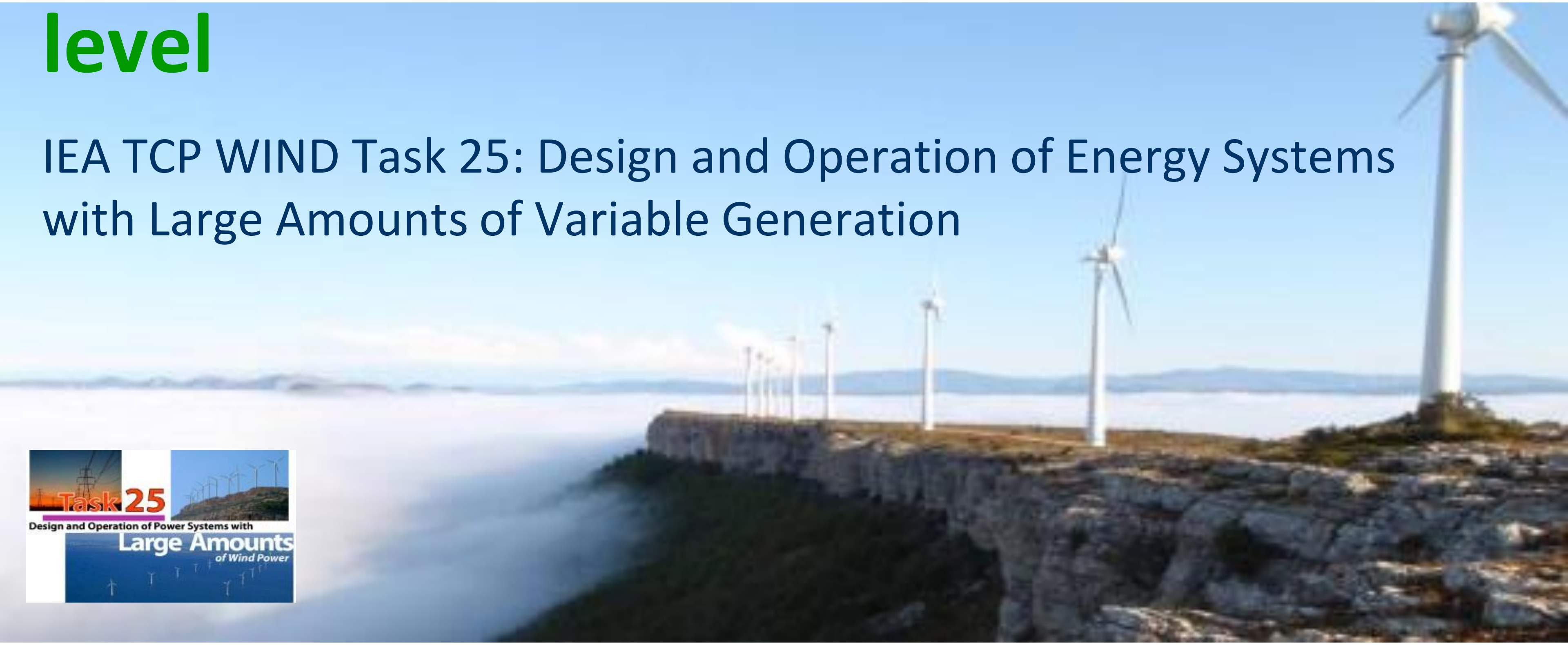
Modelling flexibility needs and contributions of wind/PV at system level



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

Hannele Holttinen, Operating Agent Task 25

J. Kiviluoma and N. Helistö, VTT

IEA Paris inter-TCP webinar 6 April 2020

iea wind

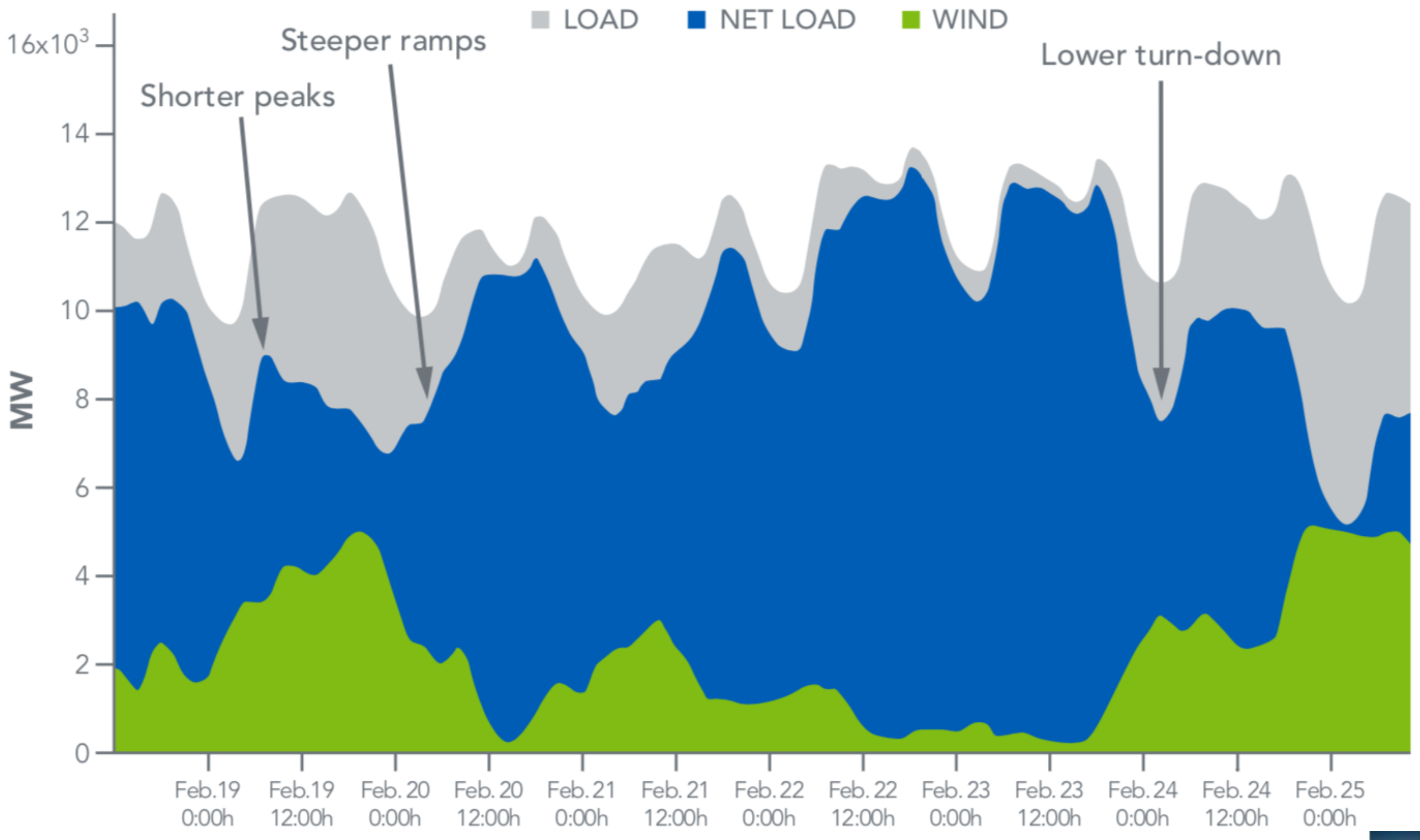
Contents

- Flexibility needs – simple and system approaches
- Modelling future flexibility adequacy
- Wind/PV flexibility

***Flexibility** is the power and energy **system's ability to adapt** to variability and uncertainty in demand and generation, which occur on different timescales.*

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

Flexibility needs – VG increase net load variability



Source: 21st century Power Partnership: Flexibility for 21st century power systems

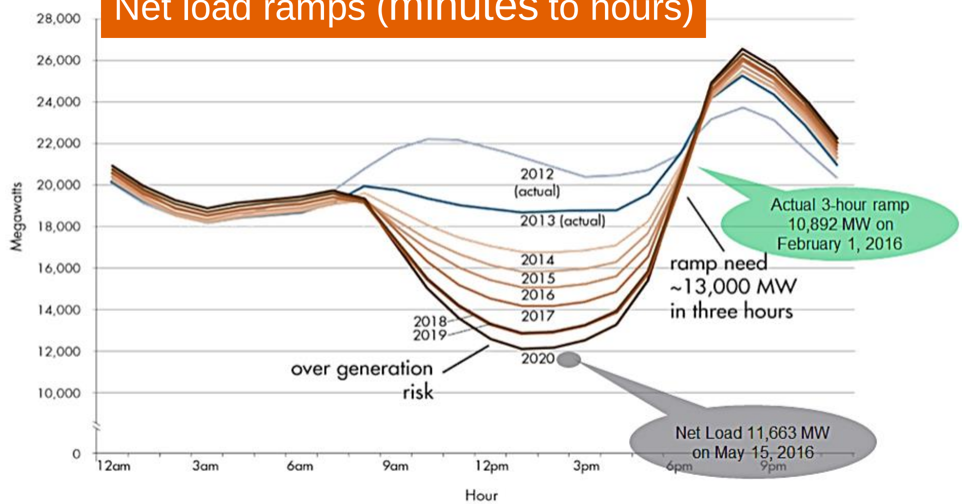
Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power

Examples of flexibility needs: hourly, daily, seasonal

1. Ramping, min. load
2. Start/stop cycling, min. load
3. Storage in fuels, thermal and electricity

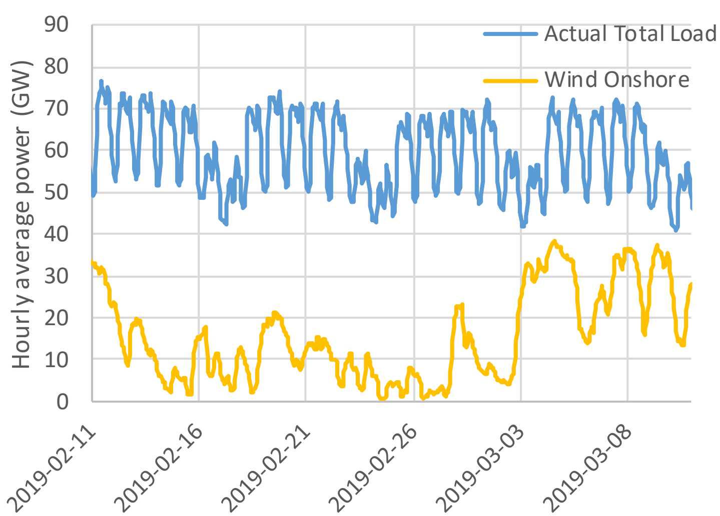
[1] California Independent System Operator (CAISO)
[2] Data from Germany (ENTSO-E)
[3] Data from Germany (ENTSO-E)

Net load ramps (minutes to hours)

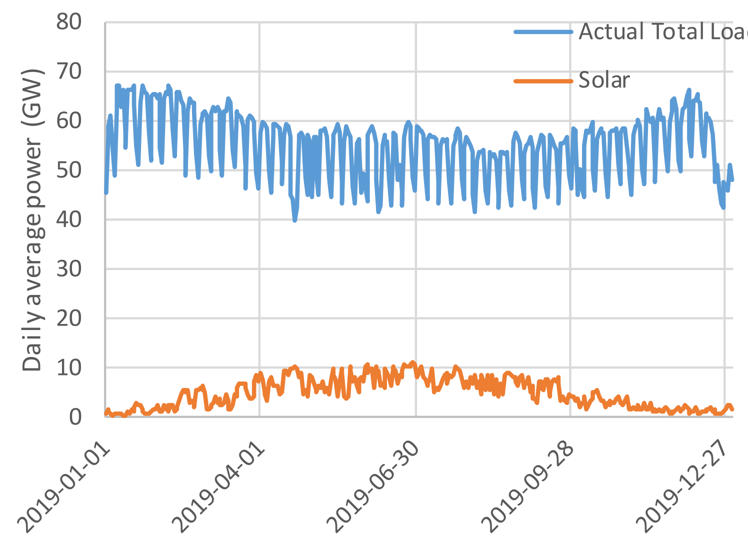


[1]

[2]



Weather patterns (days)



[3]

Seasonal variations (months)

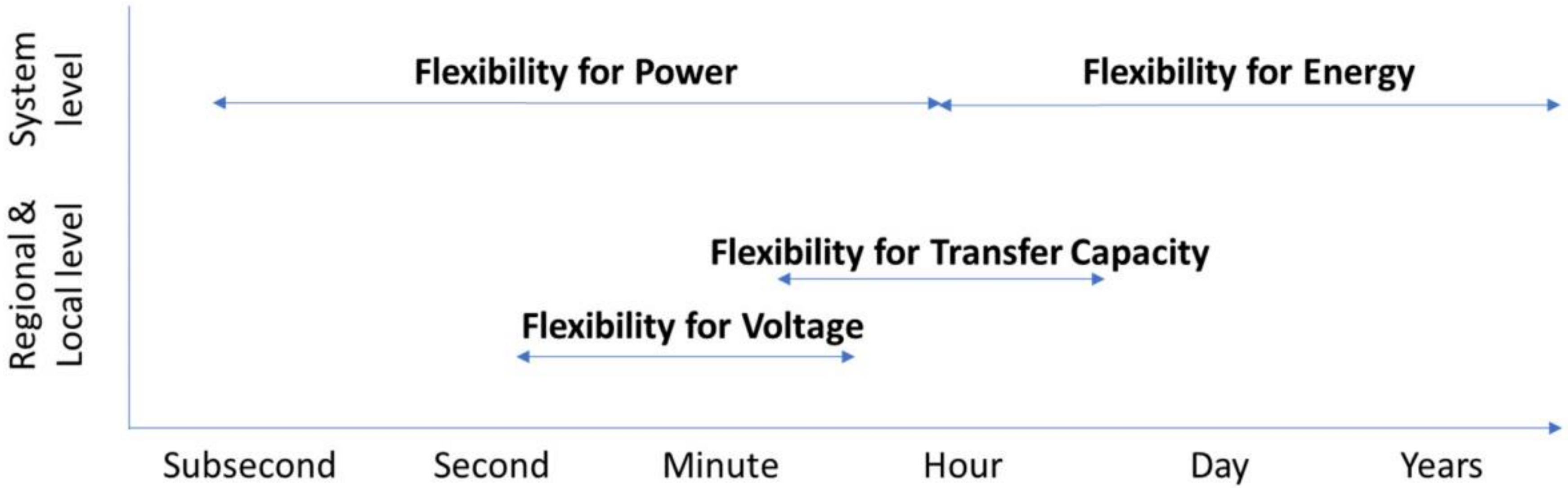
Different challenges as wind/PV shares increase

Phase	Description
1	VRE capacity is not relevant at the all-system level
2	VRE capacity becomes noticeable to the system operator
3	Flexibility becomes relevant with greater swings in the supply/demand balance
4	Stability becomes relevant. VRE capacity covers nearly 100% of demand at certain times
5	Structural surpluses emerge; electrification of other sectors becomes relevant
6	Bridging seasonal deficit periods and supplying non-electricity applications; seasonal storage and synthetic fuels

Short term flexibility

Long term flexibility

Flexibility need – temporal and spatial scales



https://www.iea-isgan.org/flexibility-in-future-power-systems/

PLUS from power systems to energy systems:

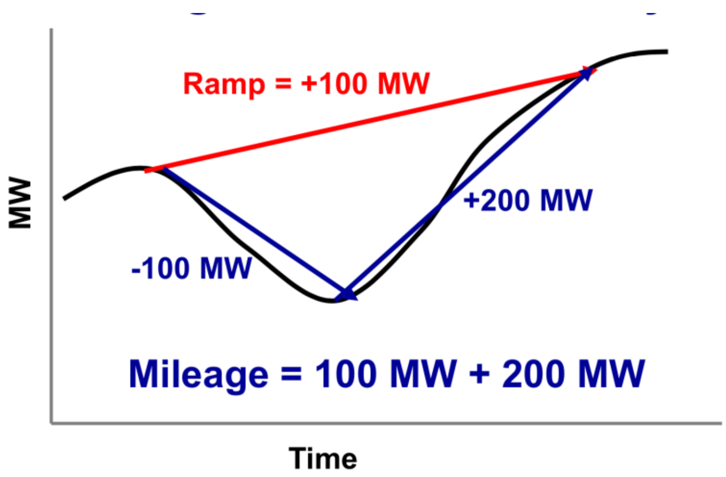
- Sector coupling – flexibilities from linking power and heat etc

Quantifying flexibility needs

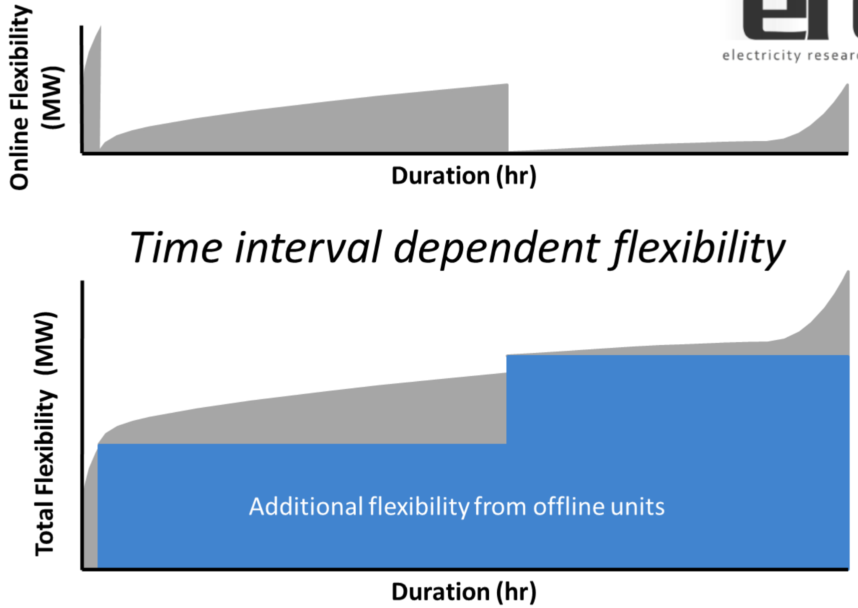
Often for generators ramping up/down, Or for storages for energy. Interconnectors role, VG flexibility, flexible load and storages should be taken into account.

Simplified assessments:

1. Short term variability: Ramping
2. Uncertainty: Operating reserves
3. Power and energy, as storage needs



EPRI: E Lannoye. Finding the Limits to Flexibility. WIW18 Stockholm



Flexibility assessment - system

- Simple quantifications do not capture whole picture
  - Many sources of flexibility inherent in a power system
  - What is critically needed for variability and uncertainty?
- System optimization – both for capacity and operation – can determine how the system copes with added variability and uncertainty with flexibility
  - Results seen as system costs, also the use of flexibility options and their value
  - If capacity/generation mix and transmission not optimized, then may see scarcity of flexibility: not fulfilling reliability requirements (operating reserves), increased/unnecessary curtailment of VG

FlexTool for a simple system approach available at
https://www.irena.org/publications/2018/Nov/Power-system-flexibility-for-the-energy-transition

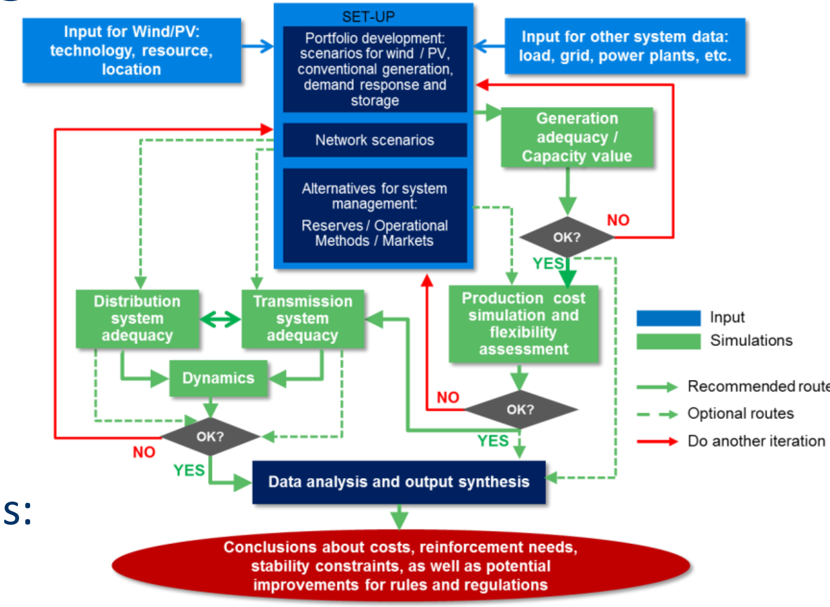
Capturing flexibility needs and sources in simulations

Needs: temporal/spatial resolution of VG

- Not to overestimate: Smoothing of variability
- Not to underestimate: Uncertainty/forecast errors

Sources: capture characteristics

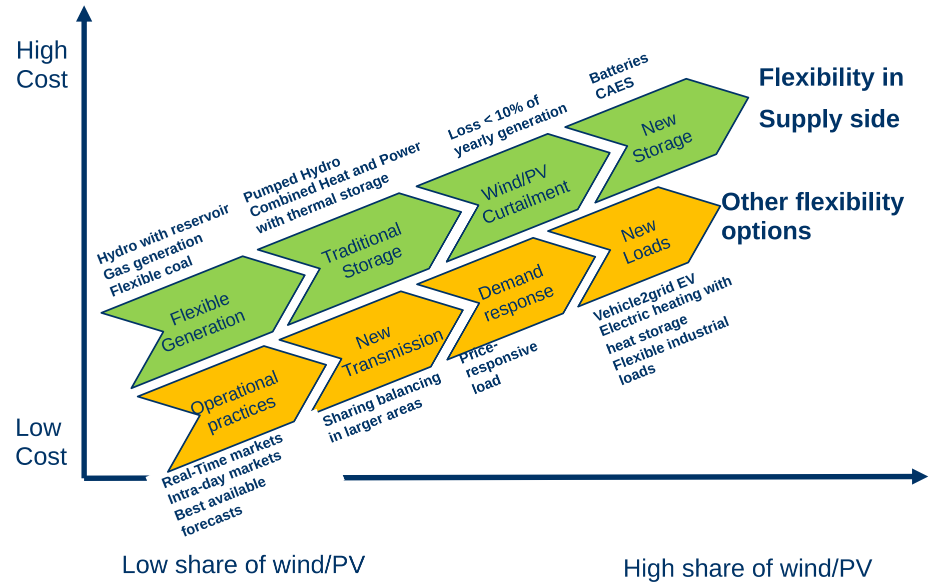
- Not to underestimate:
  - Sharing flexibility with neighbouring areas: take into account interconnections, but model the limitations
  - Generation flexibility in future, also VG providing
  - Demand response, storages, energy sector coupling
- Not to overestimate, model all limitations, technical and economical!



Recommended practices for Wind/PV Integration Studies RP16 Ed 2
https://community.ieawind.org/publications/rp
Collaboration btw IEA TCPs Wind and PVPS

Challenges in system simulations to capture flexibility adequacy

- Data for costs, and technical limitations of flexibility options
  - Hydro power river coupling constraints
  - Demand response costs? Rebound
- Time scales are different and bring a complexity
  - Short term flexibility needs and options require sub-hourly resolution
  - Long term flexibility related to security of supply
- Details cost computation time



Modelling enablers:

Transmission and operational

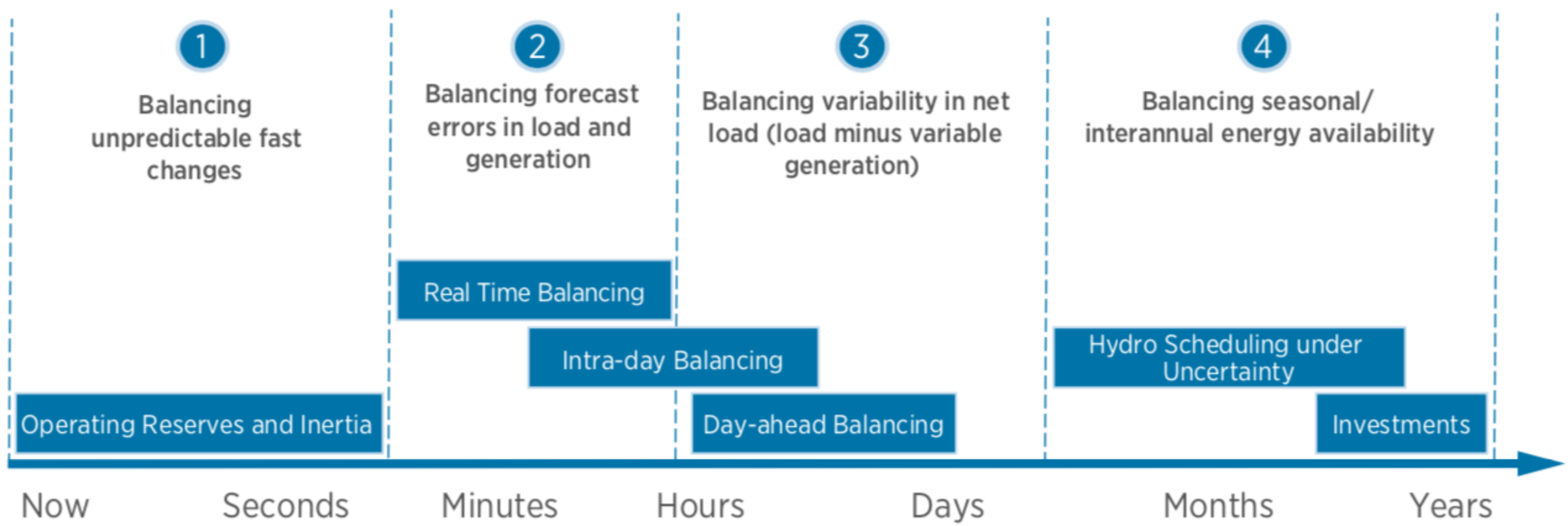
- Reduction of variability
- Benefits from using flexible resources in neighboring countries

Smart grids/ digitalization

- local flex resources, DR

Value of flexibility

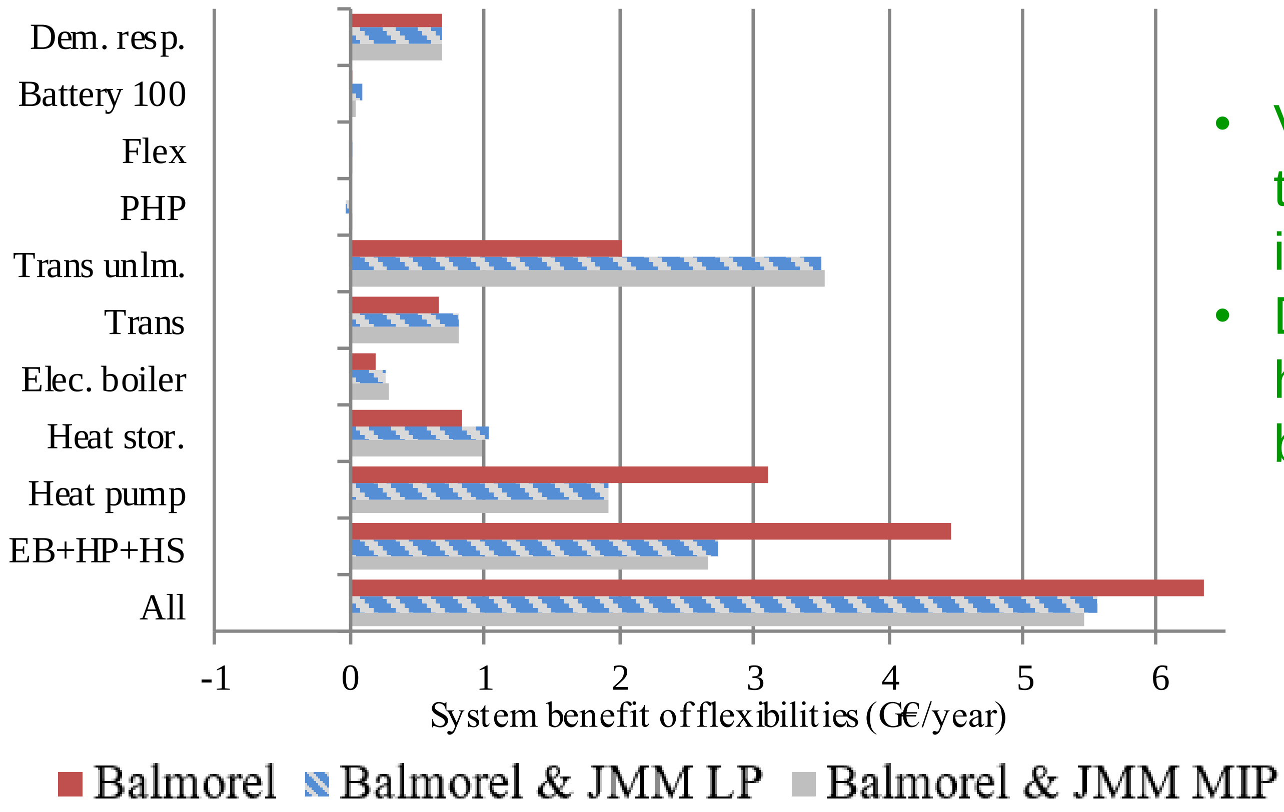
- Short term: increasing AS payments: for frequency control, but also new services like inertia and black start
- Medium term: paid through ability to pick the highest priced energy-only-market hours: future markets see higher (scarcity) prices more hours of the year
- Long term: capacity payments (and scarcity pricing)



https://www.irena.org/publications/2018/Nov/Power-system-flexibility-for-the-energy-transition

Flexibility sources are competing

Cost Benefit of Flexibility options: Case >40% wind/PV around Baltic sea



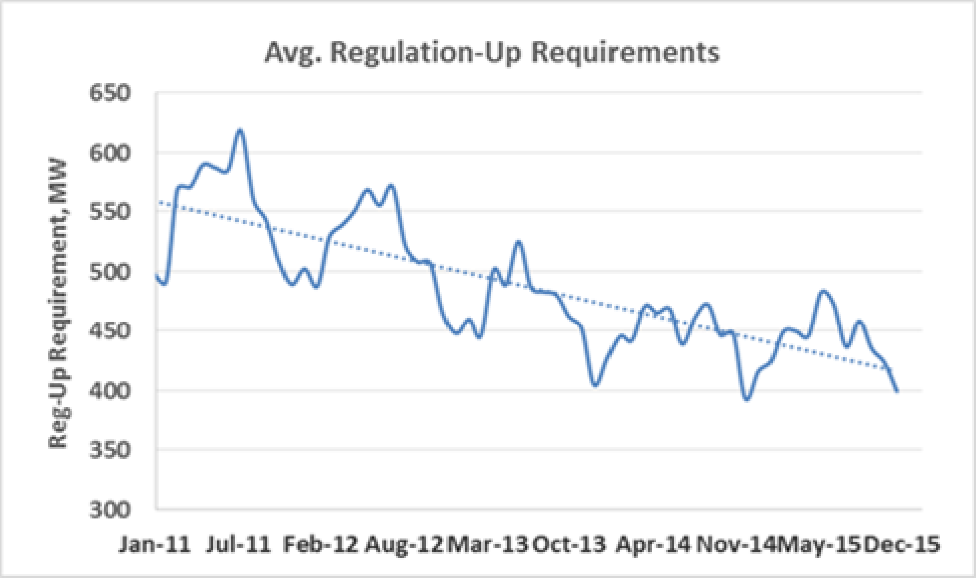
- Value of All less than sum of individual options
- Detail of simulation has impact on the benefit estimated

VTT

Kiviluoma, J., Rinne, E., & Helistö, N. (2018). Comparison of flexibility options to improve the value of variable power generation. *International Journal of Sustainable Energy*, *37*(8), 761–781. https://doi.org/10.1080/14786451.2017.1357554

Flexibility – grid support services from wind and solar

- Asking for capabilities in grid codes, and paying for services of system support if needed/used
  - Texas: fast response of WPPs help reduce the overall need for automatically activated frequency support services
  - California: responses from PV better than conventional generators
  - Spain: 14 GW wind compliance tests. Wind providing ~ 5 % of downward reserves in 2017
  - Europe: Utilizing large numbers of PV + storage systems in a VPP configuration to provide flexibility and fast frequency control



Source: Julia Matevosjana, ERCOT

https://www.caiso.com/Documents/UsingRenewablesToOperateLow-CarbonGrid.pdf

IEA Wind Task 25: Design and operation of energy systems with large amounts of variable generation

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); Ea analyse (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	UCD (D. Flynn); SEAI (J. McCann); Energy Reform (J. Dillon);
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 (Arjen van der Meer, Simon Watson)
Norway	NTNU (Magnus Korpås); SINTEF (John Olav Tande, Til Kristian Vrana)
Portugal	LNEG (Ana Estanquiero); INESC-Porto (Ricardo Bessa)
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 (Jian Fu)
Wind Europe	European Wind Energy Association (Vasiliki Klonari, Daniel Fraile)

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

Thank You!!

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

Hannele Holttinen

Hannele.Holttinen@recognis.fi

+66 61 473 5255

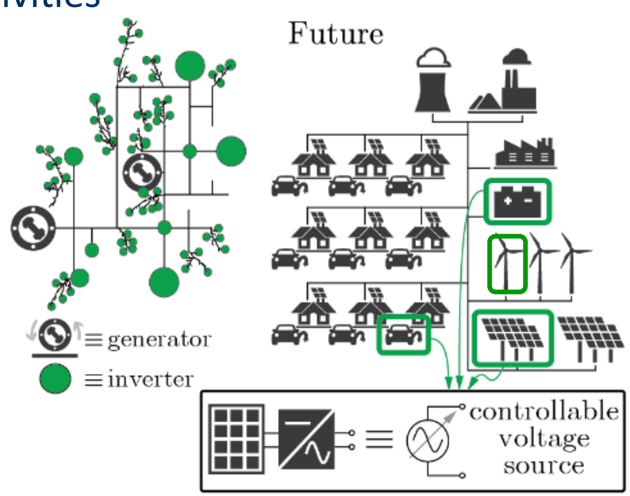
+358 40 5187055

recognis

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.

IEA Wind Task 41: Enabling Wind to Contribute to a Distributed Energy Future

- Progressing Distributed Wind Technology Design Standards for Small- and Mid-Size Wind Turbines
- Expand Learning and Support of the Integration of Distributed Wind into Evolving Electricity Systems
- Innovation and Downscaling of Utility-Scale Technology
- Distributed Wind Data Information Catalog
- Outreach and Collaboration with Other R&D Activities

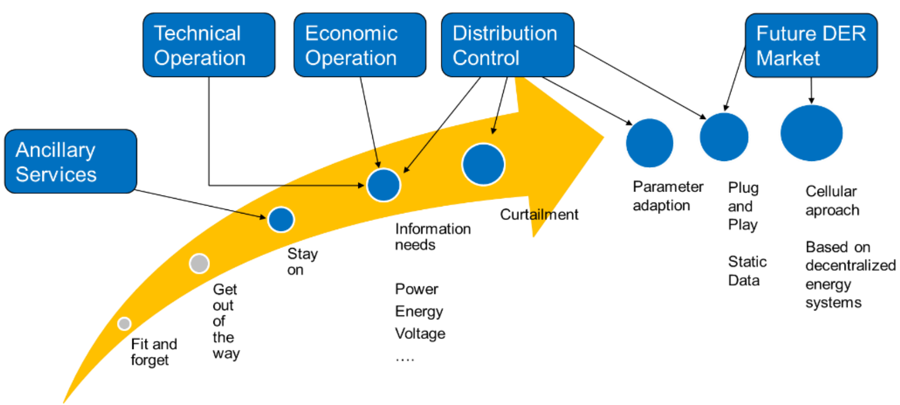


Country	Contacts	Organization
Austria	Mauro Peppoloni	University of Applied Sciences Technikum Wien
	Kurt Leonhartsberger	University of Applied Sciences Technikum Wien
Belgium	Mark Runacres	Vrije Universiteit Brussel
Canada	David Wood	University of Calgary
	Sergio Gualteros	Nergica
China	Jia Yan	Inner Mongolia University of Technology
	Charlie Dou	Chinese Wind Energy Association
	Li Yan	Goldwind China
	Bian Qiying	Chinese General Certification Center
Denmark	Tonny Brink	Nordic Folkecenter for Renewable Energy
	Anca Hansen	Technical University of Denmark
	Kaushik Das	Technical University of Denmark
	Tom Cronin	Technical University of Denmark
	Anna Maria Sempreviva	Technical University of Denmark
Germany	Immanuel Dorn	Enbreeze
	Sudheesh Sureshkumar	Enbreeze
Ireland	Raymond Byrne	Dundalk Institute of Technology
	Paul Mac Artain	Dundalk Institute of Technology
Italy	Francesco Castellani	University of Perugia
Poland	Maciej Karczewski	Windtak
	Piotr Domalgaski	Windtak
South Korea	Seokwoo Kim	Korea Institute of Energy Research
Spain	Ignacio Cruz	CIEMAT
	Luis Cano	CIEMAT
Taiwan	Chung-Chun (Wallace) Hsu	Taiwan Institute of Economic Research, Taiwan Small/Medium Wind Turbine Association
United States	Robert Preus	National Renewable Energy Laboratory
	Jeroen van Dam	National Renewable Energy Laboratory
	Danielle Preziuso	Pacific Northwest National Laboratory
	Alice Orrell	Pacific Northwest National Laboratory
	Ian Baring-Gould	National Renewable Energy Laboratory
	Trudy Forsyth	Wind Advisors Team
	Bret Barker	U.S. Department of Energy
	Sarah Barrows	Pacific Northwest National Laboratory

https://community.ieawind.org/task41/home

Task 14: Solar PV in the 100% RES Power System

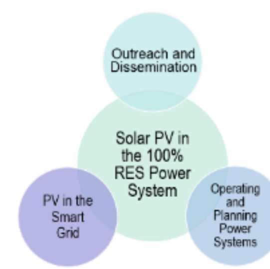
- Operating and planning power systems with Solar PV
- Solar PV in the Smart Grid
- Comprehensive international studies and experiences with PV grid integration.
- Global platform for exchange, outreach and collaboration
- **Preparing the technical basis for Solar PV as major supply in a 100% RES based electric power system**



16 Countries

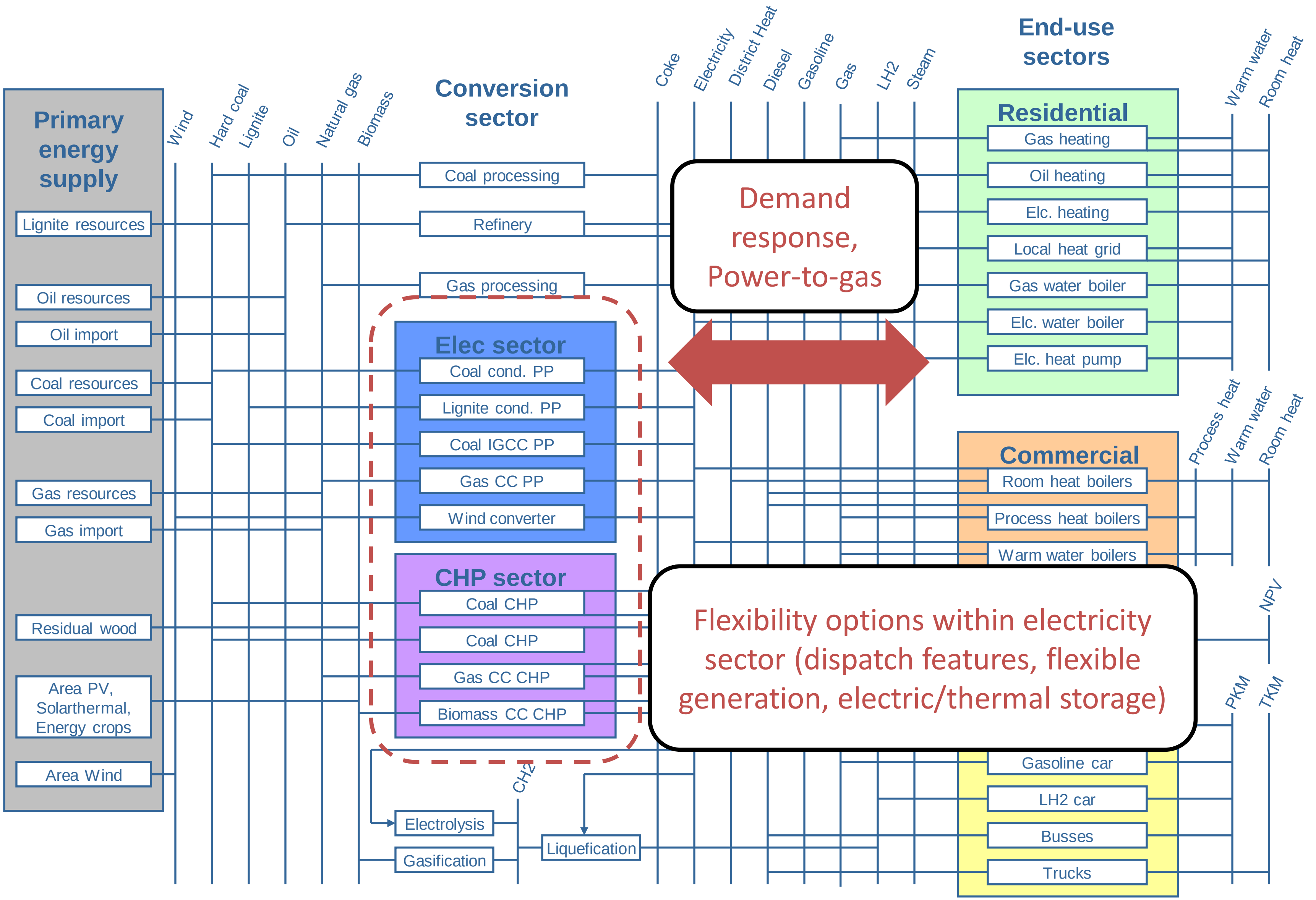
European commission

Broad expertise from
- Utilities, DNOs
- Applied research
- Universities
- Industry



Contacts: Link

Modelling flexibility within energy systems models



Integrating short term operational constraints

Multi-model approach

TIMES ⇄ PLEXOS® Integrated Energy Model

Energy Systems Model Low Carbon Roadmap 12 time slices	Dispatch Model 15 min – 1 hr temporal power plant detail

New Dispatch features in TIMES

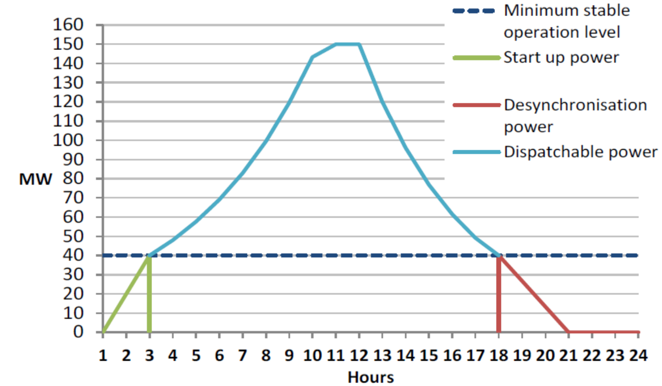
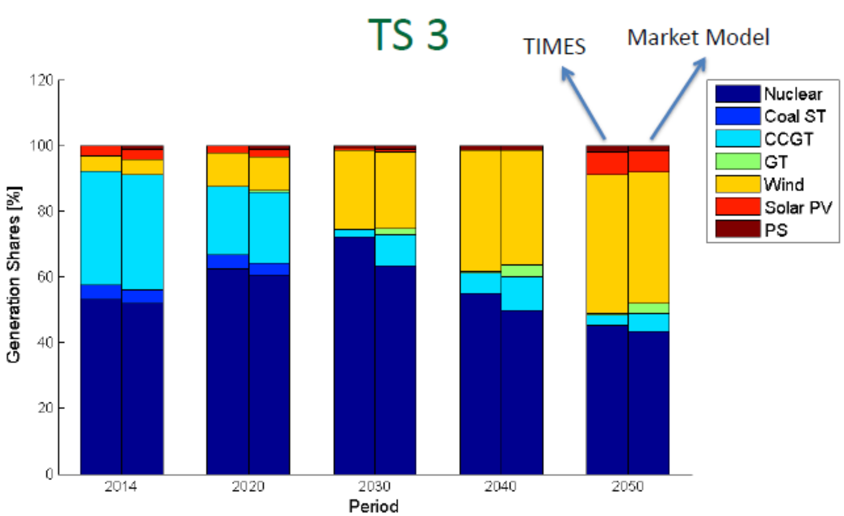
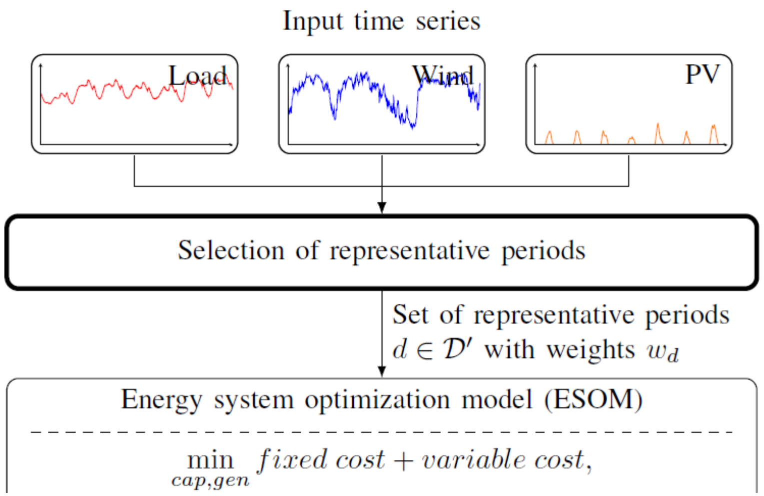


Figure 2: Operating stages of a thermal plant in the unit commitment problem.

Increase Time Slices



Model representative days



Collins, S., Deane, J.P., Poncelet, K., Panos, E., Pietzcker, R., Delarue, E., Ó Gallachóir, B.P., 2017. *Integrating short term variations of the power system into integrated energy system models: A methodological review.* **Ren & Sus En Rev**76 839–856

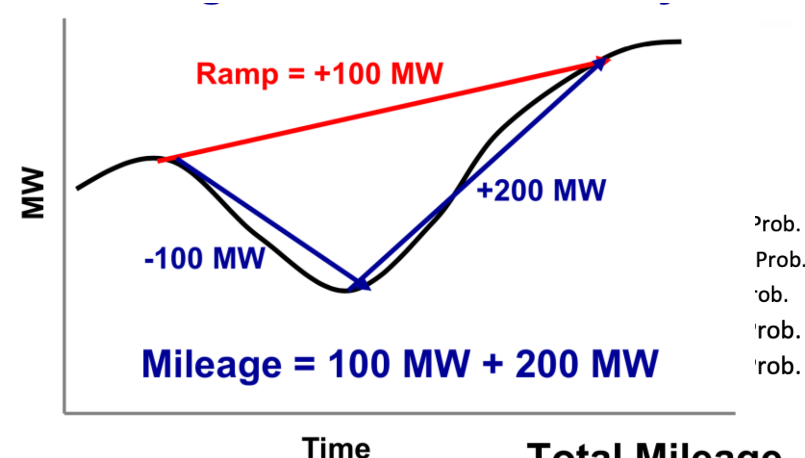
Discussion – collaboration?

- Flexibility adequacy and value in future power systems: System approach
- Collaboration on getting the opportunities and limitations of each technology to system models

Extra slides for simple flexibility assessment examples

1. Ramping needs

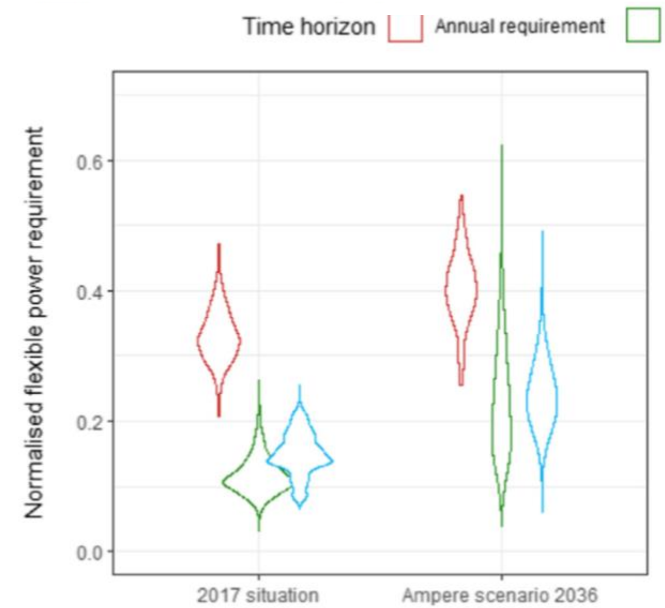
- (net-) load curve: expressed in terms of power and energy – for different time scales
- For one or multiple hour ramp
  - Ramping: derivative of net load over time
  - Ramp acceleration: Double derivative of net load over time. Volatility: Sum of ramp accelerations over a certain time period [1]
- Day/week/annual, important for high VG shares



$$\text{RUN RATE} = \frac{\text{Total Mileage}}{\text{Total Energy}}$$

As % of how much ramping to serve a MWh of loa

E Lannoye: Finding the Limits to Flexibility. WIW18 Stockhol



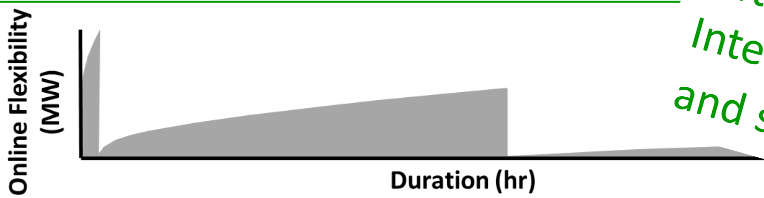
[1] Deetjen T A et al The impacts of wind and solar on grid flexibility requirements in the electric reliability council of Texas. Energy 123 (2017)

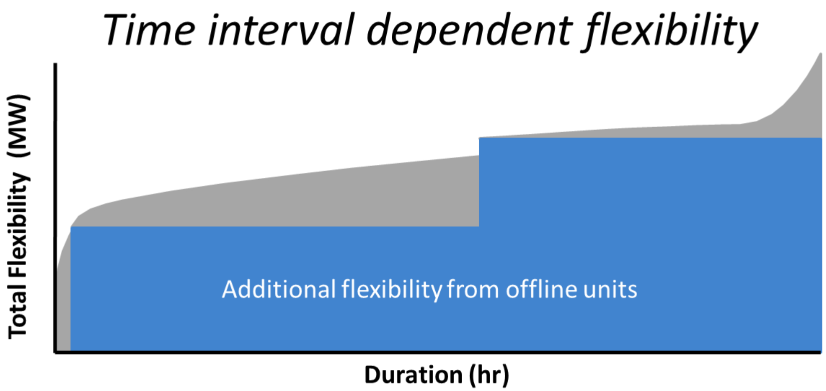
Heggarty T. et al Multi-temporal assessment of power system flexibility requirement. Applied Energy 238 (2019) 1327–1336

M Milligan et al. Advancing System Flexibility for High Penetration Renewable Integration https://www.nrel.gov/docs/fy16osti/64864.pdf

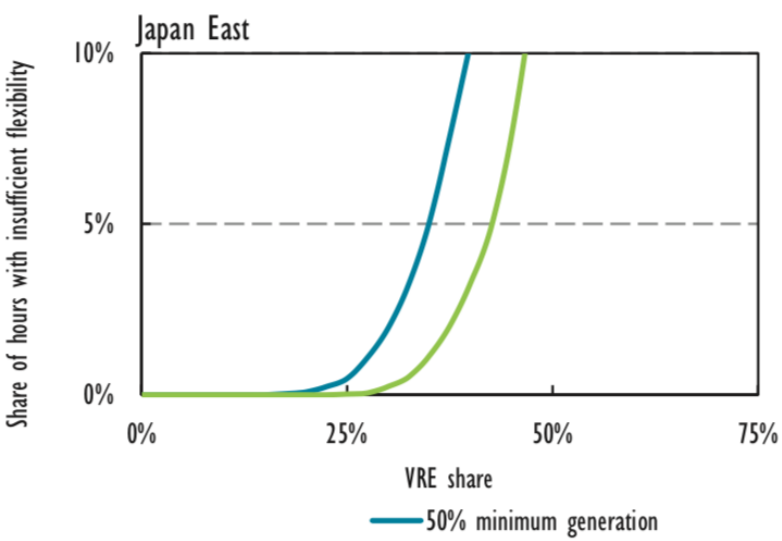
1. Flexibility adequacy

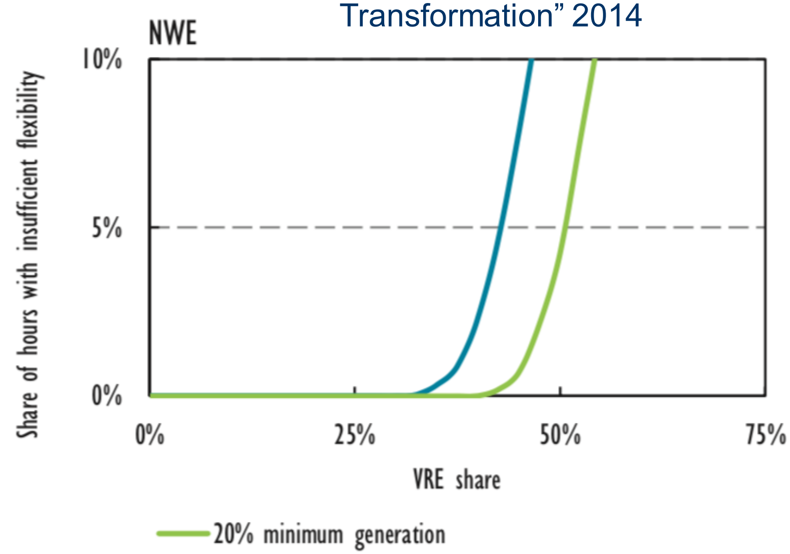
Often for generators ramping up/down. Interconnectors role, VG flexibility, flexible load and storages should be taken into account.





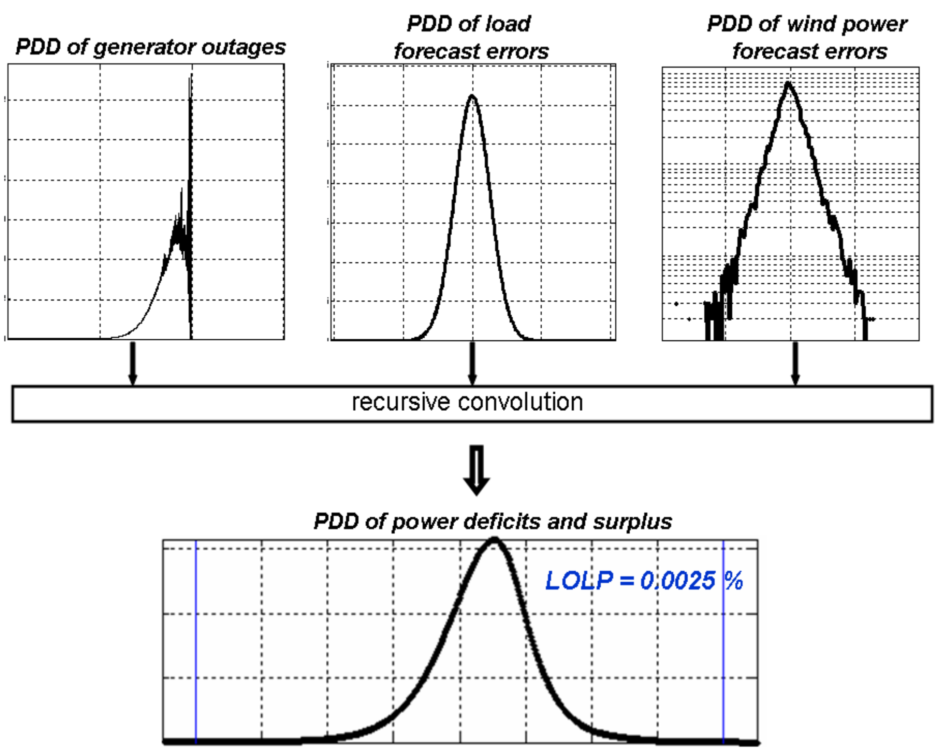
IEA FAST2 Tool "The Power of Transformation" 2014

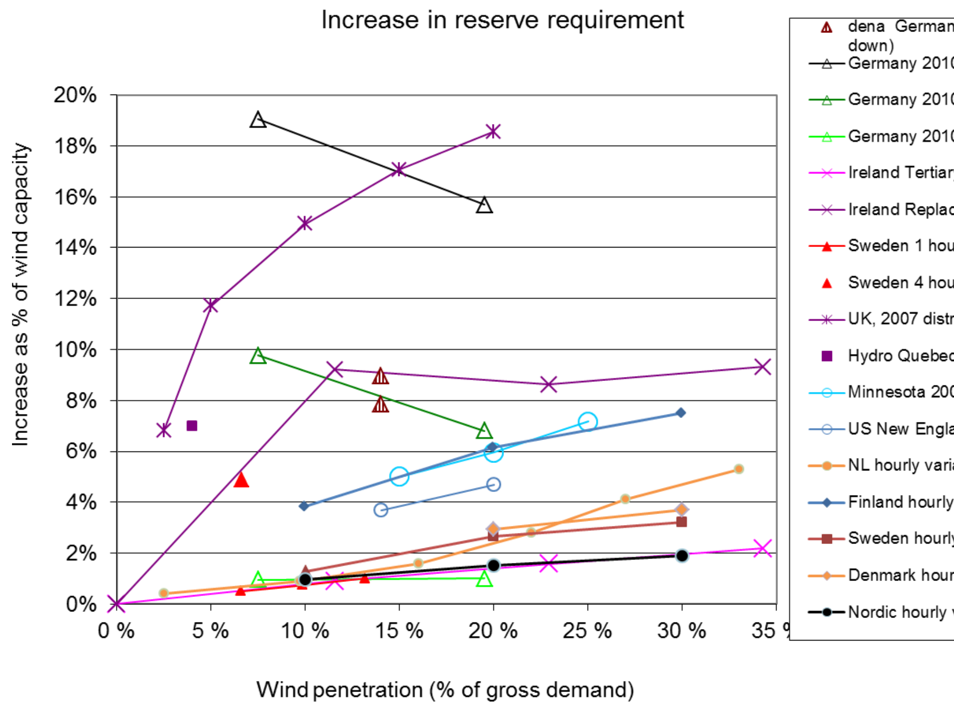




2. Operating reserve requirements

- Flexibility during operating hour – allocating reserves
  - forecast errors determine the need for operating reserve – combining uncertainty from load, wind, solar and generation





Source: Fraunhofer IWES

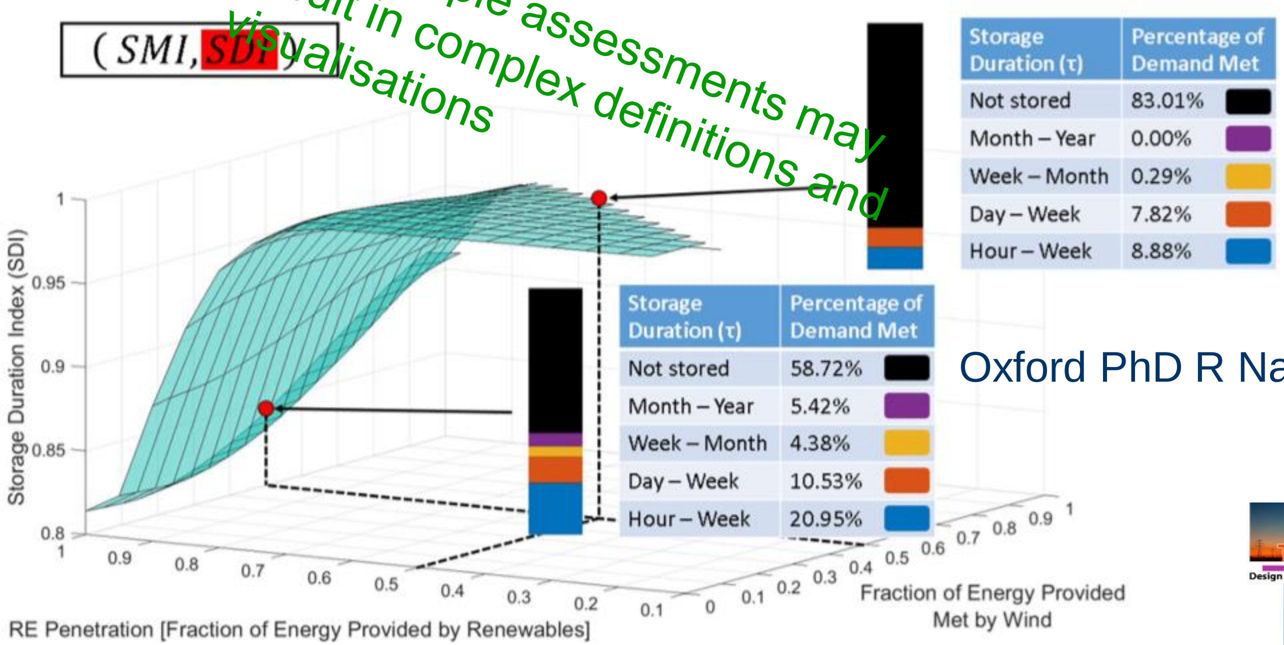
Task 25 summary report
https://community.ieawind.org/task25/ourlibrary

3. Power and energy

- Curtailed (surplus) VG energy one measure of flex needs
- Fill in surplus and scarcity of power and energy
- Optimise a storage portfolio for different "remaining load profiles" = load minus VG and conventional generation

Even simple assessments may result in complex definitions and visualisations

Storage energy capacity requirement is much more affected than the power capacity requirement



Oxford PhD R Nayak-Luke