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Super Grids, Smart Grids & System Flexibility

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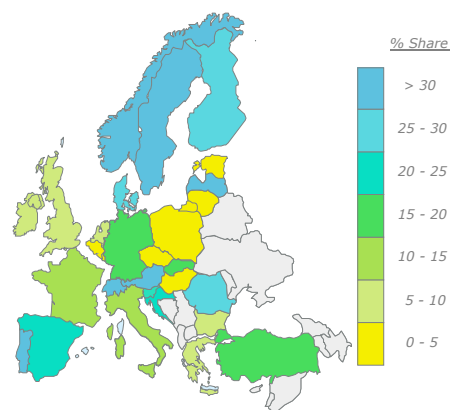


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EU Response to Climate Change Challenge

- *EU 2020:*
 - *20% of all electricity demand to be met by renewable generation*
- *EU 2030+:*
 - *Decarbonise electricity generation*
 - *Electrify segments of transport*

... in order to reduce CO₂ emissions by 80% by 2050



Not a question of technical feasibility, only cost and acceptability

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Asset Utilization Implications without Smartness

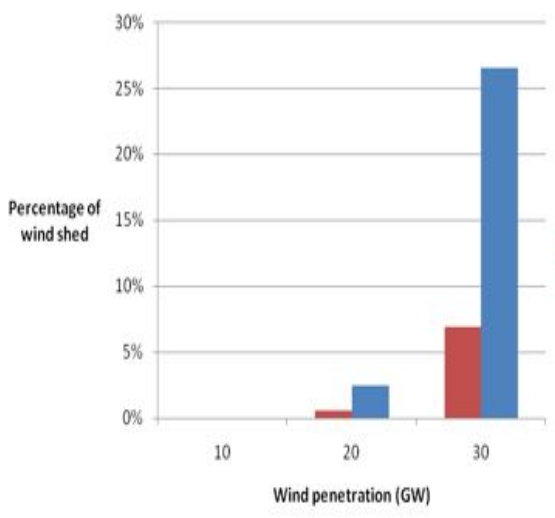
2020: Wind generation will displace energy produced by conventional plant but its ability displace capacity will be limited: more than 35% of conventional generation operating at less than 10% load factor

2030+: Electrification of segments of transport and heat sectors: increase in peak demand disproportionally higher than increase in energy

Year	Utilisation
2010	55%
2020	35%
2030+	<25%

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Low Carbon Energy System without Flexibility

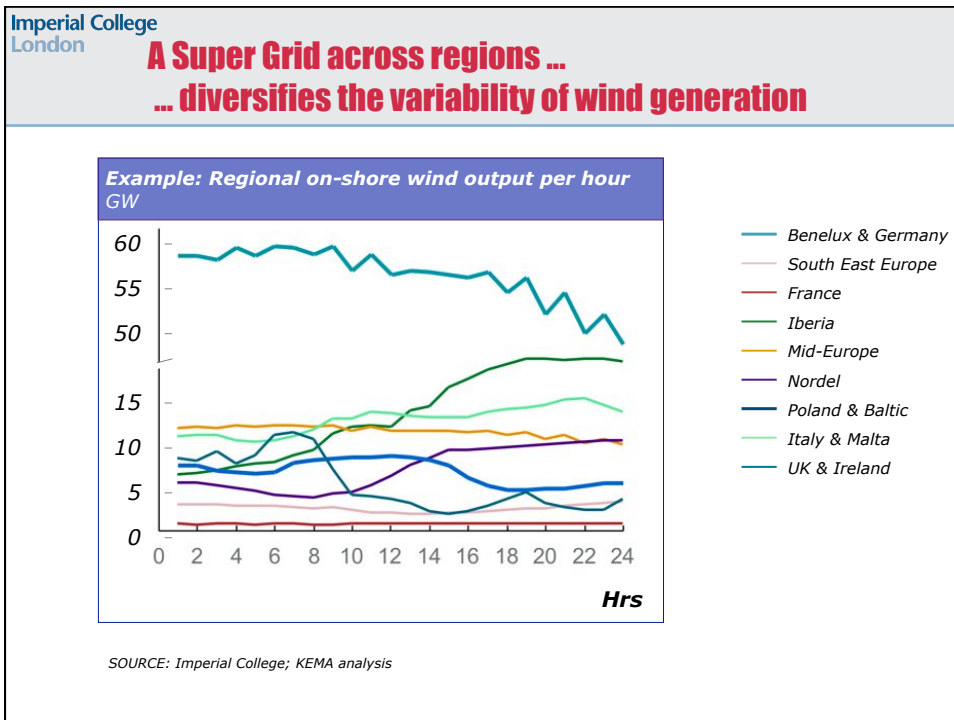
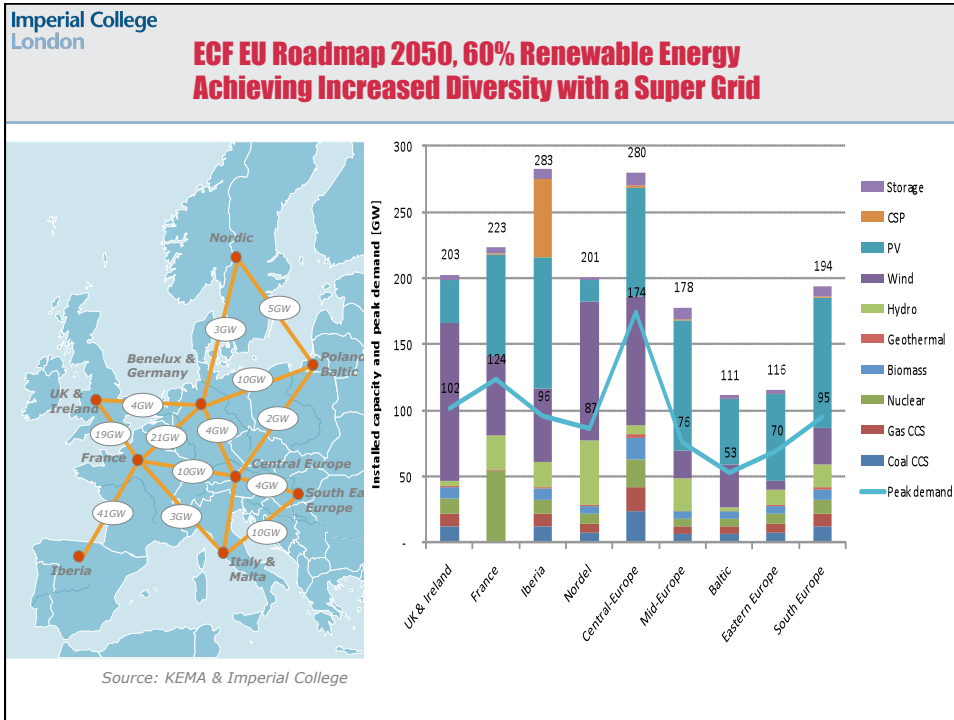


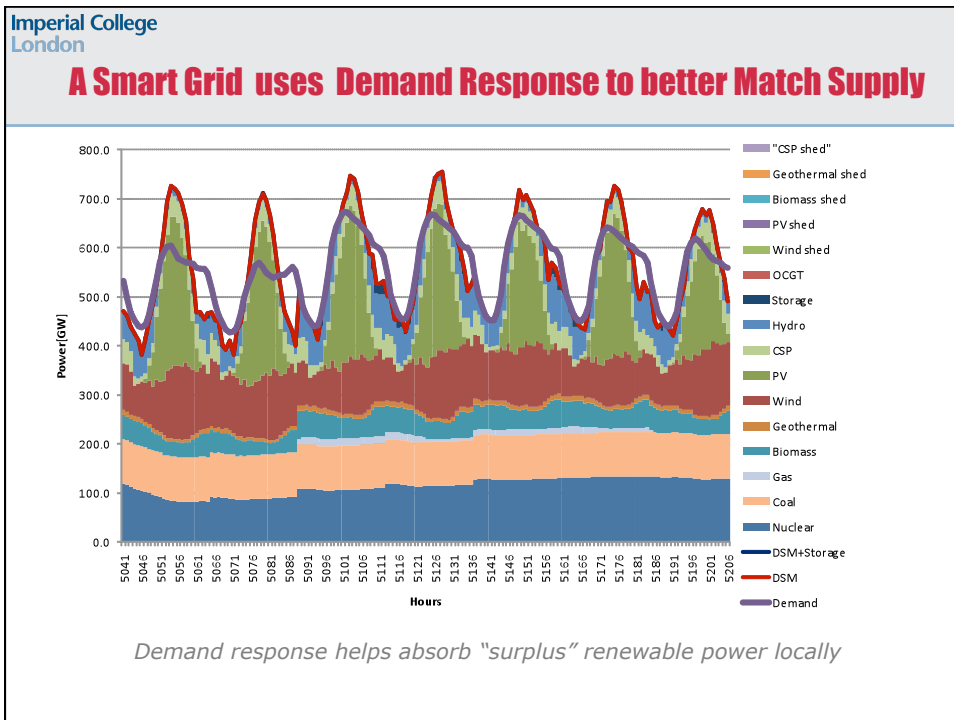
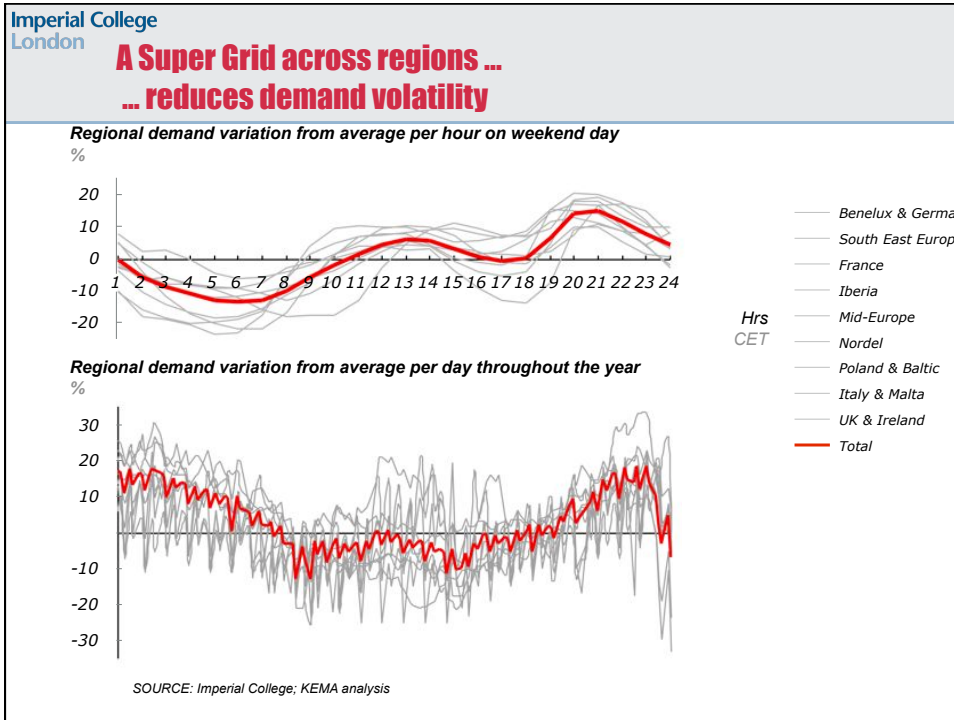
With enough renewable energy sources to meet peak demand, we might "spill" wind when demand is low

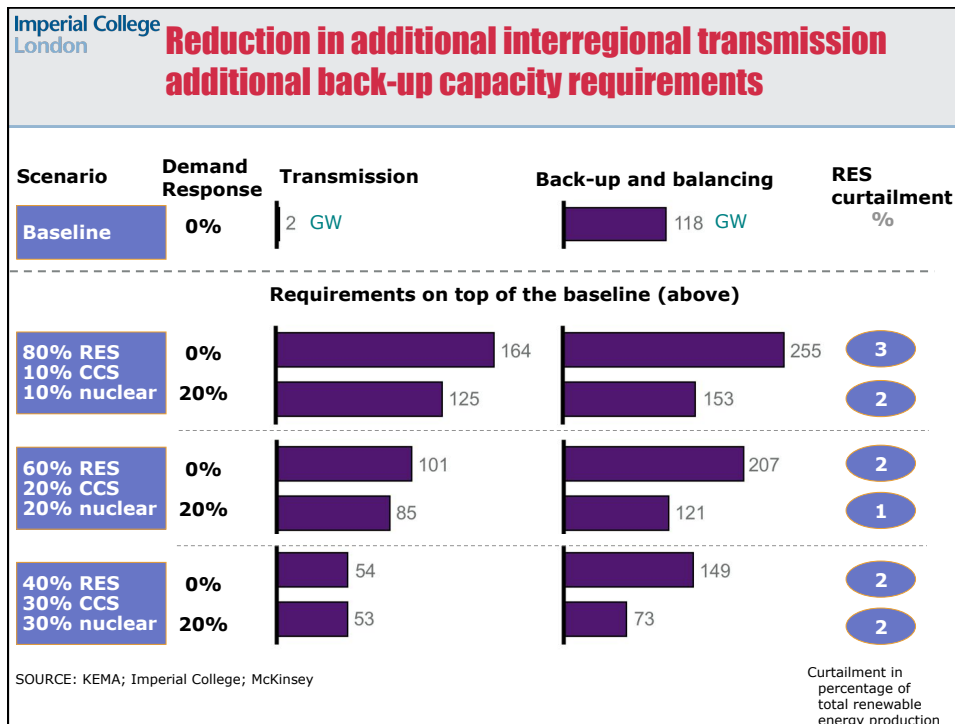
Flexibility is needed

- of generation,
- of storage,
- of demand, or
- of super grid to reach across regions.

The cost of these technology options is system specific.







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The Case for Super Grids and Smart Grids

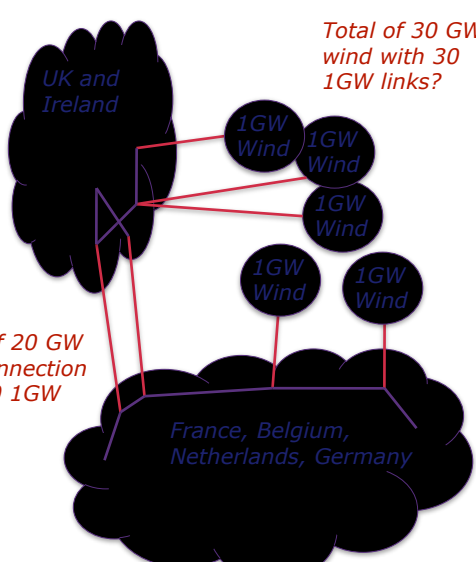
- Strong case for using Super Grid capacity to provide flexibility to integrate renewable generation
 - Super Grid accesses generation diversity. Wind becomes less correlated over larger areas, wind and PV combine better over larger areas.
 - Super Grid accesses demand diversity and reduces ratio of peak demand to minimum demand. This allows wind and PV energy to be used more effectively
- A key aspect of the Smart Grid is Demand Response which can significantly reduce the amount of transmission network and generation reserve required
- The Super Grid requires new subsea and land routes so is a challenge to plan. HVDC is essential in some cases and provides routing flexibility in others.

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North Sea Wind Collection with Point-to-Point HVDC

- Voltage Source HVDC links of about 1 GW and matching wind farms indicated in North Sea.
- Subsea HVDC links between UK, Ireland, France, Norway, Benelux
- Simple approach is lots of individual connections

Total of 20 GW interconnection with 20 1GW links?

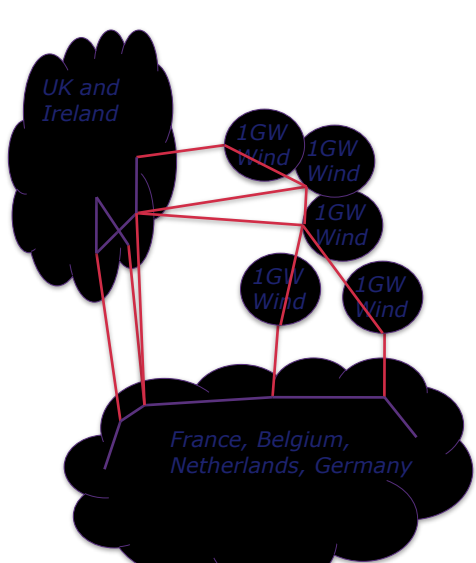


Total of 30 GW wind with 30 1GW links?

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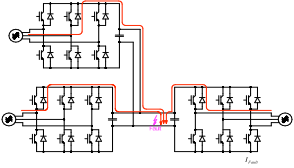
A Networked North Sea?

- Interconnection between wind farms allows
 - Better resilience to faults
 - Fewer “beach crossings”
 - Staged interconnection to other regions
 - Relief of onshore routes
- But
 - This scale of DC network not yet attempted
 - Planning and finance issues to resolve
 - Operational Issues to resolve
 - Fault management is particularly unclear



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Multi-Terminal Voltage Source Systems



- + Controllability of VSC allows management of multi-terminal systems
- Diodes in VSC converter stations cause every converter to pass fault current from AC to DC sides.
 - Status of DC circuit breakers is unclear
 - The fault could be "cleared" with AC circuit breakers but this would be needed on *all* terminals and require a shutdown of the whole system
 - Solution might be in different converter topologies that can block the fault current themselves
 - Concern over stability of AC networks while DC fault is being "cleared"

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Super Grid and Smart Grid Acceptance

- We know what benefits that Super Grids and Smart Grids bring for renewable generation
- We know much of the technology required
- But we need to achieve higher power ratings in voltage source HVDC and resolve some key planning and operation issues.
- We need achieve acceptance by the publics of Europe of the new Super Grid infrastructure and the new Smart Grid demand response.