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Power, Hydrogen and Storage

- The essential role of Hydrogen in Long Duration Energy Storage

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Our strategic framework

WHO WE ARE

OUR VISION
Making Future

OUR MISSION
We accelerate the transition towards a sustainable society

OUR VALUES
Brave
Devoted
Team players

OUR PEOPLE
Inclusive and diverse teams with deep sector knowledge

OUR AMBITION

A leader in sustainable engineering, design and advisory with a global reach

Our hydrogen expertise

KEY FIGURES

1. Over 80 projects delivered globally in over 30 countries since start of 2021
2. Technical/engineering on project capacity over 10GW electrolyser capacity
3. Expertise covers the entire value chain from production to end-use
4. Expertise in Ammonia, e-methanol and Sustainable Aviation Fuels
5. Over 50 experts located globally involved in projects

INDUSTRY

TRANSPORT

POWER

HEAT

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Hydrogen is essential to enable supply security in RES dominated markets

KEY POINTS FOR TODAY

- Power markets will decarbonise and become **dominated by Renewables** (RES) with a corresponding reduction in current dispatchable thermal generation
- RES dominated power markets will have to manage **increasing imbalances** between supply and demand
- **Flexibility requirements will increase** but some forms are only suited to short-duration
- Hydrogen offers the **most cost-effective solution** to energy storage and can meet supply/demand imbalances lasting weeks
- Hydrogen can also be effective in **managing the locational issues** encountered in RES systems

GB power sector decarbonisation will lead to a system dominated by Offshore Wind in 2050

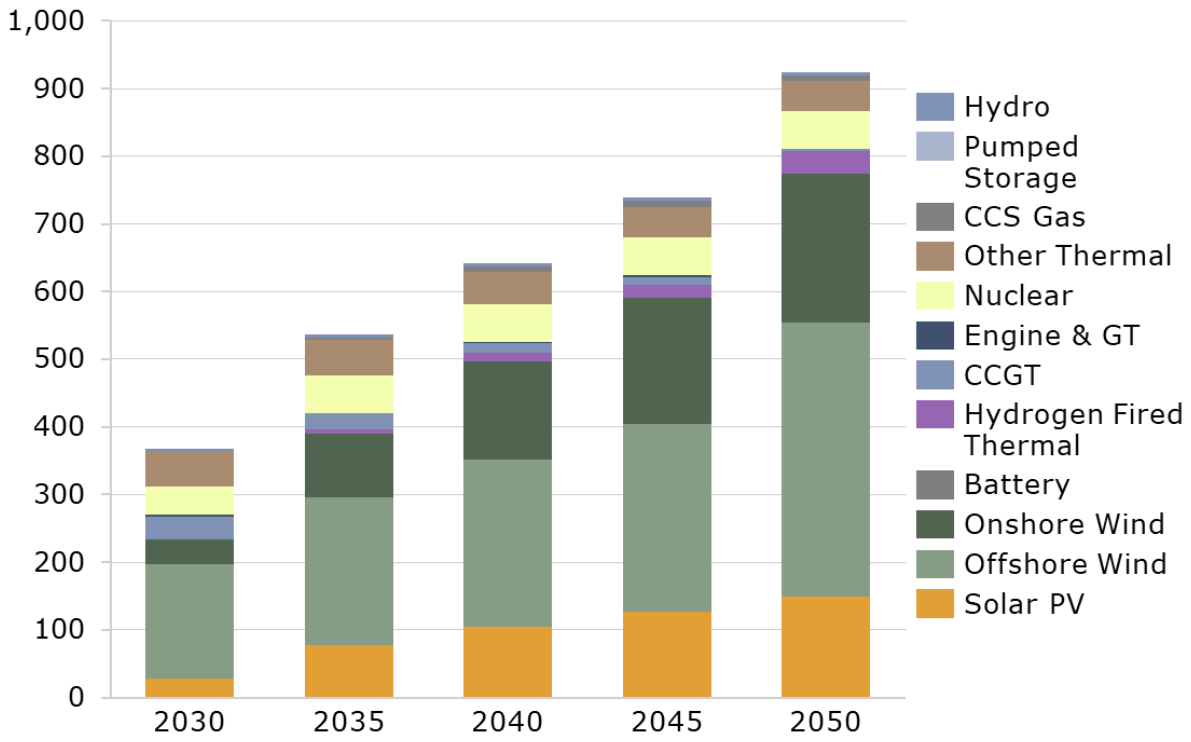
2050 WILL SEE 92GW OFFSHORE WIND CAPACITY

- Power system will become **dominated by Renewables** and in particular offshore wind
- **92GW** of offshore wind in 2050 meeting 44% of demand
- Some **unabated gas generation** left which is offset by negative emissions
- Requirement for **peaking capacity** results in some CCS/gas and hydrogen generation

How does this generation mix impact system security and supply/demand?

What impact does the inevitable increase in intermittency have?

POWER SECTOR GENERATION MIX HIGH POWER DEMAND SCENARIO, GREAT BRITAIN (TWh)



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A power sector dominated by wind will have to manage increasing imbalances between supply and demand

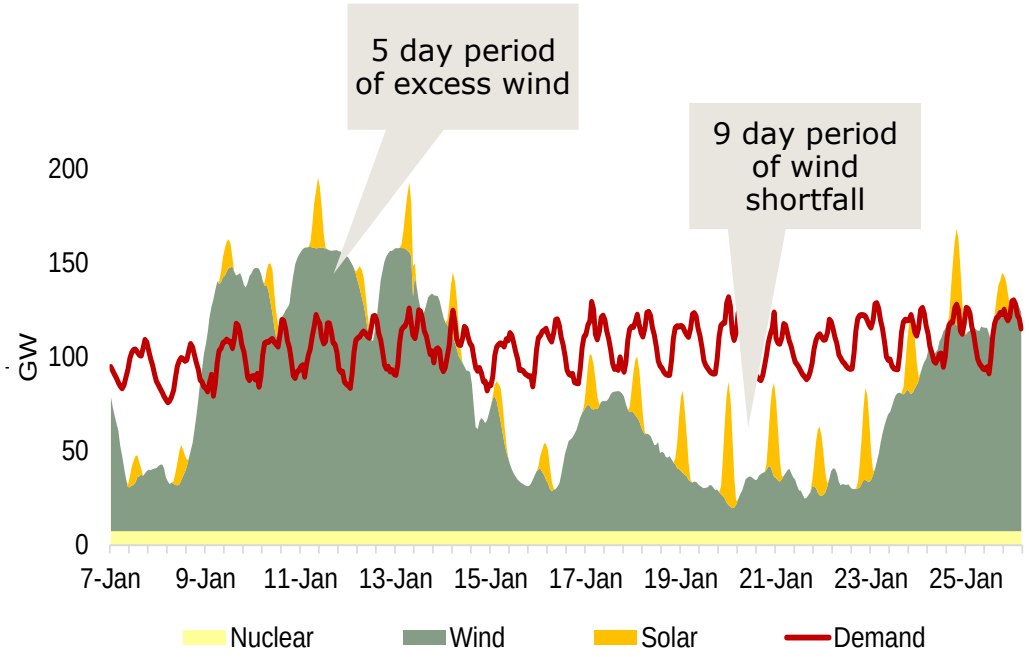
RENEWABLE INTERMITTENCY INCREASES IMBALANCES

- A power system dominated by RES will experience **Diurnal and Seasonal variations**
- But also there will be variable weather patterns that are likely to lead to **longer periods of excess or shortfall**
- **The impact of this increases over time** as more RES included in the generation mix
- **Imbalances will be more severe during winter periods** when power demand is highest

Key question:

How can these imbalances be managed?

JANUARY 2050 GENERATION AND CONSUMPTION GAP



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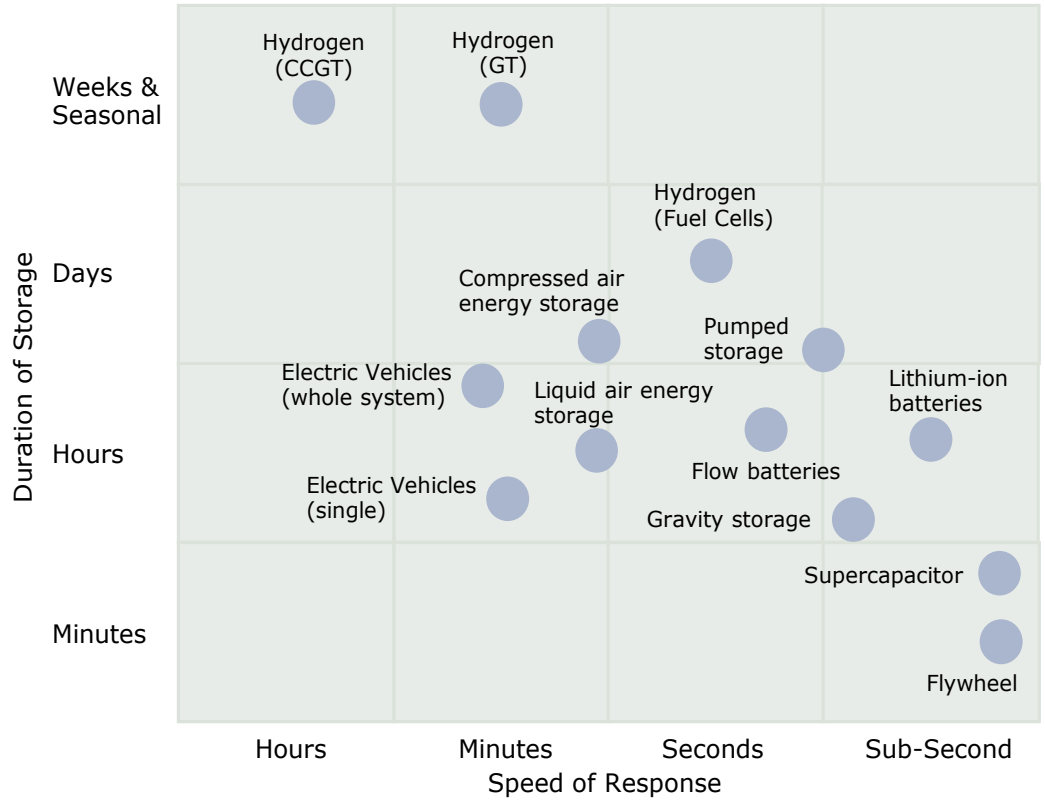
Meeting imbalances will require a range of flexibility and storage technologies providing different duration and response times

STORAGE MANAGES SHORT AND LONG TERM IMBALANCES

- The power sector will no longer be able to depend on **flexible gas fired generation**
- The requirements for **new forms of energy storage** will materialise
- There are a **wide range of storage technologies**, each has different characteristics
- The electricity system will need a **mix of different storage technologies**
  - to meet **short term variations** between supply and demand and
  - **longer term imbalances**
- There exists **many technologies** to meet short term variations

Longer term imbalances require large volumes of energy to be stored over periods of weeks to months

CHARACTERISTICS OF STORAGE TECHNOLOGIES



Hydrogen storage can provide the flexibility to cope with extended periods of low wind

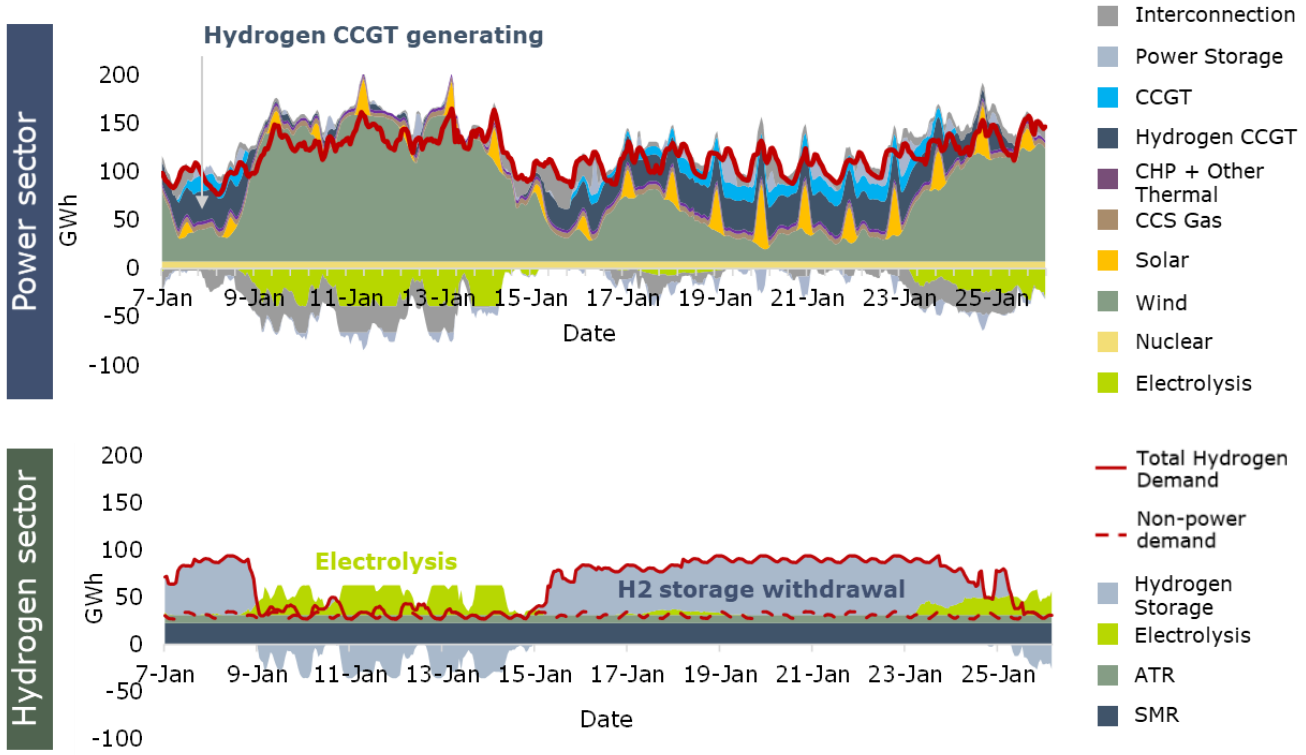
HYDROGEN PROVIDES FLEXIBILITY TO THE SYSTEM

- **Hydrogen** is likely to be the one of the most optimal technologies to manage **longer term imbalances** between generation and demand

- Our analysis shows in 2050
  - **33GW of electrolysers** producing 124TWh of hydrogen predominantly from excess renewables
  - **73TWh of hydrogen** withdrawn from storage of per year
  - Total hydrogen **storage capacity of 15TWh**, with injection/withdrawal capability of 2TWh/day

What does this mean for existing gas infrastructure?

JANUARY 2050 POWER AND HYDROGEN SECTOR ANALYSIS



Note: chart shows data from the higher power demand core scenario

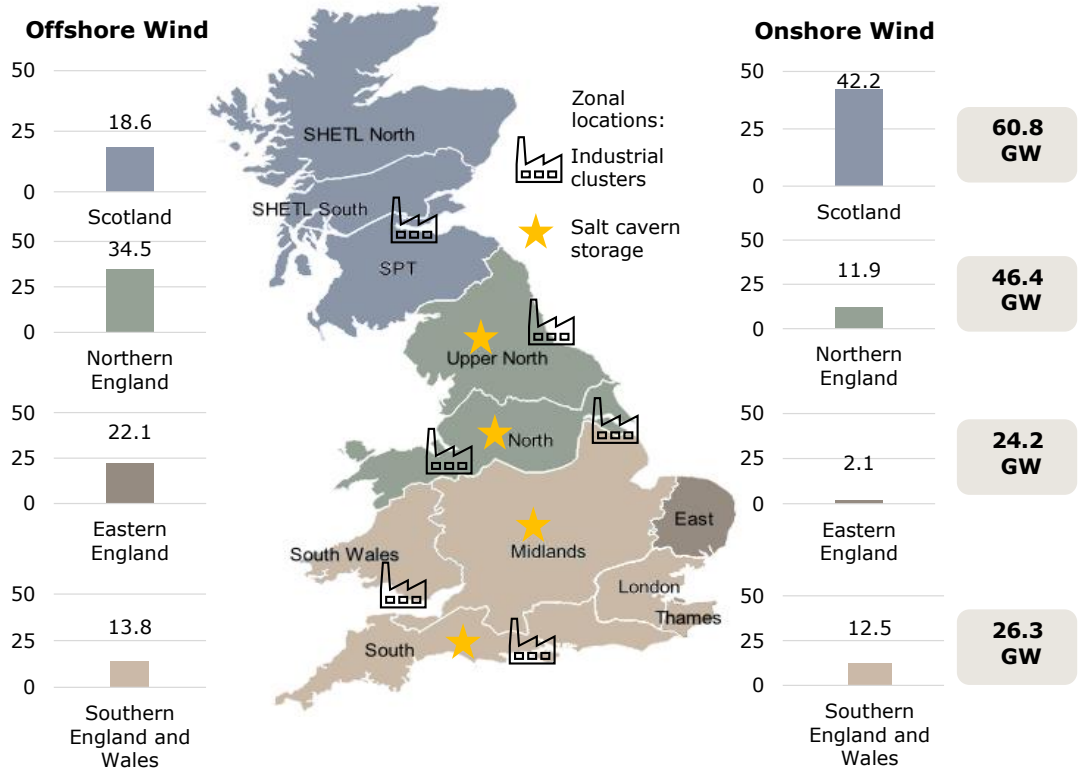
Hydrogen also helps optimise energy transmission around GB

DEVELOPING HYDROGEN TRANSMISSION

- Locating **electrolysis close to renewable production** will **reduce investment** in electricity transmission, as it will absorb 'excess' generation at source
- It is **cheaper** to transport molecules than electrons and to reuse existing infrastructure
- A **hydrogen transmission backbone** connecting electrolysis (mainly focussed in the North) with storage sites, H2 CCGT and other **users across GB**
- Creating a **hydrogen transmission system** may use a mix of new and repurposed pipes and will also provide flexibility through **system line pack**

What does this mean for other energy markets?

HYDROGEN INDUSTRIAL CLUSTERS AND STORAGE, GB WIND CAPACITY (GW)



Lessons for other energy markets

KEY TAKEAWAYS

- All power markets that are decarbonizing will experience **intermittency to a lesser or greater degree** depending on the availability of low carbon resources including hydro and nuclear
- A solution to **longer-term energy storage will be essential** to manage supply and demand
- The limited potential of **CCS at scale** in many markets may result in a greater requirement for electrolysers to produce hydrogen OR hydrogen imports
- **Hydrogen storage** will be a key requirement to enable power markets to store energy for durations longer than days
- **Hydrogen transmission** will be required to enable locational variations in RES, electrolysis and hydrogen demand to be managed
- Future technology developments may result in different outcomes
  - E.g. **Direct Air Capture (DAC)** of CO_2 could enable more unabated natural gas usage – but timing is critical

CONTACT INFORMATION

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