

Advances in wind integration

Recent findings from international
collaboration IEA WIND Task 25

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

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Introduction: On Task 25 work and Status of wind integration

Highlights from recent wind integration experience and results from integration studies

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iea wind

IEA Wind Task 25 – What Does It Do?

Started in 2006, now 17 countries + WindEurope participate to provide an international forum for exchange of knowledge
State-of-the-art: review and analyze the results so far: **latest report fall 2018**

Formulate guidelines- Recommended Practices for Integration Studies: **Update expected in July**
Fact sheets and wind power production time series. Literature list.

<https://community.ieawind.org/task25/>

Task 25 Fact Sheet

WIND INTEGRATION ISSUES

Large Amounts of Wind Power

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

Final summary report, IEA Wind Task 25, Phase three 2012-2014

How is wind power different from other generation?

The main characteristics that differentiate wind power from other forms of generation are its variability and its uncertainty.

- Conventional power plants generate at specified levels that operators can vary up or down as needed—they are dispatchable (except in cases of operational failure).
- Wind power generation varies depending on how wind fluctuates. However, the variations in output are smoothed when many wind power plants are aggregated over an area in a power system (Figure 1).
- To deal with uncertainty, wind power output can be forecast minutes, hours, and even days ahead. Forecasts for minutes or a few hours ahead are more accurate than for 12 to 48 hours ahead. Aggregating wind power plants over a wider geographic area will improve the forecast accuracy at all time frames.

See Fact Sheet: Variability and Predictability of Large-Scale Wind Power

How do operators balance wind plant output? Does wind power need dedicated back-up?

Electric power systems experience varying electricity consumption (demand), as well as failures that cause power plants to go off line; all of these are balanced together with wind power.

- To balance the variations in demand and supply, system operators adjust the output of some plants. In this way demand is met at all instants and demand and supply are balanced.
- Variations of system demand and wind output often cancel each other out. Sudden, large changes of wind and demand are rare and tend to occur simultaneously.

Figure 1: The short-term variations of the single turbine's output (top) are smoothed when aggregated to the output of a group of wind plants (middle). Aggregation of the output from all turbines in one many different countries, the variations even more. (Source: Task 25 summary report, 2009)

Agency Report on Recommended Practices for Integration Studies

Executive Committee Agency Implementing Agreement for the Development, and Deployment of Energy Systems

Sept. 12, 2013





IEA Wind Task 25

Design and operation of power systems with large amounts of wind power

18 countries + Wind Europe participate

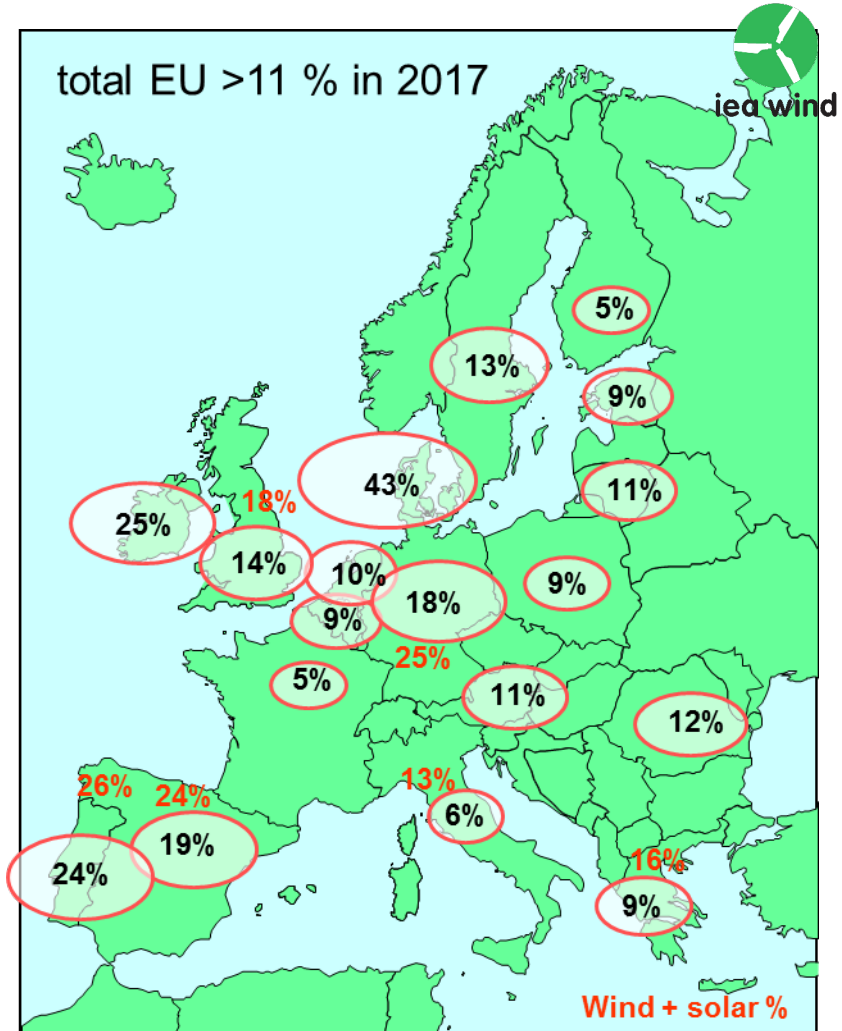
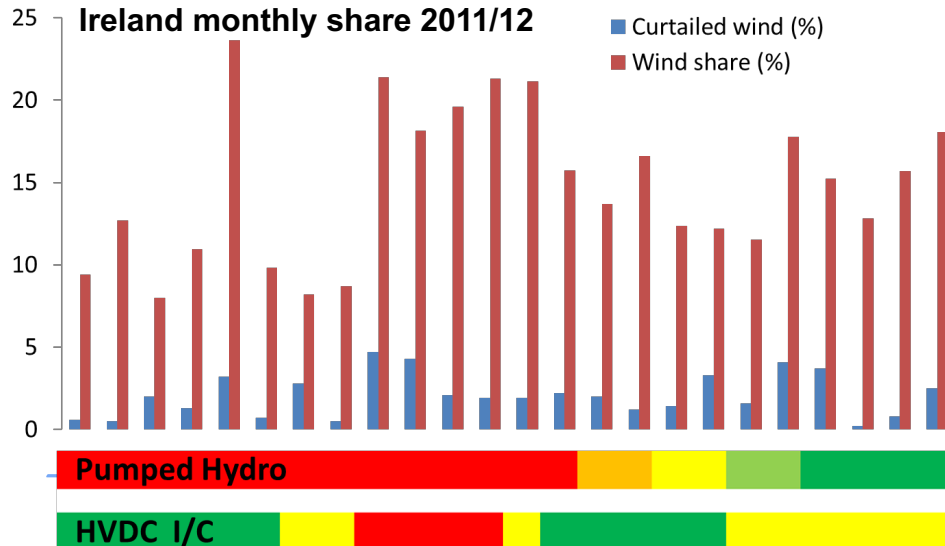


Country	Institution
Canada	Hydro Quebec (Alain Forcione, Nickie Menemenlis); NRCan (Thomas Levy)
China	SGERI (Wang Yaohua, Liu Jun)
Denmark	DTU (Nicolaos Cutululis); Energinet.dk (Antje Orths, Peter Börre Eriksen)
Finland (OA)	VTT (Hannele Holttinen, Juha Kiviluoma)
France	EdF R&D (E. Neau); TSO RTE (J-Y Bourmaud); Mines (G. Kariniotakis)
Germany	Fraunhofer IEE (J. Dobschinski); FfE (S. von Roon); TSO Amprion (P. Tran)
Ireland	Energy Reform (J. Dillon, M. O'Malley); UCD (D. Flynn); SEAI (J. McCann)
Italy	TSO Terna Rete Italia (Enrico Maria Carlini)
Japan	Tokyo Uni (J. Kondoh); Kyoto Uni (Y. Yasuda); CRIEPI (R. Tanabe)
Mexico	INEEL (Rafael Castellanos Bustamante, Miguel Ramirez Gonzalez)
Netherlands	TU Delft (Simon Watson)
Norway	NTNU (Magnus Korpås); SINTEF (John Olav Tande, Til Kristian Vrana)
Portugal	LNEG (Ana Estanquero); INESC-Porto (Ricardo Bessa)
South Africa	CSIR (Robbie van Heerden, Jarrad Wright)
Spain	University of Castilla La Mancha (Emilio Gomez Lazaro)
Sweden	KTH (Lennart Söder)
UK	Imperial College (Goran Strbac); Strathclyde Uni (Olimpo Anaya-Lara)
USA	NREL (Bri-Mathias Hodge); UVIG (J.C. Smith); DoE (Charlton Clark)
Wind Europe	European Wind Energy Association (Ivan Pineda, Daniel Fraile)

Experience of wind integration is increasing

Higher and higher shares are being integrated in European countries, on average and as hourly maximum share:

- Denmark and Portugal > 100% of demand, Ireland > 60 % of demand



Experience: US

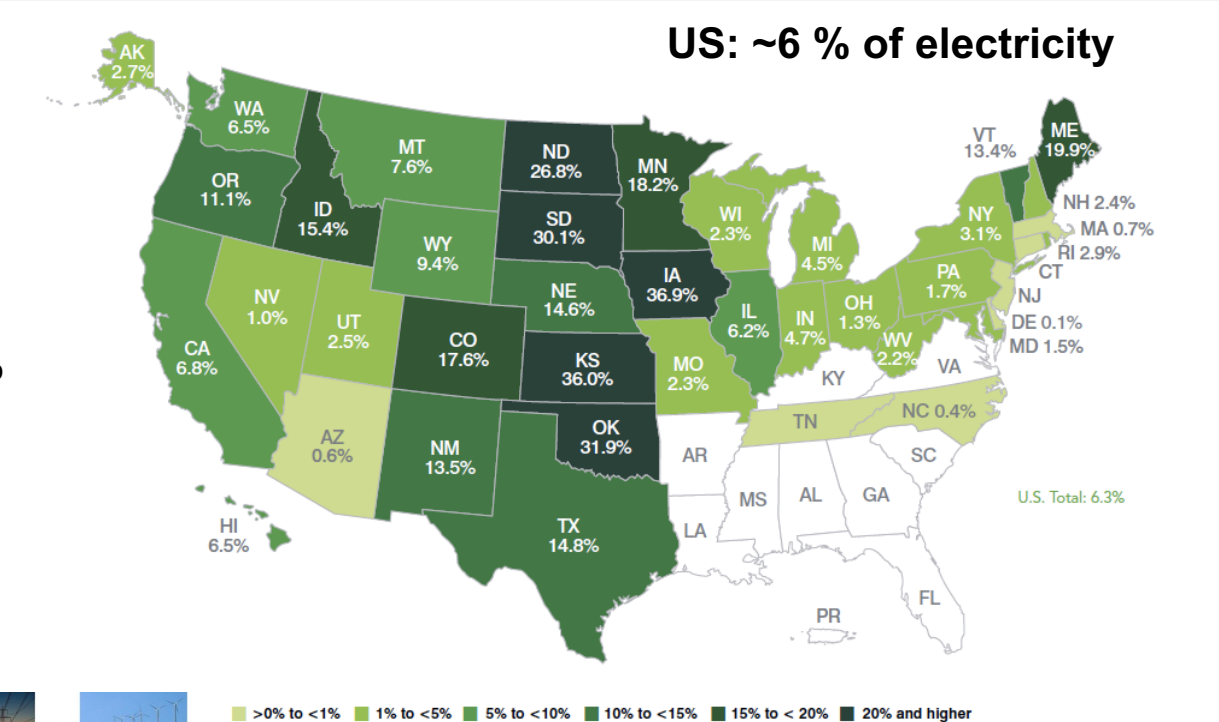
US states > 30 % share of wind:

- Iowa, Kansas, Oklahoma, South Dakota

Highest hourly shares > 50 %

- SPP (Southwest Power Pool) and Ercot (Texas)

Figure 24
U.S. Wind Energy Share of Electricity Generation, by State



Source: EIA



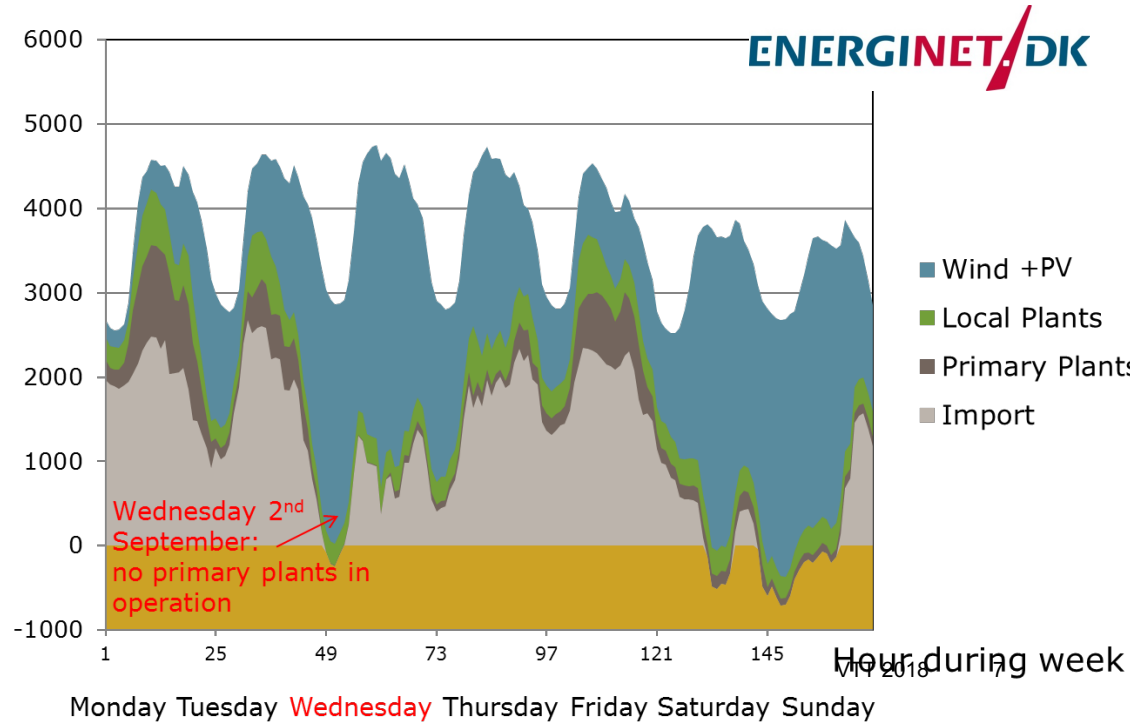
Experience: Denmark operating the system without central power plants

First time in 2015 and several ^{MW} times since then, all central power plants shut down. The necessary system support is built into the grid:

- HVDC link: 700 MW Denmark-Norway
- synchronous compensators 4 in DK-W and 2 in DK-E
- and small scale power plants



2nd September 2015 without central plants
- hourly dispatch 31 August – 6 September 2015



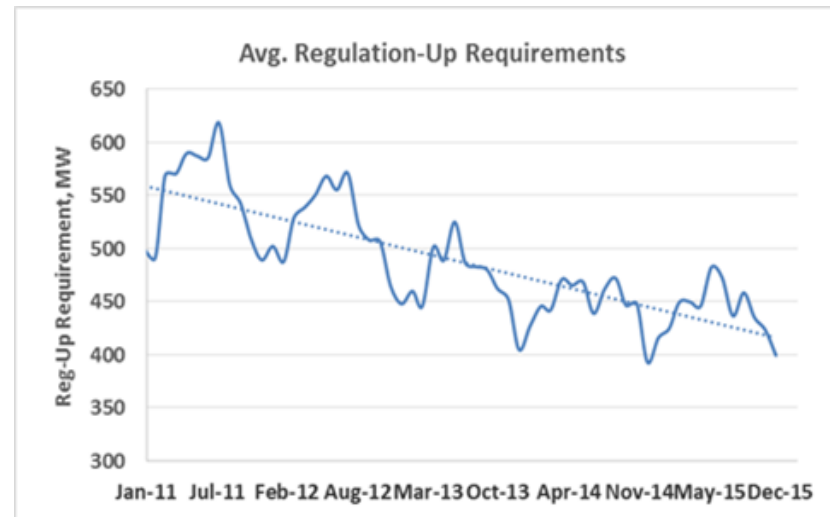
Experience: Wind power giving frequency support

Colorado: wind used as AGC (secondary control) when curtailed

Texas: wind power plants actively used in frequency control: fast response actually contributes to reducing the overall need for frequency support services

Spain: more than 50 % of wind power plants provide frequency support

- 6 % of tertiary reserves from wind power in 2017

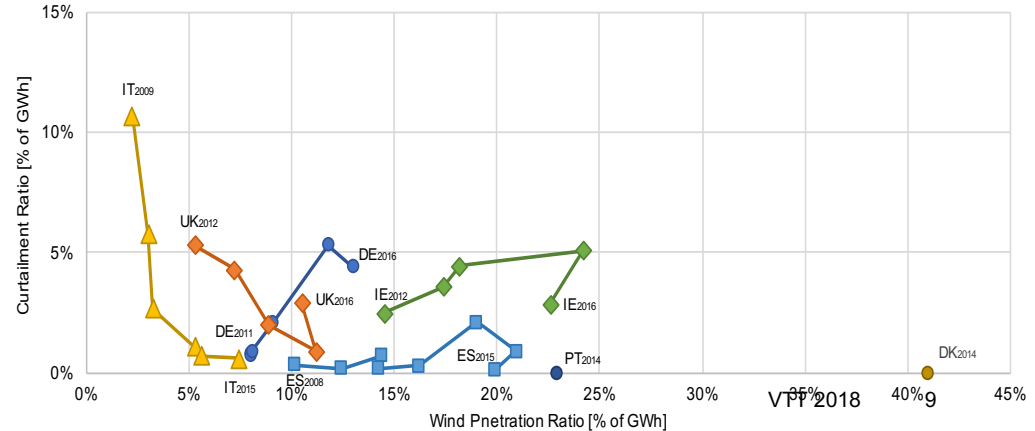
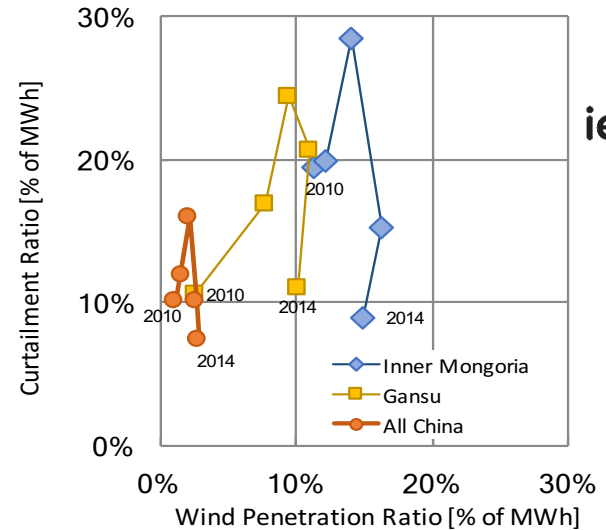


Source: Julia Matevosjana, ERCOT

Experience: curtailments

Curtailing wind power generation is one signal of lack of flexibility in the power system

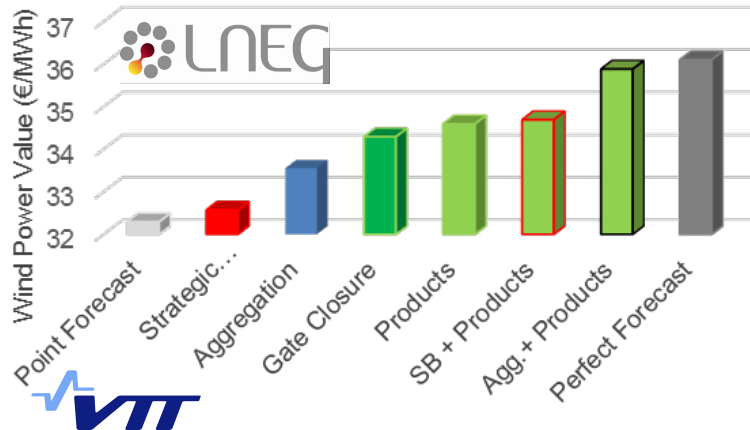
- Due to delays of transmission: Italy and Texas – diminished after grid build out. Germany, still an issue
- Due to inflexibilities of coal power plants and tariffs: China
- Due to limits of non synchronous generation: Ireland (small system)



Operational practices: market design to enable wind integration

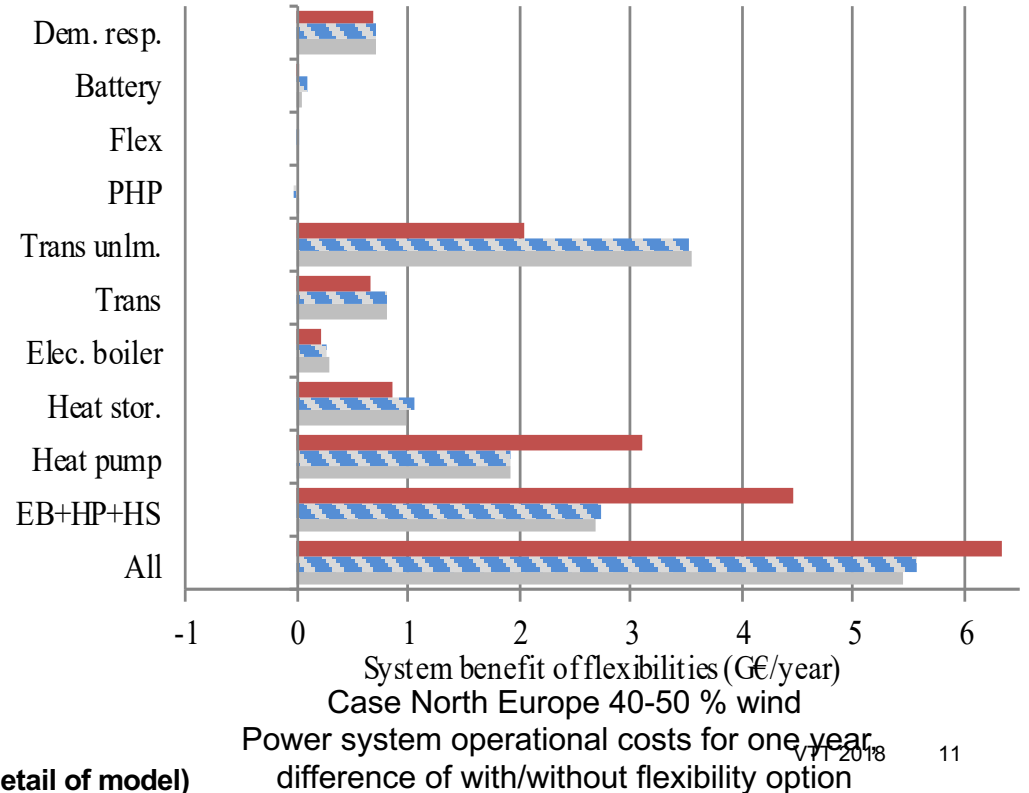
Enabling wind power plants to bid their flexibility to the markets

- With extra gains from balancing products



Value of flexibilities when large share of wind power

- Transmission and trade with neighbouring areas gives most value
- Power to heat offers flexibility in Northern Europe
- Demand response is cost effective when low costs
- Storage is still expensive
- All flexibilities together: less benefit than individual flexibilities separately



Towards higher shares of wind and solar energy

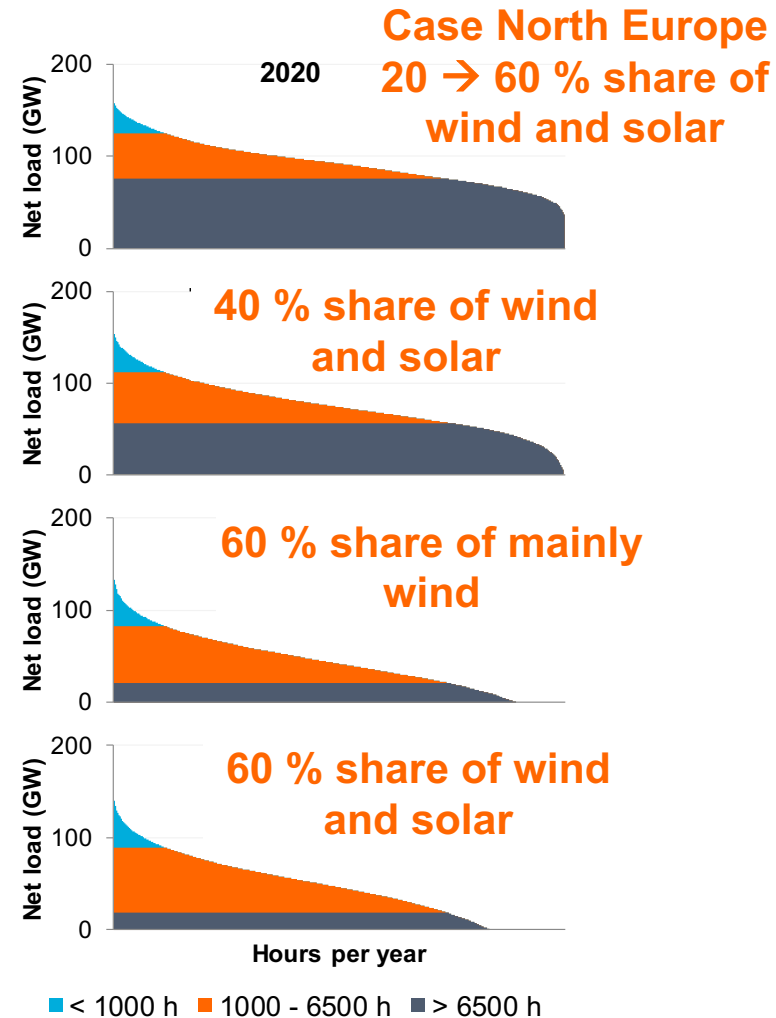
The time of base load power plants is over

- Less and less time operating (full load hours), resulting in costs/MWh getting high

The time of flexible power plants is here

- producing less than 5000 hours per year, much of that time at part load operation

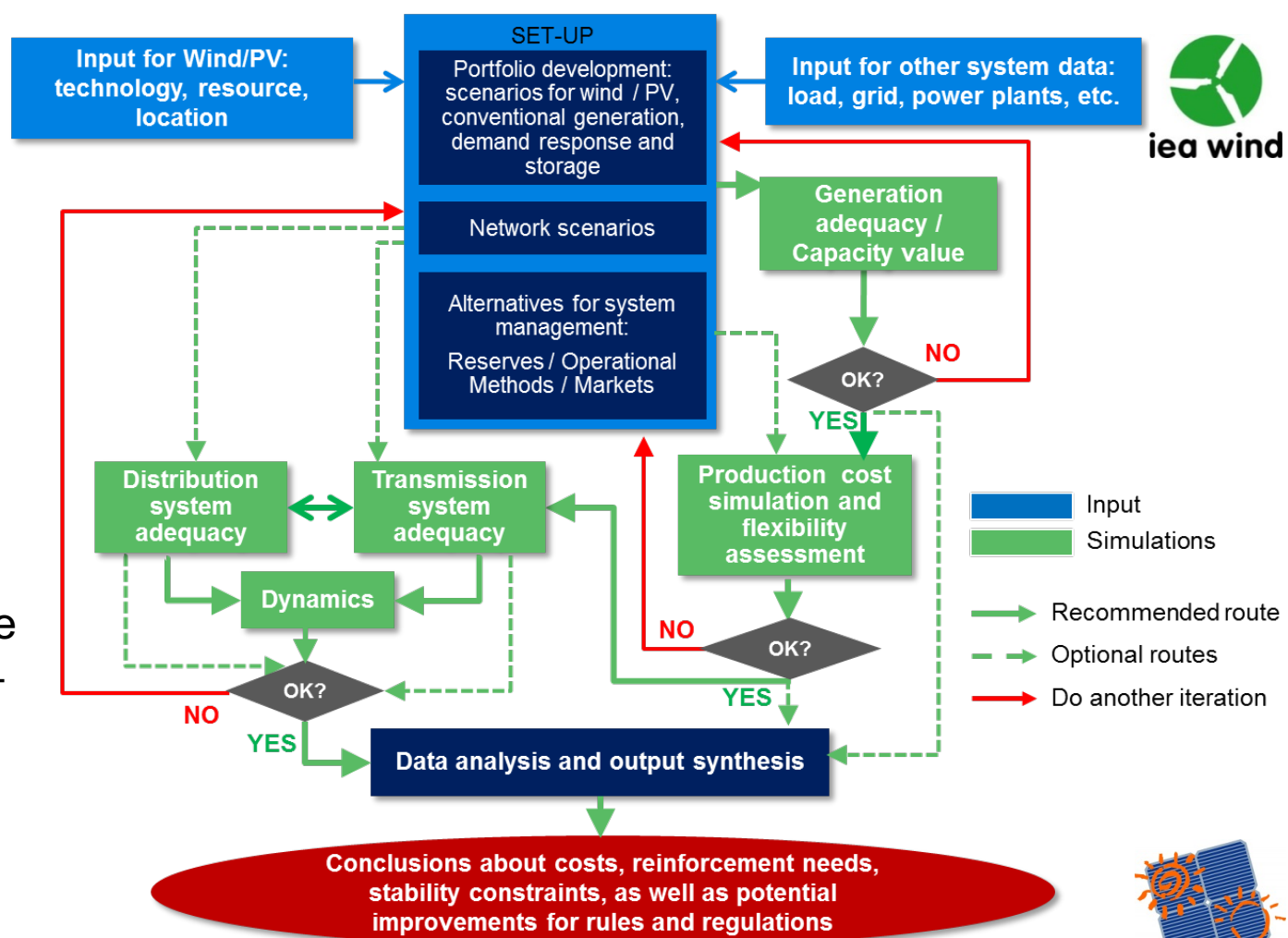
NOTE: graph simplified presentation, flexibility options like demand side, storages and power to X will impact the net load and optimisation of generation mix



Recommended Practices for wind/PV integration studies

A complete study with links between phases

Most studies analyse part of the impacts – goals and approaches differ

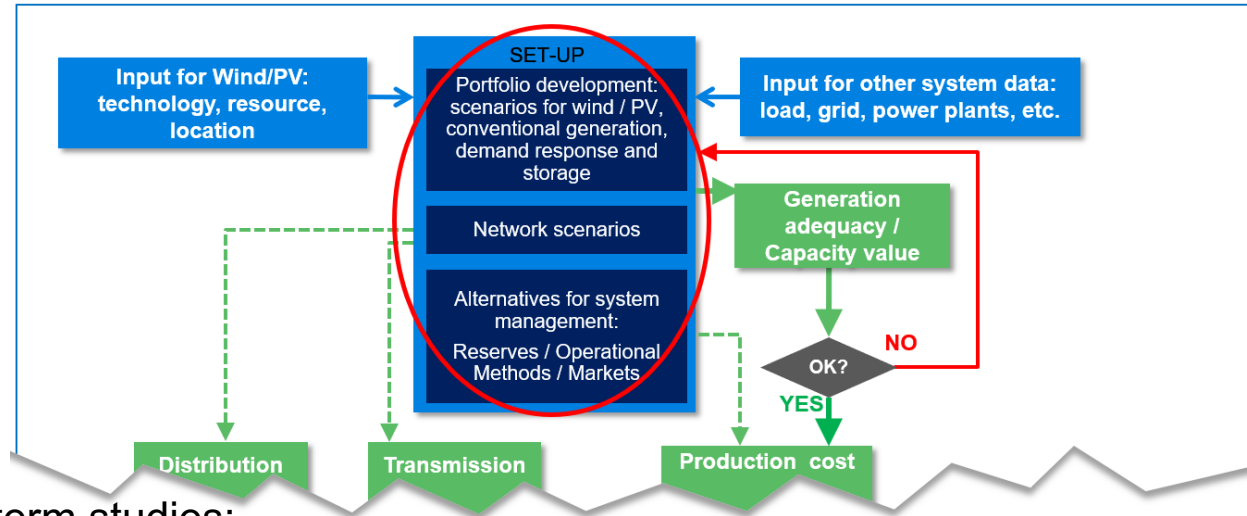


What to study - Portfolio Development and System Management

Set-up of study

Main assumptions –Critical for results!

Future system, how wind/PV is added, what is remaining generation mix, operational practices



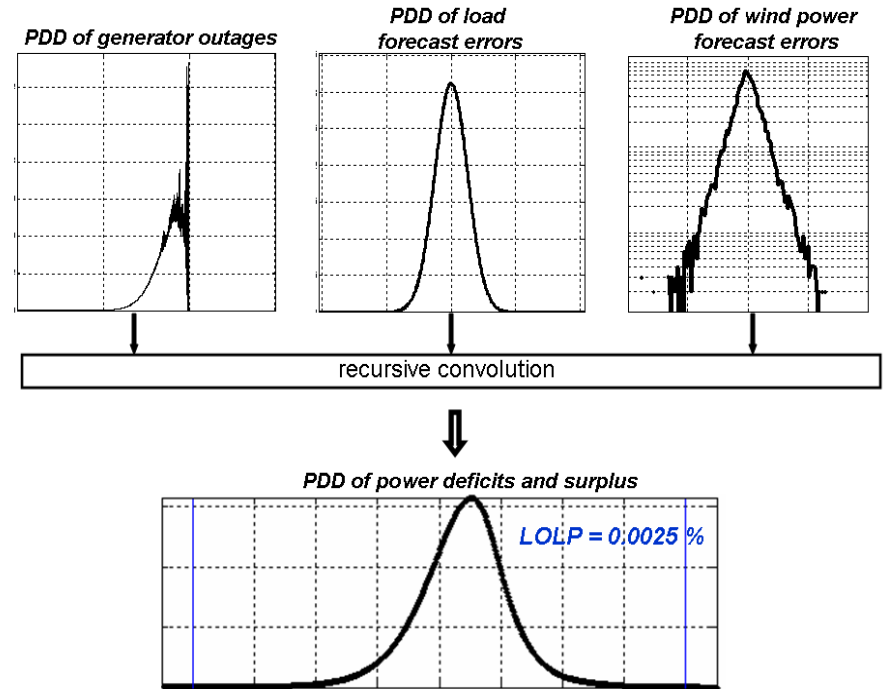
For larger shares and longer term studies:

- changes in the assumed remaining system become increasingly necessary, and beneficial: generation portfolio and network infrastructure, taking into account potential flexibility and technical capabilities of power plants. Additional scenarios for operating practices recommended



Operating reserve allocation with wind/PV

1. Synchronous wind/PV and load time series + forecast error distributions + generation outage distribution
2. Calculate for appropriate time scales, f.ex. automatically responding (secs-mins) and manually activated (mins-hour). Split data for categories with care not to double-count
3. Combine uncertainty keeping the same risk level before and after wind/PV
4. With increasing shares, use dynamic, not static reserves



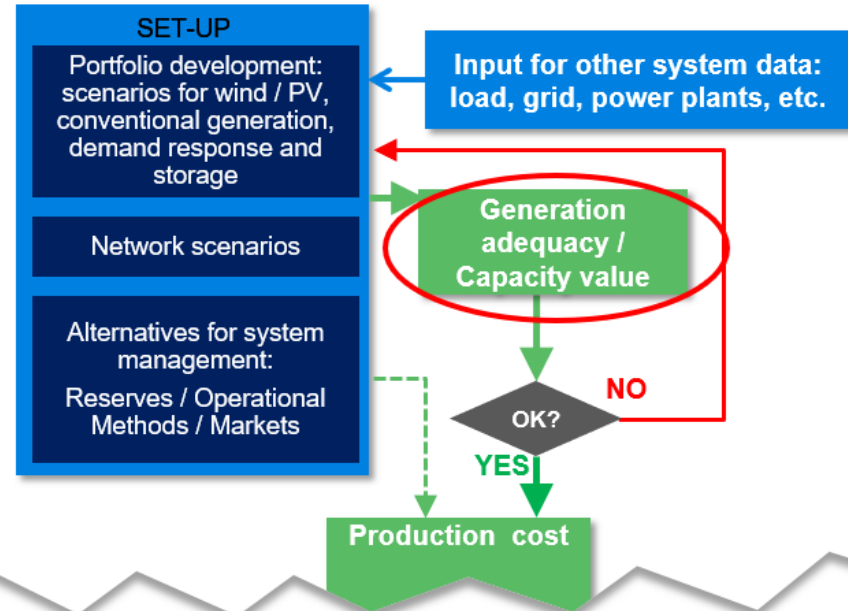


Generation capacity adequacy

Needed for making consistent future scenarios (how much capacity will wind/PV replace), as integration study result: capacity value of wind or solar PV

Recommendations:

- How much increase in load will bring same reliability/LOLP in the system when adding wind or solar (ELCC method) recommended
- Input data – synchronous wind/PV/load data. Number of years critical for robust results, more than 10 years

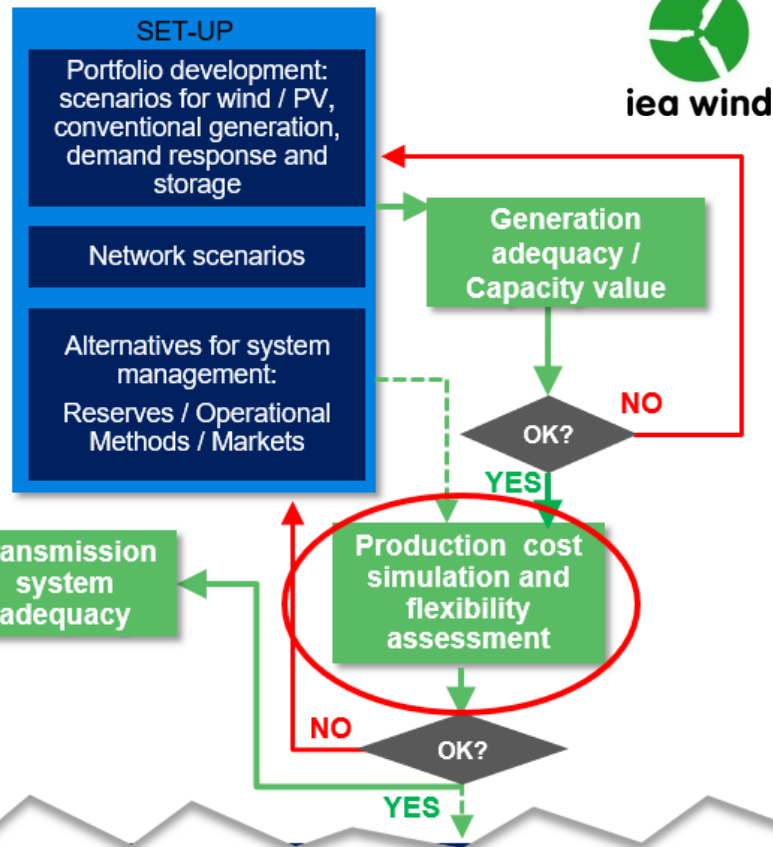


Production cost simulation – flexibility assessment

Impact of wind/PV on other power plants' operation. Simulated with Unit Commitment and Economic Dispatch (UCED) tools

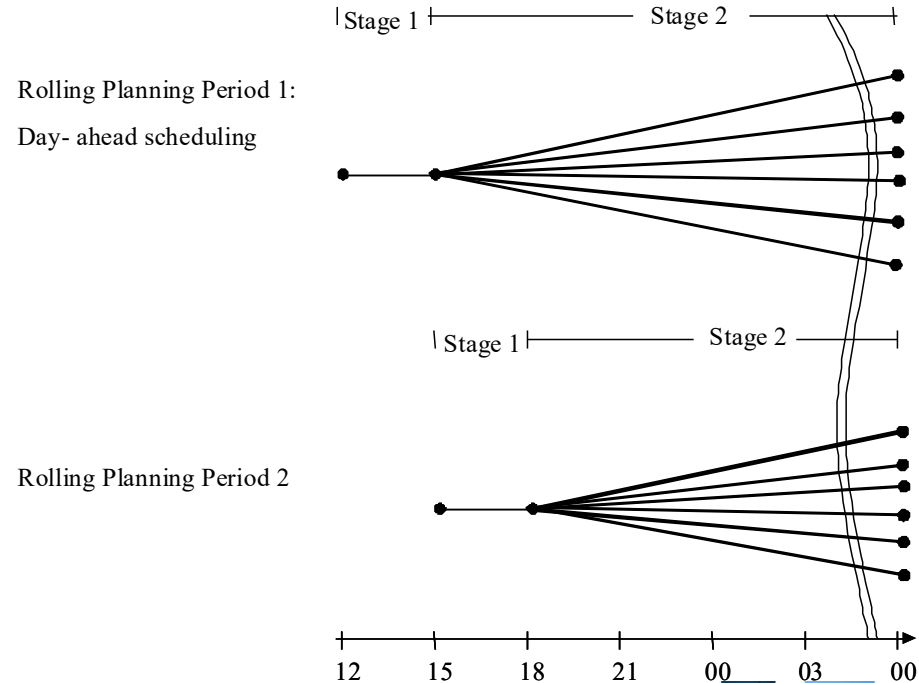
Iteration loops /sensitivities often needed: results sensitive to base case selection (non-wind/PV case of comparison)

Input data: one year of hourly wind/PV data – synchronous with load (and hydro) and capturing smoothing impact and forecast accuracy



Recommendations for Unit Commitment and Economic Dispatch (UCED)

1. Impact of uncertainty on commitment decisions with possibilities to update forecasts (rolling planning)
2. Increased operating reserve targets
3. Flexibility limitations and constraints: min.generation levels, ramp rates, part load efficiency,..
4. Possible new flexibilities (power2heat, EVs, storages, demand response, dynamic line rating)



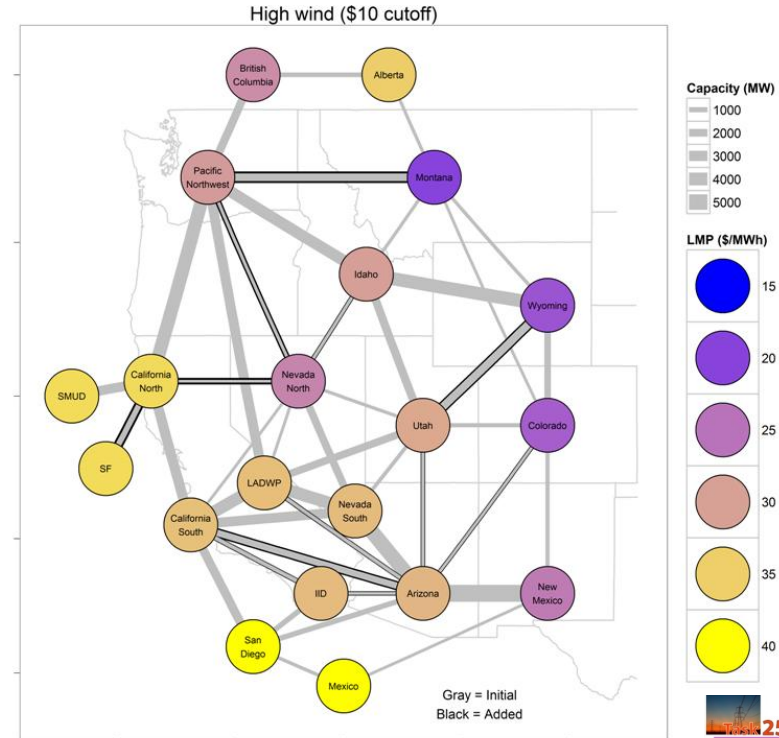
Recommendations for Unit Commitment and Economic Dispatch (UCED)

5. Possibilities and limitations of interconnections

- model neighbouring system or mention assumption (over- or underestimating transfer possibilities)

6. Limitations from the transmission network require modeling of congestion and N-1 security

- Net transfer capacity, or iterative methods can be used. Additional stability constraints for very high wind/PV shares.

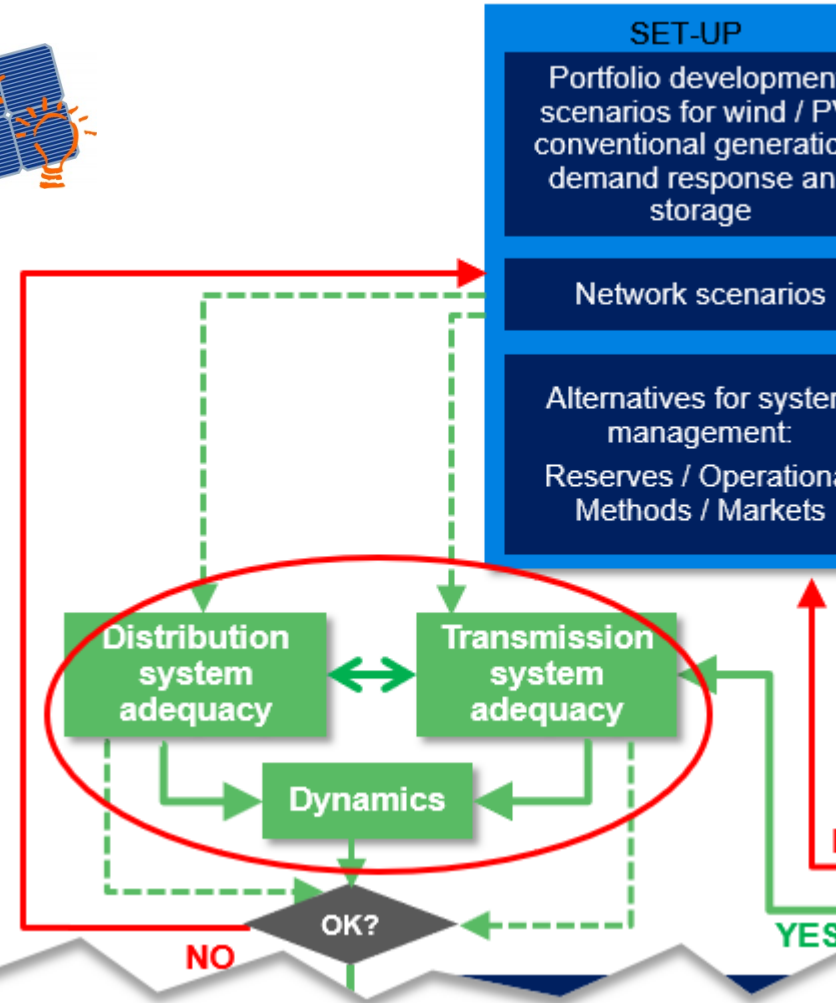


Distribution network

Distribution Grid Reinforcement Analysis: grid optimization, before grid reinforcement, before grid expansion

Grid Losses Analysis: a detailed study of the grid losses for a certain number of reference grids, which represent other distribution grids, combined with statistical analysis or data-driven methods is recommended

Stronger coordination of transmission and distribution grid studies will be required with higher shares of wind/PV

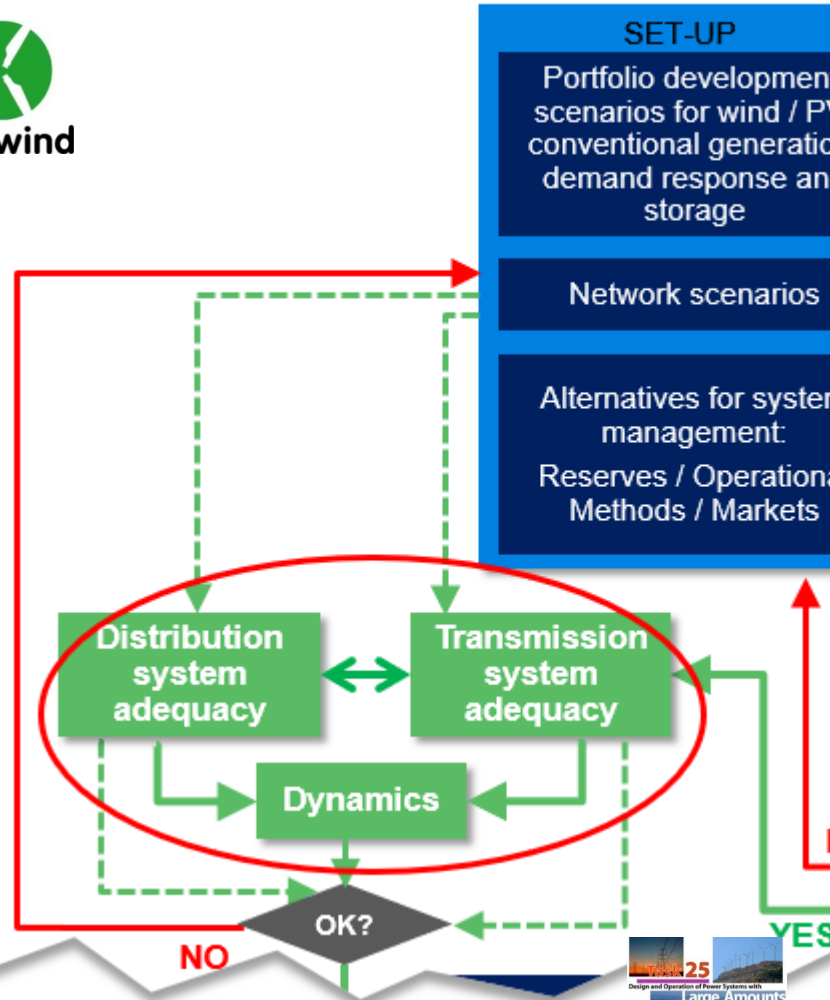


Transmission network

Creating a number of credible power flow cases:
more snapshots than peak and low load: critical situations regarding wind and solar power

Steady-state power flow analyses with N-1 security criteria:

- Voltage profiles and network loading (congestion) assessment (probabilistic)
- Time series power flows for operation of discrete controllers and cross border flows
- Short circuit levels and protection



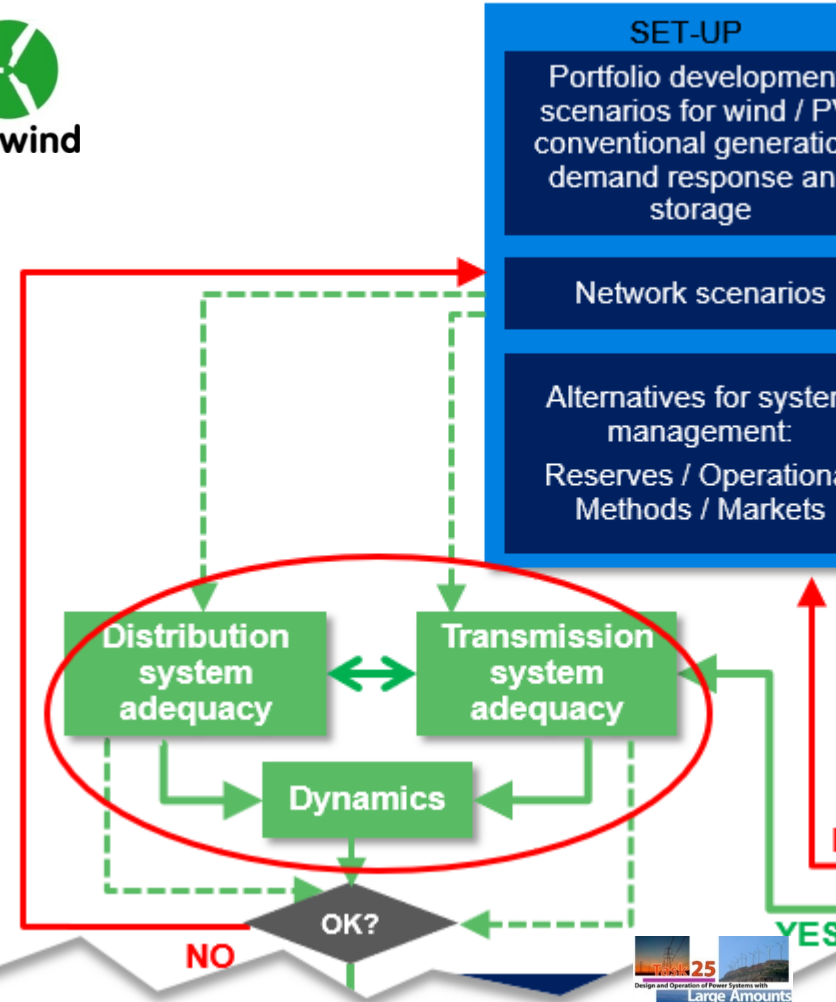
Power system dynamics

Wind/PV models important, validation also for other generators and load needed

Transient stability: include protection. Many mitigation options exist.

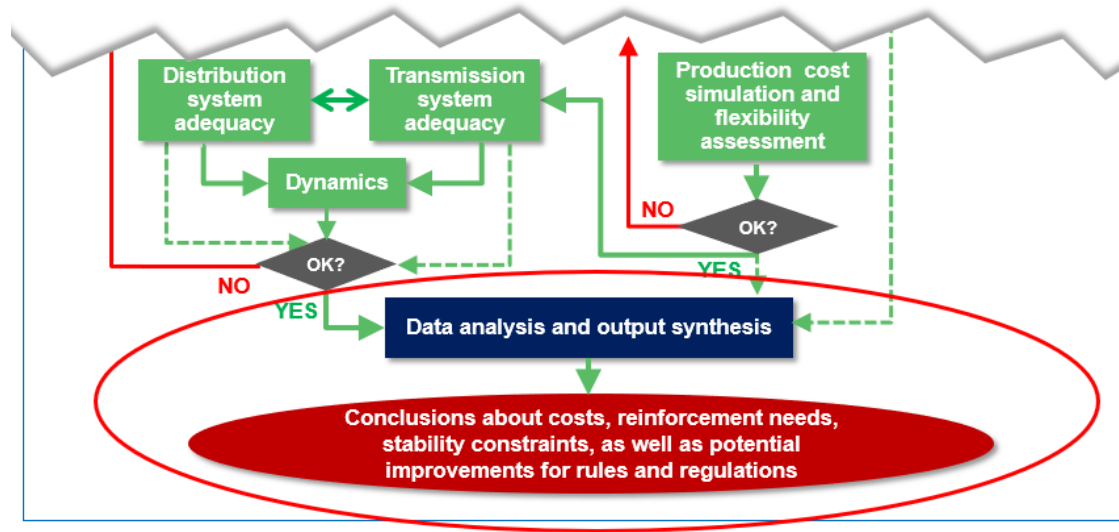
Voltage and frequency stability at higher shares of wind/PV

Small-signal stability, Sub-synchronous oscillations also when wind/PV displacing a lot of conventional generators, also transient events might become more severe (common-mode fault events)



Analysing and Presenting the Results

- Iterations provide significant insights
- Comparisons to base case selected may impact results. Integration cost contradictory issue – so far no accurate methods found to extract system cost for a single technology
- Present the share of wind/PV for easier comparison with other studies



Future work: integration studies are still evolving, towards 100% renewable studies



Metrics and tools for flexibility needs of the power system, and ways to achieve flexibility

Simulation tools that consider uncertainty of wind in different time scales, and combine **network constraints with UCED constraints**

Ways to set up simulation cases to efficiently extract impacts and system costs – **from cost of integration to cost of inflexibility**

Stability issues with very high penetration cases. Future grids with more DC transmission.

Implications of market design and/or regulatory processes for wind/PV integration.

Use the recommended practices check-list for benchmarking your study!





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