Community Energy Scotland position paper on Hydrogen

Community Energy Scotland

Empowering Communities

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COMMUNITY ENERGY SCOTLAND

Community Energy Scotland (CES) is a Registered Scottish Charity and company limited by guarantee established in 2007. Our main charitable objectives are community development, environmental protection and the alleviation of poverty. Our mission is to build confidence, resilience and wealth through sustainable energy development at community level.

CES has been at the heart of community renewable energy development for over a decade and with our substantial experience, we are best positioned to offer advice and support to Scotland's communities. As Scotland's first, and only, national charity dedicated to supporting community renewable energy development, we have firmly established ourselves as impartial, independent specialists.

CONTENTS

INTRODUCTION

Community Energy Scotland (CES) have been asked to provide a position paper on hydrogen fuel within the context of smart local energy systems (SLES) to support the Hydrogen Integration for Accelerated Energy Transitions (HI-ACT) centre. This report contains statements about hydrogen that together form CES' opinion about hydrogen in Scotland at the time of writing (October 2022).

CES' vision is of communities actively shaping a low-carbon society that values wellbeing for all. CES have supported community groups in numerous hydrogen related innovation projects including: Outer Hebrides Local Energy Hub (OHLEH), Surf 'n' Turf and Building Innovative Green Hydrogen systems in Isolated Territories (BIG HIT). The Creed recycling facility near Stornoway formed part of the OHLEH project from 2015-21, where the electrolyser was intended to supply hydrogen and oxygen to a local fish hatchery, a hydrogen internal combustion engine refuse vehicle, and an off-site fuel cell, using electricity produced on site from wind and anaerobic digestion. On Orkney, the Surf 'n' Turf project aimed to reduce curtailment for wind and tidal generators on Eday by using otherwise curtailed energy to produce hydrogen, to be transported by road and ferry for use in a private wire network in Kirkwall. The BIG HIT project built on this, with the installation of a 1MW electrolyser on Shapinsay, a hydrogen boiler system at a school, and a hydrogen refuelling station, which supplies five hydrogen fuel cell range-extended electric vans operated by the local council.

Throughout this document, any reference to hydrogen production means hydrogen produced through electrolysis using electricity from renewable energy sources. For the avoidance of doubt, CES do not consider nuclear power as a renewable energy source.

HYDROGEN STATEMENTS

Hydrogen production should use renewable resources

CES don't view hydrogen as a goal but as a potential way to reduce human impact on the climate. We do not see hydrogen as 'the answer' to climate change either. We do not support hydrogen production that uses fossil fuels and emits carbon dioxide as a by-product as it hinders our vision of "communities actively shaping a low-carbon society that values wellbeing for all". Hydrogen should not be used as a way to justify medium- to long-term oil and gas activity across the globe.

Electrolysis using electricity from renewable electricity such as wind, solar, tidal, wave should be prioritised. CES recognises that there are challenges to overcome to enable electrolysis to be the leading method of hydrogen production; however, we strongly believe that the large effort required to move towards hydrogen should only be undertaken if it is with the primary goal of minimising climate change which impacts all communities.

Hydrogen system integration readiness is low

Care has to be taken when considering the 'readiness levels' of the technology. Individual components may score relatively highly in terms of Technology Readiness Level (TRL) in that they have been demonstrated in many contexts, and are commercially available. However, the market readiness level is still really quite low, without many systems operating on a commercial basis; effectively at (or even before) the 'early adopter' stage. It is also important to note that the

Integration Readiness Level (IRL) appears to be low at present; although the components may work individually, there isn't a robust product available combining all elements. This system-level maturity is essential for complex integrated energy systems that may involve the generation and dynamic control of renewable energy in tandem with hydrogen electrolysis, integration with Active Network Management (ANM) systems, compression and storage of hydrogen, and use within fuel cells. From experience to date, the interfaces between these elements are not sufficiently robust to form a strong business proposition around use of hydrogen at scale.

The real-world performance of the equipment is still far below that required to build a robust business case for most applications

Very significant challenges have been experienced with hydrogen equipment. During the OHLEH project the Creed electrolyser failed after only 2 weeks of full operation and couldn't be repaired or replaced for over a year due to prohibitive costs, preventing many aspects of the project from continuing.

When in operation, the electrolysers in Orkney were not able to fully modulate output, limiting the extent to which they could be used to absorb energy from the community turbines. Various parts of the system experienced significant and minor faults resulting in multi-year downtime of some components. As a result of the different problems, neither of the turbines connected to the electrolysers have been able to meaningfully reduce curtailment, and hydrogen production has been limited.

Local upskilling should be included when developing a supply chain at the start of any hydrogen project

The findings from the Orkney and Lewis hydrogen projects demonstrated that it is very challenging to develop leading edge projects without an established supply chain or local maintenance/repair service. Suppliers are often based in England or overseas which results in long fault investigation times as engineers may take multiple days to travel to site and at a high cost. The investigation may result in a quick onsite fix or require further parts and additional engineers all of which adds to cost and downtime of equipment. Downtime of one piece of equipment likely means downtime of the entire hydrogen system. Unused equipment can result in failures which means a minor fault could result in cascade failures across the system if not dealt with promptly. Engineers should be relocated or preferably, local engineers trained to be able to provide reactive call out and maintenance support.

Building in resilience and developing supply chains (equipment & maintenance) should be a key consideration and built into any hydrogen project from the start, as it is a major recurring issue we have experienced on Hydrogen projects. Without an established market for hydrogen, commercial viability is some way off.

Water supply is a concern

Splitting water into hydrogen and oxygen obviously requires a source of water. That water also needs to be treated. In industrial parks where water demand is high, an electrolyser may not make much difference to the nearby water treatment plants. However, in the most remote and rural areas in Scotland water treatment is often on a much smaller scale due to the low volume of demand. The existing demand may only be a few hundred houses, if that. In the Surf 'n' Turf and BIG HIT projects, water demand for the electrolyser was higher than that for each island. Getting a water connection could be challenging as the water company (Scottish Water in Scotland) needs to ensure the water treatment plants can cope with the additional demand.

Water demand across the UK is increasing year on year and with climate change pressures, water is becoming a scarcer resource. Aquifers in England are depleting. Techniques to produce treated water from seawater should be considered along with the careful environmental management of the by-products. Consideration should be given to harnessing the water by-product from fuel cells to be reused in hydrogen production.

Co-locating hydrogen with existing renewable energy has merit but requires complex commercial agreements

An attractive source of renewable energy for electrolysis is renewable generators that are currently curtailed without compensation. There is potential for the generator to increase their revenue when they cannot export to the grid, and there is potential for the electrolyser operator to decrease their electricity costs. If the curtailment pattern is frequent but with short durations, the electrolyser may not be able to ramp up to start producing hydrogen, or once producing hydrogen has to shut down fairly rapidly. The electrolyser operator may wish to import electricity from the grid to be able to produce higher volumes of hydrogen when there is no curtailment of the renewable generation. There then needs to be careful consideration of the technical import connection and the commercial arrangements between all parties. Existing renewable generators are more than likely to have loans with banks and to change the operation and income streams will likely require permission from the funder.

Hydrogen systems are likely to include batteries on both the generation and demand side.

Fuel cells are not responsive enough to meet rapid changes in demand. As part of the Surf 'n Turf project, the Kirkwall fuel cell (75kW) container includes 80kWh of battery storage, which acts as a buffer to respond quickly to changes in demand on the (effectively islanded) network which it supplies at the harbour. Buffer batteries are also seen in other fuel-cell based applications, including in vehicles.

Similarly, electrolysers are not responsive enough to meet rapid changes in electricity availability. If an electrolyser is going to use only curtailed electricity from a wind farm then the curtailment pattern is very important and may be frequent but not for long periods of time. A battery could store this energy in the short term and support longer periods of consistent electricity supply to the electrolyser. Whether this is likely to be financially attractive will be on a case-by-case basis.

For renewable generation sites set up with the sole purpose of providing electricity for electrolysis, there may be a requirement for a battery in order to ensure that fluctuations in wind / solar / tidal / wave output don't lead to export 'spill' to the grid, or to variations in power quality that cause the generators to trip off. This would be a particularly key problem to solve if the supply from the generation is on an islanded basis (i.e. there is no electrical connection of the generation to the wider grid at all, and the electrolyser is the sole load). In this setup, bespoke control settings may be required, in addition to a buffer battery.

Hydrogen will not be primarily used for private travel

We are very doubtful that hydrogen will take off for family vehicles given the lower operating efficiencies, higher purchase cost, and dwindling range/refuelling benefits compared to electric vehicles. The case is better for large commercial (and possibly agricultural) vehicles, but much development is needed before being able to say whether hydrogen or batteries will become the predominant storage vector. It also won't come down to total cost of ownership – infrastructure, ease of use, safety, and local maintenance are all key considerations for individuals and fleet operators.

Transportation of Hydrogen should be minimised

Reducing the distance that hydrogen needs to be transported could reduce the energy required, logistical effort, and carbon impact. LPG and petrol/diesel deliveries are considered Dangerous Goods on ferries; that can often mean special sailings, or reduced passenger capacity and/or an inability to transport certain other goods on the same sailing. That all comes with an associated cost and carbon impact. Equally, the same would apply to hydrogen being exported via road tankers on the ferries; dedicated large vessels might be better if hydrogen export was seen as a major future market.

We do however wonder how realistic it would be in carbon and economic terms to export hydrogen from Scotland as far as continental Europe by sea. One limitation of hydrogen is that, given the low energy density compared to oils, it really only makes sense to transport it relatively short distances before more energy is used than will be carried. Transporting it using conventional oil-fuelled ships would be untenable in cost or carbon terms. A decentralised model is preferred with local hydrogen being used locally before being exported.

End use applications need to not be solely reliant on hydrogen when creating a local hydrogen economy

One of the biggest challenges in creating a hydrogen economy is ensuring there is a consistent supply of hydrogen and that there is a use for that hydrogen. Due to the challenges we've seen with hydrogen production, it is sensible to choose end users that have back-up plans for if there is a lack of hydrogen.

Local authorities are well placed to provide demand for hydrogen services. In Lewis, a dual-fuel refuse collective vehicle was purchased which can operate on hydrogen and diesel and is used to collect local waste. In Orkney, the hydrogen electric hybrid vans purchased by the Council could be plugged in and charged with electricity when there wasn't hydrogen. The local Councils were able to support the project and continue their function if there was not sufficient hydrogen. Other large players may be present that can provide the demand for hydrogen such as ferry operators.

This 'non reliance on hydrogen' approach is also evident in hydrogen gas grid projects where hydrogen can be added, but the end user can still heat their homes if the hydrogen is not injected into the grid.

Of course, this reliance on back-up systems or alternative fuels will need to be phased out to also achieve a low carbon economy. However, the reliance of hydrogen supply must first be established in an area.

There is also a possibility of an oversupply of hydrogen in the early stages of a hydrogen economy; however, we have not witnessed this to date. The merits of hydrogen storage versus the hiatus of hydrogen production should be considered.

Hydrogen fuelled ferries could be a significant driver in island hydrogen economies

An expected high value (financially and environmentally) end use for hydrogen is in ferry propulsion. This should be a real driver in island communities for a local hydrogen economy. Much of island ferry fleets are extremely old and in need of replacement. Hybrid vessels are likely to be required in the first instance unless a consistent and reliable supply of hydrogen can be realised or back-up traditional vessels are available. This consistent supply could in the future take the form of multiple hydrogen production sites although the demand in the short term (e.g. 1 vessel) is unlikely to be sufficient to support multiple sites. Hybrid vessels could be electric or fossil fuelled. Projects to develop both types are underway. Electric/hydrogen hybrid vessels would require charging which at some harbours could require significant upgrades to the electrical infrastructure. However, cold ironing using electricity is becoming more standard as a way to reduce pollution when tethered at night (when only auxiliary supplies are needed).

Lower energy efficiency may be an acceptable trade-off in some locations or applications compared to alternative fuel sources

Hydrogen technology is not highly robust yet, and falls down in efficiency compared to some alternatives. The efficiency of different components in hydrogen production and use is still relatively low, which compounds over the cycle of conversion from electricity to hydrogen and back, meaning overall system efficiency might commonly still be in the order of 30%. Whilst lab efficiencies may be higher, commercially available electrolysers are typically 55-70% efficient (and this may decrease when modulating output, in response to intermittent generation for instance). Commercial fuel cells may only be around 45% efficient. Further losses will occur if the hydrogen has to be stored at high pressure. As an example, most Hydrogen Fuel Cell Electric Vehicles (HFCEVs) will use hydrogen stored at 700bar and the energy efficiency of an electric vehicle is higher than that of a HFCEV.

This reduction in energy efficiency may be an acceptable trade-off in some locations or applications compared to alternative fuel sources, supply chains, and their constraints. It is important to consider all alternatives in a whole system context, and to ensure that proposals represent the best solution for the consumers and end users as well as the generators. For example, swapping from fossil fuels to electric options (electric vehicles, heat pumps, heaters, cookers, hobs) will increase the amount of energy that needs to come from electricity but also the peak demand for electricity. The generation capacity needed to meet this increase in demand is very dependent on the peak electricity demand unless sufficient demand side management and sufficient storage is included in the system. The cost of installing all of the additional generation capacity and/or storage and demand side measures may be less attractive than producing more of an alternative fuel, which is currently less efficient. An appropriate site for additional generation may also not be available.

Hydrogen could reduce the amount of renewable generation that is required to meet electricity peak demand in the UK in the long term but the mechanisms to realise this value do not exist

The expected value of converting electricity into hydrogen as a short-term storage vector and then back into electricity is low. In part because batteries are able to provide short-term storage as well as reacting quickly to provide services such as frequency response. The expected long-term storage value of hydrogen is much higher than that of batteries. Between seasons, hydrogen can be produced when generation is high and demand low and converted back to electricity when demand is high and generation is low.

The alternative to long-term energy storage is increased generating capacity. Hydrogen could therefore reduce the overall capacity (GWs) of renewable generation that is needed which in turn reduces the carbon emissions related to manufacture. There could be a case for savings for the system as a whole; however, the mechanisms to trigger investment in, and award, this approach do not exist.

Hydrogen electrolysis could provide existing grid services

Much of the constraint on the electrical networks in Scotland is due to the amount of generation compared to demand. There are many areas in Scotland where the distribution network would be able to host generation but the constraint is at a transmission level. It is expected that a hydrogen electrolyser could provide some Constraint Managed Zone services and ancillary services. Given the challenge we have seen with modulating output of electrolysers, the level of service provision and commercial viability is unknown.

Traditional network reinforcement is preferable to replacing diesel with hydrogen in power stations run by Distribution Network Operators (DNO)

At present, multiple island groups have diesel power stations to provide backup generation to meet local demand during planned and unplanned outages of subsea cables. In some cases they also provide ‘peak lopping’ to meet local demand when embedded wind generation is low, and import demand exceeds the capacity of the interconnector. Ultimately, it will not be economically or environmentally sustainable for DNOs to keep operating diesel plant in this role.

Co-firing of hydrogen with diesel in the existing generator sets might be possible as an interim measure; fuel cells as a replacement to the generator sets would be more acceptable long-term. The cost of fuel cell backups, or even a co-firing retrofit of the aged generator sets, would almost certainly be prohibitively high for assets which would be used very infrequently; it would also be very difficult to size the storage required to meet demand during cable outages, which can last from a few hours to many months.

The need for backup generation at scale will reduce substantially if/when traditional network reinforcement in the form of additional interconnectors are built. Traditional network reinforcement in these cases will also increase the amount of renewable generation possible in these areas, which are also natural resource rich.

Traditional network reinforcement should not be delayed due to what a hydrogen industry might be able to provide in the future

Across Scotland, significant network reinforcement is required to enable more renewable generation to be built out and contribute towards governmental targets. Unfortunately, traditional network reinforcement (uprating or installing circuits and/or transformers) can be slow (multiple years) and the volume required will not speed this process up. Delay of reinforcement would hinder deployment of renewable generation and therefore hinder meeting targets. Hydrogen could play a complementary role to network reinforcement in the long term but is not currently a viable route to deferring network reinforcement due to: lack of required hydrogen and long-term energy storage markets; low Integration Readiness Level; lack of skilled workforce; and the volume of renewable generation currently required.

Hydrogen heating won't be ubiquitous

Just as electricity and gas play different roles in providing power and heating so too will hydrogen. Existing infrastructure will partly shape how hydrogen is used. For example, areas with gas grids are more likely to be enabled to use hydrogen to heat their homes in the future compared to areas without gas networks. It is more likely that non-hydrogen dependent methods will be the main route to decarbonise heating. Hydrogen electrolysis produces excess heat which could be harnessed and used in existing or new district heating systems. A trial of this approach would be interesting.

Hydrogen by-products should be considered when planning production sites

Whilst the OHLEH project demonstrated that there is some local industrial demand for oxygen at fish hatcheries, the volumes are such that this would not be a cornerstone industrial demand for an electrolyser business. Oxygen provision is seen as a supplemental income stream rather than a driving force for hydrogen production, as is the access to excess heat. Any by-product should be utilised where possible. We do not currently see oxygen or excess heat as being key drivers for hydrogen production. However, the by-products should influence exact locations within a local area.

CONCLUSION

Community Energy Scotland see that the integration of renewably generated hydrogen into Smart Local Energy Systems has the opportunity to deliver on low carbon societies in the future but only if the hydrogen is produced using renewable energy and not using fossil fuels. At present, the real-world performance of hydrogen technology is lacking and the Integration Readiness Level is low. Without an established market for hydrogen, commercial viability is some way off. Two major barriers for hydrogen production are the need for upskilling local workforces to be able to maintain hydrogen systems and the sourcing of water.

Hydrogen production should be focussed close to the end use to reduce the requirement for transporting it. Co-locating hydrogen with existing generation has merit but requires the unpicking and creation of complex commercial agreements. Due to the challenges we've seen with hydrogen production, when creating hydrogen economies, it is sensible for the initial end users of hydrogen to not be entirely dependent on hydrogen; with hybrid systems or separate back-up systems. Batteries will be inherent in many hydrogen systems. There is potential for hydrogen ferries to be a cornerstone of island hydrogen economies. We do not think that hydrogen will be the primary energy vector used for private travel but can see potential for longer range and heavier duty vehicles.

While many hydrogen systems have a lower energy efficiency than other systems that provide the same function, these may be an acceptable trade-off in some locations and applications. It is important that the whole system context is considered.

In the long term, hydrogen could reduce the amount of renewable generation capacity that is needed to meet peak demand by providing long-term energy storage, peak lopping, and other grid services. Traditional network reinforcement is required across most of Scotland to enable further renewable generation. It is our opinion that traditional network reinforcement is preferable to replacing diesel with hydrogen in power stations run by DNOs.

A trial of excess heat from hydrogen electrolysis being fed into district heating systems would be interesting. While there is potential, this should not hold up the roll out of decarbonised heating in homes such as heat pumps.

