaerme.ch

Acknowledments

Swiss Federal Office for Energy (SFOE)

International Energy Agency Bioenergy Task 32

Plant owners of district heating systems

IEA IA on District Heating and Cooling

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D. Schelker, F. Hemmerlein

J. Ködel, M. Cueni

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www. task32.ieabioenergy.com

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qmfernwaerme.ch