External cost of system integration for variable RE, comparing options on equal power quality

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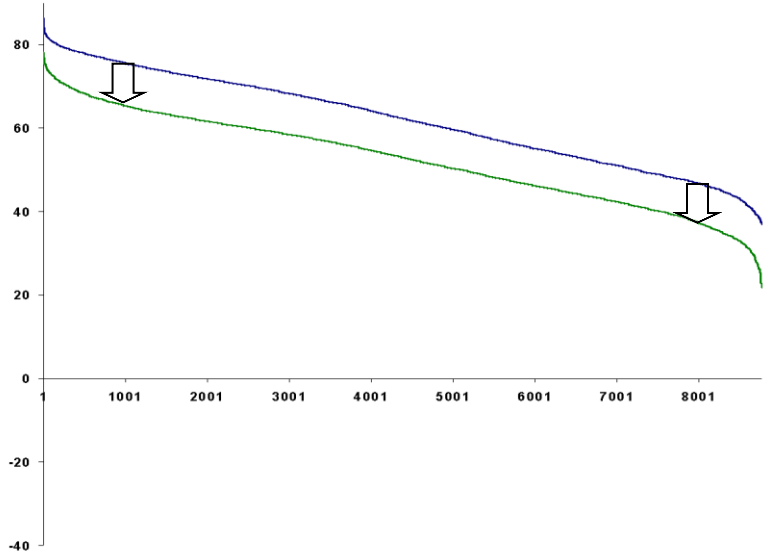
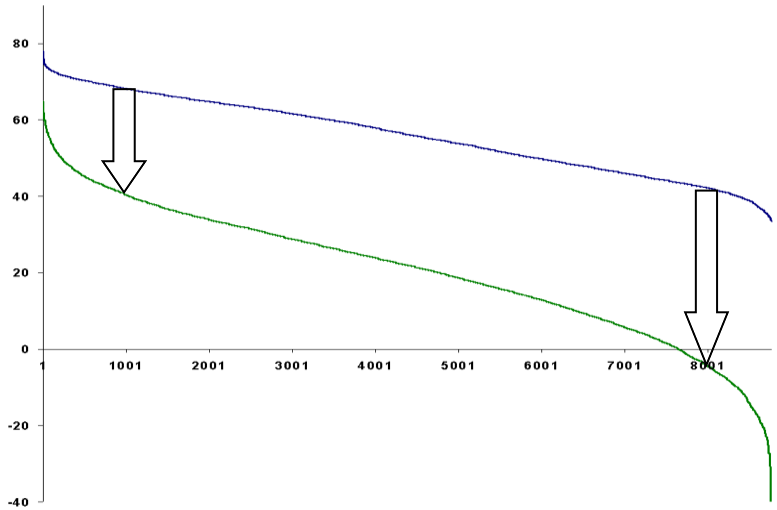
Effects of system integration
1 – Load duration curves for conventional power

Load duration 2010 in Germany

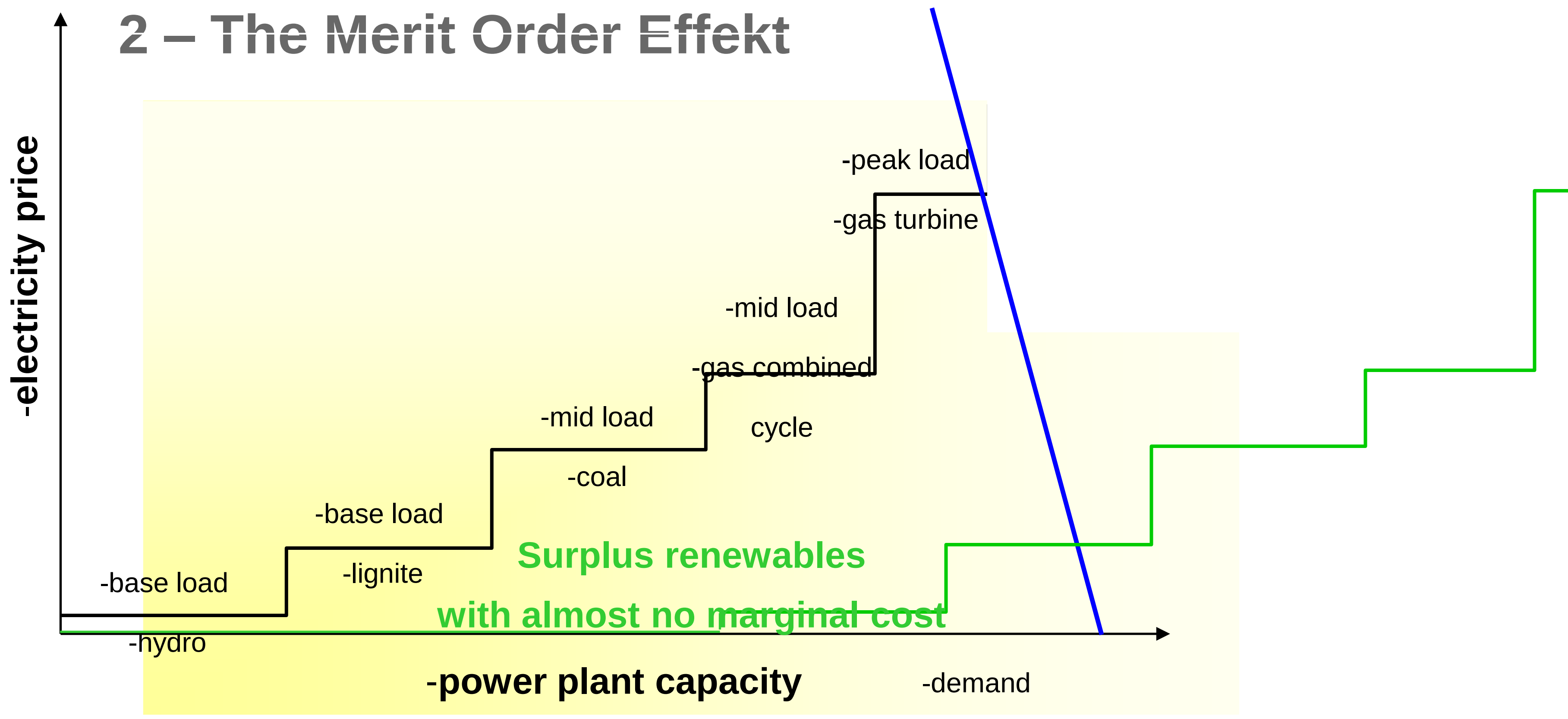


Load duration 2030 in Germany



RE contribution lowers full load hours of the residual system, which will lead to an increase in cost
(RE share in power generation 2030: 65%)

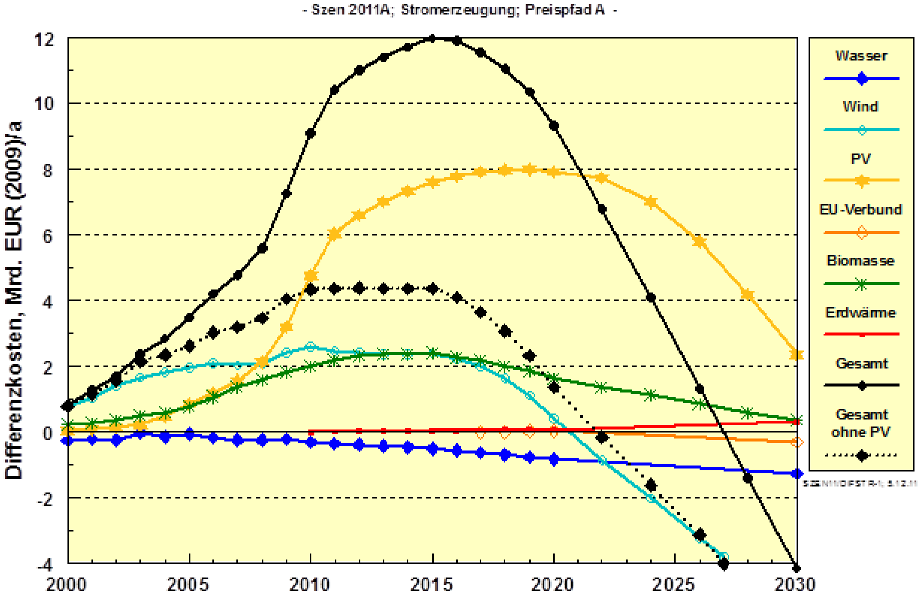
Effects of system integration
2 – The Merit Order Effekt



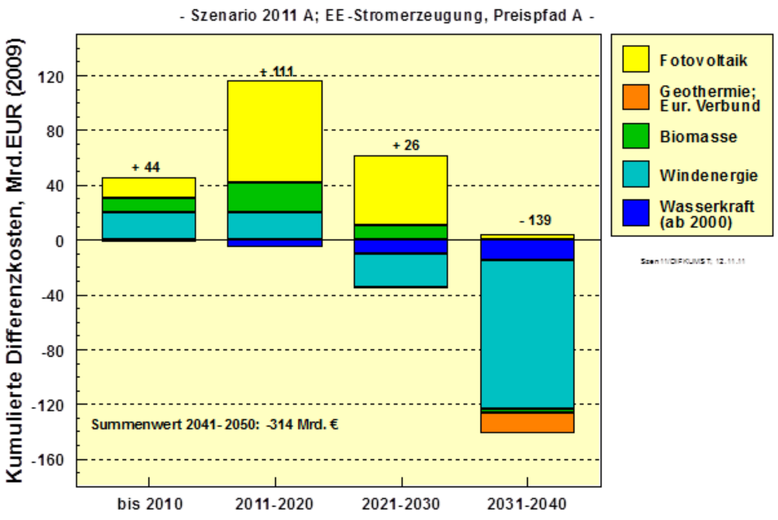
RE contribution pushes the most expensive conventionals out of the market creating a tendency to lower the price of the residual system

System Analytical Differential Cost for Germany

Annual differential cost



Cumulated differential cost

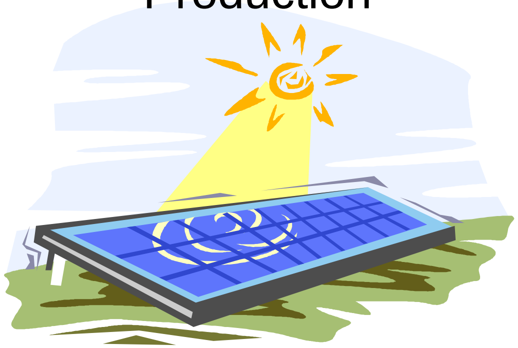


scenario for Germany up to 2050, RE share in power generation up to ~85%, compared to fossil generation scenario (fossil fuel price path A = significant increase, CO_2 costs up to 75 €/t)

Source: Long term scenarios and strategies for the deployment of renewable energies in Germany, DLR 2012

Cost of Renewable Energy? Where to look?

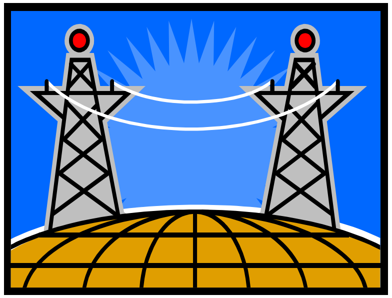
Production



$$\text{LCOE} = \frac{\text{investment + operation}}{\text{kWh}}$$

- Very low for a number of RE technologies, especially fluctuating PV and wind

Transmission

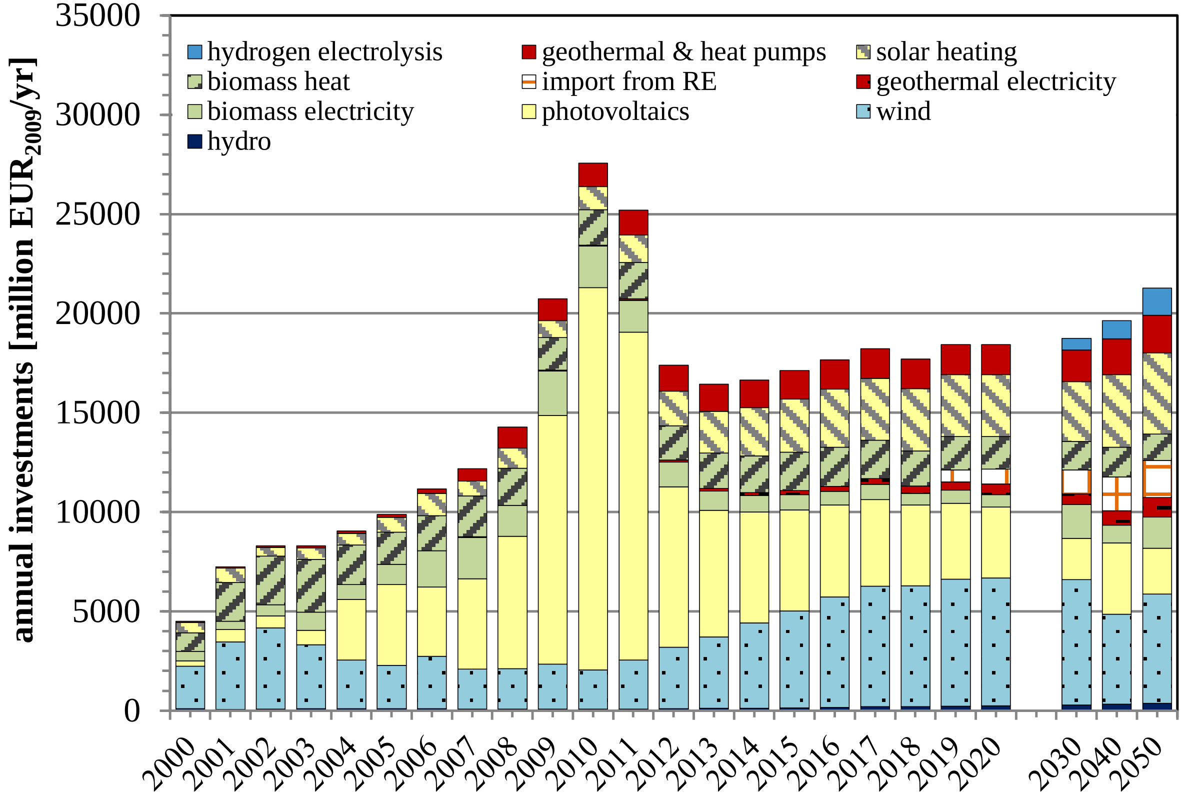


Consumption

- need for secure power on demand
- What is the price to make RE dispatachable?

The main function of the Energy system is to serve power on demand!

Annual volume of investment



scenario for Germany up to 2050, RE share in power generation up to ~85%, electricity, heat and hydrogen generation. Estimated additional investments for grid enhancement: 2-3 billion EUR_{2009}/yr

Source: Long term scenarios and strategies for the deployment of renewable energies in Germany, DLR 2012

Roles of RE in the Energy System I

- **RE as a fuel saver (low to medium RE share) – the comfort case**:
  - Existing (conventional) power system is able to fulfill peak demand at any time
  - Situation for many OECD countries, stable power demand, complete power park
  - RE contribution << total power demand (e.g. 25% in Germany), no or low RE curtailments
  - The existing power park can be used to balance variable RE, prices will increase with lower full load hours
  - **LCOE for production is a fair measure to compare power generation**

- **RE as a fuel saver (high RE share)**:
  - RE curtailments increase: the denominator decreases, e.g. the investment has to work on less full load hours.
  - RE investments get less attractive due to the increasing cost.

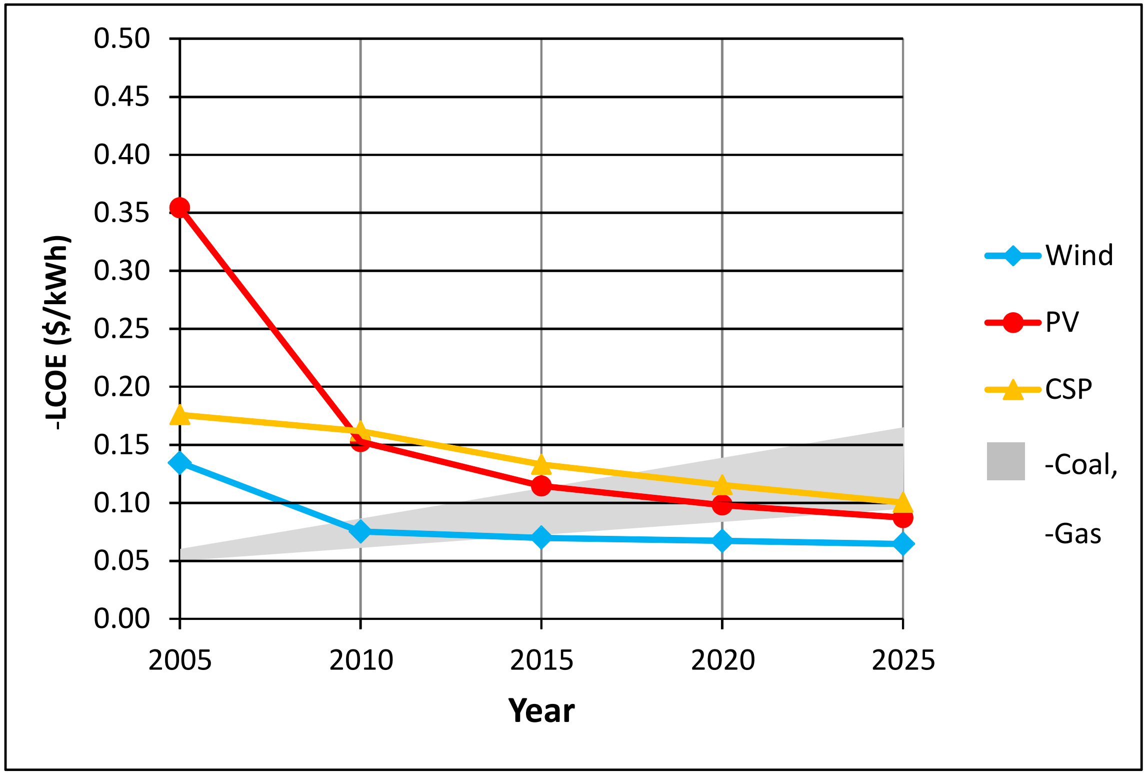
Roles of RE in the Energy System II

- **RE as added capacity in growing power systems – the ambitious case**
  - Power demand is growing over time due to economic development
  - Situation for many developing and emerging economies
  - **The existing power park CAN NOT balance the system** (anymore)

  - **Electricity options have to be compared on quality of supply (looking from the demand side)**

  - **New power has to increase secured capacity.**
  - Cost for storage
  - Cost for additional balancing power
  - Danger of technology lock-in, stranded investments which don't pay off due to rising fuel prices and reduced full load hours

CSP, PV, Wind, Fuels: cost of generation in MENA



- Installed capacity: 100 MW
- Site: North Africa
- Linear fuel cost escalation as in 2000-2010, market prices
- PV 2000 h/yr, 30 yr
- Wind 2500 h/yr, 20 yr no storage, no backup
- CSP 5500 h/yr, 40 yr incl. thermal energy storage and 10% hybrid operation with natural gas

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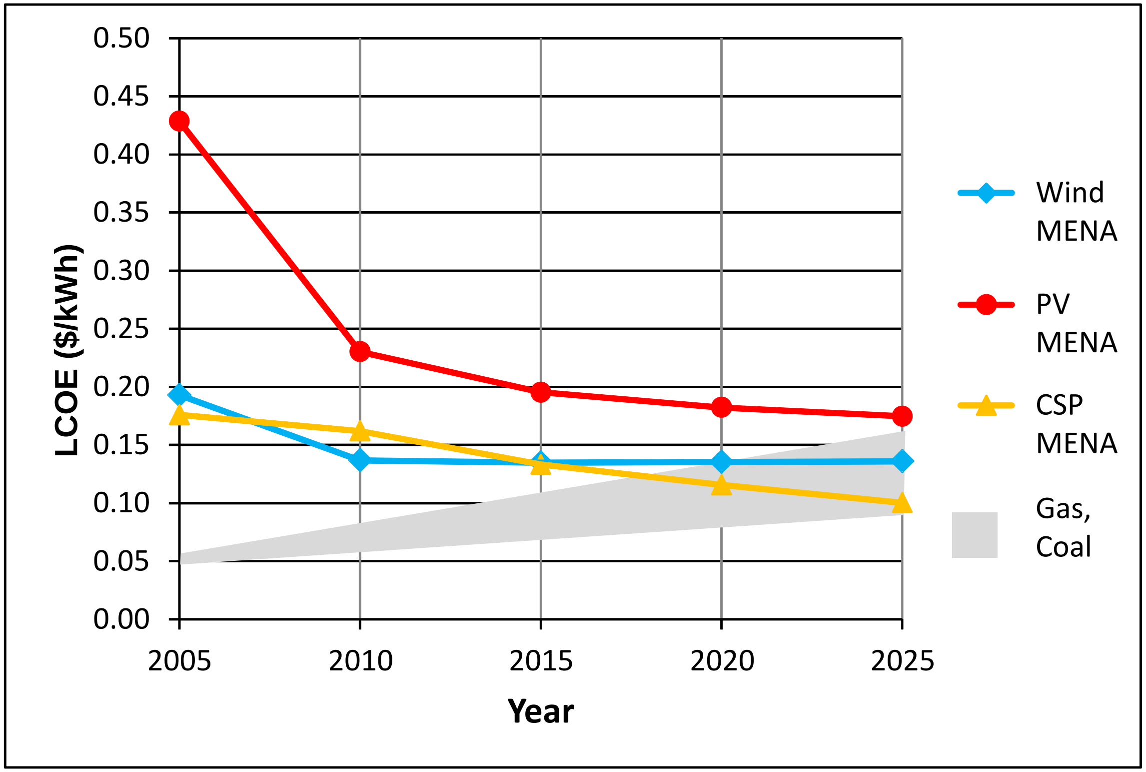
CSP, PV, Wind, Fuels: cost of flexible power in MENA



- Load: 100 MW, 5500 h/y, 40 yr
- Site: North Africa
- Linear fuel cost escalation as in 2000-2010, market prices
- PV, Wind incl. pump storage; 10% backup by natural gas combined cycle
- CSP incl. thermal energy storage and 10% hybrid operation with natural gas

Pitfalls – Technology Lock-In or Stranded Investments – Examples

- A system based on PV, wind and gas backup
    - RE penetration may not go beyond 60-70% due to nature of the sources
    - Remaining power produced from gas with rising fuel prices
    - Full load hours of conventionals decrease, stranded investments
    - Must run conditions for newly installed conventionals to pay of the investments

- Balancing by Bio-energy
    - There is a number of scenarios which use a lot of Bioenergy
    - Are there enough sustainable resources? Resource competition for food, recreation, energy, nature conservation, …

Pitfalls – Examples

- Supergrids
  - The grid transports everything from everywhere
  - Huge grid capacities are needed
  - HVDC grid technology is not yet developed and may be possible within reach only for smaller capacities (< 1 GW)
  - Balancing occurs in large regions over large distances.
  - Statistical balancing of stochastic sources (no real firm capacity)
  - (DLR vision: dedicated import of RE balancing power into smaller control zones to increase firm capacity)

Pitfalls – Examples

- Limited storage options:
  - The main large scale storage is pumped storage, which is only available in mountains with water and rain.
  - Other large scale options are still in R&D.
  - Norway is not the battery for Europe.
  - If chemical storage implemented, pumped storage may turn into a stranded investment

- Hydrogen and Methane: Production facilities need high full load hours and limited transients.

Conclusions

- RE technologies have gone a long and great way in cost reduction and are already competitive in a number of market segments!

- These technologies have gone this way in a comfortable environment of highly developed power systems which could balance their deficiencies.

- The next step to go for a high share of RE is challenging:
    - Cost will increase to make RE dispatchable
    - There are many pitfalls of technology lock-in and stranded investments

- We need to search for a balanced RE system with suitable shares of cheap variable and more flexible (dispatchable) RE, the complete investment cylce (>40 years) has to be looked at

- It’s a challenge we look forward to solve

Takeaways for Policy Makers

- It is the right well balanced mix of different renewable sources, variable and flexible which makes the power system run sustainable. If one source starts to dominate the mix, integration costs are like to rise

- Analysis needs to cover long time frames which cover complete investment cycles (>40 years) to avoid technology lock-in and stranded investments

- Analysis needs to look at local resources in high temporal resolution to find the best mix to balance the system.

- Scenario time frame should be beyond 2050 by now.