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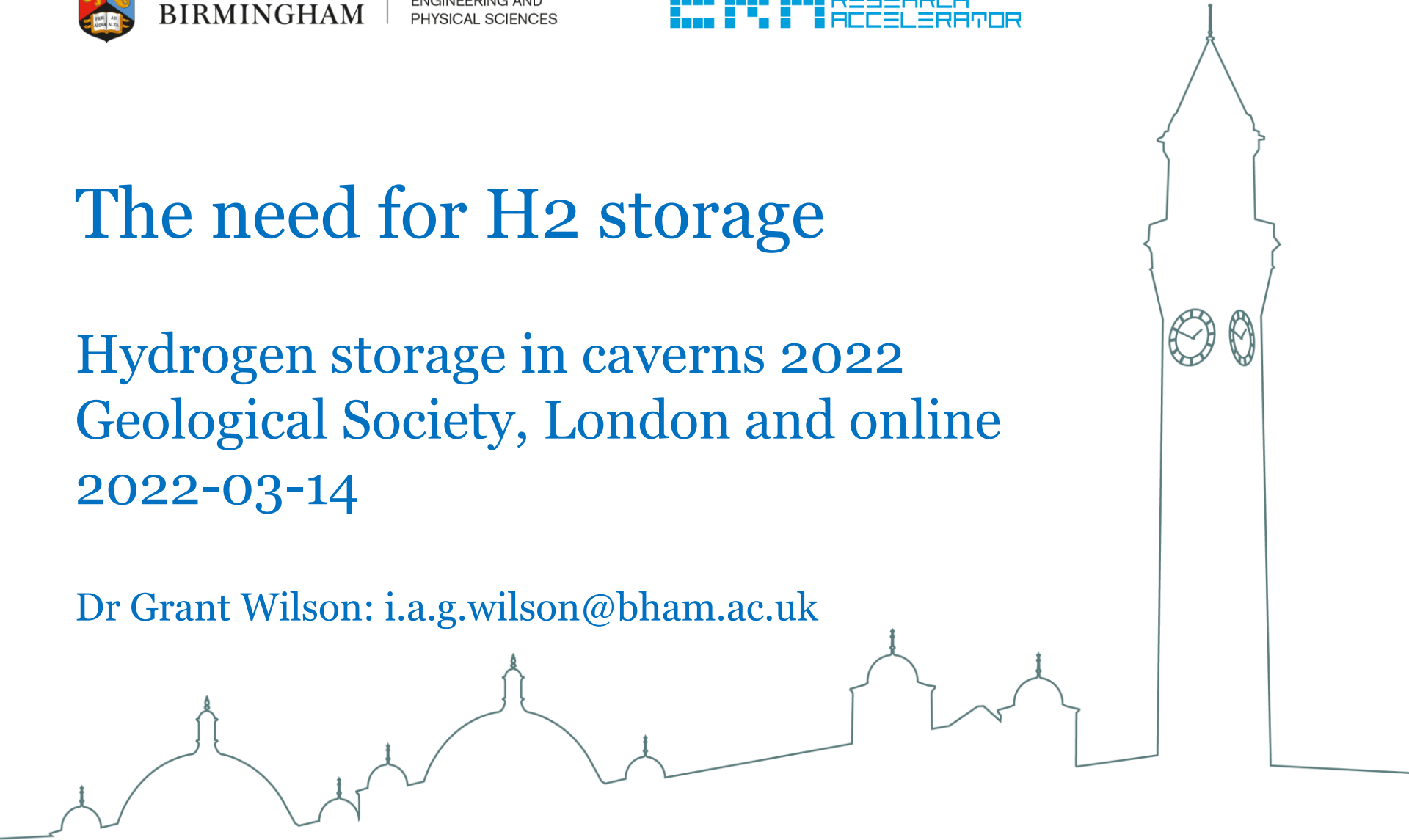
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ERA ENERGY
RESEARCH
ACCELERATOR

The need for H₂ storage

Hydrogen storage in caverns 2022
Geological Society, London and online
2022-03-14

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Leads the Energy Informatics Group: activities include analysis on energy system flexibility, using multi-vector, multi-scale data analytics at a national and local level.

National Grid opening stock gas data (from 2010) has been combined and can be downloaded from: <https://doi.org/10.5281/zenodo.5555011>

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20 minute presentation – focus is only on longer term storage

How much energy do we currently store with gas and why?

How much energy might we need to store in future ... and why?

Why hydrogen in caverns?

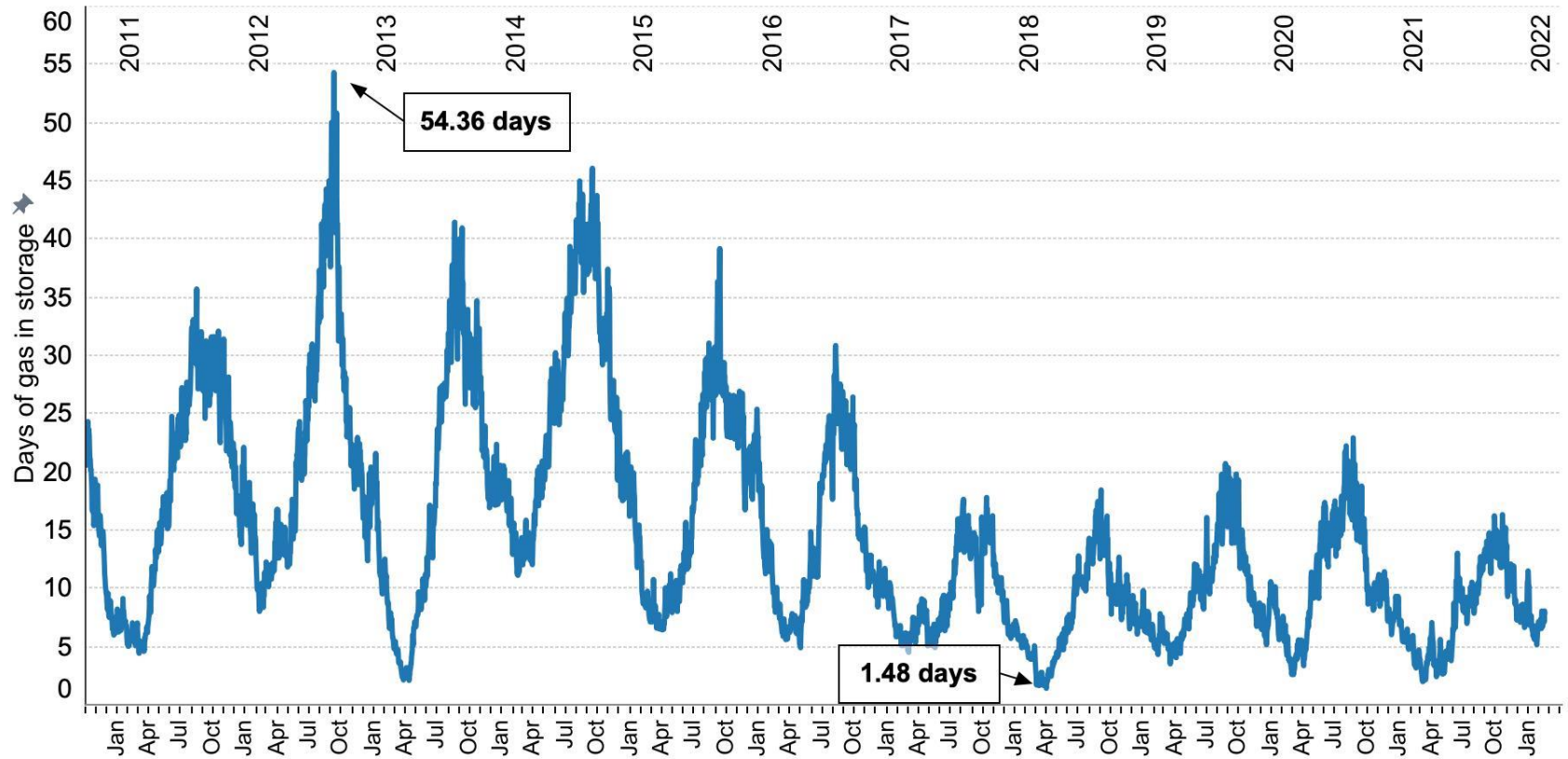


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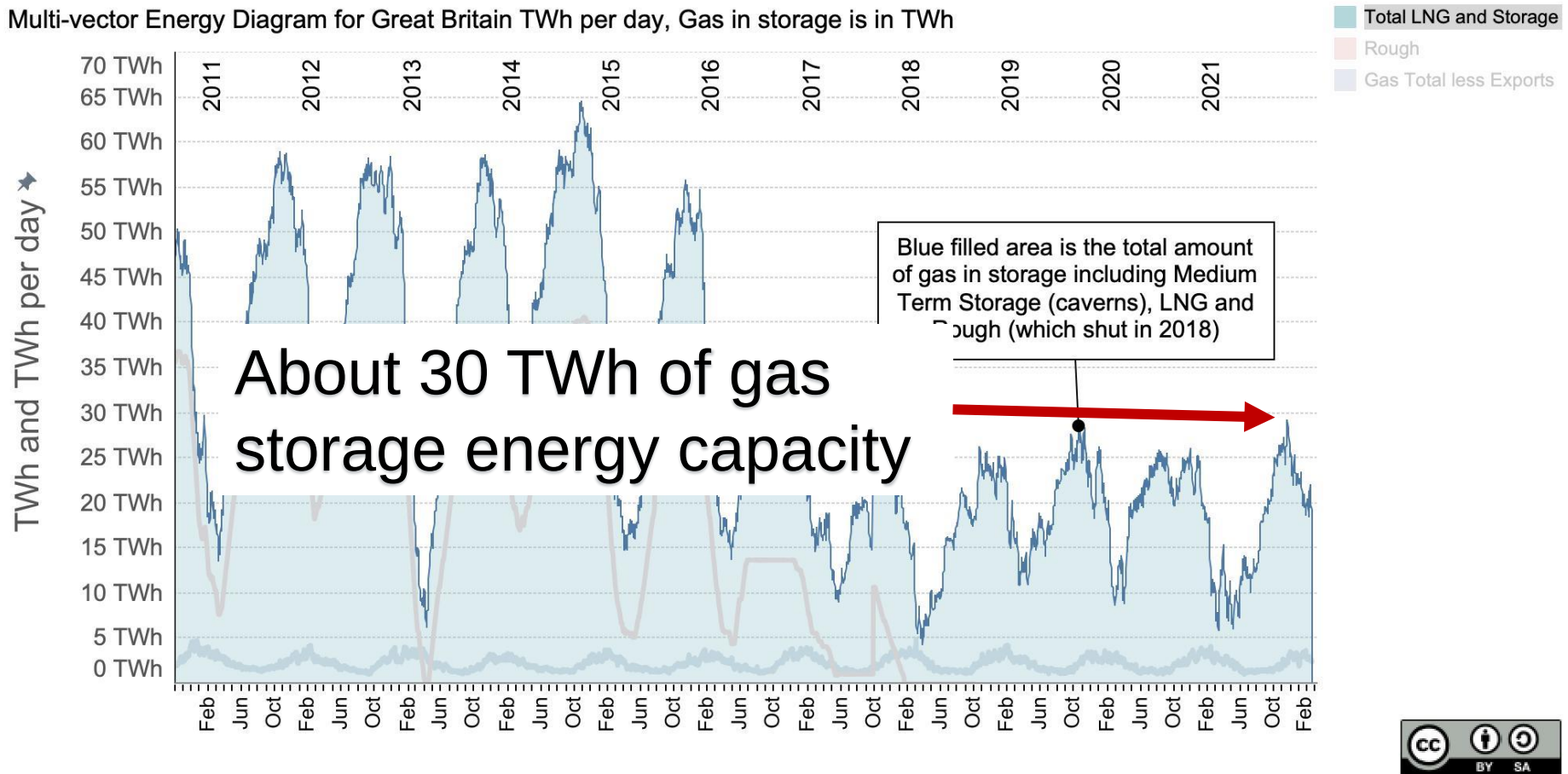
How much energy do we currently store with gas and why?

Amount of days of gas in storage == Gas in LNG and Caverns / daily gas demand less exports



Scale of gas storage in Britain

Multi-vector Energy Diagram for Great Britain TWh per day, Gas in storage is in TWh



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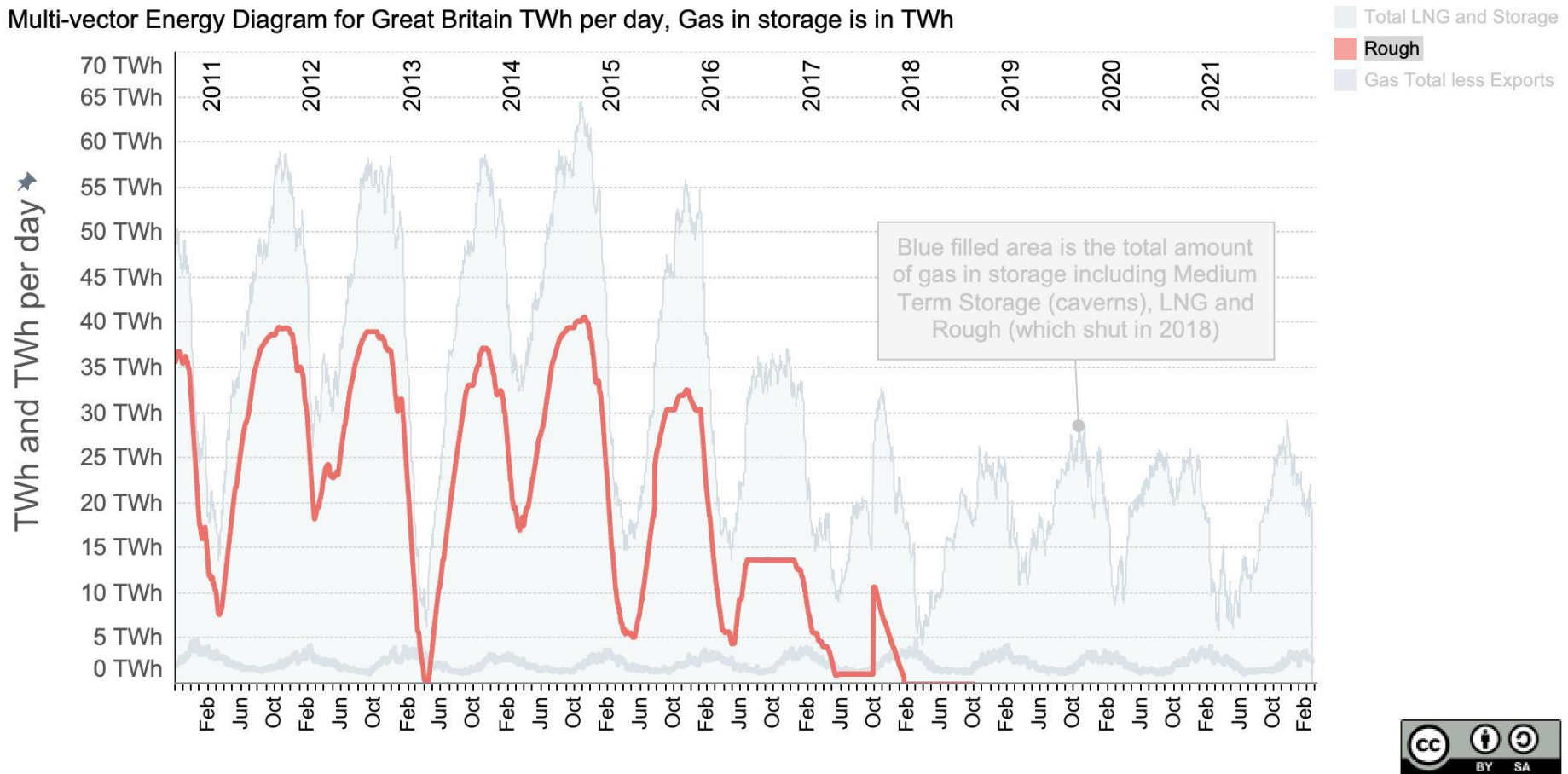
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Underlying data are from National Grid
Figure created by Dr Grant Wilson: i.a.g.wilson@bham.ac.uk
Energy Informatics Group, University of Birmingham

Opening stock gas data (from 2010) can be downloaded from: <https://doi.org/10.5281/zenodo.5555011>

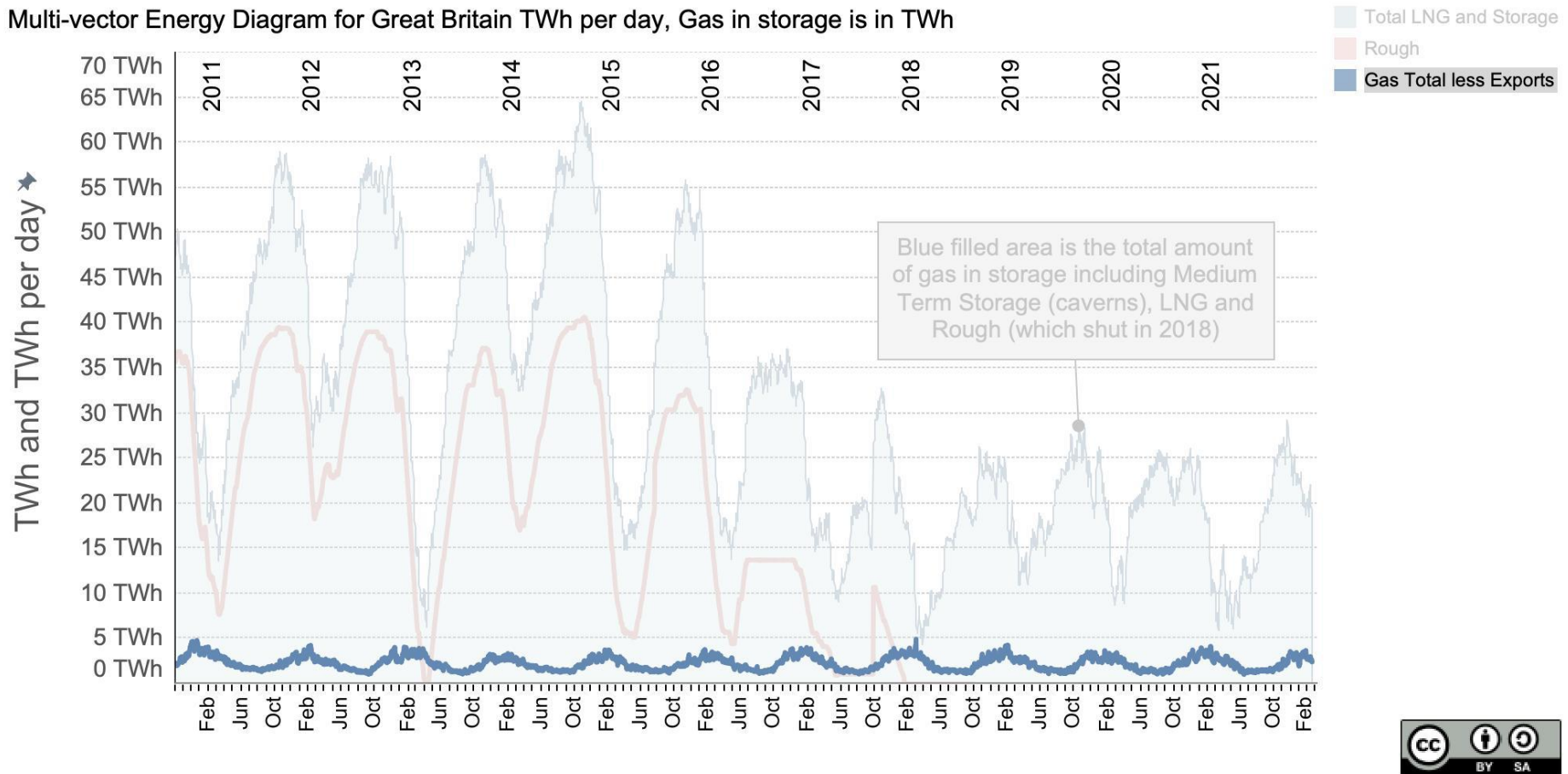
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To summarise so far:

In terms of existing gas storage there is nearly 30 TWh of capacity, with a broadly 50:50 split between LNG and cavern storage.

Assumption that LNG infrastructure is unlikely to be changed to accommodate liquid hydrogen (but an interesting question on what happens to the LNG infrastructure longer term).

So – this leaves 15 TWh of existing ‘medium term’ storage that could potentially be switched over to hydrogen – if – technical details, costs and safety were favourable

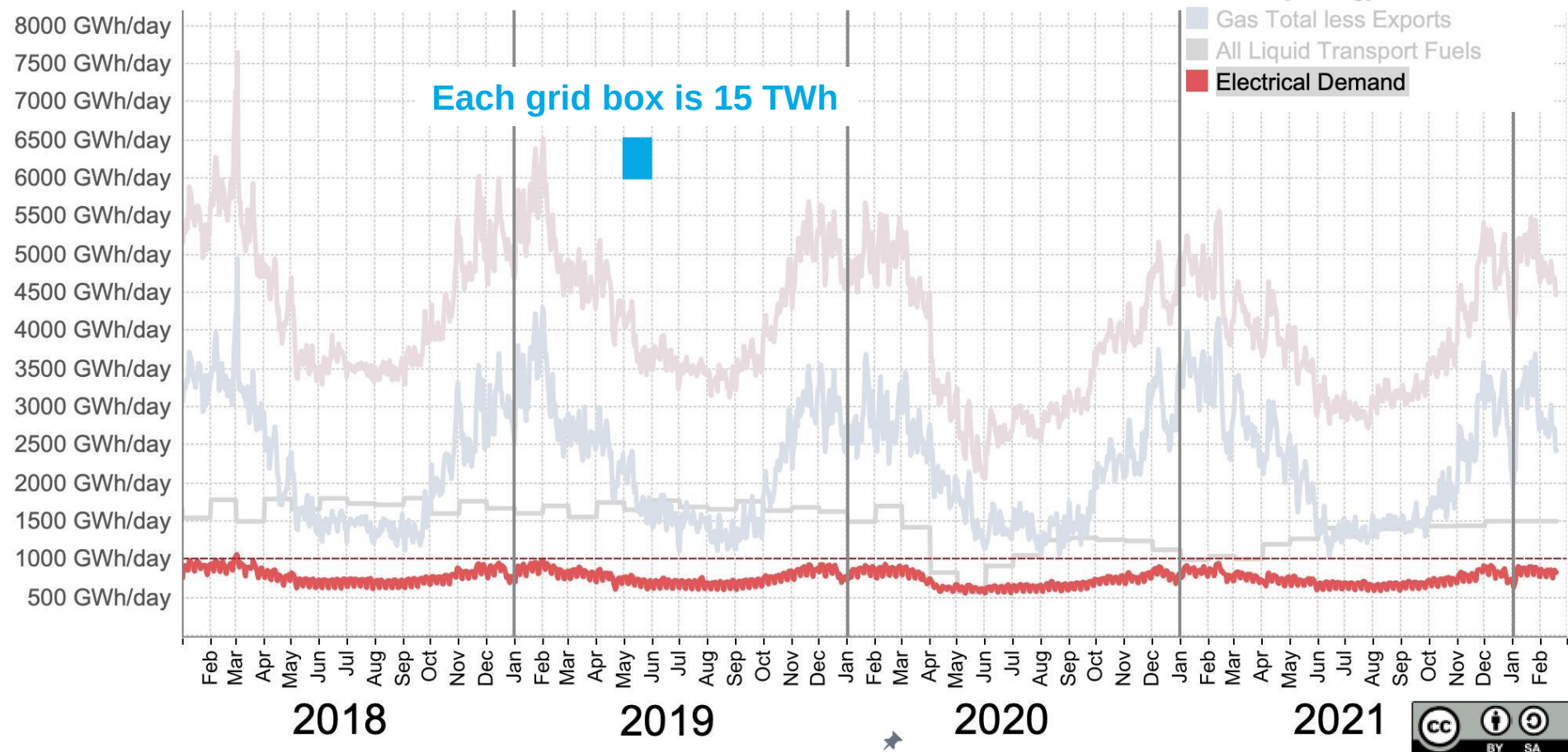


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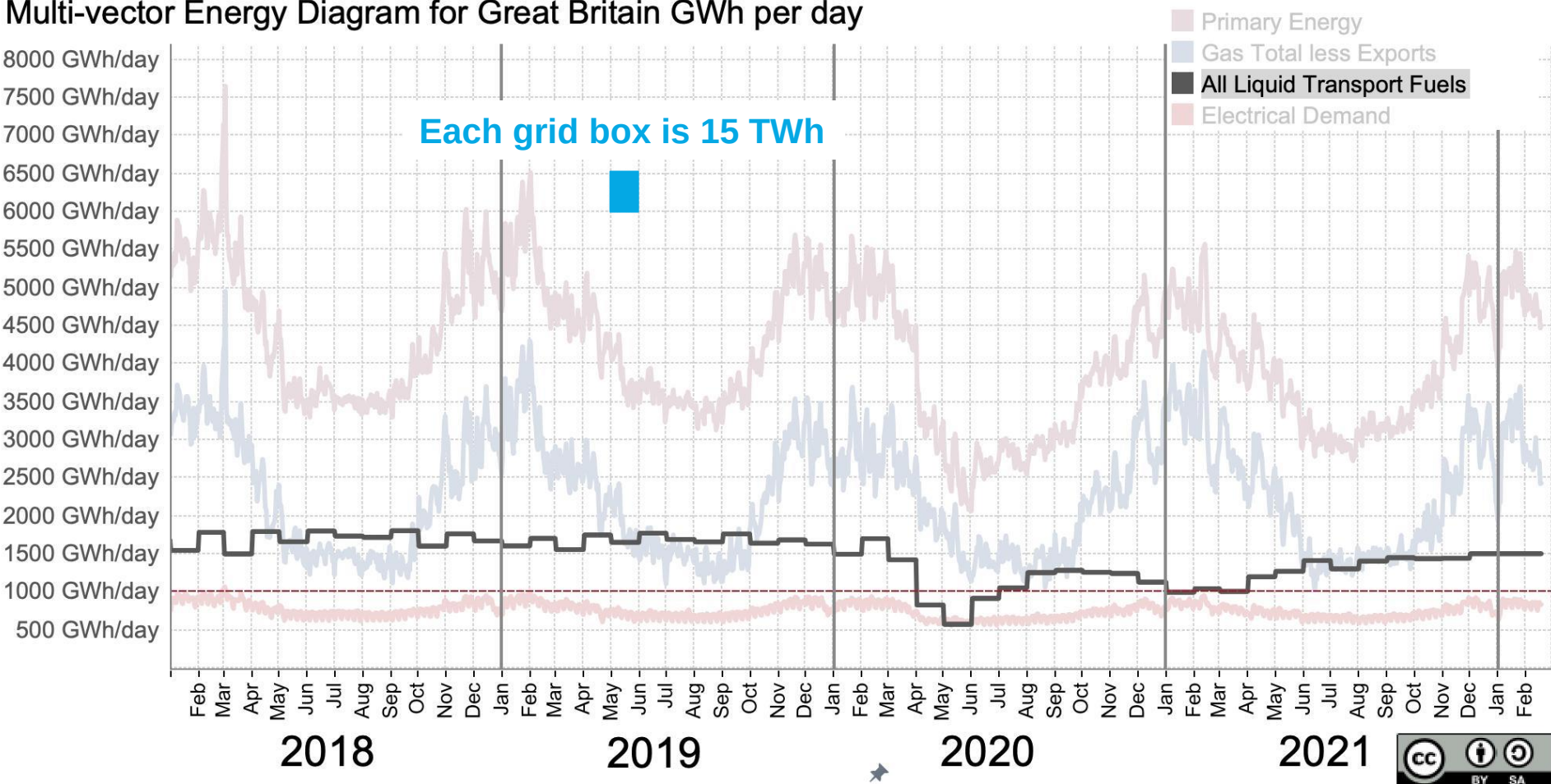
Britain's electrical demand - daily

Multi-vector Energy Diagram for Great Britain GWh per day



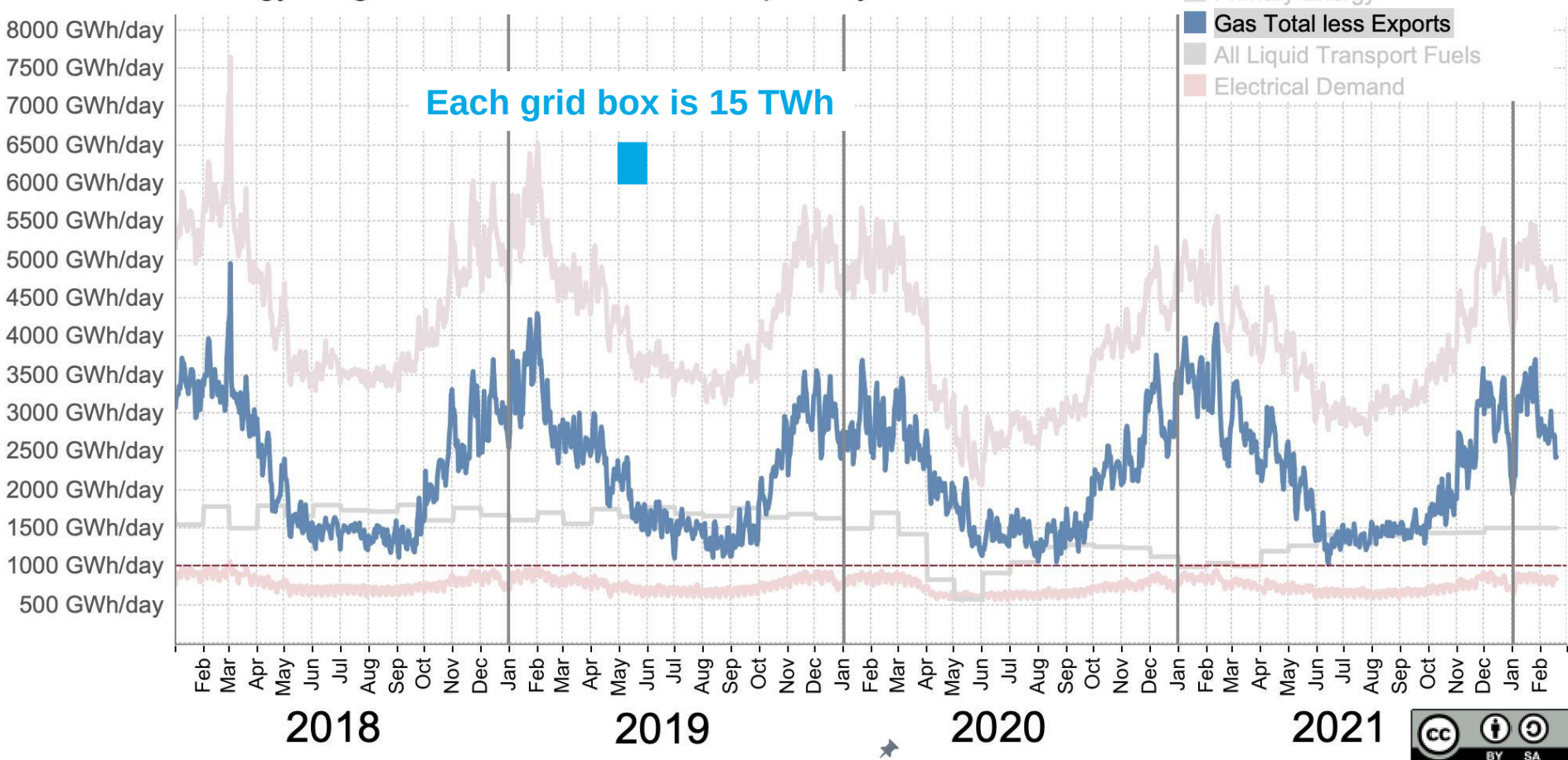
UK's liquid fuel demand - daily

Multi-vector Energy Diagram for Great Britain GWh per day



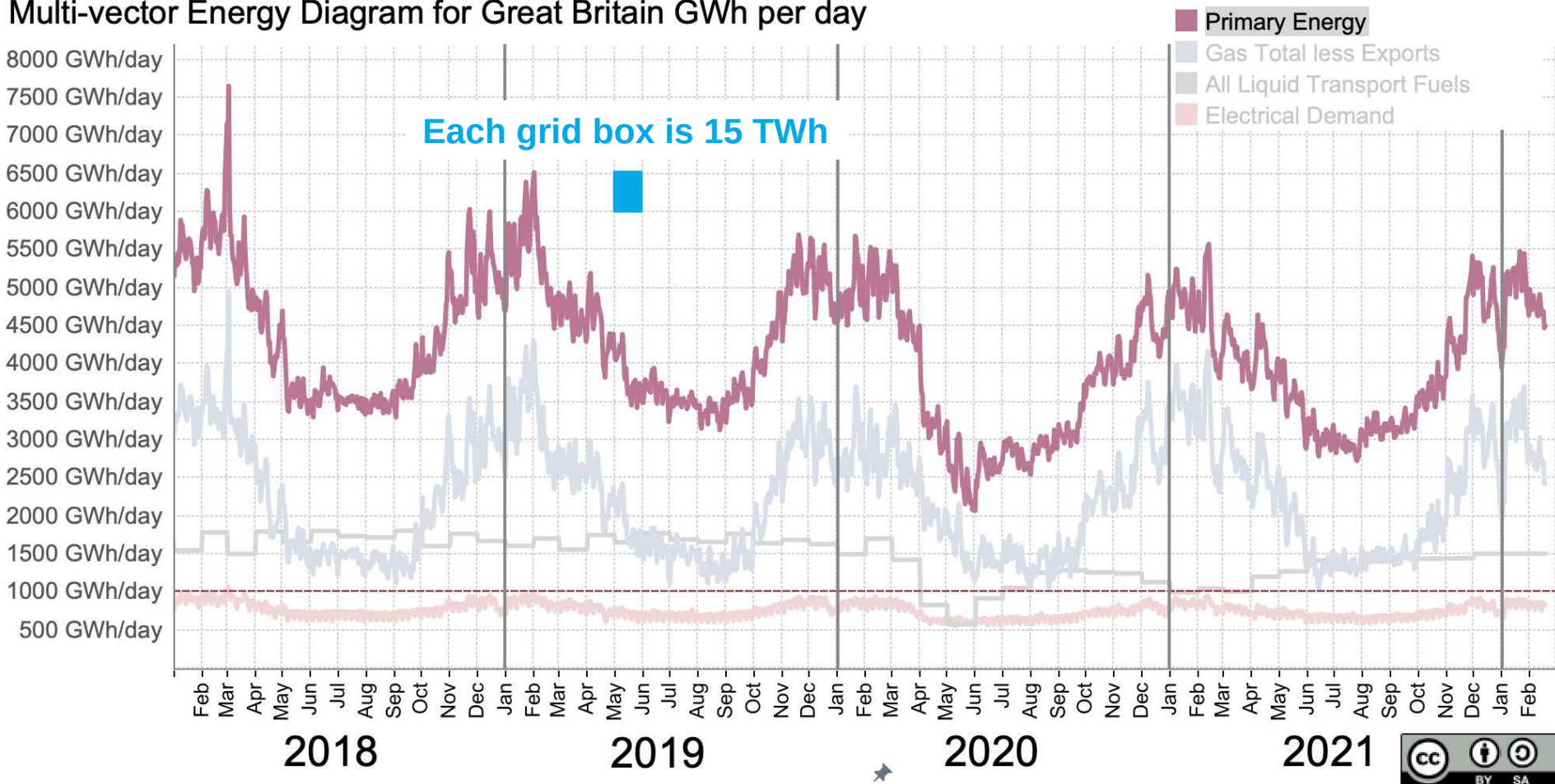
Natural gas demand less exports - daily

Multi-vector Energy Diagram for Great Britain GWh per day



Primary energy demand - daily

Multi-vector Energy Diagram for Great Britain GWh per day



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Underlying data are from National Grid, Elexon and BEIS
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Energy Informatics Group, University of Birmingham
slidepack available from <https://doi.org/10.5281/zenodo.3930970>

Natural gas is the biggest seasonal swing in demand for Britain's primary energy – driven by domestic heat

Why do we store the amount of gas currently?

- There is no primary legislative target (similar concept to the IEA or previously EU targets on the amount of liquid fuels required to be stored)
- Therefore it is a market based decision influenced by a number of factors
- Natural gas storage provides a fraction of the security of supply and the seasonal flexibility for Britain's energy system. A greater fraction comes again from natural gas, but is from increased imports in winter in comparison to summer

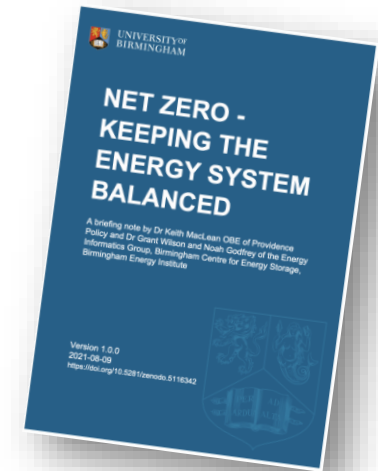


How much energy might we need to store in future ... and why?

Taken from report published last year with Dr Keith MacLean and Noah Godfrey

NET ZERO - KEEPING THE ENERGY SYSTEM BALANCED -
<https://doi.org/10.5281/zenodo.5116342>

Research looked at a future system
with very high-renewables to consider
the scale of seasonal energy balancing



The imbalance results were similar orders of magnitude to other research from Professor Chris Llewellyn-Smith (University of Oxford) , and Professor Mark Barrett (UCL)



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How much energy might we need to store in future ... and why?

The aim of the research was to consider the scale of energy system imbalances – rather than how the imbalances might be managed, e.g., the energy demand and electrical generation were considered without imports or exports: a self-sufficient approach

Therefore imports and exports could be used (as now) to manage the seasonal imbalance



How much energy might we need to store in future ... and why?

- Future orders of magnitude of system imbalance for heat and electricity are similar to today, but no longer with ready access to fossil fuel storage to manage them
- Electrifying heat shifts significant extra seasonal imbalance onto the electrical system, doubling or trebling the existing scale of daily and cumulative levels, depending on the electric heat technology used (resistive or heat-pumps)
- There are significant levels of additional oversupply of primary electricity that the system has to manage



How much energy might we need to store in future ... and why?

Based on recorded data for generation output from 2018, a renewable system using just wind and solar in an 85:15 ratio was simulated, no nuclear, no import or exports

Main findings:

Wind is seasonally well suited to the seasonality of heat demand, which helps to reduce the overall seasonal imbalance in comparison to, e.g., solar or even a flat baseload

However, the cumulative energy deficit from extended periods (weeks) of low wind are significant drivers for balancing, as well as the cumulative energy surplus from extended periods of higher wind



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Growth of surplus days of energy – what will we do with this?

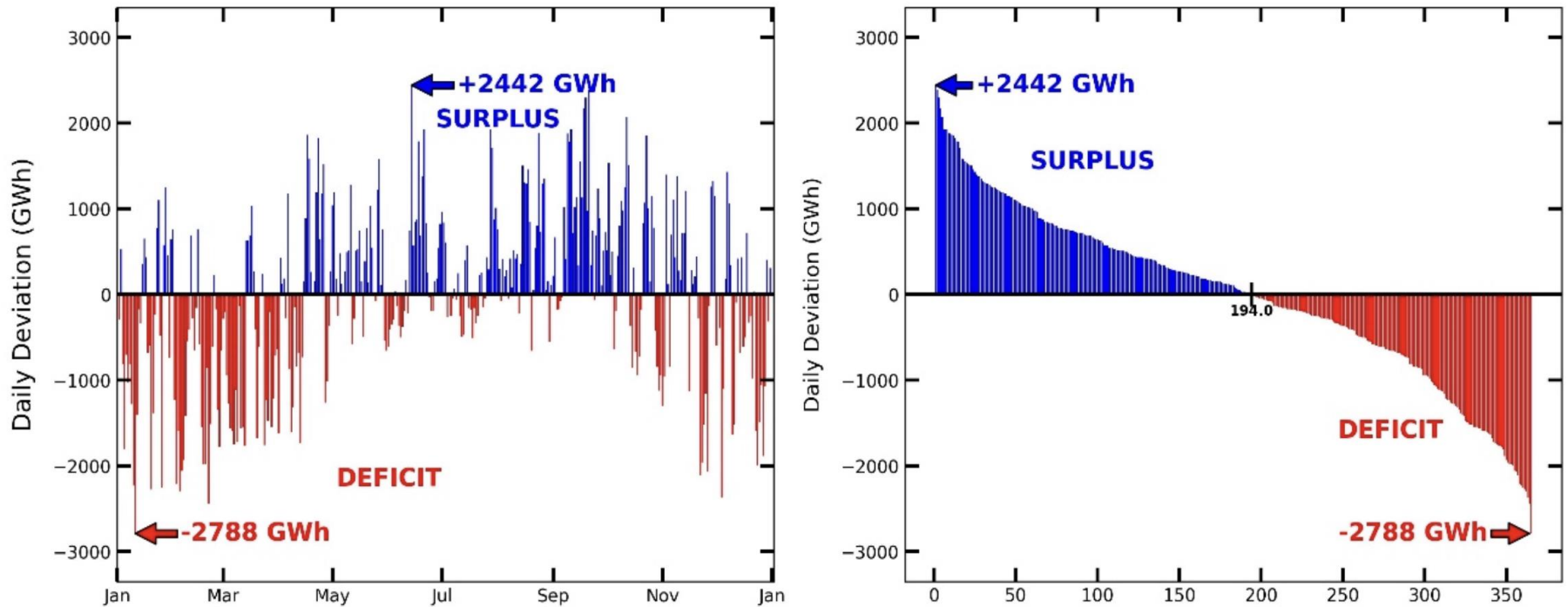


Figure 8 Daily system surplus and deficit, **a)** chronological (left) and **b)** ranked (right)



Balancing costs of the electrical system

- We have a system that is working as intended to balance the electrical system, but, I suggest will not survive the social licence required if costs continue to rise
- There is a problem of optics – of costs ballooning when fuel poverty is growing, of companies potentially making supra-normal profits rather than profits. There does not seem to be anyone incentivised to control the costs.
- From October 2021 to February 2022 inclusive, the costs of balancing the electrical system were £1.55 billion (£808 million badged as ‘Thermal Constraints’)
- What are we going to do in future with excess electricity?



Scale of imbalances

- When we consider multi-day imbalances, imbalances rise into the TWhs.
- When we consider seasonal imbalances, imbalances rise into the 10s of TWhs of imbalance
- When we consider imbalances over a 5+ year timeframe, imbalances rise into the 100s of TWhs
- Any TWh scale leads us to think of a chemical store of energy as a 'technology', as fuels are cheaper to store at scale. That is what we use now – but in future these chemical stores will have to be from sustainable and lower carbon primary energy sources



TWh of chemical stores of energy leads to hydrogen

- If we are considering TWhs of low carbon fuels, we naturally start to think of hydrogen as a fuel itself, or as a feedstock to create other fuels
- We have choices on how we might wish to store the hydrogen, as ammonia? as a synthetic hydrocarbon?
Or, just as hydrogen?
- These all have comparative advantages and disadvantages, so it depends on what the hydrogen is doing for the wider energy system



Caverns of natural gas

- The design and operation of natural gas caverns is well known, and therefore provides an established and lower risk approach to energy storage at the TWh scale
- There is a growing body of evidence around caverns for hydrogen, the great set of talks today is an example of that
- Batteries and pumped storage are well suited to shorter timescales of balancing, but not to store TWhs of energy, particularly if that store has a lower amount of opportunities to make money over a year



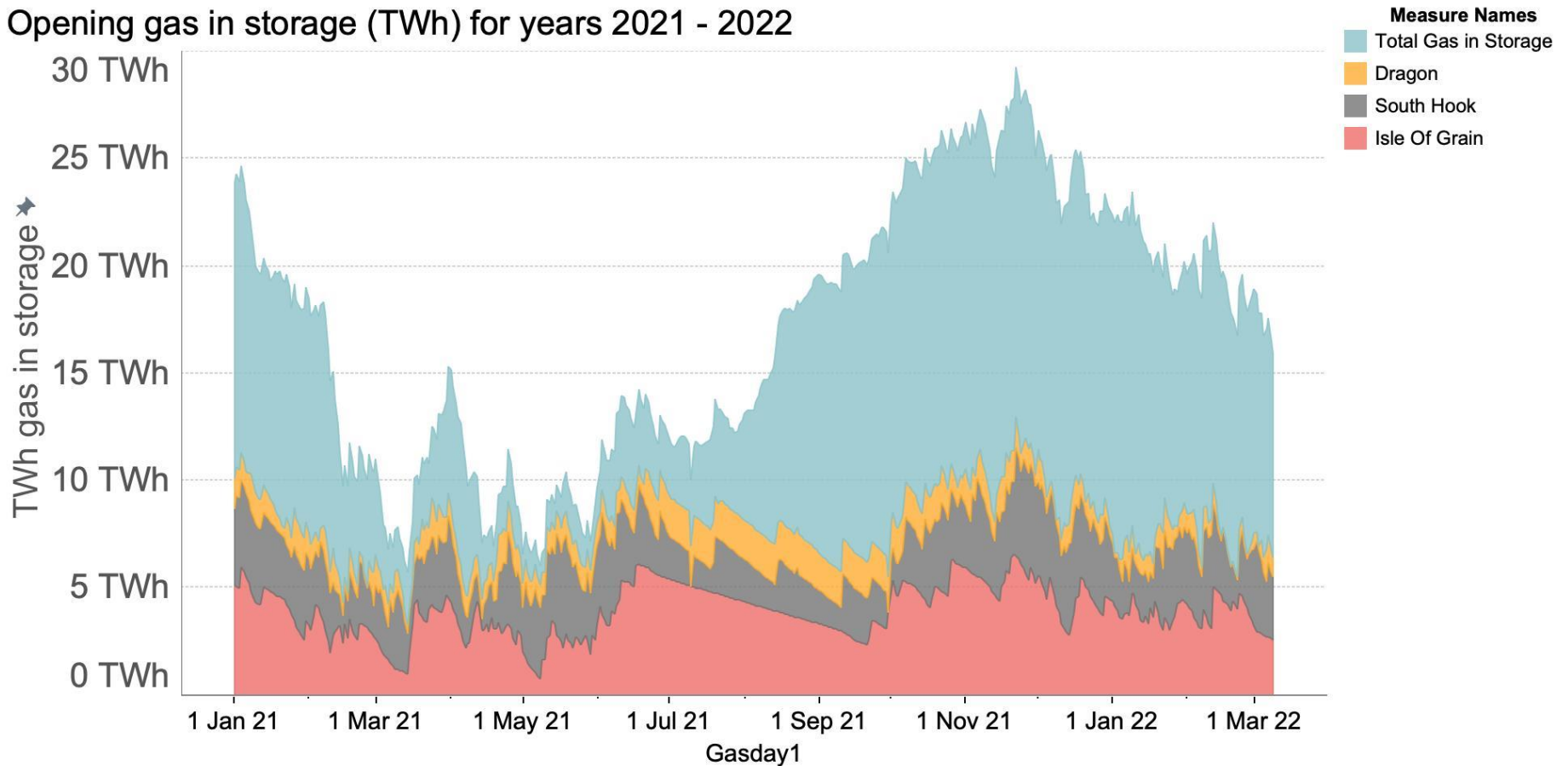
Final thoughts

- At some point there will have to be a political decision on the level of strategic stores of energy that Britain wishes to accommodate within its own national boundaries. Research can continue to help to evidence this.
- If there is a large strategic store of energy, there will have to be a publicly acceptable way of funding this too. People may continue to accept that profits are made on private (or even public) sector investment, but may draw the line at supra-normal profits. This should be factored in to regulation.
- Hydrogen and caverns for hydrogen seem highly likely candidates for TWhs of energy to be stored.



Primary energy demand - daily

Opening gas in storage (TWh) for years 2021 - 2022



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