The Impact of Renewable Power Generation on the Profitability of Solar District Heating

An Economic Point of View

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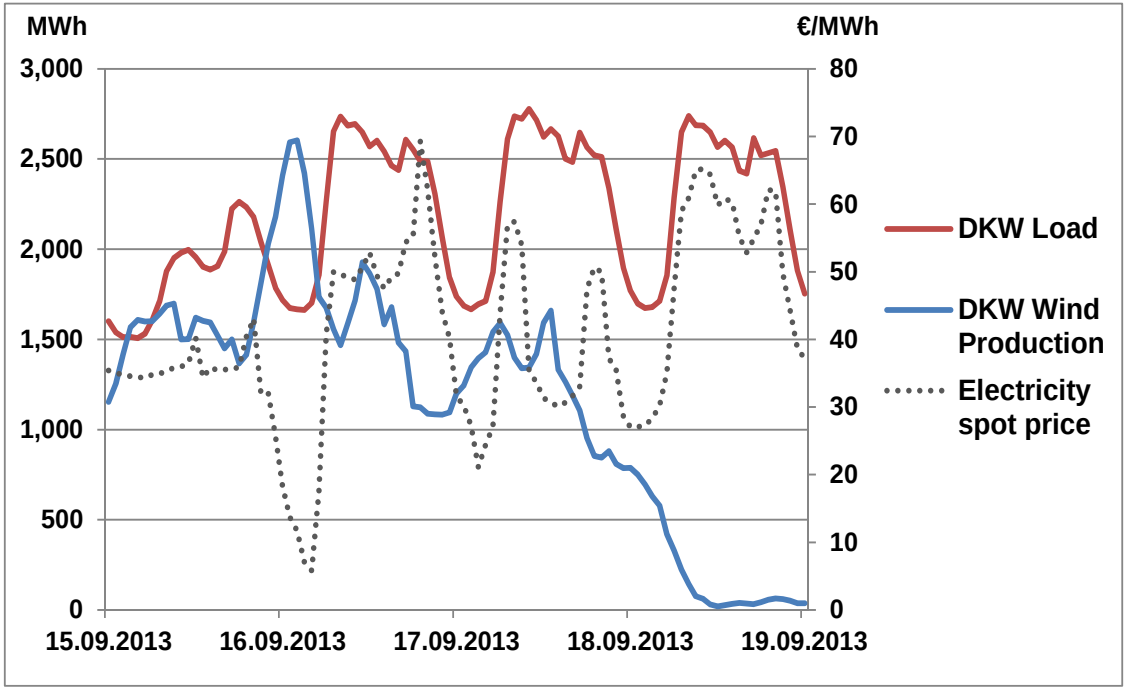
Changing Boundary Conditions for CHP…

… Arising Market Potentials for Solar DH?

Increasing power generation by intermittent RES enlarges **volatility of electricity spot market prices**

CHP production not profitable in periods with low electricity spot prices; **CHP utilization decreasing**



Data source: pfbach.dk

➡ **Can Solar replace reducing DH feed-in of CHP?**

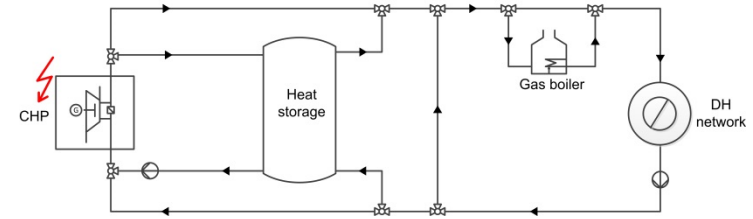
➡ **Is Solar DH profitable?**

Techno-Economic Analysis of Smart DH Systems

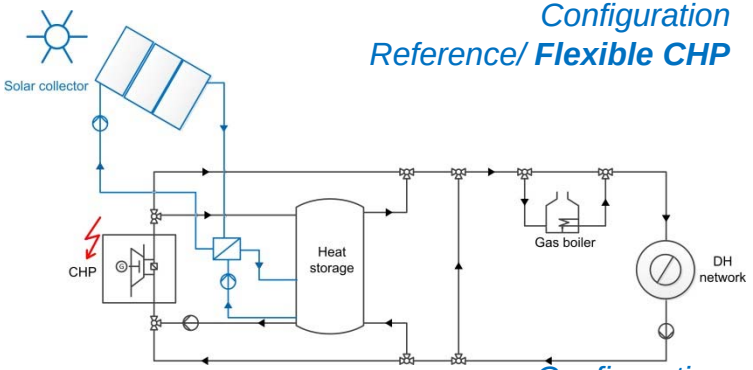
Assessment of the **technical and economic performance** of different DH configurations at **high shares of RES** in the power market

➡ Do smart **DH systems including solar** produce heat at **lower (full) cost** than those without?

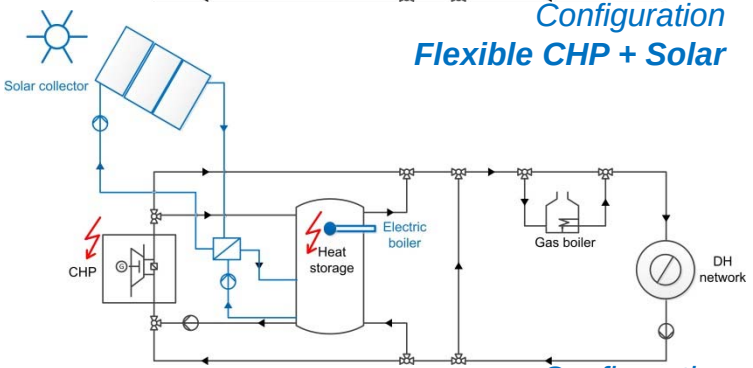
DH network	Heat demand: 12,700 MWh/a Peak load: 5 MW_{th}, Nominal DH temperatures: 95/60°C
CHP	El. capacity: 1.4 MW_{el}, th. capacity: 1.5 MW_{th} Total efficiency: 85 %
Gas boiler	Th. capacity: 5 MW_{th} Efficiency: 88 %
Thermal storage tank	Storage volume: 1,500 m³ (i.e. 12 h peak load)
Solar collector field (flat plate)	Collector area: 4,000 m² η_0=0.82, α_1=2.43W/(m²K), α_2=0.012W/(m²K²) Tilt: 40°, azimuth: 0° Flow rate: 15 l/(m²h)
Electric boiler	Th. capacity: 1 MW Efficiency: 100 %



Configuration
Reference/ ***Flexible CHP***



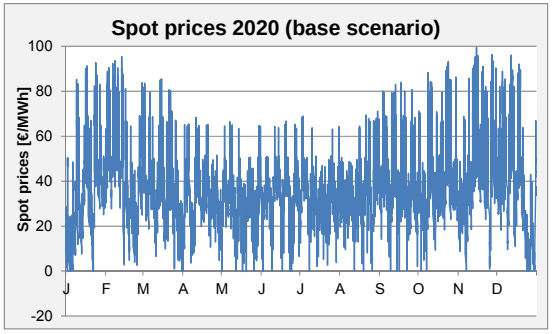
Configuration
Flexible CHP + Solar



Configuration
Flexible CHP + Solar + P2H

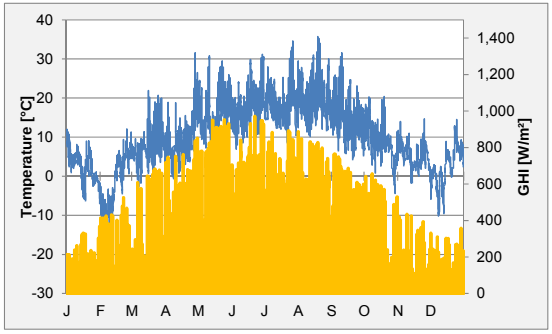
Method and Assumptions

Electricity spot prices



Simulation for two different scenarios related to the RES share in power generation

Meteorological conditions



Würzburg, 2012
Annual GHI: 1,215 kWh/m²

Financial constraints

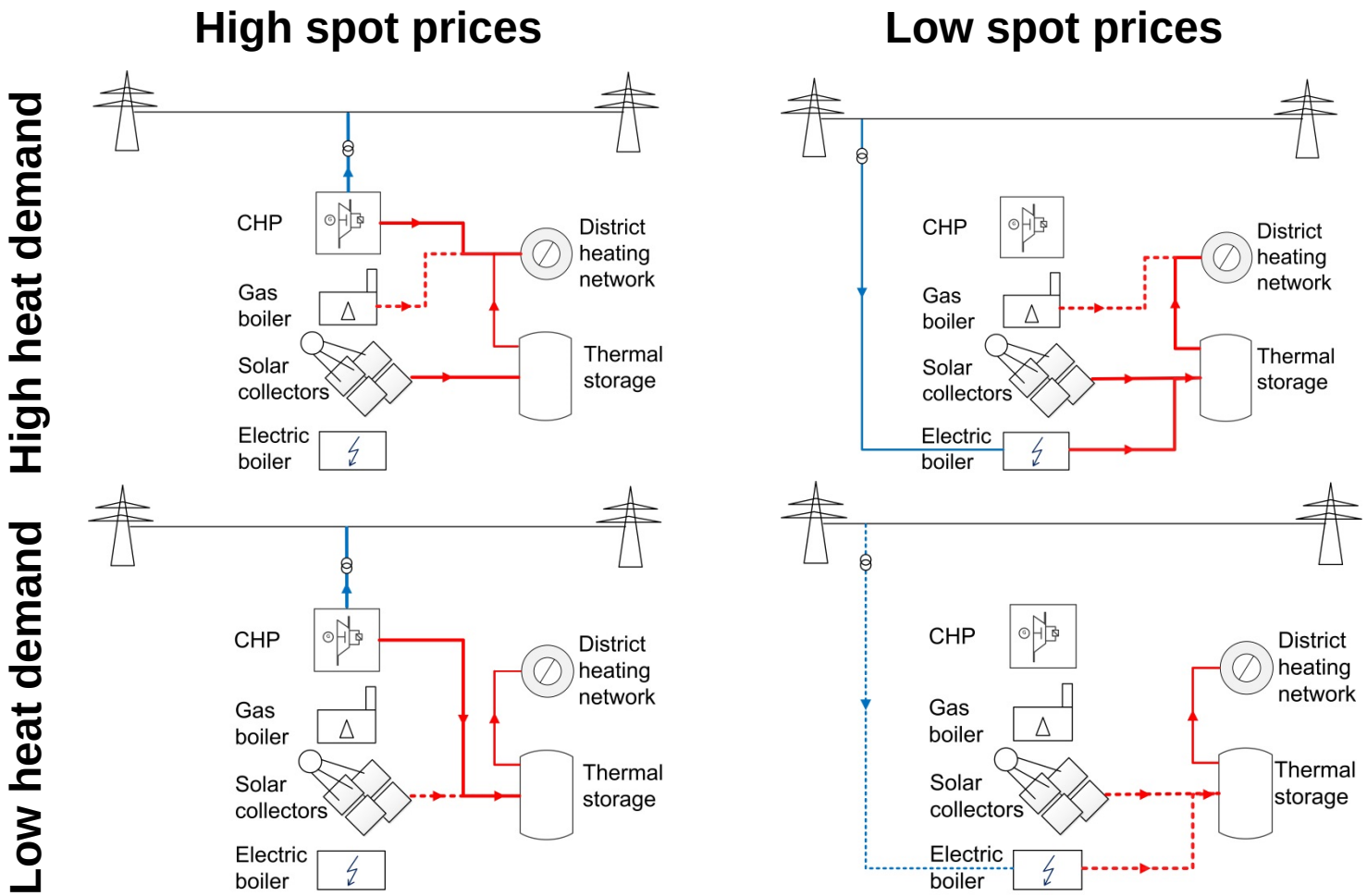
Natural gas price	40 €/MWh$_{Hi}$ (base) 55 €/MWh$_{Hi}$ (sensitivity)		
Natural gas tax	5.5 €/MWh$_{Hs}$ (CHP is exempted)		
CHP premium	27.5 €/MWh$_{el}$		
CHP Index	29 €/MWh$_{el}$		
Avoided network usage charge	5 €/MWh$_{el}$		
P2H power charge	45 €/MWh$_{el}$		
	Spec. CAPEX	**Fixed O&M**	**Variable O&M**
CHP	850 €/kW$_{el}$	2%/a	12 €/MWh$_{el}$
Gas boiler	75 €/kW$_{th}$	2%/a	0.13 €/MWh$_{th}$
Solar collector	200 €/m²	-	1 €/MWh$_{th}$
Electric boiler	100 €/kW$_{el}$	-	-
Thermal storage	500 €/m³	0.7%/a	-

Considering legal and economic framework conditions in Germany

1. **TRNSYS** simulations of the **cost-efficient operation** of heat producers for different, smart DH configurations
2. **Economic analysis**

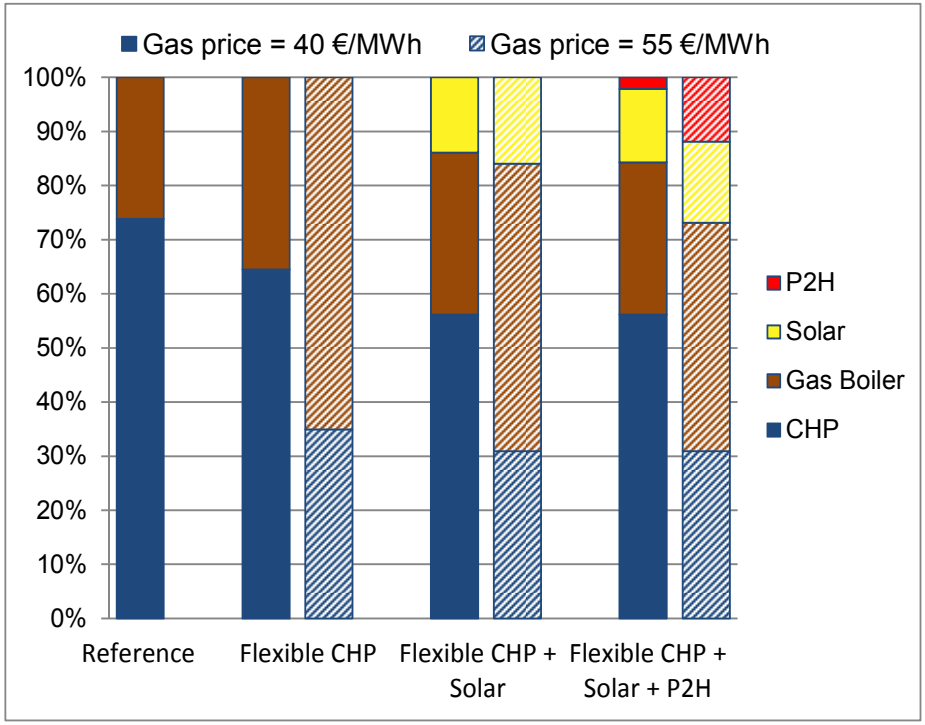
Operational Strategy of Heat Producers in the Model

Configuration Flexible CHP + Solar + P2H



Results of TRNSYS Simulations

"Base Scenario" (11% PV, 16% Wind and 13% Adjustable RES in Power Generation)



Annual shares	Reference	Flexible CHP	Flexible CHP + Sol	Flexible CHP + Sol + P2H
		Gas price = 40 €/MWh		
CHP	74%	65%	56%	56%
Gas Boiler	26%	35%	30%	28%
Solar	0%	0%	14%	14%
P2H	0%	0%	0%	2%
		Gas price = 55 €/MWh		
CHP	74%	35%	31%	31%
Gas Boiler	26%	65%	53%	42%
Solar	0%	0%	16%	15%
P2H	0%	0%	0%	12%

- Heat from **gas** boiler **displaced by solar** (and P2H)
- Displacement by solar enhancing with higher gas prices

Criteria of Profitability

Levelized marginal cost

Criterion for operating decisions

$$LMC_{conf.m} = \frac{\sum_{comp.i}^{n} an.\,marginal\ costs_i}{\sum_{comp.i}^{n} an.\,heat\ generation_i}$$

Levelized cost of heat

Criterion for investment decisions

$$LCOH_{conf.m} = \frac{\sum_{comp.i}^{n} an.\,full\ costs_i}{\sum_{comp.i}^{n} an.\,heat\ generation_i}$$

LMC and LCOH for CHP are net
(revenues from sale of electricity are subtracted)

Financial constraints			
Interest rate	4%		
Lifetime	20 a		
Natural gas price	40 €/MWh$_{Hi}$ (base) 55 €/MWh$_{Hi}$ (sensitivity)		
Natural gas tax	5.5 €/MWh$_{Hs}$ (CHP is exempted)		
CHP premium	27.5 €/MWh$_{el}$		
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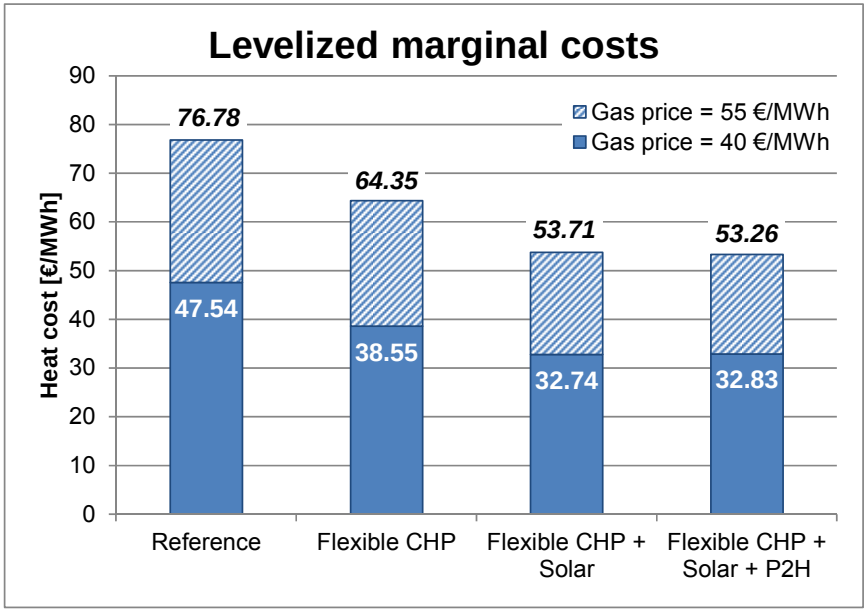
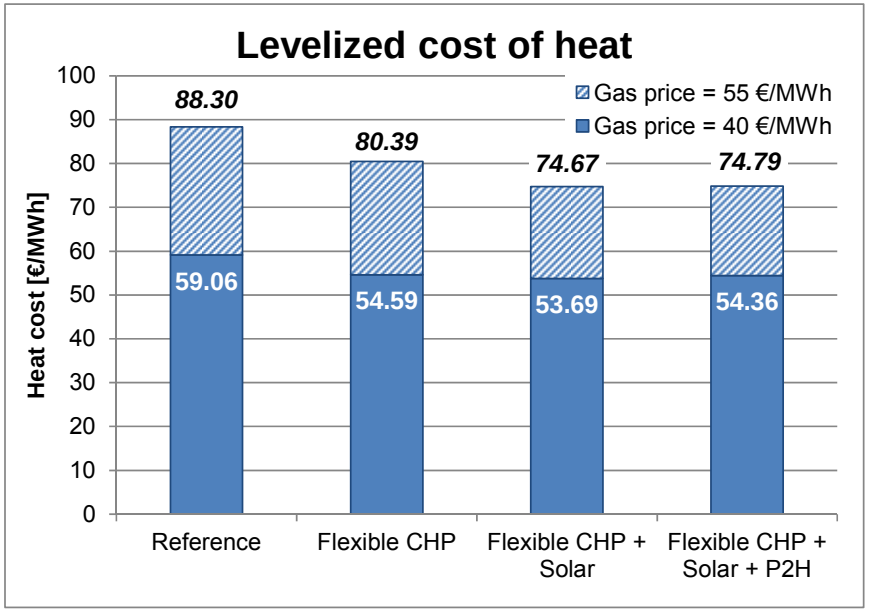
Costs of the DH network are not included

Results of the Economic Analysis

"Base Scenario" (11% PV, 16% Wind and 13% Adjustable RES in Power Generation)



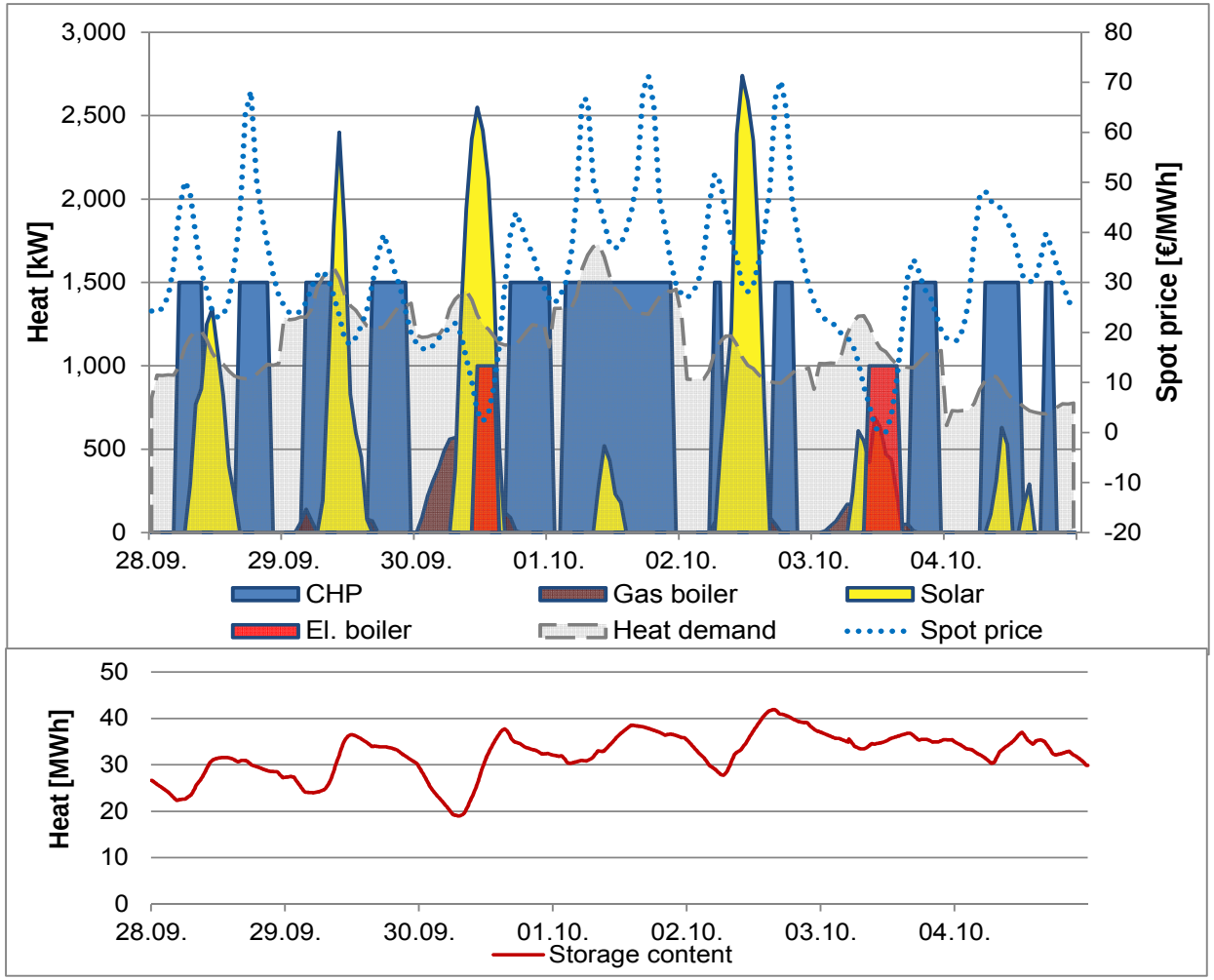


- Flexible operation of CHP reduces LMC
- **Solar** assisted DH systems have **lowest LMC**
- Systems including solar are **less sensitive to gas price increases**

- Flexible operation of CHP lucrative despite necessary investment in large heat storage
- **Solar DH profitable** even from a full cost perspective
- P2H feasible equipment in flexible CHP based DH systems

Operation of Heat Producers in an Autumn Week

Configuration Flexible CHP + Solar + P2H

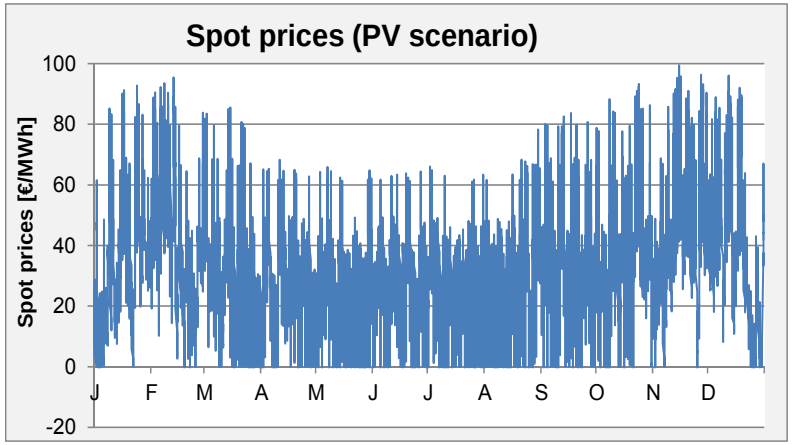


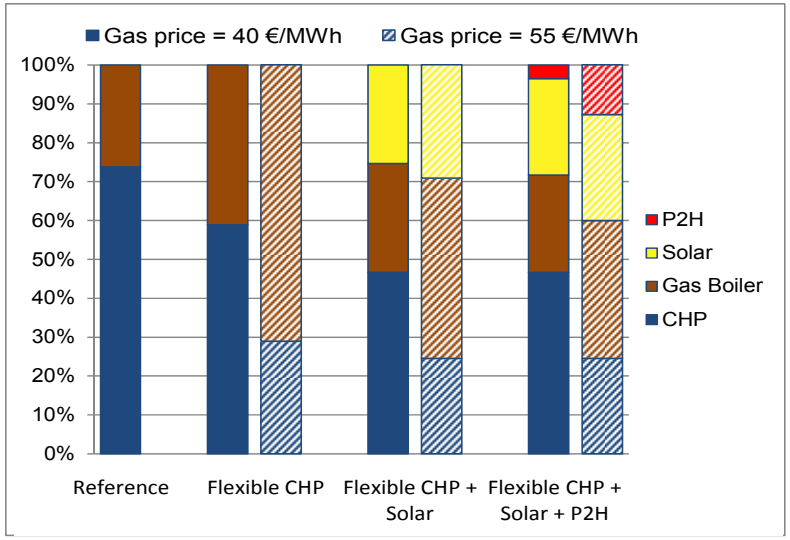
Sensitivity: Higher Share of PV in the Power Market

"PV Scenario" (20% PV, 16% Wind and 13% Adjustable RES in Power Generation)

Higher **penetration levels of PV** in the power system reasonable due to immense cost reductions of PV modules

- **Larger heat storages** and **larger solar collectors** required to cover heat demand in periods when CHP operation not feasible (especially in summer)
- **Sensitivity Analysis**:
  Investigation of the technical performance and cost of different DH configurations, incorporating a **10,000 m² solar collector** and a **3,000 m³ heat storage**
  (compared to 4,000 m² / 1,500 m³ in the base case)





Results of the Economic Analysis

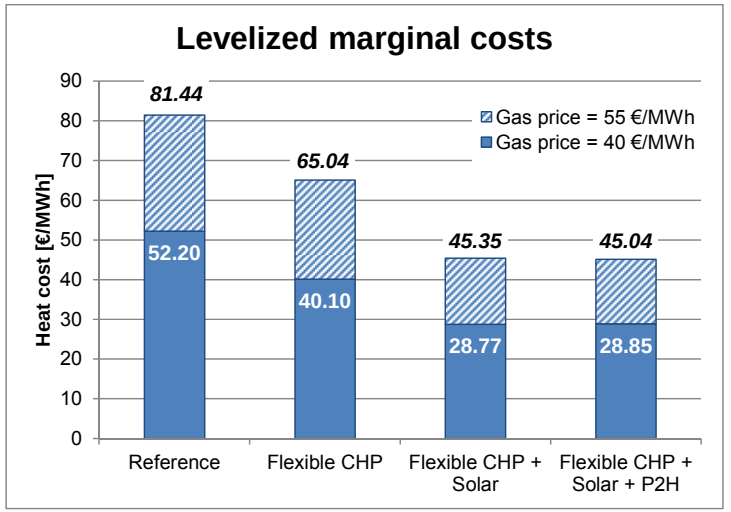
"PV Scenario" (20% PV, 16% Wind and 13% Adjustable RES in Power Generation)

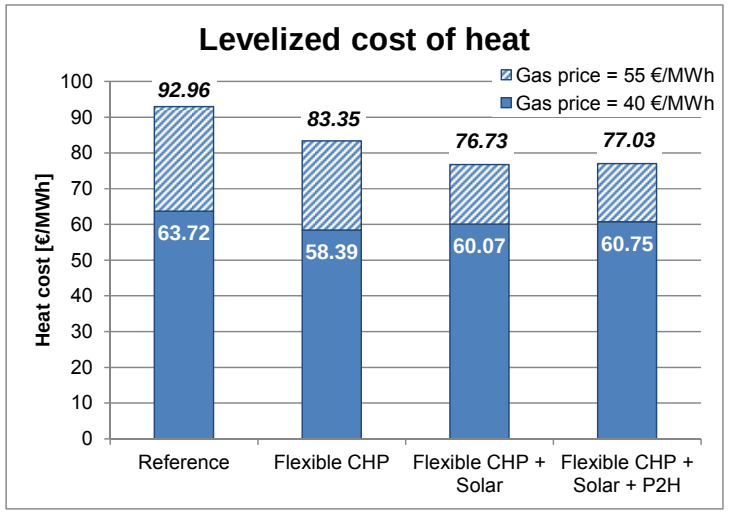
- **LMC of configurations without solar rise** due to decreasing spot prices and higher shares of heat from gas boiler

  ➡ **Solar DH especially attractive** in power systems **with high PV share**

- **LCOH** of solar assisted DH slightly higher at low gas prices
- Profitability of Solar DH **increases with** increasing prices of **natural gas**

  ➡ DH systems including **solar** are more **independent of rising gas prices**





Conclusion

- Increasing share of RES in the power market leads to volatile electricity spot prices

  ➡ **Flexible operation of CHP required**

- Utilization and heat production of CHP for DH feed-in decreasing

- Solar (and electric heaters) can displace environmentally harmful and expensive heat from peak load boilers based on fossil fuels, especially in power systems with high shares of PV

  ➡ **RES in the power sector pave the way for RES in the heat sector**

- Solar heat reduces operating costs of CHP-based DH systems and is even economically attractive on a full cost base

  ➡ **CHP and solar do not exclude each other** in power systems with high shares of RES

Thank you for your attention!

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