Future Electricity System Resilience and Security of Supply

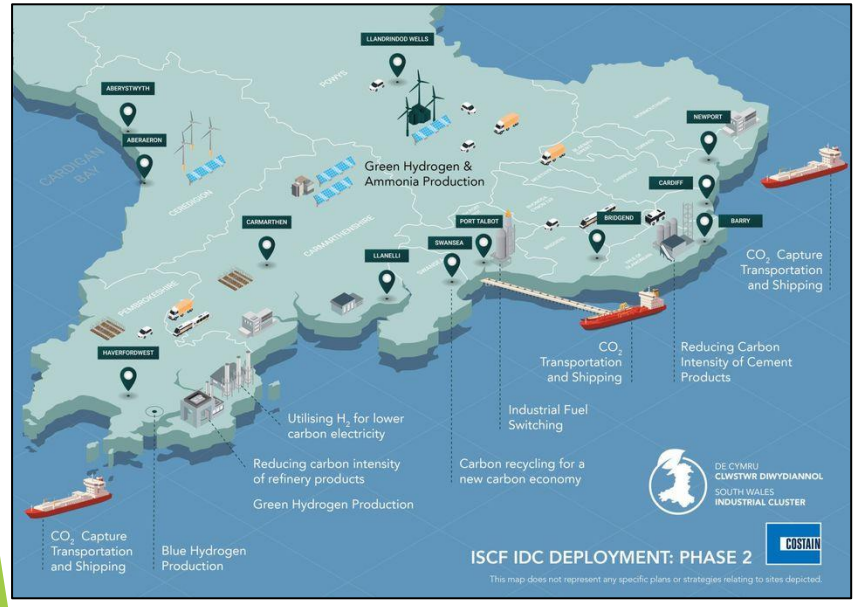
Is Hydrogen the Answer?

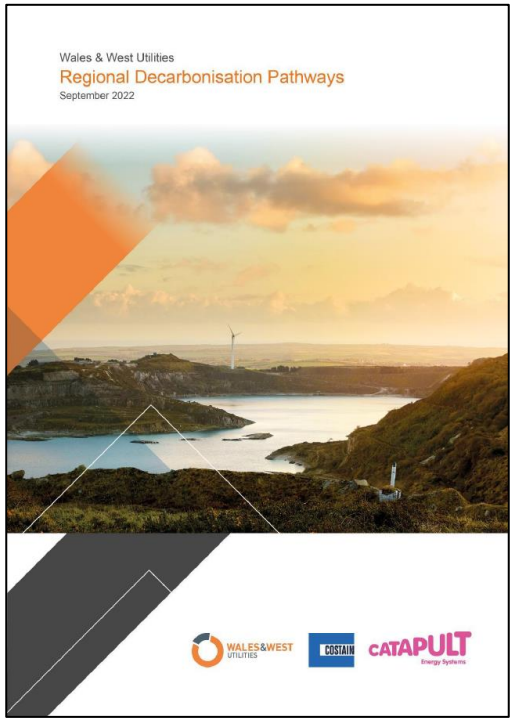
All Energy & Decarbonise 2023

Grant Spence 10th May

Net Zero Energy Systems

Strategic consultancy to support conceptual, development and delivery of net zero energy system projects and engineering.





- Programme Director SWIC Deployment IDC2 engineering with Costain (2020 – 2022).
- Now working directly with the SWIC Deployment Partners on an Integrated Programme study for South Wales.

NET ZERO ENERGY SYSTEMS

CATAPULT Offshore Renewable Energy

Institution of MECHANICAL ENGINEERS

UK Research and Innovation

Net Zero Hydrogen Fund

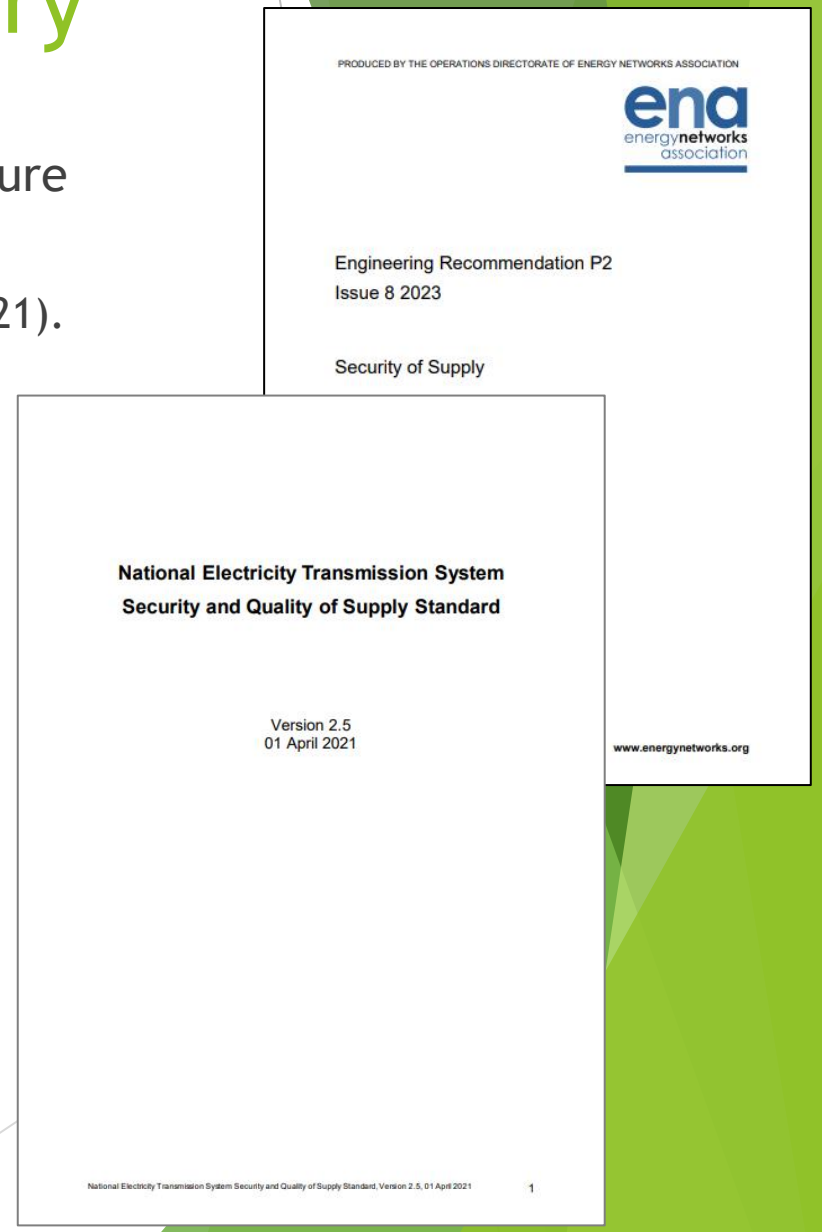
IET The Institution of Engineering and Technology

SCOTTISH Hydrogen & Fuel Cell ASSOCIATION

Electricity Security Of Supply: Theory

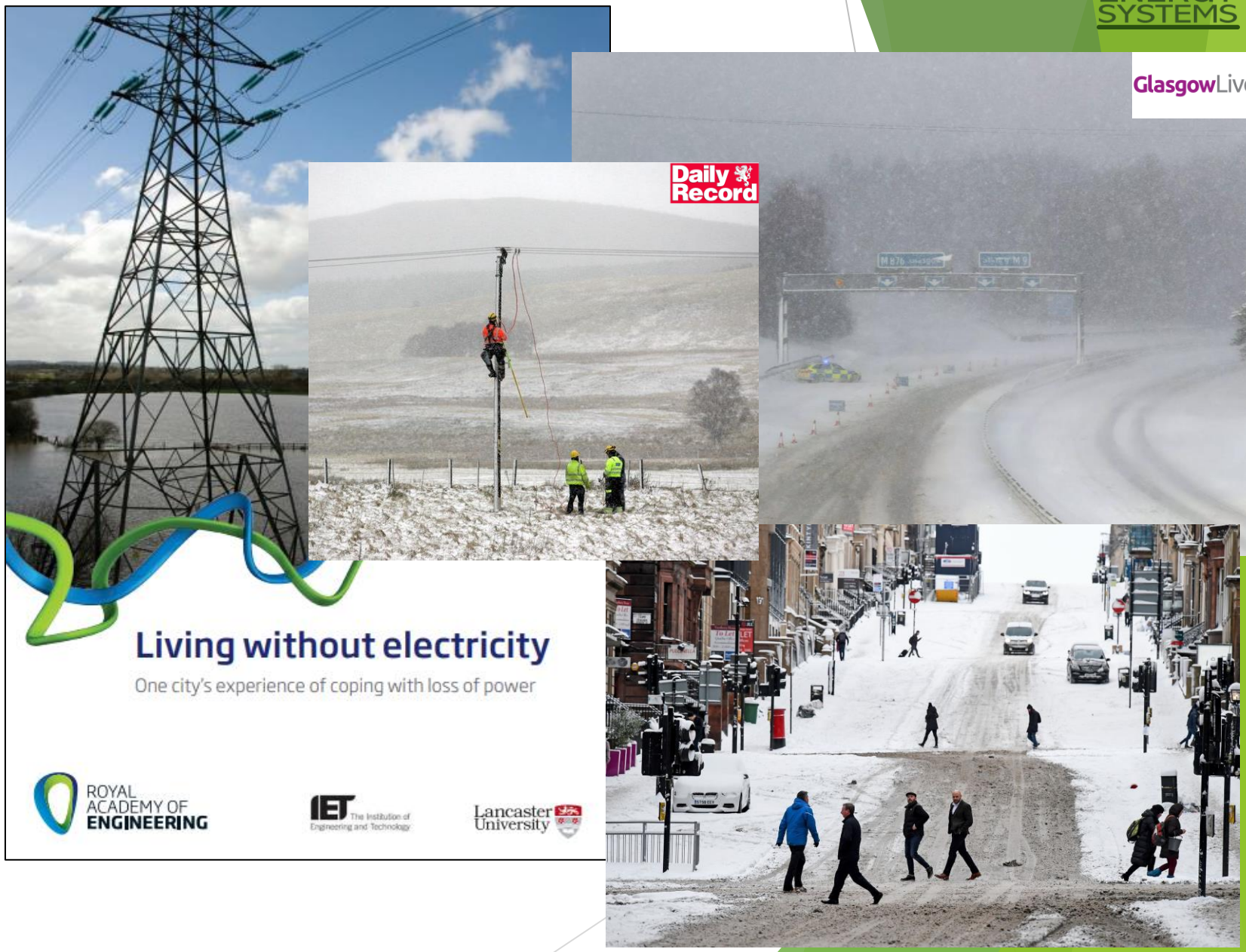
- Electricity system definition is focused on network infrastructure capacity and resilience under outage conditions ('N+2' conditions).
  - Security and Quality of Supply Standard (SQSS) v 2.5 for transmission (2021).
  - Engineering Recommendation P2/8 for distribution (2023).
- LOLE metric (Loss of Load Expectation) represents the expected number of hours per year in which supply is expected to be lower than demand under normal operation of the system.

  (I.e. In the absence of intervention by the System Operator.)
- Both heat and electricity demand are presently reliant on the natural gas network to provide security of supply…
- Natural gas network is designed to be capable of supplying a calculated 1-in-20-year peak demand taking account of climate effects and power generation demand.

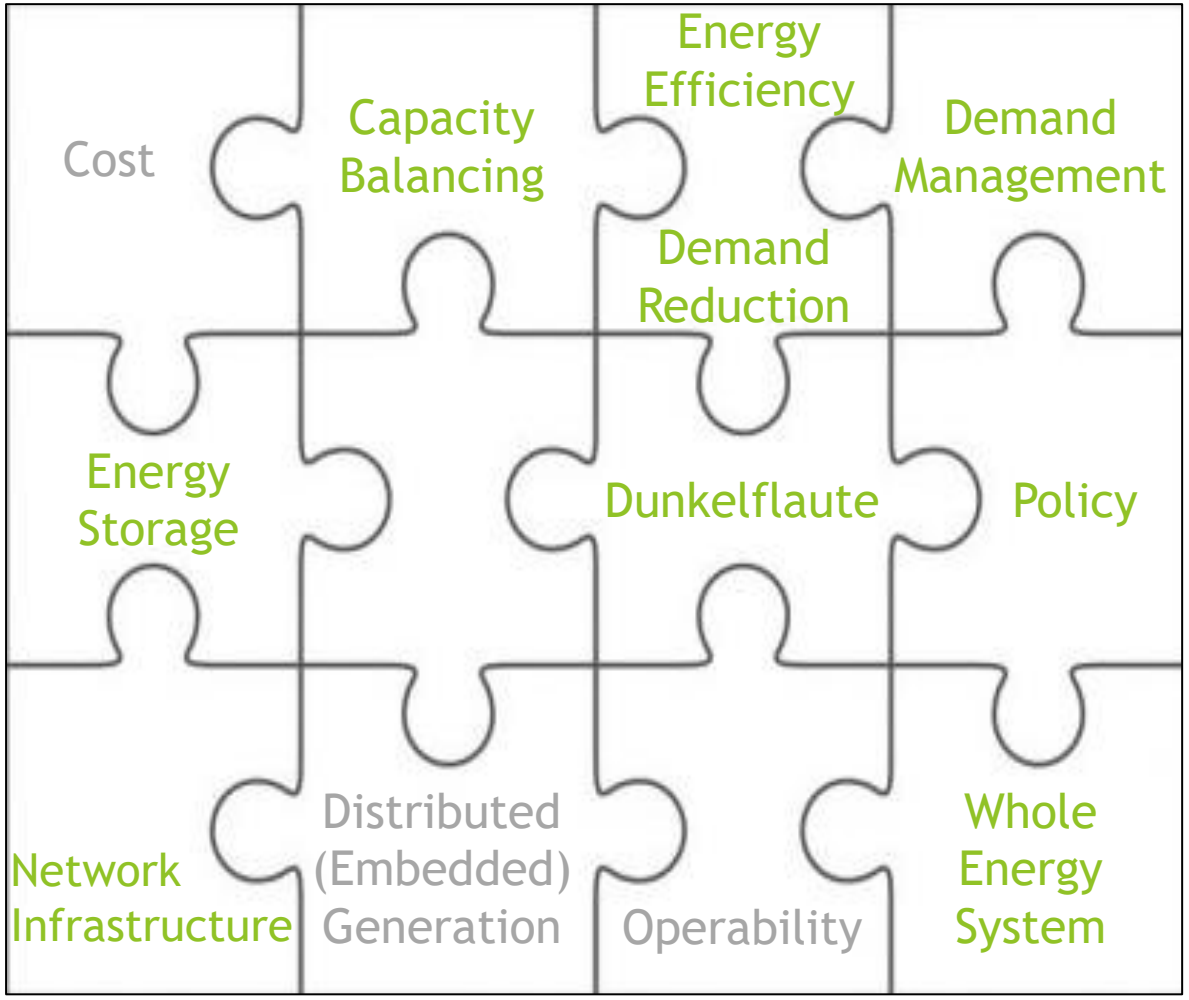


SoS In Practice:

- We expect the electricity system to be designed to withstand extreme events.
- And to be quickly returned to service in the event of any outages.
- Climate change predicted to cause an increase in extreme, unpredictable and unprecedented weather.
  - Storm Desmond 2015. (RA Eng Report: Living Without Electricity).
  - Beast From The East 2018.
- While the energy transition also adds complexity.



Sacred Cows & Received Wisdom



Social media has surfeit of experts, engineering by ideology and assertion:
Conclusions drawn without taking a whole system perspective are unlikely to be definitive?

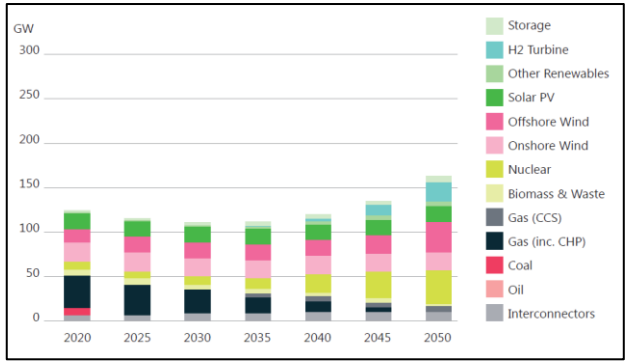
1. Capacity Balancing (and Stacking)

- Legacy of fossil fuel based system approach…
- …when electricity was dispatched on demand from fuel stockpiles (coal / gas storage).
- Electricity system historically optimised to supply maximum end use demand.
- But renewables provide energy on availability (not dispatchable capacity).
- Requires greater emphasis on energy supply, demand profiles and time correlation.

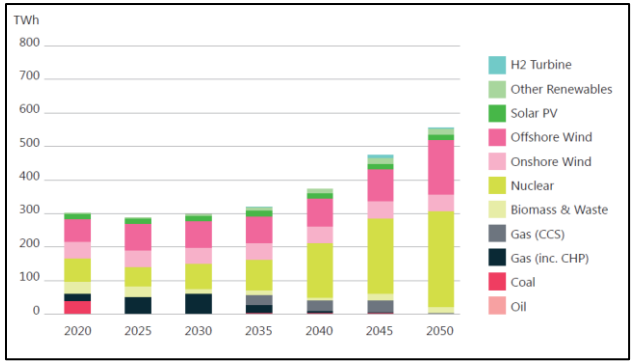
- Renewables based electricity system may need additional transfer capacity plus storage (and energy dispatch) to meet the same annual energy demand?

But what about…???

Power Generation Capacity

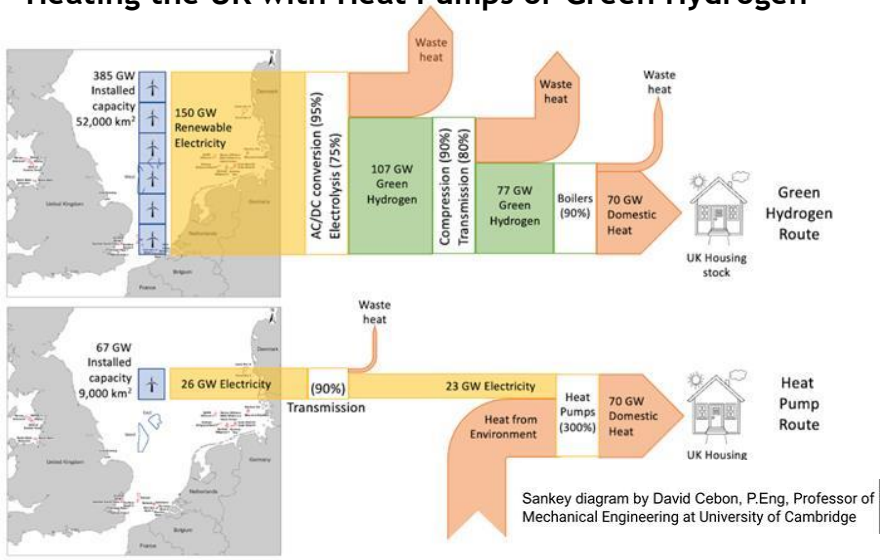


Electricity Supplied



Energy Systems Catapult: "Innovating To Net Zero", 2021

Heating the UK with Heat Pumps or Green Hydrogen

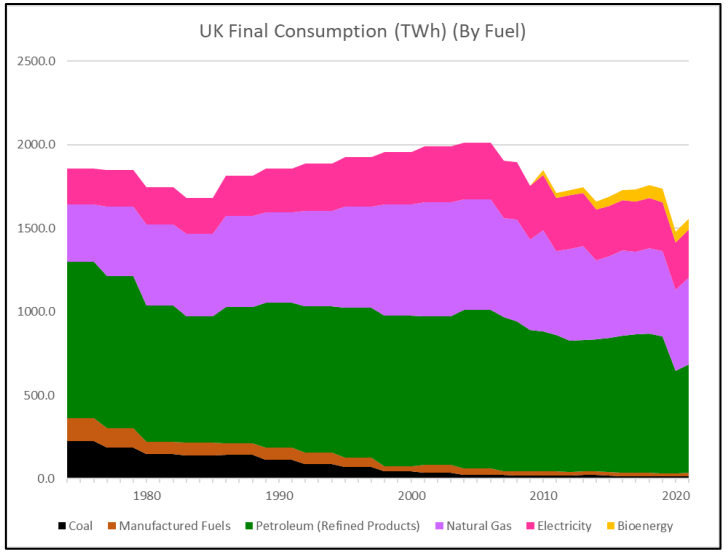


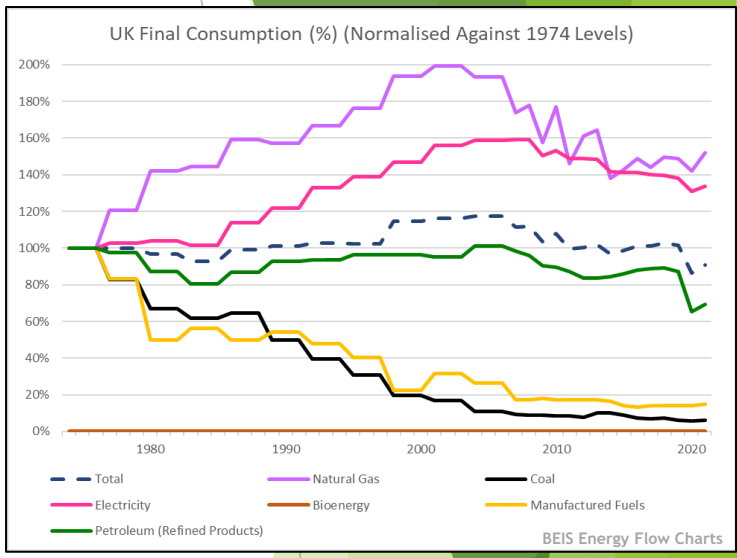
Capacity based representation does not help clarify how intermittency aspects would be addressed.

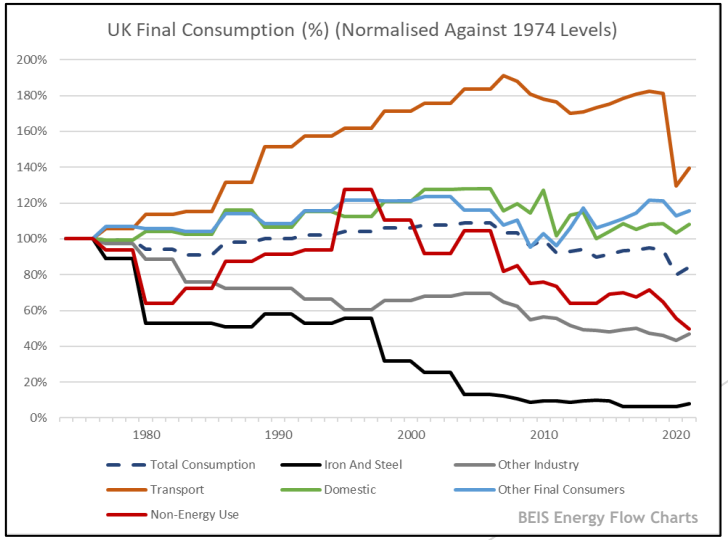
2. Energy Efficiency / Demand Reduction

- UK energy final consumption largely unchanged since the 1970s.
- Most significant recent reductions attributed to external factors?:
  - Financial Crisis (2007 - 2008),
  - Age Of Austerity (2010 – 2016);
  - Brexit (2016 – date); and
  - Covid Pandemic (2020 – 2022).
- (Easy?) Domestic energy efficiency gains largely cancelled out by inventing new ways to consume the energy available?
- Increased mobility inflated transport demand.
- Industrial / manufacturing demand reduced.
- EU target is 32.5% reduction by 2030.

Based on recent evidence, future sustained demand reduction is likely to prove difficult?







REUTERS

Energy

2 minute read · January 17, 2022 4:56 PM GMT · Last Updated a year ago

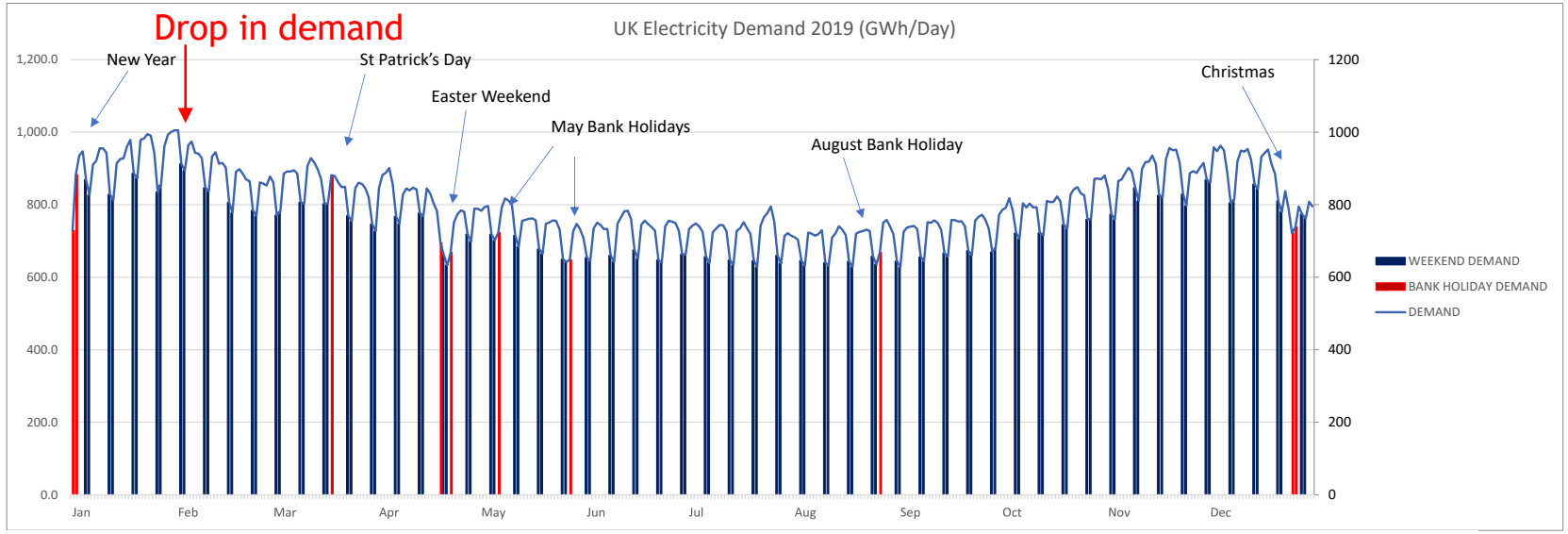
Europe misspent business energy savings funds, auditors say

By Kate Abnett

The EU spent 2.4 billion euros ($2.74 billion) from its budget over 2014-2020 to support energy efficiency in enterprises, including energy audits and measures to cut energy consumption or energy intensity in industry, services or the public sector.

The auditors estimated that projects backed by that funding achieved 0.3% of the annual savings needed to reach the EU's target to cut final energy consumption by 32.5% by 2030, compared to projected levels.

3. Electricity Demand Profile



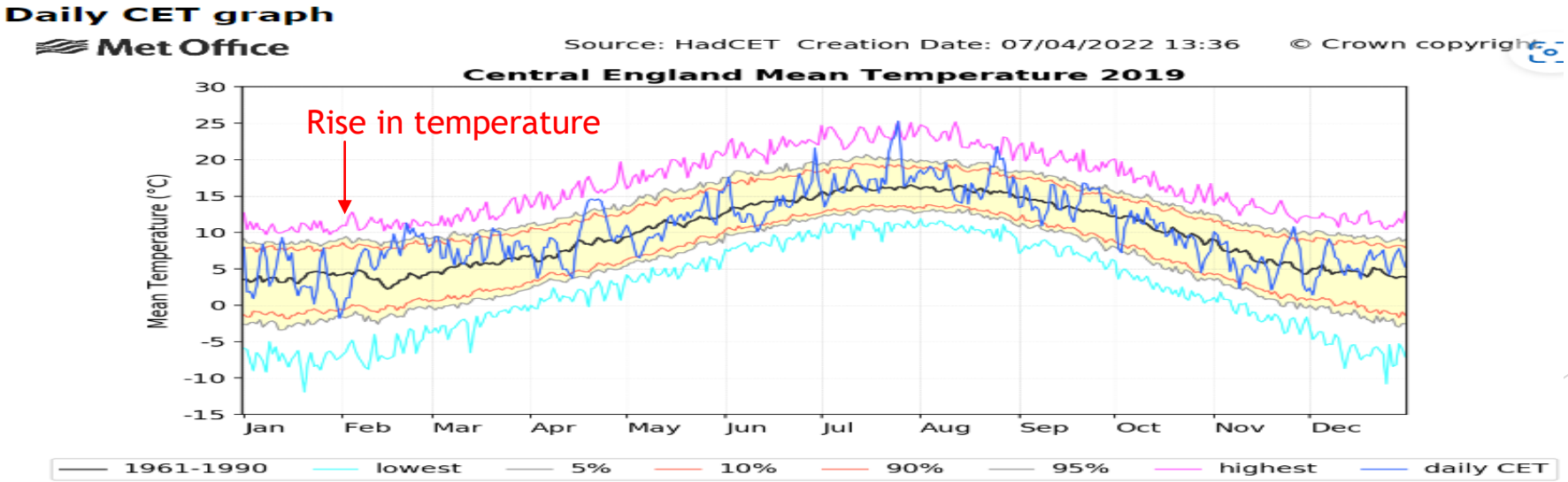


Figure: Daily temperature values for the year against 1961-1990 climatology

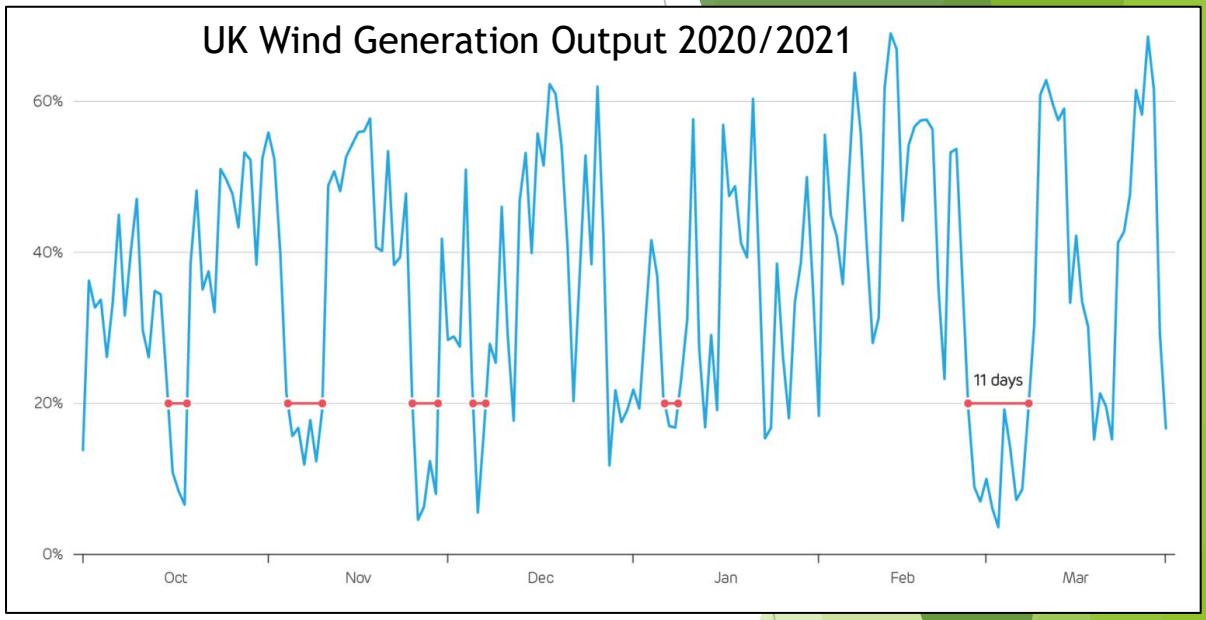
- Clear weekly profile: With electricity demand significantly lower at weekends
- Lower demand: During extended national holidays (Christmas & Easter weekend)…
- …To a lesser extent on public holidays.
- Electricity demand correlates with climatic effects:

  Temperature and wind direction (wind chill).

Demand profiles reflect societal behaviour.
Max demand is safety critical.

4. Dunkelflaute

- Anticyclone cold-calm periods normal in Western Europe… ..but don't necessarily present a credible worst case for future GB electricity system design!
- Increased future variability of (intermittent) electricity production as well as demand:
  - May require greater storage capacity vs present day.
  - Increased uncertainty: future climate & extreme weather. Hot vs cold and floods vs drought!
  - Markets don't necessarily consider security of supply costs.
- SoS requires ability to address aggregate inter-seasonal / inter-annual mismatch between supply & demand.
- One (or more) mild / severe winters vs high / low wind yield



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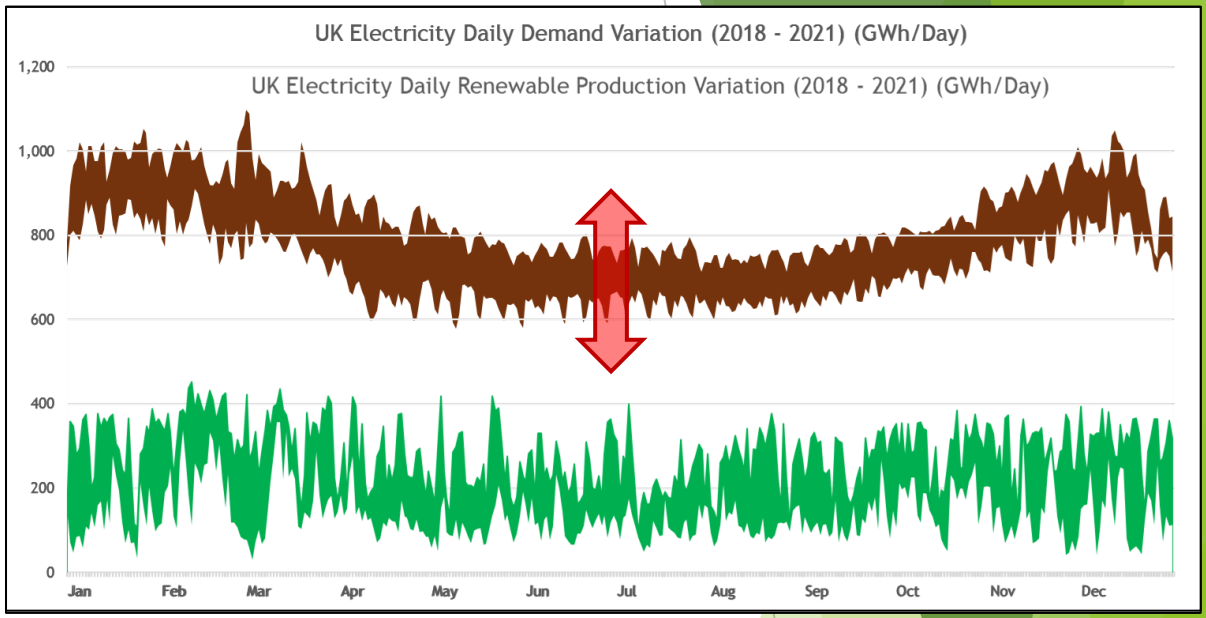
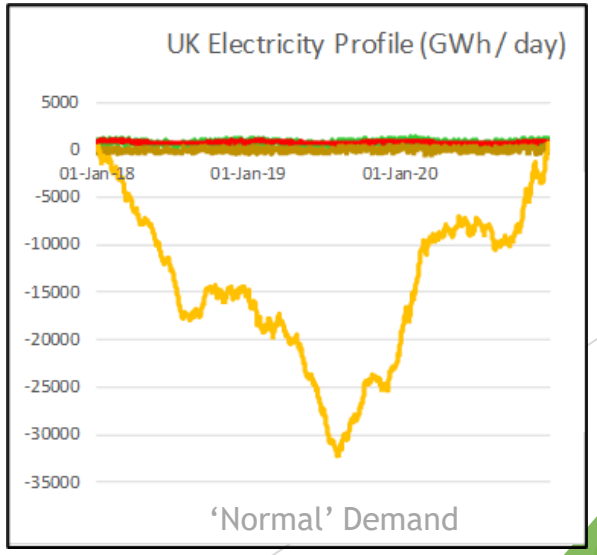
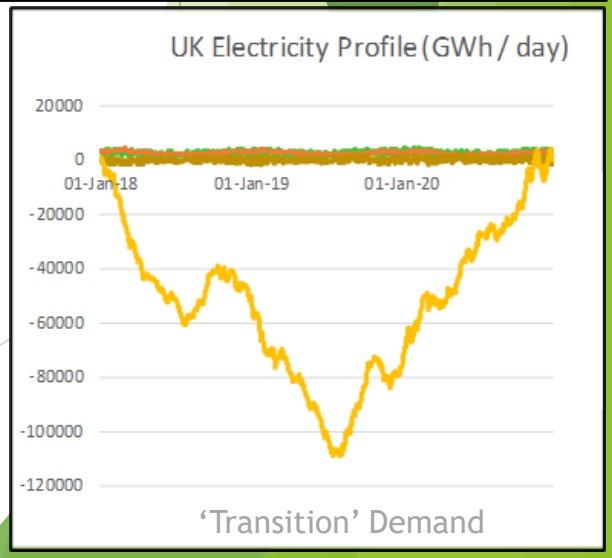
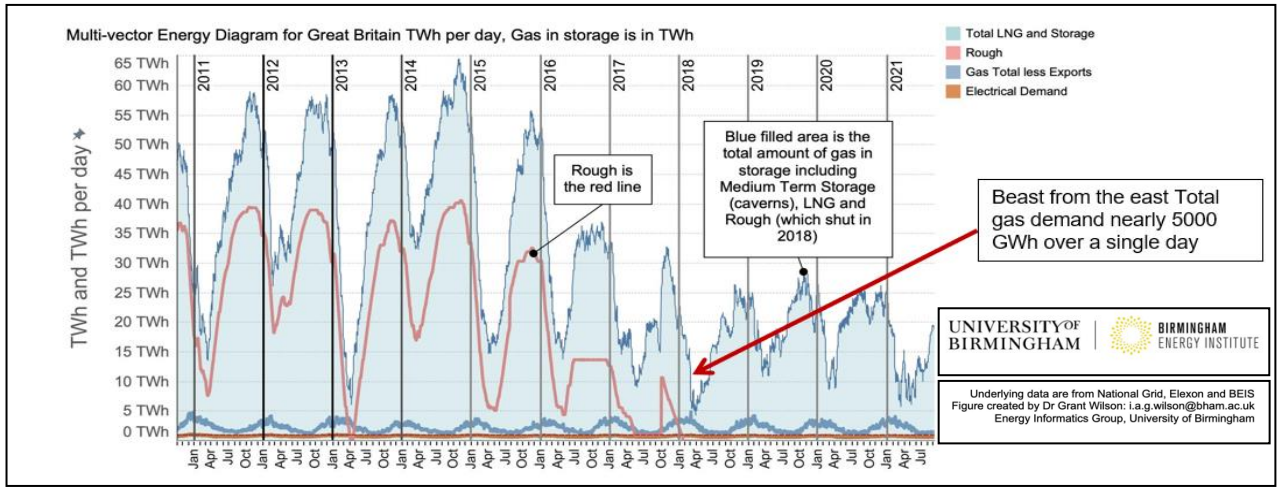
- UK Gov POST Brief Dec 2022 Long Duration Energy Storage: Estimated Long duration storage: 10s of TWh capacity for seasonal applications and ~100 TWh for multi-year applications. (UoB Keeping The Energy System Balanced).
- Solar can add diversity to wind and reduce imbalance. But is seasonally anti-correlated to heat: Eliminating solar could enable electricity production to better match heat demand?



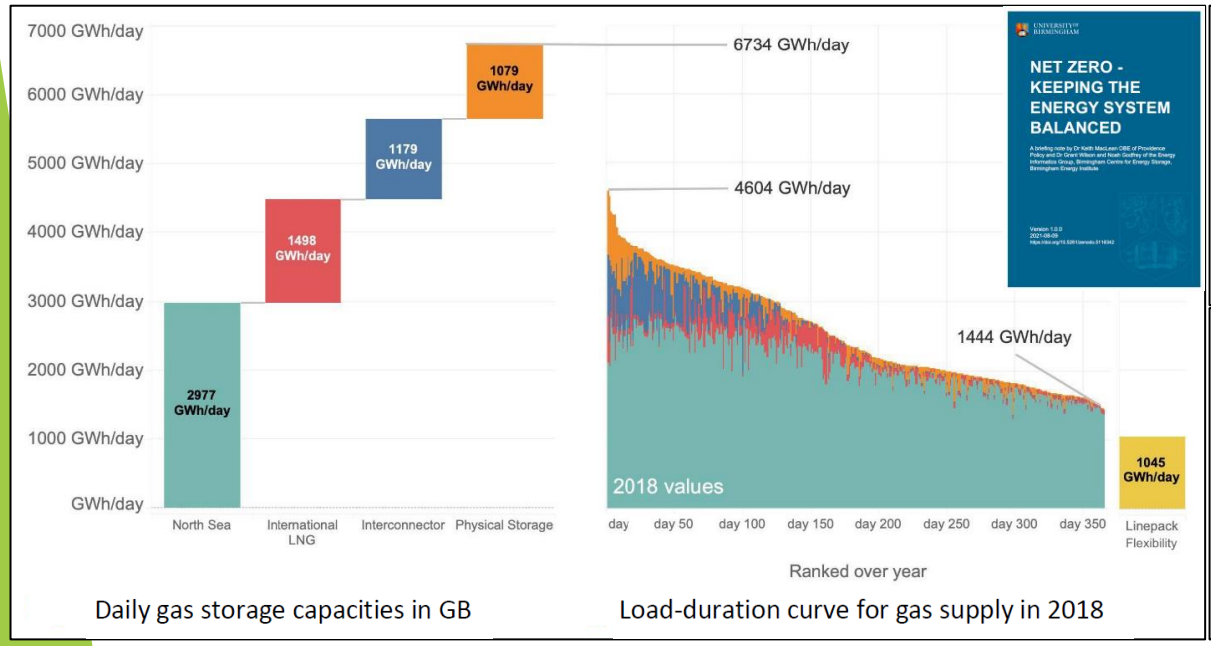




5. Energy Storage

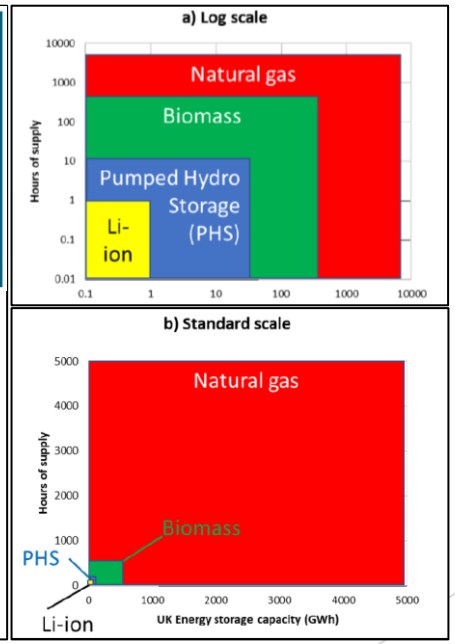


- Coal originally provided UK electricity security of supply.
- Almost entirely replaced by natural gas: providing resilience to electricity & heat demand.
- Increased reliance on European gas storage (Germany / Italy) since Rough storage closed in 2017.
  - **Pumped Storage Hydro:**
    Presently: 3GW / 30GWh
    Forecast: 30GW / 300 GWh
  - **Electric Vehicles:**
    Under 4 TWh storage achieved converting all 33 million cars to EVs with 118 kWh batteries.



Daily gas storage capacities in GB

Load-duration curve for gas supply in 2018



Energy storage approach needs to consider whole system requirements.

Long duration - large scale solutions could also be capable of addressing smaller scale & shorter term applications.

6. Electricity Network Expansion

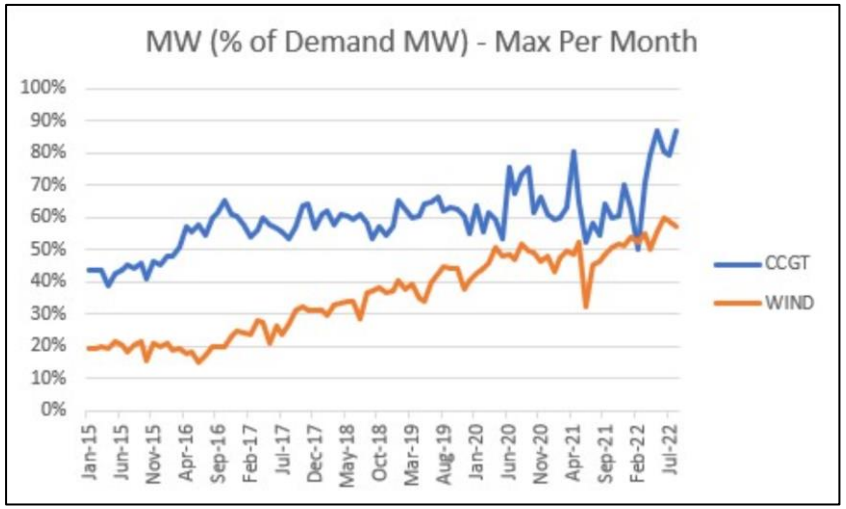
"In 2020 fossil fuels made up 84% of the global energy mix, but this figure will need to fall to less than 20% by 2050 in order to reach net zero. It's estimated that electricity consumption in the UK will increase by approximately 50% by 2036 and more than double by 2050".
National Grid website

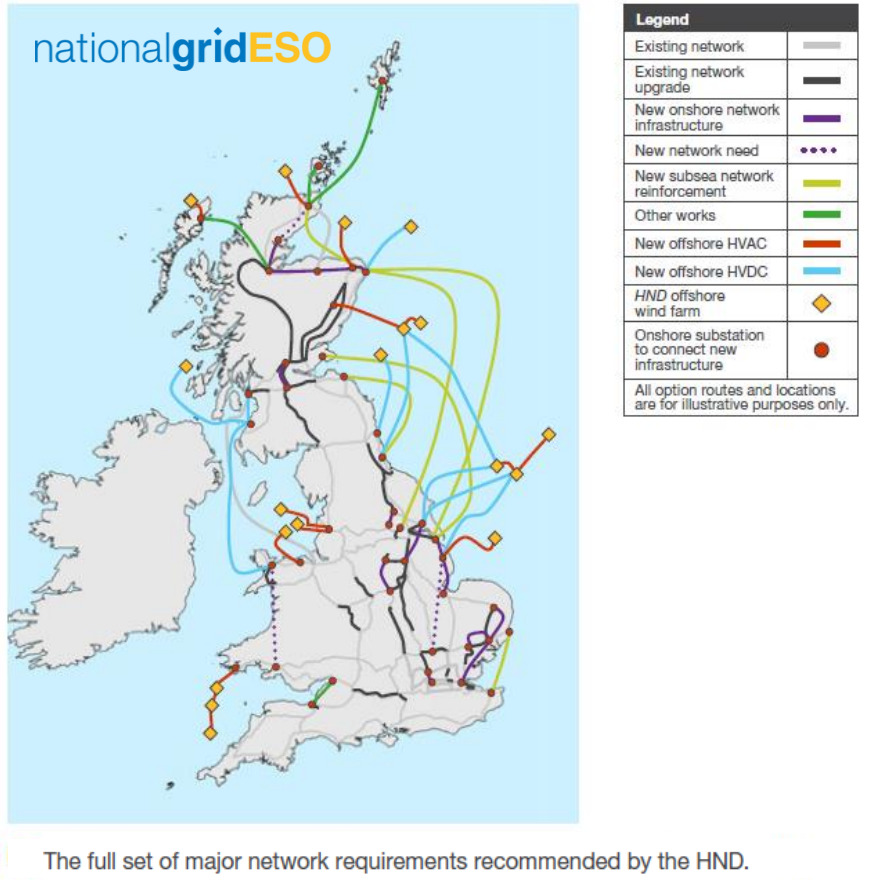
"Periods of both excess generation and demand will become more extreme and prolonged. Assuming that BECCS and nuclear run as baseload. The proportion of hours with excess generation will increase significantly by 2030 to c.50% of hours. By 2050 this becomes more than 90%. The proportion of excess demand hours becomes less frequent but more extreme".
National Grid ESO Net Zero Market Reform November 2021

Recorded data confirms trend:
Max CCGT output (% demand) is increasing in parallel with increased wind output.

What does a cost effective engineering solution look like in practice?

Do we overbuild electricity infrastructure (in excess of peak demand) with energy storage to supply annual energy demand?



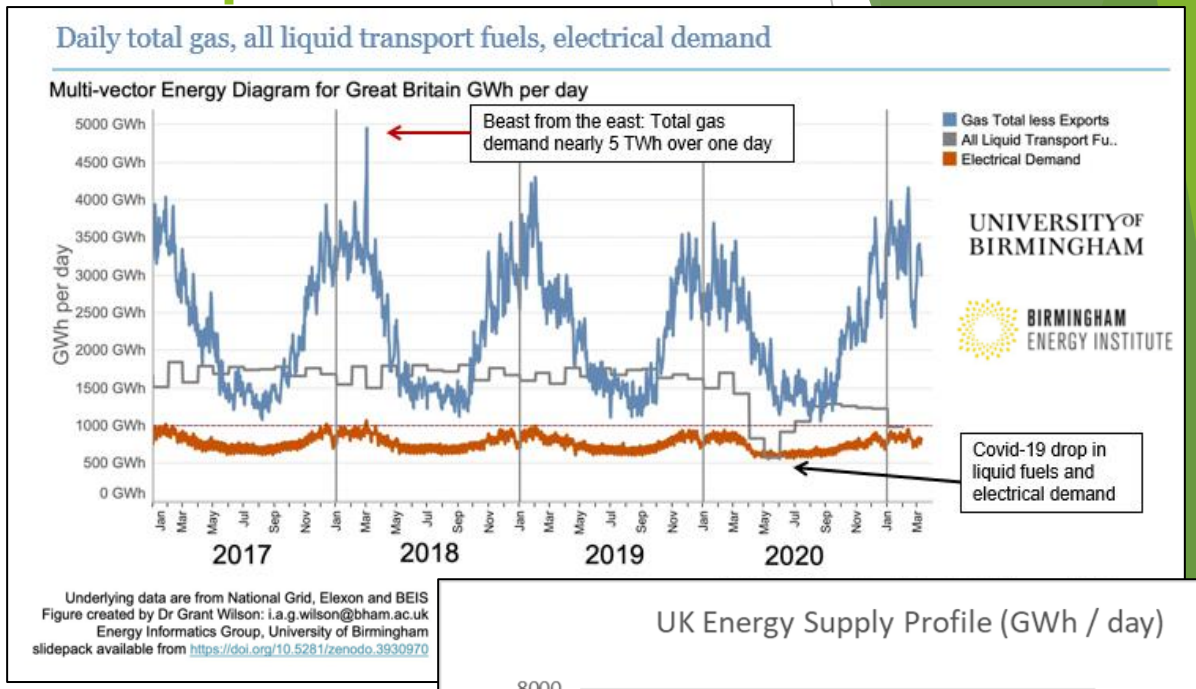


The full set of major network requirements recommended by the HND.

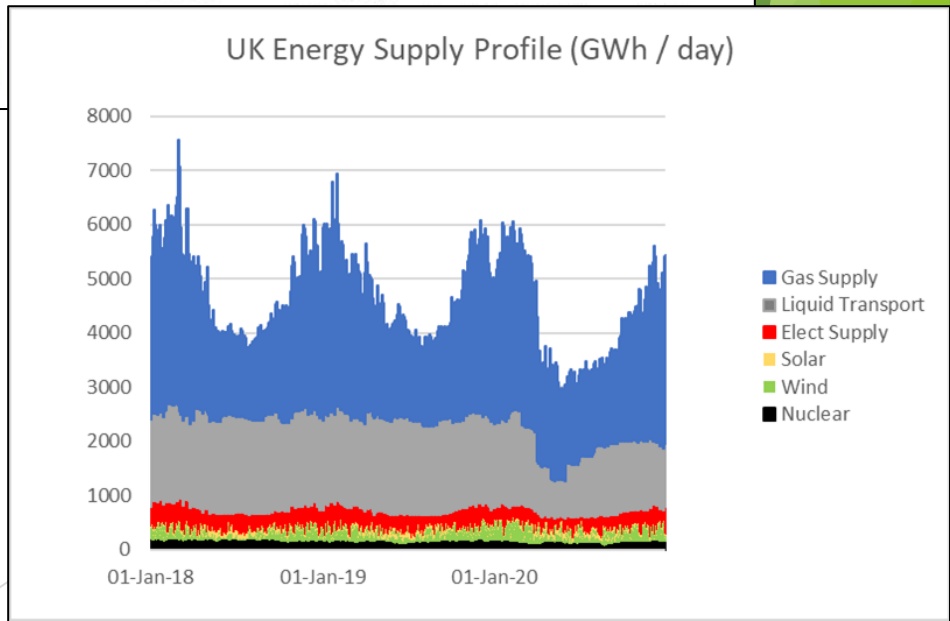
- NG ESO HND only considers 2030: Does not indicate technical requirements / timings to 2050.
- Only 1GW of Celtic Sea FLOW considered vs 24GW Crown Estate ambition & aspiration.

7. Whole Energy System Perspective

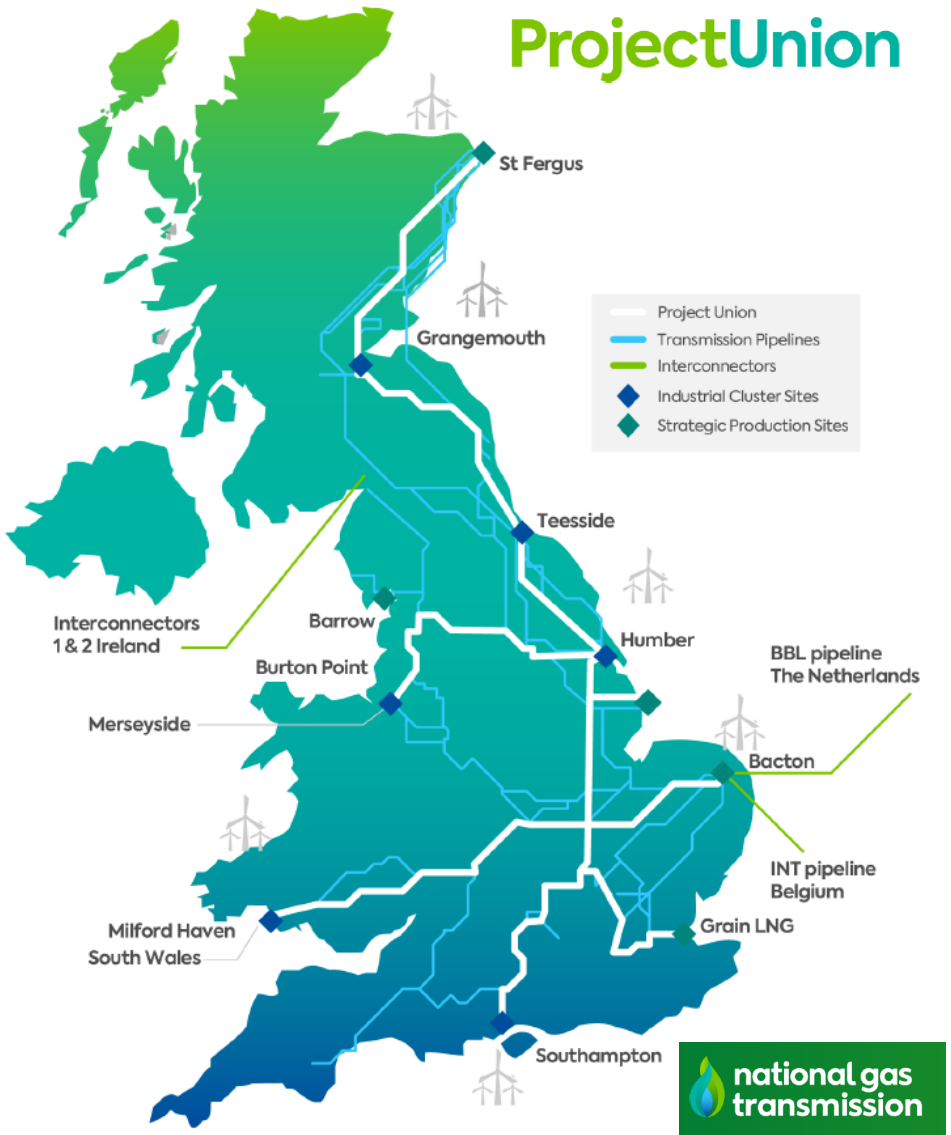
- Petrol (40%) and natural gas (34%) demand much higher than electricity (18%) in 2019.
- Peak gas demand typically between 4 and 5 times higher than electricity.
- All energy demand needs decarbonised by 2050.
- Developed pathways need to address credible worst case design scenarios (inc. security of supply), not just normal operations.



- Electricity a present solution for first mover decarbonisation of heat (heat pump) and transport (EV) demand…
- Less clear whether the electricity system offers a long-term pathway to decarbonise both heat and transport demand.
- Multiple studies conclude net zero cannot be delivered by 2050 without CCUS: Potentially requiring both Power CCUS and blue hydrogen production to provide sufficient clean energy?



8. Policy vs Practice



Key UK Policy Milestones

- **June 2019:** UK legislates to reduce GHG emissions to net zero by 2050.
- **Oct 2021:** Ambition to Net Zero UK Electricity System by 2035. Subject to Security of Supply. (2030 if Labour wins next election?)
- **Nov 2020:** UK commitment to end the sale of new petrol and diesel vehicles by 2030. All new cars and vans required to be fully zero emission at the tailpipe by 2035.
- **Oct 2021:** Gas boilers banned in new build homes from 2025. No new gas boilers installed from 2025. Almost entirely now replaced by natural gas – providing resilience to electricity and heat demand.

ProjectUnion

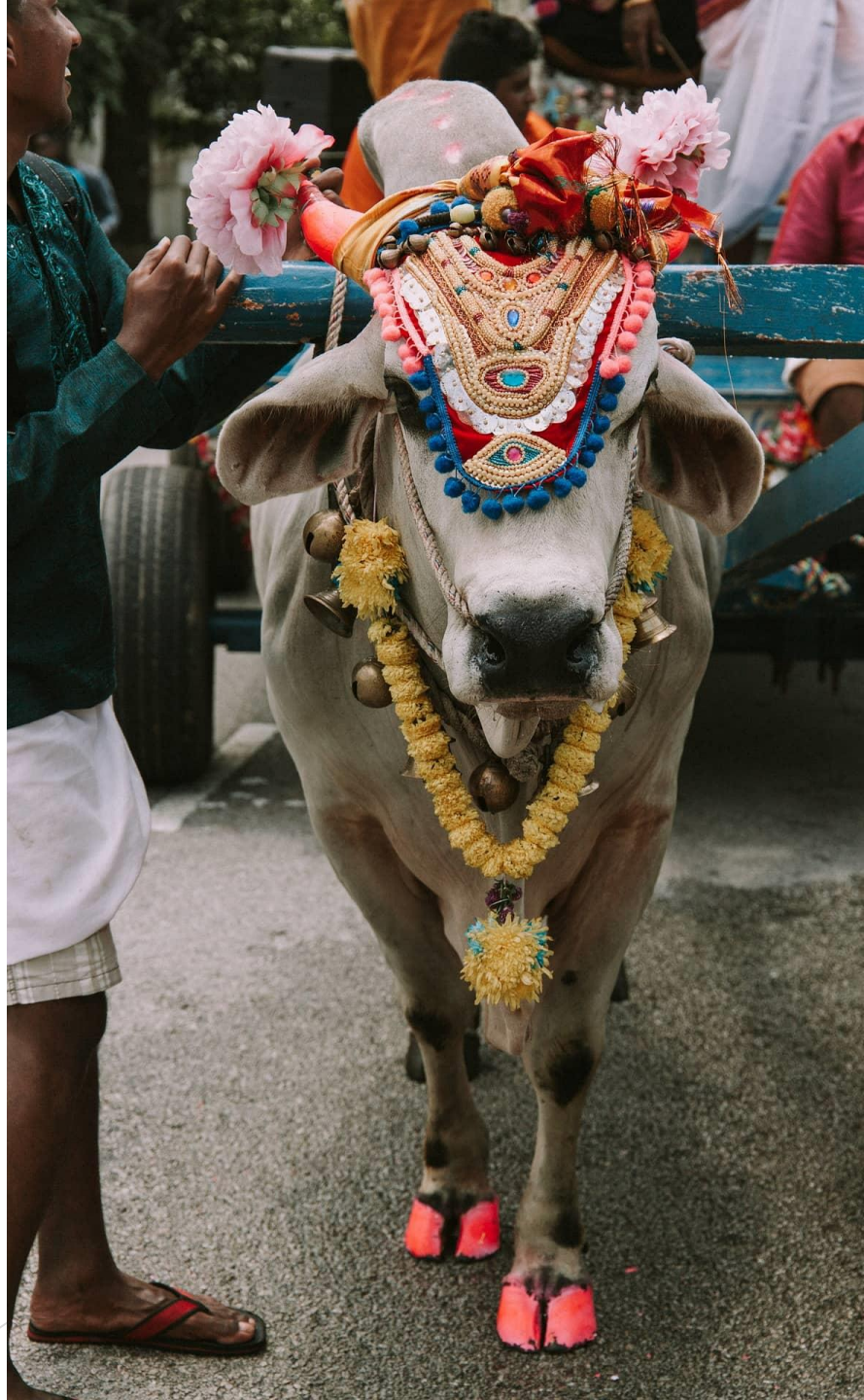
Project Union will connect, enable net zero and empower a UK hydrogen economy, repurposing existing transmission pipelines to create a hydrogen 'backbone' for the UK by the early 2030s.

- Repurpose ~2,000km of the NTS through a phased approach in line with Government's cluster prioritisation and green hydrogen development
- Connect cross GB supply, demand and strategic storage sites, enabling growth of a UK hydrogen economy
- Use existing infrastructure to deliver a low carbon future, reducing environmental impact of new construction
- Enable early and affordable market growth of a low carbon hydrogen economy to achieve net zero

- Project Union Phase 1 construction planned from early 2030s.
- 100% hydrogen transmission pipeline.
- Phase 1 fully operational by 2035.

Sacred Cows & Received Wisdom

1. Capacity Balancing
   Doesn't fully account for intermittency impacts.
2. Energy Efficiency / Demand Reduction
   Good in theory but less proven in practice?
3. Demand Management
   Least effective under network stress events?
4. Energy Storage
   PSH / EV storage capacity small vs natural gas storage.
5. Dunkelflaute
   Unlikely to reflect worst case balancing – 10s to 100 TWh required?
6. Electricity Network Expansion
   The UK's preferred solution…but unlikely to be built fast enough?
7. Whole Energy System
   Need to consider all end use / vectors and net zero 2050 outcomes.
8. Policy vs Practice
   Not joined up. Lacking an engineering based plan.



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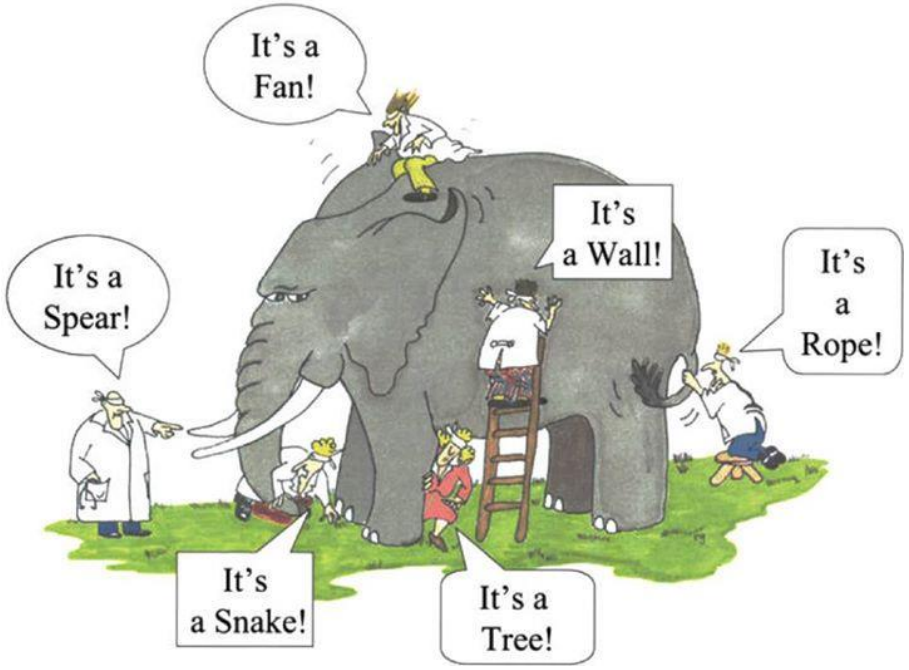
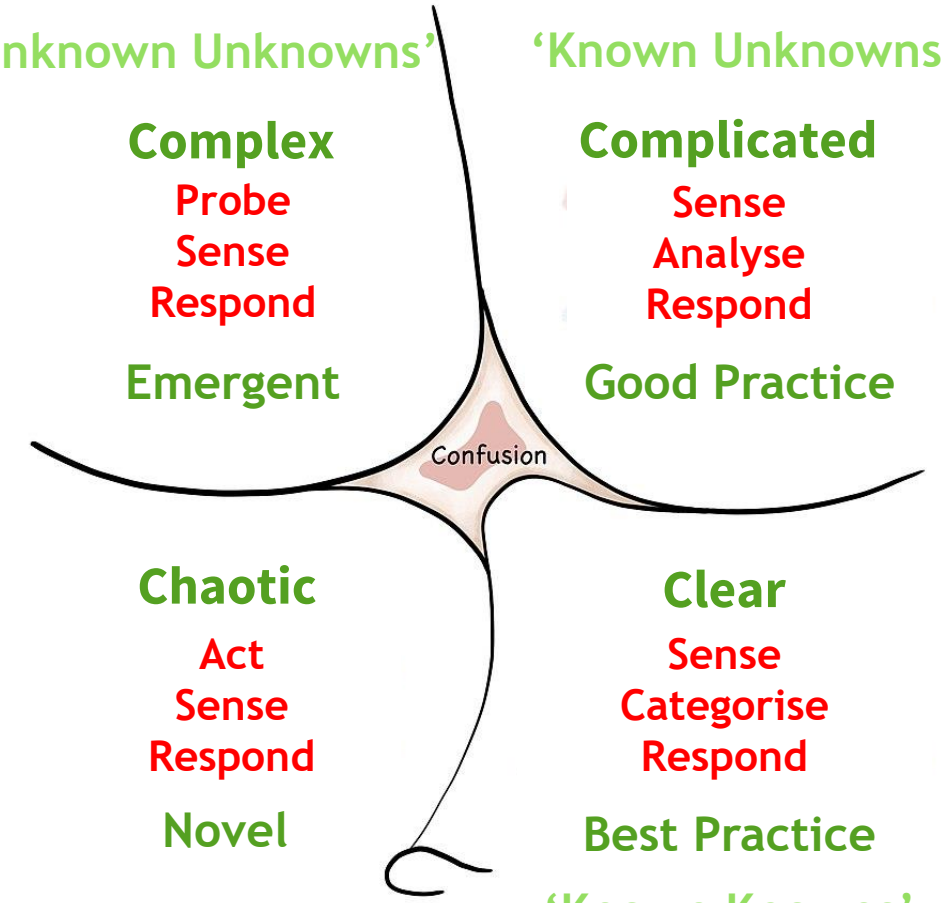


FAILURE TO JOIN UP PERSPECTIVES IS OBSCURING THE (VITAL!?) ROLE FOR HYDROGEN?

Cynefin Framework



A Method To Get To Where We Want To Be?

- Conceptual framework used to aid decision making.
- Offers decision-makers a "sense of place" from which to view their perceptions…
  … and make decisions.

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- Increasing uncertainty & unknowns as we transition to net zero.

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- Offers decision-makers a "sense of place" from which to view their perceptions…
  … and make decisions.

- Increasing uncertainty & unknowns as we transition to net zero.
- We need to reverse the cycle...
  … through investigation & analysis.

Thank You!

Grant Spence

E grant.spence@netzeroenergysystems.co.uk
grant.spence@member.imeche.org

W imeche.org/industry-sectors/power-energy