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ARTICLE

Need for New Benchmark Replacing Natural Gas as Energy Cost/Price Base

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ABSTRACT

Since Wind and Solar renewable energy costs dropped below Natural Gas (NG) prices in 2017, there has been an increasing problem setting the price for electrical energy, which this century has been based on NG because cheaper coal has declined in usage to cut carbon emissions. The background is that renewable Wind and Solar are now more economic than NG, and are increasing rapidly in application, yet calculations of energy prices are still regularly based on NG cost. For example, electricity prices today relate more to NG than to renewables although more than 50% of UK electricity now comes from Wind and other renewables in 2025. The key problem is that Wind and Solar outputs fluctuate considerably and cannot be compared directly with electricity from an NG power station which delivers continuously. Consequently, energy storage mechanisms must be added to renewable power if fair comparisons are to be made. Lithium battery and Hydrogen gas storage are plausible options. This paper compares Wind/Solar plus Lithium battery electric storage with Wind/Solar and Hydrogen gas energy stores as replacements for NG to create a new benchmark. The conclusion is that this new benchmark should be defined before 2030 when most of UK grid electricity is planned to be green.

Keywords: Energy Benchmark; Lithium Battery; Hydrogen Gas; NG Cost; Electricity Cost

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1. Introduction

Since the start of the new millennium, worldwide costs of renewable energy have been falling fast as shown in **Figure 1** from IRENA data [1].

Hydropower has been a key element in delivering low-cost electricity since 1896 when the city of Buffalo was lit up by alternating current supplied from Niagara-falls by Westinghouse application of Tesla's patent [2]. Although hydro costs have risen slightly over the past decade, it is remarkable that onshore wind costs have fallen more than a factor two in the same period, overtaking hydro, now allowing renewable wind energy to be a mainstream source of electric power across many country areas. The effects these cost changes have had on the electricity generation industry are profound but getting rid of fossil fuels is still difficult though their expansion is now slowing while renewables continue to rise [3].

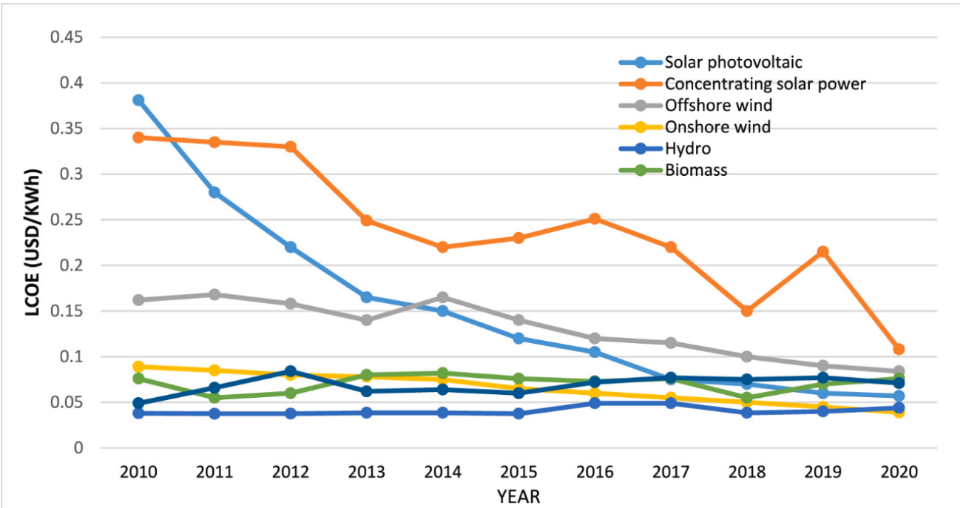

Figure 1. Rapid Fall in Renewable Energy Costs (Levelised Cost Of Energy) Showing That Onshore Wind Has Overtaken Hydropower as the Most Economic Technology [1].

It is important to consider the situation in the UK, as one of the first countries to go green electric in 2030, which is focusing on wind and solar, which are much cheaper than alternative sources like nuclear and bioenergy at present. In Britain, the costs of onshore wind, solar and offshore wind have been falling steadily over the last 15 years whereas electricity and NG prices have risen remarkably as shown in **Figure 2** [4,5]. Between 2010 and 2019, NG prices rose above Wind and Solar costs and caused substantial problems during 2022 when UK energy prices rose by a factor of 3 as the Russian invasion of Ukraine took place [4]. In particular, the price of electricity rose to unprecedented levels, even though half of UK electricity is derived from renewables like wind which are now cheaper than hydro power [5]. A breakthrough came in the year 2024 when more than half of UK electricity was delivered from renewables for the first time [6,7]. The cost of UK NG is difficult but is typically priced around £62.4/MWh, significantly higher than onshore wind and solar costs.

During the 20th century, NG became the fundamental base for UK energy prices because gas was readily available from the North Sea, Norway and nearby countries. NG from the North Sea peaked in 2000 and has since been declining but remains the principal factor in setting electricity prices across the country [8]. The less obvious problem is that imported oil is still the major fossil fuel energy causing carbon emissions in UK but is 90% used in vehicles so has little part to play in the electrical power industry. That issue has been described before, emphasising that petroleum products cannot easily be stopped until 2050 unless green fuels like hydrogen are demanded [9].

Electricity has been dominated by NG for a decade as shown in **Figure 3**, with nuclear declining and coal near zero, but wind, bio and solar energy have been rising rapidly. By 2030, such renewable energy will be massive, as shown in the dashed line predictions devised by the new UK Government, and prices should no longer be dependent on gas. Calculating energy costs and prices when this happens is the objective of this paper.

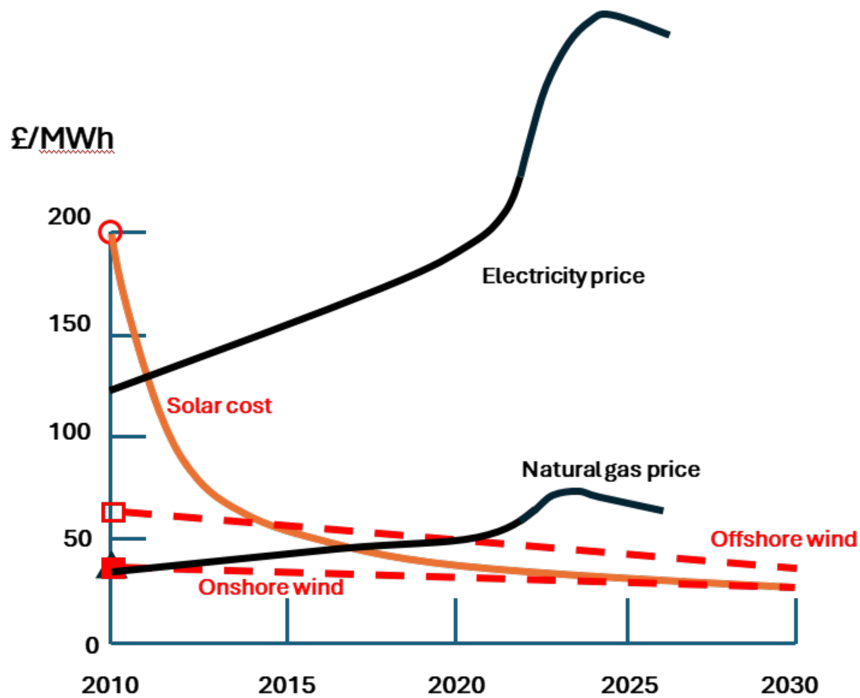

Figure 2. Smoothed UK Electric and Gas Prices (Black Lines) Rising Since 2010 While Renewable Costs (in Red) Dropped, Predicting to 2030 [4,5].

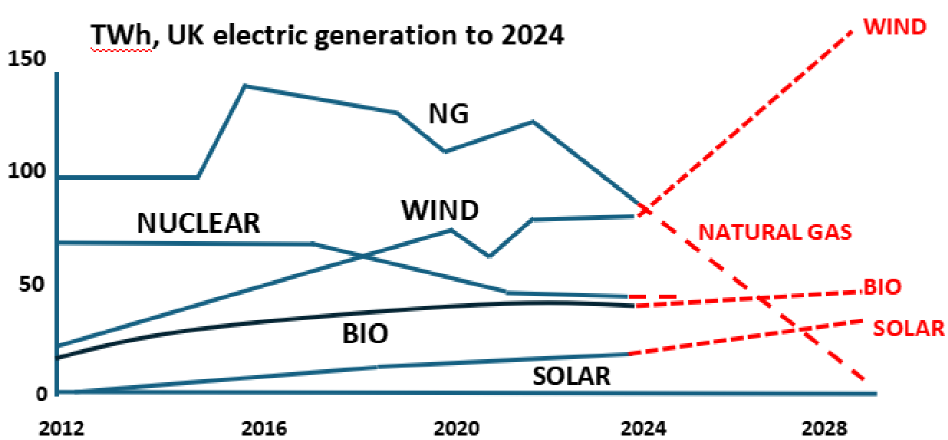

Figure 3. Dominance of Natural Gas in the UK Energy Mix from 2012, Showing Wind, Bio and Solar Rising, with Predictions to 2030 (Broken Lines) as NG Approaches Zero in 2030.

In 2024, for the first time, 50.8% of UK electricity emerged from renewables, largely from Wind and Solar and the trend now is as predicted in **Figure 3** [10,11]. The present UK electricity prices are excessively high when the cost of UK renewables is now lower than NG prices. The purpose of this paper is to predict the trend towards 95% renewables by 2030, suggesting that a new benchmark for energy costs and prices is required, based on Wind and Solar plus energy storage molecules like lithium and hydrogen.

2. Problem of Calculating Electricity Prices Due to Poor Energy Storage

The main barrier to recognition of rising renewables is illustrated by cost calculations carried out by the National Grid, and other international electric companies, compared with costs defined by other energy institutions. Choosing the best low-cost electricity is difficult because it depends on so many factors. That is why the 'Levelised Cost Of Energy' (LCOE) has been defined globally to compare the several possibilities on fairly equal terms [12].

The first thing to remember is that the price we pay at home for energy can be many times higher than the LCOE, levelized cost. For example, in England during 2023, the cost of night-time power could be as low as £60/MWh, whereas the price paid by domestic consumers might be £300/MWh, a factor of five higher, which is difficult to explain logically. The UK National Grid is a monopoly that can get away with such decisions.

Getting back to basics, the main idea behind the levelized energy cost, LCOE, is that lifetime and maintenance of the equipment are taken into account, such that the LCOE breaks even with the whole-life money spent on the process, allowing sensible comparisons between the main competing material methods: Coal, Gas, Nuclear, Wind, Solar, Biomass, Waste, Hydro, Geothermal and more. Naturally, this can prove controversial as certain cost elements may be missed, like energy storage which can be expensive. The LCOE calculation is simple: You add up all the costs over the lifetime, accounting for inflation, then divide by the total amount of energy produced at the factory gate. Other big problem areas, such as Levelised Cost Of Storage, or value to the Grid transmission system (LFSCOE Levelised Full System Cost Of Electricity) are treated separately but can have huge influence, especially for fluctuating renewables like solar and wind which the Grid cannot easily integrate [13]. Therefore, **Table 1** from Texas gives the 2022 LCOE and includes the LFSCOE (Levelized Full System Cost of Electricity) which can be viewed as a more realistic number for the consumer at the end of the Grid cables. Certainly, it makes wind and solar look an order of magnitude more costly from the Electrical Grid standpoint, changing from 'most economic' to 'least economic'. This alteration of the rational LCOE calculation is not based on true costs, but on the deficiencies of the engineering systems, which surely must be addressed by engineers, not by suppliers of materials like natural gas, biomass, etc. The cost of a material like NG must be a fundamental property, unaffected by the users' inadequate systems.

Table 1. Example of US Energy $/MWh Prices in 2022 Calculated by LCOE Method Compared to LFSCOE Showing How Poor Grid Energy Storage Pushes Renewables to the Top and NG to the Bottom.

Source	LCOE	LFSCOE
Biomass	95	117
Nuclear	82	122
Coal	76	90
Wind	40	291
NG	38	40
Solar	36	413

Table 1 shows that the electric energy storage deficit in the Grid is responsible for NG remaining as the base cost, pushing renewables Solar and Wind to the top prices. This is the concept that needs to change as renewable energy in UK electricity production has become the most important factor since October 2024.

In essence, the lack of electrical energy storage in the Grid is the cause of this difficulty. Comparing two energy storage molecules, Lithium and Hydrogen, allows this issue to be resolved here.

3. Methodology

Compare Battery Versus Gas Energy Storage for Electrical System

Many energy storage methods have been found for electrical industries [14]. The major electrical energy storage in Britain uses water pumped uphill to drive water turbines downhill when peak power is required. The main example in Dinorwig pumped power station in Wales, which provides 10 GWh of electrical energy when needed, plus two smaller Welsh pumped stations at Ffestiniog and Cruachan. But now Lithium batteries are being installed near offshore wind sites (**Figure 4**) to save the high wind energy surplus that can be available during certain weather conditions [15,16]. In 2024, there was only 2.4GW of UK battery-stored electricity available for power, and that does not last long, only a bit more than 1 hour (i.e., 2.6GWh of energy), so it is nowhere near the need. Also, it is spread across 161 sites, so it is somewhat distributed. UK runs a National Grid that has only 2.6GWh of stored electricity in 2024, when we have energy peaks around 60GW in winter evenings. If the Grid suddenly had to depend on energy storage to feed the consumers at these peaks, we would require thousands of GWh stored, that is TWh not MWh. In other words, we are only 0.1% of the way there. The target should follow UK NG storage: In Britain, gas energy storage at peak is 10,000 GWh (10TeraWatt hours TWh), about 3000 times more energy storage than the electrical National Grid has now. The problem is that lithium batteries in containers (**Figure 4**) are much more expensive than a gas tank or an underground cavern, where fuel gases are already being saved permanently.

Figure 4. Offshore Wind Electricity Feeding Directly into Containerised Lithium Batteries by Zenobe, Europe's Biggest Battery at Blackhillock, Scotland [15,16].

The purpose of this paper is to compare two immediate technologies: lithium or hydrogen that can be used for storing electrical excess power that the Grid cannot manage.

4. Defining Two Plausible Energy Storage Methods: Battery or Hydrogen Gas

Two plausible energy storage methods may be compared to overcome the present problem: First is the lithium battery that has been developed and manufactured in large quantities this century; Second is hydrogen gas that can be made easily by electrolysis of water using Wind/Solar electricity. Both these ideas are less than 100% efficient, with lithium losing around 10% of the energy stored whereas water electrolysis loses about 20% of the energy when the equipment is run at high power. Both technologies depend on the internal ohmic and other resistances within the battery or fuel cell/electrolyser. These numbers may be compared with the 8% electric energy typically lost ohmically by distributing electricity over the UK using high voltage cables.

Lithium batteries in large containers are now available and are being installed in the North Sea offshore wind project in Blackhillock Scotland (**Figure 4**) to provide 300MW of power and 600MWh of energy storage, 30% of Scotland battery capacity [15,16]. This new facility opened in 2025 stores less energy than existing hydro-storage installations, around 6% of the 10 GWh Dinorwig pumped hydro unit. The plan for 2030 is an increase of battery capacity to 22,000MW, almost double existing UK pumped-hydro plants.

The main point about the lithium battery industry is that it has expanded quickly in Asia, especially in China where hundreds of lithium battery companies have been manufacturing, mainly for the surging battery electric vehicle market. Prices of both cells and packs have been dropping rapidly over the last decade as illustrated in **Figure 5**. The limit to these developments is not known. What is certain is that a 5MWh container filled with lithium batteries now costs near £0.5M in UK.

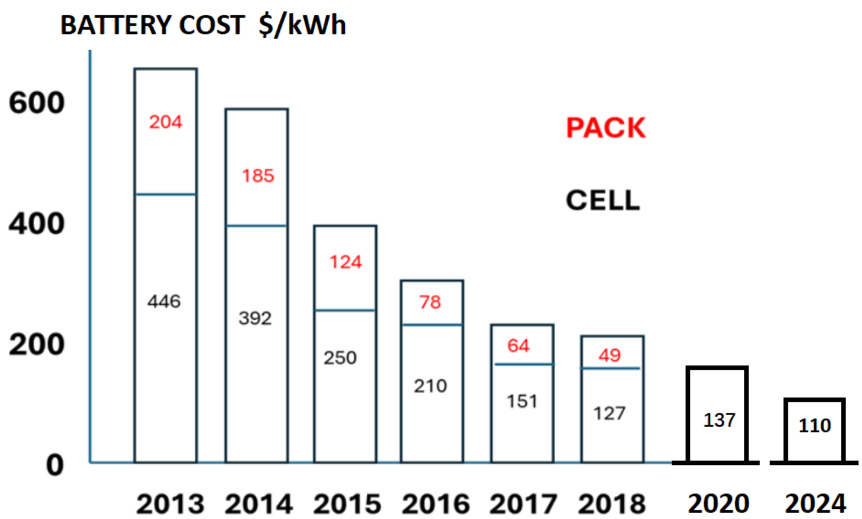

Figure 5. Drop in Lithium Battery Costs in USA from 2013 (Sources Bloomberg, Statista).

The big problem with Wind/Solar is the energy gap when the wind drops and the sun goes down. Less than 50% of the nominal renewable power is available because of these gaps and consequently a huge amount of storage is needed. If 150 TWh of UK renewable energy is coming from Wind/Solar in 2030, then it follows that approximately 150 TWh of lithium storage is required. If the lithium battery cost eventually stabilises at the 2025 price near $80/kWh (**Figure 5**), then a cost estimate for UK would be $1200 billion.

Hydrogen storage is easier than electricity because gas is delivered in pressurised pipelines that automatically hold many kilograms. Unfortunately, Britain now has only a few km of hydrogen pipes, whereas EU has many thousands. To supplement these pipes, which are being planned by UK NG companies like Cadent, underground caverns have been demonstrated in salt strata where sodium chloride has been extracted by pumping water down to dissolve the salt.

The Royal Society published a paper in 2023 recognising that salt cavern storage of hydrogen could be a recommended method for creating a massive store of energy that could rapidly be converted to electricity by fuel cells or other means [17]. Around 150TWh of energy storage are needed now in UK, backing up 50% of present electricity demand, roughly equal to 15,000 Dinorwig pumped water reservoirs. 180 clusters each of 10 caverns each would be needed, of the type shown in **Figure 6**. At present, existing salt caverns are being utilised in Teesside and Cheshire to store gas, but the costs of creating 1800 new caverns by extracting the sodium chloride have not yet been determined. But if a reasonable estimate was $1M per cavern, the total UK cost would be $1800M which contrasts with the 1000 times bigger number for lithium battery containers.

The key fact to recall is that contained hydrogen is almost ten times more effective than battery-contained lithium in storing energy. **Table 2** shows that the uncontained molecules are quite different in their energy storage characteristics. But the main point is the difference when the lithium is safely contained in metal packs, while the hydrogen is stored at 700 bar in type 4 tanks made from carbon fibre reinforced polymer, which have been demonstrated on the Toyota Mirai Hydrogen Fuel Cell Battery Electric Vehicle and many other applications, or in underground pipelines. Contained hydrogen has 8 times less weight and 7 times less cost than contained lithium.

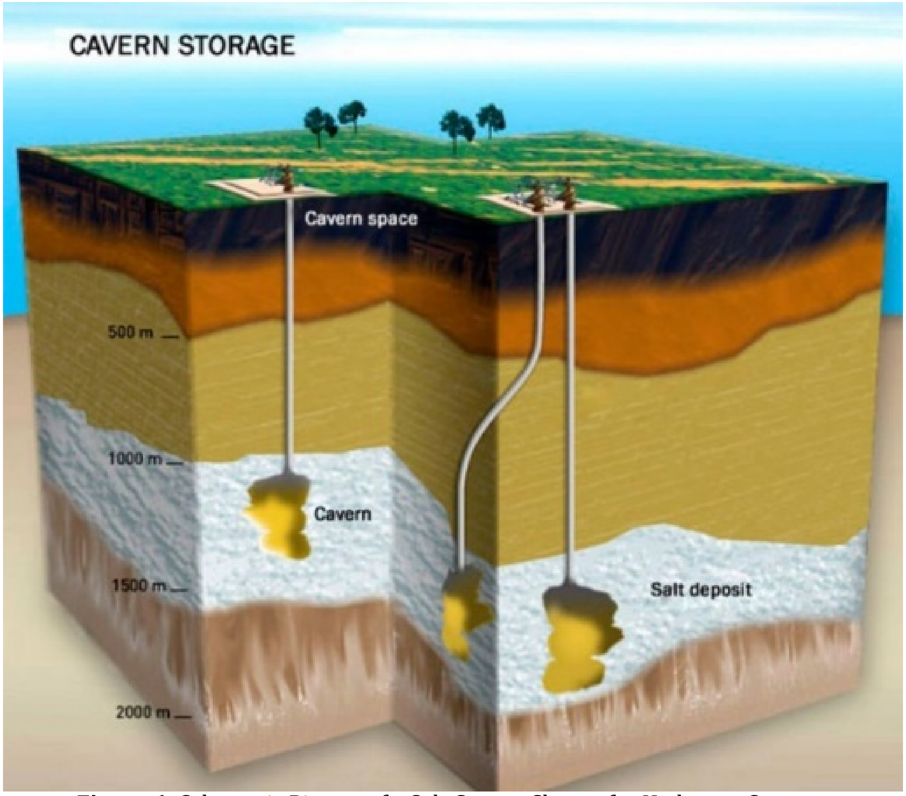

Figure 6. Schematic Picture of a Salt Cavern Cluster for Hydrogen Storage.

Table 2. Comparison of Energy Storage Molecules Lithium and Hydrogen, Both Molecules and Contained Materials: Lithium Batteries in Metal Casing, Hydrogen at 700bar in Composite Cylinders.

	LITHIUM Metal	HYDROGEN Gas
Molecule Energy	12 kWh/kg	40 kWh/kg
Molecule Cost	10 $/kg	0.8 $/kg
Contained Energy	0.2 kWh/kg	1.7 kWh/kg
Contained Cost	100 $/kWh	14 $/kWh

The main issue with hydrogen is that 100 million tons per year are manufactured globally in 2025, but most is fossil-sourced. Only about 1% of present hydrogen production is green because electrolyser utilisation is still low at the big petrochemical company's refineries. The cost of green hydrogen at this low production is estimated at $5/kg, six times higher than the figure for fossil hydrogen made from NG in **Table 2**. As green hydrogen production by electrolysis of water is increasing exponentially as 2030 approaches, its cost is predicted to drop towards $2/kg and possibly even lower. However, these predictions may take longer than 2030 to be achieved.

5. Discussion of Potential Progress Projections

Progress in both battery and hydrogen energy storage is proceeding rapidly but the costs have not yet stabilised. A typical large, containerised lithium battery may last for 20 years, cycling once a day giving a storage cost around £27/MWh, but these devices have not yet been tested over such long periods. Adding this to the onshore wind cost of £35/MWh would give an electricity cost of £62/MWh which is similar to the present UK NG cost/price [18].

Hydrogen storage in UK is being used first in Cheshire to collect the byproduct from chloralkali factories in salt caverns. The estimated cost of this hydrogen is £1/kg depending on market destination. It is low because hydrogen is a cheap byproduct from the chlorine/sodium hydroxide products. From 2021, INOVYN, a subsidiary of INEOS, has been developing the first large-scale underground facility in the Cheshire salt basin to store vast quantities of hydrogen and connect to the UK's first hydrogen network of 350km of new pipes. Each cavern is approximately 350,000m^3 in volume (roughly twice the size of Royal Albert Hall), each capable of storing approximately 3000 tonnes of hydrogen. The total energy stored by the project will be 1.3TWh (1300GWh), a thousand times more than the energy stored in lithium batteries used globally. The cost of underground storage over many years is not fully known but is suggested to be £0.1/kg. The total hydrogen cost would then be £1.1/kg which equates to £36.3/MWh, better than both lithium and NG costs [19].

Costain, the infrastructure solutions company, has been selected by Storengy UK to design the Keuper Gas Storage Project (KGSP), an underground hydrogen storage facility in Northwich, Cheshire [20]. The facility will consist of 19 salt caverns together with hydrogen treatment, compression, dehydration and transfer facilities, and Costain's multi-disciplinary engineering team will deliver two Front-End Engineering and Design (FEED) contracts to support its development. The facility will be designed to store a working gas volume of approximately 400 million cubic metres (mcm) of hydrogen, equivalent to storing 1,300 gigawatt hours of hydrogen.

The first FEED will look at solution mining, which will involve water being pumped hundreds of metres underground to dissolve the salt. The resultant brine solution is then extracted to create a cavern, with the salt solution transported from the cavern via existing underground pipelines to local customers. The second FEED will focus on the gas storage facilities needed to receive hydrogen from the proposed HyNet system, a network of new and existing hydrogen infrastructure in the Northwest of England and North Wales. The design will cover the transportation, compression, and storage of hydrogen within the caverns, as well as its transportation back into the HyNet system.

Costain's work is expected to be completed in 2026 and will inform Storengy UK's plans for entering the Final Investment Decision for the project. Costain has a successful track record designing and constructing gas storage facilities and has had a presence on the Holford brine fields for almost 20 years. It previously constructed the Stublach solution mining plant, comprising 20 gas storage caverns used for brine production and transportation.

It is important to reflect on the scale of UK green hydrogen production [21]. This must be large in the future to bring costs down. Inovyn is in a strong position with 50 tons per day produced in the Runcorn electrolyser, but this is not yet green, with plans to achieve that by 2030. The present UK plan is to run HAR1 (Hydrogen Allocation Round 1) with 11 industry projects attempting to manufacture 100MW of green hydrogen [22]. A further HAR2 is aiming for more in 2025. At present, UK is behind China and 4 other countries in generating substantial green hydrogen by electrolysis [23]. In 2018, China overtook UK and acceleration is needed now [24,25].

Most important is significant differences between lithium and hydrogen energy storage. Both are liable to catch fire, but lithium has recently been shown to be a problem because several lithium fires occur every day in Britain. Hydrogen is mainly on refinery sites where safety is paramount and no fires are found. As Hydrogen pipes are installed to give low-cost transmission across the country, energy storage naturally follows because the pipes then contain large amounts of gas energy, not found in lithium systems. Thousands of miles of hydrogen pipes are being planned by DESNZ in 2025.

By 2028 it is expected that data will be produced on replacing NG with lithium or hydrogen energy benchmarks.

6. Conclusions

The main conclusion is that Britain is changing its position on energy rapidly, with a target for 95% Green Grid electricity by 2030. This radical concept, comparable with the painful change from coal to NG in the 1980s, is underway in 2025 due to the new UK Government that has addressed the unsatisfactory status of the private UK energy companies that dominate scaling, pricing and future of present inadequate technologies. In the meantime, NG is still the UK baseline for electrical cost and price calculations. Therefore, a new energy cost benchmark, possibly based on lithium and/or hydrogen for energy storage, is required urgently as NG disappears from the UK electrical system around 2030.

An evident fact is that the National Grid supplying electricity across the country has failed to install energy storage facilities that would allow renewable energy to be integrated readily. Lithium battery containers are now being added but too low and too late. Renewable energy is being doubled across the UK by 2030 but it seems that this cheap renewable power will retain its high price until a new benchmark is created.

Installing large numbers of containerised lithium batteries is one approach that is happening now but is expensive and exhibits a large footprint.

The advantage of gas storing energy is that the new method of utilising underground salt caverns is more economic with much lower footprint underground. Using salt caverns has large potential, is currently being developed on trial scales, and can be expanded rapidly to store hundreds of TWh. No other energy storage concept can beat this idea at the present time. But creating nearly 2000 new salt caverns to feed the whole UK is a serious challenge.

A rational new benchmark could consider 1MWh of contained lithium or 1MWh of stored pressurised hydrogen to define an energy storage cost that would be widely accepted. Both molecules have pros and cons and require further exploration. Lithium has expanded rapidly since 2008, and green hydrogen has been growing since 2021, but there is insufficient experience in storing green energy from Wind and Solar. At present, green hydrogen appears to be seven times more economic than lithium, but these figures oversimplify the issues and demand scrutiny to move forward. It is essential to decide before 2030 to replace NG with more economically green molecules in the electricity generation industry.

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Not applicable.

Data Availability Statement

All data used may be found in Reference [22].

Conflicts of Interest

The author declares no conflict of interest.

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