Managing Temporary Oversupply from Renewables Efficiently: Electricity Storage Versus Energy Sector Coupling in Germany

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1. Introduction
2. Scenario definition and modeling approach
3. Results
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Introduction (1): high shares variable renewable energies (VREs) lead to large temporary excess electricity

**Electricity Storage**
(pumped hydro, CAES, batteries, but mainly hydrogen)

**Energy sector coupling**
(supply/replace other energy demand like heat, natural gas, hydrogen)
Introduction (2): Non-trivial interaction of different options to manage temporary oversupply

- Joint analysis of all options in a detailed energy system model
Scenario definition: Germany, 2020 and 2050

- **Gas price**: 25 €/MWh
- **Reference technology**: Gas reformation
  - **Storage size**: unlimited

### Power Systems
- **Solar PV**: 60 GW (2020), 129 GW (2050)
- **Wind Onshore**: 42 GW (2020), 75 GW (2050)
- **Wind Offshore**: 16 GW (2020), 43 GW (2050)

**Sensitivity analyses**: conversion paths, gas price, electrolysis costs
Method (1): URBS model generator for detailed energy system model of German power, heat and H2 system

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Method (2): distributed generation implemented URBS model and regional resolution

- Distributed generation follows local demand (relevant for space heating technologies, after Richter (2004))
- Detailed modeling of CHP technology

- Regional resolution according to dena II (2010), regions reflect well connected areas in electricity grid.
Results: System wide effects of coupling (2)
Base scenario 2050

Hydrogen Demand: 30 TWh
(excl. refinery by-products)

Natural gas: 37 TWh

Gas reformation: 30 TWh

Natural gas: 301 TWh
Biogas: 40 TWh

Power sector

Transmission and storage losses: 20 TWh
Excess: 3 TWh

Electricity Demand: 560 TWh

Gas power plants: 85 TWh
Gas chp: 117 TWh
Biogas CHP: 36 TWh
Renewable energies: 482 TWh

Electricity: 137 TWh

Heat sector

Heat Demand: 1147 TWh
(excl. high temp. process heat)

Biogas: 54 TWh
Natural gas: 1085 TWh

Renewable energy resources

Biogas: 95 TWh

Natural gas sector

Import: 1424 TWh

Losses

Losses

Losses
Results: System wide effects of coupling (3)

Excess electricity and coupling

- Heat sector acts as sink for excess electricity
- Hydrogen sector plays a minor role only
- Role of transmission grid extension changes
Results: Role of hydrogen sector is crowded out by large sink for excess electricity provided by the heat sector

- Relative costs of technologies leads to dominant role of heat sector
- Methanation is only part of cost-optimal mix with high gas price and no other option
Results: Cost-optimal heating technologies are complementary to VRE sources

- High variability of wind energy in the north fits well with electric heater
- Solar PV and CHP electricity generation are anticorrelated on a seasonal timescale
Results:
Sector coupling gives value to excess electricity

Histogram of electricity prices (marginal costs)

- Electricity prices become lower bounded by cost of the replaced fuel, natural gas (plus emission allowances)
Findings:

- power-to-heat coupling displaces long term electricity storage and the power-to-gas option.
  - Heat sector acts as cost-efficient sink for excess electricity.
  - Regional heating technologies are complementary to VRE technologies.
- Role of transmission grid changes.
- Zero price events are reduced thanks to energy sector coupling.

Future Work

- 100% renewables scenario for all sectors
- Include transport sector
- More detailed modeling of heat and hydrogen sector