Potential contribution of advanced district heating and electric heat pumps to the integration of renewable power generation in Europe

2nd International Conference on Smart Energy Systems and 4th Generation District Heating

Aalborg, 28 September 2016

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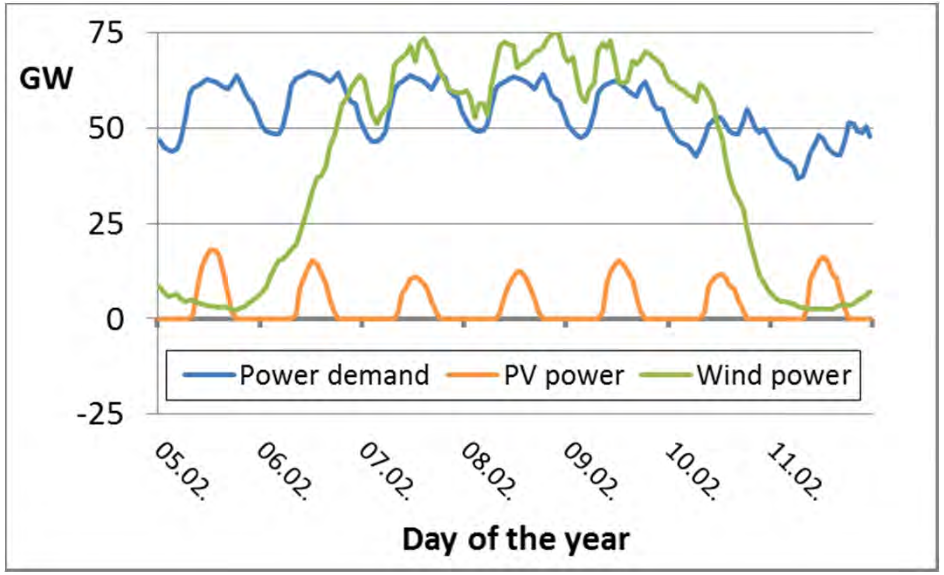
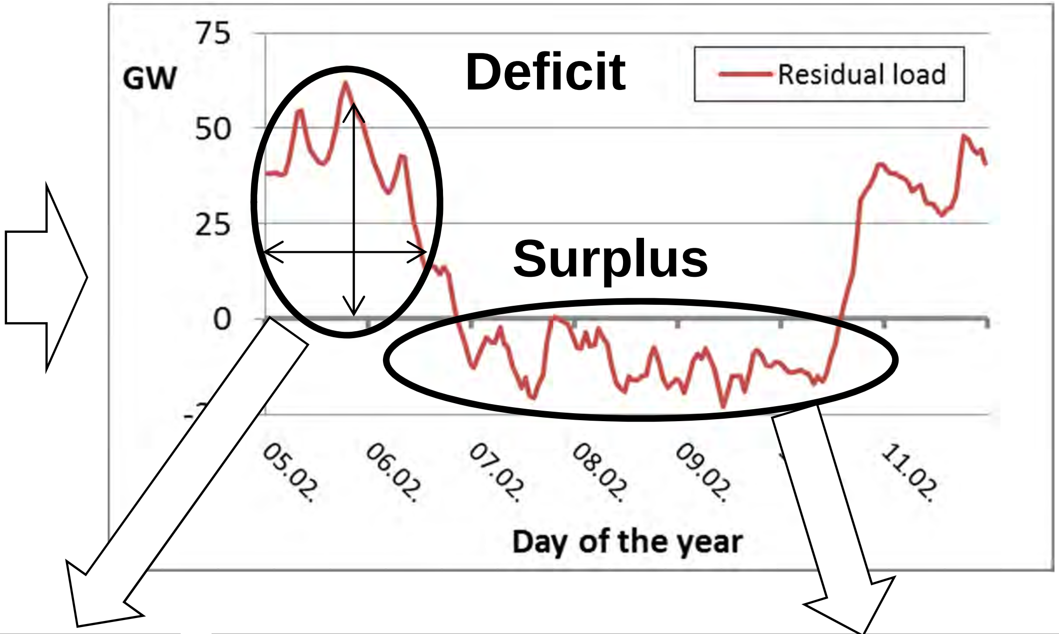
Research focus: VRE based power supply systems





Load balancing options

Coverage of deficits

- Adjustable power plants
- Storage discharging
- Power demand reduction
- Electricity import

Utilization of surpluses

- Storage charging
- Usage in other demand sectors
- Power demand increase
- Electricity export

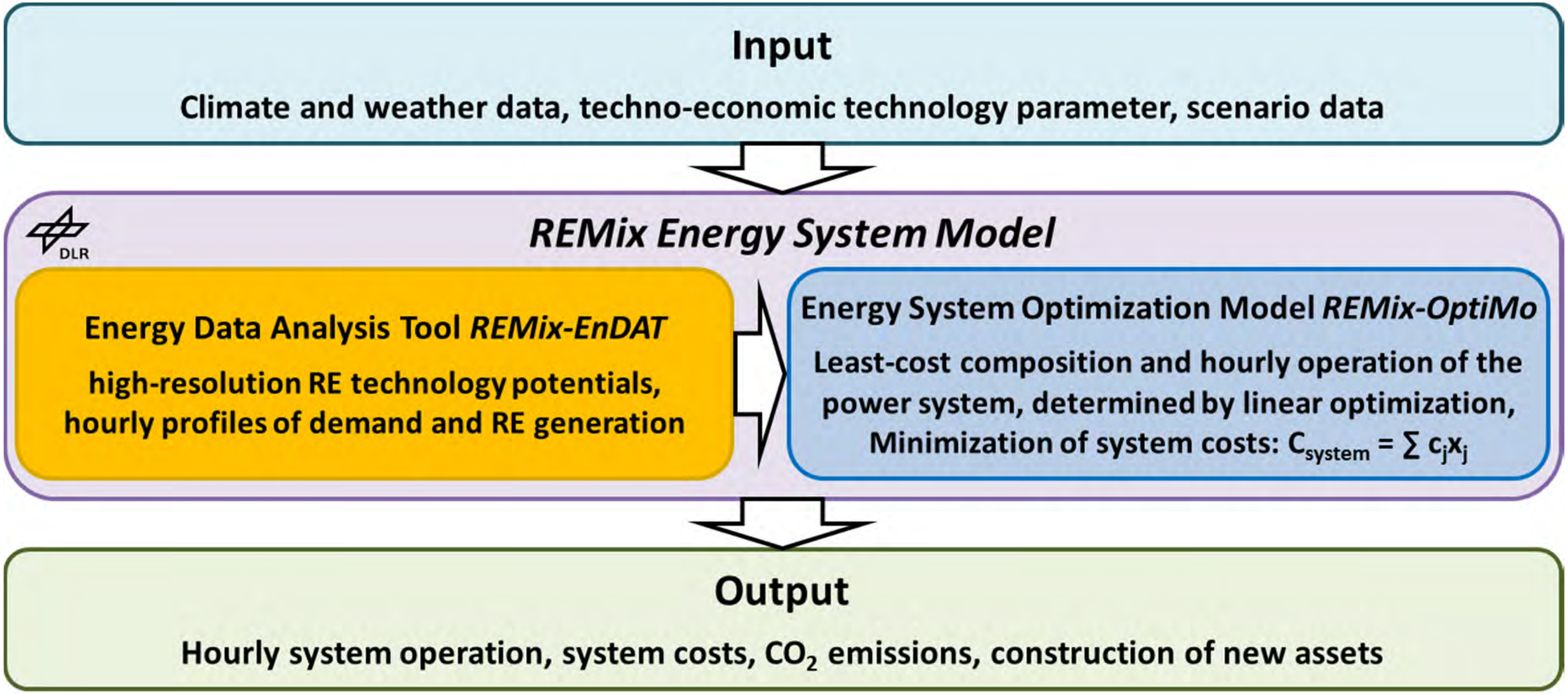
Research questions

- To what extent can a more flexible operation of electric heat pumps (HP) and district heating (DH) contribute to a mostly renewable power supply in Europe?

- Is the deployment of thermal energy storage (TES) competitive with other balancing options?

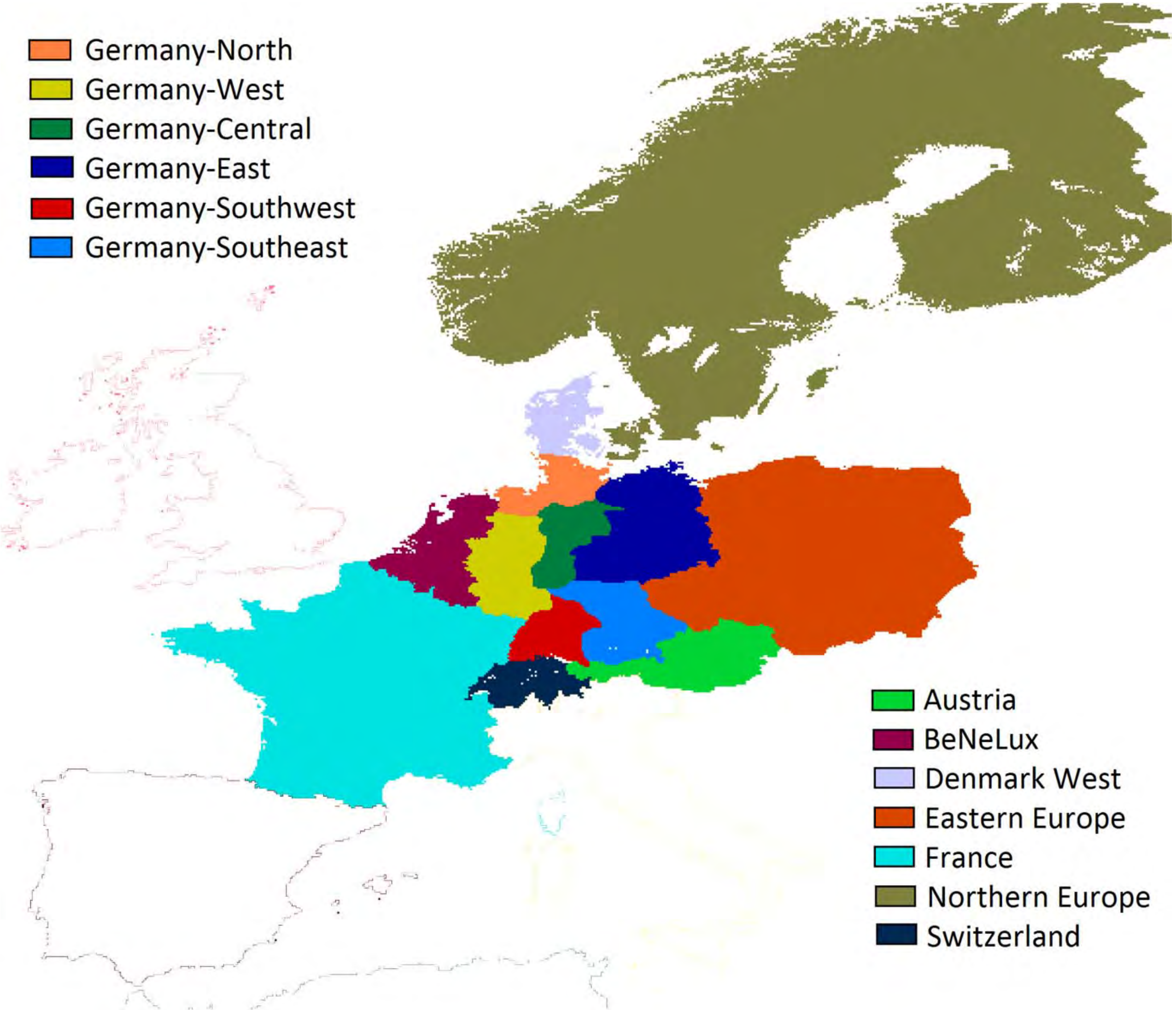
- How does a more flexible heating interact with other balancing options?

REMix modelling approach



- Deterministic linear optimization model realized in GAMS
- Assessment of investment and hourly system dispatch during one year

REMix case study on power-controlled heat – regions



REMix case study on power-controlled heat – technologies

Renewable	Conventional	Public CHP	Industrial CHP	Balancing
Biomass Power	Nuclear Power	Biogas Engine CHP	Biomass-fired Steam Turbine	HVAC power grid
Geothermal Power	Lignite Power	Natural Gas Engine CHP	Coal-fired Steam Turbine	HVDC transmission lines
Concentrating Solar Power	Coal Power	Biomass-fired Steam Turbine	Lignite-fired Steam Turbine	Pumped Storage Hydro
Solar Photovoltaic Power	Combined Cycle	Extraction CCGT	Gas Turbine CHP	Thermal Energy Storage
Offshore Wind Power	Gas Turbine	Backpressure CCGT	Natural Gas Engine CHP	Flexible electrolyzers
Onshore Wind Power		Coal-fired Steam Turbine		Hydrogen storage
Reservoir Hydro Power		Lignite-fired Steam Turbine		Hydrogen-based transport
Run-of-river Hydro Power		Waste-fired Steam Turbine		Electric vehicles
		Biogas Micro-Engine CHP		Electric heat pumps
		Nat. Gas Micro-Engine CHP		Electric boilers

REMix case study on power-controlled heat – approach

- Scenario analysis for the year 2050
  - Predefined RE and CHP power plant park (PP) based on scenario studies
    - Power supply: >80% RE, >60% VRE, ~20% CHP, ~9% gas PP w/o CHP
  - Endogenous installation of gas power plants as back-up generation capacity
  - Predefined heating supply structure
    - Res./Com.: 30% DH, 5% building CHP, 21% electric HP, 44% other
    - Industry ($\vartheta < 500°C$): 62% CHP, 4% electric HP, 34% other
- Focus on the analysis of the balancing of VRE fluctuations
  - Comparison of systems with/without power-controlled heat supply
  - Endogenous investment in thermal storage and electric boilers
  - Impact on back-up capacity demand, system operation, costs and emissions

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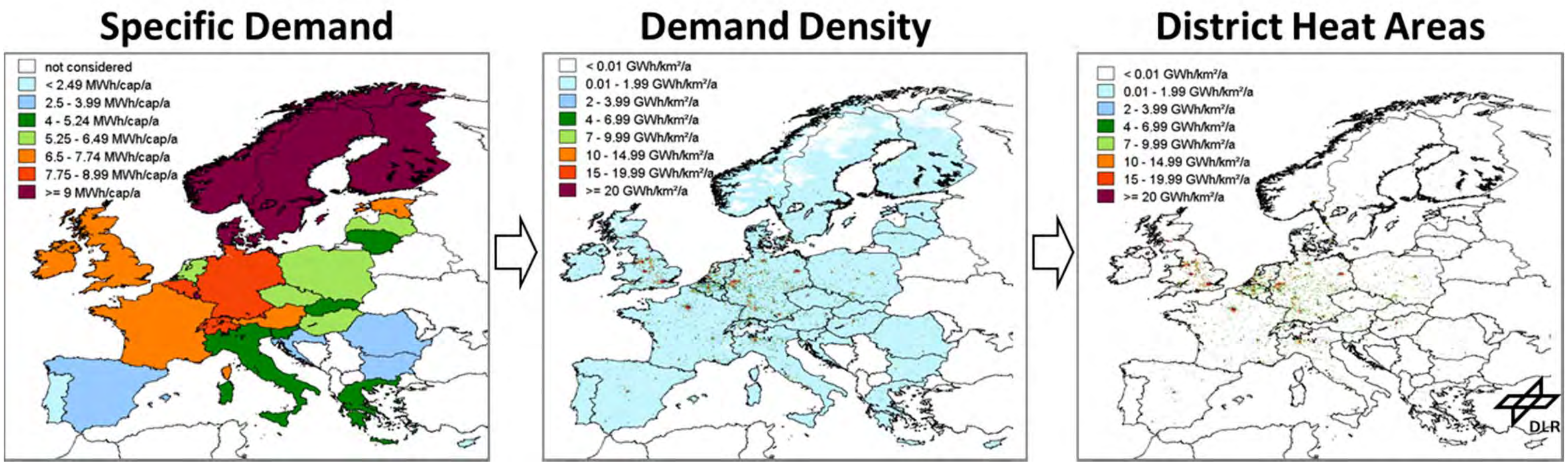
Technical potentials of district heating



- GIS-based assessment of heat demand densities
- Quantification of technical DH potentials in a spatial resolution $< 1\ km^2$

⇨ More than half of the demand in Europe can be supplied by DH

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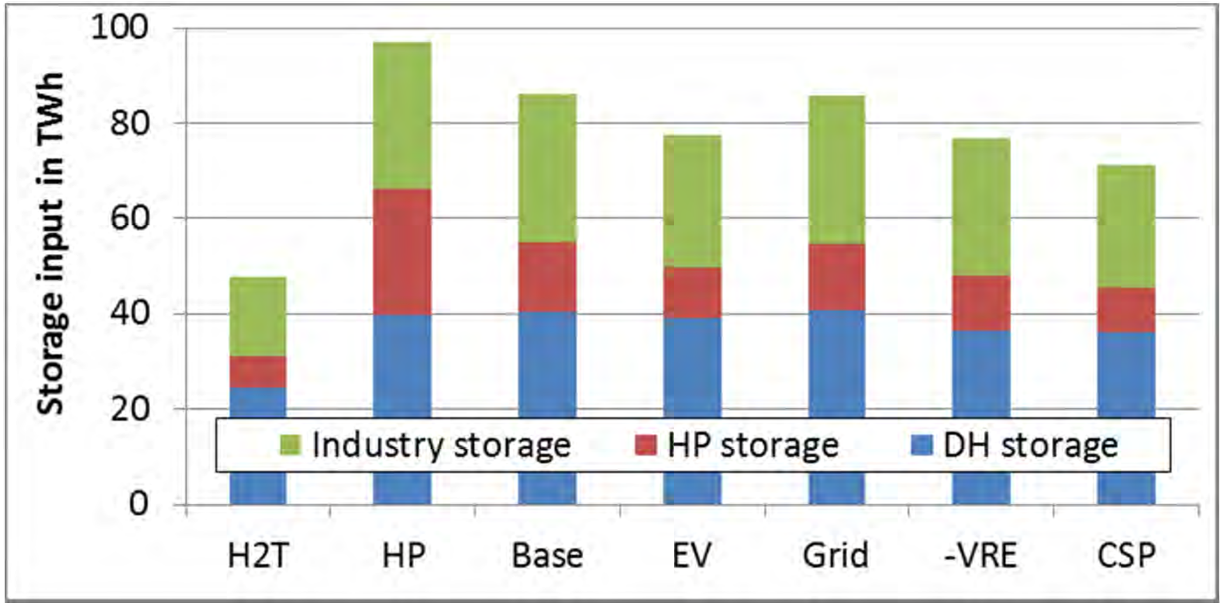
REMix case study on power-controlled heat – scenarios

Increased fluctuations ↑

H_2T	Hydrogen usage in the transport sector Production in **flexible electrolysis**
HP	**Increased heat pump** supply shares (38% Res./Com., 8% Ind.)
Base	Base scenario, electricity demand 2100 TWh, VRE capacities: PV 229 GW, wind onshore 219 GW, offshore 115 GW
-EV	**Flexible charging of electric vehicles** (60% of the fleet)
Grid	Endogenous **grid capacity expansion**
-VRE	**Reduced** full load hours of **wind and solar** (-7% / -19%)
CSP	**Import of dispatchable RE electricity** from CSP Reduced wind and PV capacities in Europe

Reduced fluctuations ↓

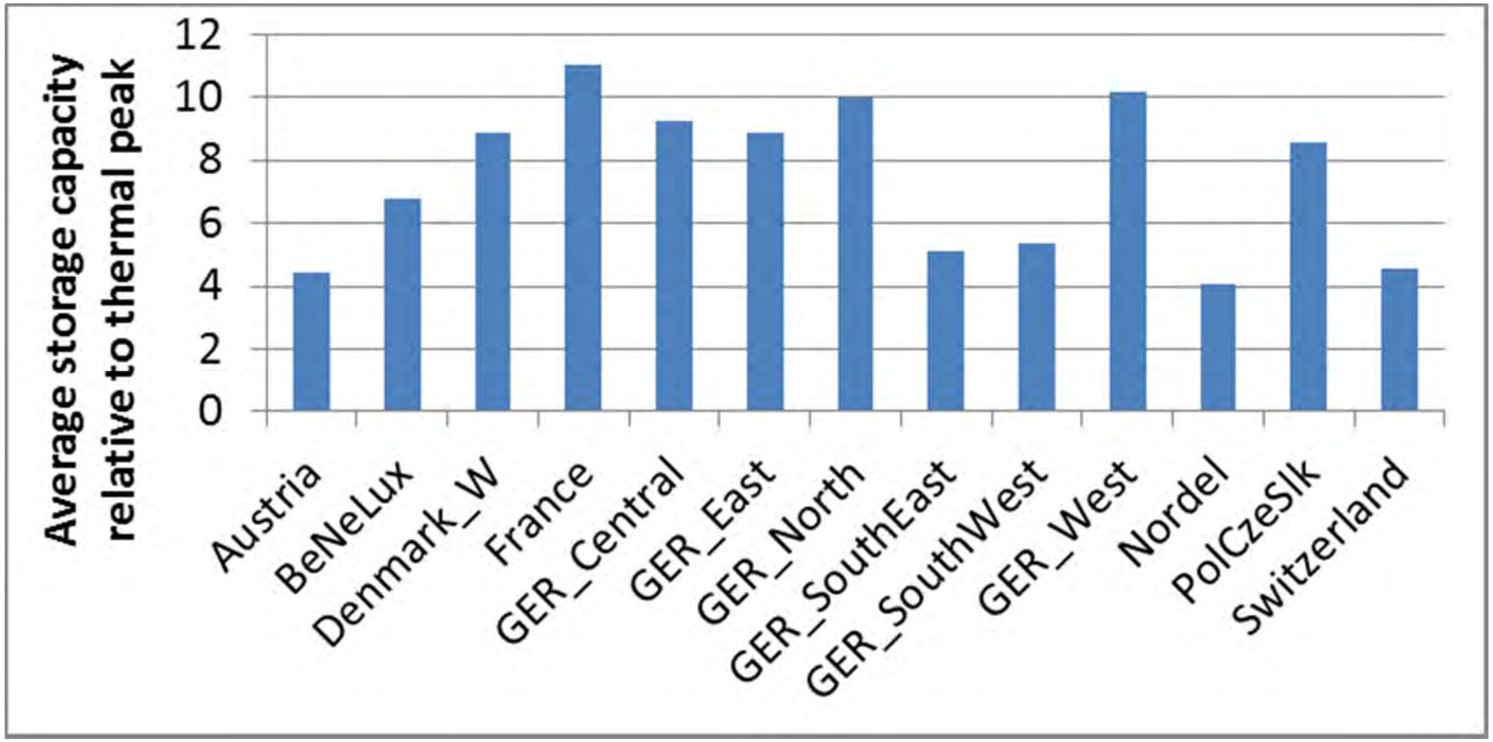
REMix output – investment and usage of TES



H2T – Flexible electrolysers
HP – Increased HP share
Base – Reference
EV – Controlled EV charging
Grid – Grid extension
-VRE – Reduced VRE generation
CSP – CSP-Import

- Investment in DH-TES across all scenarios, with capacities of 500-600 GWh
- Exogenously defined: additional 200 GWh in Industry, and 140 (260) GWh in HP systems
- Around 10% of the annual DH heat demand go through the TES
- CSP and load shifting (Electrolyser, EV) reduce TES use
- Additional HP do not affect investment in and usage of DH-TES

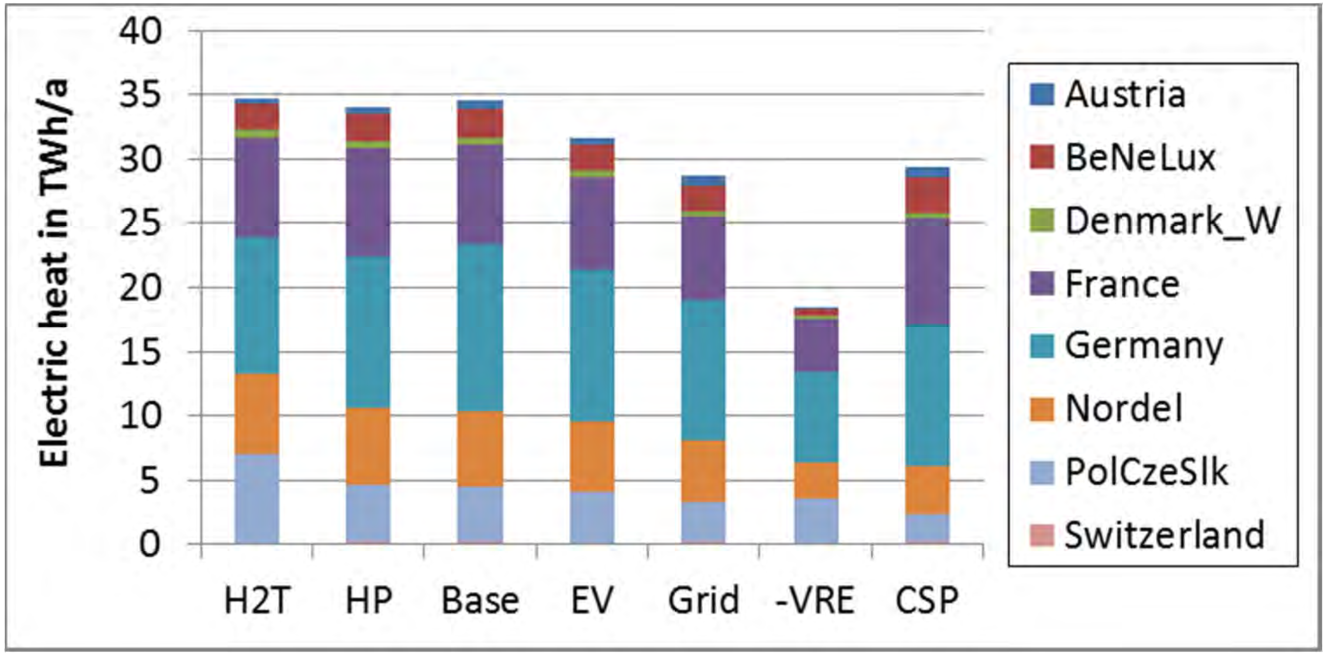
REMix output – regional storage layout



Values shown for scenario *Base*

- Relative storage capacity lowest in regions with high hydro power capacity
- Highest capacities in regions with wind power dominated supply

REMix output – investment and usage of electric boilers



H2T – Flexible electrolysers
HP – Increased HP share
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Grid – Grid extension
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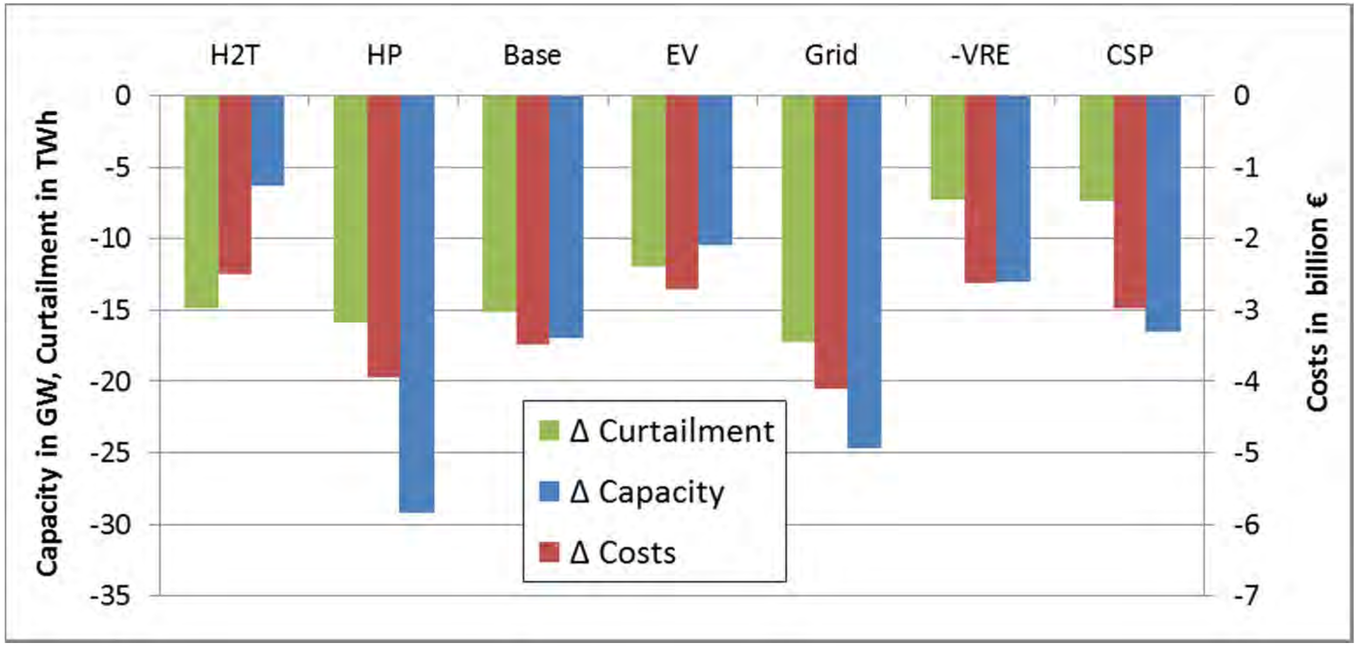
CSP – CSP-Import

- Model endogenous installation of electric boilers in DH systems reaches up to 43 GW (el)
- Significantly lower values only in scenarios with less VRE generation (CSP & -VRE)
- Grid extension, controlled EV charging and CSP imports slightly reduce electric heating
- Increased HP and flexible hydrogen production can balance additional VRE generation
- Low wind power availability has major impact

REMix output – system benefits



H2T – Flexible electrolysers
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- w/o flexibility: system costs 86-107 bln €, curtailment 11-23 TWh, back-up 96-163 GW
- Maximum reductions achieved:
  - costs 4.1 bln € (4.3%) in scenario *Grid*
  - curtailment 17 TWh (71%) in scenario *Grid*
  - back-up 29 GW (18%) in scenario *HP* (mostly due to flexible HP operation)

Summary, conclusion and discussion

- Model-endogenous investment in TES and electric boilers across all scenarios
- Geographical concentrations to wind power dominated regions
- Least-cost sizing of TES also influenced to CHP technology, fuel and size
- TES notable increases CHP/HP supply share, at the expense of the peak boilers
- Balancing strongly related to generation structure and available technologies
  - ➢ Grid extension has positive impact on economics of flexible heating
  - ➢ Controlled EV charging and flexible electrolysis can not substitute TES
  - ➢ Yearly and hourly wind and solar generation have high influence
- Power-controlled heat supply is an effective measure to increase RE integration
  - ➢ TES should be deployed hand-in-hand with VRE power generation
  - ➢ Electric heat production from VRE generation peaks has high potential
  - ➢ Reductions in curtailment, back-up capacity, costs and CO_2 emissions (~2%)
- Usage on smaller temporal and spatial scales was not assessed

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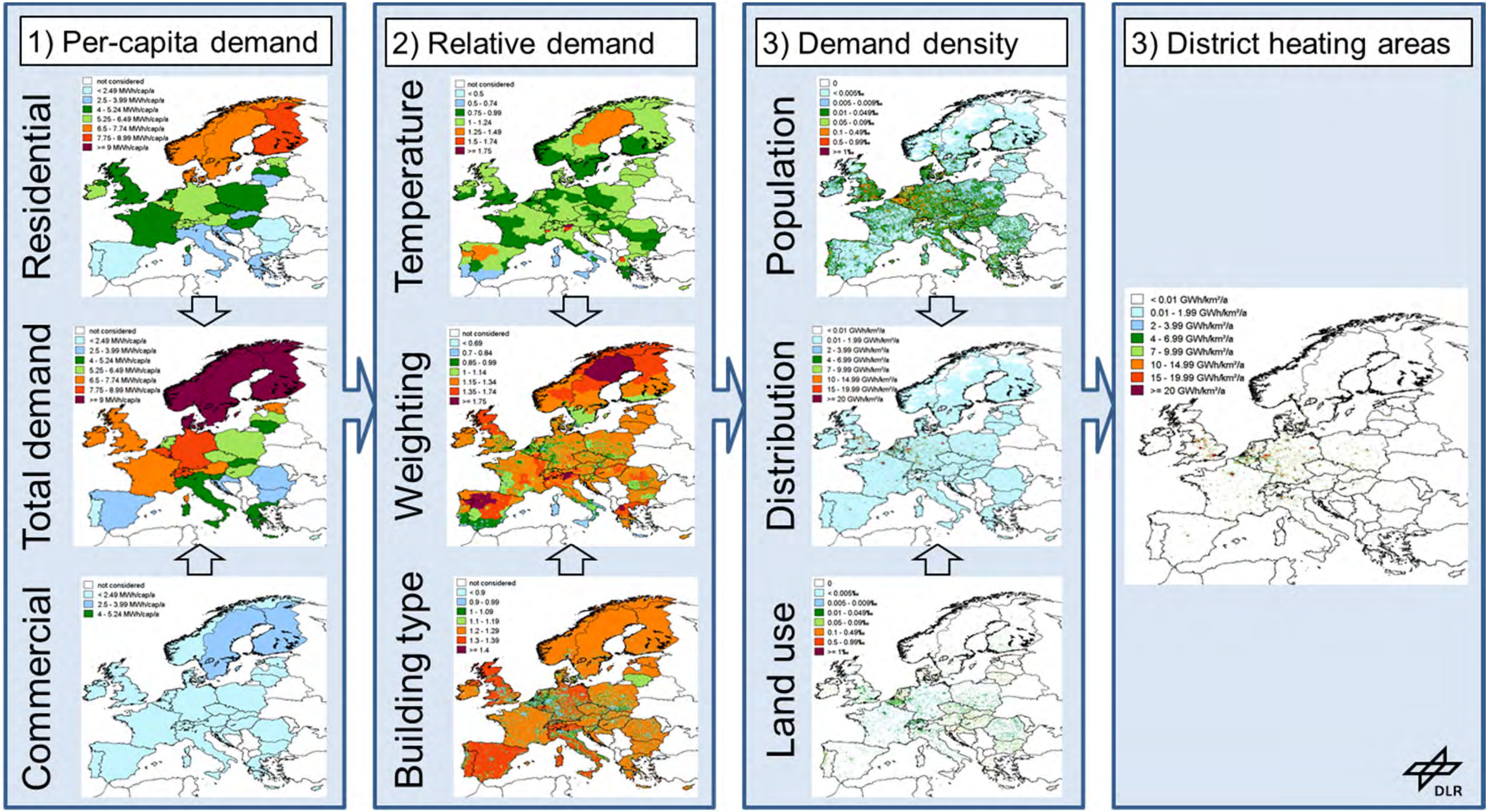
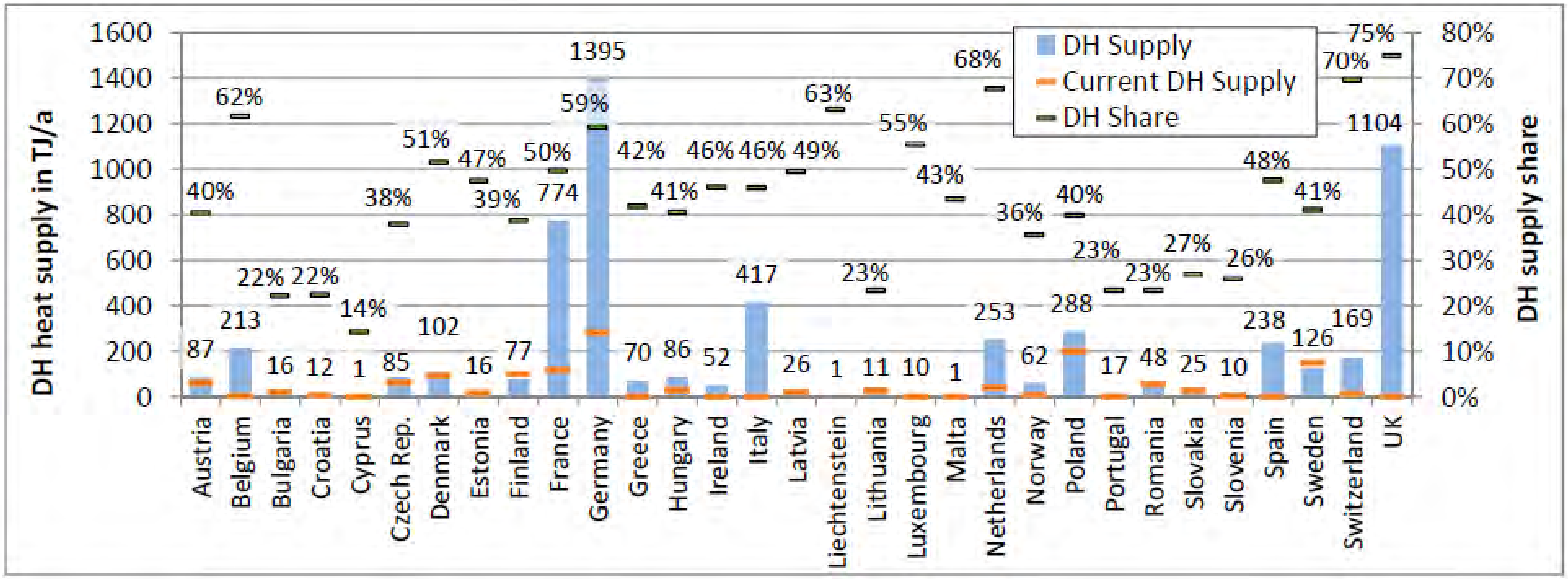
District heating potential in Europe – Methodology



District heating potential in Europe – results

- Up to 53% of the considered demand are located in areas with high demand density
- The 24.232 DH areas are distributed very unevenly over Europe
- More than two thirds of them are located in Germany, France, Italy and the UK
- DH supply shares between 22% and 75%



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District heating potential in Europe – results

- Application of higher minimum demand density values reduced potential notably
- Then, DH potentials are found only in bigger cities
- Considering significant future demand reductions, there are still potentials