

IS THE UNITED KINGDOM'S HYDROGEN STRATEGY AN EFFECTIVE LOW CARBON STRATEGY?

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ABSTRACT

The United Kingdom's (UK) clean energy shift to ensure low-carbon and affordable energy supply is regulated by the Energy Act 2013 and the electricity market reform programme. To further this energy shift and to reduce the UK's dependence on natural gas as an energy source, the (UK) launched its Hydrogen Strategy on 17 August 2021. The rationale for the Strategy is that hydrogen gas is a clean and efficient source of fuel, there is an abundance of hydrogen and that changing from natural gas to hydrogen gas will reduce greenhouse gas emissions. The question raised is whether the Government's objective of the use of Hydrogen to replace natural gas is an effective strategy to reduce greenhouse emissions caused by heating. The scope of this paper does not include an examination of the role of the oil industry as an energy source. This paper will firstly explain how the UK came to be dependent on the use of natural gas by briefly outlining the history of its development as a form of energy in the UK. It will then focus on considering the advantages and disadvantages of the use of natural gas and of alternatives in the UK for heating. It will assess the efficacy of hydrogen as an alternative to the use of natural gas in the UK for providing energy for heating in terms of reducing its carbon footprint and therefore protecting the environment and the economy.

Keywords: Hydrogen, natural gas, low carbon, environment.

1 INTRODUCTION

The object of the 2021 Hydrogen Strategy is part of the implementation of the government's Ten Point Plan for a Green Industrial Revolution revealed in November 2020. Key points from the Ten Point Plan, which apply to the low-carbon energy industry, include setting aside £500 million to support this; and accelerating the development of industrial clusters to scale up carbon capture, utilisation, and storage (CCUS) projects [1]. This plan is to move away from the use of fossil fuels to supply our energy needs. The aim is to replace natural gas with 5GW of low carbon hydrogen production capacity by 2030 to service homes, industry, and transport. Heating comprises 23% of all UK emissions [2]. The Strategy indicates that the use of hydrogen could provide 20–35% of the nation's energy consumption by 2050 [3].

The strategy states that it will use a twin track approach. This means that it will support the production of both green hydrogen which is produced by splitting water with electrolyser powered by renewable energy and blue hydrogen which is produced by splitting natural gas and capturing carbon emissions with technology [4].

The implementation of this strategy aims to minimize the UK's reliance on the use of natural gas. Therefore, this paper will briefly explain the recent history of the UK's dependence on natural gas. It will consider the efficacy of alternative energy sources when evaluating the Hydrogen strategy.

2 BRIEF RECENT HISTORY OF NATURAL GAS IN THE UNITED KINGDOM

Town gas which was used for over 150 years in the United Kingdom as a mixture of hydrogen carbon dioxide and methane produced from the distillation of oil and coal was used for

lighting, heating, cooking, and powering gas engines with the basic process of making it remaining unchanged until the 1970's; although town gas works closed in the 1960s [5].

The efficiency of gas manufacture had improved in the 20th century, and in May 1949, as a result of the Gas Act 1948, the gas industry was nationalised. This required the merger of municipal and private gas companies into 12 area gas boards. This was the start of British Gas [6]. In 1953 gas was manufactured from oil in reformer plants. From the late 1950's gas was also being made from oil products as naphtha or propane, and this produced manufactured gas at much higher pressures than with coal gasification; however, the higher pressure enabled it to be piped long distance and so compete with small town works leading to their closure [7].

2.1 New Developments

In 1965, when large quantities of natural gas were discovered 70 kilometres off the coast of Yorkshire in the West Sole Field the gas industry decided that this gas could be supplied directly to consumers. However, natural gas is predominantly methane and it has different burning properties from manufactured gas (mainly hydrogen and carbon dioxide); so a conversion process from town gas to natural gas was needed and it was started in 1967 taking 10 years to complete [8]. There were approximately 20 million gas appliances to convert and many could not be converted to use natural gas; and so although in 1970 gas usage only amounted to 5.4% of the main energy consumption in the UK, gas started to replace coal and its usage increased to 40% by 2004 [9]. From the late 1970's until 2004 gas came from the United Kingdom continental shelf and later in the 1980's under the Thatcher government the gas sector was privatised to increase competition and reduce prices resulting in the birth of British Gas under the Gas Act 1986 [10].

The Office of Gas Supply was created to protect consumers, and it later merged with the Electricity Regulator to become the Office of Gas and Electricity Markets (OFGEM); but then British Gas was divided into British Gas and Transco in 1994 though the latter only operated the downstream pipeline system [11]. In 1996 British Gas went through a further major restructuring, however, the UK's gas field reserves were in decline by the late 90's and the government looked outside the UK Continental Shelf so that in 1999 the UK-Belgium Interconnector was formed, enabling the UK and European countries to both export and supply gas to each other [12, 13].

2.2 From 2000 to 2020

Due to the UK's natural gas production falling by an average of 8.0 per cent per year from 2000 to 2013, and factors associated with the Interconnector [14] and a range of infrastructural issues, the UK gradually increased its gas imports [15].

These factors led to various consultations and the Energy Review Report of July 2006 and the Climate Change Act 2008 heralded a carbon reduction transition for the energy industry by committing future governments to cut greenhouse gas emission by 2050 by at least 80% of the 1990 levels [16]. Yet in 2008 UK gas supply sources included the Netherlands and Norway and pipeline interconnections with the continent, and between 2008 and 2010 the UK doubled its import of gas supplies [17]. In March 2013 the UK Oil and Gas Industrial Strategy stated at p. 4 "There is an over-riding case to maximise recovery of the UK's oil and gas with 70 per cent of British energy requirements still likely to be met by oil and gas into the 2040s" [18].

In 2015 the Oil and Gas Authority replaced the Department for Climate Change and Energy with responsibility for regulating upstream oil and gas supplies. OFGEM regulated

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
G.1 Imports and exports of fuels⁽¹⁾																					
																					Million tonnes of oil equivalent
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020 p	
Imports																					
6 Coal and other solid fuel	24.8	20.0	22.5	25.4	30.6	34.6	28.8	28.7	23.7	16.2	21.5	27.8	30.0	26.2	15.3	6.4	6.0	7.2	5.0	3.9	
7 Crude oil	43.2	44.6	48.7	61.4	58.1	60.8	48.2	56.8	55.3	54.5	58.5	61.6	52.8	51.2	48.1	47.2	54.9	49.8*	54.4	49.9	
8 Petroleum products	23.2	23.1	25.0	28.9	31.1	34.5	41.6	29.1	28.2	30.0	29.6	32.7	33.4	33.7	39.3	41.1	39.5	41.8	39.4	28.8	
9 Natural gas ⁽²⁾	2.6	5.2	7.4	11.4	14.9	21.0	29.1	35.2	40.6	52.8	51.9*	48.7*	47.1*	42.0*	43.1*	45.5*	44.6*	44.0*	41.0*		
10 Electricity ⁽²⁾	0.9	0.8	0.4	0.8	1.0	0.9	0.7	1.1	0.6	0.6	0.7	1.2	1.5	2.0	1.7	1.6	1.8	2.1	1.9		
Total imports	94.8	93.8	104.0	127.9	136.7	151.8	148.3	150.9	148.3	154.1	162.2	172.0	164.8	155.2	147.8	141.9	146.6	145.3	144.8	125.6	
Exports																					
13 Coal and other solid fuel	0.7	0.7	0.6	0.6	0.5	0.4	0.7	1.0	0.5	1.1	0.9	0.7	0.8	0.6	0.5	0.5	0.4	0.5	0.7	1.3	
14 Crude oil	89.6	87.1	76.0	66.1	55.2	51.4	51.2	47.0	47.3	45.4	37.1	36.6	38.8	40.6	41.0	43.5	49.9	46.4*	49.6	50.7	
15 Petroleum products	30.1	33.5	35.7	38.7	38.5	37.6	33.6	38.2	37.6	37.2	38.7	38.8	35.4	31.4	29.8	28.8	30.1	28.9	27.9	26.7	
16 Natural gas ⁽²⁾	11.9	13.0	15.2	9.8	8.3	10.4	10.6	10.5	11.8	15.2	15.8*	12.4*	9.4*	11.0*	13.7*	10.1*	10.8*	7.3*	7.8*	9.1*	
17 Electricity ⁽²⁾	0.0	0.1	0.3	0.2	0.2	0.2	0.3	0.1	0.3	0.4	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.4	
Total exports	132.3	134.3	127.7	115.5	102.7	100.0	96.4	95.9	97.5	99.3	92.7	88.7	84.7	83.8	85.2	84.1	91.5	83.3	86.3	88.2	
Net exports																					
20 Coal and other solid fuel	-24.1	-19.3	-21.9	-24.8	-30.1	-34.2	-28.1	-27.6	-23.2	-15.0	-20.6	-27.1	-29.2	-25.6	-14.8	-5.9	-5.6	-6.7	-4.3	-2.6	
21 Crude oil	46.4	42.5	27.3	4.8	-3.9	-9.5	3.0	-9.9	-8.0	-9.1	-21.4	-25.0	-13.9	-10.6	-7.1	-3.8	-5.0	-3.3	-4.8	0.8	
22 Petroleum products	6.9	10.4	10.6	9.9	7.4	3.1	-7.9	9.1	9.3	7.2	9.1	6.1	2.1	-2.3	-9.4	-11.2	-9.4	-13.0	-11.4	-2.1	
23 Natural gas	9.3	7.8	7.8	-1.6	-6.6	-10.6	-18.5	-24.6	-28.8	-37.7	-36.1	-36.3	-37.7	-31.0	-29.4	-35.5	-33.8	-37.3	-36.2	-32.0	
24 Electricity	-0.9	-0.7	-0.2	-0.6	-0.7	-0.6	-0.4	-0.9	-0.2	-0.2	-0.5	-1.0	-1.2	-1.8	-1.8	-1.5	-1.3	-1.6	-1.8	-1.5	
Total net exports	37.6	40.5	23.7	-12.4	-34.0	-51.9	-52.0	-54.0	-50.8	-54.8	-69.5	-83.4	-80.0	-71.3	-62.6	-57.8	-55.1	-62.0	-58.5	-37.4	

Source: HMRC, BEIS estimates

27 (1) See Energy Trends at <https://www.gov.uk/government/collections/energy-trends> for the latest BEIS quarterly estimates

28 (2) Physical flow

Figure 1: Digest of UK Energy Statistics (DUKES): foreign trade statistics.

downstream gas markets and infrastructure [19, 20]. Yet, by 2016 the import of natural gas increased had by 6.8% on the 2015 figure. The imports accounted for over 45% of the UK domestic supply with Norway supplying 65% [21]. With reference to Fig. 1 above, in 2019 the UK government expected that the UK's dependency on natural gas imports could increase to 90% by 2050 [22]. Despite a slight fluctuation in gas consumption in recent years the level of gas consumption has only slightly decreased since 2017 to 2020 [23].

3 NATURAL GAS EMISSIONS

The use of natural gas has a harmful impact on the environment through its drilling and extraction, through its burning and consumption, and through its use in transportation. It is well known that burning natural gas for energy produces fewer harmful emissions such as carbon dioxide, than burning coal or oil, however it does produce methane, a very harmful greenhouse gas, as well as carbon monoxide, nitrogen oxides (NOx), and sulfur dioxide (SO2). It lowers air quality [24]. However, it has been a reliable eco-friendly choice in the UK compared to oil or coal. This is due to a low level of emissions; it also can be stored effectively, although maintaining large volumes is expensive, it can be transported effectively; and until very recently, it has been a cheap source of energy. Globally, there is also a rich untapped supply available [25].

The use of natural gas therefore seems to be a bridging source of energy between fossil fuels and renewable energy sources such as solar panels and wind farms. However, it is accepted that its use does contribute to the global warming problem, and the increasing reliance on foreign gas imports is a concern for the UK [26]. Consequently, the government produced its Hydrogen strategy [27].

This paper will now highlight key features of the Hydrogen Strategy [28] and analyse its comparative effectiveness in relation to other sources in terms of an efficient, reliable and cost effective source.

4 THE HYDROGEN STRATEGY

For homes the change would simply mean that hydrogen gas would be powering central heating and gas cooking instead of natural gas; however, engineers would need to inspect existing appliances and convert them and whole streets would need to be converted at any one time, requiring the natural gas to be disconnected and all inert gas removed from the pipelines before checking again and refilling with hydrogen, reconnecting and reservicing [29]. The 2019 Transitioning to Hydrogen report concluded that although the engineering risks in changing to hydrogen networks may be minimal, the necessary levels of carbon capture technology and infrastructure for the production of green or blue hydrogen have yet to be developed [30].

4.1 Finance

A £240m Net-Zero Hydrogen Fund, taken from the £1billion Net Zero Innovation Portfolio was announced in 2019 for new production plants to support industry to decarbonise and to develop the market for low carbon industrial products [31]. The government allocated a budget of £1billion to allocate part of its March 2020 Carbon Capture and Storage Infrastructure Fund (CIF) to industry clusters created through its March 2021 Industrial Decarbonisation Strategy [32].

The accompanying New Hydrogen Business Model to be finalised would only support domestic production and consumption and also protect low-carbon hydrogen producers from volatile wholesale prices, yet the proposed financial price support mechanism based on contracts for a difference (CfD) auction scheme is geared to provide long-term revenue stabilisation for low-carbon generation projects [33, 34].

4.2 Low Carbon Clusters & Technology

The Strategy also directs that five low carbon clusters will be created for the creation of Carbon Capture and Storage Infrastructure (CCSI) and hydrogen technologies. The Nov 2020 Ten Points for a Green Industrial Revolution is to allocate four clusters by 2030 for the creation of CCSI. Proposals for the allocation of the CIF funding are still being finalised [35].

The Strategy also provided details about the steps that will be taken to grow and support hydrogen storage and use. It sets out measures to increase the uptake of hydrogen in sectors such as heavy industrials, road transport and shipping as well as domestic usage. At present the existing gas supply includes some use of 23% hydrogen blends, and using the Strategy involves trialling 20% hydrogen blends in the existing gas supply, which required the current infrastructure and appliances to be upgraded [36].

However, the first project called HyDeploy conducted grid-injected hydrogen blend trials for the UK at Keele University in 2018 [37]. Northern Gas Networks then began trialling a 20% hydrogen blend and then opened two show homes in the region which used 100% hydrogen [38]. The UK's major gas companies agreed to create a neighbourhood served by 100% hydrogen by 2023 and a village by 2025 [39]. However, this evidences a minimal reaction to the support of hydrogen storage and use by industry.

The report of the H21 project conducted by Northern Gas Networks partly explains this, as it explains that to convert the city of Leeds from natural gas to 100% hydrogen gas, the Iron Mains Replacement Programme that commenced in 2002 had been required to upgrade most of its distribution pipes to polyethylene, as this material was suitable for transporting 100% hydrogen. The Health and Safety Executive required this to be completed by 2032. Yet the report concluded that the H21 project showed that minimal new energy infrastructure will be required compared to alternatives [40, 41]. So, the question is why has uptake been so slow.

Only some manufacturers have recently begun to develop new household appliances, and with success. For example, in February 2020, Worcester Bosch launched the award winning prototype of its hydrogen-ready boiler to run firstly on natural gas and then, after a servicing visit, 100% hydrogen [42, 43]. Could the gas industry assist with the takeup?

5 WHY THE FOCUS ON BLUE HYDROGEN-DISADVANTAGES

The gas industry has been pushing the use of blue hydrogen rather than green hydrogen as a natural gas alternative because of how the gas is produced. Hydrogen comes from the extraction from other substances, that is, natural gas or water, and, by promoting the extraction of hydrogen from natural gas, the gas industry companies could maintain their current operations [44].

Yet, a disadvantage of this is that such hydrogen is mostly produced by steam reforming of methane in natural gas called grey hydrogen, with high carbon dioxide emissions. The process of carbon capture and storage required to reduce these emissions produces so-called, blue hydrogen. This process has the decided disadvantage of being expensive [45]. The government's response was to set up the financial price support mechanism referred to in the Hydrogen Strategy to develop and subsidise large scale carbon capture technology [46].

6 GREEN HYDROGEN ADVANTAGES

Hydrogen is the most prevalent element in the world, and two thirds of it comes from water. Green hydrogen also has a wide range of uses [47].

There is an argument that green hydrogen, that is, obtaining hydrogen from water by a process called electrolysis should become cheaper to produce than blue hydrogen if renewable power, such as solar or wind is used to produce the electricity. Since this process does not create any carbon dioxide the resulting pollutant-free hydrogen is called green hydrogen, and the only by product is water [48]. However, this is still a costly process, and so is its consumption. It has been suggested that, in windy months, any extra electricity generated from renewable resources such as wind and solar power could be used to make green hydrogen, which would then be stored for use [49].

However, the UK does not need to rely on a full-scale transition to hydrogen, as decarbonising the heat section is possible using existing technologies [50]. So we now further consider the generation of low carbon electricity by means of heat pumps and district heating.

7 HEAT PUMPS AND DISTRICT HEATING

The use of heat pumps and district heating can assist in switching heating from gas to electricity and it could reduce the carbon footprint, and although both methods require infrastructural changes on a national scale, some of the infrastructure is there already [51].

7.1 Heat Pumps

Heat pumps use electricity to extract heat from the air or the ground. An air source heat pump works similarly to a fridge, but instead of sucking heat out of a food compartment, it pulls heat out of the air and channels it to where it is used to heat water. It can be piped to radiators for central heating and stored in a tank for hot water [52].

This technology works at a lower temperature than existing boilers. Those that use combination boilers would have to switch to a hot water tank. Homes would need to be well insulated or to have larger radiators capable of delivering more heating power, than those currently in use for natural gas [53]. However, the heat pump technology is reliable and just

as cost effective as running on natural gas was prior to high cost rises in 2022 in the UK. It is also more efficient to run than using natural gas [54].

Modern heat pumps can also be introduced to the existing district heating systems. It is considered particularly effective in connection with small district heating systems, where they replace heat produced from fossil fuels [55].

7.2 District Heating

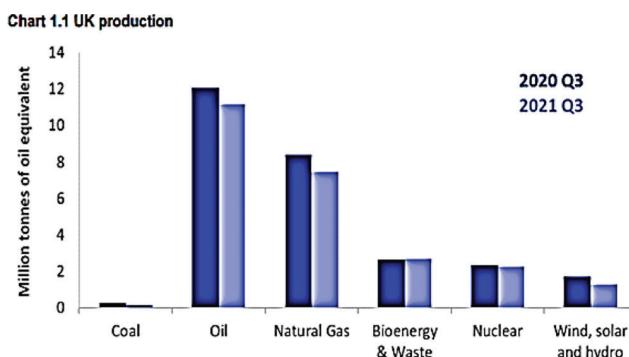
District heating would require water pipes to be laid underneath buildings. Water is heated at a central facility. The hot water is then delivered through a network of heavily insulated underground pipes to buildings. The National Transmission System is the network of pipes made of metal, and so unsuitable for the transmission of hydrogen. They also had leaks and were unsuitable for supplying other sources of energy such as renewably generated heat. A repair programme was needed and is underway [56].

It is expected that approximately 90% of the pipes will have been replaced by 2030 and that a 66% reduction in CO₂ equivalent emissions from the gas grid will be achieved by 2031 [57].

District heating only requires pipes and water. The district heating systems can therefore be fed with renewably generated heat rather than by fossil fuels, as shown in Denmark where 70% of the district heating is sourced from renewables or waste heat, and in Sweden sources over 70% of its district heating from renewables, mainly hydropower, whereas in Iceland where almost 100% is sourced from its geothermal resources [58].

7.3 Renewables

Onshore wind and solar are now cheaper globally than traditional electricity sources as a result of falling capital costs, improvements in technology and increased competition, and the production costs are continuing to fall lower than the use of coal [59]. In 2020 the government announced plans to secure 40GW of offshore wind capacity by 2030 [60]. However, the government seems unlikely to achieve even this. As you can see from Fig. 2 below, renewable sources make a minimal contribution to energy consumption in the UK compared to the use of other sources of energy.



In the third quarter of 2021 total production was 25.1 million tonnes of oil equivalent, 8.8 per cent lower than in the third quarter of 2020. Production on the UKCS was impacted by the shutdown of the Forties Pipeline System (FPS) for planned maintenance, as well as reduced capacity at several major gas terminals also due to maintenance. Wind, solar and hydro output fell due to less favourable weather conditions for all renewable technologies, with wind speeds notably lower compared to 2020.

Figure 2: (Department for Business, Energy & Industrial Strategy, Statistical release 23 December, 2021, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1043311/Energy_Trends_December_2021.pdf).

Energy industry subsidies through new or amended policies

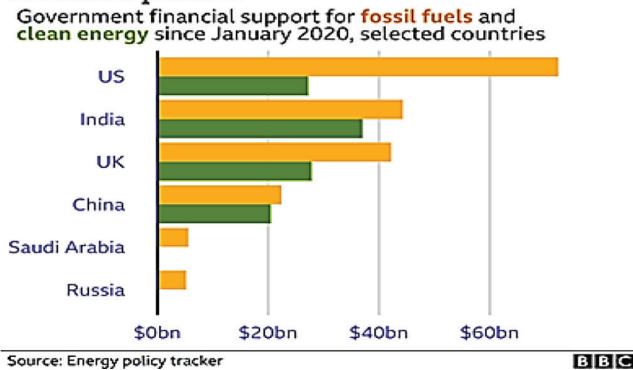


Figure 3: (<https://www.bbc.co.uk/news/59233799>).

The above Fig. 3 shows that the government is still investing much more in fossil fuels than in renewables.

This is inconsistent with its zero carbon commitments. It is inconsistent with an economically efficient and self-reliant energy future for this country, when recent events have shown more than ever, that countries should reduce their reliance on obtaining sources of energy from other countries.

8 CONCLUSION

The use of blue hydrogen as an energy source could potentially reach the parts of the country that other energy solutions cannot, however, the technology is expensive despite government support, and it may not develop quickly enough to assist reaching 2030 or 2050 goals.

Whether we are talking about blue, grey or green hydrogen, the government's Hydrogen Strategy alone will not resolve the energy crisis in terms of shortages and of high costs to consumers. Dr Lowes commented back in 2020 that 'Due to the uncertainties associated with hydrogen, in the short term, deployment of known low carbon heating technologies should be at a rate commensurate with the 2050 net-zero target with the expectation that low carbon gas including hydrogen may not prove viable at scale' [61]. It seems that the government is still considering such views.

The support and promotion of renewable energy sources in the UK needs to be taken not just as an option, but as a focal point. Although potentially less costly overall than the implementation of blue hydrogen technology, each alternative source of energy production requires sufficient government supported technology to be implemented to a substantial degree to enable a zero carbon future by 2050.

Even if the government changes from prioritising investment in oil and gas, all options to decarbonise heating systems at scale will require significant disruption and cost. While the UK government continues to deliberate, not only are we making insufficient progress towards 2050 goals, but the very fabric of our society, which runs on energy, is in jeopardy. There is no valid reason to delay a moment longer.

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