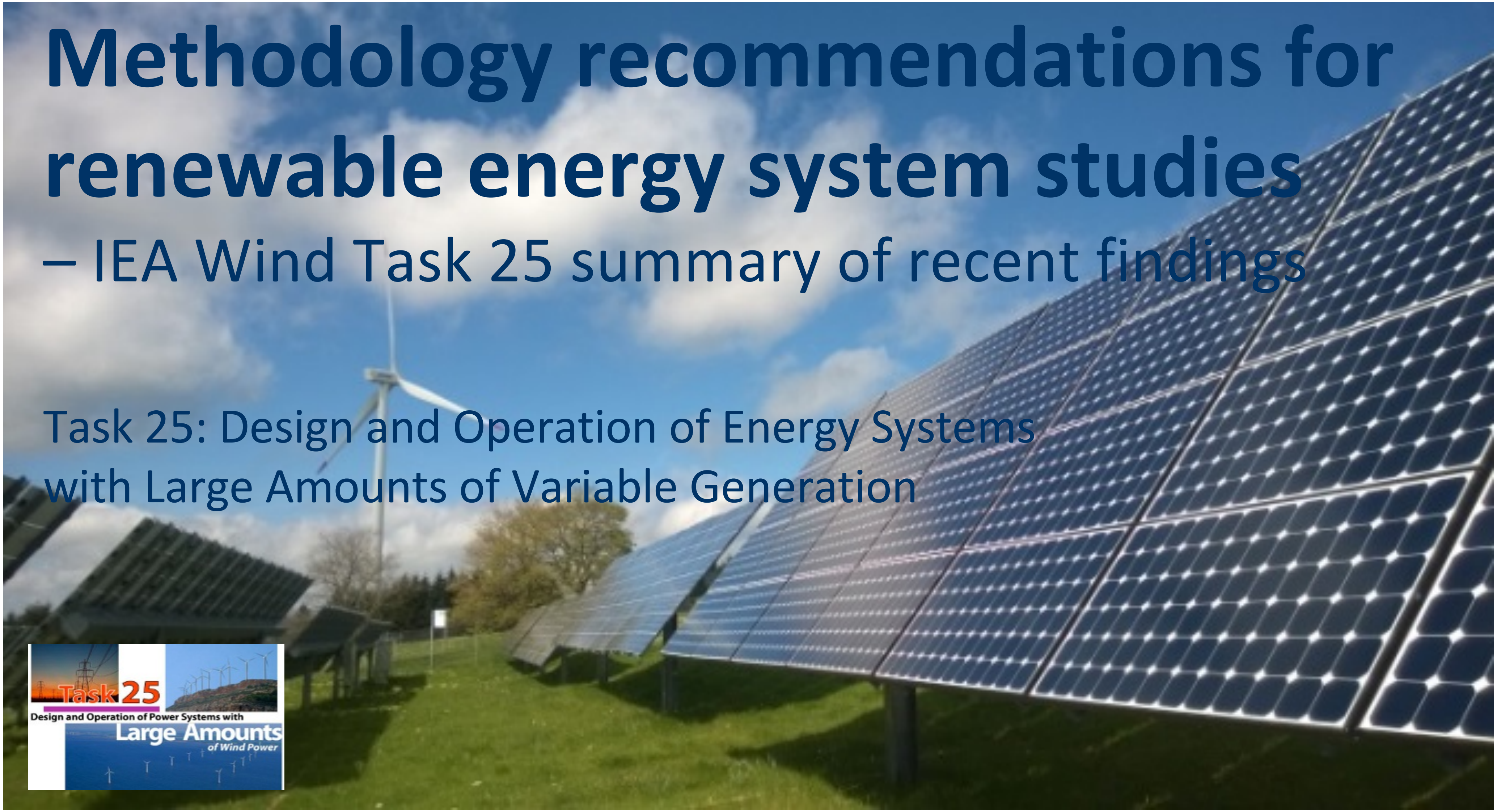
Methodology recommendations for renewable energy system studies

– IEA Wind Task 25 summary of recent findings

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



Hannele Holttinen, Operating Agent Task25

Partner, Recognis

WESC Cork June 19, 2019

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Contents

- Introduction: On Task 25 work and Status of wind integration
- Recommendations for how to perform integration studies - → Future power system studies with high shares of renewables

IEA Wind Task 25

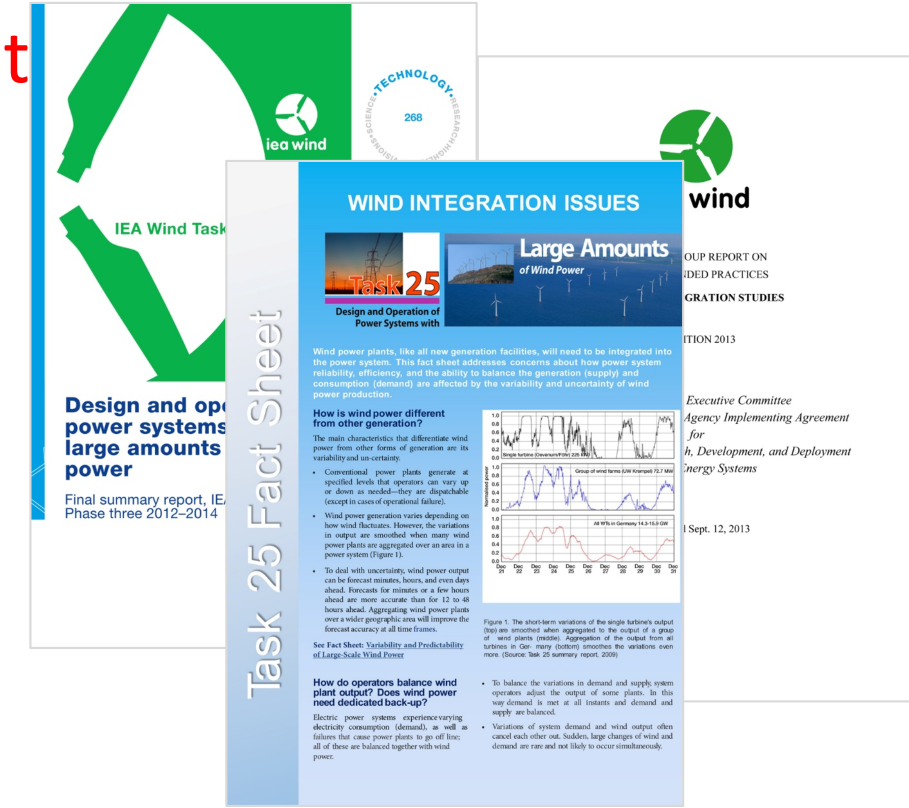
- Design and operation of energy systems with large amounts of variable generation
- Started in 2006, now 17 countries + WindEurope participate, international forum for exchange of knowledge

Country	Institution
Canada	NRCan (Thomas Levy); Hydro Quebec (Alain Forcione)
China	SGERI (Wang Yaohua, Liu Jun)
Denmark	DTU (Nicolaos Cutululis); Energinet.dk (Antje Orths)
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	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	TUDelft (Simon Watson)
Norway	NTNU (Magnus Korpås); SINTEF (John Olav Tande, Til Kristian Vrana)
Portugal	LNEG (Ana Estanquiero); INESC-TEC (Bernando Silva)
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 (B-M. Hodge, M. O'Malley); ESIG (J.C. Smith); DoE (J. Fu)
WindEurope	European Wind Energy Association (Daniel Fraile)

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

IEA Wind Task 25 – What Does It Do?

- State-of-the-art: review and analyze the results so far latest report 2019
- Formulate guidelines- Recommended Practices for Integration Studies Update 2018 with solar PV
- Fact sheets and wind power production time series.
- Literature list.
- https://community.ieawind.org/task25/



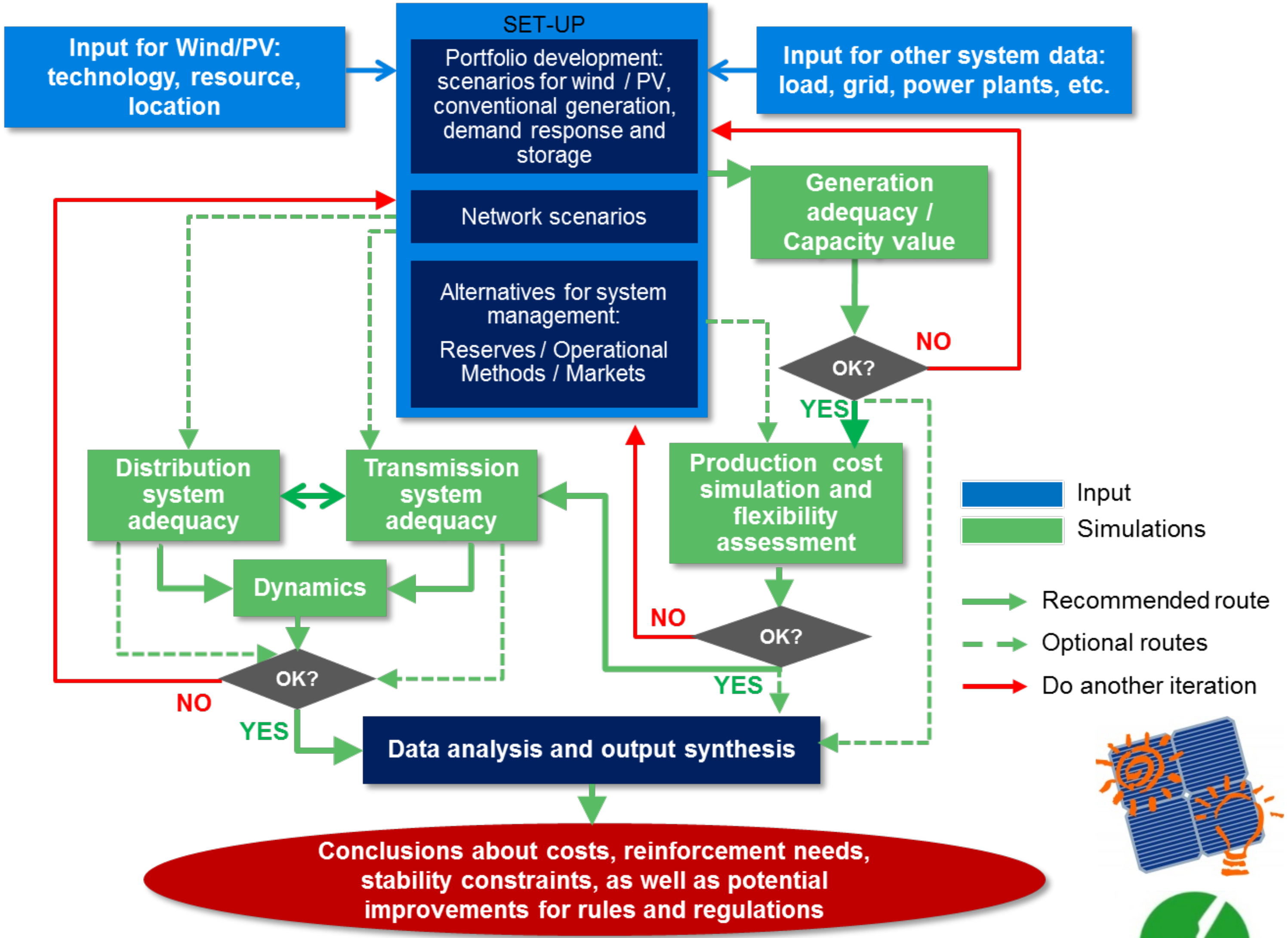
Recommended Practices – what, why and for whom

- Recommendations on how to perform studies describe the **methodologies, assumptions, and inputs** needed to conduct a grid integration study
  - No results, just discussion on methods
- to provide research institutes, consultants, and system operators with the **best available information on how to perform** an integration study
- can also be used as a **benchmark for any future power system study** - what is taken into account and what is not

RP16 ed 2 of IEA Wind TCP:
https://community.ieawind.org/publications/rp

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



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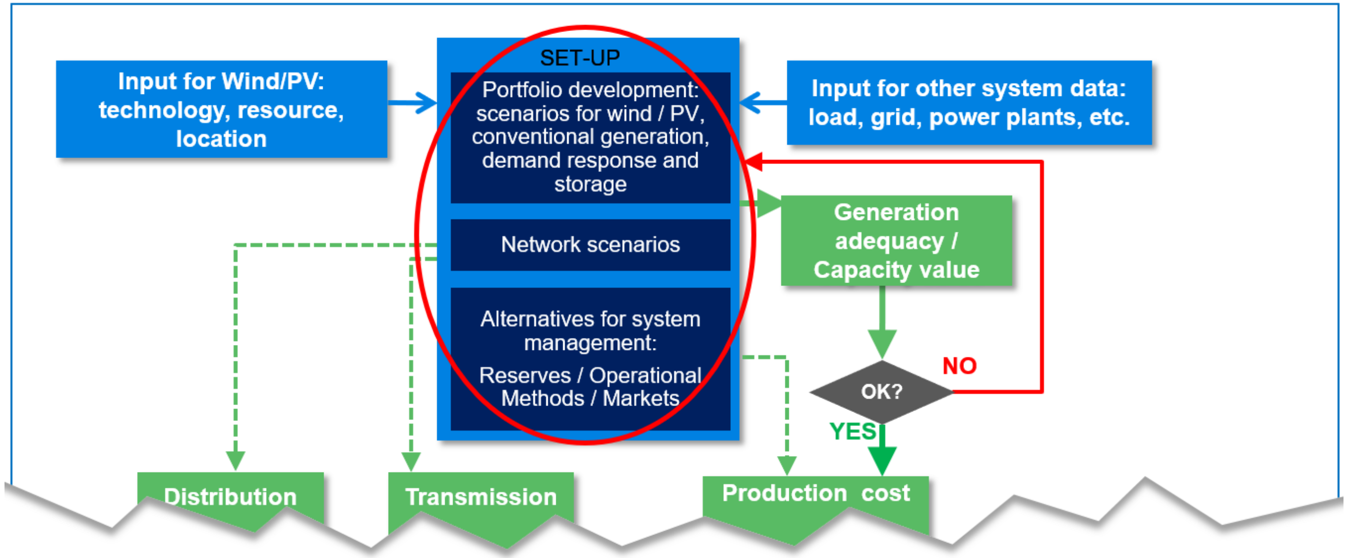
What to study - Portfolio Development and System Management

- Set-up of study
- Main assumptions – Critical for results!
- Future system, how wind/PV is added, what is remaining generation mix, operational practices

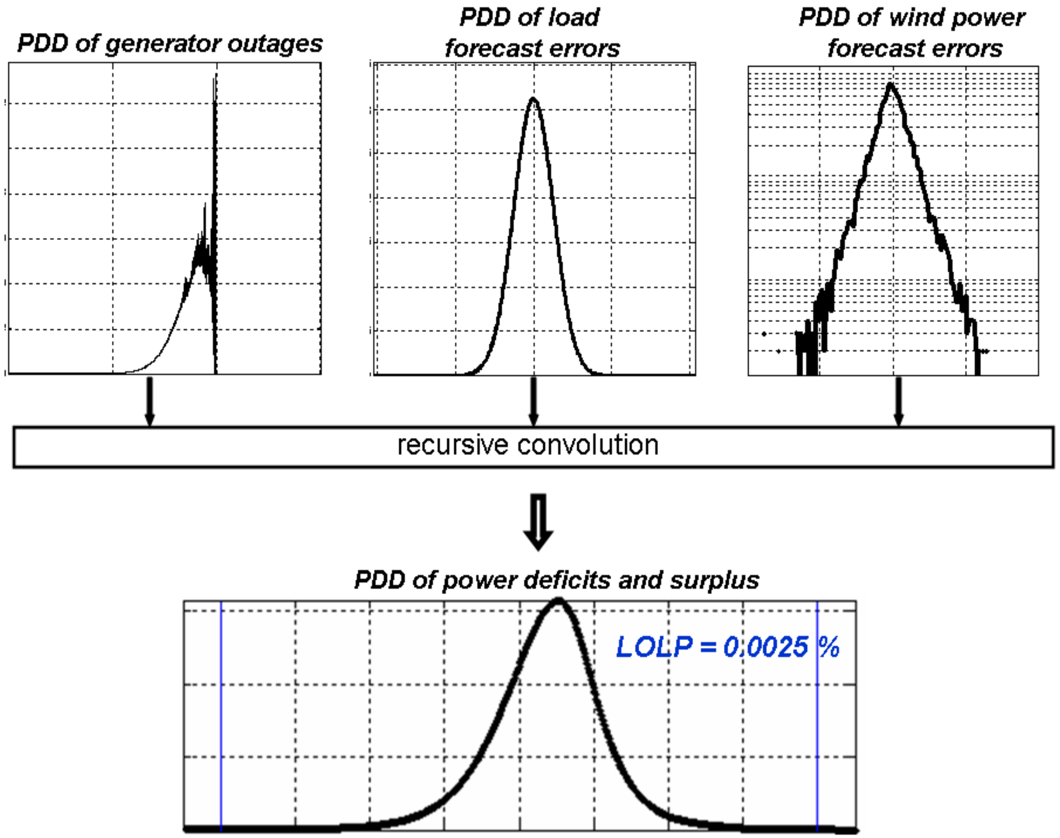


For larger shares and longer term studies:

- 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



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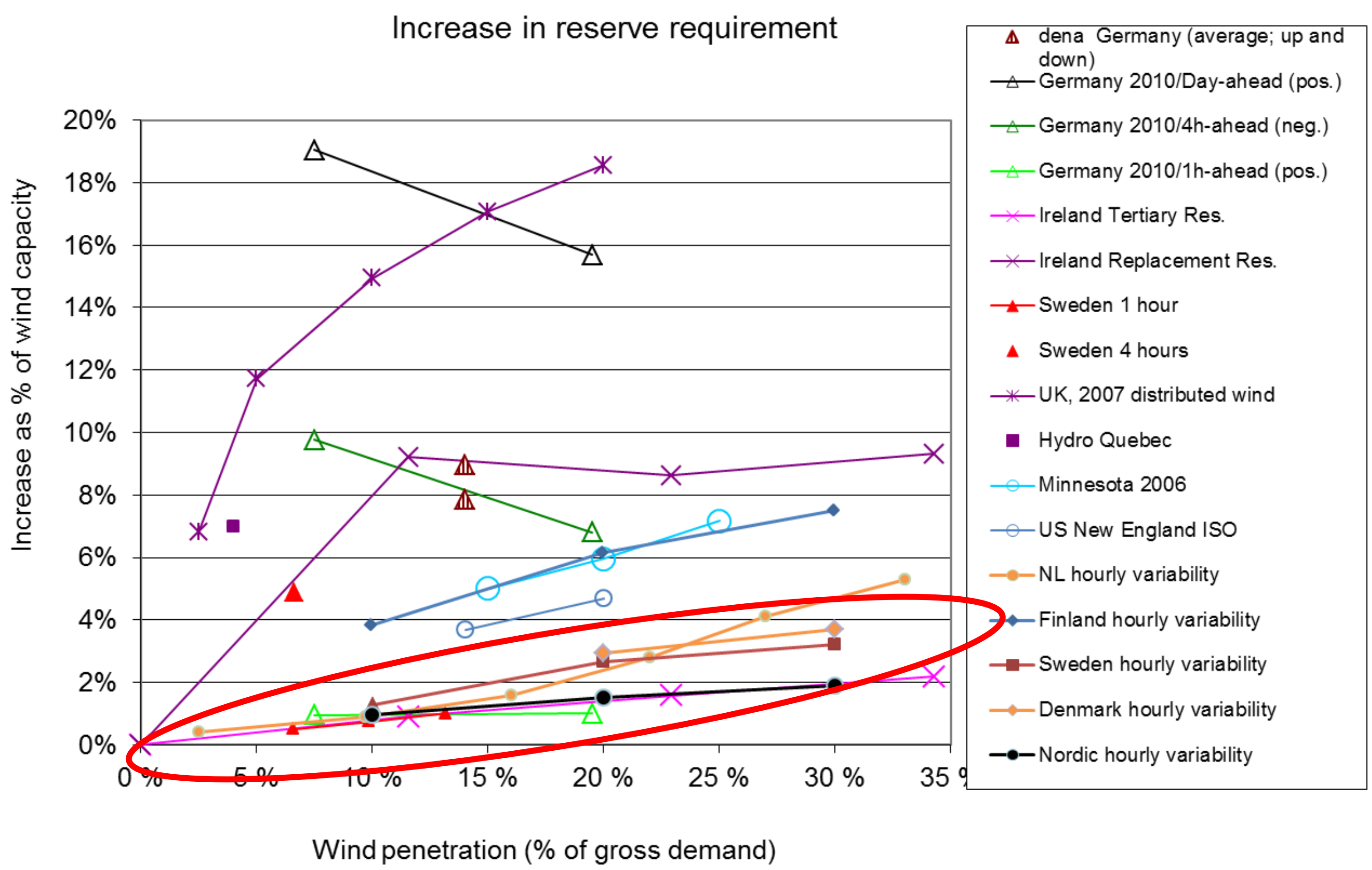
Task 25
Design and Operation of Power Systems with Large Amounts of Wind Power

Results of studies for increase in operating reserves

- Combing uncertainties results in moderate increase in operating reserve due to wind power
- Time scale of uncertainty brings large differences in results Results for hourly variability similar



Trade with neighbouring areas will help balancing more than wind adds

- Sharing balancing with neighbouring system operators in Germany has resulted in reduction of use of frequency control, while wind and solar have increased

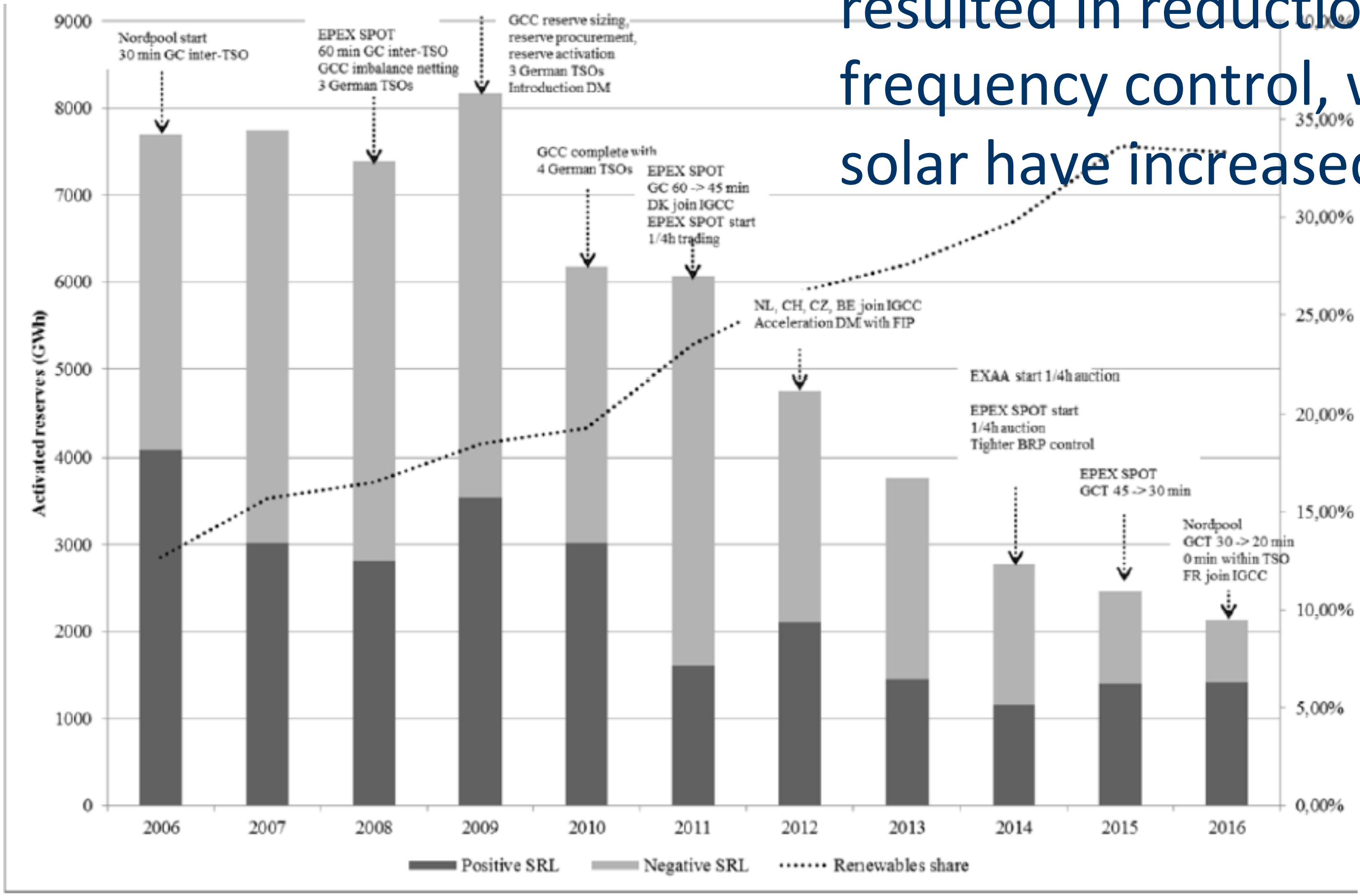
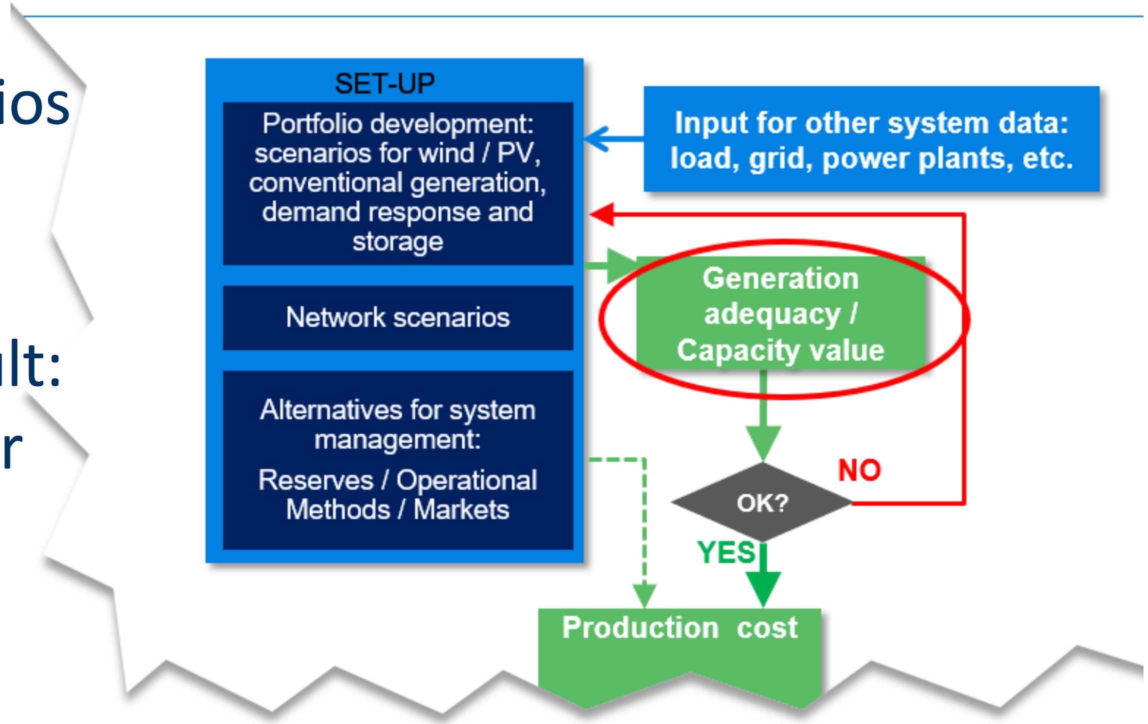


Figure 13: Total activated German Secondary Reserves (or aFRR) per year marked with events considered in this paper.

Source: Rena Kuwahata, Peter Merk, WIW17

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

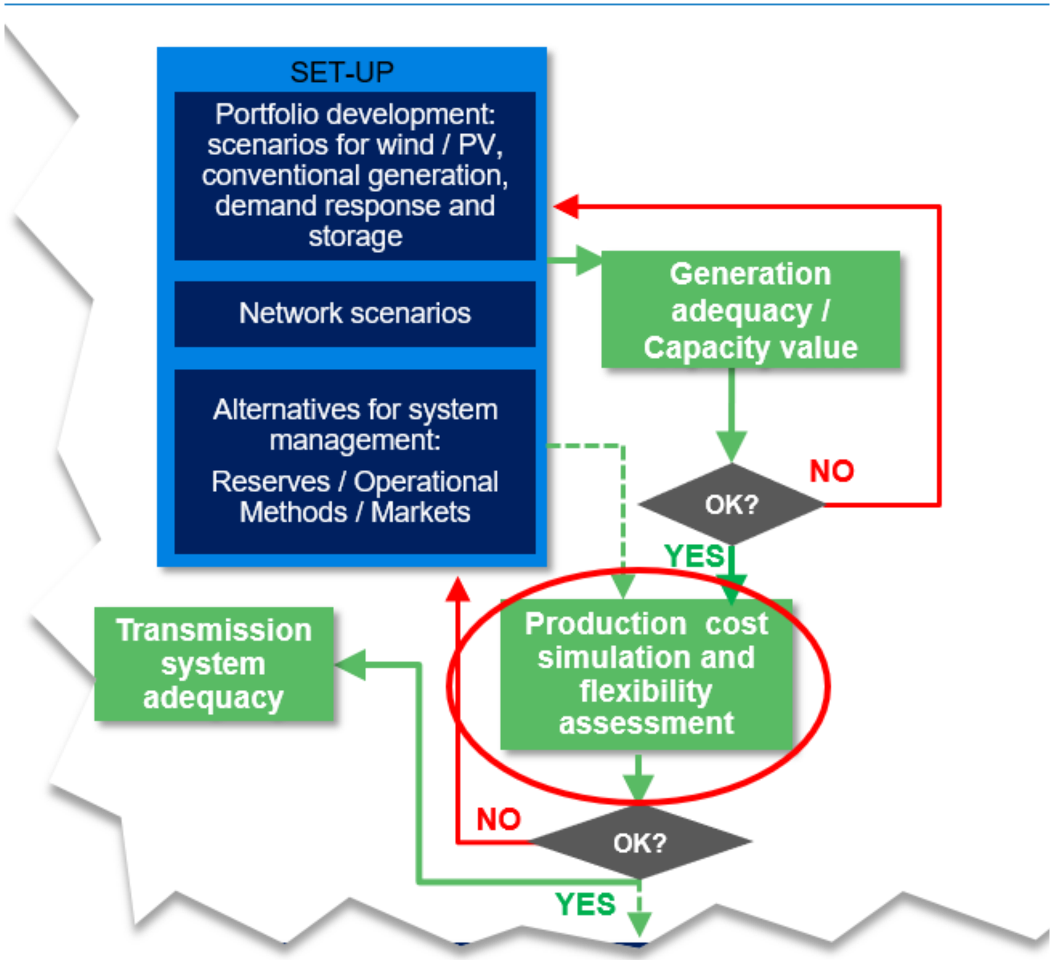


Recommendations:

- Assess how much increase in load will bring same reliability/LOLP in the system when adding wind or solar (ELCC method)
- 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)
- Iteration loops /sensitivies often needed: results sensitive to base case selection (non-wind/PV case of comparison)
- Input data: hourly wind/PV data synchronous with load (and hydro), smoothing impact and forecast accuracy



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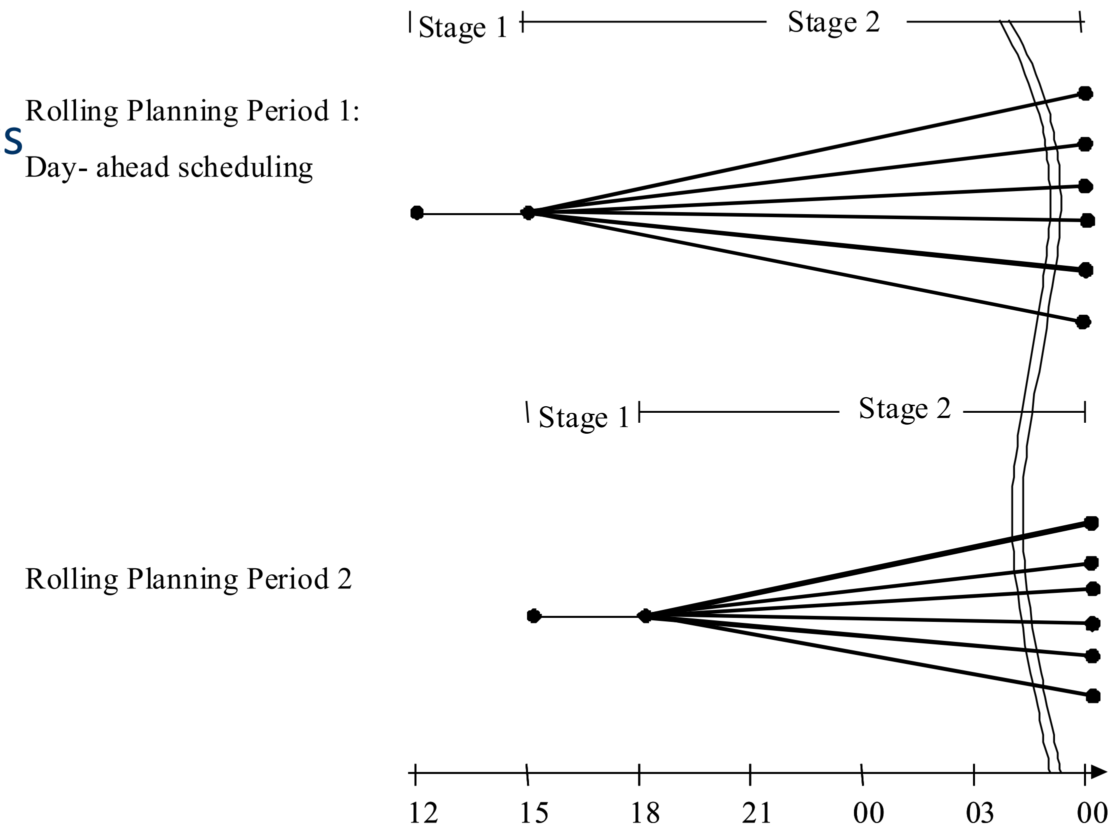
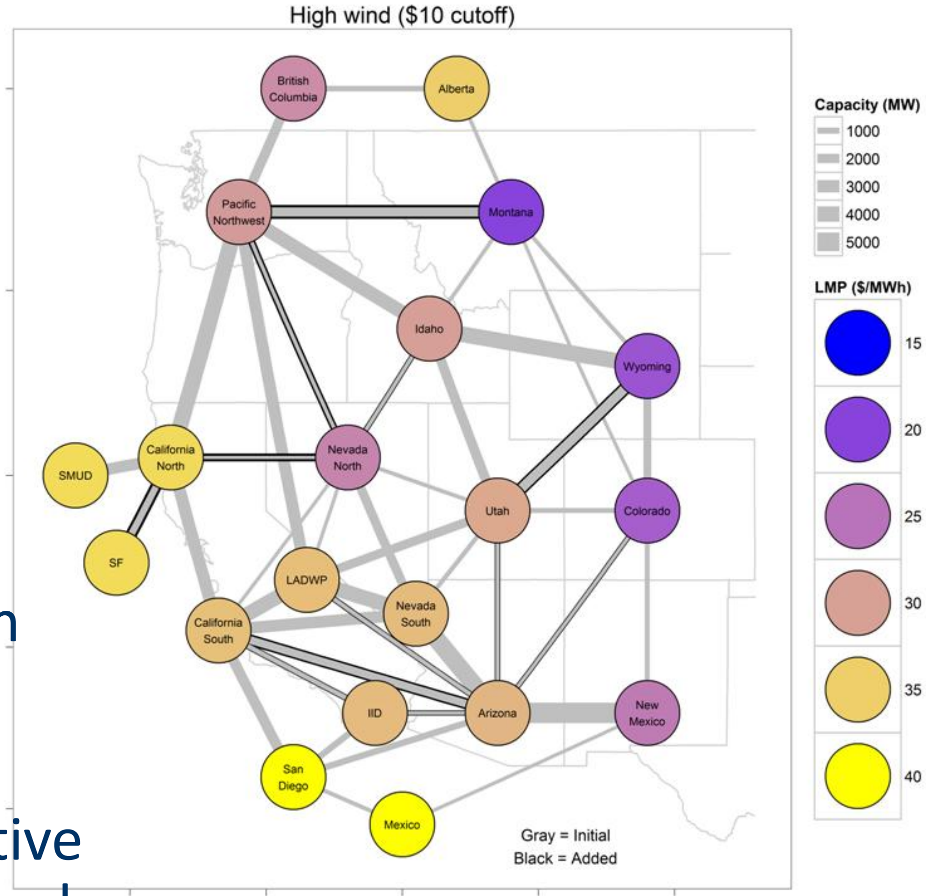
Recommendations for Unit Commitment and Economic Dispatch (UCED)

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.



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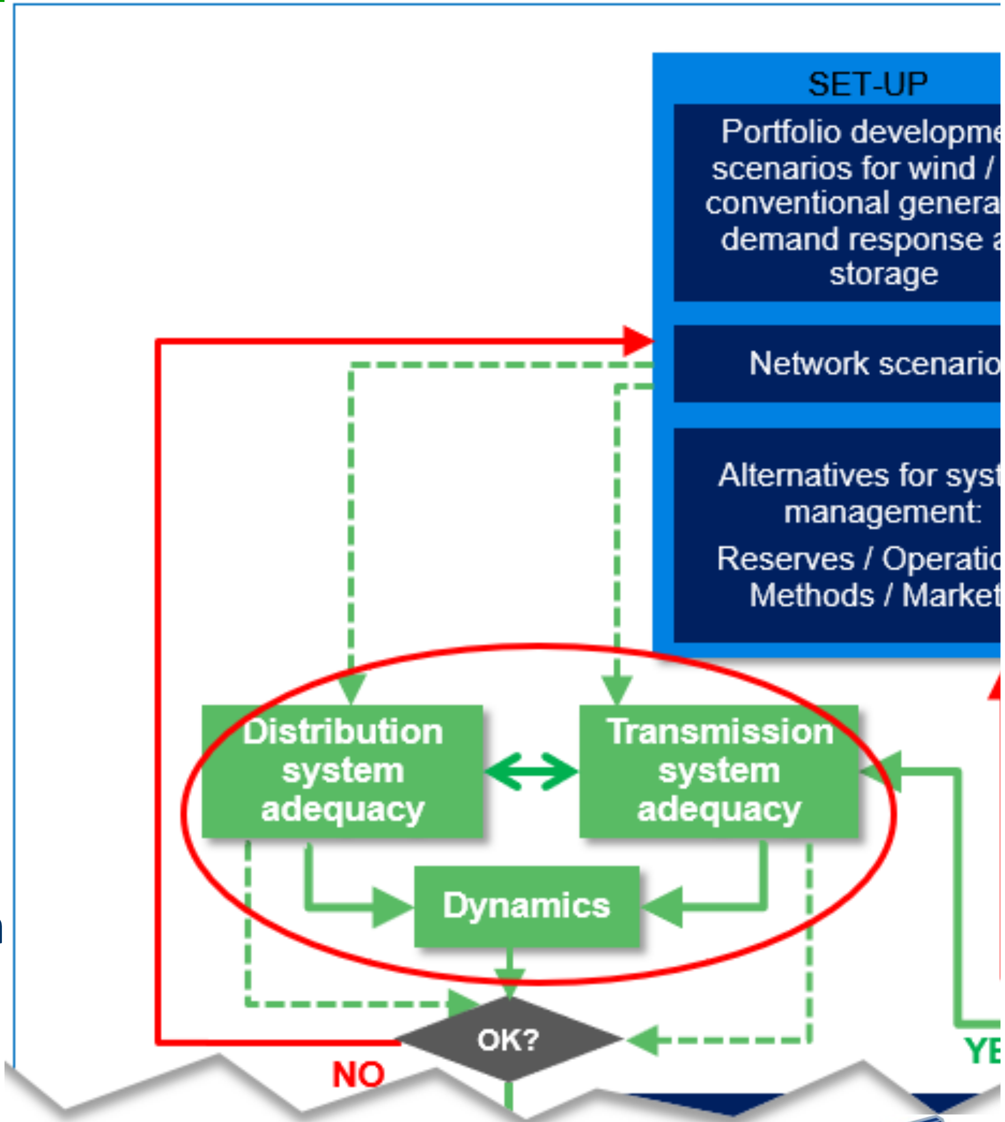
Distribution network

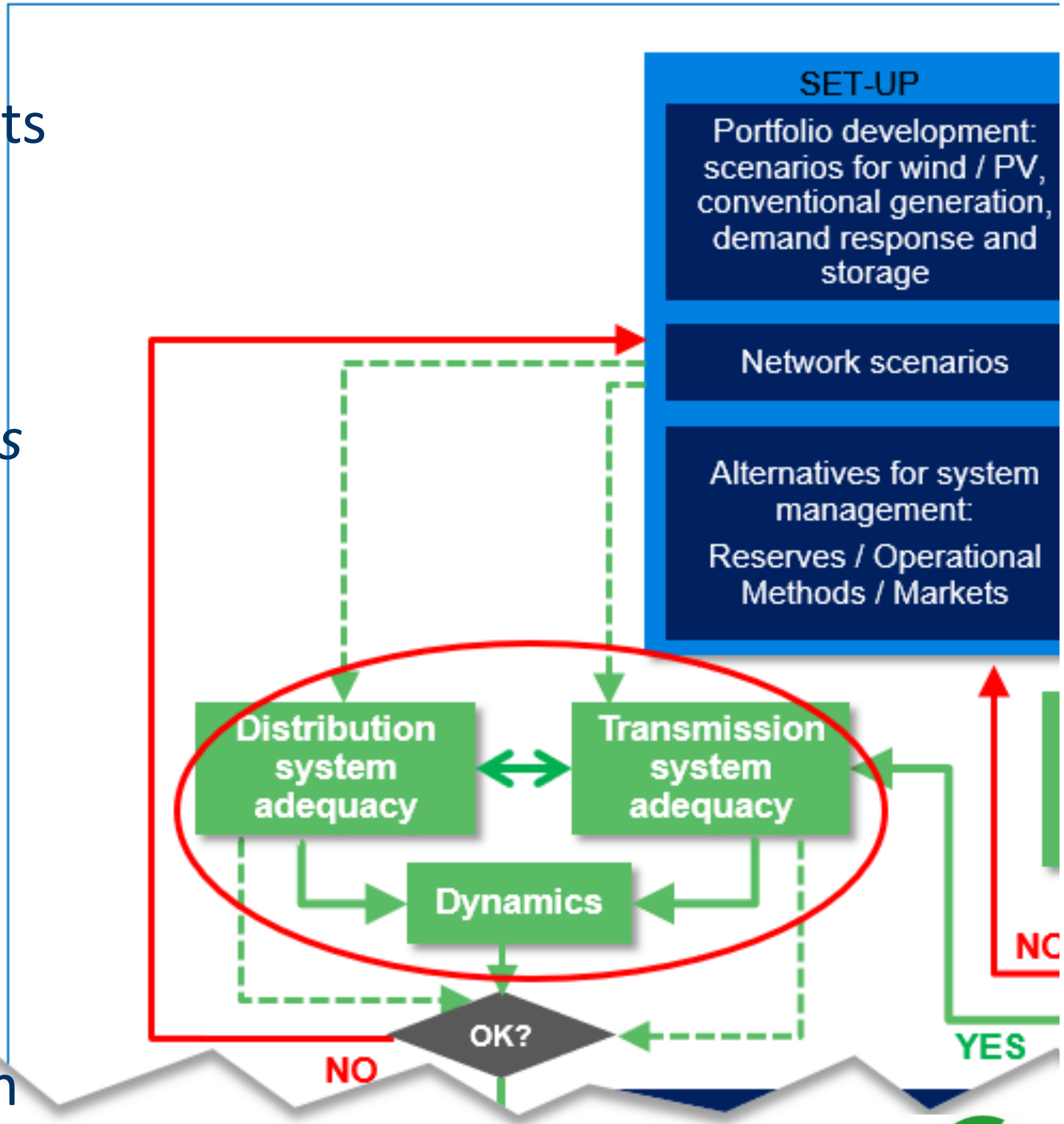
- *Distribution Grid Reinforcement Analysis:* grid optimization, before grid reinforcement, before grid expansion
- *Grid Losses Analysis*: a detailed study of the grid losses for a certain number of reference grids, which represent other distribution grids, combined with statistical analysis or data-driven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

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



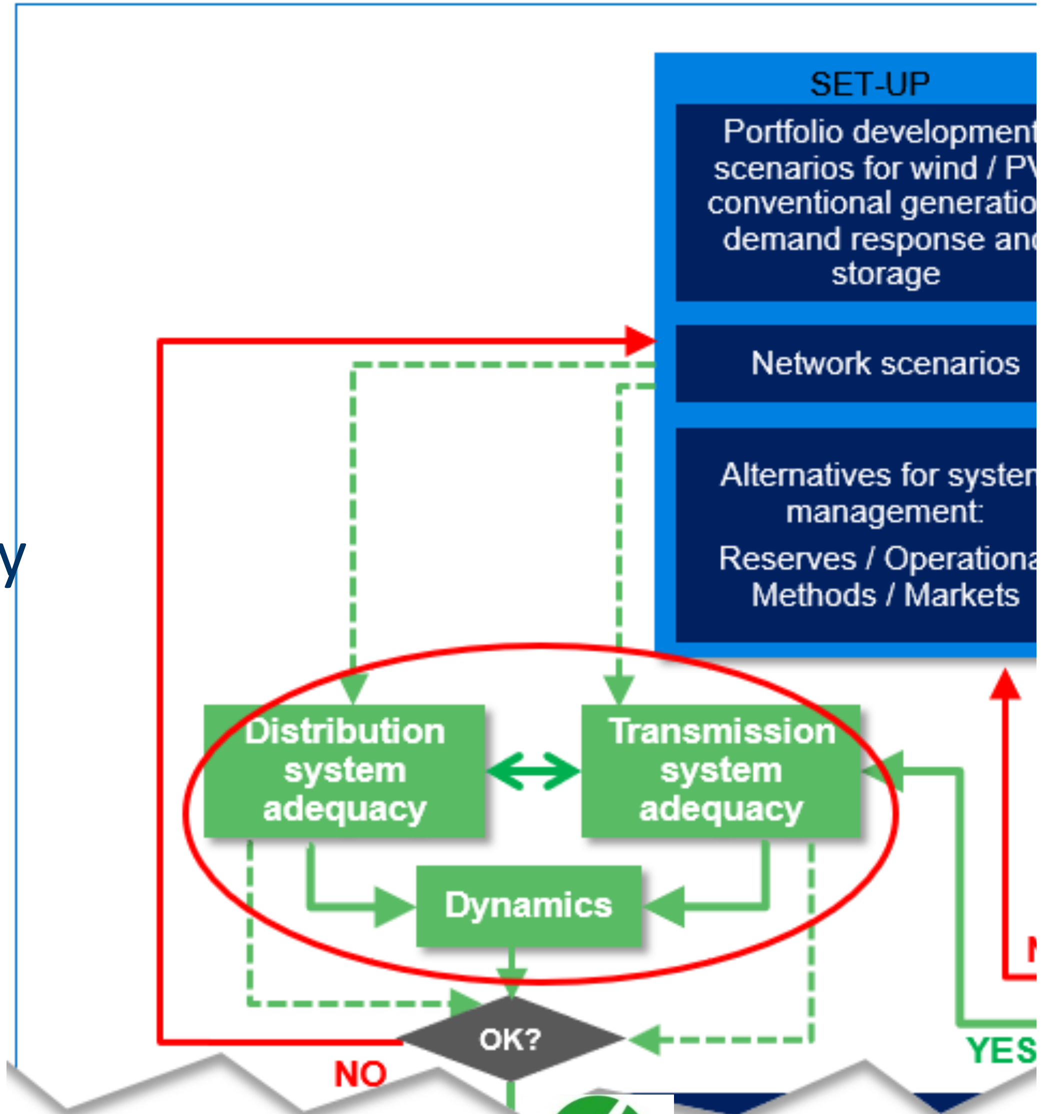
Transmission network

- *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)



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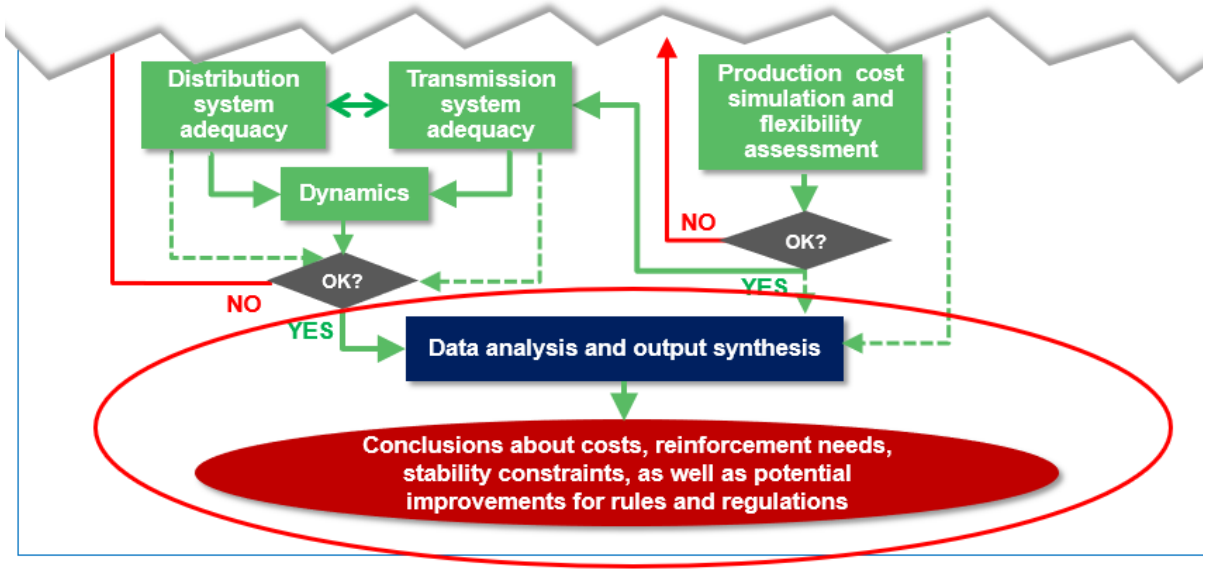
Analysing and Presenting the Results

- 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



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

Input data summary

	Capacity Value/ Power (resource) Adequacy	Unit Commitment and Economic Dispatch (UCED)	Power Flow	Dynamics
Wind/PV	Hourly generation time series for distributed wind/PV energy covering the area. Especially for wind, more than 10 years recommended	5-minute to hourly generation time series of at least 1 year for distributed wind/PV power covering the area	Wind/PV capacity at nodes, high and low generation and load snapshots, active and reactive power capabilities	Wind/PV capacity at nodes, high and low generation and load snapshots, dynamic models, operational strategies
Wind/PV Forecasts	Not needed	Forecast time series, or forecast error distribution for time frames of UCED	May be needed in future	Not needed
Load	Hourly time series coincident with wind/PV data, at least 10 years recommended	5-minute to hourly time series coincident with wind/PV, of at least 1 year	Load at nodes, snapshots relevant for wind/PV integration	Load at nodes, high and low load snapshots, dynamic capabilities
Load Forecasts	Not needed	Forecast time series, or forecast error distribution for time frames of UCED	May be needed in future	Not needed
Network	Cross border capacity, if relevant	Transmission line capacity between neighboring areas and/or circuit passive parameters	Network configuration, circuit passive and active parameters	Network configuration, circuit parameters, control structures
Other Power Plants	Rated capacities and forced outage rates	Min, max on-line capacity, start-up time/cost, ramp rates, min up/down times. efficiency curve, fuel prices	Active and reactive power capabilities, system dispatch	Dynamic models of power plants

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

- **Metrics and tools for flexibility needs** of the power system, and ways for more 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**

Need for research

- **Stability**: better understanding, which requires improved simulation tools and generator models and better predictive tools and metrics. Future grids: DC transmission, grid forming converters.
- **System operation: agile market rules** to make revenue from solutions that are optimal for the system – also taking benefits from local trade. **energy system coupling, new demands**
- **Adequacy**: new methods to optimise the varying generation and flexible loads (from LOLP metrics)
- **New ways of modelling loads for all of these!**

Jse recommended practices check-list for benchmarking your study!

Thank You!!

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The IEA Wind TCP agreement, also known as the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems, functions within a framework created by the International Energy Agency (IEA). Views, findings, and publications of IEA Wind do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.

Based on

- Recommended Practices for wind/PV integration studies, IEA WIND RP16 Ed.2

  https://community.ieawind.org/publications/rp

- IEA WIND Task 25 summary report

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

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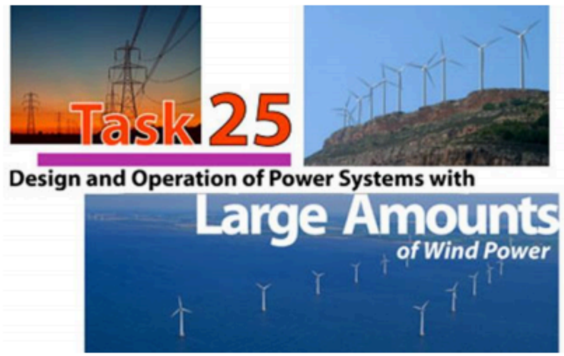
EXPERT GROUP REPORT ON RECOMMENDED PRACTICES

16. WIND/PV INTEGRATION STUDIES

2nd EDITION, 2018



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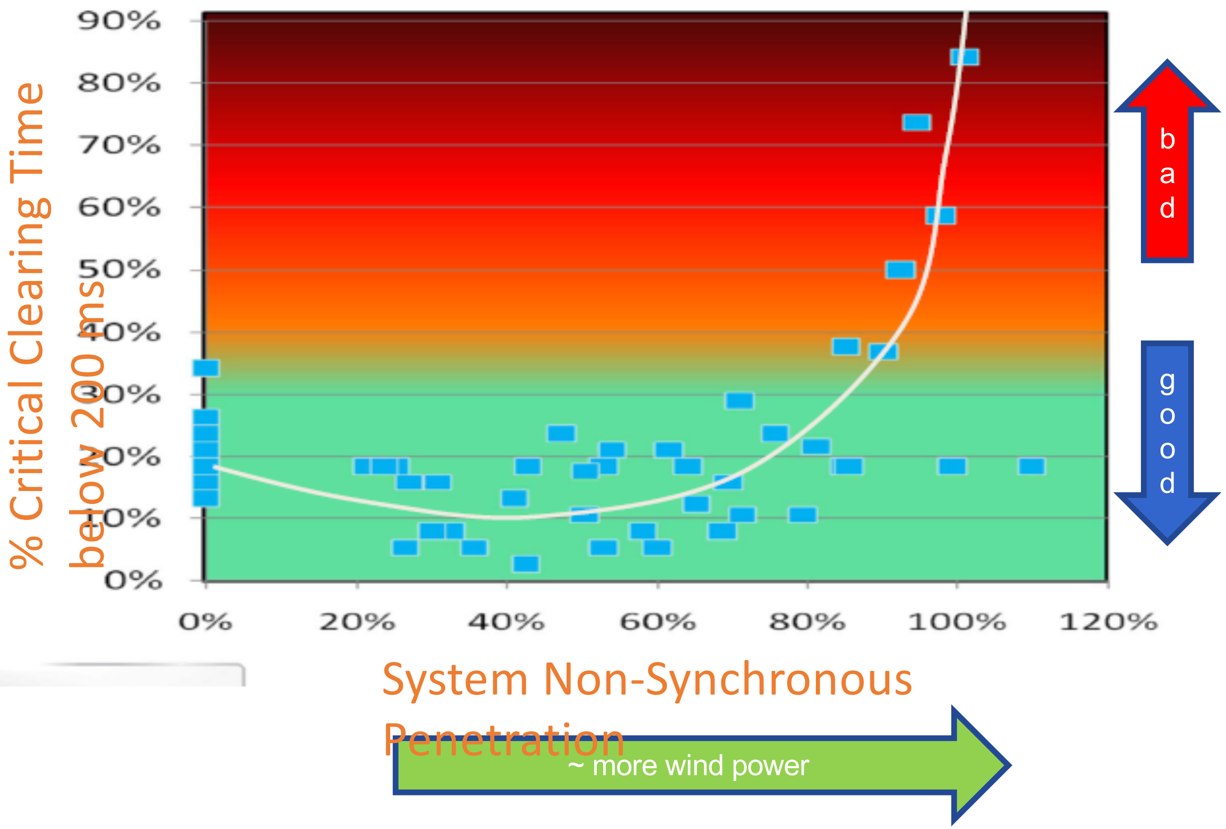
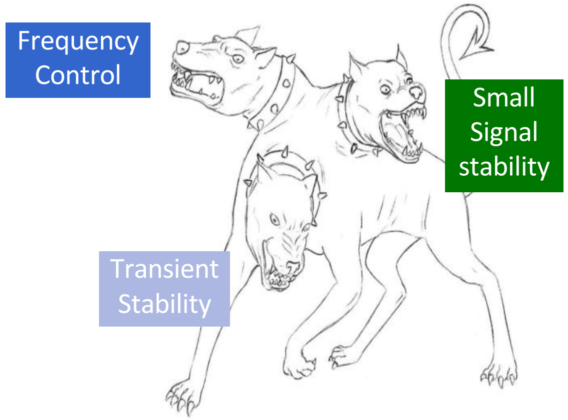
Ireland study: ok for 80-90%

- Transient stability (as measured by critical clearing time) first slightly improves, until around 80-90%, where instability becomes a big issue.



Challenges to tackle

- Stability: solving all 3 at same time at high VIBRES. What new methods and technologies to use?
- Balancing, flexibility and adequacy: how much new loads can help, for short term operation and for seasonal mismatch?
- Market operation: market design with new services, how to design so that paying for the new services as they become beneficia for the system? Local versus global, DSO/TSO collaboration



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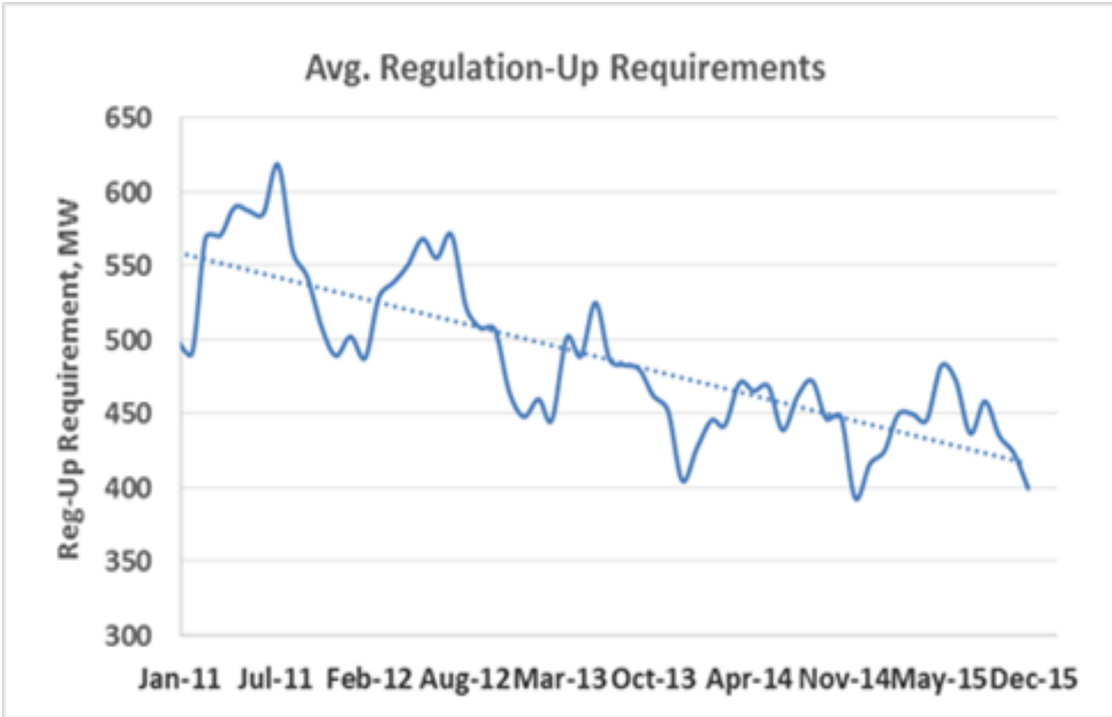
Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power

Opportunities: development happening at the same time

- Load transition: changing the fixed load paradigm
- Smart grids, DSO role
- Inverter controls: rapid responses, synchronous machine characteristics and they don't swing against each other (more stable).

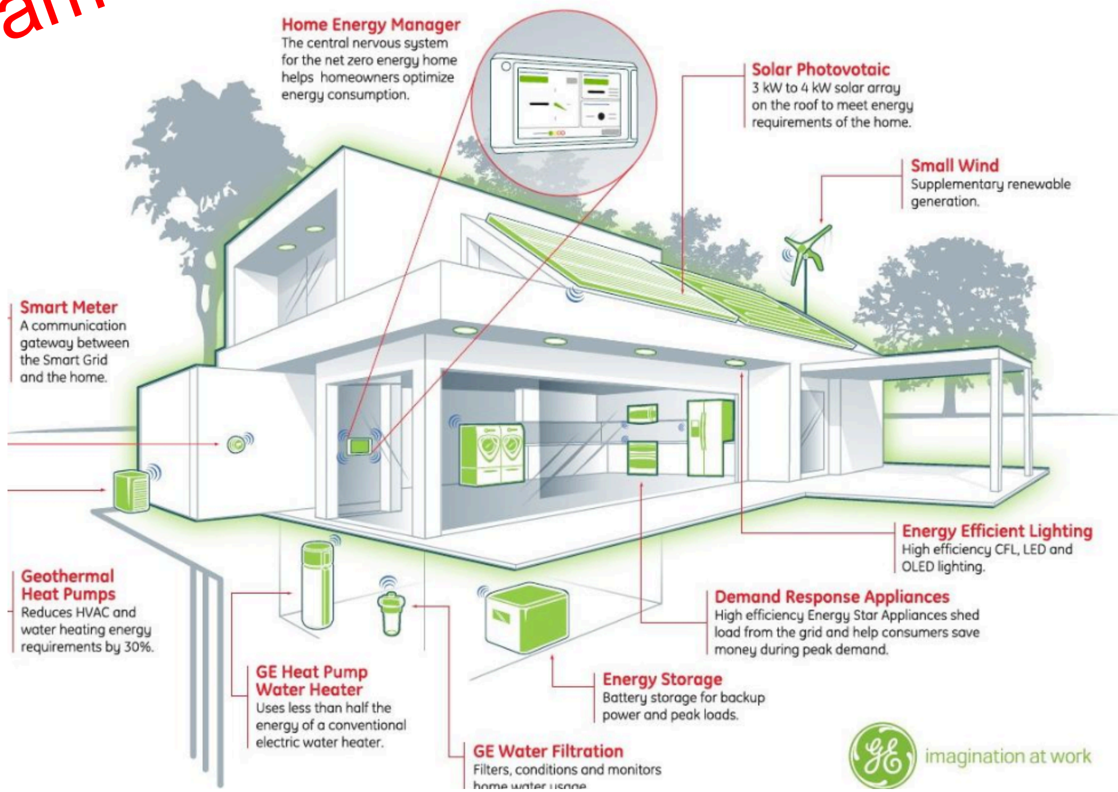


Texas experience, less need for fast frequency support after wind power plants provide good response (Source: Julia Matevosjana, ERCOT)

The traditional load becomes active

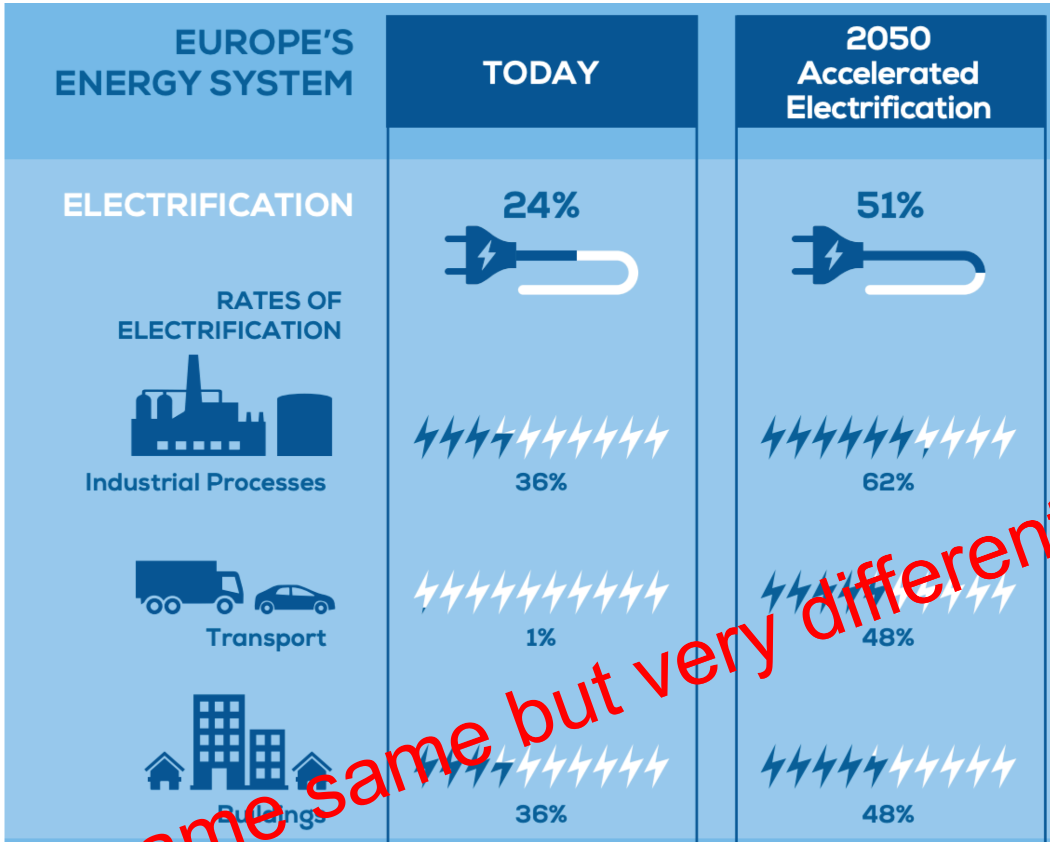
- Aggregators: offering same comfort/service and aggregating flexibility
- Prosumers: optimise use of (solar) generation. HEMS, BEMS, energy communities, local markets

same same but different



Sector coupling will more than double electricity demand

- Heating and cooling with air pumps
  - Combined with thermal storage
- Electric transport
  - Vehicles used less than 50 % of time
- Electrolysers for synthetic gas, industry processes



not same same but very different