Reflections on the System-Cost Computation Approach and recent insights from the IEA Wind Task 25

Task 25: Design and Operation of Energy Systems with Large Amounts of Variable generation

Hannele Holttinen, Operating Agent Task25

Partner, Recognis

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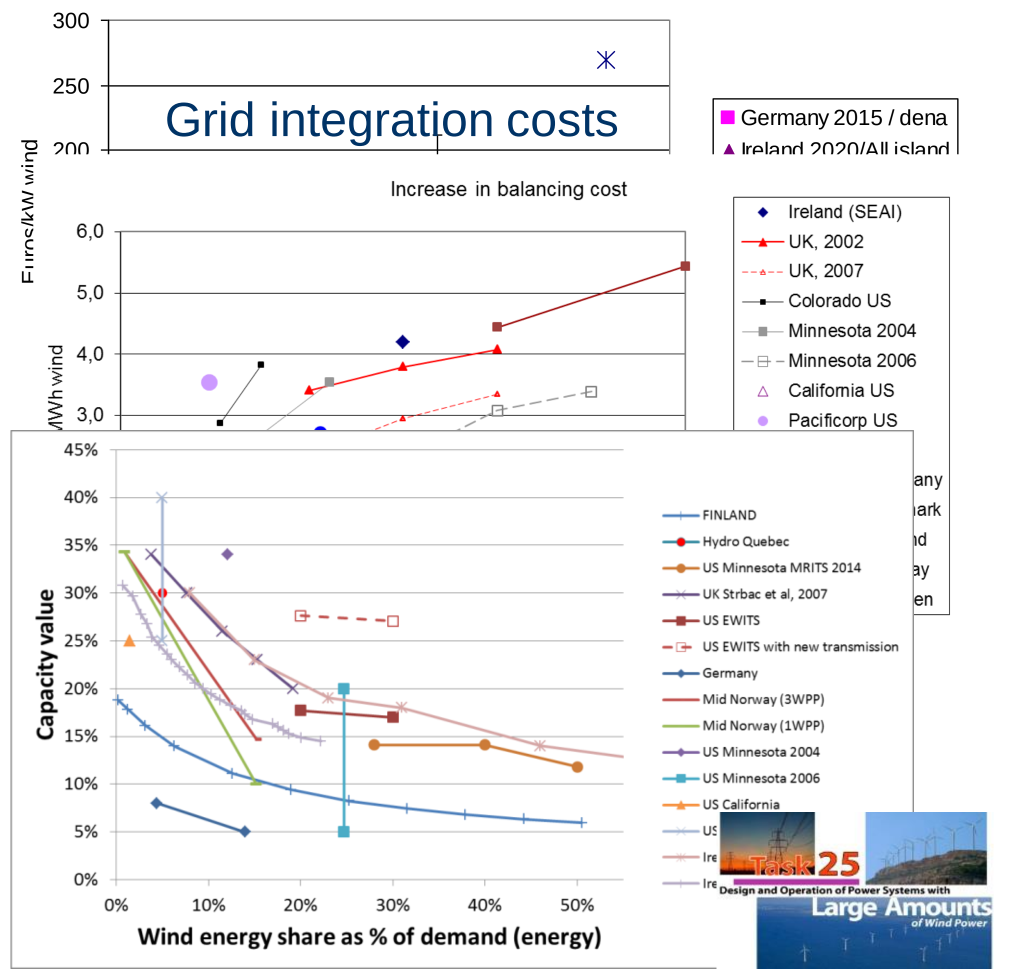
- background on previous efforts
- challenges
  1. isolating, extracting, allocating
  2. categorising to grid/balancing/profile
- approaches for assessing system integration costs
  – Total cost comparisons; Markets

Task 25
Design and Operation of Power Systems with
Large Amounts
of Wind Power

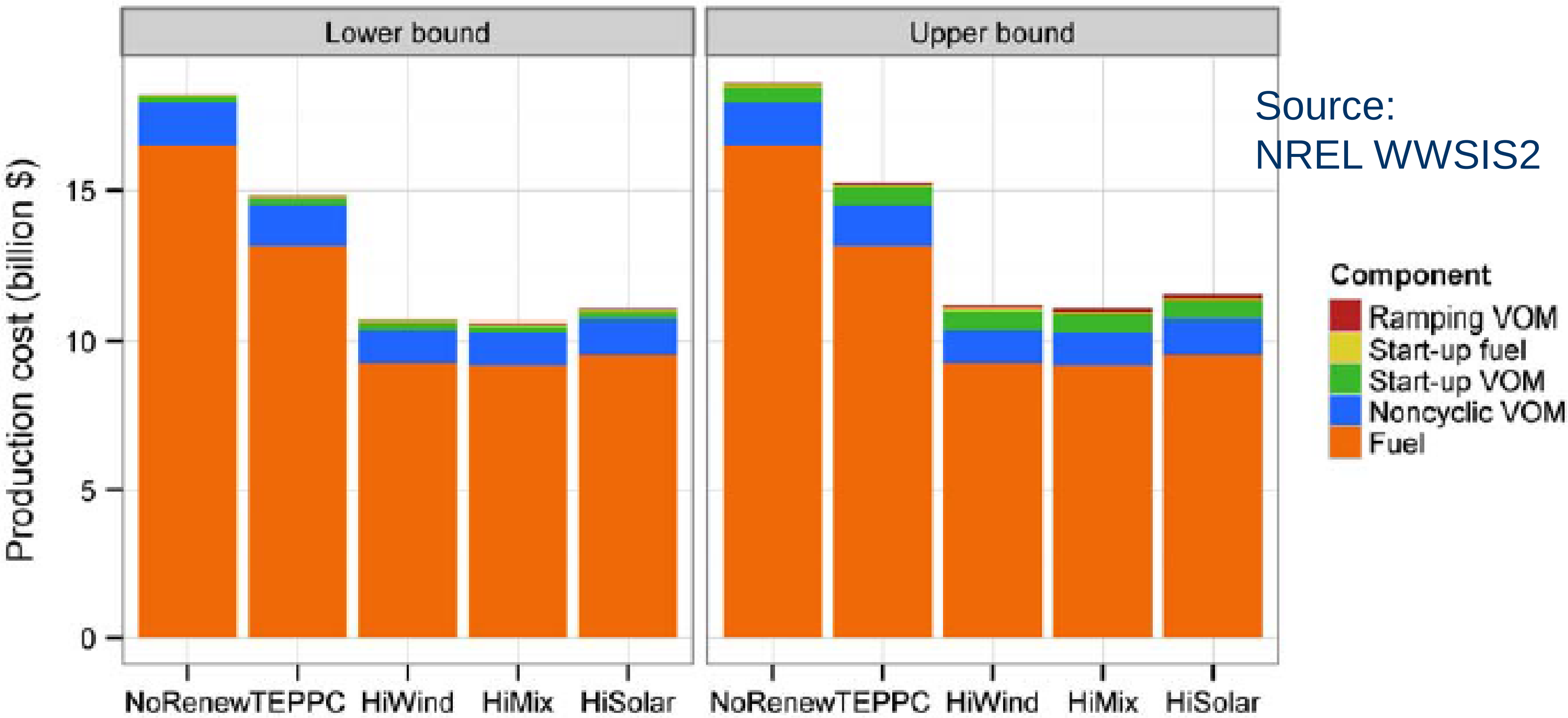
Recommending methods for integration costs – work of IEA WIND Task 25

- Comparing studies for Balancing costs, Grid infra costs, and Capacity value of wind;
  - Depend on share of VRE and flexibility available
- Recommended practices on methods: **Outcome was that we cannot find a correct way to draw estimates of integration costs**



Challenge of capturing balancing costs (operational variability and uncertainty)

Operational costs go down when adding VRE, what is the added cost?



VRE: 0% - 13% - 33% - 33%- 33%

Source:
NREL WWSIS2

Relevance of the question – with declining cost of energy of wind and PV

Wind and PV becoming mainstream → Confidence of system operators, focus more on total system integration of more renewables → Interest in balancing costs decline in the US and EU

More interest to invest in new countries → Comparison to other investment options relevant → A new interest in integration costs in some countries

Shift of interest from original integration costs as a tariff charged, for more complex system operation towards more integrated assessments

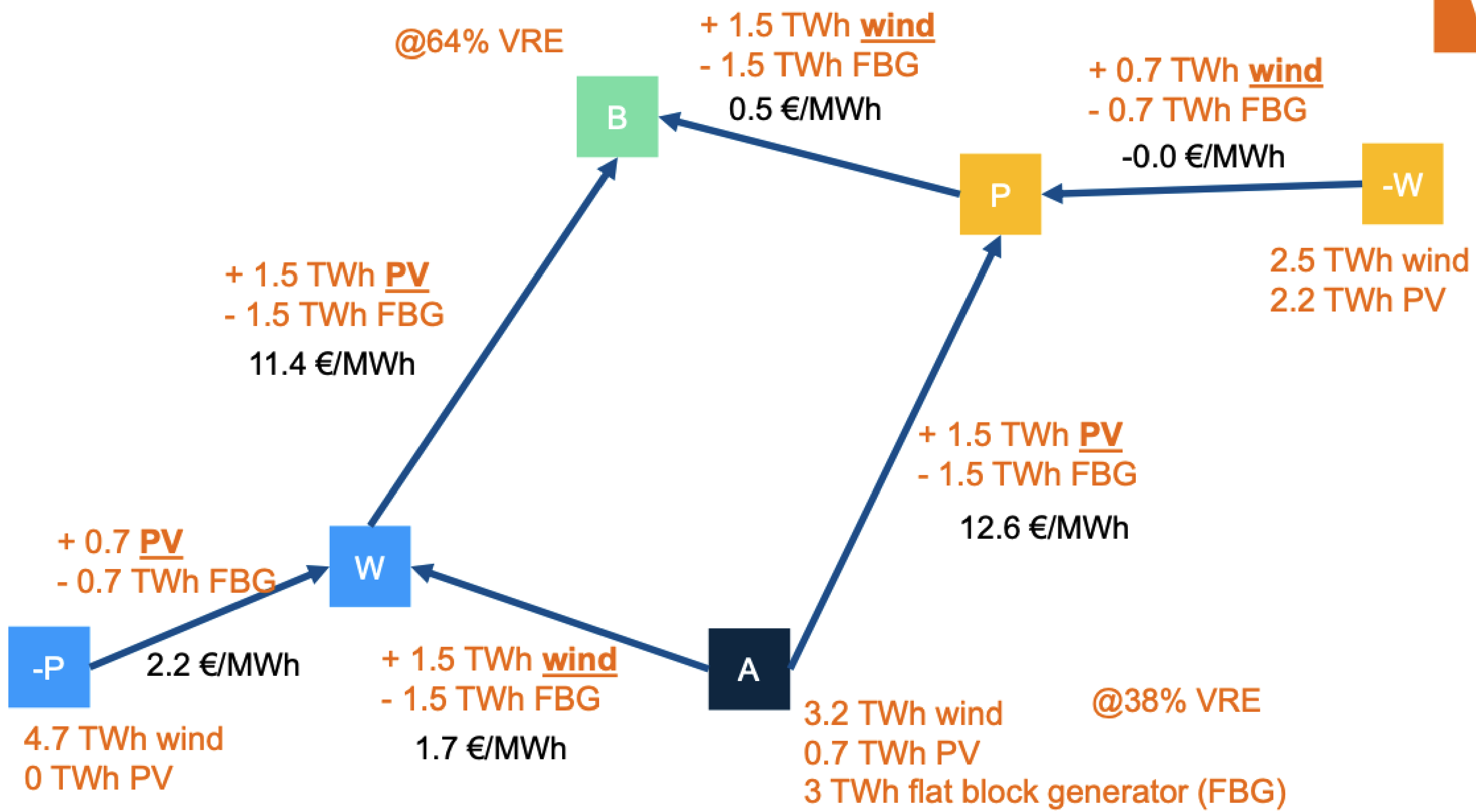
Challenge 1: isolating system costs

- How much cheaper would it be for the power system to use VRE, if VRE was *non-variable*?
- To answer, need to strip away the impact of variability from *all other* impacts VRE bring to the power system
  - generating electricity at very low short-run marginal cost and displacing other generation
  - **So far no suitable benchmark used**
  - Recent thinking: a 100%-load-correlated generator that satisfies the condition: total cost in residual system drop 1:1 with the increase of the generator

Challenge 1: extracting and allocating the cost

- **Extracting the cost** from system cost: Impacts of VRE are a result of an interaction – system specific and time specific
  - Flexibility and operational practices matter
  - Timing/order of technology, is it the first or second of third addition to system will impact the results
- **Allocation** is difficult: any flexibility build out to manage variability will have benefits for all

Wind, PV and battery, from A to B at different paths



Source: Juha Kiviluoma presentation May 2021 **EERA/ESIG Joint Webinar: Towards a Common Understanding of Energy System Costs**

Related challenge: system boundary

- Neighbouring areas: Result from previous comparisons: assumptions of the interconnector use to neighboring systems has a large impact on results
- System boundary in future: decarbonizing challenge leading to electrification: energy sector coupling, flexibility from heat and transport and industry sectors

Challenge 2: categorising effects

→ Grid cost, balancing cost and long term capacity cost (profile cost)

- TSOs see the grid and balancing costs, and resource adequacy related security of supply as a physical challenge
- Profile costs as discussed, more an economical issue – not reaching optimal, efficient system due to VRE variability

Challenge 2: categorising effects to grid

- Grid costs can be separated
- Allocation problem:
  - How to allocate a cost of an asset that is used by all users, and increases reliability of system, to one single cause to build that asset?
  - Especially when multiple reasons to build
- Optimising transmission and generation expansion will be beneficial for larger VRE shares

Challenge 2: categorising effects to balancing

- Balancing: costs for short term variability and uncertainty in balancing and operating reserves
- How to choose the non VRE case

→ generator behaving like load, reducing cost of remaining system 1:1

- Quantifying impact of VRE, as main impact is reduction of use of fuel and operational costs

→run UCED without any extra reserves needed = flexibility part of profile costs

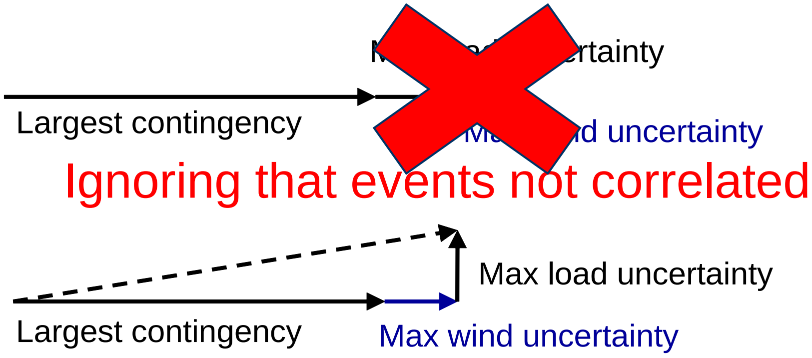
→ Balancing cost as uncertainty = cost of increased reserve allocation and use of them

- Allocating costs to VRE may still be questionable

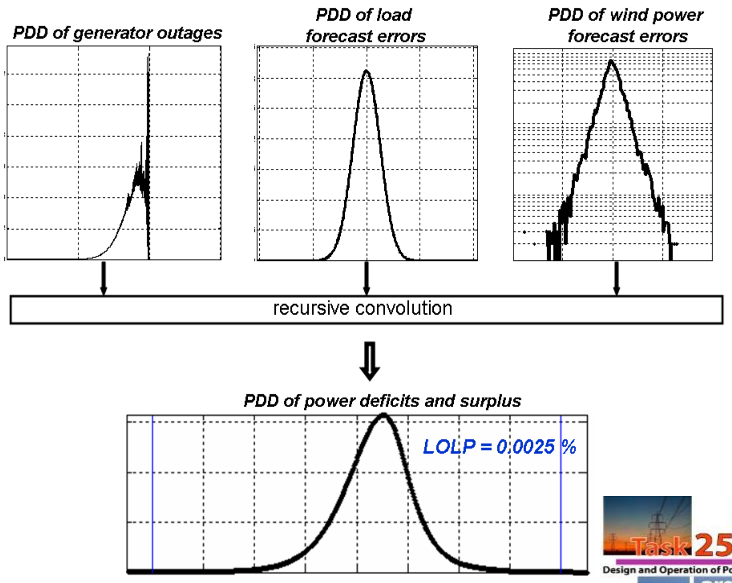
Balancing costs

System copes with variability and uncertainty of loads – and sudden failures of large thermal power plants. Combining variability and uncertainty of all sources is key.

From simple rule of thumb:



To probabilistic analyses:



Experience: sharing balancing will help more than wind adds

- Sharing balancing task with neighbouring system operators in Germany has resulted in reduction of use of frequency control, while wind and solar have increased
- Denmark integration of close to 50% wind share is based on using Nordic hydro power system flexibility

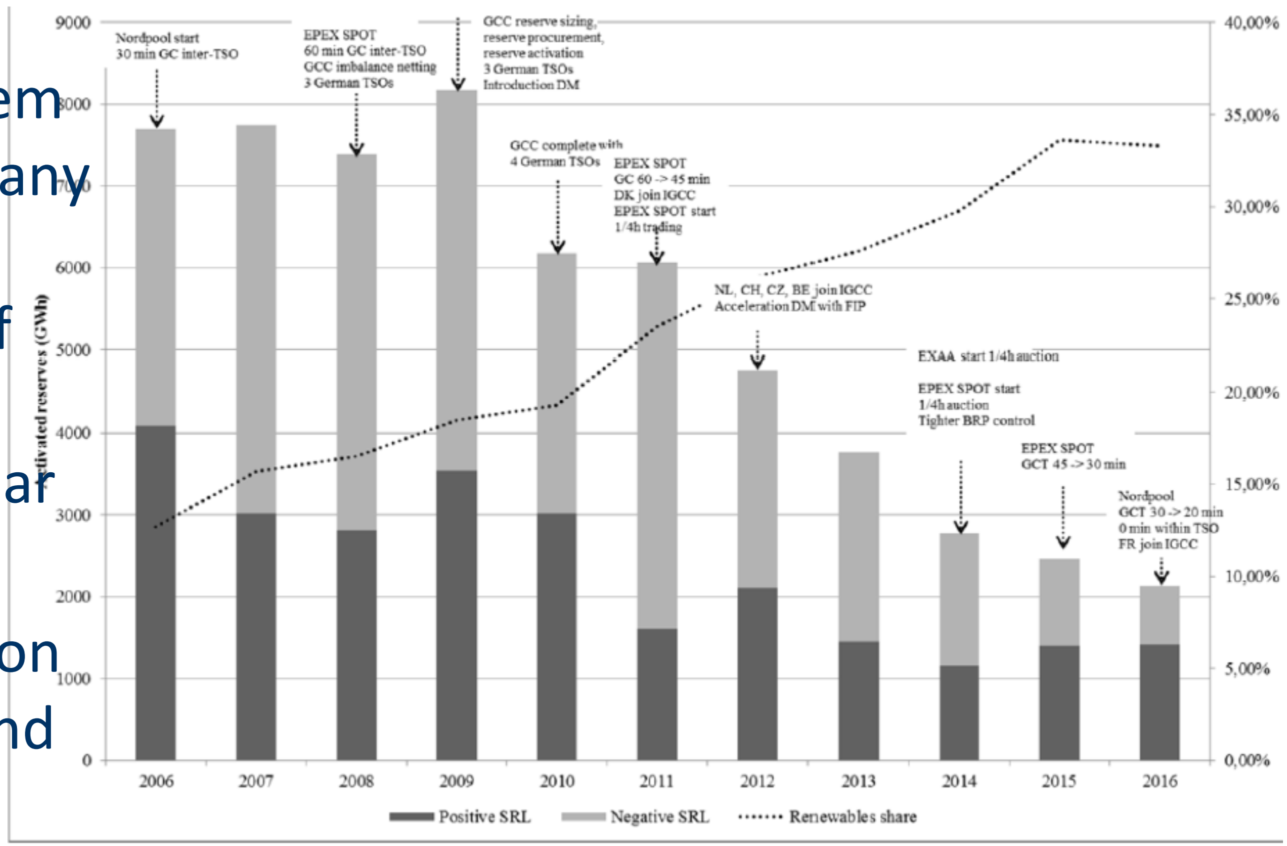


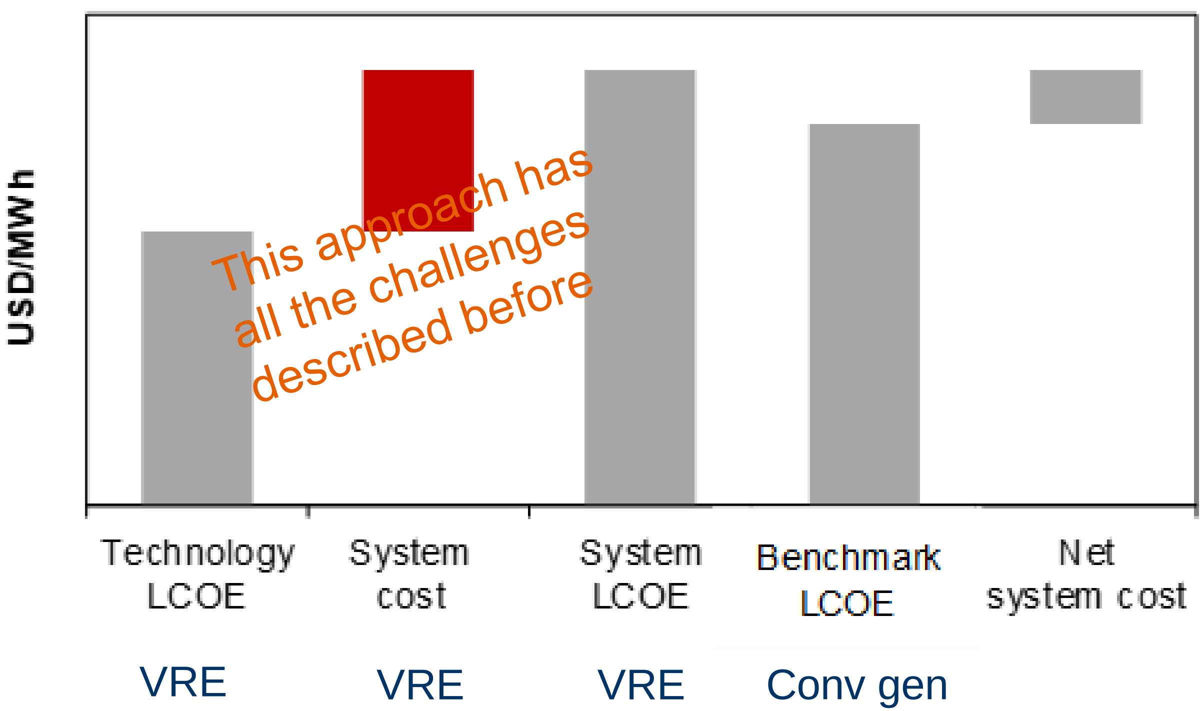
Figure 13: Total activated German Secondary Reserves (or aFRR) per year marked with events considered in this paper.

Rena Kuwahata, Peter Merk, WIW17

Challenge 2: categorising effects to long term capacity

- Security of supply, resource adequacy in future
  - peak load contribution of VRE converted to a cost of peakers added to cover for lower capacity value of VRE
- Economical impact: lower cost to meet demand from non-VRE sources, but higher specific cost /MWh
  - The short term reduction of utilisation rate, also a system property, a ”private cost” or allocated to someone?
  - Long run costs for the new generation mix – from a generation mix optimised for VRE: a system cost of VRE in comparison to an alternative way of covering the load
  - Extracting this cost: double counting with balancing impacts

A nice to have: system integration cost component on top of LCOE

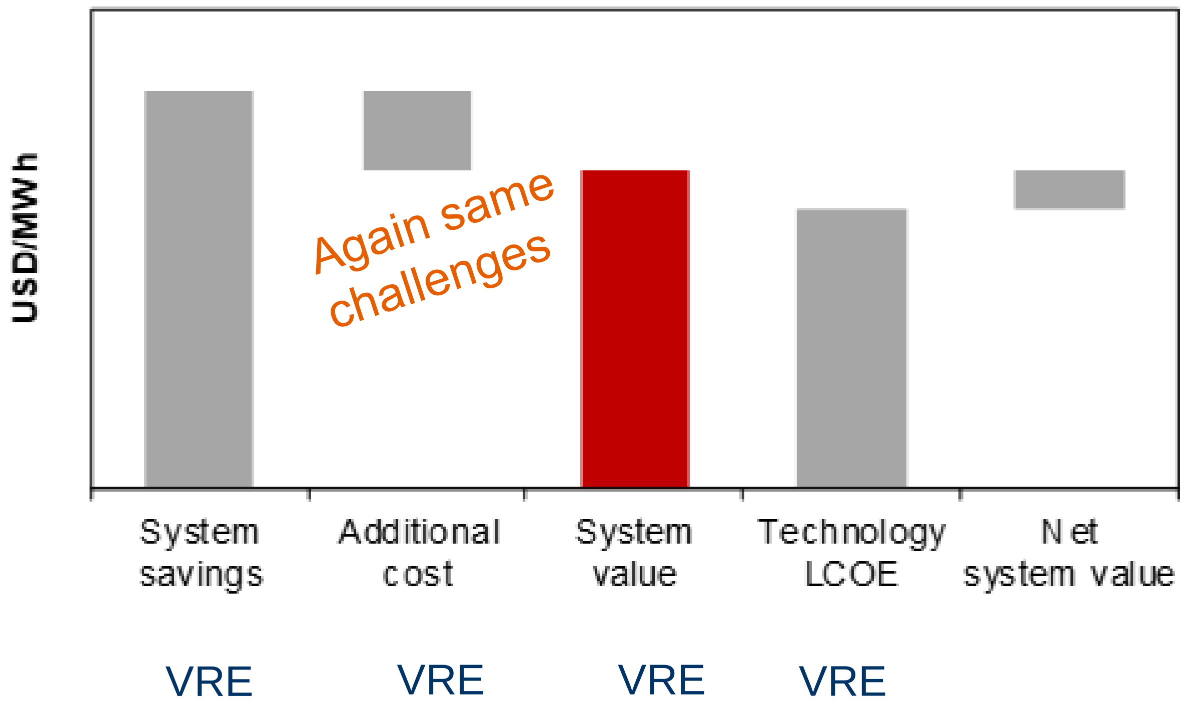


System cost defined relative to scenario with less VRE and benchmark. Valid for specific system and VRE share only.

(Benchmark technology can also include system cost)

LCOE levelised cost of energy

…or additional system cost for system savings



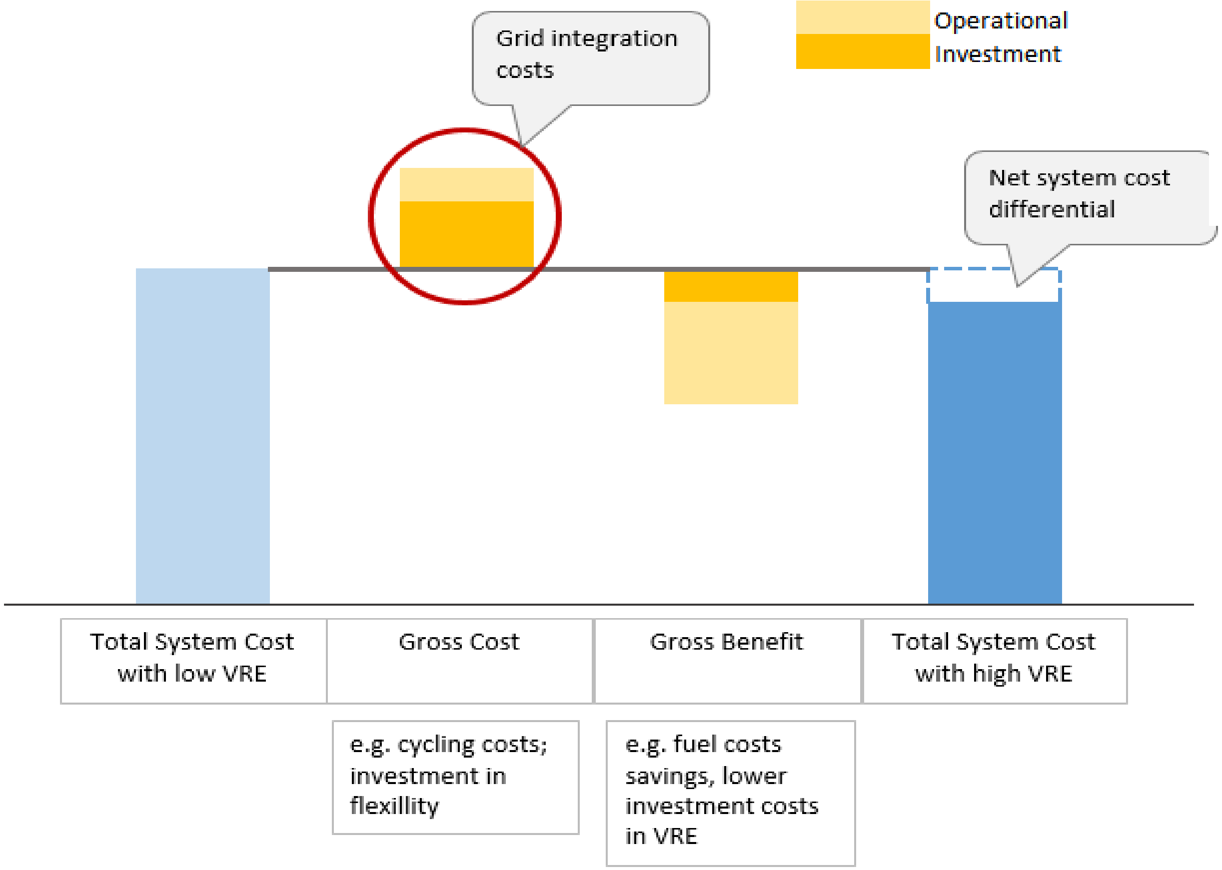
System value defined relative to scenario with less VRE (plus environmental). Valid for specific system and VRE share only.

Check if value larger than LCOE of VRE

Total system cost comparison

- Change question to How much cheaper or more expensive will it be for the power system to rely on a certain amount of VRE generation compared to an alternative scenario?
- Compare the all-in system costs of different scenarios – CAPEX & OPEX. Results still depend strongly on what is chosen as reference scenarios for the comparison.
  - avoid the pitfalls of introducing a benchmark technology

Total system cost comparison



- does not provide a direct quantification of different VRE related effects – although some of them may be extracted from simulation results

…from Juha 26 May 2021

Total system cost

- Is not misleading
- The audience can immediately understand that the whole system matters
- Directs the attention to finding cost-effective solutions for fulfilling objectives (e.g. emission reductions) at least cost
  - Improve markets, transmission, flexibility, sector coupling,…
  - Analyzing the particular system
- Discuss the assumptions, modelling methodology, etc.
  - Is the sector coupling considered
  - Is VRE allowed to provide reserves
  - How many years were considered
  - …

Capturing the future challenge of high VRE and high IBR operation, as costs in the models, is still meaningful (G-PST!)

Integration costs directly to VRE from market operation

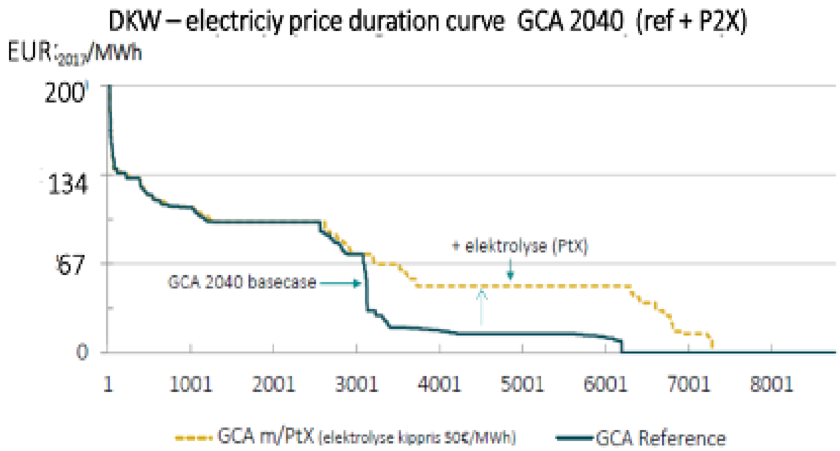
- System integration costs increasingly visible and carried by VRE
  - Grid costs in (locational) connection fees and tariffs
  - Balancing costs allocated in a cost reflective, transparent imbalance settlement for VRE generation
  - Reduced system value as market income decrease, the profile cost
- Market price evaluation considers short term only (no information about investment cost differences)
- Simulated future market prices – historical market prices have several other issues

Reduced system value – in future

– Reduced system value as market income decrease, note that extensive low prices – and volatile prices – would incentivise demand response, especially new electrification demand (power2heat, EVs, power2X)

ENERGINET

P2X CAN INCREASE THE VALUE OF WIND/ PV



No P2X in the basecase.

In P2X scenario there is:

- 750 MW electrolysis in DK
- Ca 26 GW in DE, UK, NL and DK in total

The average annual settlement price for wind and PV in DKW increases from ~20 €/ MWh to 40 €/ MWh in the P2X scenario

Summary – challenges

- Capturing "system integration cost" component is a challenge
  - Isolating/extracting integration from other costs, no good benchmark exists (benchmark technology; benchmark system)
  - Defining system boundaries – energy sector coupling
  - Dividing costs to variability, uncertainty, location without double-counting
  - Allocating the cost to single technology – when multiple benefits

Summary – total costs; markets

- Total system costs including operational and investment costs – still, results are system and share of VRE -specific
  - Assumptions about future systems – and system boundaries crucial: Flexibility of generation fleet (including VRE) and demand; storages and operational practices
  - Need to check are all costs covered in the modelling
  - VRE dominated systems, >50% share: how to design the most efficient system. From cost of integration to cost of inflexibility
- Market based approach: balancing, market value
  - simulated transparent market rules for future
  - VRE increasingly carrying the costs, not ”hidden”

From discussions yesterday:

- Transparent method for all technologies
  - fully load following benchmark
  - a range of system costs instead of one number, different systems
  - LCOE affecting the system integration cost?
  - cost for overproduction/curtailments?
  - cost for reduced full load hours?
- marginal costs easier to assess
  - dangerous to compare 2 very different systems and allocate costs to VRE
  - are marginal impacts meaningful to assess?
- comparable/ref scenario depends on what question you are asking

Based on

- System integration costs - a useful concept that is complicated to quantify? S Müller (IEA), H Holttinen (VTT), E Taibi (IRENA), D Fraile (WindEurope), J C Smith (ESIG), T K Vrana (Sintef). WIW18 paper.
- Email discussions of L Söder (KTH), S Müller, L Hirth 2019
- Juha Kiviluoma presentation May 2021 **EERA/ESIG Joint Webinar: Towards a Common Understanding of Energy System Costs**
- Recommended Practices for wind/PV integration studies, IEA WIND RP16 Ed.2

  https://iea-wind.org/wp-content/uploads/2021/06/RP-16-Ed-2-Wind-PV-Integration-Studies-Final.pdf

  IEA WIND Task 25 summary reports

  https://iea-wind.org/task25/

Thank You!!

Hannele Holttinen

Hannele.Holttinen@recognis.fi

+44 7864336354

+358 40 5187055