Impacts of renewables on the electricity market

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What are the integration costs of renewables?
Integration costs of renewables

• Costs increase because of specific characteristics of wind and solar generation
  – Variability
  – Uncertainty
  – Location

• Costs of variability or profile costs
  – Increased operating costs from ramping up and ramping down of conventional plants
  – Higher costs of conventional generation because of reduction in full-load hours
  – Costs of back-up capacity needed for periods with low wind and low solar production
  – Costs of curtailment of wind and solar

• Costs of uncertainty or balancing costs
  – Increased balancing costs to adjust for forecast errors on the intraday market

• Location costs or grid costs
  – Costs of increased grid investments for connection and transport
Levelized costs of electricity (LCOE)
costs/MWh\textsubscript{IRES}
Quantifying the impact of renewables on the Dutch electricity market
Electricity markets

1. **Future markets**
   - Trade in electricity up to several years ahead

2. **Day-ahead (or spot) market**
   - Trade up to 24 hours ahead of real time
   - Producers and consumers (or their retailers) submit planned generation and demand schedules

3. **Intraday market**
   - Trade to compensate for deviation from schedule because of
     - Unexpected plant outages
     - Higher or lower than expected demand
     - Forecast error wind and solar generation

4. **Balancing mechanism TSO**
   - Final balancing by system operator with contracted reserve capacity
Methodology

• COMPETES electricity market model European electricity market
  ▪ Unit commitment => individual power plants
  ▪ Detailed flexibility characteristics
    – start-up costs, ramping rates, minimum load levels, minimum up- and down time

• Profile costs
  ▪ Back-up costs
    – Costs of optimal capacity investments NL for 2030, given post-2010 available capacity
  ▪ System operation costs day-ahead market

• Balancing costs
  ▪ Additional investments needed for intraday/balancing markets
  ▪ System operation costs intraday market
    – Based on forecast error (expected - realized hourly wind production)
    – Adjustment of flexible units (such as gas) compared to day-ahead market
Background scenario

- NEV2014
  - Fuel prices
  - Installed capacity
  - Demand
  - Incumbent generation capacities (commissioned after 2010)
  - Varying penetration levels of variable renewables
    - 5%-61%
- Wind profiles based on 2012 realizations, solar profiles based on solar radiation data
- Two variants for transmission
  - 2012
  - 2030
    - Doetichem - Weser
    - COBRA
Results: integration costs
Levelized system costs of 28% wind electricity production, Netherlands 2030

- Investment costs: €60/MWh (68% of total)
- Profile costs: €9/MWh
- Balancing costs: €11/MWh (6% of total)
- Grid costs: €2/MWh (2% of total)
- Transmission costs: €32/MWh (32% of total)
Results: Market value renewables
Reduction in market value

- WIND: -10, -13, -26
- SOLAR: -10, -15, -18
- WIND OFFSHORE: -9, -12, -17
- WIND ONSHORE: -11, -14, -32

- medium wind & solar
- medium wind & solar, transmission 2012
- high wind & solar, transmission 2012
Market value and system costs
Costs and market value: two sides of the same coin

- Integration costs reduce the value of renewable electricity on the market
  - Assuming that all costs are reflected in market prices
  - However, markets are not perfect
    - e.g. subsidized renewables

- Profile costs
  - Upward effect on day-ahead prices, lower market value for wind

- Balancing costs
  - Higher prices for balancing wind = lower net revenues
    - reflected in SDE+ subsidy, not in market value

- Grid costs
  - Socialized, no effect on market value
Discussion and policy implications
Discussion

- Costs fall within the range reported in the literature
  - Local circumstances determine more precise results
    - generation mix, interconnections, grid
- Calculated integration costs are based on flexible generation
  - If other options have lower costs, overall integration costs will decline
  - Other options (demand response, storage) have to “beat” those costs of flexible generation for a viable business case
- Further increasing interconnections might further lower integration costs at limited costs
- Balancing costs might be lower than calculated
  - Cross-border balancing markets
  - Better forecasts of wind production
  - More efficient markets
- Overall, costs will change with new developments,
  - Availability of pumped-hydro storage, more flexible renewables, more demand response (power-to-heat),
Impact on market actors

- SDE+ subsidy increases per MWh with increasing penetration levels because of increasingly lower market value for wind and sun
  - Higher SDE+ surtax (ODE)

- Net lower electricity prices
  - Upward effect on wholesale electricity prices of because of profile costs
  - Downward effect because of higher levels of low-cost renewables

- Higher grid tariffs
  - Grid extensions (e.g. socket at sea)
  - Increased reserve capacity TSO

➢ Overall costs (= SDE+ plus grid tariffs) increase
Policy implications

• Integration will become a significant part of the costs of renewables, about 1/3 of total costs

=> policy measures to reduce integration costs
  ▪ Improve market design of electricity markets, for example
    – More consistency between subsequent markets (day-ahead, intraday, balancing)
    – Further cross border market integration (intraday, balancing)
  ▪ Further increasing interconnections appears to be a cost-effective flex option
  ▪ Provide incentives for renewables to minimize integration costs
  ▪ R&D policy should also focus on options to reduce integration costs, in addition to research on renewables themselves

• Without a sufficiently high CO2 price, in line with CO2 emission reduction ambitions, subsidies for renewables will remain necessary because of declining market value
Additional research questions

- What is the optimal level of interconnections?
- Which flexibility options are the most promising (merit order of flex options)?
- How do integration costs influence the optimal energy mix with high CO2 reduction targets?
- Integration costs of solar?
- How can incentives be provided for renewables to minimize integration costs?