conrad energy

The critical role of hydrogen in keeping the lights on

Neil Filkin, 28 June 2022

Conrad Energy overview

- We are the UK's largest flexible power producer with over 700MW of generation and storage assets across 45 plants and a development pipeline of 1GW+ portfolio made up of flexgen, storage and solar projects which will be delivered by 2024.
- We develop, construct, own, operate and maintain generation & storage assets, employing over 130 people.
- Our in-house trading desk and technology trades and optimises our assets and those of third parties; we are a licensed electricity supplier, supporting customers through Power Purchase Agreements.
- Rapidly growing provision of behind the meter and private wire solutions to businesses.
- We have 2 consented hydrogen projects with grid-connected electrolysers, which will use renewable power.
- We are developing several more hydrogen production projects, intending to supply hydrogen to others, and also to develop hydrogen as a fuel for flexible power generation.

The priority for hydrogen is for “hard to electrify” sectors

This implies there is also going to be a lot of electrification – and big changes in the electricity industry

It is commonly agreed that decarbonisation priorities are energy efficiency, electrification, then hydrogen

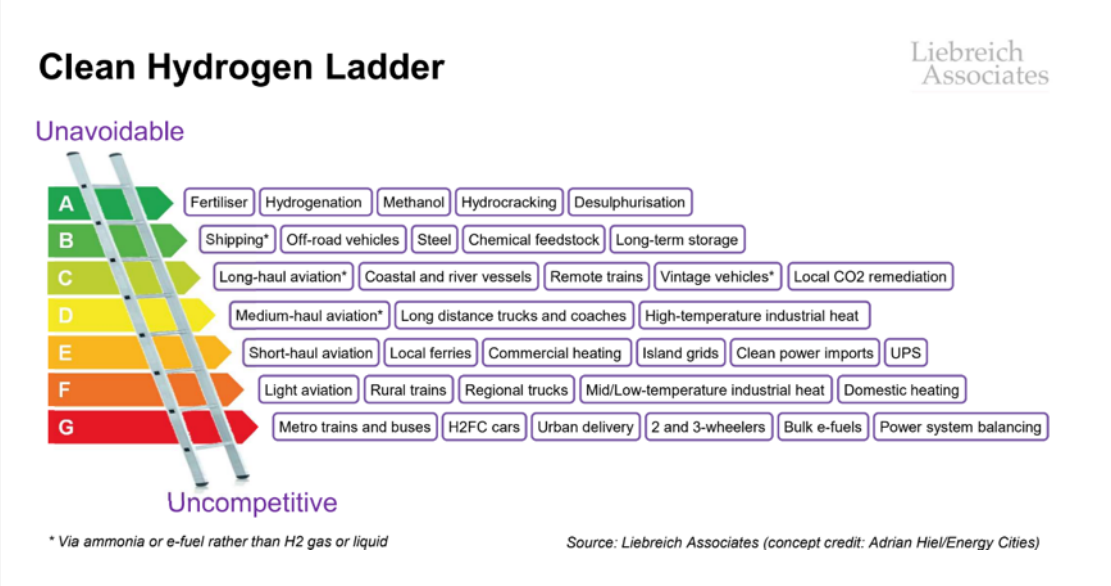
For example, see Michael Liebreich’s Hydrogen Ladder

Things at the top of the ladder are hard to electrify and will switch to hydrogen:

- Chemical feedstock
- Industrial fuel
- Long range transport

Things at the bottom are likely to be electrified instead:

- EV’s – electric cars, and short-range buses/trucks
- Heating – heat pumps



Electrolytic hydrogen production will itself increase demand for electricity

What does this mean for the electricity industry?

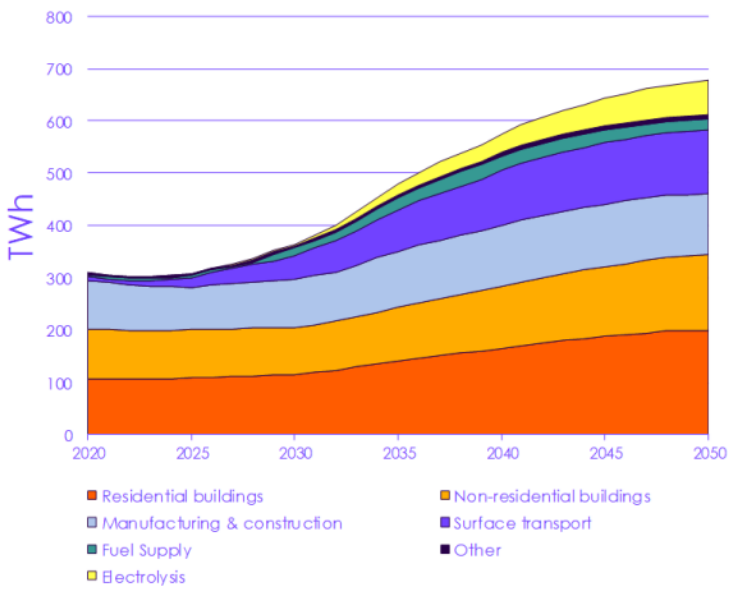
Forecast growth in electricity demand – and decarbonisation

Doubling the production whilst reducing carbon intensity from 220g CO_2/kWh to zero

Total UK demand will double by 2050, particularly due to EVs and electrification of buildings (heating)

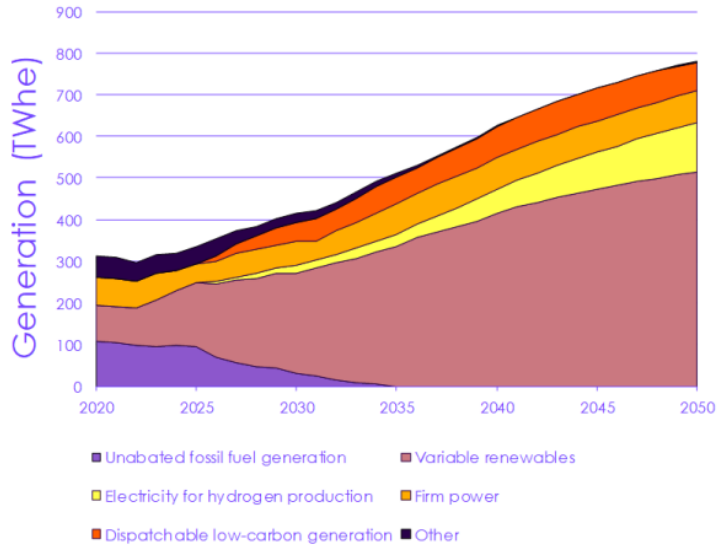
Five-fold growth in intermittent renewables is supported by firm nuclear power, and low carbon flexible generation

Figure 3.4.a Electricity demand by sector in the Balanced Net Zero Pathway (2020-50)



Source: CCC analysis.
Notes: Other category includes agriculture, aviation, direct air capture, shipping and F-gases.

Figure 3.4.c Illustrative generation mix for the Balanced Net Zero Pathway (2020-50)



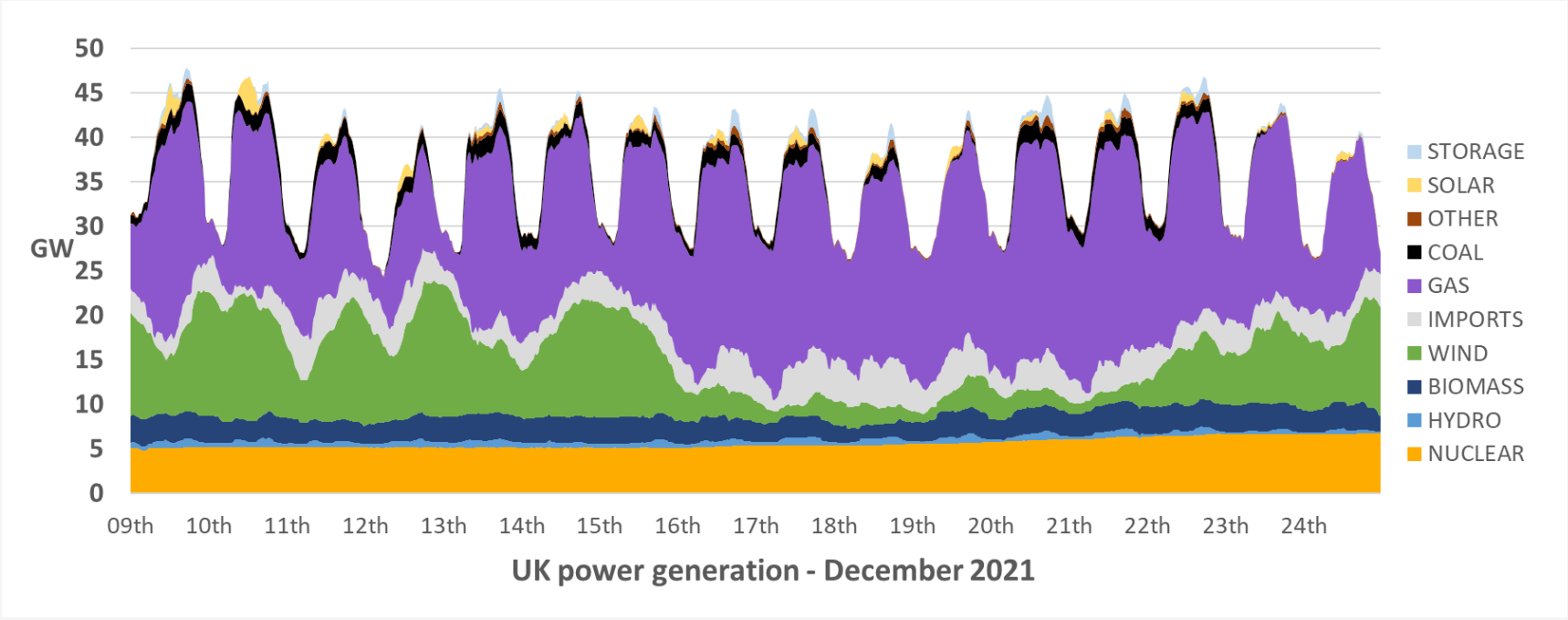
Source: CCC analysis.
Notes: Chart reflects UK electricity generation. Additional capacity is available through interconnection. Unabated fossil fuel generation includes coal and gas. Variable renewables include wind and solar. Firm power includes nuclear. Dispatchable low-carbon generation includes gas CCS, BECCS and hydrogen.

The UK's 6th Carbon Budget, Committee on Climate Change, https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf

More renewables needs more flexible generation or “countermittency”

The electricity system operator, National Grid ESO, constantly balances generation with demand

If there is too big an imbalance, key parameters like voltage would move outside limits, causing blackouts



Data source: National Grid ESO
https://data.nationalgrideso.com/carbon-intensity1/historic-generation-mix

- From December 10th to 14th the UK wind output (green area) swung between about 15 and 5 GW from one day to the next
- It also swung between 8% and 51% of national demand
- From 16th to 22nd the wind output was low at 4GW or less, meeting less than 10% of national demand

Lots of gas-fired dispatchable plant is needed for National Grid ESO to manage these swings – without gas, the lights would go out!

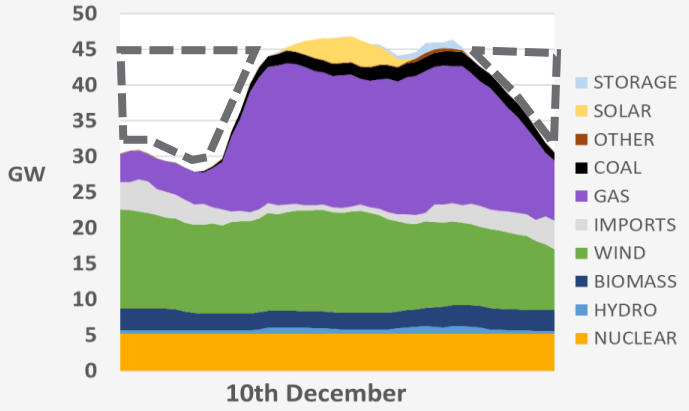
Low carbon dispatchable flexible generation

A mix of batteries and hydrogen will be needed

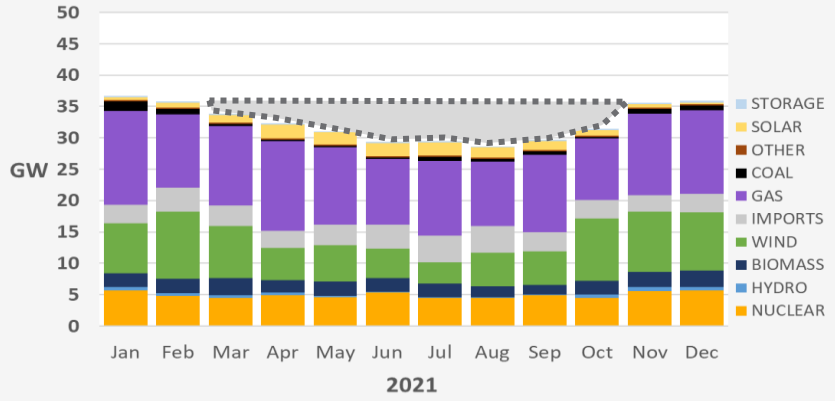
How do we decarbonise this dispatchable power generation?

Conceptually – it seems obvious to charge batteries when it's windy, and to use that energy when renewables are unavailable

- The dashed areas (left) indicate opportunity where there is in principle some spare capacity/energy
- However, the total area of the dotted areas is less than the purple – difficult to store enough energy short term to cover all the demand
- Also see previous page – there was a 6-day period where wind was not available – during this time, all batteries would have been emptied
- Batteries are a key part of the mix for shorter term grid balancing, but they cannot do it alone



- Hydrogen is different to batteries, because the quantity of energy stored is decoupled from production, and instead depends on the size of the storage tank, salt cavern etc
- The graphic on the right shows UK monthly averages in 2021
- It also shows that in principle storage from summer to winter is feasible, using hydrogen (grey dotted area) – to cover periods of prolonged low wind



Using hydrogen to fuel dispatchable plant

Only a few projects have been announced – more government support is needed to get this moving

Gas turbines

Current UK installed capacity (CCGT) 31.8 GW

- Combined Cycle Gas Turbines (CCGT) which use a steam turbine to recover additional energy
- High efficiency but reduced flexibility – slow to ramp up ~1 hour
- Therefore need to be scheduled to run, rather than used reactively
- Open Cycle Gas Turbines (OCGT) are lower efficiency but fast

Hydrogen

- Can be operated on gas-hydrogen blend
- Development needed for pure H2
- Projects announced: Keadby (1.8GW), Rocksavage (0.8GW), Teesside (0.35GW)

Gas reciprocating engines

Current UK installed capacity about 1.1 GW

- Medium efficiency but very fast and flexible
- May be operated at a few minutes' notice and for short periods

Hydrogen

- Can be operated on gas-hydrogen blend
- Development needed for pure H2
- Projects announced: Conrad Energy Nottingham (0.001-0.03 GW)

Despite low round-trip efficiency, we need to do this!

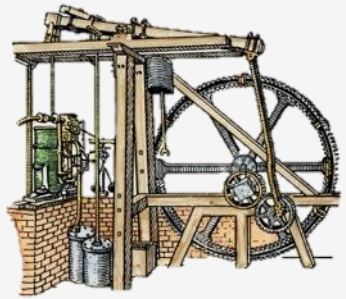
There are many critics of the idea of power-to-hydrogen-to-power, based on low efficiency

Let's say the hydrogen production process (electrolyser, compressor, storage) has an efficiency of 60%. Let's assume we're turning the hydrogen back to power using a gas reciprocating engine at efficiency of 40%. This means the round-trip efficiency is 60% * 40% = 24%

Using a CCGT at 55% or fuel cell at 65%, gives round trip efficiencies 33% and 39% respectively

While this might look low compared to a lithium-ion battery, there are many precedents for adoption of technologies at similar efficiency values – as the only available option at scale

- James Watt steam engine 10%, original Otto petrol engine 14% (now 30%), original Diesel engine 17% (now 55%)
- Nuclear power station around 32-35%, similar to a modern coal-fired power station
- Round trip efficiency is really about economics – lower efficiencies can be cost effective with low-cost input energy



Are there other alternatives?

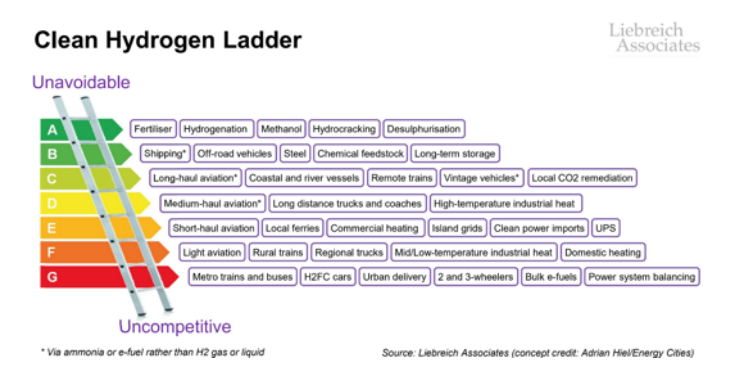
a) Pumped Hydro – proven but there are no new UK sites of scale
b) Compressed Air Energy Storage – has potential, but hydrogen has other applications as well as power generation – broader security of supply benefits
c) Biomethane – technically viable now, but insufficient volume, constrained by feedstock availability
d) Long duration battery technology – low TRL/immature
e) Continue to burn natural gas and fit carbon capture to exhaust – low TRL/immature – not being developed for smaller plant
f) Demand-side response – charge EVs when it's windy, time of use tariffs – requires massive consumer behaviour change, can the infrastructure cope?

Hydrogen can be done now! The main technical challenge is storage volume, and getting from blends to 100% H_2

Summary

1) There will be a massive growth in electrification to move away from fossil fuel
2) This will need a huge growth in renewables, and huge growth in dispatchable low carbon flexible generation
3) This means both batteries and hydrogen fuelled power generation
4) A small number of hydrogen power generation projects have been announced
5) More Government support is essential to enable this part of the hydrogen economy to develop
6) Despite low round-trip efficiency, power-hydrogen-power is necessary to allow time-shifting of renewable power

Hydrogen for power generation should be higher up the hydrogen ladder – “long term storage” is there at level B, but this should really say “*dispatchable flexible power*”



Thank you

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