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Impacts of renewables on the electricity market

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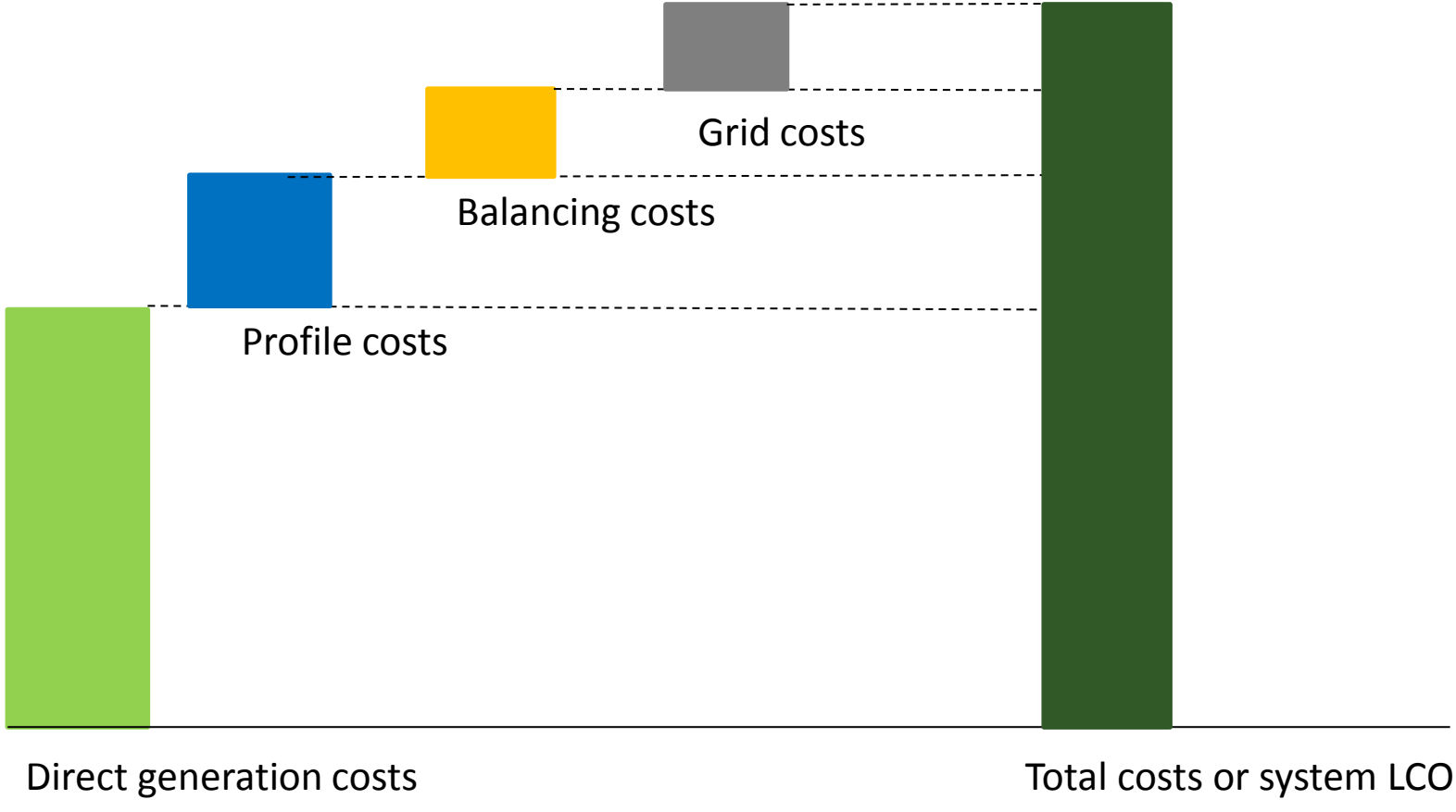
What are the integration costs of renewables?

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_{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

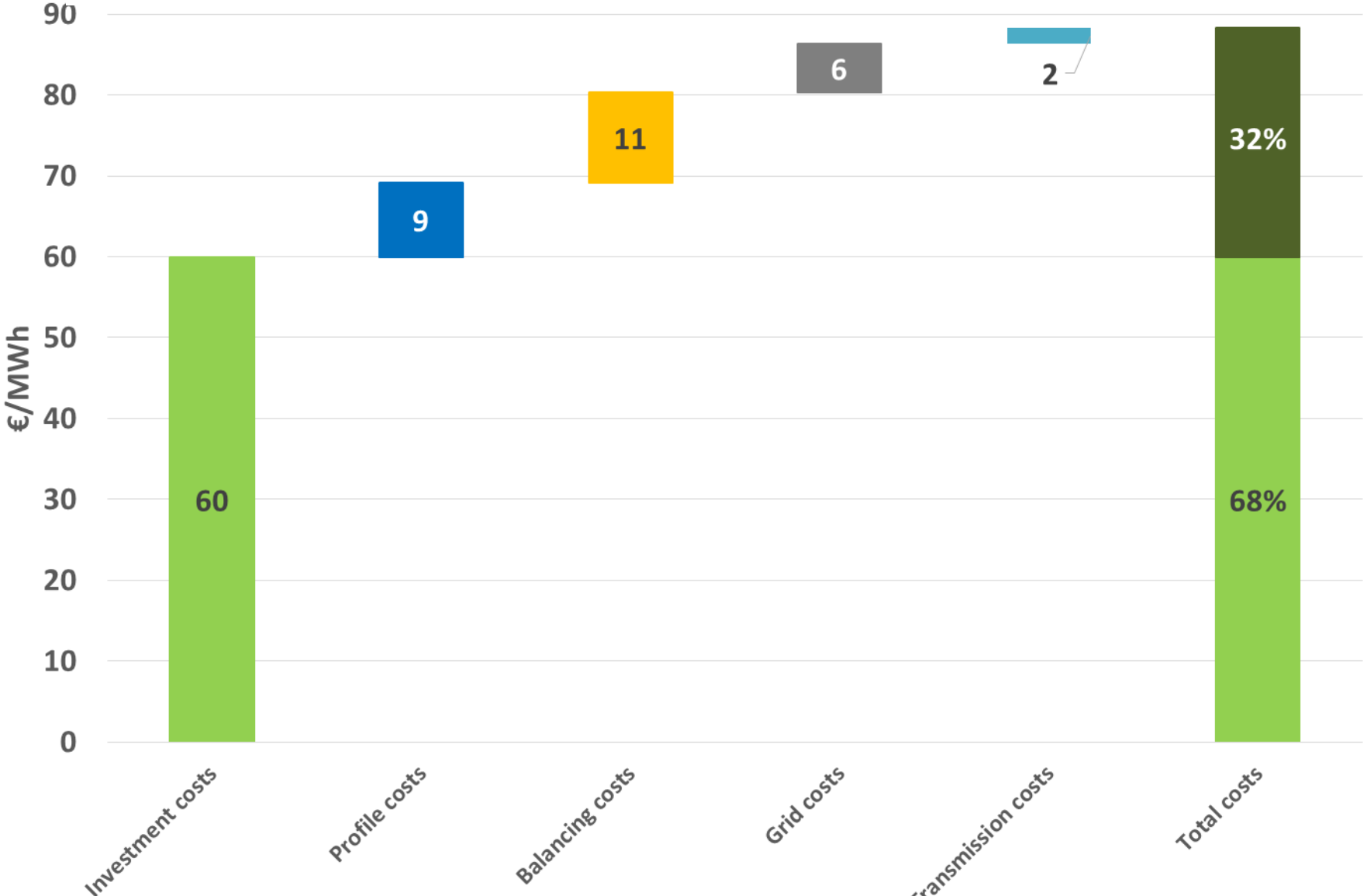
- COMPETES electricity market model European electricity market
  - Unit commitment => individual power plants
  - Detailed flexibility characteristics
    - start-up costs, ramping rates, minimum load levels, minimum up- and down time
- Profile costs
  - Back-up costs
    - Costs of optimal capacity 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

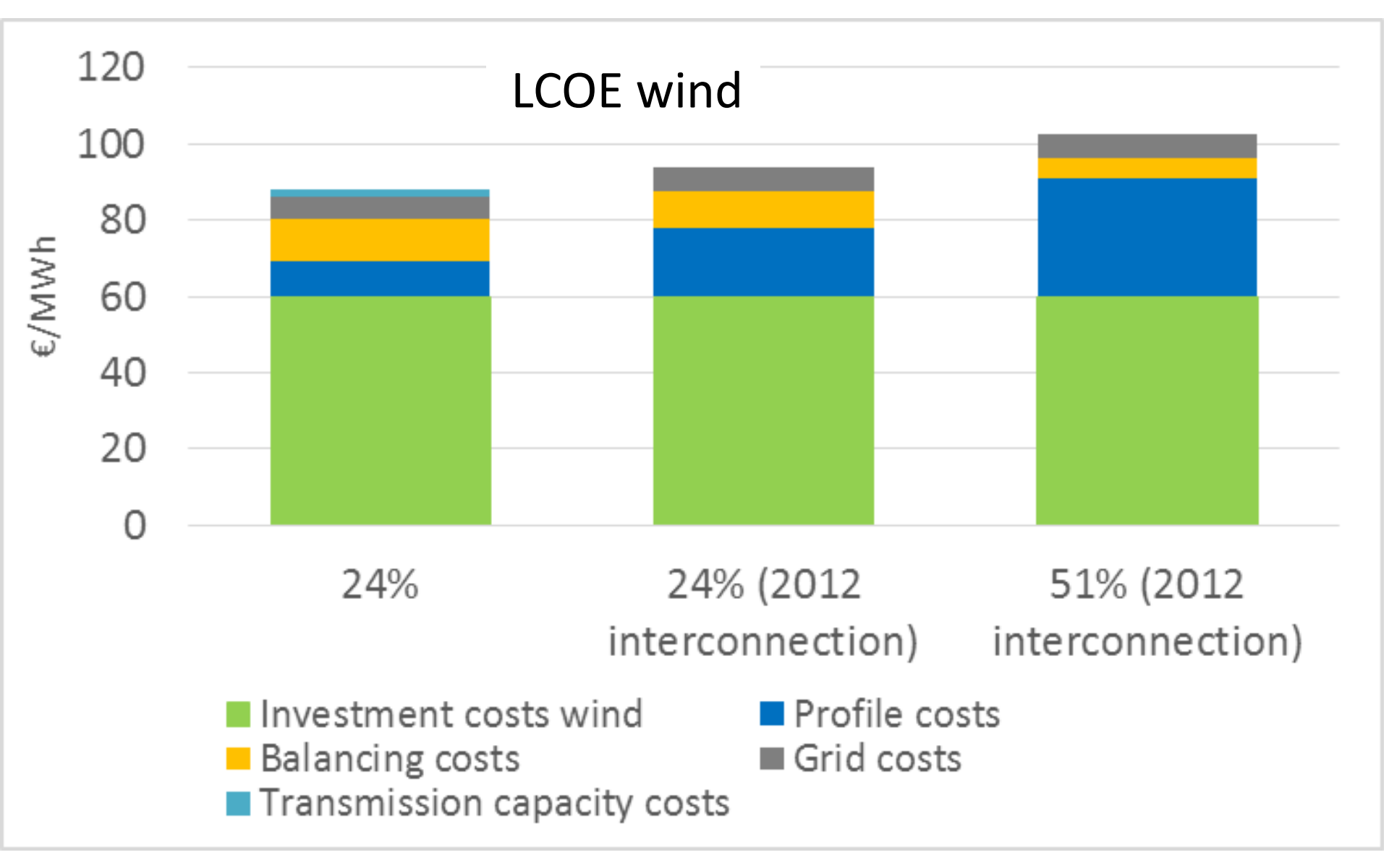
Background scenario

- 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

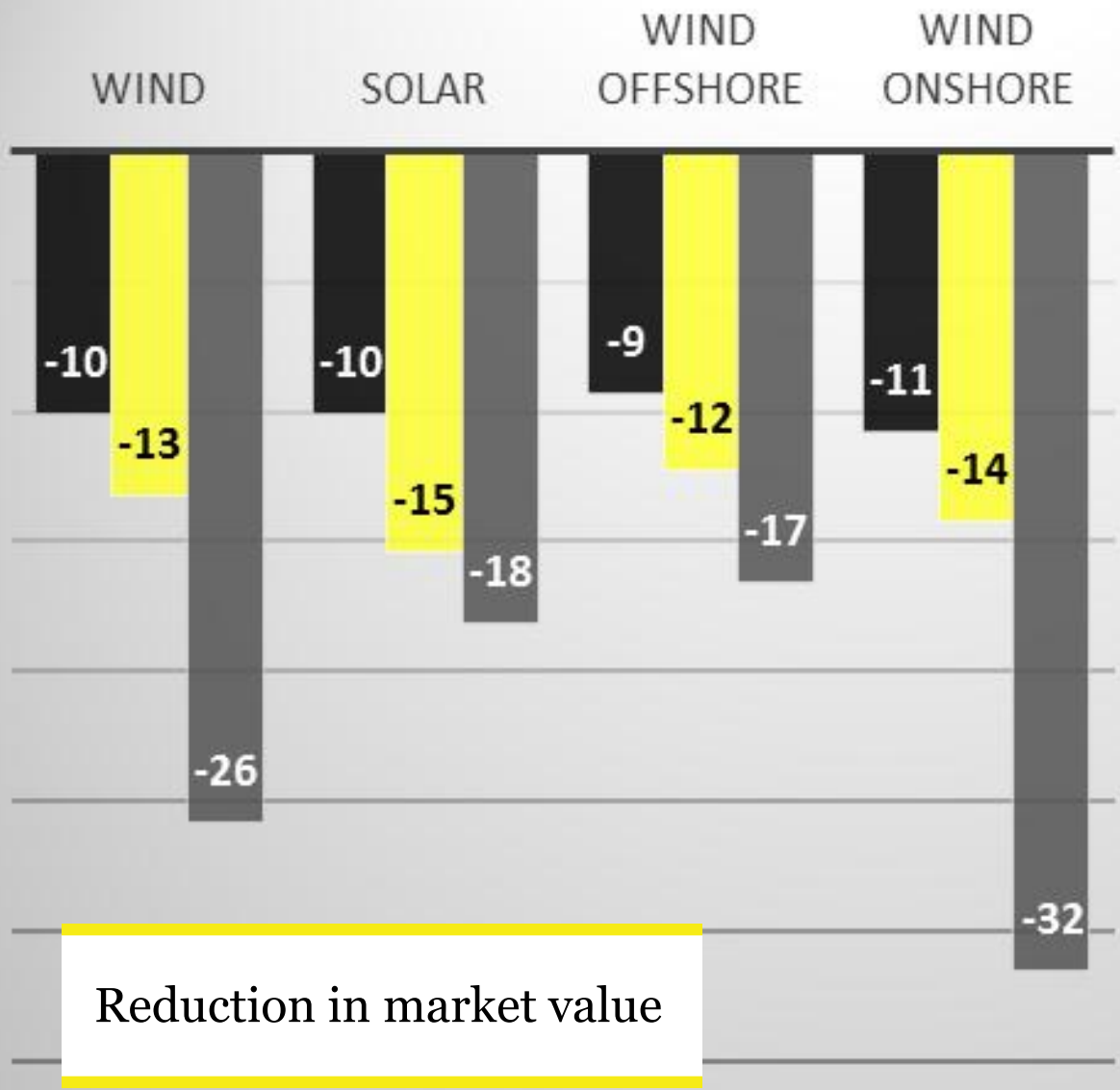
Results: integration costs

Levelized system costs of 28% wind electricity production, Netherlands 2030



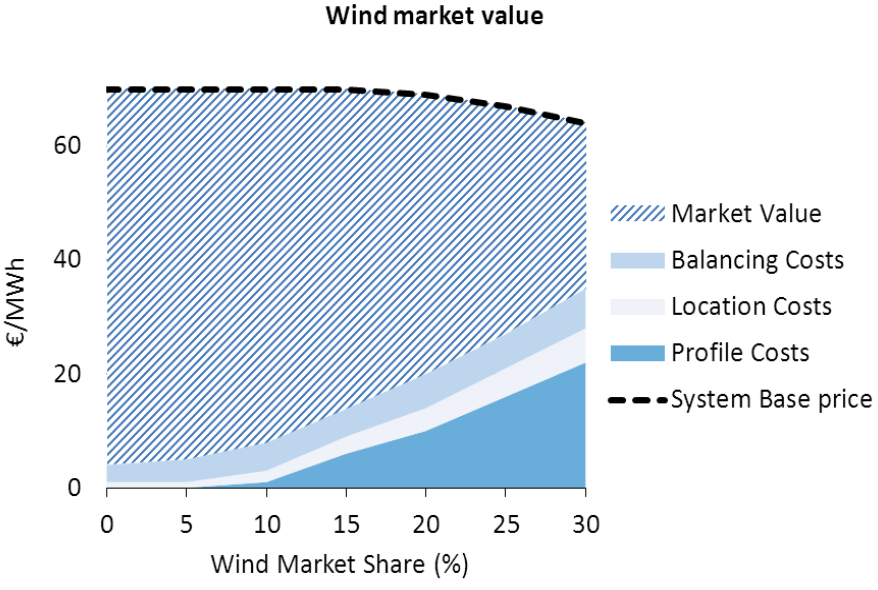

LCOE wind
120
100
80
60
40
20
0
€/MWh
24%
24% (2012 interconnection)
51% (2012 interconnection)
Investment costs wind
Profile costs
Balancing costs
Grid costs
Transmission capacity costs

Results: Market value renewables


WIND
SOLAR
WIND OFFSHORE
WIND ONSHORE
-10
-13
-26
-10
-15
-18
-9
-12
-17
-11
-14
-32
medium wind & solar
medium wind & solar, transmission 2012
high wind & solar, transmission 2012
Reduction in market value

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 intergation 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 CO_2 price, in line with CO_2 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 CO_2 reduction targets?
- Integration costs of solar?
- How can incentives be provided for renewables to minimize integration costs?