

Research proposal:

Wales Ability to Support Hydrogen as a Primary Fuel Media in Portable Application



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Abstract

With growing concerns over the availability of power supplies, coupled with social demand for a more renewable focused system and international turmoil, the ability to support and implement the next generation of fuel technology has never been so urgent.

This report focuses on the current demand on the power network, for the typical use of electrical power a surplus will be needed to be converted into hydrogen. A key part of this research will be to use established conversions of electrical energy to hydrogen in order to provide guidance as to the quantity of additional electrical productions needed.

The availability of technology to manufacture hydrogen is also key. With government supported hydrogen manufacturing facilities, investment has already started however, the technology currently in service is lacking the ability to manufacture in the volumes needed to replace fossil fuel in any means.

Investigation into the current methods of refuelling will reveal if this can be utilised as a viable option to adopt a national refuelling network. This aspect of research will advise what and if any further investment would be needed. In addition, research will be conducted into human behaviour and the ease of technology adoption by keeping the process “familiar”, or if this holds no bearing on the end users decision in the adoption of hydrogen fuel.

The UK has an extensive natural gas supply line supporting over 90% of homes in the UK. If this system could be switched over to hydrogen fuel, portable appliances could be refuelled at home as per battery cars in use today.

While focus on hydrogen fuel is in renewable or clean energy, it is common practice for hydrogen to be extracted from natural gas. Essentially, refining the natural gas further by removing the carbon locally. While this is still classed as a fossil fuel this option may act as a stop gap while power generation is invested in to accommodate the additional load needed by hydrogen.

Hydrogen power allows for portable power applications, however if the supporting technology is not available to replace conventional fossil fuels, then the exercise is without merit. For this reason, a technology review is needed with the view of confirming what is available or in development to make best use of the hydrogen infrastructure being built.

The proposal will look to capture the key aspects needed to make hydrogen fuel a viable primary fuel source and the infrastructure needed to support it.

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Introduction

As Wales enters the 21st century, the dependency on traditional fossil fuels remain paramount, with 84% of Welsh homes reliant on natural gas supplies (Regen, 2018). Of the cars registered in 2022, more than 85% used petrol or diesel (including HEV/PHEV) as a primary fuel source (Statistics, 2022).

Initially, the UK government incentivised the investment in renewable energies and shifting its focus to fossil fuels that were deemed to have a lower impact on the environment. However, these incentives were unsustainable and revoked, while further research found alternative fossil fuels to be as hazardous the fuels they replaced.

This has prompted the investment and development of electric and battery technology to replace traditional, portable internal combustion applications. Whilst this technology has had promising progression into portable and off grid applications, it still is subject to user limitations including the use of materials harmful to the environment, time consuming re-fuelling, increased weight to power ratio etc.

The story of hydrogen power has being long promised as the portable power solution however, the seemingly ready supply of fossil fuels and the development of alternative solutions have resulted in stunted hydrogen technology development and lack of supporting infrastructure.

The disruption in supply of fossil fuels from 2019 – current, driven via global political disruption and the pandemic, has highlighted the need for an alternative fuel supply and the weaknesses in the current alternative technologies. This in turn has re-focused the need for a sustainable fuel medium that can replace the systems that are currently in place.

Hydrogen offers one potential solution to the problem. Having a higher energy density than that of traditional fossil fuels (Layton, 2008), hydrogen is able to meet portable powered application demands that are still in need of a viable replacement. However, hydrogen is not without its problems.

Under typical environmental conditions of use, Hydrogen is a gas, whereas the fossil fuel counterparts are typically liquid such as petrol, diesel and paraffin. However, some fossil fuels used are in gas form such as natural gas and LPG. To replace fossil fuels, hydrogen will require new or a re-purpose of technology.

Literature Review

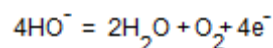
When starting this project, what was clear is the total volume of hydrogen literature available. To give this some scale, within Google Scholar the search term “hydrogen” generated 4,610,000 results and even using the University of Wales Trinity Saint David’s library and filtering for peer reviewed entries, there are 819,457 results.

This is not surprising given the importance of the topic at hand. However, finding literature with quality input and that is applicable to the research at hand will be a challenge.

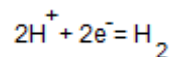
The Production of hydrogen in the UK is lacking to meet an overnight change over without considerable investment. This challenge is in part being addressed by Air Products whom are in the process of investing in a renewable hydrogen production facility in the Port of Immingham. This strategic location will provide access to already established off shore power generation projects for the manufacture of hydrogen. It is also close to an area of industry and logistics, allowing for utilisation for already existing logistic routes. (Wescoe, 2022). This point was further supported by (Balat, 2009)

The basic principles of Hydrogen via electrolysis is:

Reaction at the anode:



Reaction at the cathode:



In addition to using renewable power generation in the production of hydrogen, there are also key opportunities to manufacture hydrogen from biomass. The article from Oxford Elsevier Ltd (Martínez-Pérez, et al., 2007), identify the use of biomass via the use of crops within the manufacture of hydrogen. Drawing on this idea further it does occur that this ideology could be used for the re-processing of food waste, food waste from domestic homes estimated at 8.3 million tonnes in the UK as of 2011 (T. E. Quested, 2011).

The idea of using existing infrastructure systems could be key to the success of hydrogen fuel as a portable fuel solution. By utilising systems long established via the petrol industry, production of hydrogen can be maintained locally and the resulting fuel transported to where it is needed (Sai P.Katikaneni, 2014).

In addition to UK manufactured hydrogen, international trade partners will be key to satisfying any surge demand within the UK and to reinforce supply. A perfect example of such supporting countries is Iceland, where the naturally present geothermal heat supply could allow for the over production of electrical energy, that in turn can be exported in the form of hydrogen (Helgi ThorIngason, 2008).

Manufacture of hydrogen also needs to be commercially viable in order to be adopted by the masses and replace congenital fuel. (S.Koumi Ngoh, 2014) Demonstrates how this process can be balanced. While the logistics etc. of transporting the hydrogen to its customers, it demonstrates that 1kWh was able to produce 150³. Using today's commercial electricity pricing (£0.045/kWh – 05.10.22), we can place the cost to produce 1000mm³ of hydrogen at £0.30. To produce hydrogen via photo voltaic solar panels on a commercial scale large areas of land will be needed to facilitate the panels. It is estimated that 12,901 Kg/week of hydrogen can be manufactured utilising the surface area of 13.2 acres of land (S.Koumi Ngoh, 2014).

The use of hydrogen fuel can be compared to vehicles that use LPG as a primary fuel. Both are supplied in a gaseous form and are replenished under pressure. In addition, both are at risk of leakage and the resultant dangers associated with it. A parallel also concluded in the study (A Rosyid, 2007).

Areas of Focus

The research will be looking to confirm the status of the Welsh infrastructure to support hydrogen as a primary portable fuel. Key areas identified are:

- Advantages of Hydrogen fuel
- Hydrogen generation including primary power source for production and the production technology availability.
- Import and international energy trade
- Supporting infrastructure of hydrogen such as logistics, storage and redundancies
- Technology development to support hydrogen as a primary fuel. This includes automotive, domestic and commercial heating and electrical generation etc.

Method

1) Analyse current power need.

Key infrastructure power demands that are relevant to hydrogen are three key sections:

- Electrical power
- Domestic and industrial gas supply
- Automotive hydrocarbon fuels

Given the highly monitored nature of electrical power consumption, public records are available providing the annual power demands of Wales for both domestic and industrial. The power is recorded in Wh or a variant according to volume i.e. KWh, GWh. However for the interest of commonality across different power Medias, I will look to convert this into a Joule value to aide a like for like comparison.

The conversion for this will be $1\text{Wh} = 3600 \text{ J}$.

As per the electrical power consumption, gas supply is monitored and consumption figures published into public record. Using analytical research, these values will be gathered to confirm the consumption of gas across Wales. While domestic gas supplies can measured in cubic feet or cubic meters or KWh, for the benefit of this study gas usage will be take taken in cubic meters (M^3).

The conversion for this will be $1\text{M}^3 = 38,300,000 \text{ J}$

Hydrocarbons used in automotive applications “benefit” form strict taxations allowing for accurate records of consumption. Due to the accuracy of these records, public records again allow for accurate consumption data.

Unlike electrical and gas data, automotive fuel has several options, each with a different energy density

Diesel fuel traditionally has been used for more industrial automotive applications however, with engine refinement and improved mileage performance supported with UK government tax breaks, popularity grew throughout the 00’s creating a surge in domestic diesel demand.

The energy density to be used for Diesel will be $1\text{L} = 36,900,000 \text{ J}$

Petrol has predominately been the preferred fuel for domestic applications and remains dominant in the automotive market.

The energy density of petrol is $1\text{L} = 31,536,000 \text{ J}$

With the growing popularity of electrical cars, this cannot be missed in this analysis however, as the current systems of refuelling electric cars is via the national grid, using domestic and commercial power sources, the consumption due to the use of these automotives would have already been captured within the electrical consumption analysis.

There are alternative fuels also currently in service such as LPG, bio-fuels, solid fuels however, for the benefit of this study their usage will not be captured.

2) Future demand.

Due to the reliance of electrical power, multiple forecast models are in use to support government strategic investment and policy decisions to ensure that there is no disruption in supply.

Using these models, we will be able to produce an upper, lower and mean forecast analysis of Wales's electrical demand.

As per the electrical system of forecasting, the dependence of natural gas has resulted in detailed forecast models in support of infrastructure support and security of supply.

Unlike electric and gas, the automotive market is currently undergoing a state of change, with new technologies and social attitude changes. This has resulted in some very different opinions in how the automotive fuel demand is going to progress in the mid to long term. This difference in opinions between the automotive sector, government targets, scholars and the power sector, has to be acknowledged while being consolidated into one coherent set of data.

While this consolidation method has yet to be realised, it is anticipated that some of the opinions will share commonality and present the most probable demand model. Should this not happen, further research will be needed into each of the opposing opinions to better understand the mythology behind the results and use the data that supports the most logical approach to forecasting

As per gas and electric, forecasting automotive fuel demand will also consider an upper, lower and median demand scenarios.

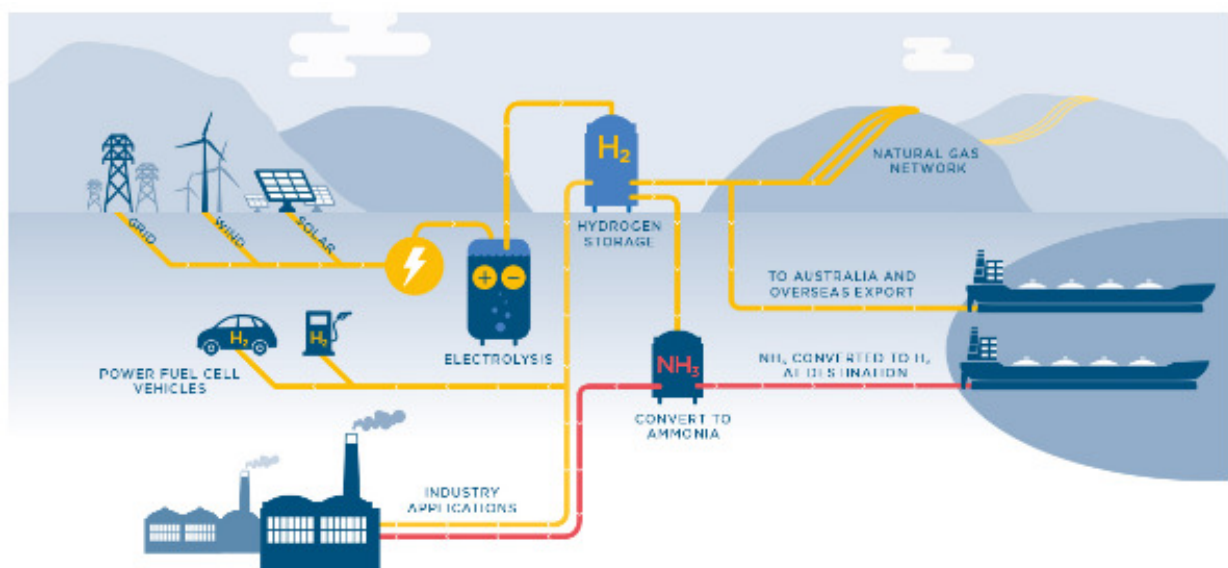


Image source: (<https://hsfnotes.com/energy/2019/03/20/developing-green-hydrogen-projects/>, n.d.)

3) Limitations

While every effort will be taken to capture data relevant and accurate data to provide a concise and clear report, there are areas that the report will not cover that may have an impact on the overall feasibility of hydrogen use in Wales.

While the power generation needed to support the production of hydrogen will be a key point of study within the research, the ability for the infrastructure to support the anticipated increased power demand will not form part of this research. It will be assumed that any increase in power production will be supported with the necessary infrastructure.

In addition, the study will review infrastructure that can support the supply and distribution of hydrogen. While considerations will be made to developing technologies this will be limited to technologies that are in or near to field service. While this point may seem obvious, the advancement in technologies in recent history have been substantial, and the advancements that can be made within the coming decade has the potential to generate unforeseen results. For this reason, the research will be presented as a snapshot in time and open for amendment as and if needed.

4) Technical study

The technical study will be split into the key phases of hydrogen supply.

Hydrogen manufacturing methods

Storage and Logistics

Refuelling

End user power recovery.

5) Implementation

Using the data collected in the above points, a review will then be conducted to confirm where the hydrogen infrastructure is adequately supported and where infrastructure reinforcement is needed.

Identifying the infrastructure needs and where the existing systems are sufficient, will allow the focusing of resources and investment. This focusing of investment would hopefully have the net impact of accelerating the adoption of hydrogen fuel.

With the supporting infrastructure recommendations, there will also need to be a review of health and safety policy around the use of hydrogen. Some points of consideration include refuelling policy, storage best practices, skill level of engineers to conduct installation and maintenance. A prudent starting point of this would be to review the current policies for gas based fuels and, where practical, adopt points that are relevant and draw new policies where gaps in current processes exist.

In addition to the changes in policies, supporting changes in law will also be needed. In addition to the changes in legally supported health and safety, changes will be needed in consumer taxation laws. This could be in the form of the growth of hydrogen fuels, government grants and support for hydrogen supported technology. Changes in storage capacity allows for greater storage in high power applications such as industrial vehicles.

Results,

The gathering of the data will use quantitative results, presented in graphs and tables to support the ease of interpretation. In addition to the supporting quantitative data gathered, the report will rely heavily on qualitative data collected via industry representatives, academia and government sources.

The collected data will support the production of a road map towards the adoption of hydrogen fuel as a primary fuel source. This road map will highlight systems that are existing in Welsh infrastructure today that can be re-purposed and assimilated in to a potential hydrogen supply chain.

This data will also advise where infrastructure is lacking and has the potential to hinder the progressing of hydrogen supply. Should the research yield potential solutions to the issues highlighted, then of course these recommendations will be included within the final report.

Research Goals

The research is looking to confirm the status today of Wales readiness to use hydrogen fuel.

In presenting Wales's current ability to support hydrogen as a primary fuel, any investment within the current system will be made clear.

This in turn will highlight areas that require target investment. The development in this infrastructure will future proof the portable energy sector and reduce implementation time by pre-empt issues that would otherwise hamper the introduction of hydrogen on a mass scale.

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