Cost-Supply Curves of renewable electricity in Germany - First Results

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Issues addressed

The deployment of electricity production from variable renewables has a considerable impact on both

i. **the electricity generation portfolio and the power plant operation**
ii. **the electricity grid**

- **What are the system effects and the impacts of variable renewables on the total cost of electricity supply?**
- **What are the flexibility and storage requirements to integrate larger shares of variable renewable power plants?**

→ Derivation of Cost-Supply Curves

Approach

- Analysis of total electricity supply costs due to required electricity generation, storage as well as transmission and distribution including:
  i. Balancing and provision of adequate back-up capacities
  ii. Grid connection, extension and reinforcement
  iii. Environmental externalities: Climate-change externalities taken into account by a price for the usage of CO_2 allowances
- Comparison of scenarios with equal electricity demand and reliability of supply but with different shares of variable renewable generation
- Quantitative analyses based on fundamental electricity system models:
  i. Linear optimization model of electricity provision with hourly time resolution
- Total electricity supply costs of different shares of renewable electricity are used to generate the cost-supply curve

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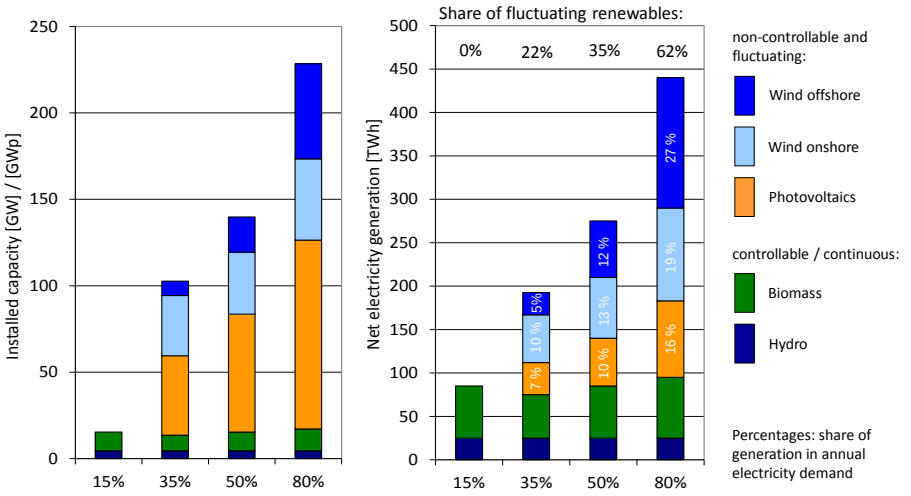
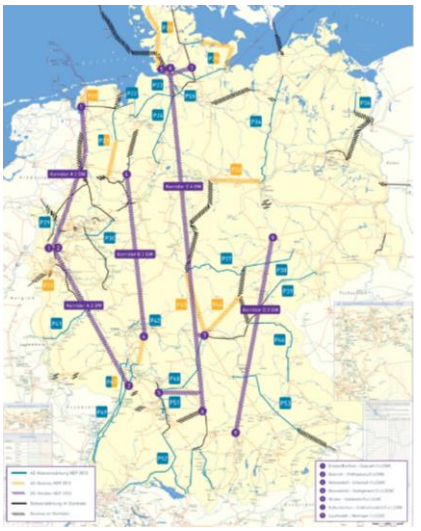
Scenario characterization

- Different contributions of renewables (15%, 35%, 50% and 80%) to the annual electricity demand of 550 TWh (2030)
- Fuel prices of coal and gas corresponding to projections of World Energy Outlook 2010 “New policies scenario” for the year 2030, CO_2-allowance prices: 50 €/t CO_2
- No export or import possibilities to neighbouring electricity systems
- Original state of present transmission and distribution grid of the exemplary electricity system sufficient to accommodate conventional electricity generation

Installed capacities and electricity generation based on renewable energies



Necessary transmission-grid extension until 2022

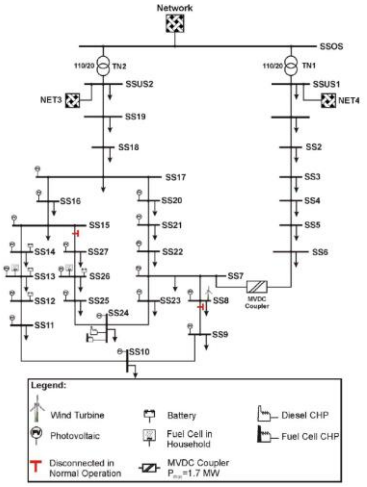


- Grid extension:
  - i. AC-lines: 1,700 km
  - ii. Additional AC-circuits: 2,800 km
  - iii. Upgrading of AC-circuits: 1,300 km
  - iv. DC-lines: 2,100 km
- Investment: 20 billion €
- Szenario 2022:
  - i. Wind offshore: 13.0 GW
  - ii. Wind onshore: 47.5 GW
  - iii. Photovoltaics: 54.0 GW
  - iv. Share of renewable energies in electricity generation: 50 %

→ Investment: 400 €/kW$_{PV\ \&\ Wind(on-\&offshore)}$

Source: TSOs, Netzentwicklungsplan , 2012

Distribution network extension and reinforcement until 2020



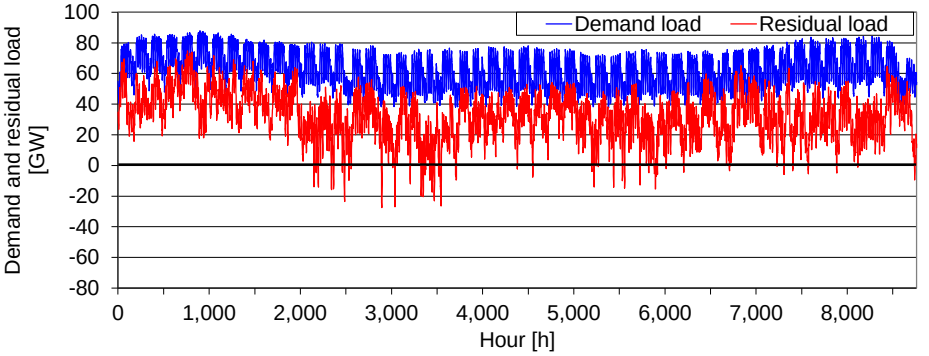
Source: CIGRE, MV-Network, 2005

- Grid extension based on wind and photovoltaics:
  i. Lines: 380,650 km
  ii. Transformers: 63,000 MVA
- Investment: up to 27 billion €
- Installed capacity:
  i. Wind (onshore): 35.8 GW
  ii. Photovoltaics: 51.8 GW

→ Investment: 500 €/kW$_{PV\ \&\ Wind(onshore)}$

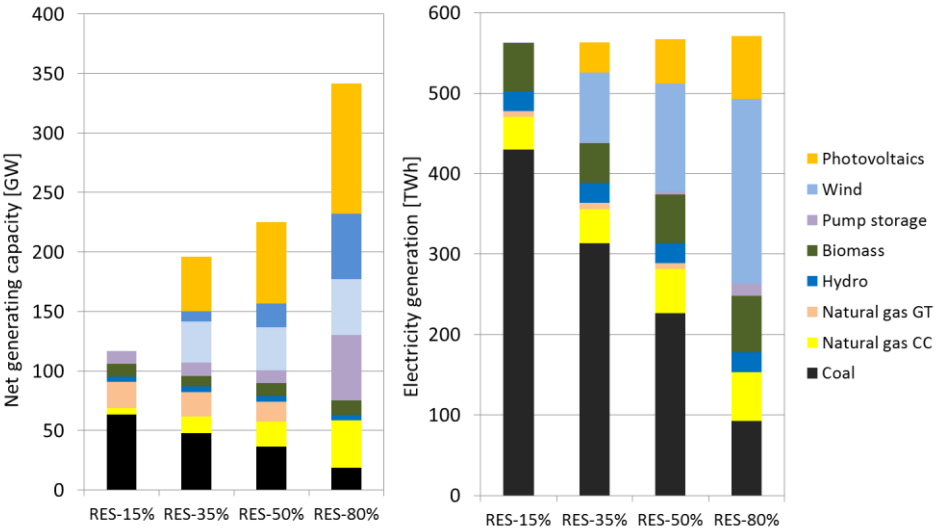
Source: BDEW, Ausbaubedarf in deutschen Verteilnetzen, 2011

Demand load and residual load - 50 % share of RES

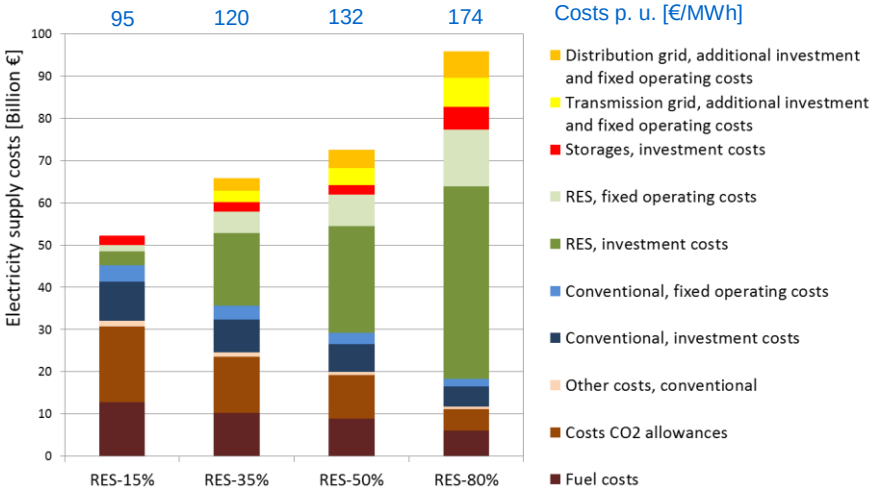


- Excess renewable power up to 27 GW
- Renewable surplus production ~ 2 TWh, about 1 % of the electricity production by wind and photovoltaics
- Storage capacity requirement ~ 250 GWh
- Present pump storages: 7 GW / 40 GWh

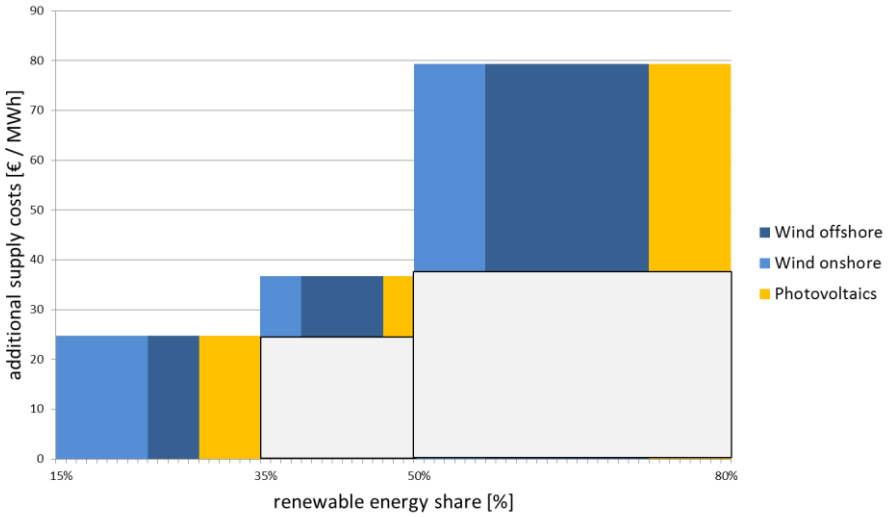
Electricity portfolio & generation



Total and specific electricity supply costs



Cost-Supply Curve



Some Conclusions

- Due to the low capacity credits of variable renewable power plants, increasing shares of variable renewables will not reduce the required capacities of dispatchable power plants.
- With increasing share of variable renewables, the costs for transport and distribution constitute a growing part of the total electricity supply costs.
- The integration of large shares of variable renewables requires large storage capacities. Although the curtailment of some variable power generation is more cost effective.


Thank you for your attention!
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