# CAN HEAT PUMPS HELP TO INTEGRATE FLUCTUATING RENEWABLE GENERATION?

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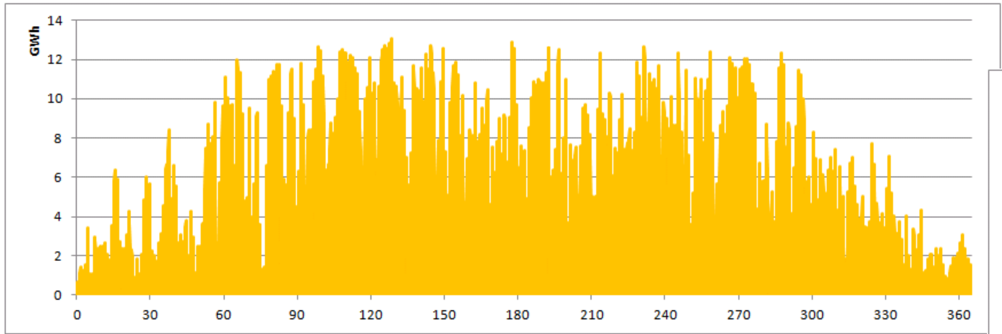


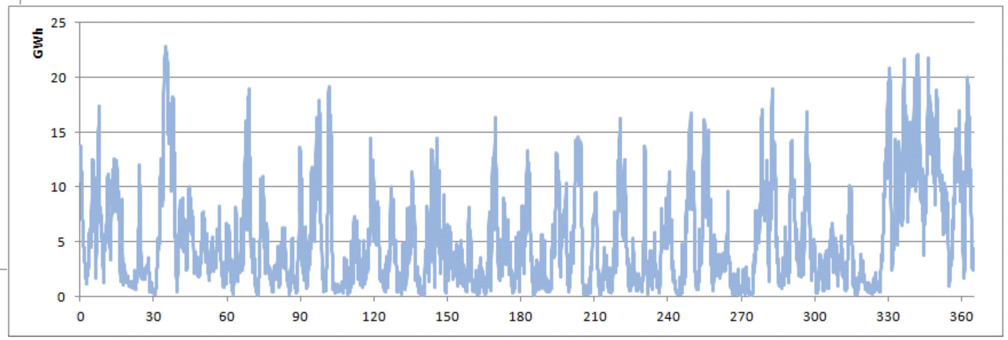


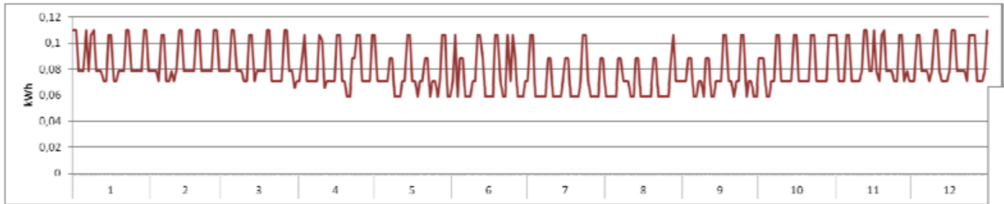


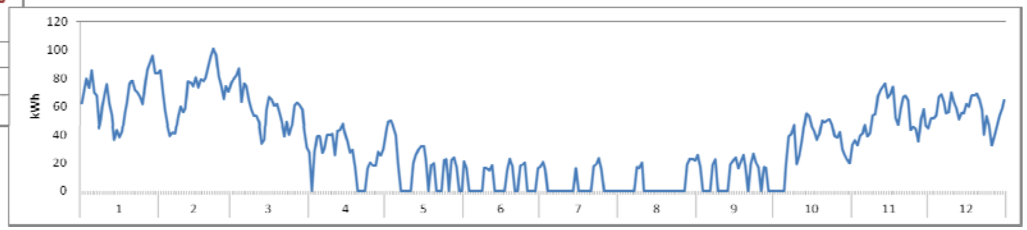




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# Framework

- Different goals on the way to convert the German energy system
  - Long term:
    - Up to 80% renewable electricity until 2050
    - 450 ppm $CO_2$
  - Short term:
    - 35% renewable electricity until 2020 (coalition agreement)
    - 14% renewable energy to cover heating and cooling needs until 2020 (EEWärmeG) (2011: 11%, 70% of it from biomass)
- More renewable energies on the electricity and heating market
  - Fluctuating RES change the electricity system → cause flexibility needs
  - Heat pumps based on "green" electricity are, besides biomass, one option for a decarbonisation of the heating market
  - Heat pumps can provide flexibility to the electricity market
- Heat pumps are one possible option to provide flexibility for the electricity sector together with low-emission heat for the heating market.

# Methodology
# Analyzed Scenarios

- Cost optimized scenario of the electricity system for germany
  - Existing plants are taken into consideration with their lifetime
  - Endogenous optimization of fossil and renewable generation in a fundamental model
- Additional electricity demand caused by heat pumps to cover heating demand
- Main input parameters:

| | 2020 | 2030 | 2040 | 2050 | Source |
|---|---|---|---|---|---|
| electricity demand (excluding heat pumps) [TWh] | 611 | 630 | 670 | 700 | Own assumption |
| heating demand covered by heat pumps [TWh] | 26 | 58 | 90 | 120 | BWP 2011[1] |
| Fuel price gas [€/MWh] | 38 | 40 | 40 | 39 | EC 2014[2] |
| Fuel price hardcoal [€/MWh] | 14 | 15 | 17 | 19 | EC 2014[2] |
| Fuel price lignite [€/MWh] | 3,7 | 3,7 | 3,7 | 3,7 | EC 2014[2] |
| Fuel price nuclear [€/MWh] | 3,1 | 3,1 | 3,1 | 3,1 | EC 2014[2] |
| Fuel price oil [€/MWh] | 54 | 57 | 63 | 68 | EC 2014[2] |
| $CO_2$ price [€/t] | 10 | 35 | 65 | 100 | Own assumption |

- Sensitivities on storage size (no storage, 2h, 12h) and heat source (ground water, air)

[1] Bundesverband Wärmepumpe 2013 Branchenreport Scenario1
[2] EC, 2014, Trends to 2050 Reference Scenario 2013



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# Methodology
# Heat pump integration

- Heat demand included  as a heat demand supply constraint and storage constraint

$$\text{heat demand}[h] = hp_{out}[h] + s_{out}[h] - s_{in}[h]$$

$$s_{content}[h] = s_{content}[h-1] \cdot (1-\eta_s) - s_{out}[h] + s_{in}[h]$$

$$\text{electricity demand}[h] = hp_{out}[h] \cdot \eta_{hp}[h]$$

- Electricity consumption of the heat pump is included in the electricity demand supply equation of the fundamental electricity model
  - Electricity demand has to be delivered by the electricity system
  - Flexibility can be used by the electricity system
- Efficiency for ground water heat pump: 5,5 (ground water 10°C)
- Efficiency for ambient air heat pump: ~3,2 (ambient temperature -10°C to 15°C)
- Heat losses of the storage: 1% per hour




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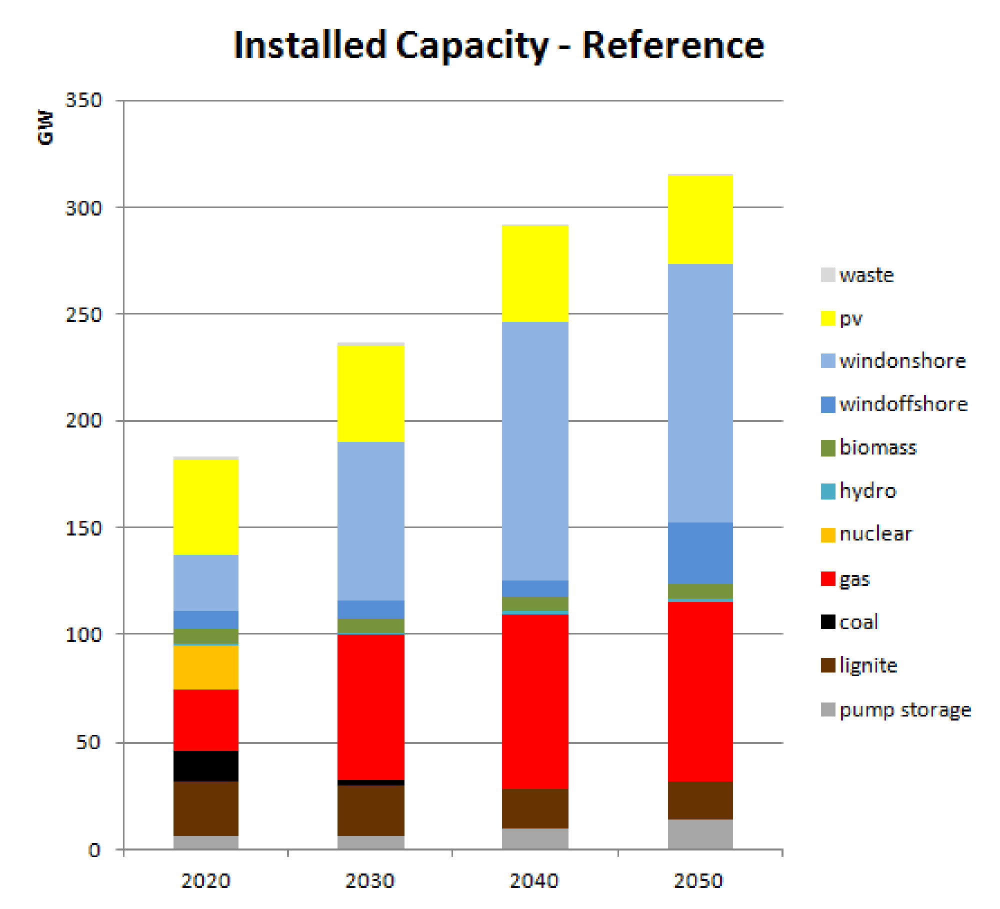
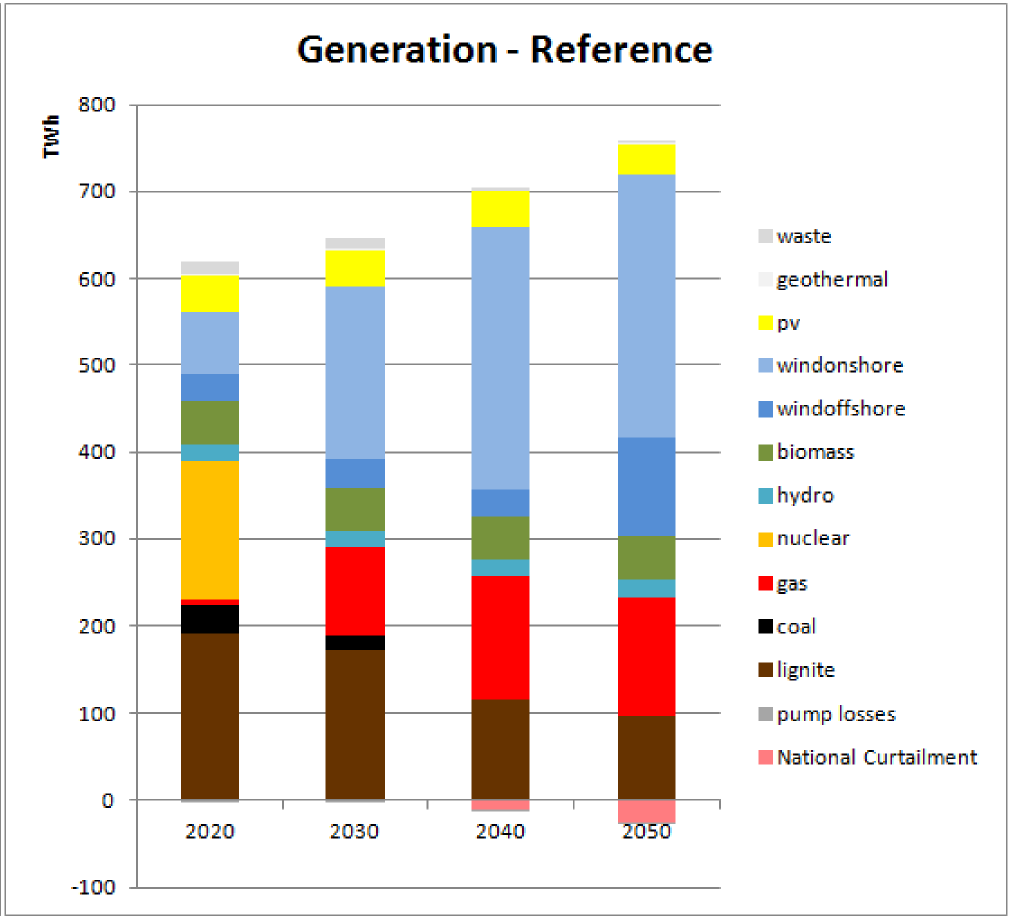
# Results
# Reference Case without heat pumps







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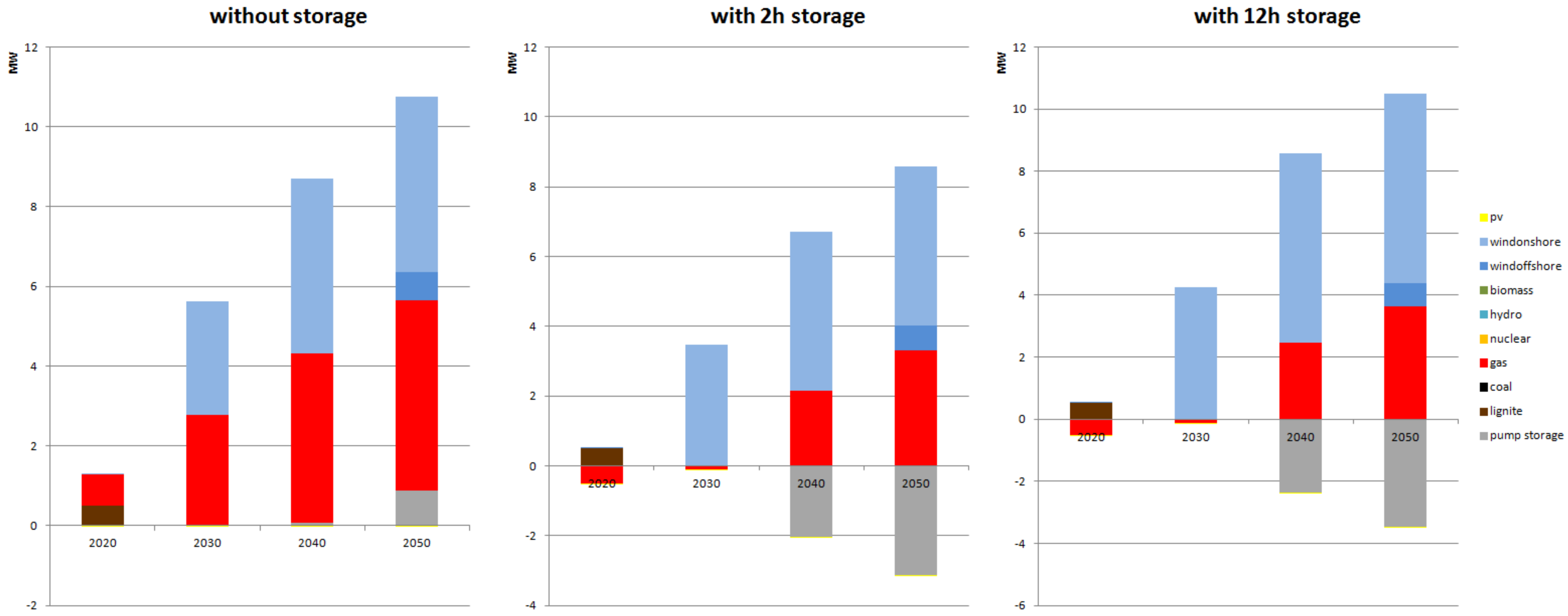
# Results - chances in installed capacity
# Heat Pump ground water



# Differences in storage demand and curtailment

- Heat losses of the heat storage (1% per hour) are less than losses for pump storages (20%)
- → for heat pumps with heat storages these storages are used to substitute pump storages
- → a 2h and 12h heat storage have similar pump storages savings

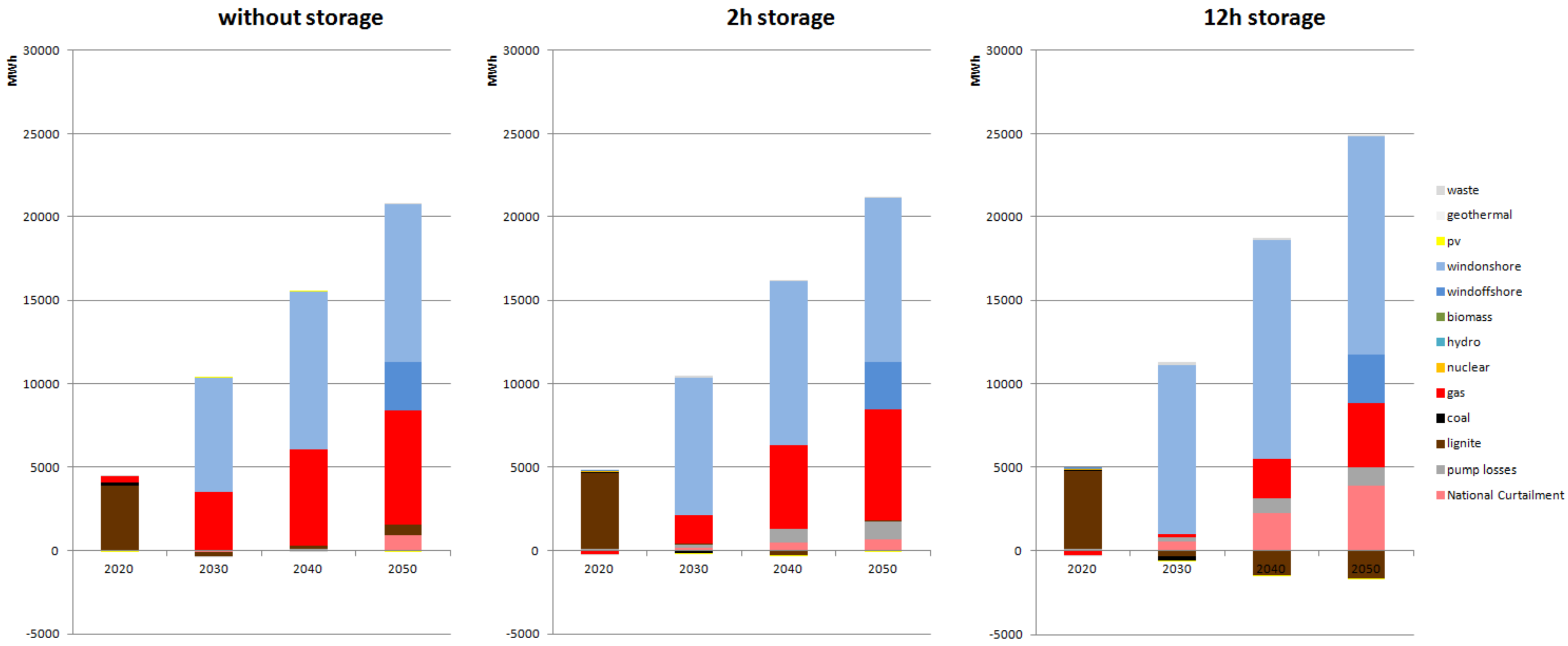
| pump losses [TWh] | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| water_0 | -2,6 | -1,9 | -2,9 | -3,3 |
| water_2h | -2,4 | -1,6 | -2,1 | -2,2 |
| water_12h | -2,4 | -1,6 | -2,1 | -2,2 |

| pump storage capacity [GW] | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| water_0 | 6,0 | 6,0 | 9,8 | 13,5 |
| water_2h | 6,0 | 6,0 | 7,7 | 9,5 |
| water_12h | 6,0 | 6,0 | 7,4 | 9,1 |

- A 12h heat storage reduces curtailment, a 2h storage has only small effects

| curtailment [TWh] | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| water_0 | 0,0 | -0,9 | -14,8 | -30,3 |
| water_2h | 0,0 | -0,6 | -14,4 | -30,6 |
| water_12h | 0,0 | -0,3 | -12,6 | -27,4 |

# Results – changes in generation Heat Pump ground water



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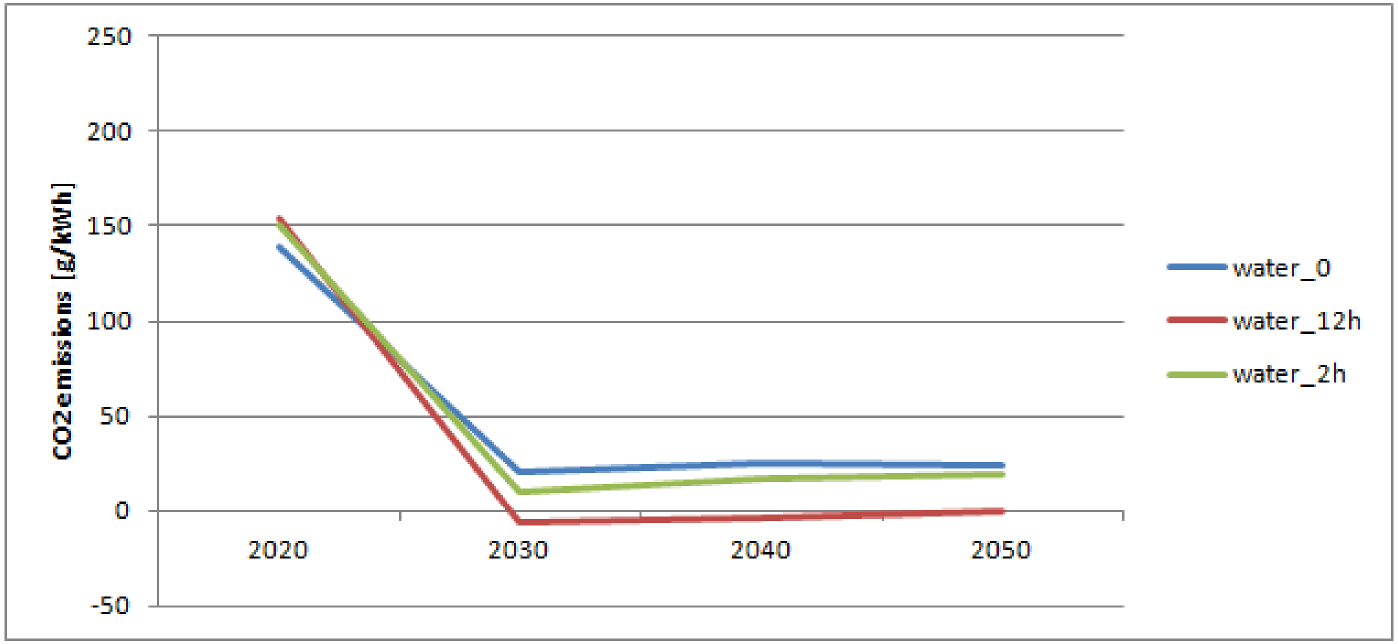
# Differences in CO2 Emmisions

- Difference of overall system emissions compared to Reference scenario per covered heating demand

$$CO_2 = \frac{CO_{2ref} - CO_{2water}}{\text{heating demand}}$$



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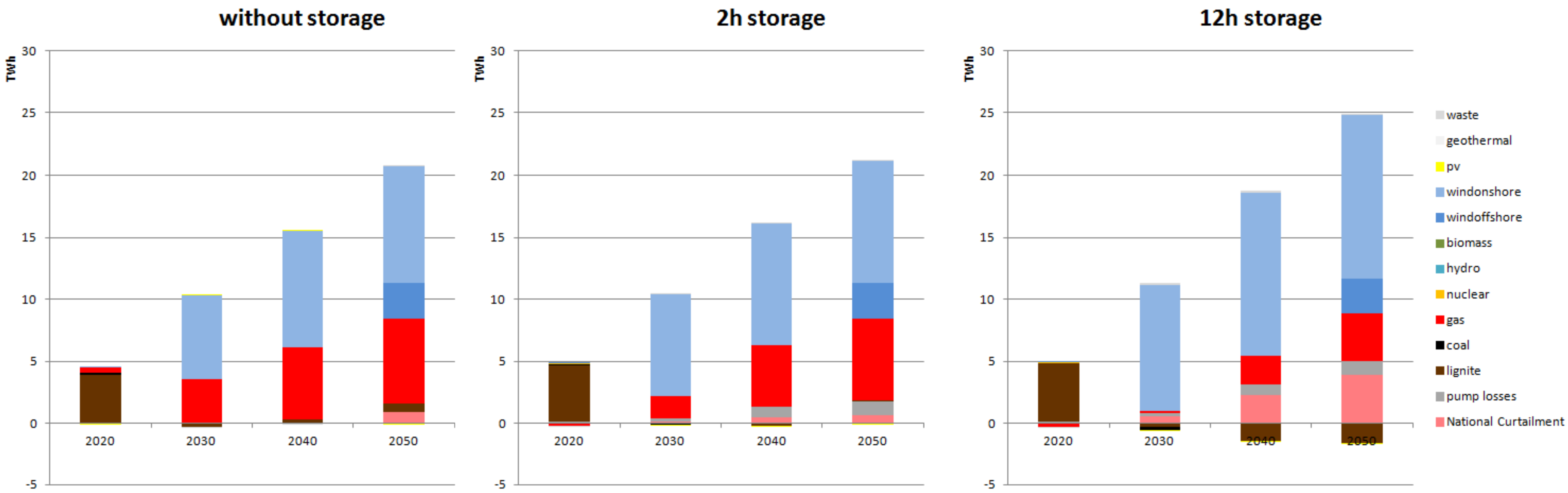
# Conslusions

- RES-Integration and flexibility
  - Heat pumps can contribute to integrate fluctuating RES generation if they are combined with large heat storage sizes
  - Heat pumps can provide flexibility for the electricity market even with typical heat storage sizes, assuring an operation based on "market signals"

- $CO_2$ emission savings on the heating market
  - $CO_2$ emission savings depend on the efficiency of the heat pump
  - $CO_2$ emission savings on the heating market are correlated with share of renewable electricity and the ability to integrate fluctuating RES generation on the electricity market

# Remarks? Questions?

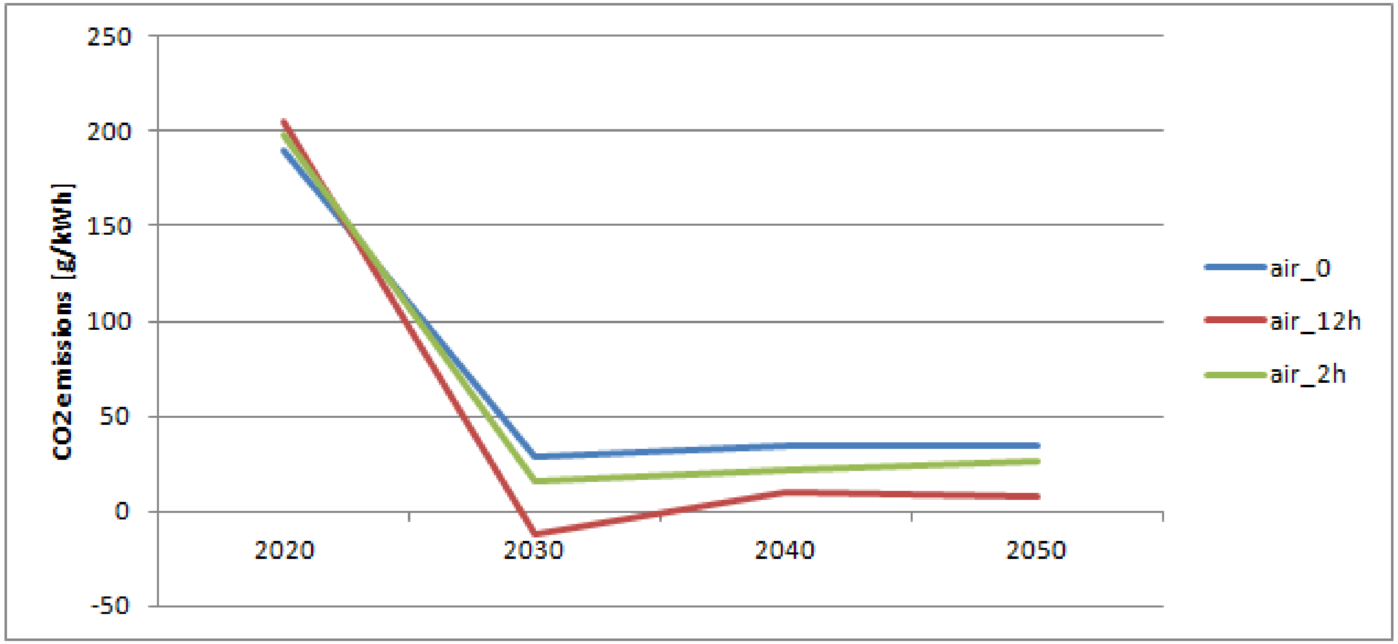
# Ambient Air Heat Pumps



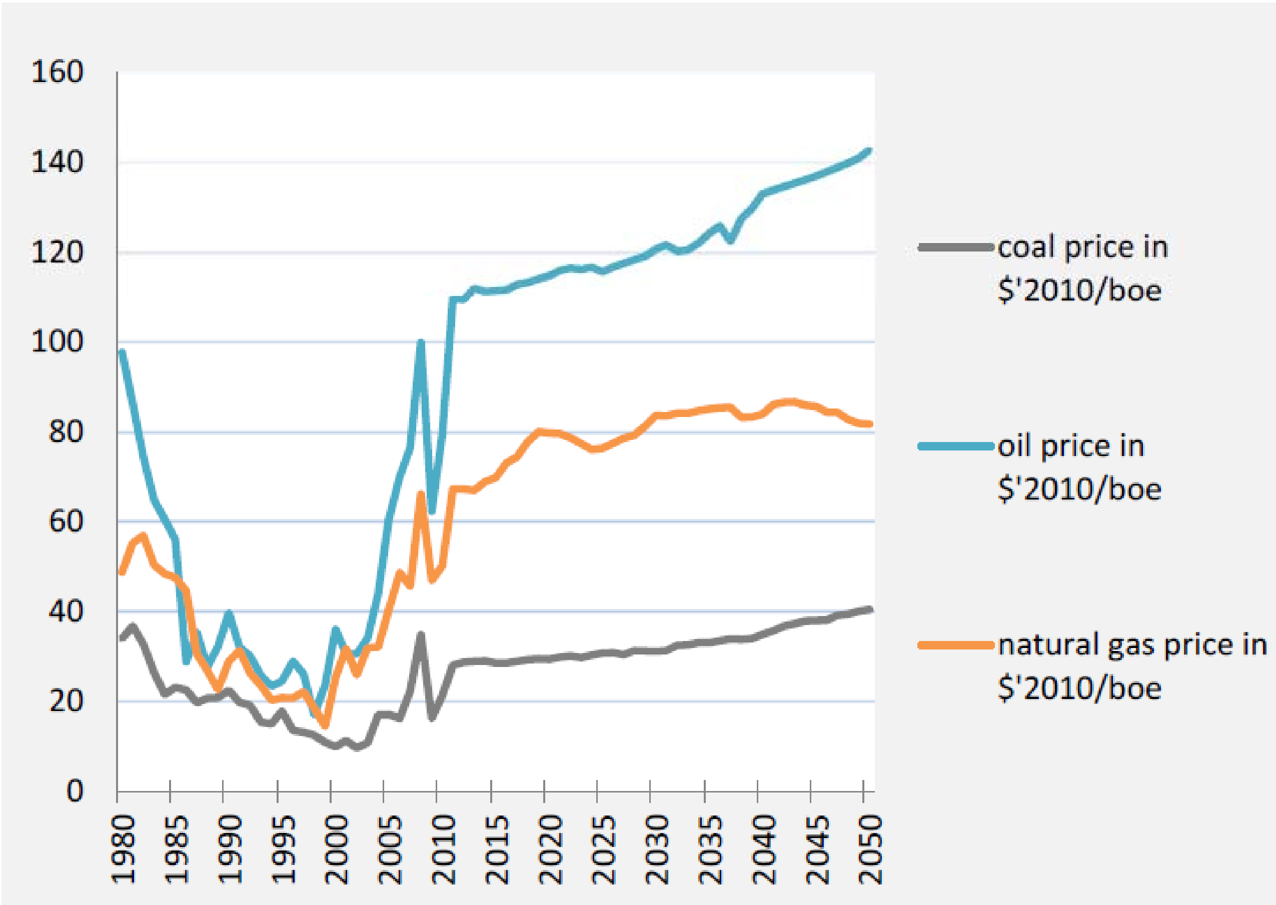
# Differences in CO2 Emissions for ambient air heat pumps

- Difference of overall system emissions compared to Reference scenario without heat pumps per covered heating demand

$$CO_2 = \frac{CO_{2\,ref} - CO_{2\,water}}{\text{heating demand}}$$



# Fossil fuel Prices
# EC, 2014, Trends to 2050 Reference Scenario



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