USING INDUSTRIAL EXCESS HEAT IN DISTRICT HEATING NETWORKS:
A SIMULATION ASSESSMENT OF POTENTIALS AND COST-EFFECTIVENESS FOR A REFINERY IN PORTUGAL

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Presentation at 4DH conference, Copenhagen, 12/09/2017

4DH
4th Generation District Heating Technologies and Systems

Using excess heat from refineries seems viable..

Selected refineries providing excess heat to nearby district heating:

Refinery	Location	Installed capacity [MW]	Total delivierd heat [GWh]	Share of DH heat [%]
MiRO	Karlsruhe, Germany	90	520	50%
OMV Schwechat	Vienna, Austria	170	500-600	10%
Preem and Shell	Gothenburg, Sweden	85 + 60	1.100	30%
Shell	Fredericia, Denmark	55	510	26%

Refinery Karlsruhe

- Largest refinery in Germany: ~15 million tonnes of mineral oil products
- 5 km pipe to connect to existing DH
- Construction in 2010 and 2015
- Investment: 54 million, of which 5 million Euros support by Government

Research question

- Assess economic and technical feasibility to decarbonize H&C supply in the focus area comparing alternative options
  - Using solar thermal, heat pumps, photovoltaics and/or biomass?
  - Using excess heat from nearby oil refinery via a DHC network?

Methodology

- Techno-Economic energy systems modeling with hourly time resolution for demand and supply
- Using tool Energy Pro
- Two perspectives distinguished:
  1. (Simple) socio economic perspective (1.5% discount rate, no excess heat price)
  2. and private economic perspective (7% discount rate, excess heat price)
- Inclusion of local stakeholders was planned and partly achieved (work together with local energy consulting company INEGI)

The focus area

Matosinhos

- North of Portugal at the coast near Porto
- ~175,000 inhabitants
- No DHC infrastructure in the city and surroundings

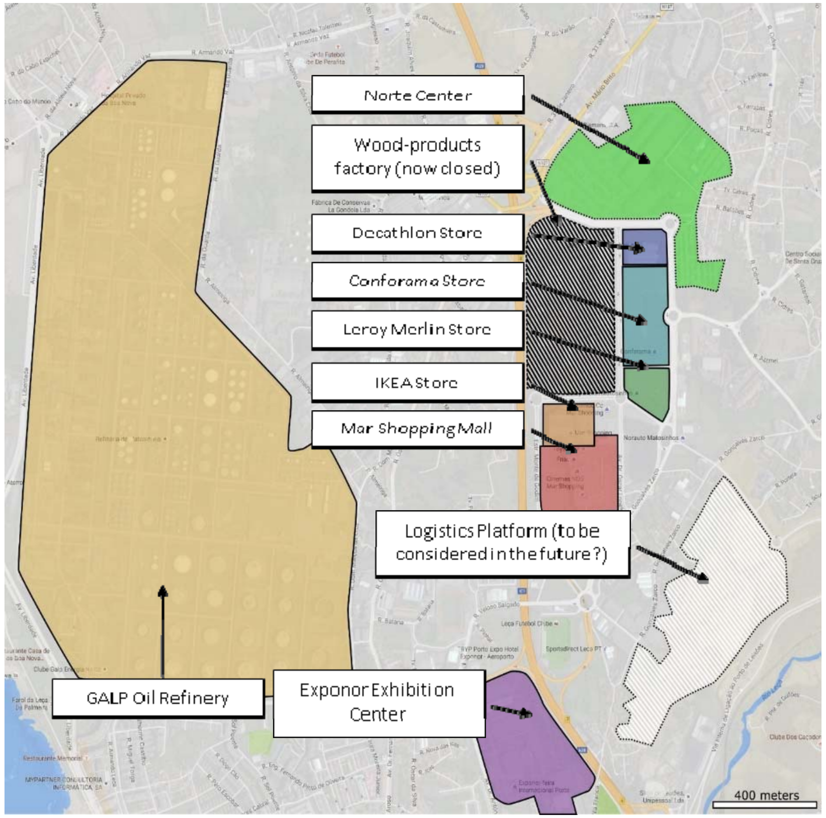
Focus area

- Shopping mall and large stores
  - Individual gas boilers + compression chillers
  - Demand for cooling three times higher than heating
- Residential area under construction
- Refinery as potential excess heat source

Energy demand in focus area

- Cooling: 28 GWh/a
- Heating: 15 GWh/a
- Both included on hourly basis

Buildings covered



Assumptions

Scenario set-up: supply options

H&C supply scenarios defined

Scenario	Heating source	Cooling source	Electricity source	District H&C network?
1.Status Quo	Natural gas boiler	Compression chiller	Grid	-
2.Status Quo (incl. Capital Costs)	Natural gas boiler	Compression chiller	Grid	-
3.Status Quo with solar thermal	Natural gas boiler	Compression chiller	Grid	-
4.Heat pump	Heat pump (air-source)	Compression chiller	Grid	-
5.Heat pump with PV	Heat pump (air-source)	Compression chiller	Photovoltaic + Grid	-
6.Heat pump with solar thermal	Heat pump (air-source) and solar thermal	Compression chiller	Grid	-
7.Heat pump + solar thermal and PV	Heat pump (air-source) and solar thermal	Compression chiller	Photovoltaic	-
8.Refinery waste heat	Waste heat	Absorption chiller	Grid	yes
9.Biomass trigeneration	Biomass CHP	Absorption chiller	Own	yes

Assumptions excess heat

- **Estimated excess heat potential**
  - *Estimated based on refinery publications, literature and comparison to other refineries*
  - Refinery energy consumption for heating estimated: ~ 2,500 GWh/a
  - Excess heat used from several sources:
    - Flue gas: ~30 GWh/a)
      - Heat exchanger
    - Hot water from coolers: ~40 GWh/a
      - Absorption chiller with 90°C at generator and 20°C at condenser (sea water)
    - Total: 70 TWh (+3%) -> Much more heat is available...
- **Costs DHC network**
  - Heating network: 600 EUR/m (diameter 120 mm)
  - Cooling network: 1500 EUR/m (diameter 500 mm)
  - Trench Length: ~5 km
  - Lifetime: 30 years

Assumptions: Technology characteristics

Techno-economic technology data

	Natural gas boiler	Compression chiller	Flat plate solar collector	Air source heat pump
Investment (CAPEX)	250 €/kW_{th} [2]	650 €/kW_{th} [3]	290-500 €/kW_t [6]	700 €/kW_{th} [8]
Efficiency/SEER	90%	230 – 380 % [4]	82.7 % [7]	198-500 % [10]
Lifetime	25 years [2]	20 years [3]	30 years [6]	20 years [9]
Variable O&M	7.2 €/MWh [2]	2 €/MWh [3]	1 €/MWh [6]	1.5 €/MWh [9]
Fixed O&M	4 €/kW [2]	4% of Inv. [3]	-	1% of Inv. [9]
	Photovoltaic	**Shell and tube heat exchanger**	**Absorption Chiller**	**Biomass CHP**
Investment (CAPEX)	1350-1550€/kW [11]	*2000 €/m^2 [14]	***250 €/m^2 [15]	650 €/kW_{th} [18]
Efficiency	****17.32% [12]	85% [15]	65% [15,16,17]	80% [19]
Lifetime	20 years [11,12]	15 years [15]	20 years [15]	20 years [19]
Variable O&M	-	**2 % [14]	**2 €/MWh [3]	4.3 €/MWh [19]
Fixed O&M	0.5 - 1 % of Inv.[13]	**1.5 % of Inv.[14]	**4% of Inv. [3]	4.5% of Inv.[19]

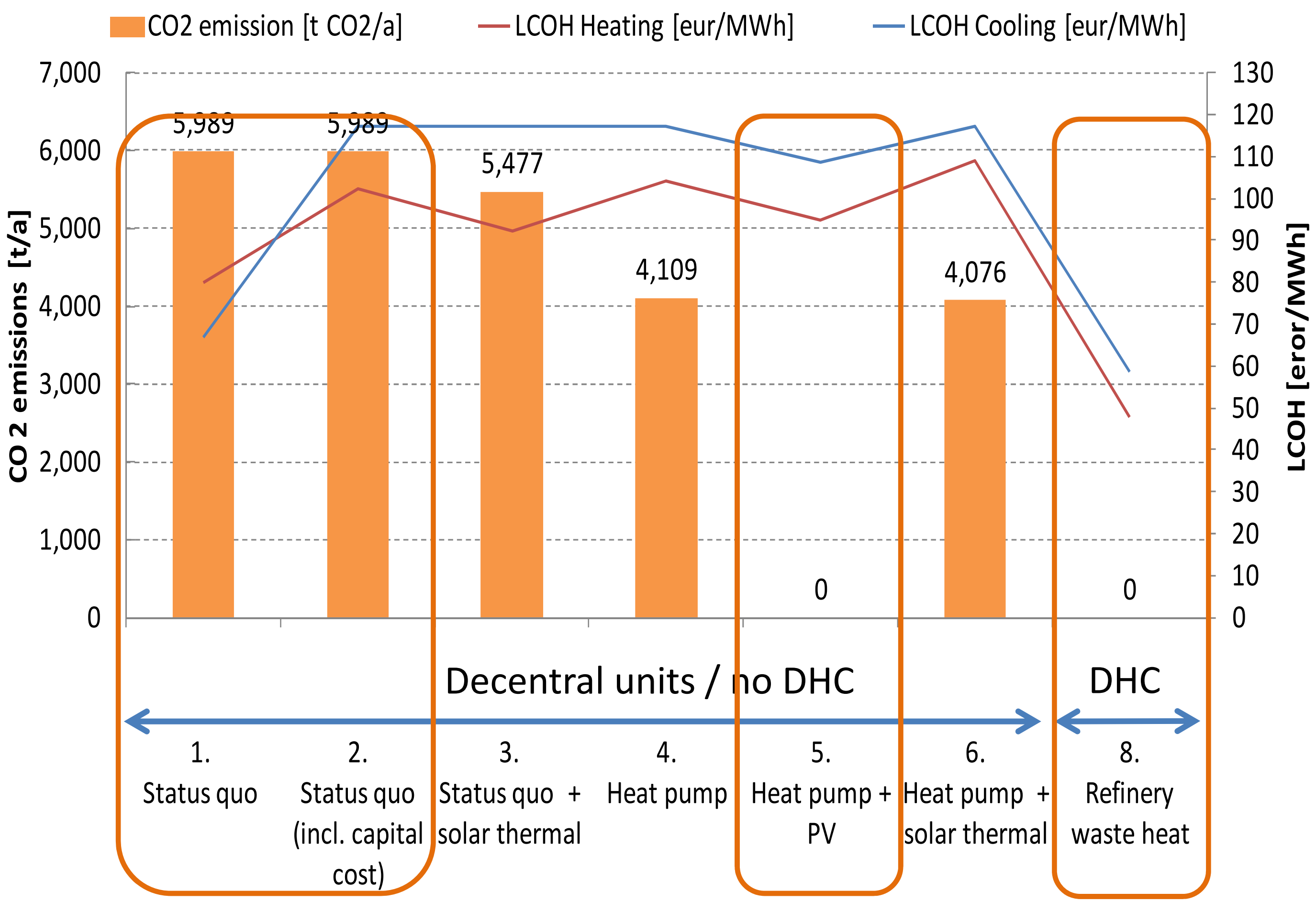
*Project Costs Factor for additional equipment = 3.5 [15]
** Assumptions based on [3,14]
*** Project Costs Factor for additional equipment = 2.5 [15]
****Performance ratio = 0.84 [13]

Results for

1. (simple) socio economic perspective
   (1.5% discount rate, no price for excess heat)
2. private economic perspective
   (7% discount rate, 15 euros/MWh price for excess heat)

Results for socio-economic perspective
(1.5% interest rate, excess heat price 0 euros/MWh)

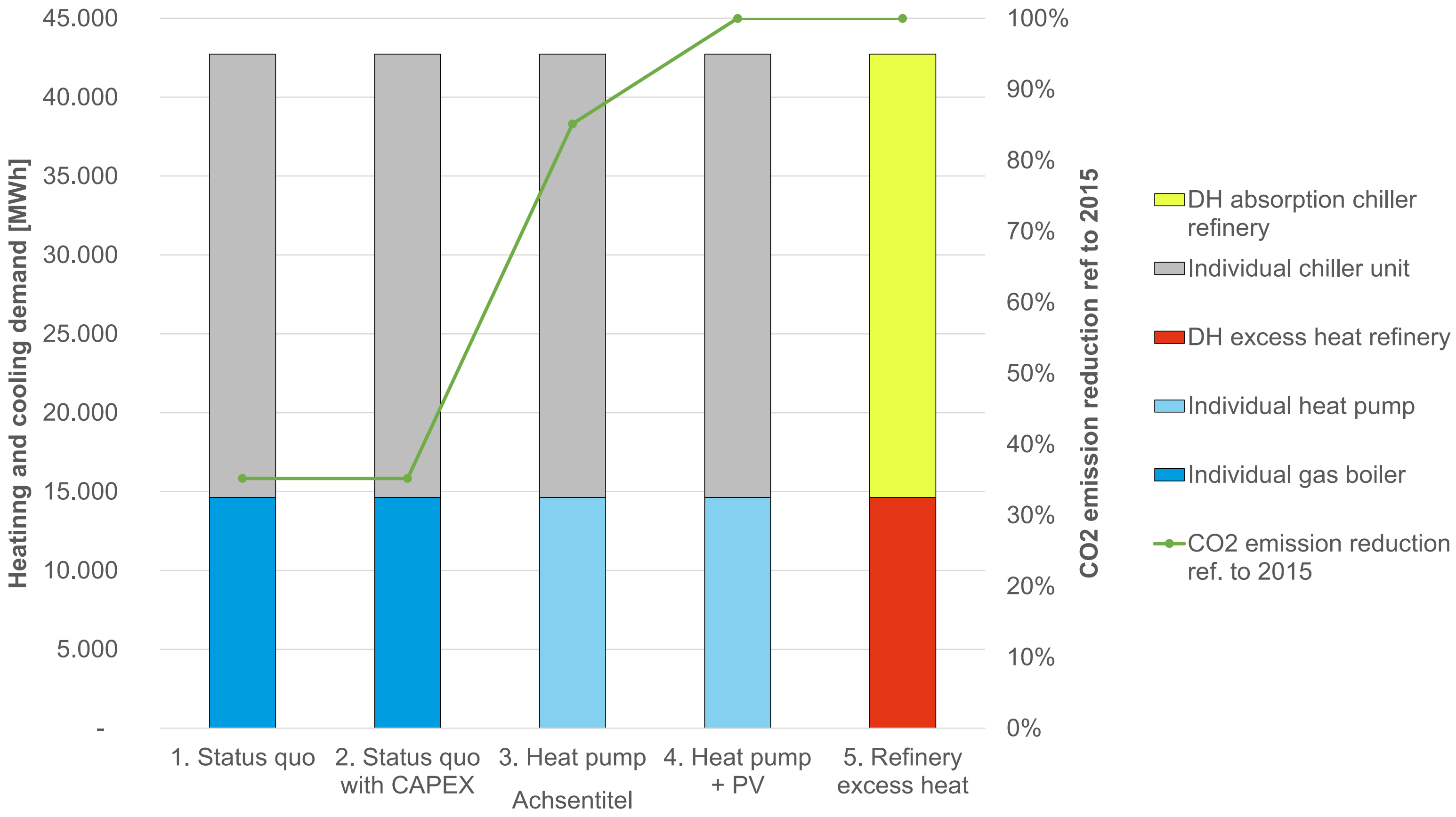
CO2 savings and Levelised cost for heating and cooling by supply option



Results: Private economic perspective

(7% interest rate, excess heat price 15 euro/MWh)

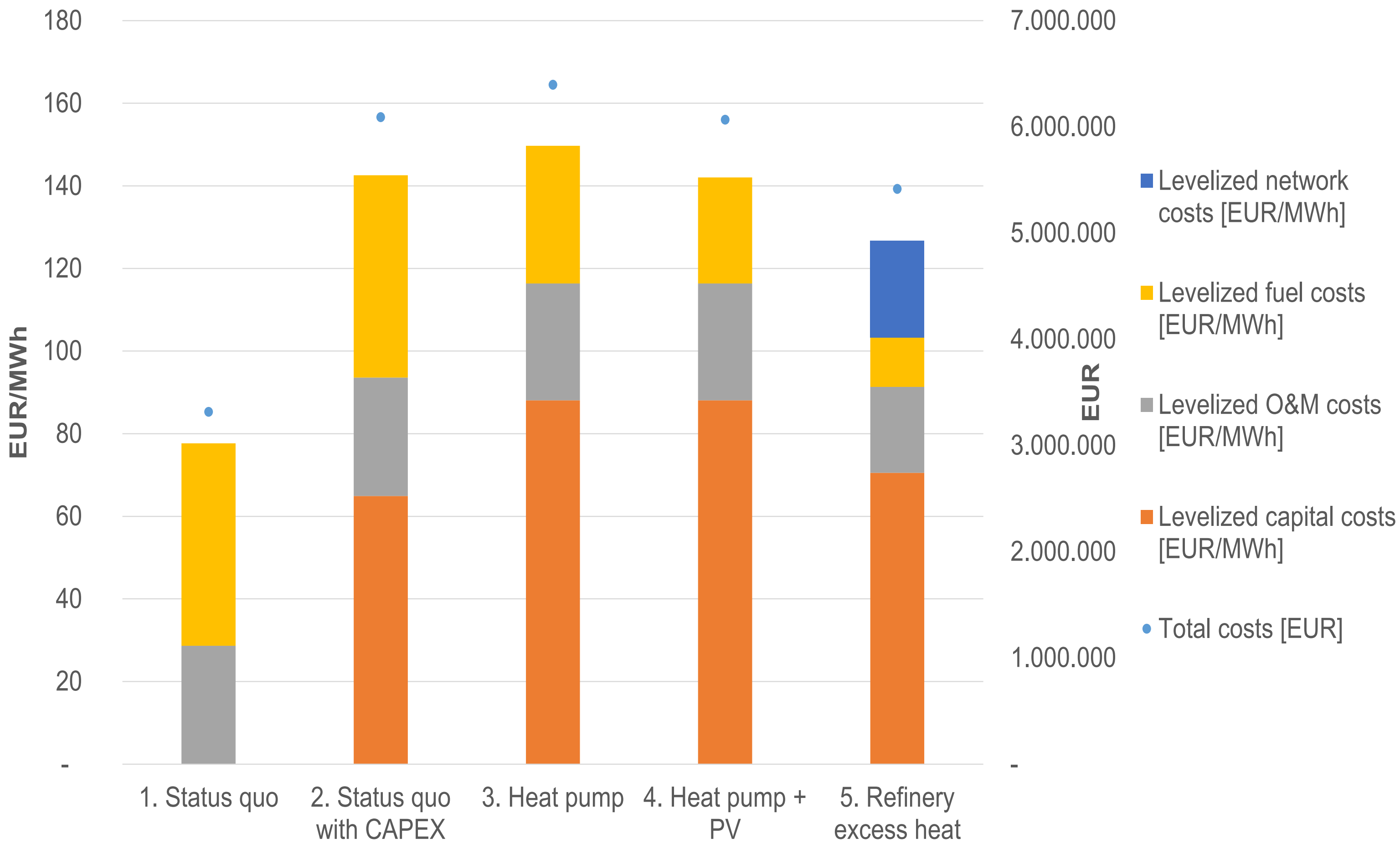
Heat supply and achieved CO2 reduction



Results: Private economic perspective

(7% interest rate, excess heat price 15 euro/MWh)

Levelised cost for heating and cooling by supply option



Conclusions

- **Excess heat cost-effectiveness**
  - Potential is sufficient to supply all buildings within the scope
  - From socio-economic perspective the LCOH for excess heat use are cheapest, even cheaper than status-quo only running cost
  - From private economic perspective, the excess heat use is cheaper than HP+PV and status-quo (incl. capital cost), but more expensive than status-quo without capital costs
  - Considering the depreciated capital costs of the existing system might result in comparable costs as the use of excess heat
- **Policy recommendations**
  - Policies are needed to make the use of excess heat also profitable from a private economic perspective to reflect the benefits seen at the socio-economic perspective
  - Using excess heat from the refinery as door-opener for building a DHC grid that can in the future be extended by other RES

Thank you for your attention!

Next: Webinar on estimating and mapping excess heat potentials (September 29, 10am)

http://www.progressheat.eu/

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Funded by the Horizon 2020 programme of the European Union

Energy price assumptions

Energy carrier	Price for 2015 (incl. tax, no VAT)	Price for 2030 (incl. tax, no VAT)	Price for 2050 (incl. tax, no VAT)
Natural gas	60	72	77
Electricity	115	128	101
Decentral PV LCOE	126	98	78
Excess heat	0/15	0/15	0/15