TECHNICAL AND ECONOMIC ANALYSIS OF THE EUROPEAN ELECTRICITY SYSTEM WITH 60% RES

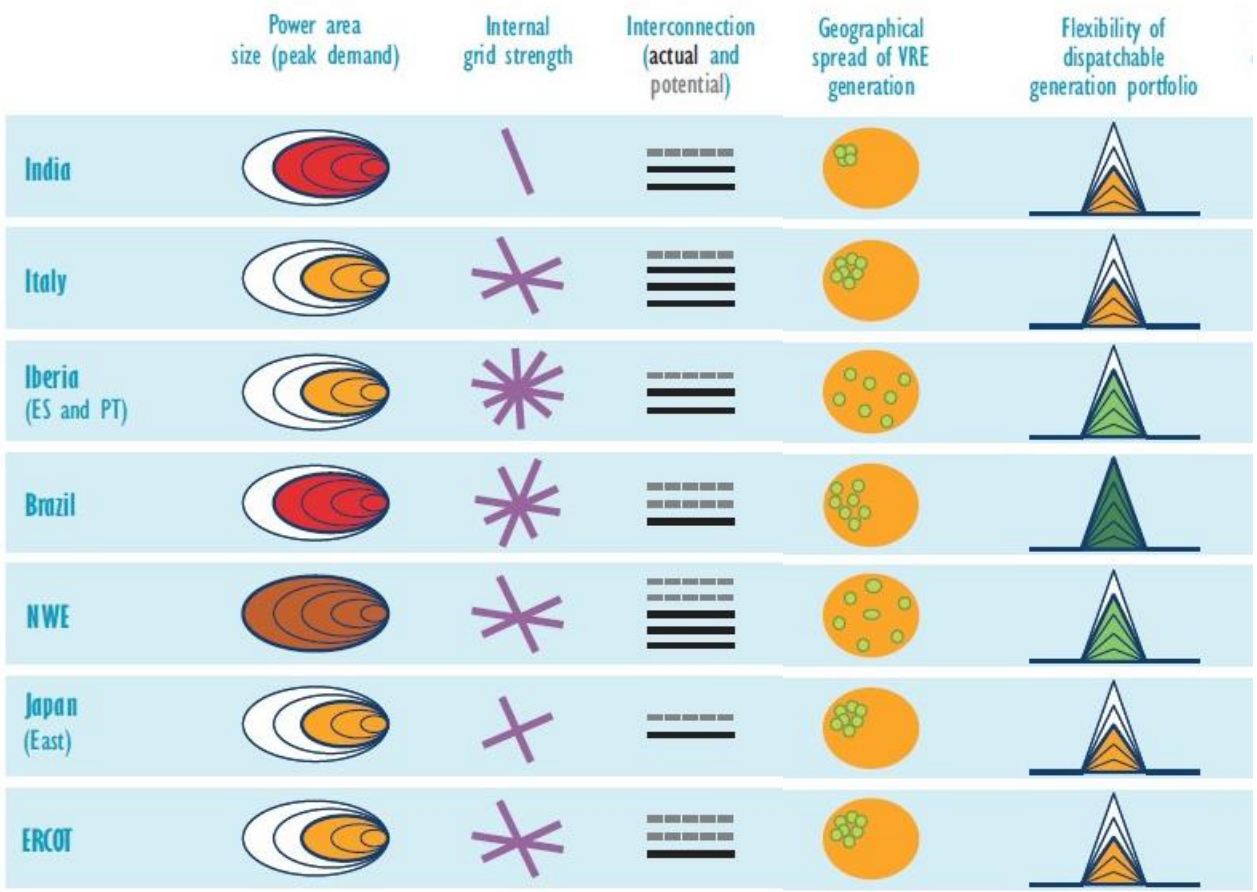
EDF R&D

The full costs of electricity provision

OECD NEA

Paris, 20 January 2016

System effects are strongly country specific and depend on the penetration level of VRE



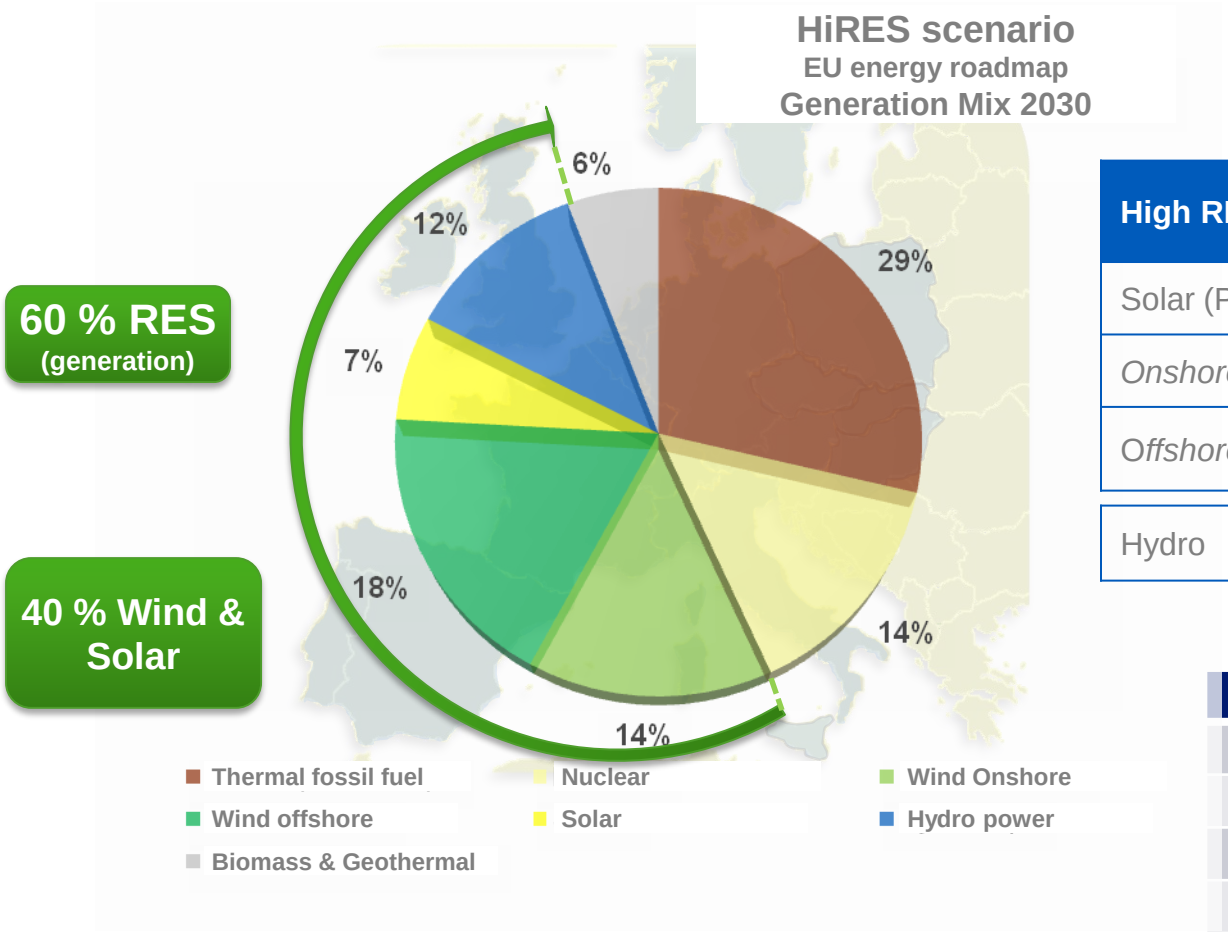
	VRE (2012)	Curtailment
India	3%	0%
Italy	11%	1,6%
Iberia (ES and PT)	21%	<0,3%
Brazil	1%	0%
NWE	8%	< 0,1%
Japan (East)	2%	0 %
ERCOT	9%	3,8 %

Source: IEA

% of demand

% of RES generation

Simulation of the EU Energy Roadmap « HiRES 2030 » scenario

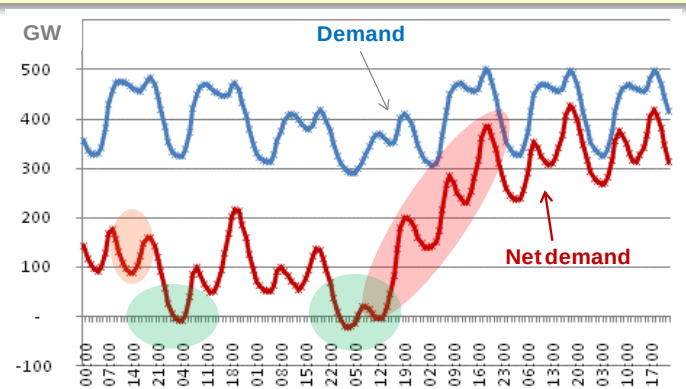


High RES 2030	GW	Load factor (h/yr)
Solar (PV)	220	1100
Onshore wind	280	1900
Offshore wind	205	3200
Hydro	120	3800

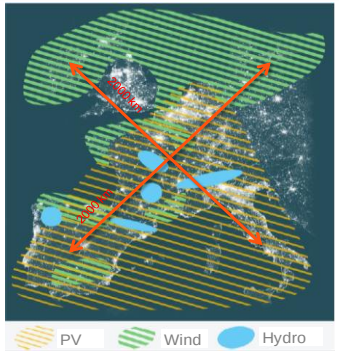
Fuel	Price
Coal	86 €/t
Gas	10 €/MMBtu
Oil	107 €/baril
CO_2	35 €/t

What is this study about?

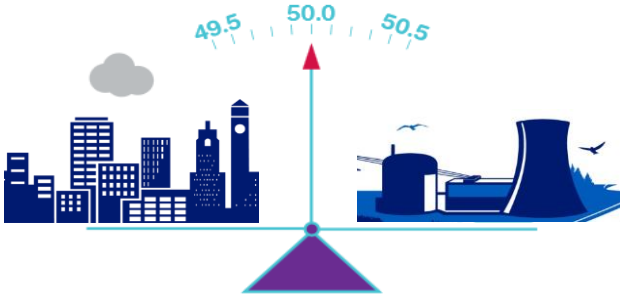
Flexibility to handle variability



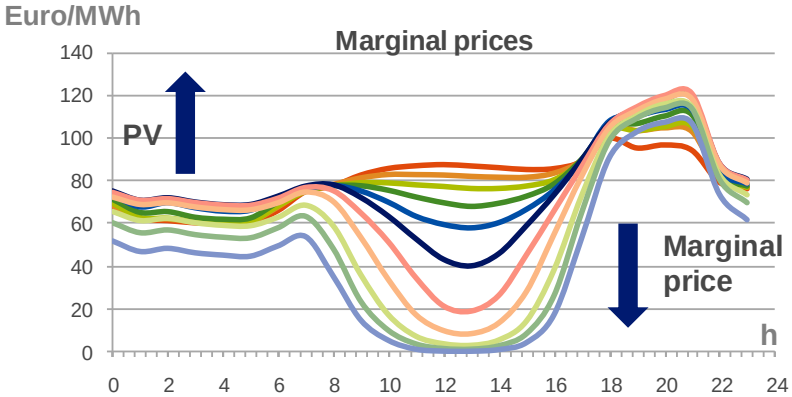
Connecting RES and load



Keeping the lights on



Balancing the economics



And the good news are…

The lights will stay on so no emerging market for candles!

That said …

Geographical diversity does help, but there is still significant variability at European level

Integrating a large share of variable RES requires a coordinated development of RES and networks

Variable RES are key to the decarbonisation of electricity production but the system still needs backup capacity for security of supply

Not only conventional generation, but also variable RES, will contribute to balancing and ancillary services

Storage and active demand may to a certain extent supplement generation to balance supply and demand

Variable RES production should potentially provide new services like fast frequency response (inertia)

The pace of deployment of RES should be optimised in order to limit costs of storage or excessive curtailment

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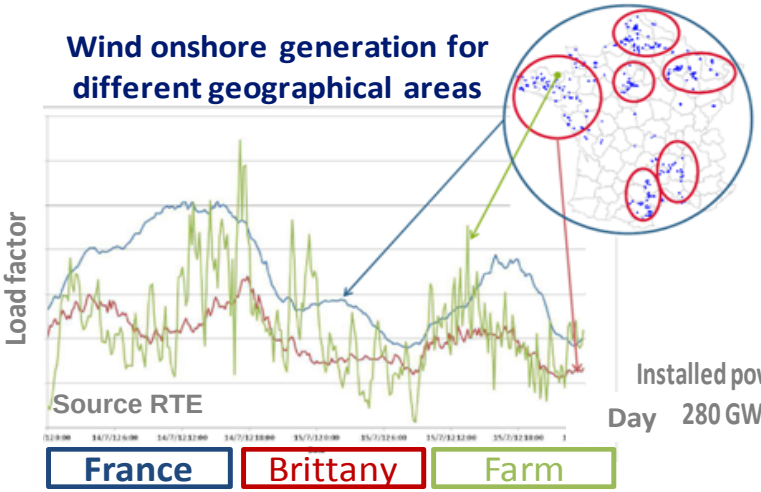
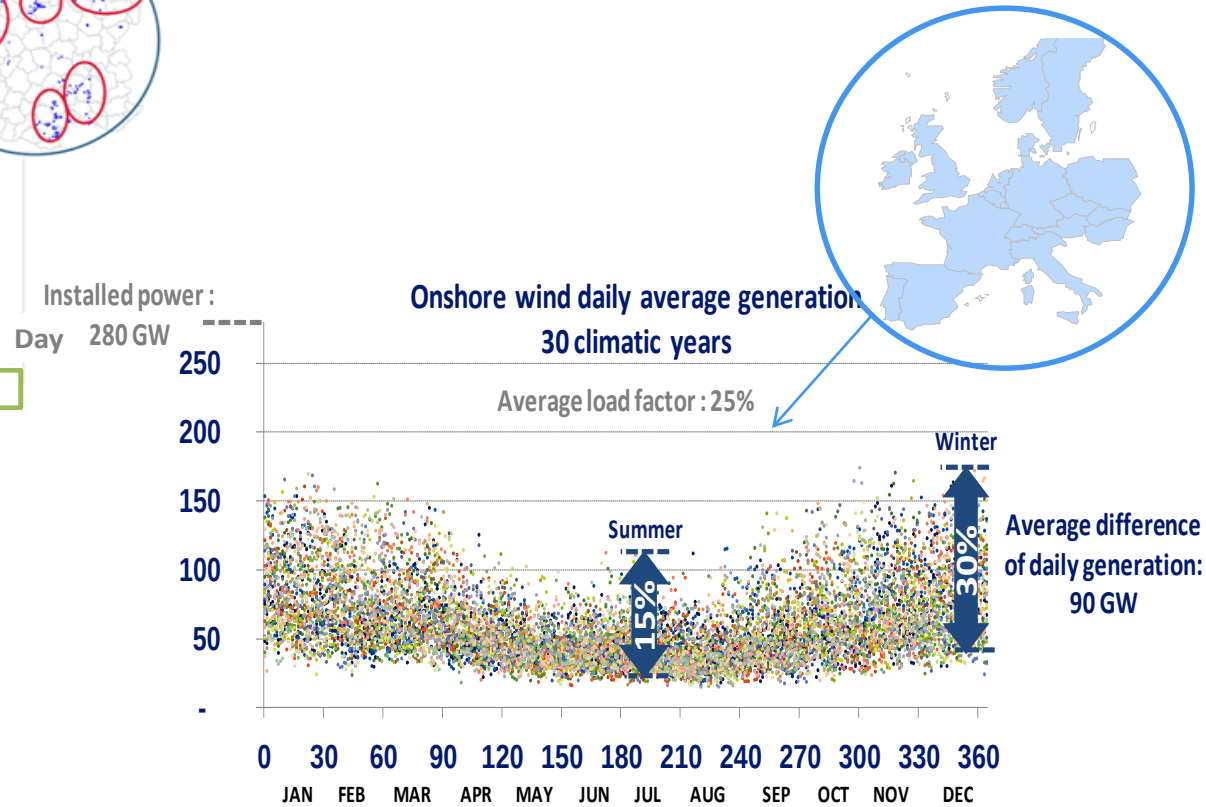
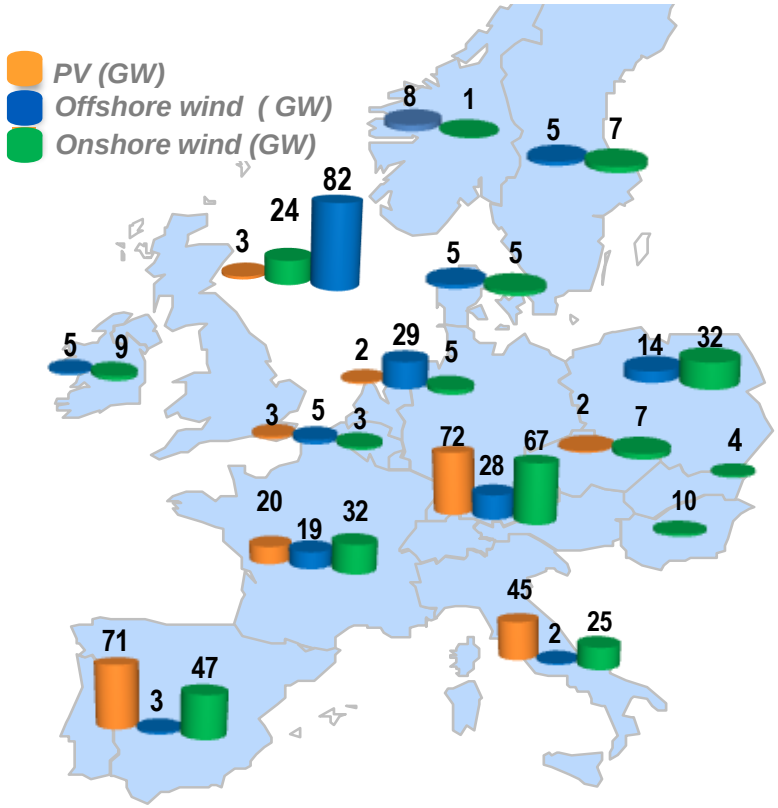




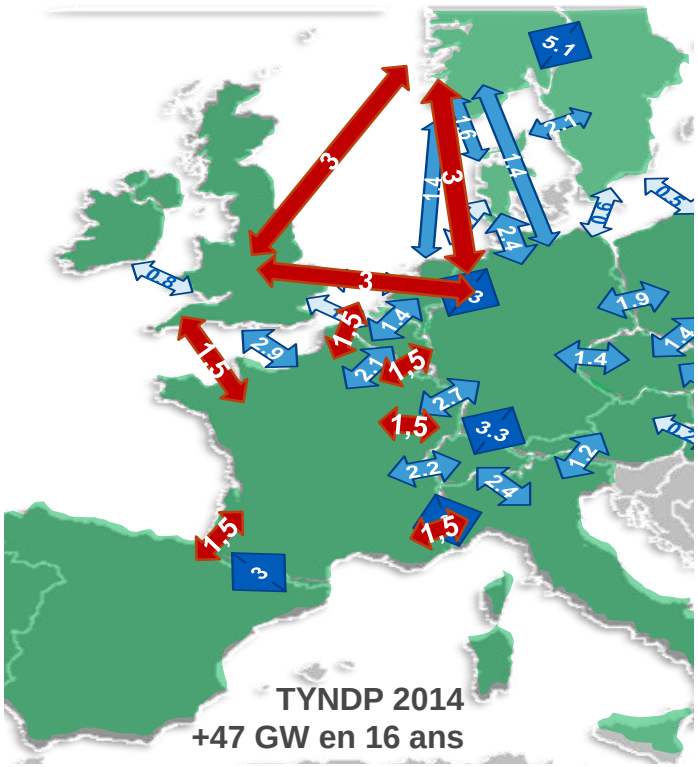
You can reduce the variability of wind and PV at local level but the correlation in wind regimes acts as a limit at continental level

Integrating a large share of variable RES requires a coordinated development of RES and networks

RES geographical distribution



Network development scenario



Interconnection reinforcement (GW) similar to TYNDP 2014

Interconnection reinforcement TYNDP 2010 (GW)

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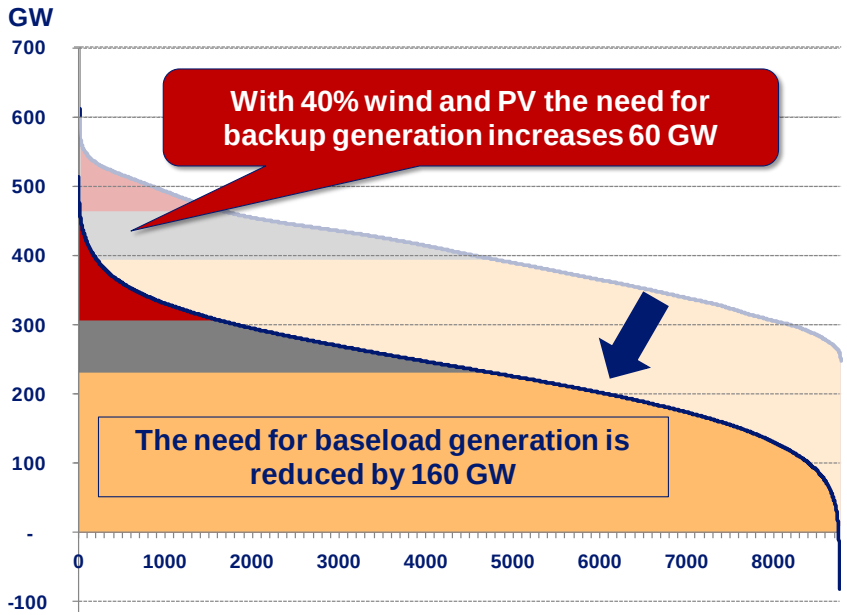
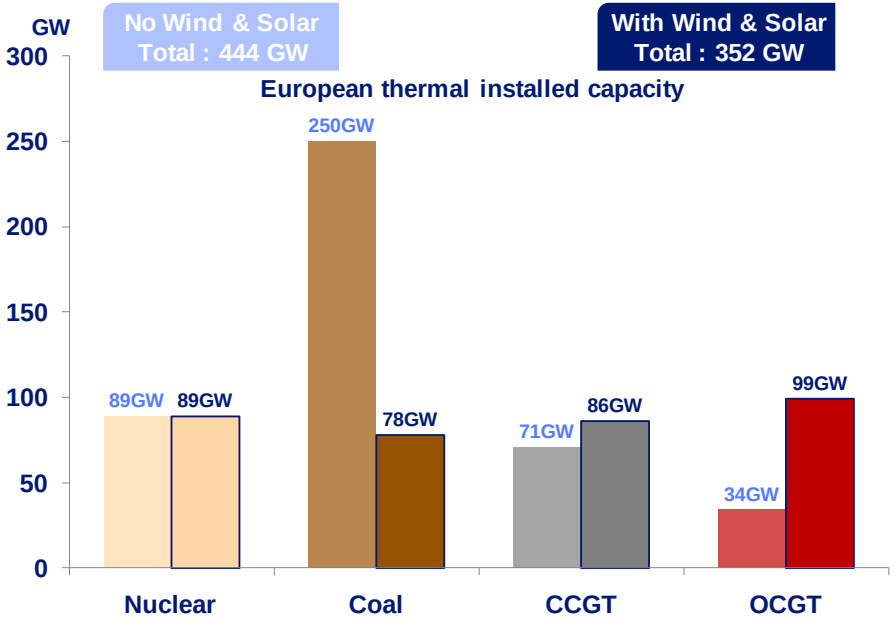




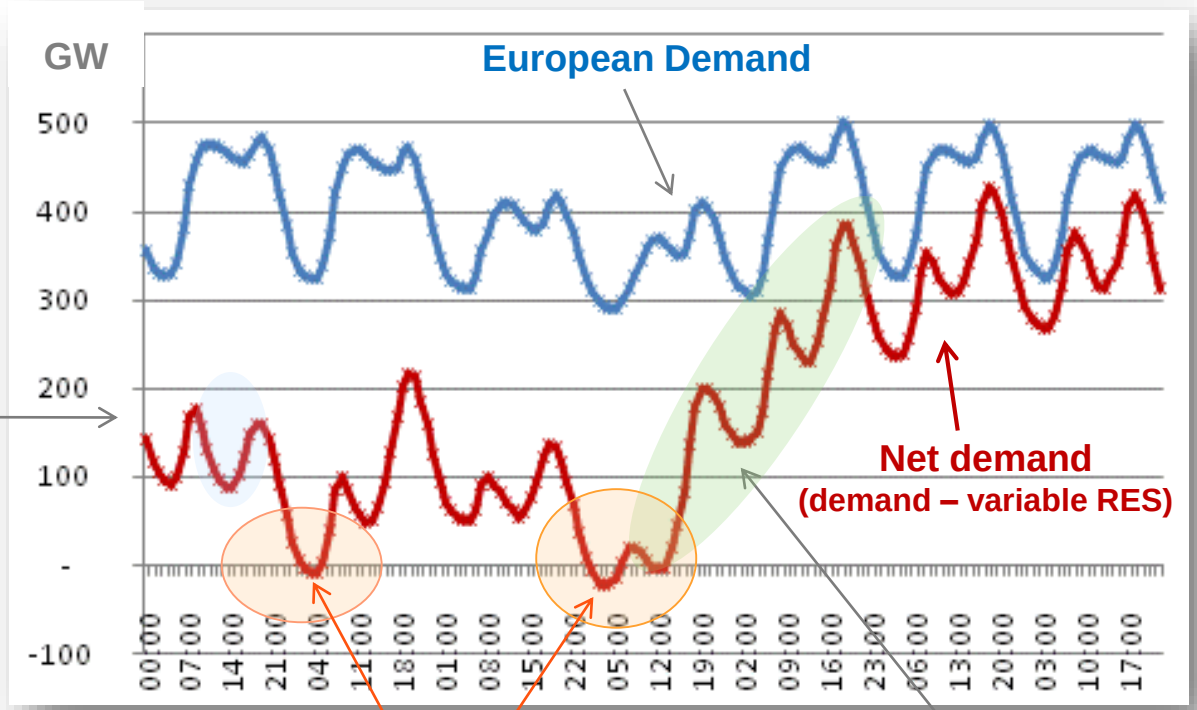
Average CO_2 with 60% RES = 125 g CO_2 /kWh

Average CO_2 with additional coal/gas replacement = 73 g CO_2 /kWh

(average CO_2 today = 350 g CO_2/kWh)

Full decarbonisation can only be achieved with a significant share of carbon free base load, such as nuclear

Not only conventional generation, but also variable RES, will contribute to balancing and ancillary services



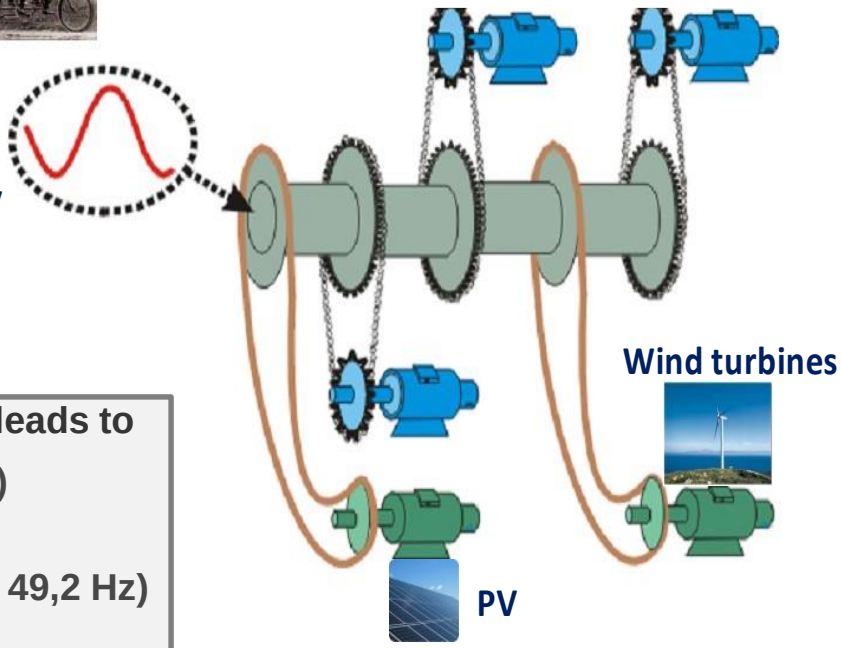
Middle of the day valley

Penetration of RES > 100 %

400 GW ramp between Sunday and Monday

RES need to provide downward flexibility as well as ancillary services

Variable RES production should potentially provide new services like fast frequency response



Due to lower inertia a reference incident leads to

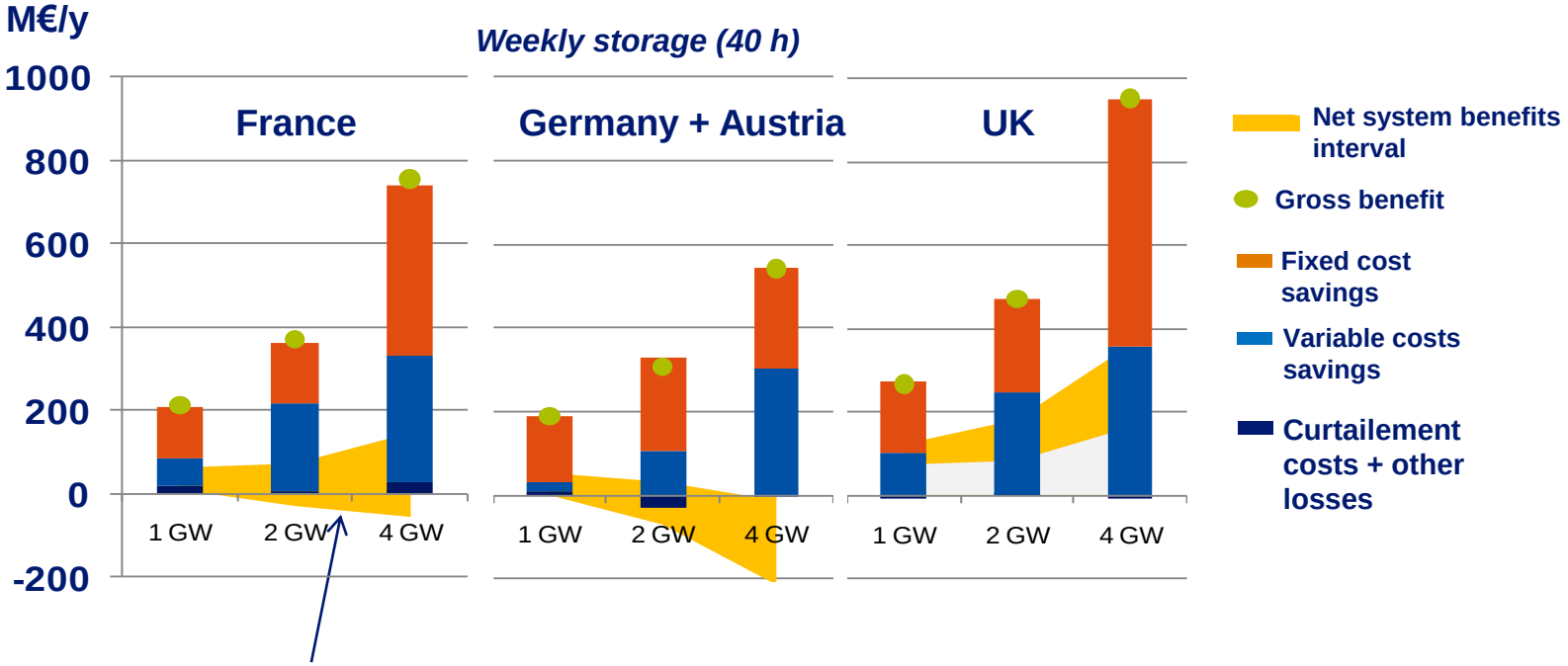
- a risk of load shedding (f< 49 Hz)
0,8 % of the time

- a violation of ENTSO-E security limit (f< 49,2 Hz)
25% of the time

Curtailment to avoid stability problems during critical periods can only be limited if variable RES have the technical capability to provide fast frequency response (synthetic inertia)

Storage and active demand may to a certain extent supplement generation to balance supply and demand

Net benefit of storage for different countries

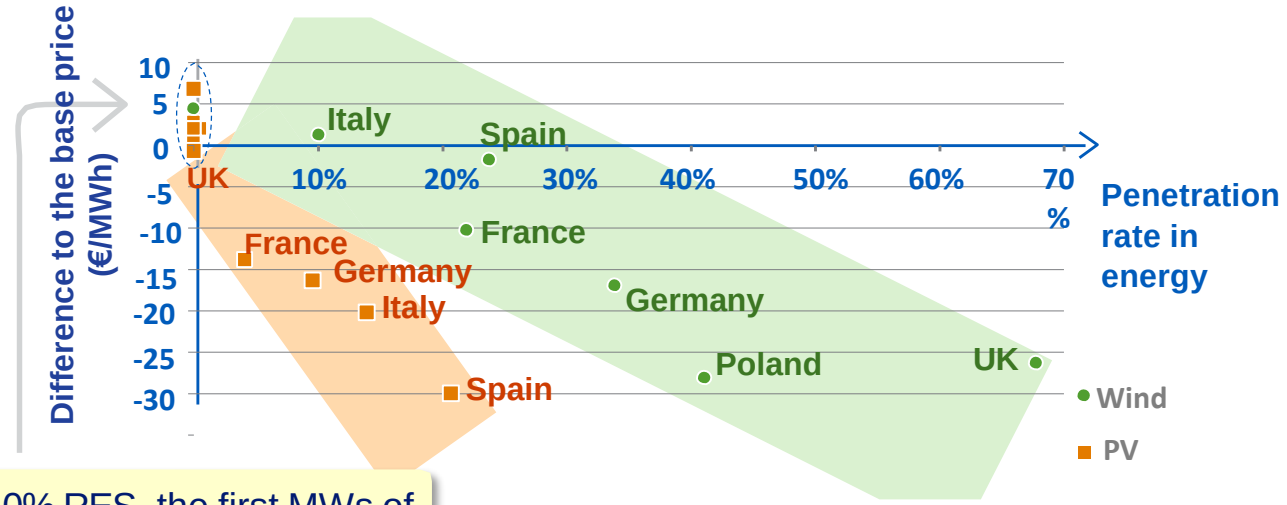


Net benefit interval as a function of storage cost and installed capacity

Storage and flexible demand contribute to the flexibility required for balancing but do not replace the need for backup generation

The pace of deployment of RES should be optimised in order to limit costs of storage or excessive curtailment

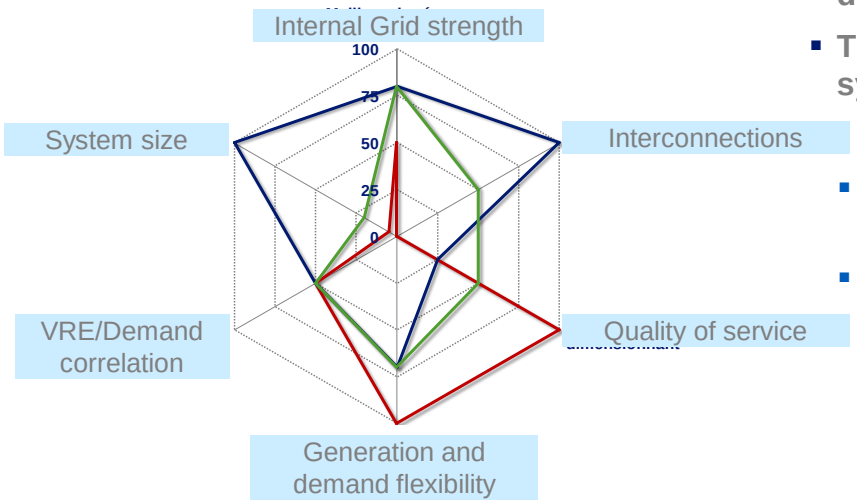
VRE value in comparison to base price per country



With ~0% RES, the first MWs of RES have a value close to the base price

The system value of variable RES will decrease as their penetration levels increases and this is more pronounced for PV

VARIABLE RES INTEGRATION COST ARE SYSTEM SPECIFIC SINCE THESE DEPEND ON THE TYPE OF SYSTEM AND THE CHARACTERISTICS OF THE SYSTEM



Large interconnected systems

Large island system

Small island systems

- System effects depend on grids and the generation mix.
- We see RES integration costs as the difference between the total system cost of two alternative pathways to serve a given demand: a pathway with VRE and a pathway without VRE
- The key cost components required in order to estimate total system cost are
  - **Grid** infrastructure investment
  - **Production costs** : energy, flexibility, reserves and other ancillary services
  - **System adaptation costs :** Costs associated to technologies and services required to ensure the reliability, operability and security of a system with a large share of VRE
    - Adaptation/replacement of protection systems
    - Investment in new technologies to mitigate the effects of low inertia and short circuit strength and advanced solutions for voltage and frequency regulation
    - Advanced supervision and control solutions to operate a system under a new paradigm

System adaptation costs to ensure reliability, operability and security add to these costs and increase significantly for penetrations above 40 %.
The cost for reaching ultra high penetrations (> 80%) are still uncertain

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THANK YOU FOR YOUR ATTENTION!

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