CELSIUS Talk:
Integration of heat, power and intermittent renewables

2017.10.04

This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement no 314441.

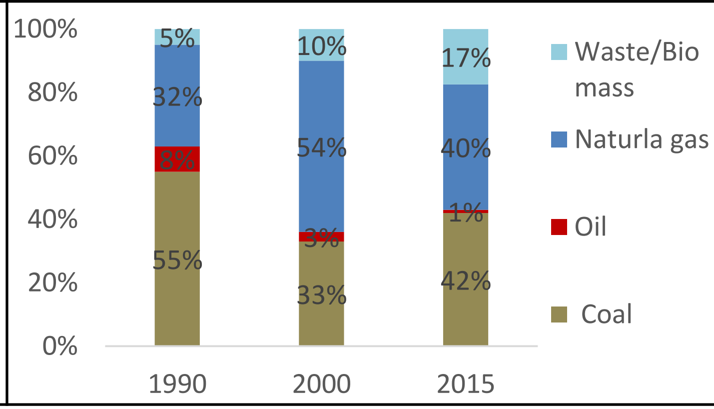
Cost-effectiveness of large-scale heat pumps in district heating networks: a simulation model for a case study in Germany

Eftim Popovski
Research Associate
Fraunhofer ISI

Content

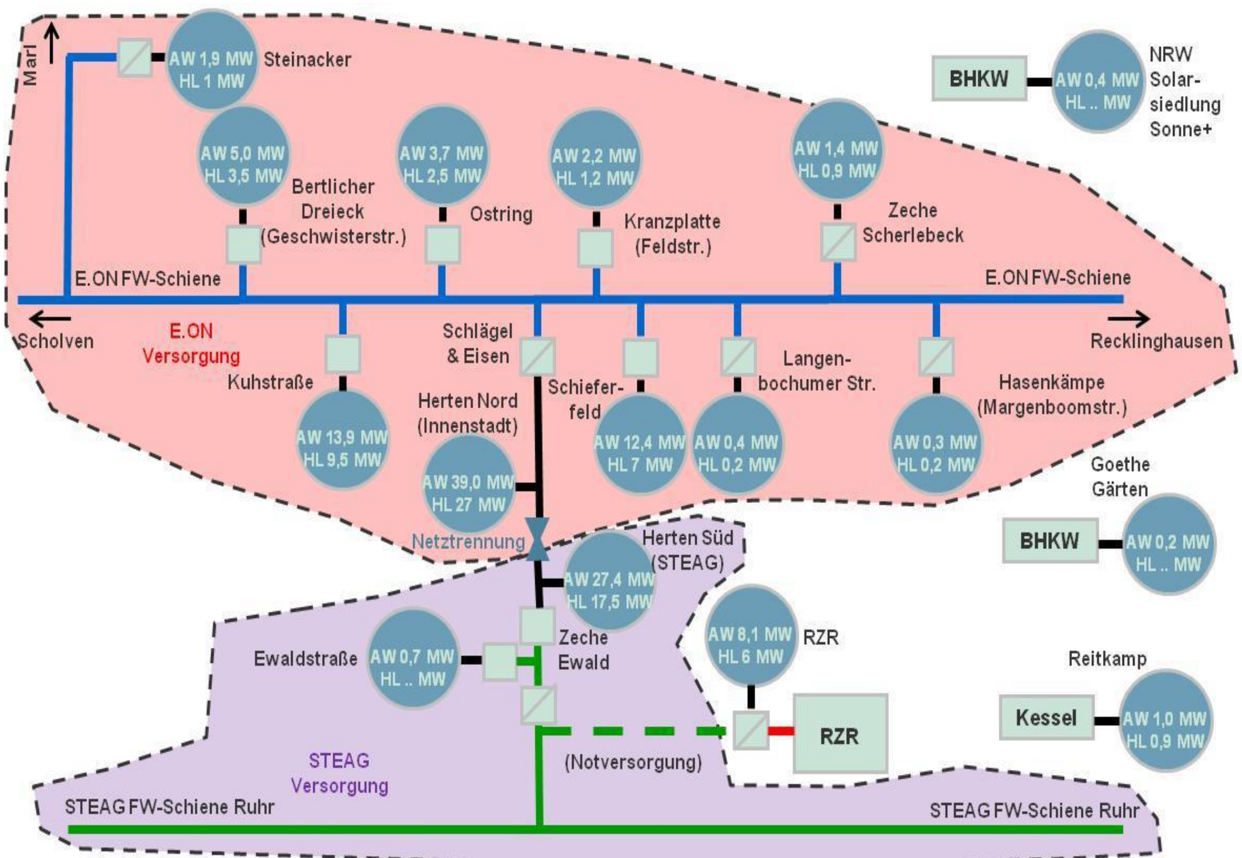
- District heating in Germany
- progRESsHEAT project and the case study of Herten
- Research questions and methodology
- Results
- Conclusion

District heating in Germany

DH network length	100 000 km [1,2 km/1000 pers.]
Total installed DH capacity	49 931 MWth
DH market share	**13,1%**
Average DH price in 2011 (excl. VAT)	**73 EUR/MWh**
Heat losses in the network	13%
Working temperatures	**120°C / 65°C**
Supply structure	83 % CHP plants 17 % uncoupled
Energy carriers	

Sources: AGFW (2015); UBA (2014)

City of Herten (Germany) and existing DH network



- DH network divided in two parts currently supplied by **coal-fired CHPs**
- Existing **heat exchangers** between **transmission pipelines** and **city districts**
- Possibility of fully or partially decoupling some of the districts
- **Pit water** with 20 °C from the old mines can be used as a heat source

Source:
Feinkonzept KWK
Modellkommune Herten

- Linear density 1,28 MWh/km
- Heat losses ca. 19%
- 28% DH Share

Research questions and methodology

Research questions

1. Why are there no heat pumps currently integrated in DH networks in Germany
   - Technical reasons
   - Economic reasons
   - ...
2. How to make large-scale heat pumps competitive

Methodology and assumptions

- Costs assumptions
- Technical data based on existing projects (Helsinki, Finland)
- Hourly simulation of heat generation mix (coal-fired CHP + solar thermal+ heat pumps) by using energyPRO simulation software

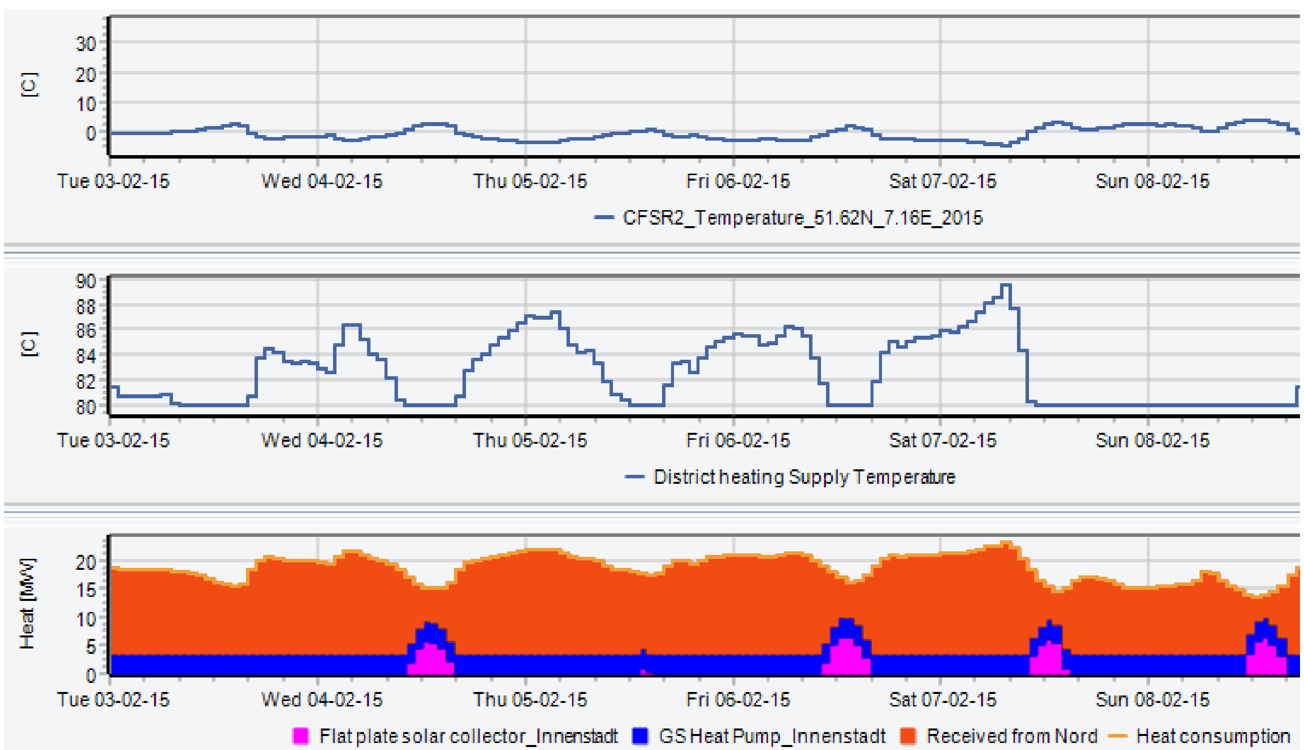
Cost assumptions

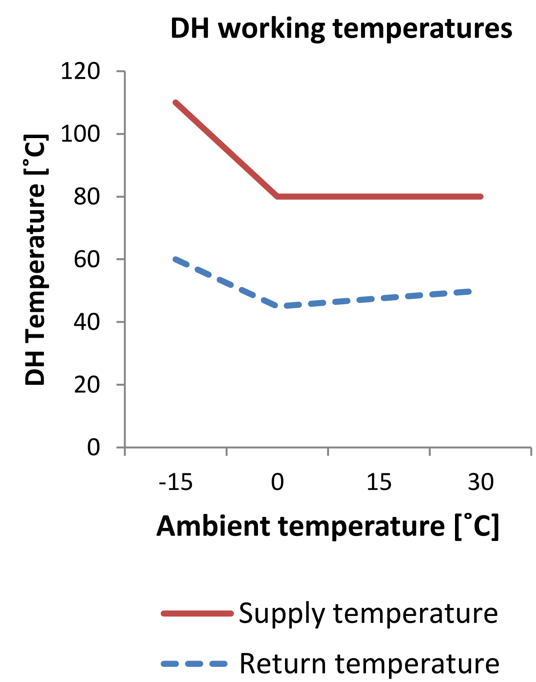
Type of costs	Value and unit
Investment costs	1500 EUR/kW_{th}
Economic lifetime expectancy	20 years
Interest rate	7 %
Variable operation and maintenance	3 EUR/MWh
Fixed operation and maintenance	1 % of the Initial Investment per year
Electricity price	176 [EUR/MWh]

- **Pit water** used as a **heat source >>>** similar investment costs as if a sewage water is used
- **No size-costs dependency >>>** assuming conservative specific investment costs of **1500 EUR/kW** for all sizes
- **Electricity price** for a **consumer** with an annual consumption of **24 GWh**
- Interest rate and taxes from a **private-perspective** (7% interest rate with taxes) are presented

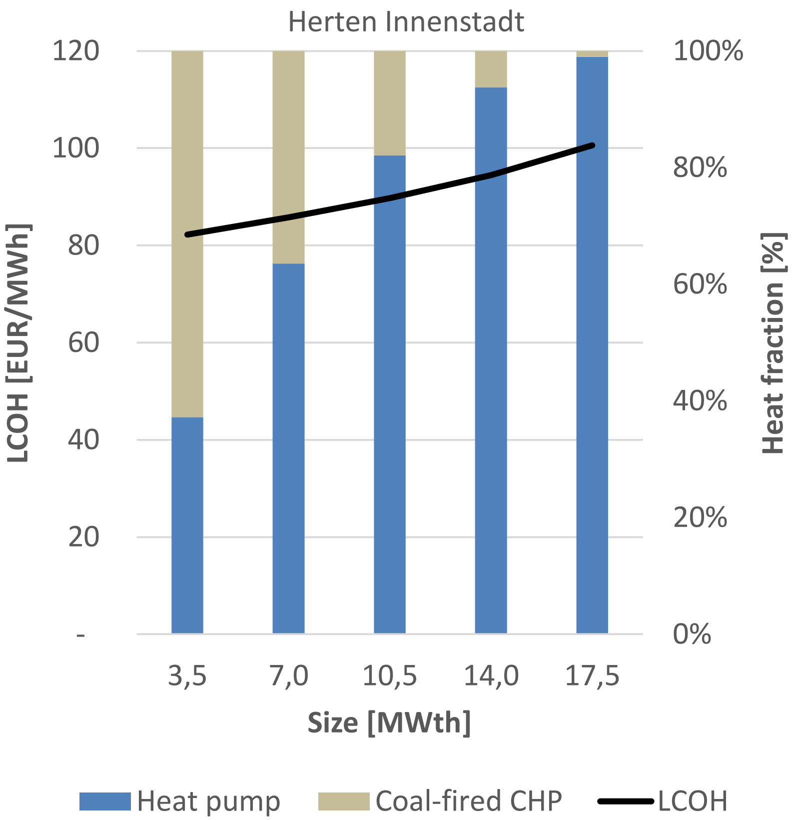
Technical data

- **The heat pump** provides heat up to **80 °C**, remaining covered by existing **coal-fired CHP plant**
- **HP efficiency = 0,52** >>> from an existing heat pump data (Helsinki, Finland)
- **COP** calculated for each time step using **energyPRO >>> average annual COP=3,02**

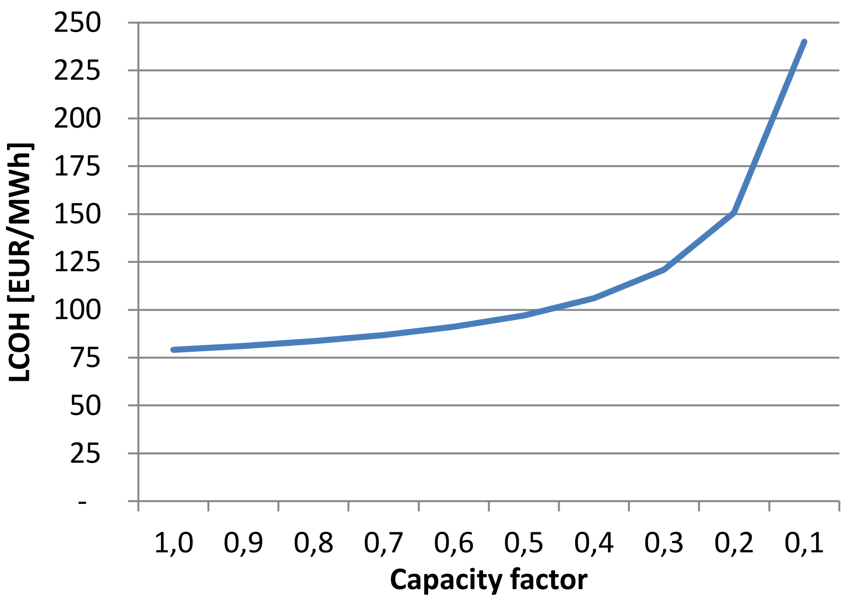




LCOH for different HP capacities



Installed capacity [MWth]	3,5	7,0	10,5	14,0	17,5
Capacity factor [-]	0,86	0,73	0,63	0,54	0,46

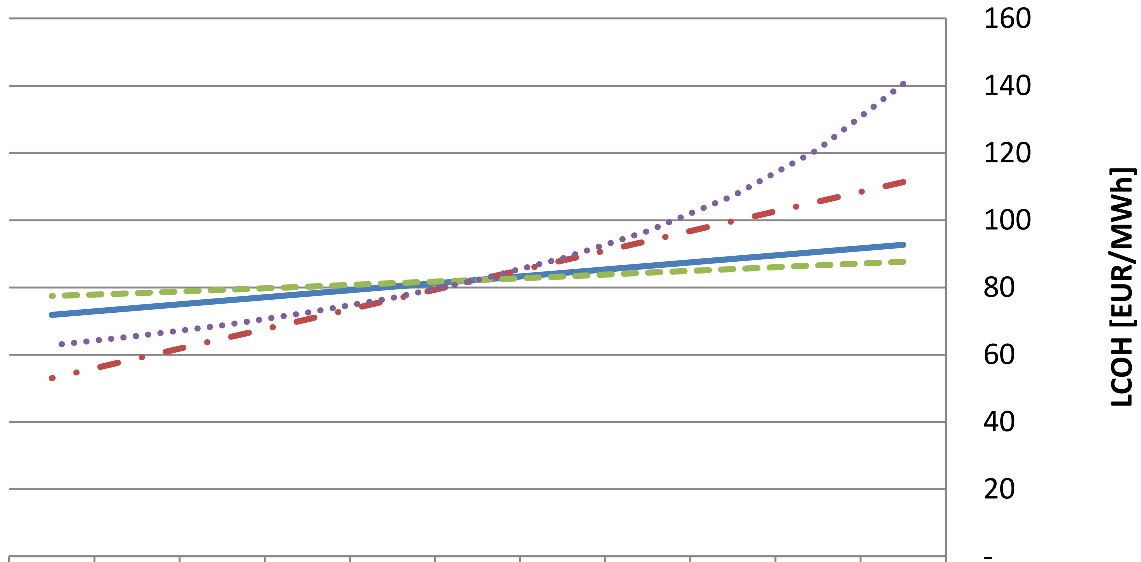


- Higher capacity factor can reduce the LCOH up to **18%**

Sensitivity analyses

Sensitivity Analysis
Heat pump Q=3,5 MWth

Cost data for base (100 %) scenario	
Investment	1500 EUR/kW
Electricity price	176.2 EUR/MWh
Interest rate	7 %
COP	3.02



	50%	60%	70%	80%	90%	100%	110%	120%	130%	140%	150%
Investment sensitivity	72	74	76	78	80	82	84	86	89	91	93
Electricity Price sensitivity	53	59	65	71	76	82	88	94	100	106	111
Interest rate sensitivity	77	78	79	80	81	82	83	84	85	87	88
COP sensitivity	63	66	69	72	77	82	89	97	107	121	141

Note: Higher COP percentage reflects lower COP

- The **capacity factor, electricity price, and COP** are the most influential factors on the **LCOH**

Electricity price

Average price level for customers with annual consumption of 24 GWh

Cost structure	Share of costs [%]	Price [EUR/MWh]	Reduction up to [%]	Reduced price [EUR/MWh]
Network cost	13.9%	20.6	80%	4.1
Billing, metering and meter operations	0.4%	0.6	0%	0.6
Concession fee	0.8%	1.2	100%	0
Surcharge under EEG	41.7%	61.7	95%	3.1
Other surcharges	1.1%	1.6	44%	0.9
Electricity tax	13.8%	20.5	100%	0
Electricity price from supplier	**28.3%**	**41.9**	**0%**	**41.9**
Total (excl. VAT)	**100%**	**148.1**	**65%**	**50.6**
Total (with VAT)		**176.2**		**60.2**

Source: *Bundesnetzagentur, Monitoring Report* 2015

Possible reductions under the law:

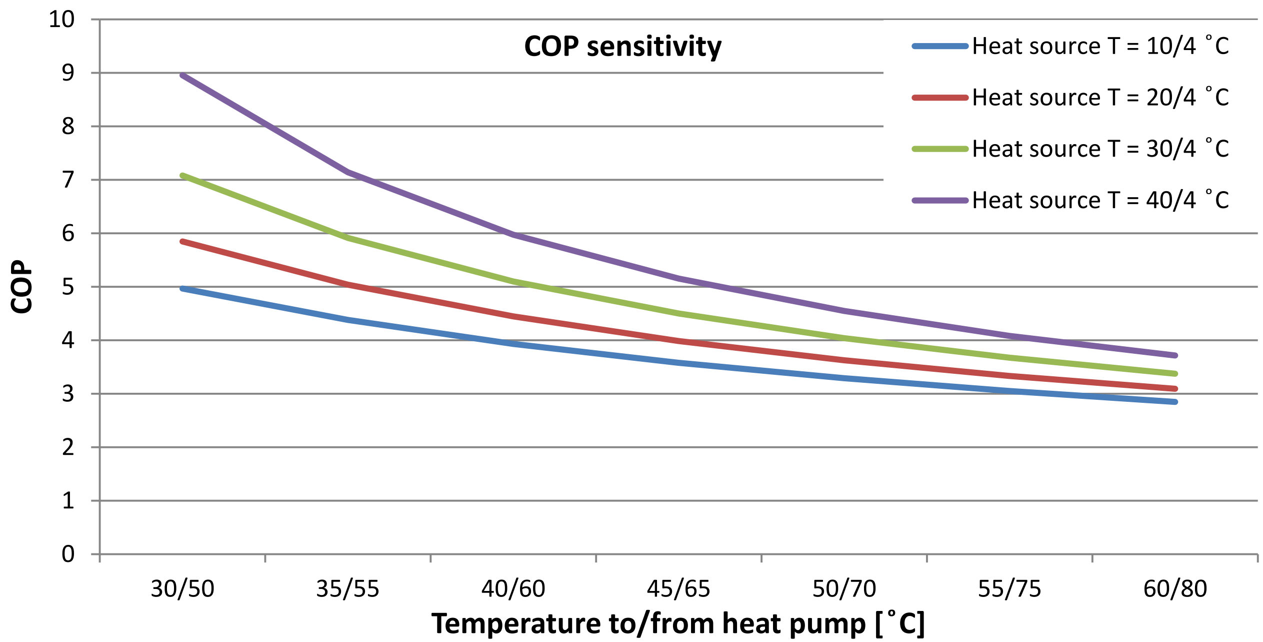
Surcharge under EEG	section 64 EEG
Network cost	19(2) StromNEV
Electricity tax	9a StromStG
Concession fee	2(4) KAV
Other surcharges	9 KWKG ; 17f EnWG

- Possible electricity price reduction due to different taxation can lead up to **40% lower LCOH**

COP sensitivity

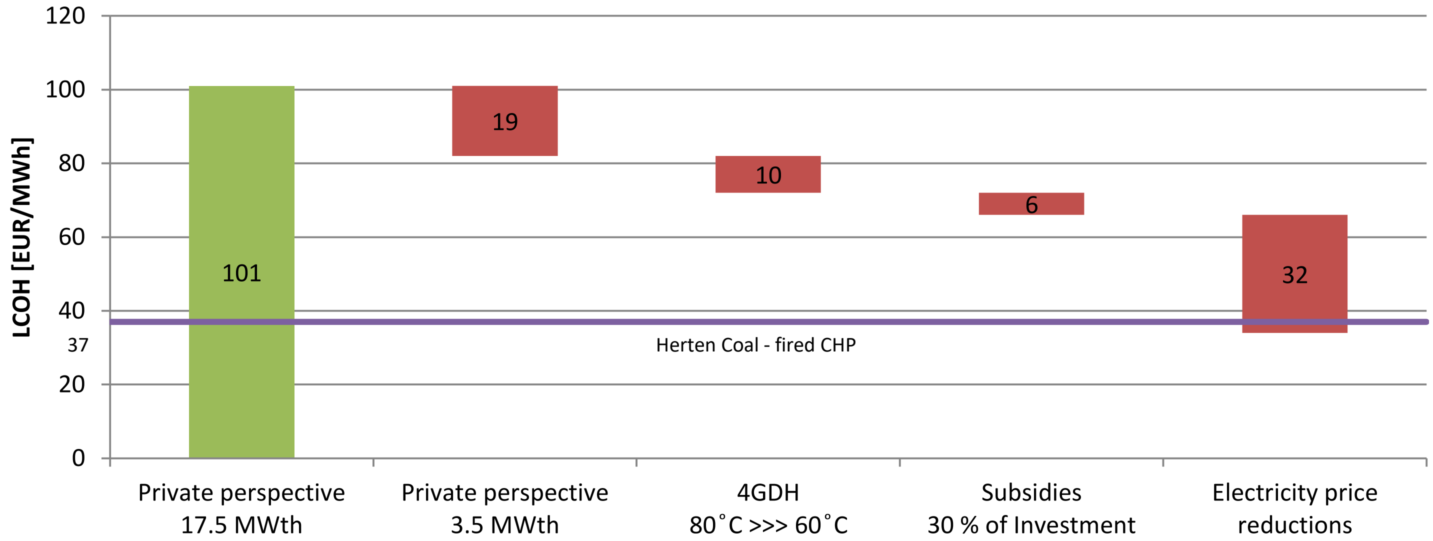
Heat pump efficiency based on existing heat pump in the district heating network of Helsinki

Evaluated HP	Temperature to/from HP	Heat source temperature	COP	Theoretical COP	Heat pump efficiency
Helsinki, Finland	50 / 62˚C	10 / 4˚C	3.51	6.72	0.52



- Transition to **LTDH** network can **increase the COP** of around **15 %** and **decrease** the **LCOH up to 12%**

How to improve the cost-effectiveness



Positive factors	Possible measures
Higher capacity factor	Proper planning, considered reduced heat demand due to better building insulation
4th Generation District Heating	Lower supply temperatures
Lower investment costs	Government loans, low interest rates, etc.
Electricity price reduction	Different classification for city utilities (same as certain industrial consumers)

Conclusion

- **Electricity price plays a major role**
  - With the current average price ratio of c.a. 3,8 between natural gas and electricity, there is no business case for heat pumps in Germany
- **Higher capacity factors**
  - Proper planning is required >>> the capacity of the heat pump should be sized to cover the base load (max share of 30-40%)
  - Consider future demand reduction due to thermal renovation
- **Lower supply temperatures in the DH network**
  - Transition to 4GDH will increase the HP efficiency
- **Competition of coal-fired CHP plants**
- **Policies should focus more on OPEX costs, less on CAPEX**

Thank you for your attention!

Questions / Discussion

Website: www.progressheat.eu

Eftim Popovski
Fraunhofer ISI
Competence Center Energy Policy and Energy Markets
eftim.popovski@isi.fraunhofer.de

Funded by the Horizon 2020 programme of the European Union