

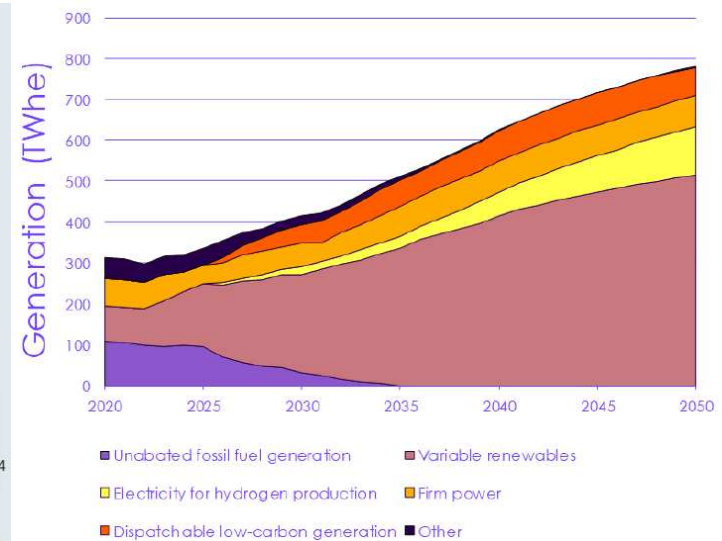
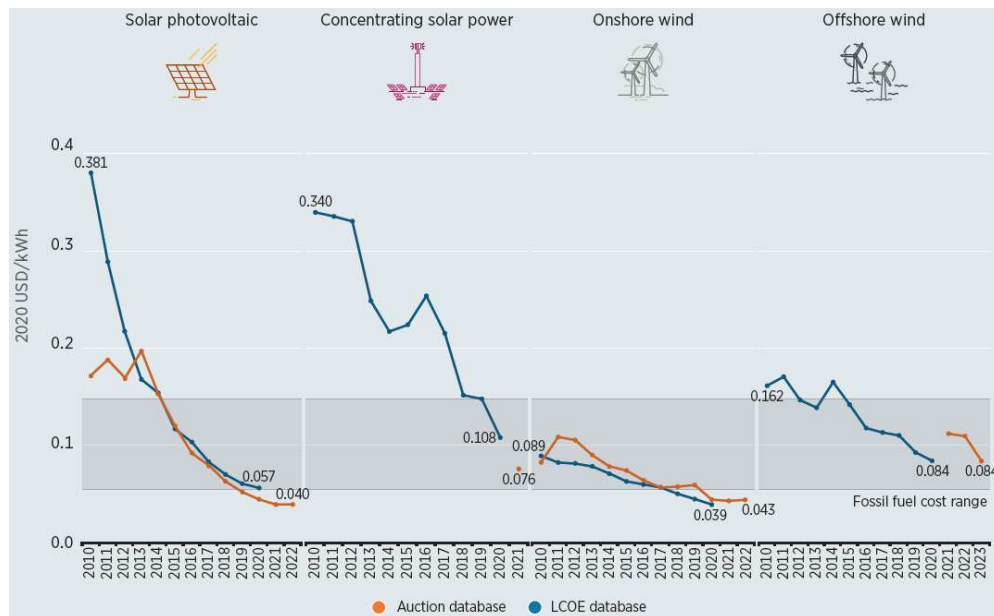
The value of hydrogen storage in the UK's net-zero emissions energy system

James Price, Paul Dodds, Ilkka Keppo

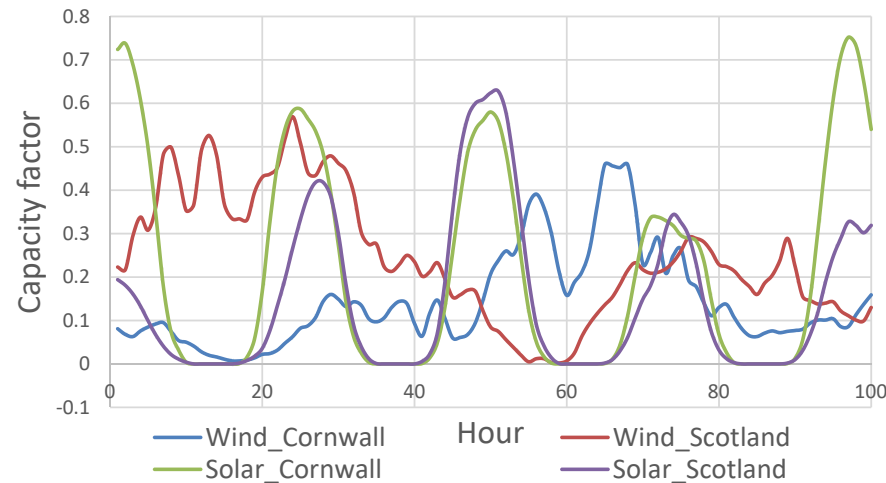
Study supported by Energy Storage Supergen Hub (Energy SUPERSTORE) and the EU INNOPATHS project

Introduction

- Rapid decarbonisation of electricity generation key to enabling a net-zero emission energy system -> supports the decarbonisation of heat/transport
- Cost of Variable Renewables Energy (VRE) sources, particularly wind and solar, have plummeted.
- Therefore VREs expected to underpin low/zero carbon power/energy system in future.



But higher VRE shares -> increases the sensitivity of energy supply to weather:

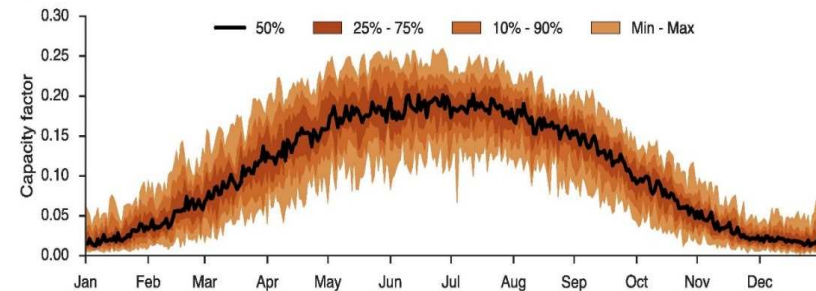


<- UK weather varies rapidly in time and space from hour to hour

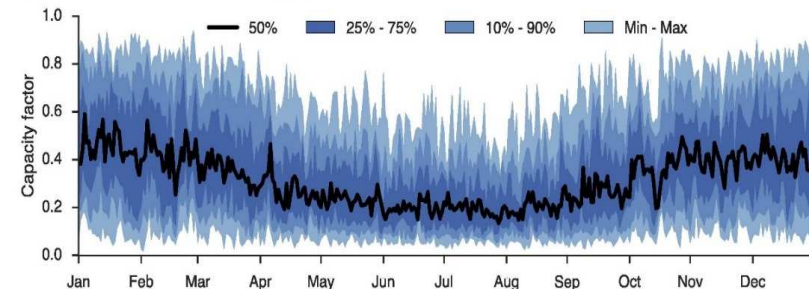
But also across the year and from one year to the next ->

Source: Pfenninger (2017), Applied Energy 197, 1–13

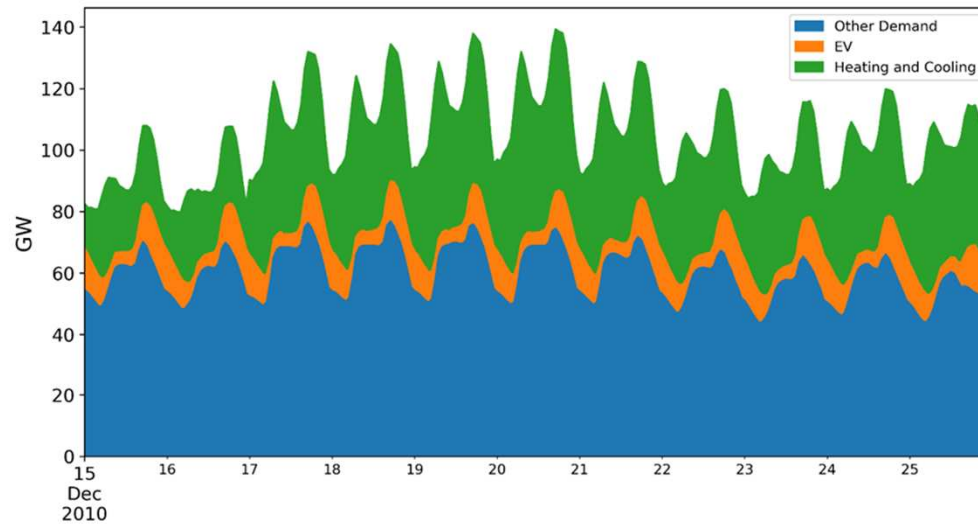
(a) Daily mean PV capacity factors 1990-2014



(b) Daily mean offshore wind capacity factors 1990-2014

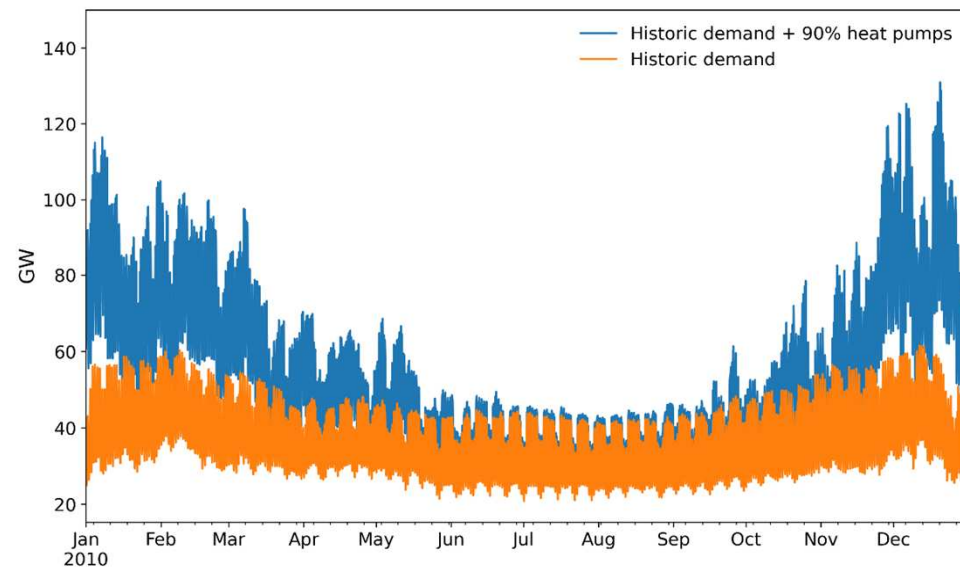


Future electrification of demand (heating/transport) adds further complexity:



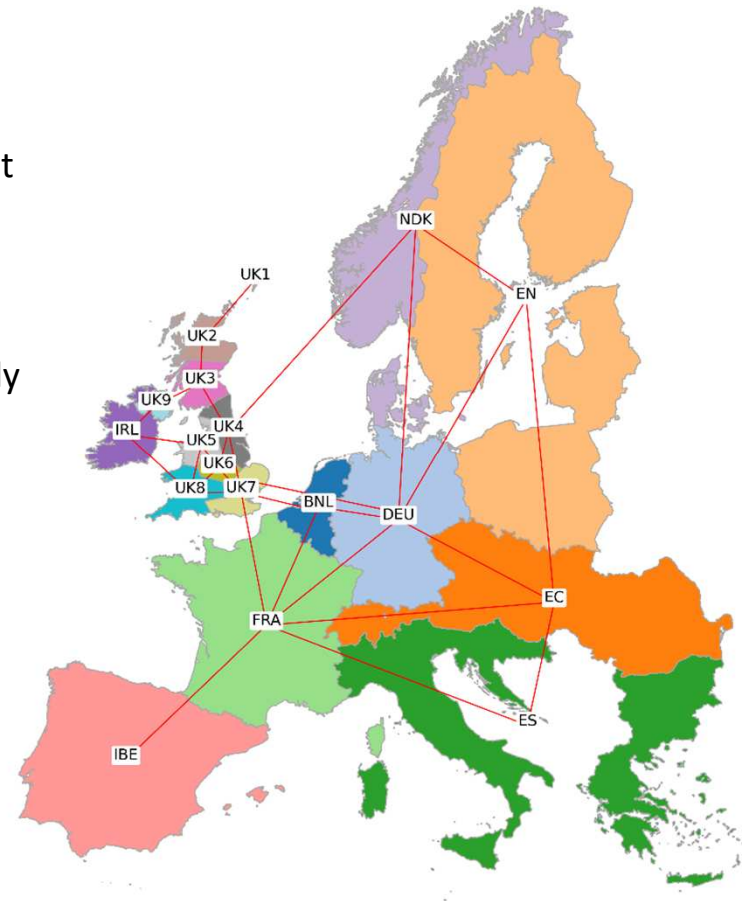
<- UK electricity demand will become even more variable mostly from heat

But also across the year ->

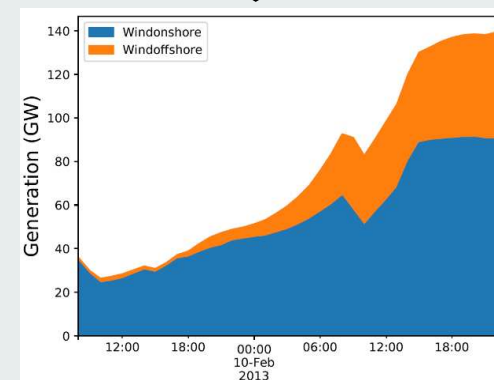
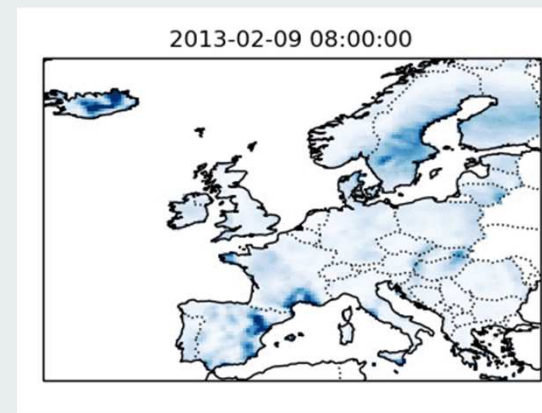
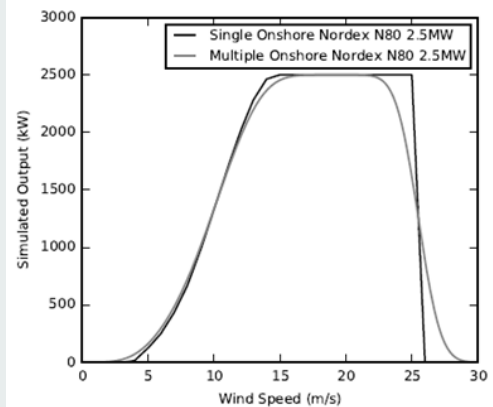
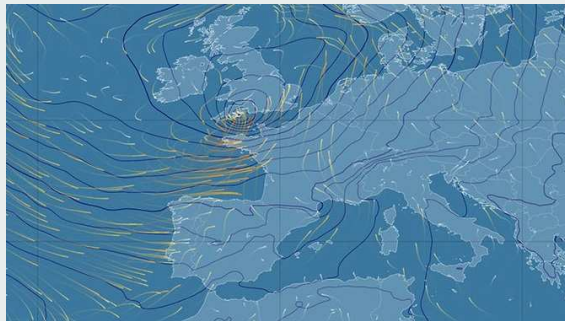


high spatial and temporal **resolution** electricity system model (**highRES**):

- Models European system for single snapshot year, 2050, at full hourly resolution (8760).
- Simultaneously makes capacity (i.e. generation, storage, transmission) planning & dispatch decisions to meet hourly demand across the year at least cost.
- Supply and demand coupled under same weather conditions for a given year
- Models flexibility options:
 - Battery storage
 - H2 storage in caverns
 - Interconnection with Europe
 - UK transmission reinforcement
 - Low carbon dispatchable power
- Models system reserves and inertia requirements to support an adequate and secure power system.



- Focus of highRES is a good representation of VREs -> use weather data (climate reanalysis/satellite data) to drive spatiotemporally detailed generation....



Study design

- Role of long term storage in power system with electrified heat and road transport
- Power system boundaries:
 - Grid carbon intensity limit compatible with wider net-zero energy system from CCC Balanced Pathway
 - 630-660 TWh/yr of electricity demand depending on weather year
 - Hinkley C/Sizewell B and today's pumped hydro still online in 2050.

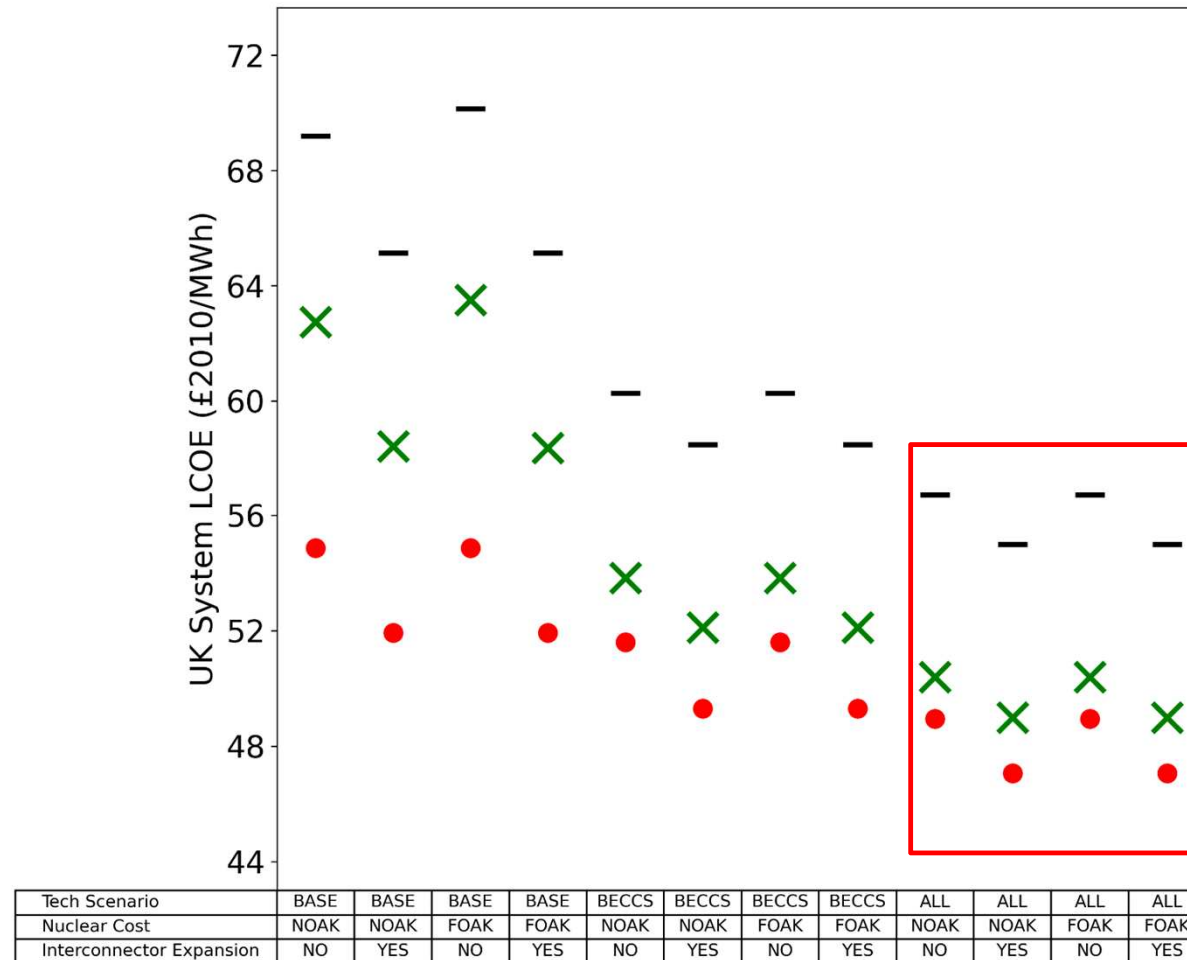
- Four scenario dimensions:
 - Technology availability:

Scenario	Technologies available
BASE	Nuclear, NGCCGT-CCS, NGOCGT, Solar PV, On/offshore wind, Li-ion batteries, Synchronous Condensers
BECCS	BASE + BECCS
ALL	BASE + BECCS + Hydrogen storage in salt caverns (H2 from electrolyzers, power from OCGT/CCGT H2 turbines)

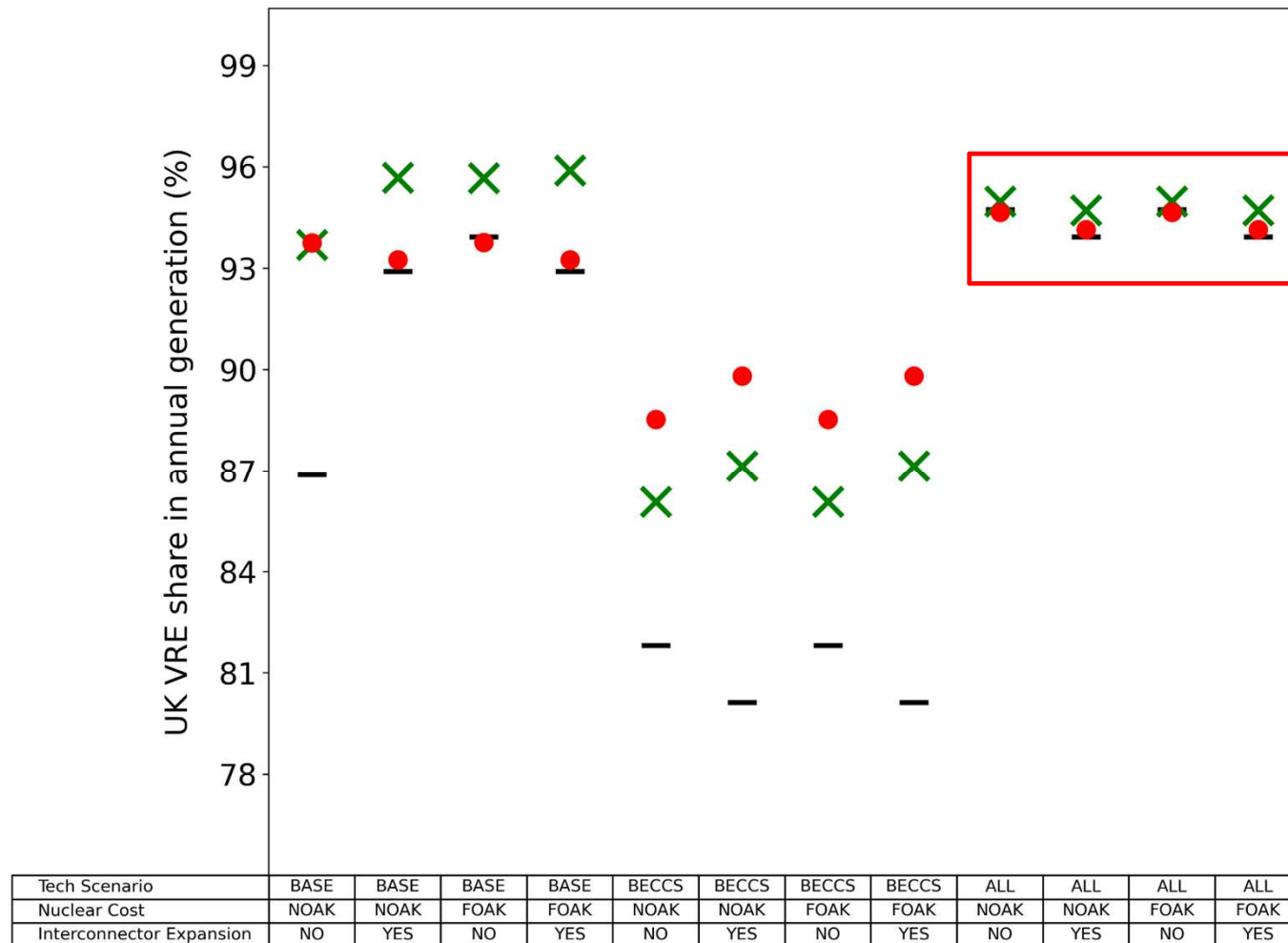
- Nuclear capex: First of a kind (FOAK) and Nth of a kind (NOAK) from BEIS
- Weather years: Worst (2010), Average (1995) and Best (2014)
- Interconnection expansion: Yes/No

Results

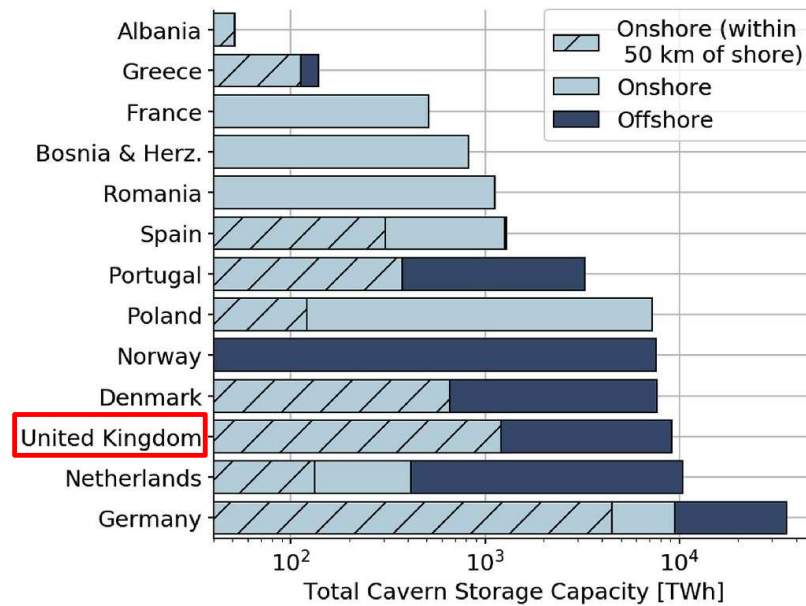
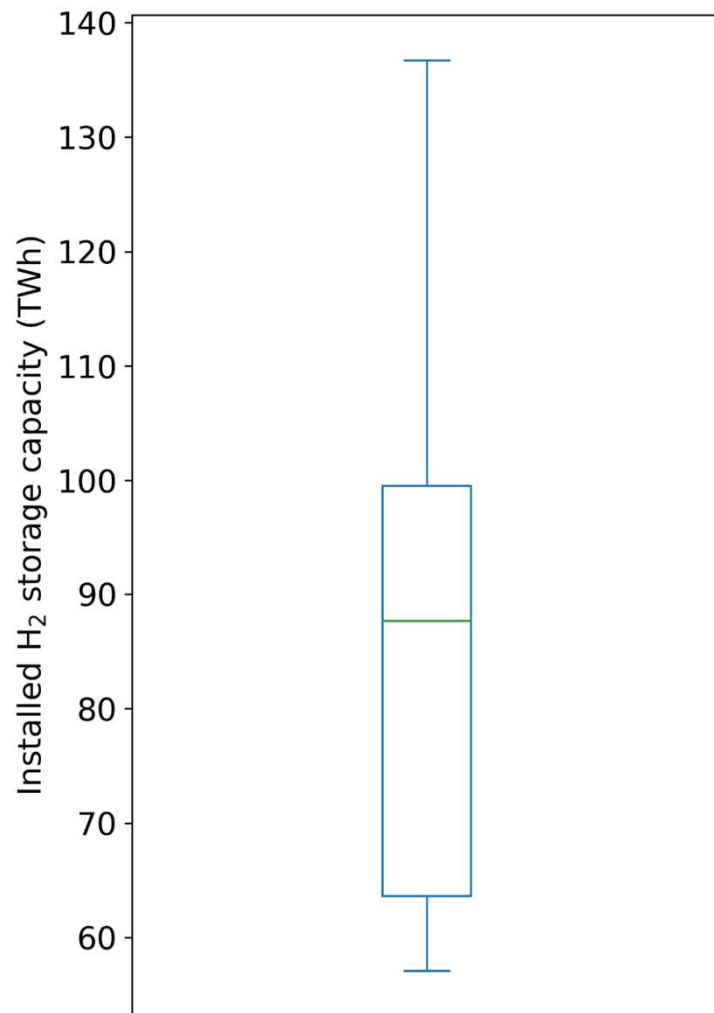
Long term hydrogen storage reduces system costs by 9-21% depending on sensitivity



Long term storage consistently supports 94-95% of annual generation from VREs

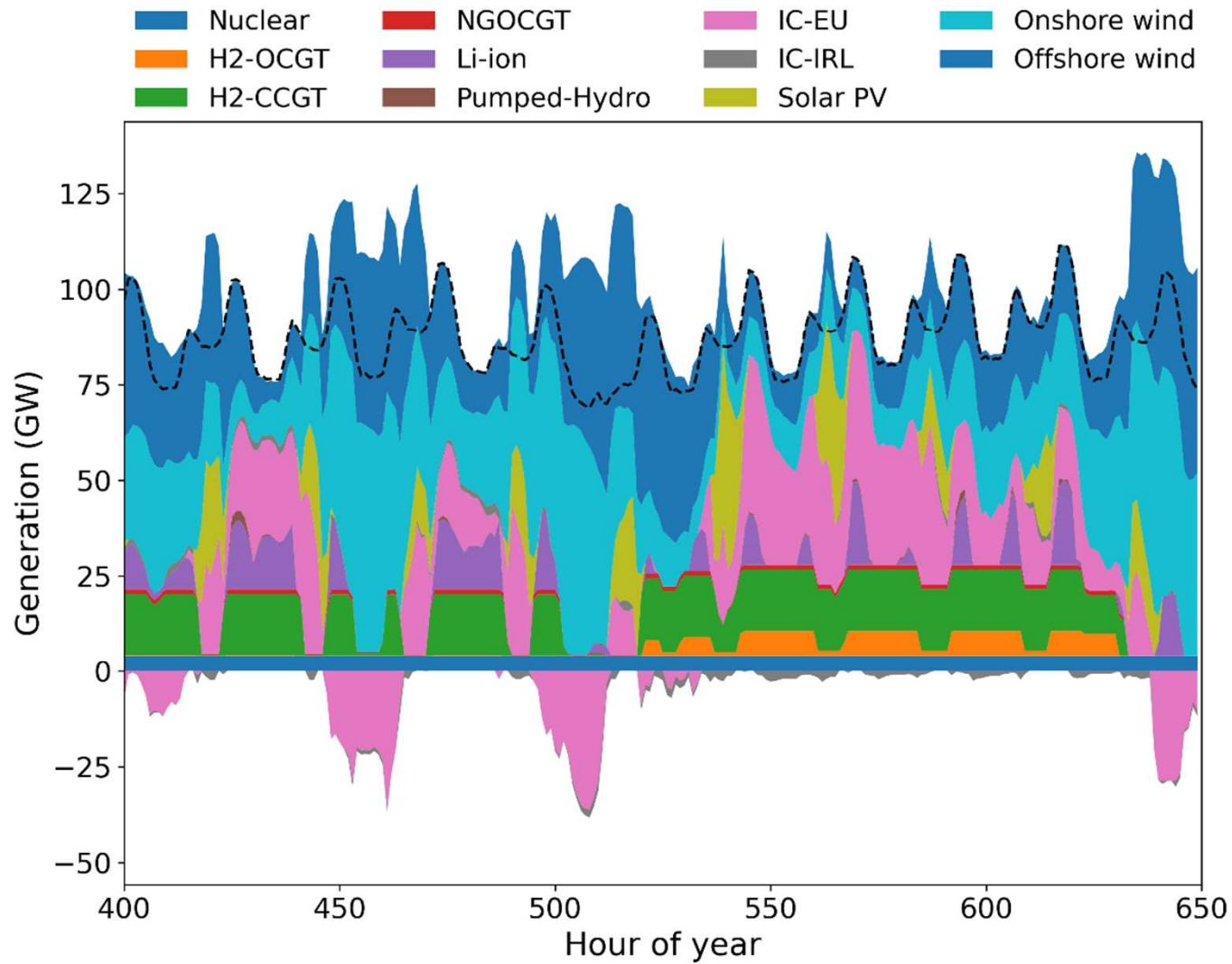


Energy storage capacity in salt caverns ranges from 60 – 140 TWh depending on sensitivity



Caglayan et al. (2020) - Technical potential of salt caverns for hydrogen storage in Europe

What does the operation of the system look like?



In summary long term hydrogen storage supports a system that:

- Is up to 20% cheaper
- Consistently integrates very high shares of VREs
- Is more energy secure (less import dependence)

Thank you for listening

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