Hydrogen and Grid Balancing

A Position Paper by the EMCCA Climate Coalition Energy Sub-Group

Abstract

As the United Kingdom accelerates towards a renewable-electricity system, balancing supply and demand becomes increasingly complex. Hydrogen is sometimes promoted as a key solution — a way to convert surplus renewable electricity into a storable fuel that can later generate power. Evidence from the Climate Change Committee (CCC) and the National Energy System Operator (NESO) as well as international reviews, suggests that hydrogen's role in grid balancing should remain strategic rather than routine. Poor round-trip efficiency, relatively high abatement cost, and unresolved storage issues argue for prioritising electrification, batteries, pumped hydro, interconnectors, demand-side response, and vehicle-to-grid first. Hydrogen retains value as long-duration or emergency reserve, and for hard-to-electrify industrial applications.

1 Introduction

Decarbonising the United Kingdom's power system is central to achieving Net Zero by 2050. Within the East Midlands Combined County Authority (EMCCA) Region, renewable generation from both solar and wind is expanding rapidly, supported by a growing programme of large-scale battery projects. The recently approved Cottam Solar Project, on the Nottinghamshire–Lincolnshire border, will be among the largest in the country [1][2]. The East Midlands also has the largest battery-storage pipeline in England, totalling over 10 GWh [3].

These developments prompt an important question: should hydrogen play any role in balancing the regional or national grid? Hydrogen's potential to convert surplus renewable power into a storable fuel makes it an attractive concept, yet its efficiency and cost remain contentious. This paper therefore examines the available evidence and sets out practical recommendations for policymakers, network operators, and regional stakeholders.

2 The Grid Balancing Challenge

Electricity supply and demand must match in real time. Historically, coal and gas plants provided controllable output that made balancing straightforward. As variable renewable energy (VRE) grows, the system now faces periods of both surplus and scarcity. Proven tools already carry much of the load: short-duration battery storage, pumped hydro, demand-side response (DSR), and cross-border interconnectors. However, multi-day shortfalls in wind and solar, often termed dunkelflaute, can still stress the system during certain seasons [4].

3 Hydrogen's Possible Role

Hydrogen can be produced via electrolysis when renewable electricity is plentiful, stored above or below ground, and later converted back to power through turbines or fuel cells [5]. In theory this provides large-scale, long-duration storage that complements batteries and hydro. In practice, every step sacrifices useful energy: electrolysis typically delivers 65 to 75 percent efficiency; storage, compression, and handling incur further losses; and reconversion to electricity returns roughly 40 to 55 percent. Overall, round-trip efficiency rarely exceeds 30 to 45 percent, compared with 80 to 90 percent for batteries and about 70 to 75 percent for pumped hydro [6].

4 System Efficiency and Cost

Low round-trip efficiency implies higher system cost: to deliver 1 kilowatt-hour back to the grid, about 2.2 to 3.3 kWh or more must be produced initially. Analyses indicate hydrogen-to-power abatement costs sit markedly above those for direct electrification options, even under optimistic assumptions [7]. By contrast, heat pumps and battery storage often achieve substantially lower £ per tonne CO_2 avoided [8]. Where hydrogen is derived from natural gas with carbon capture ("blue hydrogen"), upstream methane leakage and incomplete CO_2 capture further erode climate benefit [9].

5 Environmental Considerations

Hydrogen is an indirect greenhouse gas: when leaked, it increases the atmospheric lifetime of methane and influences tropospheric chemistry, raising near-term warming [10]. Electrolysis requires water and materials; compression and storage introduce additional footprints. Geological storage, especially in depleted oil and gas fields, faces uncertainties around containment integrity, mixing with residual gases, microbial activity, and the cost of purification. Laboratory and modelling studies confirm that subsurface microbes can consume hydrogen, generating methane and hydrogen sulphide that both reduce stored-gas quality and corrode infrastructure [11]. These factors make careful site selection and monitoring essential.

6 Alternatives and Emerging Options

Alternatives continue to advance rapidly. Battery storage is scaling across the UK, with emerging chemistries (iron-flow, sodium-ion, solid-state) extending discharge durations beyond today's two-to-four-hour norm. Vehicle-to-Grid (V2G) will add distributed flexibility as bidirectional charging becomes standardised [12]. Liquid-air energy storage (LAES) and compressed-air energy storage (CAES) are demonstrating medium-duration potential [13][14], while expanded pumped-hydro schemes offer proven multi-day capability [15]. Taken together, these options already outperform hydrogen on efficiency for routine balancing.

7 East Midlands Context: Geology and System Fit

Regional studies have explored hydrogen storage in depleted fields and other formations in and around the East Midlands [16]. Evidence points to technical risks — containment, contamination, and microbial conversion — that require further R&D and careful appraisal [17]. By comparison, the region's near-term advantages lie in large-scale solar generation, grid-connected batteries, and growing V2G capability.

8 Policy Perspectives

The CCC advises targeting hydrogen at hard-to-abate sectors and using hydrogen-to-power primarily as a strategic, long-duration reserve rather than day-to-day balancing [18]. NESO's Future Energy Scenarios 2025 likewise limits hydrogen-to-power's contribution while batteries, DSR, and interconnectors provide the main balancing capacity [19].

9 Government Power-Sector Modelling and System Integration

The Government's recently published Carbon Budget and Growth Delivery Plan [20][21]treats hydrogen use in the power sector as part of an integrated electricity-system model rather than as a stand-alone technology. Within this framework, all forms of generation and storage—including hydrogen-to-power—are dispatched together to balance supply and demand. The resulting outcomes are therefore system-wide, showing that the emissions and cost benefits of hydrogen depend on how it interacts with renewables, battery storage, and interconnectors, not on any single technology's performance in isolation. This modelling reinforces our conclusion that hydrogen-to-power should be regarded as a strategic reserve for long-duration balancing, complementing rather than competing with grid-scale batteries and demand-response.

10 Conclusions and Recommendations

Hydrogen is not the most efficient tool for routine grid balancing. Its conversion losses, environmental uncertainties, and storage risks make it a poor competitor to direct electrification and battery-based flexibility. Hydrogen's appropriate role is as an insurance option for prolonged shortages and to decarbonise applications that cannot readily electrify. Policy and investment should reflect an efficiency-first hierarchy: use scarce clean electricity as productively as possible, and deploy hydrogen only where it delivers unique value.

Policy should therefore be:

1. Prioritise high-efficiency balancing: demand-side response, batteries, V2G, pumped hydro, and proven medium-duration storage (LAES/CAES).
2. Reserve hydrogen-to-power for strategic, long-duration backup rather than routine operation.
3. Focus regional hydrogen investment on industrial decarbonisation and displacement of grey hydrogen.

4. Treat geological hydrogen storage cautiously until risks and costs are better constrained through evidence.

5. Design any support schemes to avoid locking hydrogen into low-value, inefficient power uses.

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