Valentia Island Hydrogen Energy Opportunities Feasibility Study

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Summary Document
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Summary

This Feasibility study was commissioned by Valentia Island Development Company ('the clients') with the support of South Kerry Development Partnership CLG to investigate the feasibility of community owned hydrogen energy (H2) opportunities in Valentia Island.

Energy Cop-operatives Ireland referred hereinafter as 'the authors' conducted this study on behalf of the clients between May 2019 and October 2019.

This report investigates three Case Study Opportunities:

- **Case 1: Light Industrial Hydrogen to Heat application in the Cable Station at Knightstown, Valentia**
- **Case 2: Combined Heating and Fuel Cell Vehicle Application**
- **Case 2a: Co-fuelling a Car Ferry H2 and Diesel**
- **Case 3: A large Scale Electrolysis and H2 Transport production and distribution project powered by large-scale (>3MW) offshore wind generation**

The report from the authors can be summarised as:

Case Study 1 appears overall to be under-ambitious; it does not utilize the specified electrolysers to its fullest and most efficient extent. The personnel, capital and political commitment necessary to ensure that the project is successful in its implementation is under-rewarded by the project even in the best-case scenario.

Case Study 2 is ambitious, innovative and achievable. There is likely to be strong interest in participation from partners in the research community. It makes excellent use of the H2 generated in the most rewarding and visible application. It is appropriately scaled and matches the output of the specified electrolyses in a flexible and efficient manner. It also takes advantage of one of Valentia's unique selling points as an offshore west coast island with a road connection. The ambition of the project will reward the commitment of the clients and the community and is likely to receive considerable support from policy makers and other significant regulatory decision makers.

Case Study 3 appears the most worthwhile of the opportunities in terms of revenue and employment generation. However, it is large scale and requires extensive background work to be conducted by the clients and the community before it can be considered definitively achievable. The clients may wish to commit to achieving the success of Case Study 2 with the target of putting themselves in the position of taking up the opportunity offered by Case Study 3.

This document which is intended for public information purposes accompanies the full feasibility study.

Contents

1.0 Context

This report is specifically tailored for needs of the client and the geographical, economic and social conditions of Valentia. We outline these conditions to contextualize the report.

1.1 Geographical

Valentia Island is located in the South West of Ireland. It is 11km at it longest and 4.23 km at its widest. It is 26km^2 in area. It is connected in the South of the island by a road bridge to the mainland at the village of Port Magee. The village of Knightstown in the North East of the island is served by a roll-on roll off passenger ferry which connects to Reenard Point (700m across the sound) and operates for 6 months of the year.

The land in Valentia is hilly (the island is 266m at the peak of Geokaun, its highest point) but is much more fertile when compared to most Irish offshore islands. As a result, it is able to sustain viable dairy herds (see economy below).

While Valentia has a sráidbhaile settlement pattern typical of Western Ireland, there are two distinct villages: Chapel Town and Knights Town.

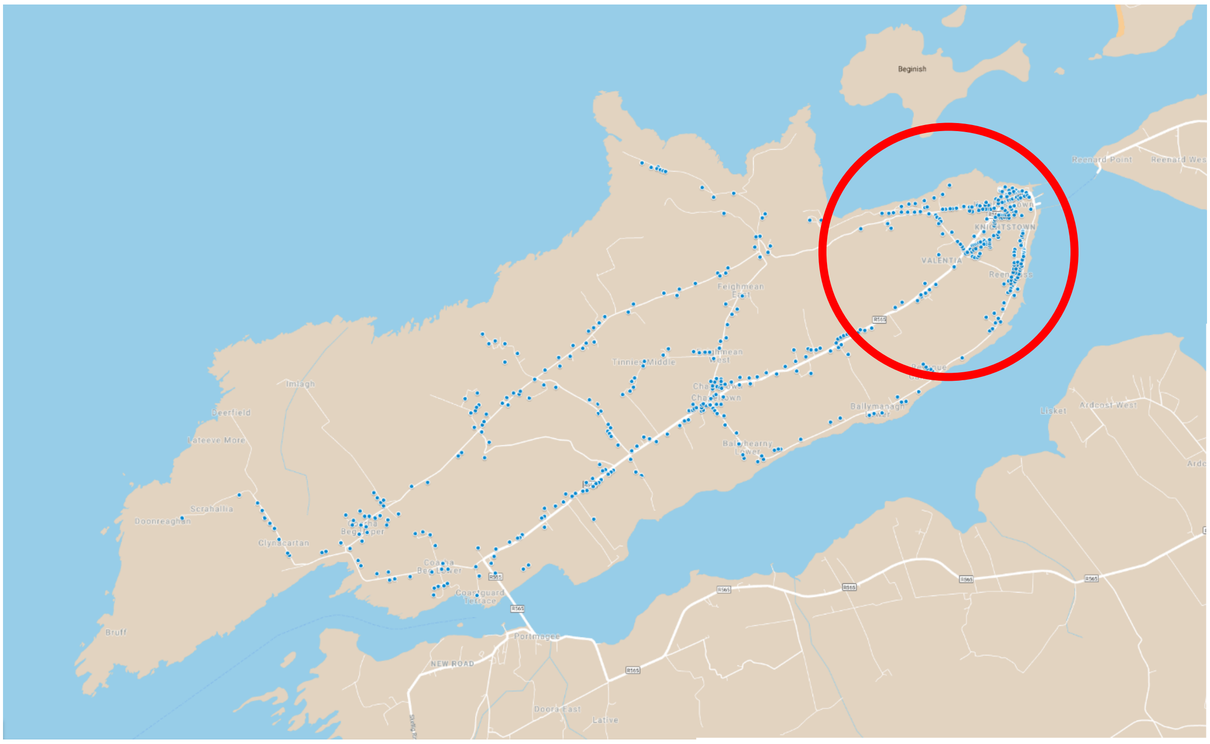


Figure 1.1: Map of Valentia, settlement pattern

The map shows the Sráidbhaile settlement pattern but with a concentration around Knightstown.

The nearest town of significant size is Cahirciveen. This lies to the North East of Valentia Island approximately 4.6km from the Harbour in Reenard Point. Thus, when the ferry is in operation, typical journey distance from Knightstown to Valentia is very short. However, when the ferry is not operating, Knightstown residents use the road bridge from Portmagee which means the journey distance to Cahirciveen is 22.8km.

Cahirciveen is a local hub for the islanders (supermarkets, secondary schools, etc) and so it is normal for people from the island to make the trip to and from the town a number of times a week.

The regional hub towns are Killorglin 38.5km from Cahirciveen, and Killarney (nearest rail connection) which is 57.9km from Cahirciveen.

Census 2016[1] figures show that 82 people living on Valentia had a journey time to work, school or college longer than 30 minutes: probably journey distances of 20km or above. Journey distances (many by car) are thus largely the same as those of mainland residents in the West of Ireland as opposed to residents of other Irish islands. This has significant impacts on Hydrogen opportunities.

1.2 Demographic

The population of Valentia Island was recorded in the 2016 census as 657. However, out of the total of 653 houses on the island, 302 (46%) were registered as holiday homes. This compares to a norm of 10.8% in County Kerry as a whole.

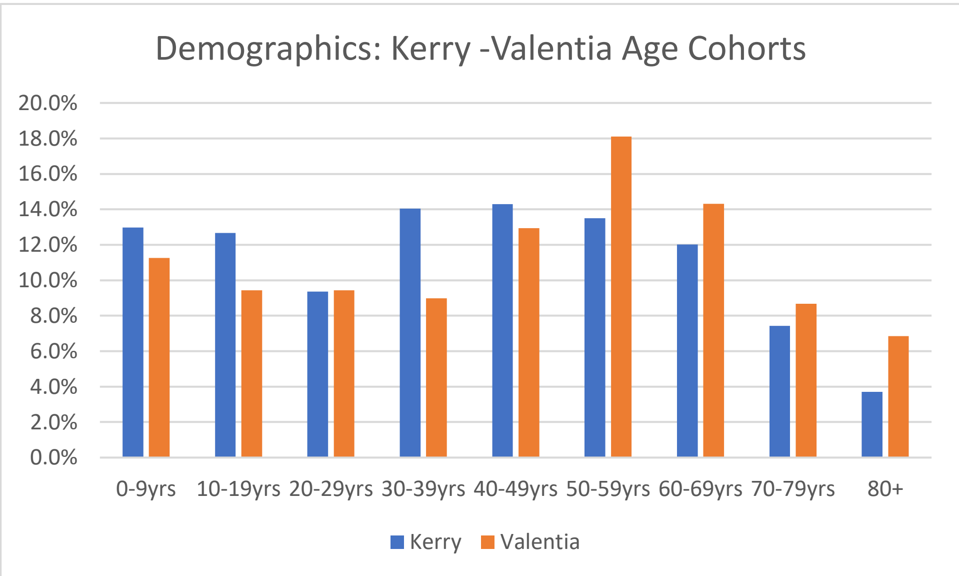


Figure1.2: Demographics of Kerry v Valentia.

[1] Irish CSO online data http://census.cso.ie/sapmap2016/Results.aspx?Geog_Type=ED3409&Geog_Code=2AE19629223913A3E055000000000001#SAPMAP_T11_1103 last accessed 17/09/19

This would support the anecdotal evidence from islanders and tourist organisations that the summer population of the island could be up to twice the number of those normally resident.

The population structure on Valentia is not reflective of that of County Kerry as a whole. It is, in general, older. There is a disparity between the percentage of inhabitants between 30 and 39ys/a. Thus, the commissioners of this study were cognisant of the need to contextualise its findings within the trend of overall aging of the island’s population leading to a decline over time.

1.3 Households:

There are 266 occupied dwellings on Valentia, 302 holiday homes and 85 unoccupied dwellings. According to the census of 2016, of the year-round occupied dwellings, 143 use ‘oil’. This cohort of fuel users could be seen as an H2 opportunity for home heating fuel replacement. There are also 7 homes that use LPG for space heating. Recently conducted research[2] estimates that permanent residents using ‘home heating oil’ and LPG on Valentia consume 2,283,049 kWh per annum. This opportunity for Carbon Fuel replacement by H2 is significant but could be considered a long-term opportunity.

1.4 Economic Context

The economy of the island is quite varied. Sectors of employment as identified in the 2016 census indicate that agriculture plays a greater role in the local economy than it does for County Kerry as whole. However, there is manufacturing on the island which is not normally found in offshore locations. This manufacturing sector is identified as one of the key areas of opportunity.

[2] VIDCO Commissioned an Energy Master Plan from Purtill Energy Consulting funded by the SEAI which provides very useful energy consumption data used in thus report. It is discussed in greater detail below.

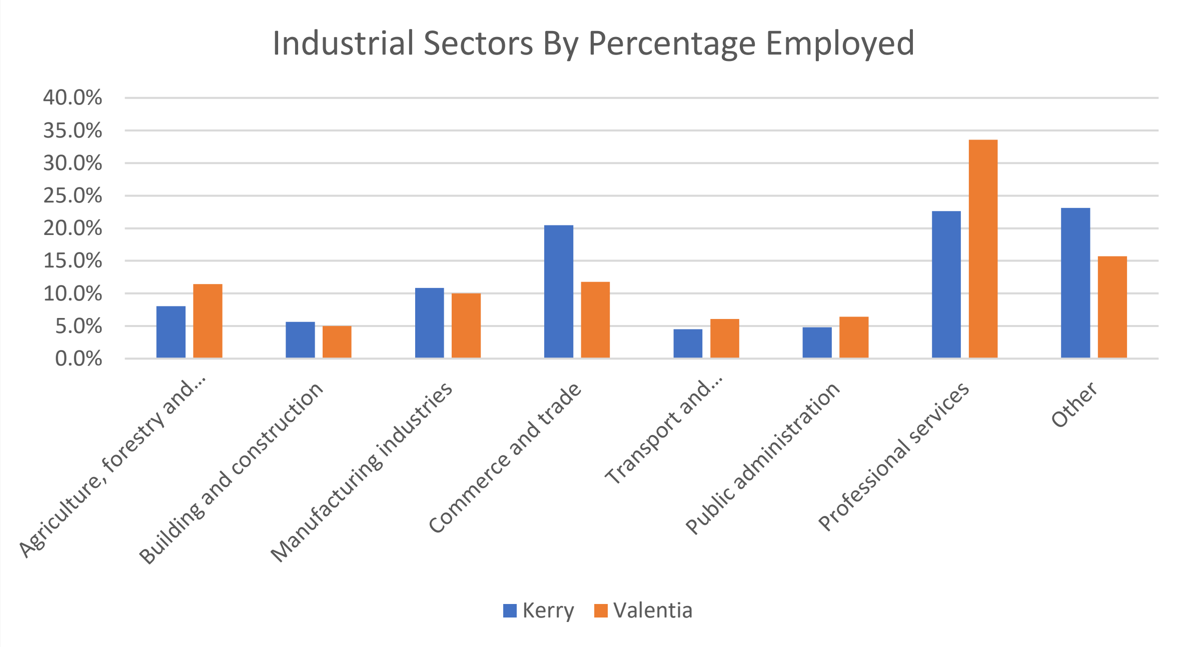


Figure 1.4: Employment by Sector

There are a number of larger employers on the island which need to be considered when assessing the opportunities of H2 use on Valentia. These are: marine transport, marine construction, light industry, large catering, heavy industry. Each of these are considered below.

There are off-island opportunities that can also be considered, however. H2 is used in transport in light commercial vehicles. Therefore, businesses which transport goods over distances greater than 250km round trip can be considered as potential users of H2 as a transport fuel.

1.5 Planning

Valentia Island is a location of considerable natural beauty as well as rich historical and cultural heritage. It is thus an area which has been given a number of significant planning protections by local government. This will have impact on the design and location of the H2 generation/production opportunities that are discussed in this report.

1.5.1 Special Protected Areas (SPAs)

'The EU Birds Directive (79/409/EEC) requires designation of SPAs for: listed rare and vulnerable species; regularly occurring migratory species, such as ducks, geese and waders; wetlands, especially those of international importance, which attract large numbers of migratory birds each year.'[3]

Kerry County Development Plan 2015-2021 reflects the designation of the areas around Valentia as SPA. Thus any development that this study proposes will take into account the

[3] https://data.gov.ie/dataset/special-protection-areas

fact that planning officials will likely refuse permission for schemes that interfere with the birdlife in the area indicated by the SPA, that is: on the Northern side of the island within approximately 400m of the cliffs/coast.

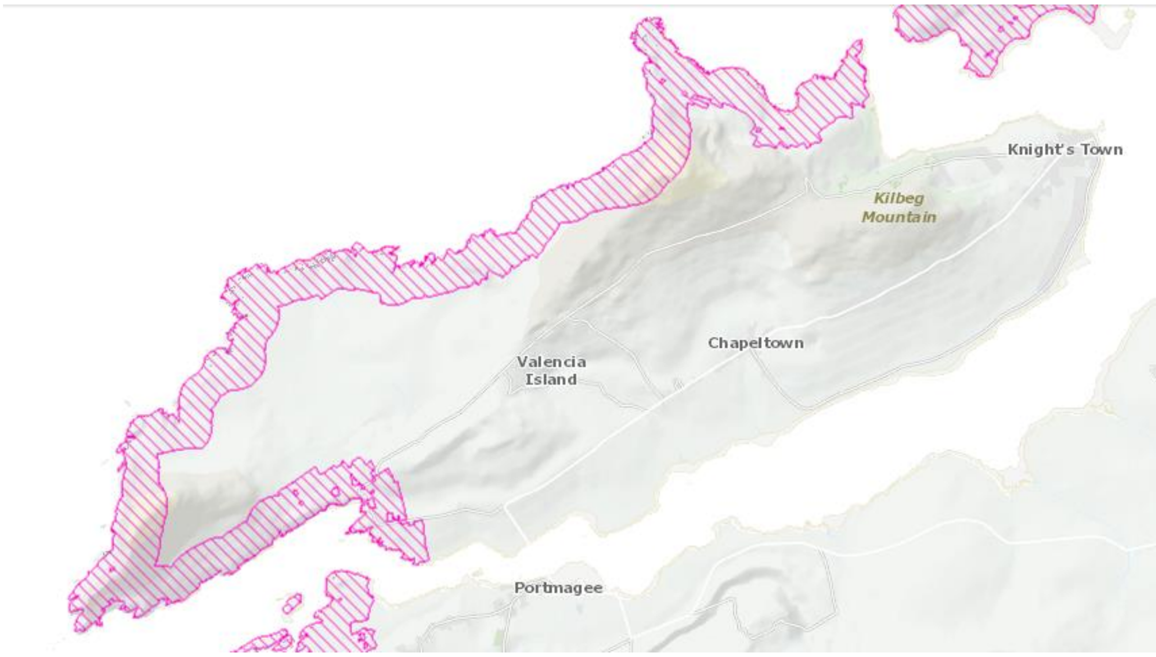
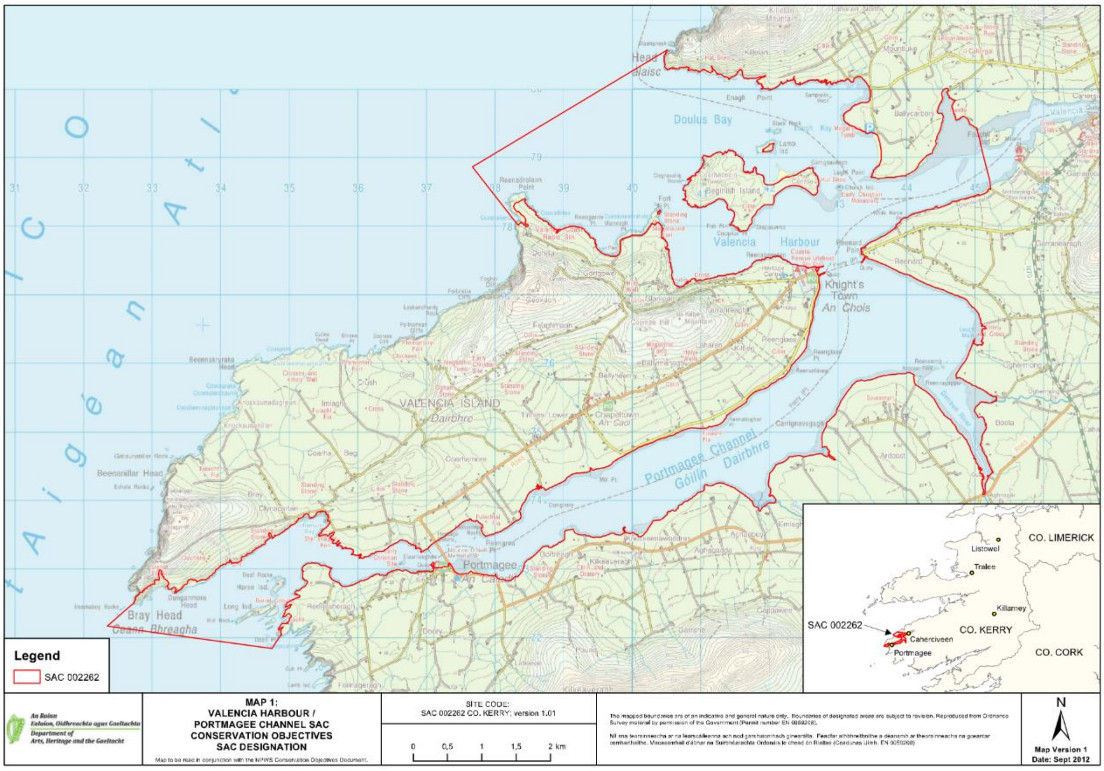


Figure: 1.5.1 Kerry Co. Co. Map Showing SPA Valentia

1.5.2 Special Area of Conservation (SAC)

These are prime wildlife conservation areas in the country, considered to be important on a European as well as Irish level. SACs are selected and designated under the EU Habitats Directive, transposed into Irish law by the European Communities (Birds and Natural Habitats) Regulations 2011 (S.I. No. 477 of 2011).

The relevant SPA is the Valencia Harbour/Portmagee Channel SAC. Which is intended to protect: ‘mudflats and sandflats not covered by seawater at low tide’.



1.5.2 Figure Showing SAC Valentia Island: Valentia Harbour and Portmagee Channel

1.5.3 Zoning

The Kerry County Development Plan 2015- 2021[4] Figure X and Y shows that there are few areas on Valentia Island not deemed to be Prime Special Amenity, Secondary Special Amenity or are considered 'Views and Prospects'.

[4] http://cdp.kerrycoco.ie/wordpress/

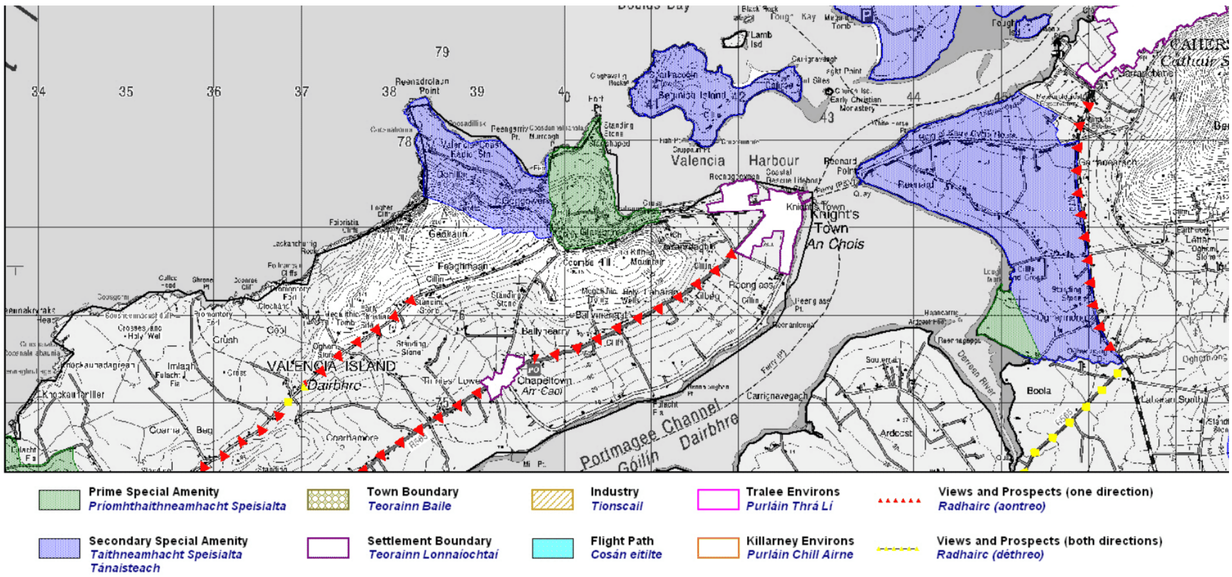


Figure 1.5.3 Kerry County Development Plan 2015- 2021 Zoning
Valentia Island North (detail)

The Development plan states:

"It is not proposed that the protection and conservation of these views and prospects should give rise to the prohibition of development along these routes, but Kerry County Development Plan 2015 - 2021 12 Zoning & Landscaping 197 development where permitted, should not seriously hinder or obstruct these views and should be designed and located to minimise their impact"

There is a risk that certain developments of scale could be deemed to hinder these views. There are however areas that are not subject to 'Views and Prospects, and thus could be seen as open to development for example the area around Feaghmaan East.

Even here there would be a requirement to avoid potential impact on the visual amenity to the south west, the terrain slope towards Geokaun to the North and historical monuments circled in red[5]. However, in and around this area there is approximately 81 hectares that in the opinion of the authors are suitable for Photo Voltaic Electricity generation, subject to landowner involvement and planning.

1.6 Context of this Feasibility Study

1.6.1 VIDCO and SEAI

In 2017 The Valentia Island Development Company established a sub-committee tasked with investigating sustainability and renewable energy opportunities. It contacted the

[5] Standing stone in Tinnies Upper (KE078-013), Standing stone in Feaghmaan East (KE078-004) and a Megailthic Wedge Tomb at Ballyhearny East (KE079-076) http://webgis.archaeology.ie/historicenvironment/

Sustainable Energy Authority of Ireland (SEAI) with a view to gaining support for their sustainability work by joining the SEAI's Sustainable Energy Community (SEC). On becoming an SEC, the SEAI appointed Xavier Duboisson of XDL Consultants as the 'mentor' Valentia Island SEC. XDL brought the Valentia Island SEC process which included drawing up a sustainability charter and gathering signatories to that charter.

1.6.2 Energy Master Plan

The SEC, with XDL guidance applied to SEAI for an Energy Master Plan Grant Application in September 2017. It was successful in this application and was supported by the SEAI to engage an outside consultant to conduct an Energy Master Plan (EMP). This involves a two-step process:

1. A data collection exercise to establish a base-line energy audit of the Valentia Island community looking at energy consumed by businesses, families, and community groups in transport, heating, industry as well as electrical usage for all purposes.
2. The drawing up of a 'Register of Opportunities' (RoO) to map out how energy consumption could be reduced and how energy could be produced through non-fossil fuel and renewable sources.

The consultant to conduct the EMP was chosen through a competitive tendering process, with Purthill Energy Consulting conducting. A community engagement meeting took place in the Royal Valentia Hotel in January 2018 explaining the process and objectives of the Master Plan study. The EMP was completed in September 2018. The findings of the master plan were presented at a public meeting in Knightstown.

One of the findings of the EMP was to:

"Conduct a feasibility study on the potential of developing a renewable energy sourced hydrogen fuel cell ferry for Valentia Island."

This study was commissioned by VIDCO to fulfil this finding but is conducted in accordance to the other findings of the EMP which is taken as a guiding document. Thus, the EMP is referenced as a supporting document for many of the proposals contained here and some tables from it are reproduced here with the permission of VIDCO.

1.6.3 Timeline

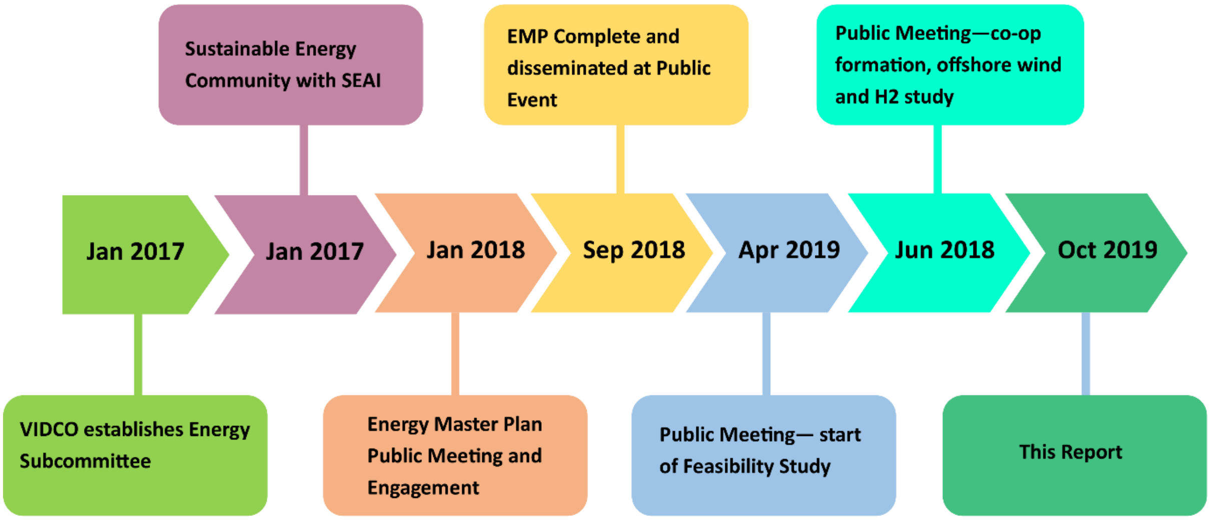


Figure 1.6.3: Timeline of VIDCO, public meetings and consultations

1.6.4 Public Consultations

There have been a number of public consultation processes adopted during the conduct of this study. In April 2019 VIDCO hosted a seminar open to the public on the progress of the SEC's work to that point, but also on the specifics of the Hydrogen Energy Feasibility study that was in process. VIDCO invited Dr James Carton, Dublin City University (DCU), Dr Rory Monaghan, National University of Ireland Galway (NUIG), Elizabeth Johnson MBE, Business Development Manager at Pure Energy Centre, Lerwick, Shetland Islands, Lúgh ó Braonáin, Energy Co-operatives Ireland, and Duncan Stewart who presented at the event. There was upwards of 120 in attendance at the event. The event presented initial scoping from the Feasibility Study as well as giving a broad picture of the latest research into H2 as a renewable fuel, the state of the H2 supply chain and market in Europe generally. Ms Johnson presented on the experience of Pure Energy and the island communities in Shetland of their development of H2 projects and their role as technology leaders.

A subsequent event was held in 14 June 2018. It further presented on the progress of this study (Cormac Walsh, Energy Co-operatives Ireland) as well as detailing the steps necessary to take in establishing an energy co-operative (Darragh Walshe, Irish Co-operatives Society). It discussed the potential for offshore wind as an electrical energy supply for H2 production via electrolysis. A non-binding, indicative public vote was taken at that meeting which supported the investigation of offshore wind in the Feasibility study.

This feasibility study and its findings will be published at an open community event in October 2019.

2.0 Regulatory Context

2.1 Hydrogen and Irish Renewable Electricity: Coping with Intermittency

Ireland has a target to achieve, by 2020, a 40% share of electricity generation from renewable sources. It has further targets to meet 12% of its national heating demand and 10% of its transport requirement from renewable sources. These targets are widely perceived as not being achievable by the date required. Indeed, they have been replaced by 2030 goals. However, achieving the renewably generated electricity portion of those targets is not as far off as for other sectors.

Wind energy, generated from 2,440 MW[6] of installed capacity at the end of 2015, accounted for 21% of total electricity generated in that year[7]. Hydro and other renewable electricity sources had a combined share of 4% of total electricity generation. Thus, the overall renewable electricity share was 25% at the end of 2015. Between start 2016 and August 2018 an additional 1,049 MW of wind generation have been added to the grid, bringing the total wind to 3,496 MW[8]. There have been no significant other renewables additions during the period. In 2017 approximately 29.6% of the electricity in the Republic of Ireland was generated by renewables[9]. Eirgrid, the national grid management body, estimate that a band of 3,900 – 4,400 MW of on-shore wind capacity is required to meet the 2020 RES-E targets for Ireland, with 4,200 MW being the most likely figure. If wind generation connections continue at the current rate (approximately 330MW per year), by the end of 2020, Ireland will be 4,156 MW, just short of 40% of its electricity wind generation[10] – this will be approximately at the 2020 targets.

Other renewable energy generation technologies are expected to start coming on-stream during 2020: approximately 842 MW of PV generation has passed through both planning and grid application process[11].

Thus, the vast majority the renewable energy generation required by Ireland to meet its 2020 targets will be from non-dispatchable, intermittent sources. This is set to increase over time as Ireland commits to a greater share of renewable generation.

Interconnection between Ireland and other countries (i.e. Britain) is at present limited to 1,000 MW. The East West Interconnector (EWIC) connecting Ireland and Wales, has the capacity to transport 500 MW. The Moyle Interconnector linking the electricity grids of Northern Ireland and Scotland, has a capacity of 500 MW. There are plans for another

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[6] https://www.seai.ie/resources/publications/Irelands_Energy_Projections.pdf
[7] Implies a total generation capacity from all sources of 9,384MW
[8] http://www.eirgridgroup.com/site-files/library/EirGrid/Wind20Installed20Capacities.png
[9] http://www.eirgridgroup.com/site-files/library/EirGrid/Fuel20Mix.jpg
[10] http://www.eirgridgroup.com/site-files/library/EirGrid/Generation_Capacity_Statement_2018.pdf
[11] http://www.eirgridgroup.com/site-files/library/EirGrid/2018-Batch-(ECP-1)-Eligible-Applications-Joint-SO-Publication-31.8.18.pdf

interconnector between Ireland and France of approximately 700 MW. Surplus dispatchable renewably generated power is cheap when in surplus. However, dispatchable power when energy is scarce (i.e. when there is less intermittent power available and demand is high) is expensive: thus, interconnection will more likely favour UK and France consumers of electricity even if it does Irish generators to upscale without over-constraining generation.

These two features of the Irish electricity supply (high intermittency and low interconnection) mean that Ireland may find itself relying far into the future on imported fossil fuel-powered dispatchable back-up generation capacity (using for example natural gas from Norway or Russia to power generators on standby), which are carbon emitting. Alternatively, it will need to build-out vastly more interconnection with its neighbours. It could in another scenario hope that the rapid uptake of electric vehicles could act as a distributed national 'battery' for converting excess intermittent generation into useable power. In yet another scenario it could also explore how to develop dispatchable non-carbon emitting generation technologies.

According to Eirgrid, in 2017, the total dispatch-down energy from wind generation in the Republic of Ireland was 277 GWh[12]. This is equivalent to 3.7% of total available wind energy here. Thus, while there is currently a need to constrain wind generation, the excess capacity that is constrained and that could be diverted to generation of hydrogen was 277 GWh in 2017.

Hydrogen is a potential energy storage solution to this dispatchable power issue. The potential for Hydrogen within a renewable energy matrix has been studied in relation to Ireland, with mixed results.

Carton and Olabi (2010)[13] found that

'Hydrogen storage and efficient fuel cell utilisation is a possible answer to some of the current energy storage and delivery issues. Hydrogen and electricity together represent one of the most promising ways to realise sustainable energy, and fuel cells provide the most effective device for converting hydrogen into electricity'.

They pointed to technological and societal challenges as obstacles to this potential. These range from societal and public attitude issues. The relevance of policy maker attitudes to hydrogen is discussed below.

Connolly et al., (2011)[14] compared three scenarios: Biomass-based, hydrogen-based and electricity-based energy systems. They suggested that Hydrogen to Electricity where

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[12] http://www.eirgridgroup.com/Annual-Renewable-Constraint-and-Curtailment-Report-2017-V1.pdf

[13] J.G. Carton, A.G. Olabi, 'Wind/hydrogen hybrid systems: Opportunity for Ireland's wind resource to provide consistent sustainable energy supply', *Energy*, Volume 35, Issue 12, 2010, Pages 4536-4544, http://www.sciencedirect.com/science/article/pii/S0360544210004895

Hydrogen is produced by otherwise curtailed wind would be an expensive process involving much energy loss. They found that hydrogen produced by curtailed wind energy which is subsequently used as transport fuel is more efficient.

Truc et al (2017) [15] looked at combining Hydrogen produced from curtailed wind and combined with biomass generated CO2 as transport fuel. They found that there is potentially enough feedstock to produce the biogas required, but that there is frequently not enough surplus electricity.

Hanley, Dean, and ó Gallachóir (2018)[16] suggested that the significance of Hydrogen within the transition to fossil free energy network may only gradually emerge post 2030. However, one clear pathway towards greater significance for hydrogen is its greater use as a result of 'increased wind electricity in the power system in particular'.

However, there is a role for hydrogen storage of intermittent wind electricity generation in areas where it would reduce the requirement for large scale grid re-enforcement, i.e. in more 'remote' areas. It should be noted that much of Ireland wind resource is located in Western parts of the country. Eirgrid's 'Grid West' project which sought to re-enforce the grid in North Connacht in the West of Ireland, to enable increased wind generation in the area and the subsequent transmission of large-scale wind generated electricity was announced in 2012 but shelved in 2017. This was partly as a result of the scaling-back of a large wind farm by the national planning authority, An Bord Pleanála, in Co Mayo, but also in the face of considerable community and political opposition to the erecting of large electricity pylons Grid West necessitated.[17]

Thus, there are critical public acceptance issues related to getting electricity generated in coastal areas to the national grid.

2.2 Hydrogen Policy in Ireland: Transport

There has been little policy development on a national level in relation to the possible hydrogenization of transport in Ireland.

[14] D. Connolly, H. Lund, B.V. Mathiesen, M. Leahy, 'The first step towards a 100% renewable energy-system for Ireland', *Applied Energy*, Volume 88, Issue 2, 2011, Pages 502-507, http://www.sciencedirect.com/science/article/pii/S030626191000070X

[15] Truc T.Q. Vo, Ao Xia, David M. Wall, Jerry D. Murphy, 'Use of surplus wind electricity in Ireland to produce compressed renewable gaseous transport fuel through biological power to gas systems', *Renewable Energy*, Volume 105, 2017, http://www.sciencedirect.com/science/article/pii/S0960148116311491

[16] Emma S. Hanley, JP Deane, BP Ó Gallachóir, 'The role of hydrogen in low carbon energy futures–A review of existing perspectives', *Renewable and Sustainable Energy Reviews*, Volume 82, Part 3, 2018, Pages 3027-3045, http://www.sciencedirect.com/science/article/pii/S1364032117314089

[17] https://www.irishtimes.com/news/environment/mixed-reaction-to-scaling-back-of-240m-grid-west-project-1.3230977

The Irish Department of Transport's (DTTAS) latest policy document, *National Policy Framework Alternative Fuels Infrastructure For Transport In Ireland 2017 to 2030*, DTTAS, 2017[18], says that

'Post-2030, it is likely that hydrogen will increase its penetration across the entire fleet spectrum with a correlated decline in the predominance of vehicles run solely on fossil fuels. It is Ireland's ambition that all new cars and vans sold in this country from 2030 will be zero emission (or zero emission-capable). The freight and bus sectors will continue on a positive trajectory towards full penetration of low emissions vehicles (LEVs).'

However, for the medium term, i.e. prior to 2030, the Irish government expects electrification of the national transport fleet to be more significant, with some biofuel technology complimented by LNG also expected to feature.

'Biofuels will continue to play a key role over the coming years and natural gas, along with some electrification, will provide an interim alternative solution for larger vehicles, i.e. freight and buses where significant reductions in CO2 could be expected from integrating biomethane with CNG/ LNG. LNG and methanol are likely to increase their penetration as fuels in the shipping sector.'

The Biofuels Obligations Scheme[19] places an obligation on suppliers of mineral oil to ensure that 8.695% (by volume) of the motor fuel (generally gasoline and motor diesel) they place on the market in Ireland is produced from renewable sources, e.g. ethanol and biodiesel. It is presumed that ethanol and biodiesel as an additive to petrol and diesel offers Irish policy-makers a more straightforward means of reaching 2020 targets of 10% of transport energy being met from renewable sources.

Hydrogen was not expected by the department to deliver mass-market uptake between 2017 and 2030 as it believed the costs of the refuelling infrastructure (which it estimated as costing €800,000 each), are likely to remain prohibitive until the middle of the next decade.

There has been rapid progress since this policy paper was delivered, not least that driven by Hydrogen Ireland[20] whose proposals are discussed in detail below.

2.2.1 Freight

The policy proposals outlined in the report were that while Hydrogen was considered versatile and suited to use in freight, and while there were arguments for further

[18] http://www.dttas.ie/sites/default/files/publications/public-transport/english/npf-picture/6186npfalternative-fuelsengv5.pdf

[19] http://www.nora.ie/biofuels-obligation-scheme.141.html

[20] http://hydrogenireland.org/

investigation of hydrogen as a freight transport fuel, there was a feeling that there was no current market in Ireland.

Transition to a hydrogen-based transport system would involve ‘massive technological change and economic investment by consumers’. Ireland’s unusual driving environment where right-hand drive vehicles predominate was cited as likely to slow-down the adoption of hydrogen freight vehicles. The report felt that Ireland would be ‘unlikely to see a range of right-hand drive affordable hydrogen trucks coming onto the Irish market for some years to come’. The report took the position, that investing in costly infrastructure ahead of the market would be a high-risk strategy and could lead to early infrastructure becoming obsolete as the technology advanced. In short, Ireland would let other countries take the lead in technology development and adoption and would then follow when the case was proven. This is not an uncommon strategy for policymakers in Ireland. In renewable generation for example, Ireland did not take the early adopter approach of set Feed in Tariffs per MWh/KWh generated to stimulate renewables generation in the manner of the UK, Germany or France. Now likely to meet it’s 2020 targets, it appears that policymakers may feel vindicated in taking a ‘wait and see approach’. That Ireland will not meet its renewable transport and renewable heat targets – and thus faces fines for failing to do so – could however be given as a counterexample.

2.2.2 Shipping

The DTTAS policy document suggested that fuels such as LNG and methanol, rather than hydrogen, were promising alternatives in the shipping sector. Particularly if they were to be used alongside a biofuel counterpart, such as biomethane or bio-methanol. However, here again, the policy took a sanguine view of new technologies and cautioned against ‘investing in costly infrastructure too far ahead of the market’. There was no discussion of the experiences of BIG HIT and other hydrogen-fuelled shipping research projects.

2.2.3 Buses

There was some treatment of innovation in relation to hydrogen in the bus fleet. The reported acknowledged that, a hydrogen fuelled buses have been introduced to European fleets in recent years but did not go into detail on this. While the feeling was that this demonstrated the potential of Hydrogen to meet real-life operation demands, the long-term commercial feasibility was still being examined. It felt instead that CNG was a more mature technology and could offer some improved air quality benefits especially where older buses are being replaced.

2.2.4 Private Cars

On the whole, there was very little examination of hydrogen in the DTTAS’ policy document. It reflects a general sense at policy level that hydrogen is a nascent technology and that Ireland should await developments elsewhere before committing tax-payer support for Research and Development, let alone supporting a hydrogen refuelling network. The Sustainable Energy of Ireland is charged with informing and supporting government policy in the area of sustainable energy. In the area of transport, it has worked to promote the adoption of electric vehicles[21] within the context of increased presence of renewables on the grid. It would therefore be reasonable to presume that increased adoption of electric vehicles for private and small commercial transport, has been the accepted model for the decarbonisation of the transport sector in Ireland. The former Minster for Communications, Climate Action and Environment (DCCAE), Denis Naughten T.D., said last year:

‘I would like to see a greater uptake and not just by private car owners but in the public sector as well. I am encouraging the Office of Government Procurement to actively engage and advise the public sector on the use of electric vehicles across all areas.’

However, it should be noted that policy makers are open to new approaches. Minister Naughten also has said he was open to the potential of hydrogen powered cars after examining them first hand and he made a series of videos on social media to mark the event.[22] While the current Minister, Richard Bruton TD, has not taken a strong approach on Hydrogen in private transport, there is a noticeable change in the political mood towards hydrogen in the past 12 months.

Figure 2.2.4 Former Minister Denis Naughten’s tweet on his FCV driving experience

21 https://www.seai.ie/news-and-media/drivingelectric-campaign-launched/
22 http://www.nweurope.eu/media/4096/gencomm-h2go-news-june2018.pdf

2.2.5 Hydrogen and the Climate Action Fund 2018 onwards - Policy and Practice:

The policies outlined above are supported by recent funding decisions under the Irish government's Climate Action Fund[23]. This is a fund established under the National Development Plan 2018-2027 as part of Project Ireland 2040. The fund supports initiatives contributing to the meeting Ireland's climate and energy targets. The first call[24] awarded €10m (13% of the fund), towards an EV fast charger network extension, €8.5m (11% of the fund), towards an agri-biogas project[25], and €15 (19.5% of the fund), towards the hybridisation[26] of the rail stock. This would appear to indicate that the policies outlined above are being supported by financial aid decisions.

It should be noted that Ireland's 'wait and see' approach is in contrast to that of our nearest neighbours. In Scotland there is active research into Hydrogen in weak grid locations as an answer to the constraint of intermittent renewables (i.e. BIG HIT in Orkney[27]). There is also an active pilot of hydrogen in transport (with a fleet of ten buses) in Aberdeen[28]. The UK's Committee on Climate Change is quite clear about the necessity of engaging early on in the development of hydrogen technologies in a variety contexts.[29]

'Deployment of hydrogen should start in a 'low-regrets' way over the next decade, recognising that even an imperfect roll-out is likely to be better in the long term than a 'wait-and-see' approach that fails to develop the option properly.' (UK Committee on Climate Change, Hydrogen in a low-carbon economy, 2018, p7)

The UKs 'low-regrets' approach could be a valuable framing of the promotion of VIDCO's hydrogen ambitions with policy makers.

3.0 Outline Scenarios

3.1 Introduction

We looked at the opportunities that exist for H2 deployments on Valentia across a range of technologies and their applications. Notwithstanding the fact that H2 technology is not yet widely considered to be a mature technology, we focus on projects that are feasible either as commercial or as viable research opportunities.

3.2 Technical Opportunities

As discussed above there is likely to be a very significant role for Hydrogen as a complimentary energy store for renewable energy intermittencies. There are many

[23] https://www.dccae.gov.ie/en-ie/climate-action/topics/climate-action-fund/Pages/default.aspx
[24] https://www.dccae.gov.ie/en-ie/climate-action/topics/climate-action-fund/call-for-applications/first-call-2018/project-assessments/Pages/default.aspx
[25] Biogas injected into the national natural gas grid
[26] Battery and diesel hybrids
[27] https://www.bighit.eu/about/
[28] http://www.all-energy.co.uk/__novadocuments/30431?v=635060505159530000
[29] https://www.theccc.org.uk/wp-content/uploads/2018/11/Hydrogen-in-a-low-carbon-economy.pdf

European Commission funded Horizon 2020 and INTERREG projects researching the potential opportunities integrating Hydrogen and Renewable Energy:

Hybalance[30] demonstrates the use of hydrogen in energy systems. The hydrogen will be produced from water electrolysis, enabling the storage of cheap renewable electricity from wind turbines. It will thus help balance the grid, and the hydrogen will be used for clean transportation and in the industrial sector.

GENCOMM[31] addresses the energy sustainability challenges of NWE communities through the implementation of smart hydrogen-based energy matrixes. It will have a demonstration site linked to a large wind farm in Northern Ireland.

SEAFUEL[32] aims to demonstrate the feasibility of powering local transportation networks using Hydrogen produced by renewable energies (PV and Wind) and seawater. It will install a demonstration plant, a framework for policy implementation and a sustainability analysis of production, distribution and usage of hydrogen as an alternative fuel in remote Atlantic regions.

BIG HIT[33] produces hydrogen on the islands of Eday and Shapinsay in Scotland's Orkney Islands using wind and tidal energy. Renewable electricity generated is used by electrolysers to produce hydrogen, by electrolysis of water. This hydrogen is then stored as high-pressure gas in the tube trailers, which can be transported to mainland Orkney.

Thus, there is interest in the possibility of H2 being used:

1. As a compliment to intermittent renewable energy
2. A carbon free transport fuel
3. A replacement of fossil fuels in heating
4. A potential resource for grid-balancing in more remote areas where there is poor interconnectivity.
5. As an alternative route to market for renewable energy generation in grid poor areas

These technical opportunities are addressed individually below, but also frame the discussion of the case study scenarios.

3.2.1 Compliment to intermittent renewable energy

3.2.1.1 Wind

There is no electricity generation by wind of scale as yet on Valentia Island. Although the natural resource for wind generation is very high, grid and possible public acceptance

30 http://hybalance.eu/
31 https://www.nweurope.eu/projects/project-search/gencomm-generating-energy-secure-communities/
32 http://www.seafuel.eu/
33 https://www.bighit.eu/

issues have meant that as yet there are no turbines on the island. In fact, South Kerry as a whole has little in the way of wind generation.

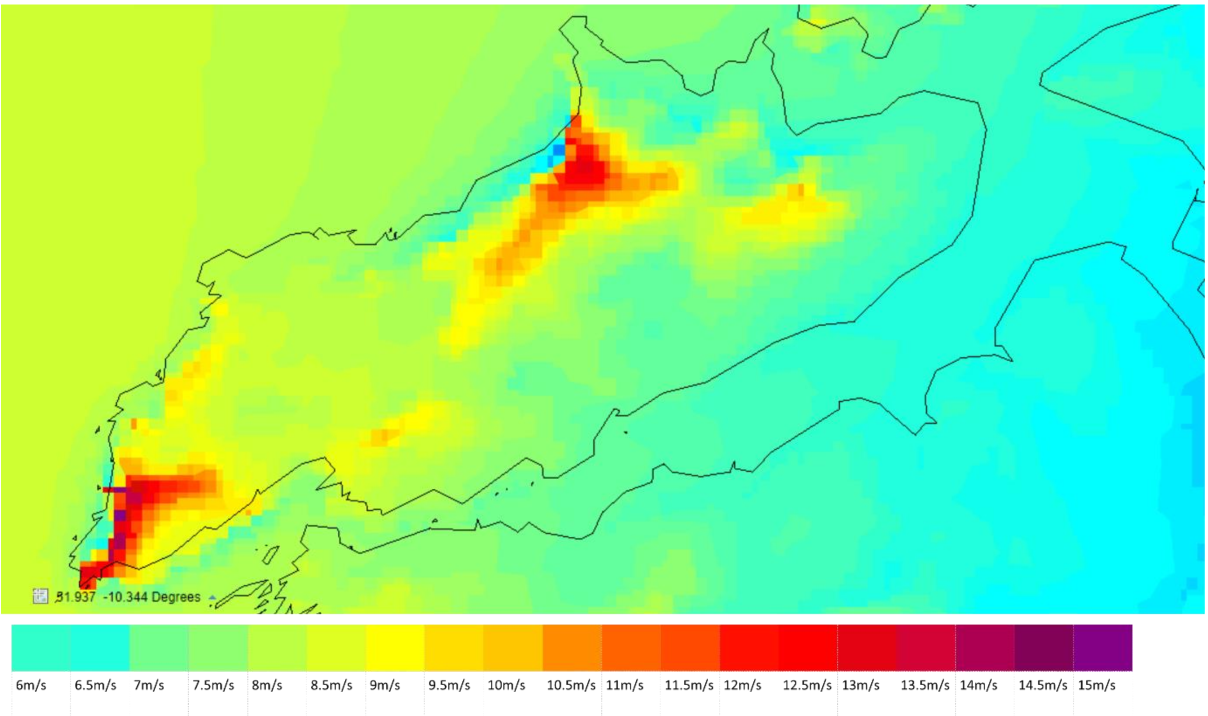

Figure 3.2.1.1a: Wind Resource Valentia Island: Wind speeds at 20m[34]

Figure 3.2.1.1a above shows that there is a very high onshore wind resource on Valentia Island. Off shore speeds at 100m are also high with an average of 9.2m/s – perhaps unsurprisingly more than enough to make wind turbines onshore or offshore viable in terms of wind resource.

There is therefore a viable wind resource which all things considered offers an opportunity for renewable generation from wind to Hydrogen. The scale of wind generation is dependent upon the scenarios which determine what the uses of Hydrogen could be and so this is addressed for each scenario below. However, there are useful baseline assumptions which can be made.

Onshore wind is the cheapest and least carbon intensive means of generating energy.

[34] http://maps.seai.ie/wind/

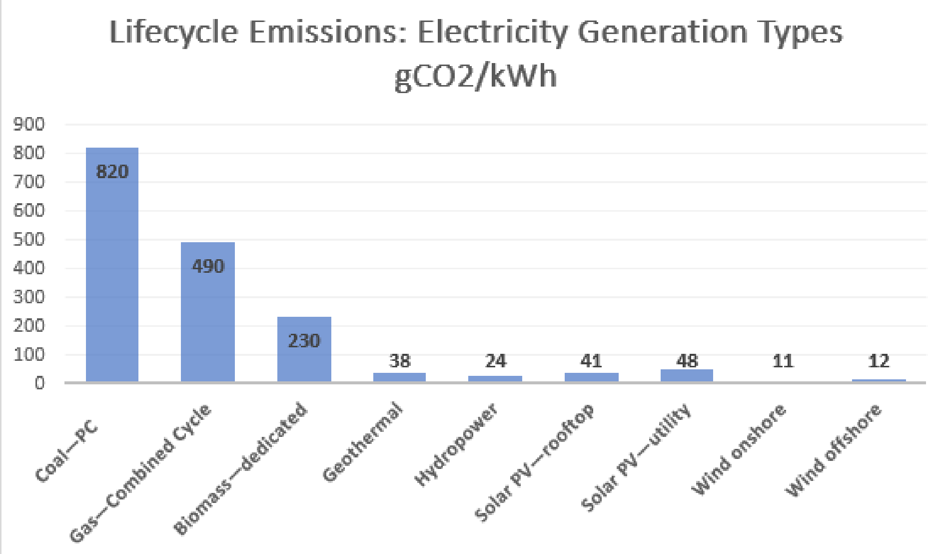

Figure 3.2.1.1.b: Technology-specific Environmental Costs
Source: IPCC, 2014, Annex III. [35]

From the point of view of lifetime carbon emissions wind outperforms all other forms of electricity generation[36]. Onshore wind generation is also considered to be one of the most cost-effective forms of renewably generated electricity. The global averages in Table do not take into account the availability of the wind resource in Ireland discussed above.

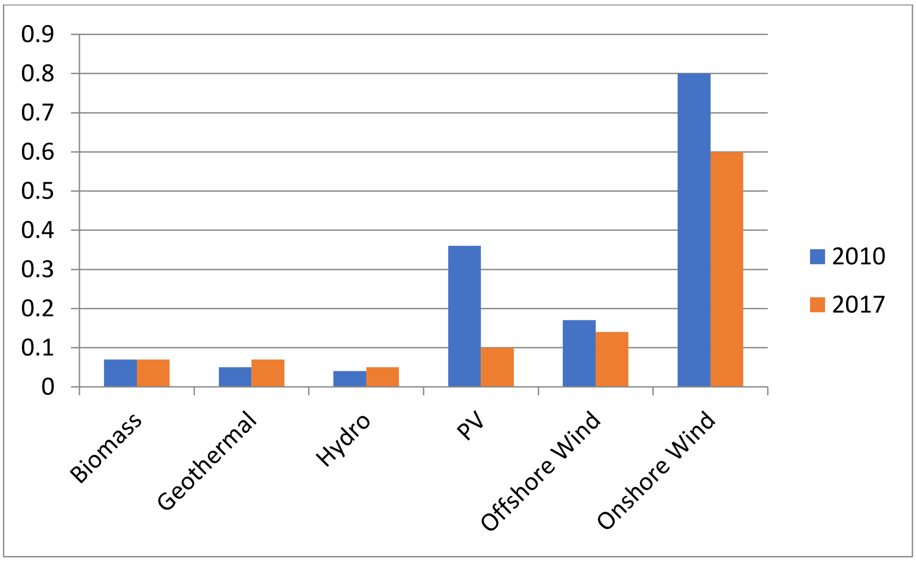

Figure 3.2.1.1.c: Levelized cost of electricity (LOE) for each technology type US Dollars per kWh

[35] https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf. Median values from the IPSS data are used here.

However, it is understood, that there are sometimes significant public acceptance issues in relation to onshore wind, and as was noted in Section 1.5.3 above, the county development plans would appear to limit the available locations for onshore wind in South Kerry in general and Valentia Island in particular. There may well be social and policy constraints to onshore wind as the energy source for electrolysis of H2 in Valentia.

3.2.1.2 Offshore Wind

There has been some initial investigation of the level of public acceptance for offshore wind. At two public meetings this was discussed by Valentia Island residents present in some detail, including the examination of a specific turbine type. At the second meeting a show of hands was recorded as unanimous in favour of looking at the feasibility of the turbine type identified.

Offshore wind turbines are larger and more expensive than onshore. The traditional type is set into the seafloor which is very costly. To compensate for the expense of foundations, offshore turbines are often much larger than onshore. This tends to be more publicly acceptable as they are sited far out from the land and are less obtrusive visually.

3.2.1.3 Grid Analysis

The authors commissioned Mullan Grid Consultancy to do a grid connection analysis with costings for two scenarios: Small scale <600kW of on island generation, and a larger <6MW offshore wind generation project.

The Mullan report found that there was 11.5MW of generation capacity available in Oughtragh 110kV substation. It explored two options outlined below. It also recommended early exploratory engagement with the CRU, which the authors of this report initiated.

Option 1, to connect to MV network on Valentia <600kW was thought marginally economically feasible from the point of view of a small community-owned PV farm. If it were to qualify for RESS, the level of that support would need to guarantee a power price of >€0.18c to achieve a payback of less than 8 years. This does not seem realistic, and not relevant to the Hydrogen scenarios at issue here.

Option 2: involved a 6MW underground MV cable connection to Gurranbane 38kV substation appeared more feasible at the scale of a 6MW offshore turbine. However, on the advice of Mullan Grid's study, the authors of this report did consult with the CRU and were discouraged from pursuing or recommending a simple power to grid scenario. This has informed our exploration of the Case Study 3 opportunity.

3.2.1.4 Photo Voltaic Resource Valentia

Valentia Island has good solar radiation levels relative to those of the country as a whole. The Valentia Island weather station reports annual global solar irradiation levels of 351,794 joules/cm2, which is reasonably good. With the efficiency of PV panels available today this is likely to generate between 900 and 1,000kWh/y per kW installed. This would represent therefore a reasonable opportunity as a supply of power for electrolysis and so is considered in the economic models below.

Discussed above, there are locations on Valentia that would be suitable for PV generation at scale (Section 1.5.3). Initial examination of these locations suggests possible locations in the North East of the island. There have been no contacts made with local landowners as yet, but there are certainly good potential sites – more than enough to meet the demand for power that an electrolyser would need in an off-grid auto-production scenario.

3.2.1.5 Tidal and Wave Energy

There have been considerable advances made into both tidal and wave energy. MaREI is Ireland's marine and renewable energy research, development and innovation Centre. It is coordinated by the Environmental Research Institute (ERI) at University College Cork. There are clear benefits for achieving VIDCO's aims in renewable energy through close co-operation with MaREI who have engaged in research in tidal and wave power as well as wind. Bearing in mind the grid constraints described in Section 3.2.1.3 Grid Analysis above, the conclusions of this report point to the opportunities of integrating H2 and electricity generation.

3.3 Applications of Hydrogen in Valentia

As has been discussed, H2 has applications in three main areas of interest to VIDCO:

- As a grid balance to intermittent renewable energy
- As a vehicle fuel
- As a source of heat

The authors of this study were given a broad commission to study H2 in general as it could be used on Valentia. We felt it important to examine the broadest range of applications. We then discussed these opportunities over the course of the conduct of the study with VIDCO so as to narrow the focus down gradually to best options. This we feel was necessary for the following reasons:

- H2 research and technology development is rapidly evolving.
- The remit for the feasibility study was initially broad and required a full field study to be carried out.
- Opportunities for H2 deployment emerged as the authors engaged with the study area in Valentia.

Sections 3.1 to 3.3 below are thus the product of a winnowing process of other opportunities which were considered but not deemed feasible. Thus, while these opportunities are all found within what could be called the area of project research and demonstration, they are viable.

3.1 H2 in grid balance

There is a considerable research into the use of electrolysis to produce hydrogen as an energy store for electricity that is generated in remote locations where the electricity grid is weaker or where upgrading of electricity infrastructure may have public acceptance issues. The experience of Grid West is significant.

If H2 could be used a means of increasing electricity generation in an area in such a way as to reduce pressure on the grid (and the need for constraint) it would be a valuable asset in the move to achieving increased renewable energy penetration and the replacement of fossil fuel powered electricity generation.

This requires the costs of electrolysis, the storage of the hydrogen produced, and efficiency of the energy transaction to be better or equivalent to rival technologies. There is considerable interest in research into this area.[37] The authors have discussed the concept of H2 a grid balancing option in Valentia and in other western rural communities in Ireland with the TSO and the DSO here and have been told that this is a realistic avenue for further exploration through research and or demonstration projects. However, it is not possible as yet to quantify this benefit and so it should be seen as ancillary to the opportunities examined in the case studies.

3.2 H2 in Transport

3.2.1 Road Vehicles

Hydrogen Fuel Cell Vehicles are at a pre-mass market stage but will be widely available in Europe by 2021. Rapid advances have been made by three manufacturers who are currently leaders in the sector. These are: Honda, Hyundai and Toyota.

The Toyota Mirai, The Honda Clarity and the Hyundai Nexo are high performance vehicles (although they are saloons) with ranges of 500km and more. The cars themselves are expensive, and equally significant, to achieve these ranges require high pressure dispensed hydrogen (700 bar) which makes the refuelling stations themselves also costly. It is not proposed that 700 bar H2 refuelling stations be considered in the short term for Valentia Island. However, there are considerable opportunities available in the production and distribution of H2 (Case Study 2)

There is considerable interest in the use of Hydrogen as a vehicle fuel. SEAFUEL[38] is an Irish led project (NUIG) which is investigating the use of seawater electrolysis in the production of hydrogen to be used in transport in island locations. It is installing a water purifier, electrolyser, compressor, dispenser unit powered by renewable energy to refuel hydrogen vehicles in Tenerife. The project, receives €3.3million in funding from the EU’s

[37] BIG HIT https://www.bighit.eu/ Centurion, Runcorn, UK, https://gtr.ukri.org/projects?ref=133629, GENCOMM https://www.nweurope.eu/projects/project-search/gencomm-generating-energy-secure-communities/ Energiepark Mainz https://www.energiepark-mainz.de

[38] https://seafuel.eu

INTERREG research fund and is in its second year. The authors of this report are engaged in this research and are aware of the potential to extend some of the findings to other projects.

SEAFUEL's main engineering partner Logan Energy[39] worked on the Levenmouth Community Energy Project[40] which was supported by a grant of £4.4 million was awarded to the project through the Scottish Government. This project deploys a fleet of 17 hybrid hydrogen vehicles. The fleet includes 10 Renault Kangoo hydrogen-electric vans, which are zero emissions vehicles and integrated with fuel cell technology. These are leased at a price comparable to diesel vans, presenting the opportunity for local organisations to incorporate sustainable transport into their daily operation. There is clear potential for hydrogen vehicles in light commercial transport deployments – although it must be noted that the examples above are supported by research funding from the EU or national governments.

Figure 3.2.1: One of the Renault Kangoo hydrogen-electric vans deployed in Levenmouth (Image copywrite Logan Energy)

There are opportunities identified in this study for light commercial vans powered by Hydrogen (a Fuel Cell Vehicle or FCV[41]) to be deployed in Valentia Island. The typical range of a Hydrogen hybrid van is 250-300km with a refuelling time considerably less than that of a battery electric vehicle. Potential users of a Fuel Cell Van would be SMEs on or near Valentia (Knightstown) who distribute products in a radius of 150km. Food businesses would be ideal as there would be considerable sustainability promotional advantages to using zero emission delivery vehicles. Small commercial vehicles are also preferable as they are available (or can be converted from existing battery electric vehicles – as seen in Levenmouth and Tenerife) and can operate at reduced pressure 200-350 bar thus reducing the need for and cost of compression.

The small commercial vehicle opportunities will be included in the Case Study 2 analysis below. (Section 5.0)

[39] http://www.loganenergy.com
[40] https://www.brightgreenhydrogen.org.uk/levenmouth-community-energy-project/
[41] It is important to note that there is **no combustion** in a FCV – energy stored in the compressed hydrogen (between 300 and 700 bar) is released through the electrochemical combination of the stored hydrogen and oxygen from the air. The two bi-products of the reaction are energy to power the vehicle and water.

3.2.2 Maritime

This may well represent an area of opportunity for hydrogen fuelled transport on Valentia. The level of emissions generated by the ferry services is significant. The Energy Master Plan study estimated that 56,000 litres of diesel are used for ferry transport annually. This produces an estimated 150 tonnes of CO2. Figure 3.2.2a Below shows ferry energy use and CO2 emissions in comparison to other energy uses on the island. Ferry diesel use and consequent CO2 emissions represent 39% of all transport CO2 emissions on Valentia Island. This creates a pressing case for pursuing the reduction of carbon emissions on the islands through exploring the option for conversion to hydrogen fuel cell technology.

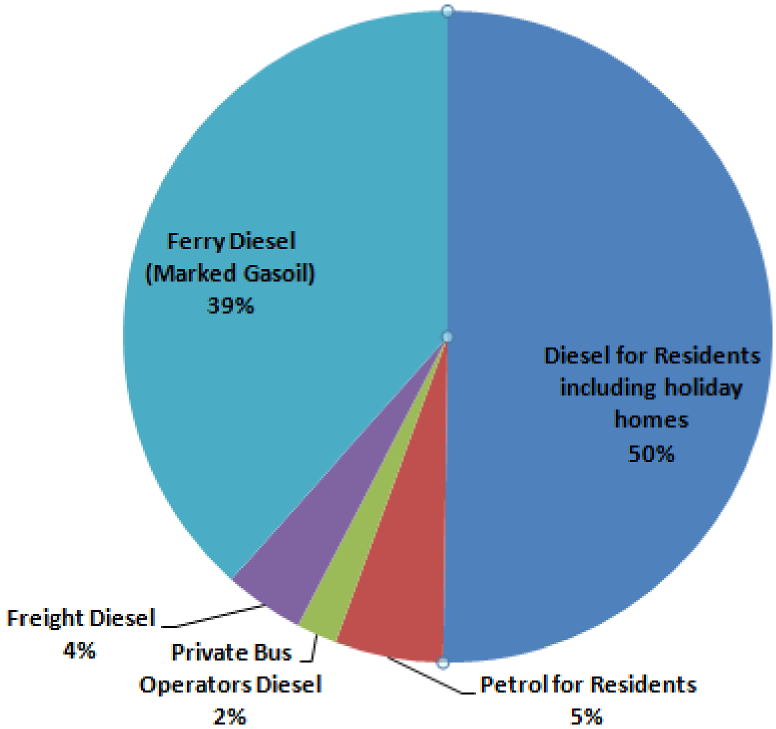

Figure 3.2.2a: Transport Fuel Use Valentia Island
(Data from Purthill Energy Consulting, *Valentia Island Energy Master Plan* 2018)

While this technology is still at the demonstration stage (BIG HIT, the Osterøy car ferry, Norway) it should be a priority for investigation in any future hydrogen feasibility work in Valentia. The limited number of decision-makers involved could represent an opportunity. It is significant that Valentia has a strong sustainable tourism reputation that would be very valuable in leveraging not only public acceptance, but also positive public attitudes as a driver of technology switching. There are also research advantages for Valentia Island over other islands in Ireland given the more relatively clement conditions the ferry operates in.

Figure 3.2.2b: Fergusson Marine Hydrogen Ferry (concept) which is being built as part of the HySeas III[42] Project (image copywrite Fergusson Marine[43])

Maritime hydrogen use feasibility is included in the case studies (Section 6) below

3.3 H2 in Heat

3.3.1 Domestic Heat

Heating for buildings accounts from more than a third of all global energy related carbon dioxide emissions[44]. In Valentia as we have seen that permanent residents using 'home heating oil' and LPG on Valentia consume 2,283,049 kWh per annum. This represents a possible deployment opportunity for a project which aimed to replace carbon fuel heating with hydrogen.

There is a wide variety of existing and new markets where hydrogen electrolysis can play a major role in the replacement of fossil fuels in heating applications. Again, there are research projects in train in Europe looking at these applications. Hydeploy[45] aims to inject hydrogen into the existing gas grid at concentrations of 20%.

Valentia's distance from the gas grid can be seen as presenting an opportunity for hydrogen research projects.

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[42] https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-transport/waterborne/hyseas-iii
[43] https://www.scottish-enterprise-mediacentre.com/news/ferguson-marine-to-develop-world-first-renewables-powered-hydrogen-ferry
44 IEA. Heating without global warming: market developments and policy considerations for renewable heat. Paris, France: International Energy Agency; 2014. Available at: http://www.iea.org/publications/freepublications/publication/FeaturedInsight_HeatingWithoutGlobalWarming_FINAL
[45] https://hydeploy.co.uk/

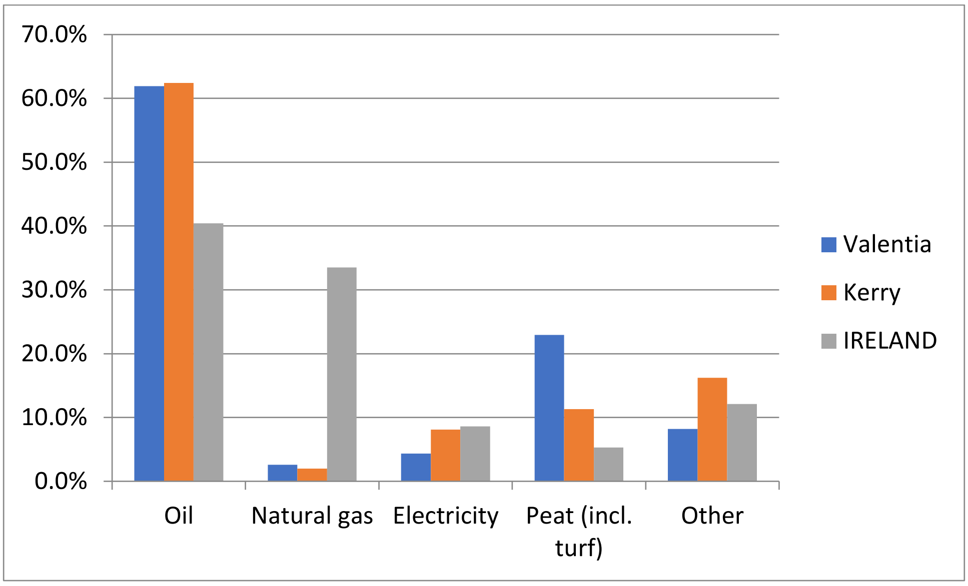

Figure 3.3.1: Fuel use of households for central heating.

The relative lack of the natural gas alternative in Valentia removes the cheapest form of heating from the system. Hydrogen would not compete with natural gas either in Valentia, or in the wider Kerry area.

3.3.2 Non-domestic heat uses.

There are a small number of commercial users of LNG and diesel for heat. These are described in Table 3.2.2 along with the energy demanded per annum for each:

	Electicity kWh	Electricity Cost	Kerosene / Gas Oil kWh	Kerosene/ Gas Oil Cost	LPG kWh	LPG Cost	Total Cost	Primary Energy kWh	CO2 Tonnes
Valentia Slate Quarry	24,240	€15,852	43,692	€2,683			€18,535	98480.4	21.4
Valentia Island Farmhouse Dairy	22,839	€3,026					€3,026	47505.12	9.3
Royal Valentia Hotel	127,075	€14,501	155,667	€8,596	144,225	€13,689	€36,786	594197.2	131.0
Murphy Marine Services	19,956	€3,291					€3,291	41508.48	8.2
Skellig Experience	126,320	€14,354					€14,354	262745.6	51.7
Cable Station/Plastics Factory	15,849	€2,892			532,524	€39,796	€42,688	618742.32	146.7
Totals	336,279	€53,916	199,359	€11,279	676,749	€53,485	€118,680	1663179.12	368.3

Table 3.3.2: Commercial & Industrial Sectors Baseline Energy Usage
(taken from Purthill Energy Consultants, *Valentia Island Energy Master Plan*, 2019, p26.)

We identify two potential opportunities for further research projects from these buildings. These are:

- Location 1: Cable Station Plastic Factory LPG replacement
- Location 2: Royal Valentia Hotel LPG replacement

These are key opportunities for hydrogen deployment. A funded research project which replaced or retrofitted existing LPG boilers with hydrogen burners is feasible. There is currently keen interest in the development and trialling of hydrogen boilers, including CHP. A Giacomini[46] boiler is currently being deployed as part of BIG HIT. A BDR Thermea boiler is being trialled in Rozenburgh in the Netherlands[47] and Toyota are testing large scale hydrogen combustion boilers. Each of these offer valuable research opportunities to VIDCO and Valentia Island generally.

These two energy users are incorporated into the case studies in Section 4 below.

Location 1: Cable Station Plastic Factory

This is a large historic building in Knightstown which was formerly the site of the administration of the transatlantic telegraph interconnector between Europe and North America.

In July 2018, the Pollmeier family of Valentia Industries donated the Cable Station building to the Valentia Island Development Company to facilitate its restoration. While it has been proposed to locate an innovation hub in the building, the authors have been informed that the plastics factory will continue to operate in its current location or within the curtilage of the building. Thus, there will be a considerable heat demand both for the factory and from the proposed innovation hub.

[46] https://www.giacomini.com/en/news/2018/05/09/official-opening-big-hit-project-kirkwall-may-15th-2018
[47] https://www.bdrthermeagroup.com/en/news/hydrogen

Figure 3.3.2a: Cable Station Knightstown Valentia

This report explores the viability of conducting research into hydrogen as a heating source within the innovation hub which will use the energy demand from the factory and the building as a whole as a demonstration opportunity.

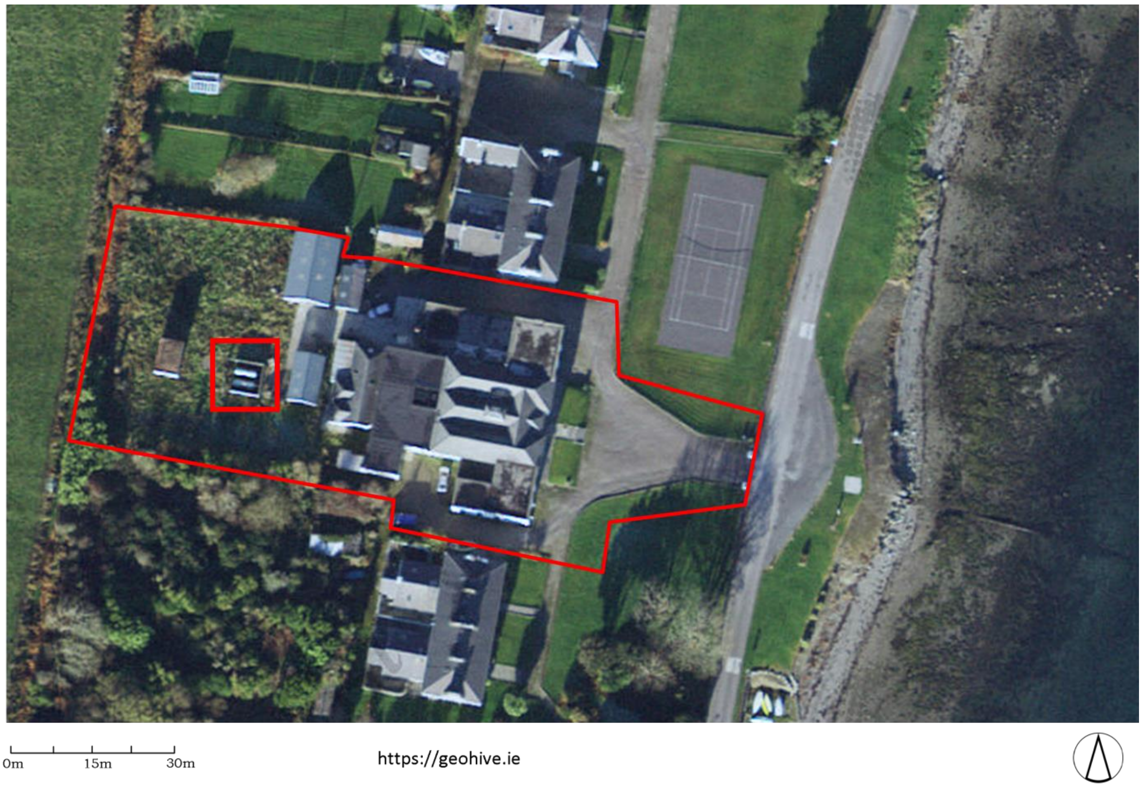

Figure 3.3.2b: Arial View of Cable Station Site (outline in red)

The smaller square box indicates the location of the LPG tanks used by the Plastic Factory Boiler.

Location 2: Royal Valentia Hotel

This is an historic family run landmark 30-bedroom hotel located in Knightstown. It has an LPG demand for water heating that is generally consistent throughout the year, with some increase in LPG use for space heating in winter. The authors were requested to examine the feasibility of including the hotels energy demand in any proposed research project owing to its significance as a community amenity and informal information hub in addition to its value as a novel demonstrator type.

Figure 3.3.2c: Royal Valentia Hotel, Knightstown – Elevation View

Figure 3.3.2d: Royal Valentia Hotel, Knightstown – Aerial View

Hotel location outlined in red

The aerial view of the Hotel’s location indicates that it is a restricted site in a built-up area. There is an LPG tank in located to the west of the hotel which it would be possible to exchange.

The two proposed locations for demonstration hydrogen boilers are between 450m (direct) and 560m (by road) of one another (see Figure 3.3.2e). Since it would be proposed to locate an electrolyser and hydrogen storage at the cable station, a smaller tank would also be needed to store adequate hydrogen at the hotel also. These storage tanks are not required to be large or high-pressure as there should be consistent hydrogen production by an electrolyser located in the cable station or at least nearby on the island.

Figure 3.2.2e: Cable Station and Royal Valentia Hotel in relation to one another

4.0 Case Study 1: Light Industrial Hydrogen to Heat

4.1 Opportunity

The opportunity outlined here is for a non-commercial research project to install an electrolyser at the cable station in Valentia Island which would be used to produce hydrogen for a medium scale community building and commercial process gas to heat application. The novel application would be to demonstrate the feasibility of competing models of power supply to gas in the heating sector.

At present there is unlikely to be cost parity between fossil fuel price and the price of hydrogen produced by electrolysis. However, it will be possible to achieve parity with the improvement of electrolyser efficiency, the identification of the most favourable heating applications and the development of intermittent renewable power supply and electrolysis integrated demand management systems.

There would be a number of research and training opportunities for adopting such an approach:

It would be possible to test the effects of the energy supply on the electrolyser and the supply of hydrogen on the electrolyser(s) installed. The supply could be made ‘virtually’ green for a large number of scenarios: wind, PV, Tidal etc. The project would take inputs from existing offsite installed intermittent generators to model their effect on the electrolysers and hydrogen supply. This research would be of value to electrolyser manufacturers, boiler developers and electricity generators who wished to investigate the value effect of electrolysis on their real-world market conditions.

The potential for real world investigation into the effects of hydrogen demand and production on the electricity grid in a demand side management scenario would also be significant. In particular as this would be taking place in where the grid is relatively under-developed.

The research programme would also support the training and development of expertise in hydrogen production in a real-world application. The goal of establishing an internationally significant innovation centre in Valentia at the cable station would be supported.

There could be significant long-term benefits to this aspect of the proposal in that there is a widely recognised opportunity for remote coastal communities to bring together a suite of technologies and practices to take on a significant role in the green hydrogen economy.

4.2 Technology

The project would engage with the manufacturers of existing electrolysers in a competitive bid process to ensure value for money. There would be minimal need for compression in this application it is proposed to produce the hydrogen at the point of consumption. There are however issues to overcome in current the lack of onsite renewable generation. It is proposed to overcome this through the use in this case study of grid mains electricity.

Therefore, the technology and equipment requirements for this opportunity would be:

1. Electrolyser
2. Storage
3. Energy Supply
4. Boiler
5. Heat System

4.2.1 Electrolyser-Hydrogen Production Type

There are two hydrogen technologies that we have considered:

1. Alkaline Electrolysis
2. Cryogenic Gas Separation

4.2.1.1: Alkaline Electrolysis:

This is a well-established and widely used electrolysis technology. Alkaline electrolysers' have greater efficiency and power (for single unit) as well as lower capital cost than PEM electrolysers. They also do not use expensive electro catalysts (such as platinum) and have lower service intervals and reasonably good durability (we apply 7 years in the calculations here). The Alkaline Electrolyser studied here is amongst the best tested and durable in comparable conditions to those proposed in Valentia that is available.

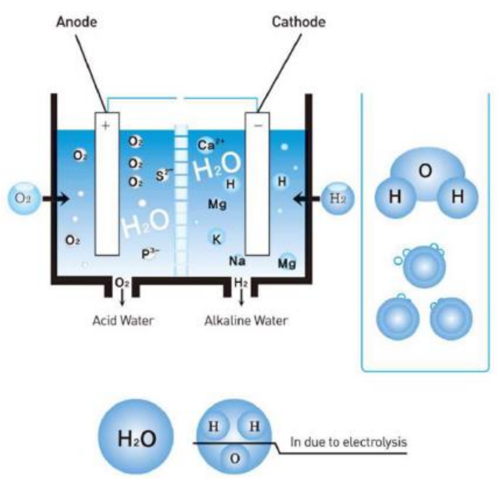

Figure 4.2.1.1(a) Alkaline Electrolysis

Figure 4.2.1.1(b) Alkaline Electrolyser

It is referred to in the case studies below as ***Electrolyser 1 (E1)***

4.1.1.2 Cryogenic Separation

This is a novel method of producing H2 from water using a non-membrane system. In simplest terms the hydrogen and oxygen that are present in H2O are separated by a cryogenic distillation process which exploits the differences in their freezing points. This is a more robust technology and in the calculations below is given a longer life-span of 10 years

It is referred to in the case studies below as ***Electrolyser 2 (E2)***

4.3 Hydrogen Demand – Electrolyser Sizing

The Valentia Plastics Factory at the Cable station operates on a five-day 40-hour week basis. The annual demand is evenly spread throughout the year. The energy demand therefore is estimated as 277kWh/h[48]. This energy demand of the factory equates to 8.39kgH2/h which will therefore determine the size of the electrolyser required.

The Cable Station is to be fully refurbished and put into use as a public resource/community building. The use of the building is expected to be similar to that of offices, and exhibition centres. Its use is assumed to be 9am - 6pm Monday-Saturday, all year round (excluding Public Holidays). The building's footprint is approximately 1,120sqm[49]. It can be presumed that the Cable Station renovations will be carried out to high energy efficiency standards, which would imply an annual heat demand of approximately 80kWh/sqm in heating. This predicts a heating demand of 89,600kWh/y. However, as the Plastics Factory is using heat on its manufacturing process for 1920 hrs per year out of the predicted 3,276 hrs the Cable Station's operation, or 58% of the time. Waste heat from the plastics factory can be recycled through the cable station, suggesting that the actual heat demand will be between 60,000 and 52,000kWh. We will use the higher figure in a more conservative estimate of the heat requirement of the Cable Station

This extra demand should not require a greater kgH2/hr requirement as it would occur outside the demand time of the factory. It could, however, increase the overall level of H2 required to be produced by the electrolysers which would be required to run for longer.

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[48] 532,000 kWh/y ÷ 48 (wks./y) = 2,216.6 kWh/d = 277kWh/h

[49] Based on authors' site survey of the building

4.4 Economic Analysis

4.4.1 Projected Demand

We examined a case whereby the heat demand of the Cable Station and the factory alone were supplied with heating from H2.

Input	Value	Preferred units
	Light industrial heating process	
Heating demand in factory	532,000	kWh per year
LPG consumption	39.191176	tonnes per year
Factory operation hours	1,920	hours per year
Estimated H2 demand	16,121	kg per year
EST COST (LPG)	**€39,796**	**EURO/y**
	Large public building	
Heating demand in building	60,000	kWh per year
Heating operation hours (est.)	3276	hours per year
Estimated H2 demand	1,818	kg per year
EST COST (LPG)	**€5,640**	**EURO/y**
	CASE STUDY 1	
Total Demand	**17,939**	**kg per year**
Total Cost	**€45,436**	**per year**

Table 4.4.1 Energy Demand and Costs

Notes to Table 4.4.1:
1kg H2 = 33kWh[50]
1kW LPG = €0.094[51] (the Cable Station will benefit from the bulk LPG purchased by the factory)

[50] https://hypertextbook.com/facts/2005/MichelleFung.shtml
[51] https://www.seai.ie/publications/Commercial-Fuel-Cost-Comparison.pdf

4.4.2 Projected Capital and O&M Costs (excluding power costs)

Capital Cost	**E1**	**E2**
Electrolyser Cost	€360,000	€450,000
Cooling	€17,500	incl
Enclosure	€32,000	incl
Install	€5,700	incl
Parts	€9,700	incl
Civils	€20,000	€20,000
Storage	€50,000	€50,000
Total	€494,900	€520,000
Life Span Yrs	7	10
Annualized Capital Cost	**€70,700**	**€52,000**
O&M Costs		
Maintenance/y	€20,000	€5,000
Operation/y	€15,000	€10,000
Insurance/y	€3,000	€3,000
Total O&M/y	**€38,000**	**€18,000**
Total Non Power Annual Costs	€108,700	€70,000

Table 4.4.2 Costs for Electrolyser 1 and 2.

Notes to Table 4.4.2

Parts requirement and maintenance costs are low for E2: there are no expensive materials needed, and the construction is stainless steel. Install costs are lower and the costs include training of local engineer to carry out maintenance. E2 also has a longer guaranteed lifespan.

Figures are based on anonymized quotations from suppliers in Appendix. Operation includes water costs, which for 17,939kgH2 is estimated to be 179,390 litres[52]or179m^3 water. For comparison, this would be in the lowest water use band for businesses in Ireland[53].

4.4.3 Modelled Energy Supply Costs

In this Case Study, electricity for the electrolysis would come from the grid. E1 operates at 60% efficiency, while E2 achieves approximately 65% efficiency. We assumed two scenarios for grid price electricity. Neither is fixed at this time and would have to be negotiated with a power supplier who was willing to be a partner in the proposed research project.

[52] Approximately 10 litres per kg H2
[53] Band 1 <1,000m3 https://www.water.ie/for-business/billing-explained/charges/

Total Heat Demand	**592,000**	**kWh per year**
	17,939	**kg per year**
	E1	**E2**
Total Non-Power Annual Costs	**€108,700**	**€70,000**
kWh electricity per kg H2	**55**	**50**
Total Power Requirement kWh/y	**986,667**	**896,970**
Total Cost per kWh delivered low	**€49,333**	**€44,848**
Total Cost per kWh delivered high	**€98,667**	**€89,697**
Total Energy Costs Delivered Low	**€158,033**	**€114,848**

Table 4.4.3a Total Delivered Energy Costs Case Study 1

These energy costs would compare with the status quo as follows:

H2 Cost/y v Existing Fossil Fuel Costs	Status Quo	Low Scenario		High Scenario	
		E1	E2	E1	E2
Light industrial heating process	€39,796	€142,016	€103,208	€186,350	€143,511
Large public building	€5,640	€16,017	€11,640	€21,017	€16,186

Table 4.4.3b Case Study Projected Delivered Energy Costs v Status Quo

Thus, it is clear that these prices for heat may not be economic when compared directly to LPG. However, there are a number of significant issues which are not captured by a simplistic like for like analysis and these are discussed below:

4.5 Benefits

As discussed in Section 3.0 there are significant opportunities for VIDCO and the community of Valentia to stimulate employment through innovation studies, product development and research.

4.5.1 Exemplars

The Pure Energy Centre[54] in Shetland is a leading technology and training company that has manufactured and installed a large number of electrolysers throughout Europe. It employs full-time engineers and business management staff and hosts training for students up to PhD level. At present its projects include €9 million INTERREG NWE

[54] https://pureenergycentre.com/about/

GenComm[55] hydrogen project, €2.5 million Hylantic[56] Atlantic Area hydrogen project, a €2.5 million Handiheat[57] Northern Periphery and Arctic (NPA) project.

European Marine Energy Centre (EMEC)[58] As well as their wave and tidal testing sites, EMEC has an onshore hydrogen production plant in Eday, Orkney Islands, Scotland, where green hydrogen is generated from surplus tidal and wind energy. Their demonstration site is a key element in a range of hydrogen projects including Surf and Turf[59](receiving £1.3 million of Scottish Government funding) and BIG HIT[60] (INTERREG funded .2m), ITEG[61] (€11 million of funding by the Interreg North-West Europe programme)

Figure 4.5.1 Locations of Hydrogen Research Islands in relation to Valentia Island

[55] https://www.nweurope.eu/projects/project-search/gencomm-generating-energy-secure-communities/.
NOTE: The authors are associate partners on the GENCOMM Project
[56] http://hylantic.com/
[57] https://www.keep.eu/project/22723/heat-and-anaerobic-digestion-for-district-heating
[58] http://www.emec.org.uk/
[59] http://www.surfnturf.org.uk/
[60] https://www.bighit.eu
[61] ITEG - Integrating Tidal energy into the European Grid https://www.nweurope.eu/projects/project-search/iteg-integrating-tidal-energy-into-the-european-grid/

Comharchumann Fuinneamh Oileáin Arainn Teo[62] on the Aran Islands in Galway is currently engaged in two Hydrogen research projects. SEAFUEL[63] (discussed in Section 3.2 above) is a €3m research project investigating the electrolysis of seawater in island locations for transport applications, and HUGE[64] which assesses the hydrogen renewable energy chain from production through storage, transport and on to the end-user in the Northern Periphery and Arctic (NPA) region.

There is an appetite for community participation in renewable energy technology development research which is being promoted within both H2020 and INTERREG. Demonstration and distribution hydrogen deployment research with partner inputs from community organisations such as VIDCO are very feasible vectors for the facilitation of opportunities such as outlined in Case 1 here.

Thus, with the level of background work done, VIDCO, with the support of local citizens and community organizations could investigate research opportunities with established third level institutions in Ireland (and their partners abroad) to part fund the capital cost of the opportunity above. There are likely downstream benefits that could accrue in terms of establishing a reputation for Valentia as a research project participant. There would also be technical training and expertise transfers that could be leveraged by VIDCO and the community to create second-stage projects both research and commercial.

4.6 Risk Analysis

As with all research projects, acquiring funding is critical. We have discussed how the electrolyser equipment and installation costs are probably too high to make the opportunity economically viable on a purely commercial basis.

With part funding from INTERREG, H2020 or other sources, the project may not incur losses and may present close to parity with fossil fuel prices for the two energy users identified. However, INTERREG and H2020 calls are very competitive processes and success in research grant applications is far from guaranteed.

There is a risk of project failure through not acquiring the necessary supports.

4.6.1 Risk Mitigation

These risks could be mitigated by:

- Choosing the correct project co-ordinator
- Identifying experienced and previously successful application partners.
- Producing the correct letters of support (from local and national policy makers, stakeholder organisations, etc)

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[62] http://www.aranislandsenergycoop.ie/
[63] http://www.seafuel.eu/
[64] https://www.keep.eu/project/20651/HUGE_preparatory

- Acquiring all necessary permissions and licenses in advance (though in principle can be enough)
- Multiple Applications to different funding bodies
- Choosing well prepared and innovative projects to apply for
- Sharing application workload between partners so that no partner takes on too much of the preparation time burden
- Explaining and promoting the projects aims to the community

These could be some of the main means by which risks can be avoided. The opportunity outlined above may not require investment of large sums prior to receipt of grant acceptance. However, grant funded reach projects require persistence and dedication and the identification of key partners and personnel and taking into account the scale of this project compared to the possible benefits, VIDCO may wish to consider other project options.

4.7 Suggested Next Steps

VIDCO assesses the viability and suitability of the opportunity

There are a number of opportunities for grant funding of research and deployment projects of this scale and these have been identified by the authors and are contained within the accompanying briefing document.

VIDCO may wish to pursue other opportunities from the Case Studies below

5.0 Case Study 2

Projects investigating the use of H2 in the transport sector have a number of key advantages over other sectors. Transport is highly visible and thus offers high public awareness rewards to policy makers. There is a strong coalition of significant stakeholders in the H2 sector being brought together in Ireland around transport and mobility. This coalition would be a powerful resource for a community that wished to enter the H2 Transport sector in these early stages. Valentia is unusual (but not unique) in that it is a Western off-shore location that is connected to the mainland via a land-bridge. Its geography therefore has advantages is terms of renewable energy resources (wind), while it is not remote from a potential H2 road transport market.

5.1 Technology

5.1.2 230kW Electrolyser

This opportunity represents an expansion of that in Case Study 1. The installation a medium scale electrolyser at the Cable Station to meet a heat demand is also investigated here, and so the same technological opportunities as were discussed in Section 4.2 and 4.3 are relevant.

The sizing of the electrolyser in Case Study 1 (230kW, 92kg H2/d) would be greater than the heating demand outlined there. These electrolyser sizes, on a 24/7 operational basis, would be estimated to produce up to 33,580kg of H2. This would be 15,641kg higher than the demand outlined Case 1. Therefore, there may be excess capacity that would be included in the Capex, but which may not be recouped by potential energy sales.

The distribution of this excess production would however involve additional Capex. There would be a requirement to install higher compression and storage. VIDCO may consider that this be at a lower pressure than the standard passenger vehicles (700 bar). 300 bar storage is feasible and may be adequate to the need of the applications discussed below. This Case Study assesses whether revenues from additional energy uses defray these additional costs.

5.1.3 Small Commercial Transport

As discussed above in relation to Levenmouth and Tenerife (Section 3.2.1) there are deployments of small commercial vehicles powered by hydrogen. These are generally conversions of light EV Vans: for example, Renault Kangoo EVs fitted with 300 bar storage tanks and fuel cells. This increases the range of the EV Vans to between 250 and 300km. This is probably a suitable range for delivery vehicles in or near Valentia and may overcome the range anxiety of most applications. It must also be noted that fill-time of an FCV is very much shorter than an EC and is close to that of a Petrol or Diesel Van.

This fast turnaround is reassuring to delivery vehicle owners. Added to this the opportunity for a food producer and distributor to demonstrate their engagement with innovative sustainability means that some fuel price differences between FCV and Diesel Vans could be tolerated. Thus, an analysis of this additional opportunity is very much warranted.

5.1.4 Buses

Deployment of Hydrogen fuelled tour buses as part is also feasible in this Case Study. EV Buses have similar range issues as EV cars, there is a problem with recharging that limits time in service for EV Buses. There are also concerns about performance in rough terrain conditions for EV Buses. There is a strong case to be made for deployment of FC Buses in Valentia specifically, but Kerry and the West Coast more generally.

Taking the lessons learnt from Case Study 1 about technology maturity, the feasibility of VIDCO being a significant partner in a research project part of which deployed FC Buses as a trial to a wider deployment of the technology throughout the region should be investigated here.

5.1.5 Grid Power

We model the same opportunities as were outlined in the Case Study 1 Section 4.4.3: that is, using a cheaper than retail price per kWh negotiated through a partnership with a supplier as part of a research initiative.

5.2 Opportunities

5.2.1 Heat

We modelled for the heat demand of the Plastics Factory and the Cable Station as in Case Study 1, however, we added the opportunity for heat in the Royal Valentia Hotel. This would likely add an additional heat demand 155,667 kWh per year which will take up unused capacity from the 230kW electrolyser. This would probably bring the total heating demand to 747,667kWh/y

5.2.2 Commercial Transport

Our model increases the specification of the installation to include a compressor (350 bar) and a H2 fuel dispenser. This would enable the refuelling of road vehicles. This opportunity models for the purchase and use of 5 delivery vehicles and 3 tour busses. We priced both for the conversion of Renault Kangoo EVs to FCVs with roof mounted hydrogen storage of approximately 3kg H2 tanks at 300 bar and for the purpose-built Renault FCV which is due to start retailing in 2020 (€48,000)[65]. We assume the vehicles will be in operation most of the year (360 days) and have journey distances of 150km per day – which would for example be the distance of a round trip from Valentia to Tralee round trip using the ferry.

[65] https://www.autocar.co.uk/car-news/new-cars/renault-launches-hydrogen-range-extender-electric-kangoo-and-master-vans

Figure 5.2.2a Modified Kangoo FCV

Figure 5.2.2a Production Model Renault FCV

We also model for tour buses as suggested in Section 5.1.4. We assume three buses each journeying 100km per day. The buses are small HIACE style 10-seaters, modified similarly to the vans and at the same cost.

5.3 Business Case

5.3.1 Projected Demand

The potential overall heat and power demand for all applications is shown in Table 5.3.1

Input	Value	units	
Light industrial heating process			
Heating demand in factory	532,000	kWh per year	
or LPG consumption	39.19117647	tonnes per year	
Factory operation hours	1,920	hours per year	
H2 Demand/day	44		
H2 demand/y	16,121	kg per year	
EST COST (LPG)	**€39,796**	**EURO/y**	
Large public building			
Heating demand in building	60,000	kWh per year	
Heating operation hours (est)	3,276	hours per year	
H2 Demand/day	5		
H2 demand/y	1,818	kg per year	
EST COST (LPG)	**€5,640**	**EURO/y**	
Large Private building			
Heating demand in building	155,667	kWh per year	
Heating operation hours	8,760	hours per year	
H2 Demand/day	12.9		
H2 demand/y	4,717	kg per year	
COST (LPG)	**€14,633**	**EURO/y**	
Delivery vehicles			
Utilisation rate	750	150	km/d/vehicle
Operational rate	360	days per year	
Diesel/y	33,480	Litres	
Energy consumption	10.5	kg per day	

H2 demand	3,780.0	kg per year	
COST Diesel	**€44,863**	**EURO/y**	
	5	vans	
Bus Transport			
Utilisation rate	300	100	km/d/vehicle
Operational Rate	270	days p/a	
Energy consumption	37.2	litres p/d	
Energy consumption	10,044	litres diesel p/a	
Energy consumption	100,440	kWh p/a	
Energy consumption	11.3	kg H2 p/d	
H2 demand	3,044	kg per year	
EST COST Diesel	**€13,459**	**EURO/y**	
	3	buses	
TOTAL DEMAND	**29,480**	**kg H2/y**	

Table 5.3.1: Energy Demand across All Case 2 Opportunities

The total H2 demand modelled is 29,480kgs. This is 3,370kgs less than 32,850kgs capacity output from the electrolysers modelled. However, we feel that this is in effect close to full capacity as it is necessary to build in the possibility of plant downtime. We have worked out a daily demand maximum (when all demands must be met simultaneously[66]) as a precaution so as to ensure that the kg/hr output of the electrolyser can match the demand. There is in effect 6kg per day 'headroom'.

5.3.2 Supply

We assume the same electrolysers as discussed in Section 4.4.2, but as Table 5.2.2a shows, there are probable additional costs in order to meet the demands of the new applications:

[66] This is purely and conservatively precautionary – there is 300kg storage built in.

Capital Cost	**E1**	**E2**
Electrolyser Cost	€360,000	€450,000
Cooling	€17,500	incl
Enclosure	€32,000	incl
Install	€5,700	incl
Parts	€9,700	incl
Civils	€20,000	€20,000
Compressor	€98,000	€98,000
Dispenser	€127,000	€127,000
Storage	€50,000	€50,000
Total	€719,900	€745,000
Life Span Yrs.	7	10
Vans, No:	5	5
Van Modification Cost	€250,000	€250,000
Buses, No:	3	3
Bus Modification	€150,000	€150,000
Annualized Capital Cost	**€202,843**	**€174,500**
O&M Costs		
Maintenance/y	€20,000	€5,000
Operation/y	€15,000	€10,000
Admin	€5,000	€5,000
Insurance/y	€3,000	€3,000
Total O&M/y	**€43,000**	**€23,000**
Total Non-Power Annual Costs	€245,843	€197,500
kWh electricity per kg H2	55	50

Table 5.2.2a: Energy Supply Costs

Notes to Table 5.2.2a
The Compressor and the Dispenser are 350bar
The Electrolyser lifespan is assumed as 7 in the case of E1 and 10 in the case of E2
The Van and Bus lifespan is assumed as 4 years
There is an Admin budget line as there will be fuel sales to administer.
Insurance is for the business (public liability, etc), not the vehicles in this model.

These costs were annualised and, taken with the power supply costs that were discussed in 5.1.6, provide for a comparison between Case Study 2 delivered Energy Costs v Status Quo in Table 5.2.2b. As with the pervious Case Study, we assume low and high energy cost scenarios.

H2 Cost/y vs Existing Fossil Fuel Costs	Staus Quo	Low Scenario		High Scenario	
		E1	E2	E1	E2
Light industrial heating process	€39,796	€178,772	€148,306	€223,105	€188,609
Large public building	€5,640	€25,162	€43,395	€25,162	€21,272
Large Private building	€14,633	€52,310	€43,395	€25,162	€21,272
Delivery vehicles	€44,863	€41,917	€34,774	€52,312	€44,224
Bus Transport	€13,459	€33,752	€28,000	€42,122	€35,609

Table 5.2.2b: Energy delivered under Case 2 high and low scenarios compared to status quo

The calculations suggest that the road vehicles (in particular the commercial vans) may offer the best opportunity. As in Case Study 1, LPG seems to outperform H2 in terms of cost for heat energy delivered. The status quo diesel outperforms FCV Buses in the scenario, but this could be misleading as discussed below. The cost of Hydrogen in the low-cost scenarios for E1 and E2 appears better than the status quo for commercial delivery vehicles, but again, this is not the whole picture.

In the case of buses, we are comparing a scenario where new buses are purchased with a status quo where no buses have been purchased. Figure 5.2.2 show the point at which the difference cost between new FCVs and New Diesel (€15,000) is outweighed by the difference in cost between Hydrogen and Diesel fuel.

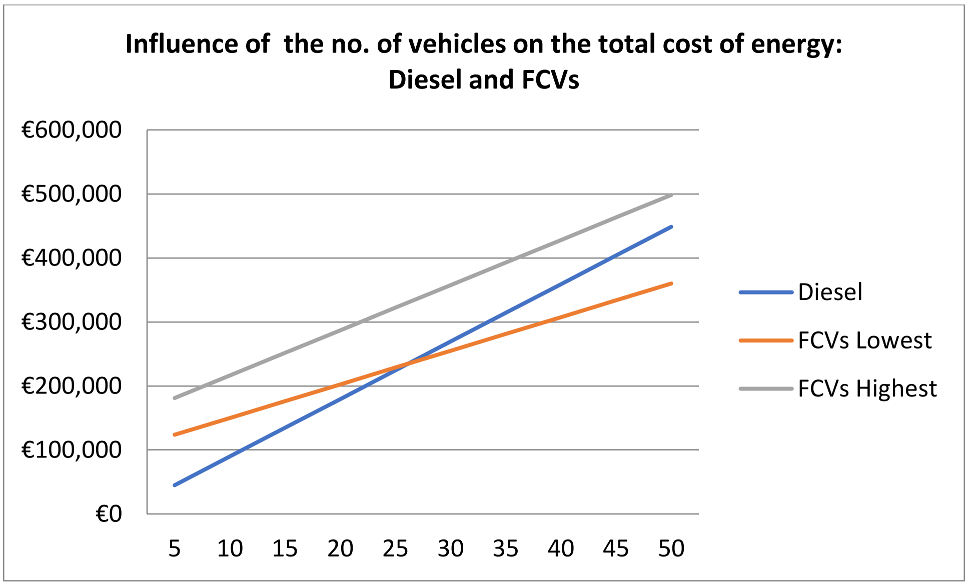

Figure 5.2.2: Influence of the number of vehicles on the cost of energy: Diesel and FCVs

The number of vehicles seems to have an impact on the viability of the price of hydrogen. The 'crossover' point in Figure 5.2.2 is 20 delivery vehicles or in effect 15,000 kgH2 as FCV fuel per year. While this seems like a daunting quantity of fuel to make a business case, it is worth bearing in mind for Case Study 3.

With this level of FCV H2 dispensing, Table 5.2.2.c shows a possible breakeven cost of kg/H2

Cost per kg delivered LOW	**€12.47**	**€9.00**
Cost per kg delivered HIGH	**€15.22**	**€11.50**

Table 5.2.2.c

It is highly significant to this Case Study, and Case Study 3, that this is break even with no subsidy. Were there to be Capex grant support, this price would be significantly lower. For this scenario, please see Section 6.4 below

In a scenario where VIDCO purchased the electrolyser and supplied the H2 to customers who bore the additional cost difference between H2 and Diesel cars themselves, it is possible that customers could in most scenarios (Low and High electricity supply cases) save enough on their fuel to recoup the additional initial outlay.

H2 Cost/y v Existing Fossil Fuel Costs	Status Quo	Low Scenario		High Scenario	
		E1	E2	E1	E2
Cost per 100k	€16.08	€12.47	€9.00	€15.22	€11.50
Annually	€8,683.20	€6,735.34	€4,860.00	€8,220.34	€6,210.00
Difference	-	€1,947.86	€3,823.20	€462.86	€2,473.20
Payback/yrs.	-	7.7	3.9	32.4	6.1

Table 5.2.2c: Fuel cost difference across scenarios

Notes to Table 5.2.2c
H2 supplier (e.g. VIDCO) bears the CAPEX of the electrolyser and dispenser and the O&M costs of the dispenser
The difference in cost between the FCV Van and a diesel van is €15,000 and this cost is borne by the customer.
Diesel cost is €1.34 per litre (though this is set to increase rapidly)
Diesel efficiency is 12L/100k, H2 efficiency is 1kg/100km

Table 5.2.2c demonstrates that with an expanded market for FCVs over time there are scenarios where there would be a value for money proposition to possible customers to choose FCVs. They could have a payback period, at present cost of diesel of between 3.9-7.7yrs. With the price of diesel set to rise, this payback could well improve over time.

5.4 Benefits

The expansion of the H2 uses from Case Study 1 suggests the benefits of:

- Increased markets for the excess H2 produced – of both kind and scale
- Engagement with the transport sector of the Hydrogen economy that has the quickest route to user value
- Gaining experience in additional engineering and hydrogen business opportunities
- Being early adopters of H2 transport in Ireland (there are discussions of the roll-out of H2 transport infrastructure, but nothing is on the ground in Ireland yet
- The opportunity of running a more publicly note able flagship project, namely high-visible road vehicles which could become mobile advertisements of VIDCO's innovation aims.
- Chance to participate in Hydrogen transport research which is at an inflexion point in adoption and public consciousness and is currently being heavily promoted by funding streams.
- Reaping the benefits of addressing head-on the consequence of unavoidable policy decision, namely carbon taxes. There is much to be gained by engaging imaginatively and actively with providing affordable and practicable solutions to the vexed issue of the decarbonisation of the rural transport network in Ireland.

5.5 Risk Analysis

As with Case Study 1, there are risks involved in embarking on ambitious innovation projects. We feel however that these have been adequately addressed in Section 4.6 and that there is only the need to add these observations that are particular to this Case Study.

1. The dispensing of fuel is a business. It involves managing a forecourt that would carry public liability risks
2. There are responsibilities to those employed to run the dispensing station
3. There is a higher Capex cost.
4. There is additional equipment that needs to be maintained.
5. There is a risk that customers will be reluctant to purchase the FCVs

5.5.1 Risk Mitigation:

1. There is training and support available from supportive organisations who are highly experienced in this area
2. Project employees would likely become assets both to VIDCO and to the community.

3. As with Case Study 1, it is not proposed that VIDCO bear the full burden of the Capex – the opportunity is still very much in the realm of demonstration or early deployment and so could reasonably be predicated upon receiving research supports.
4. Maintenance of the equipment is important and will require the training of personnel – as in point 2 above, this must be seen within the context of the desire of VIDCO to establish an innovation hub in Valentia
5. Some thought should be put into the model of FCV ownership that is involved in the opportunity. VIDCO could look to investigate the possibility of using the buy to lease model of Levenmouth

5.8 Next Steps

VIDCO to assess the viability and suitability of the opportunity

As with all the Case Studies in this report there are a number of opportunities for grant funding of research and deployment projects of this scale.

6.0 Co-fuelling a Small Car Ferry With an onboard H2 Electrolyser

This is an expansion of Case Study 2 but considered here separately as there are no cost or technological cross-over issues between this opportunity and the other opportunities in Case Study 2

6.1 Technology

There are hydrogen ferries (FCFs) in various stages of development in various parts of the world. It must be noted that existing FC Vessels are deployed inland. Nordled's world first FC Ferry[67] is under construction and not due into service until 2021. At that it will operate in a sheltered fjord rather than on the open sea.

Therefore, at this point a FC Ferry is not feasible for deployment in Valentia for some time to come.

However, there is the potential for Valentia to take an innovative step on the journey to H2 Maritime deployment.

Clean Power Hydrogen Ltd has developed a very interesting technology for improved performance of internal combustion engines on vehicles and as used to drive electricity generators.

[67] https://www.norled.no/en/news/norled-to-build-the-worlds-first-hydrogen-ferry/

Their CPH2 gas generation system provides a variable volume of hydrogen and oxygen gases in a 2:1 ratio from water. The system draws electricity of low current at 12V or 24V DC, which is applied to a ‘stack’ which separates the water into its constituent gases by electrolysis. The gas is produced in ‘real- time’ as the vehicle engine runs. There is no gas stored on the vehicle. The system uses little water supplied from a reservoir onboard the vehicle.

The speed of the combustion reaction of hydrogen is seven times that of diesel. Combustion of the hydrogen and oxygen occurs early in the diesel firing reaction, breaking up the droplets of diesel fuel injected into the engine. This offers a much smaller droplet (and significantly higher surface area) to the oxygen for a more complete combustion. This results in more power output from the engine and contributes to lower emissions of particulates and gaseous hydrocarbons, better fuel consumption and reduced CO2 emissions.

This technology has been tested and has been deployed with existing diesel engines. Thus, it could potentially be fitted to the exiting ferry for relatively low cost.

6.2 Opportunity

The option of purchase and fitting four CPH2s to the existing car ferry in Valentia could be considered. There are four propellers on the ferry with one engine for each propeller set. This requires four CPH2s each costing €5,000, i.e. a total of €20,000. There could be between 5-10% fuel savings as a result of the installation as well as a cleaner burn for the engines. In effect the engines may have improved in efficiency and engine life extended. There may also be a marked reduction in NOx emissions and reduction in diesel fume odours for passengers and crew.

The technology is novel, but not untested. VIDCO may wish to consider that it could serve the purpose of improving the sustainability image of the ferry company which may reflect well on the perception of Valentia as a sustainability leader.

Current Ferry Fuel cost is € 33,600, a 5%-10% increase in efficiency represents a saving of €1,680-€3,360.

The manufacturers' projections for payback for the installation of four CPH2s are between 11.9 years and 5.9 years. The authors' opinion is that it will be close to 8 years.

6.3 Next Steps

VIDCO may consider approaching the local ferry company with these findings to assess receptiveness.

7.0 Case Study 3

7.1 Introduction

Hydrogen has the capability of replacing fossil fuels outright. To do this however, it has to solve the problem of technology *switching costs*: this again can really only occur when a certain 'network effects' are achieved[68]. In this context this means diesel is cheap relative to hydrogen in part because the diesel distribution network is already in situ and has thus been paid for. In order to replace diesel, H2 will have to bear the cost of creating a new distribution network. This can only be done at considerable cost. These costs can be overcome by leveraging scale. With large projects, a hydrogen infrastructure can be established that will generate network effects which will overcome the switching costs incurred by moving away from the incumbent technology.

This social sciences approach is relevant in that it points to the viability of opportunities at scale: even in the medium term in Valentia

7.2 Technology

This opportunity is an expansion of that described in Case Study 1 and 2. Our decision to investigate this level of opportunity is based on our observation of a number of realities both policy and technological in the hydrogen research sphere.

Hydrogen production has a number of key characteristics that have a bearing on the influence of scale:

Hydrogen electrolysis is gaining in efficiency but represents best value at the larger scale. This was evident in the effect of scale albeit at a lower level on the viability of Case Study 2 above.

[68] For a treatment of this across a range of technologies see https://escholarship.org/content/qt9n26k7v1/qt9n26k7v1.pdf

The potential significance of the opportunity is guiding EU policy makers to take brave funding decisions.

The gains to be realised need to overcome issues of storage and transport of hydrogen. These issues are better solved at the large scale.

7.2.1 Electrolysis

We investigate here electrolysis at the >1MW scale. At this level and above there may be grid balancing demand side management opportunities. This could involve enabling the large-scale generation of electricity (offshore wind) in such a way as to remove the need for substantial grid upgrade as was discussed in Section 3.2.1.3 Grid Analysis

Electrolysers of the >1MW scale are not overly large. The electrolysers that form the basis of the previous case studies are 230kW – for illustration as to size, the electrolyser, the cooler, the compressor and the dispenser would all fit into a standard 12m shipping container. The storage however for a potential daily output of 360kgs of Hydrogen is large. VIDCO may consider that a >1MW electrolyser system is not sited at the cable station. Other locations should be investigated.

7.2.2 Generation

7.2.2.1 Grid Scale Photovoltaic

The Appendix discusses the relative scale of generation required to meet the demand of the case studies. The calculations show that 1MW of power requires a theoretical minimum of approximately 2.5 hectares of PV Farm. However, 1MW of PV in Valentia is likely to yield 1,000,000 kWh of power a year this will produce at maximum 18,182kg H2 just covers the energy requirement in Case 1 for the Plastics Factory and the Cable Station. To achieve the power requirement of Case Study 2, 3.5 hectares of PV would be required. This however does not take into account the fact that the additional three electrolysers needed to cope with the intermittency of this PV supply would likely make the Capex unviable.

7.2.2.2 Tidal

The County Development Plan as it stands in particular in relation to the Special Areas of Conservation (Section 1.5.1) makes it difficult to envisage the exploitation of the tidal resources around Valentia: the Channels between the island and the mainland on the Southern and Eastern coasts are designated as significant. An assessment carried out for the SEAI[69], albeit some time ago, did not identify South West Kerry as an area with high tidal resources.

7.2.2.3 Offshore Wind

We noted in Section 1.5.3 that the County Development Plan appears to limit the available locations for onshore wind. There was widespread support for offshore wind

[69] https://www.seai.ie/publications/Tidal_Current_Energy_Resources_in_Ireland_Report.pdf

expressed at a number of consultation events, and so the authors have modelled for offshore wind as the energy source for a large-scale hydrogen project.

Offshore wind is an established technology. The 25 MW Arklow Bank Wind Park was connected in 2004. It remains however Ireland only offshore wind farm. There are plans however to expand it and there are also a number of other offshore farms in development (none close to construction however). There are a number of reasons while offshore has not developed at the same pace as onshore:

- It is more expensive to construct: The investment cost of offshore wind in Europe has fallen from €4.41 million/MW in 2013 to €2.45 million/MW in 2018. This is due to the rise of competitive tendering, larger turbines, and more capacity.[70]
- Licenses from the State have to be acquired (the State owns the seabed and the foreshore)
- The cable distances are longer and also more costly
- The grid tends to be weaker where the offshore resource is strongest

There are opportunities to engage in a research space in relation to offshore wind, and it is a recommendation of this report that VIDCO look to find technology and other partners to help it engage in offshore wind generation at the scale that will match the ambitions of the hydrogen opportunity discussed here: that is approximately 3 MW.

7.3 Opportunity

With large scale electrolysis in the >1MW level there are new opportunities for Valentia to become a key player in the roll-out of H2 as a diesel replacement, not just locally, but regionally.

There are plans for the installation of H2 refuelling stations arranged in clusters throughout Ireland. These plans[71] devised by a consortium, Hydrogen Ireland[72], map out a staged rollout according to this schematic map:

[70] https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Statistics-2018.pdf
[71] http://hydrogenireland.org/wp-content/uploads/2019/10/HMI_report_final_Oct3rd2019-2.pdf
[72] http://hydrogenireland.org

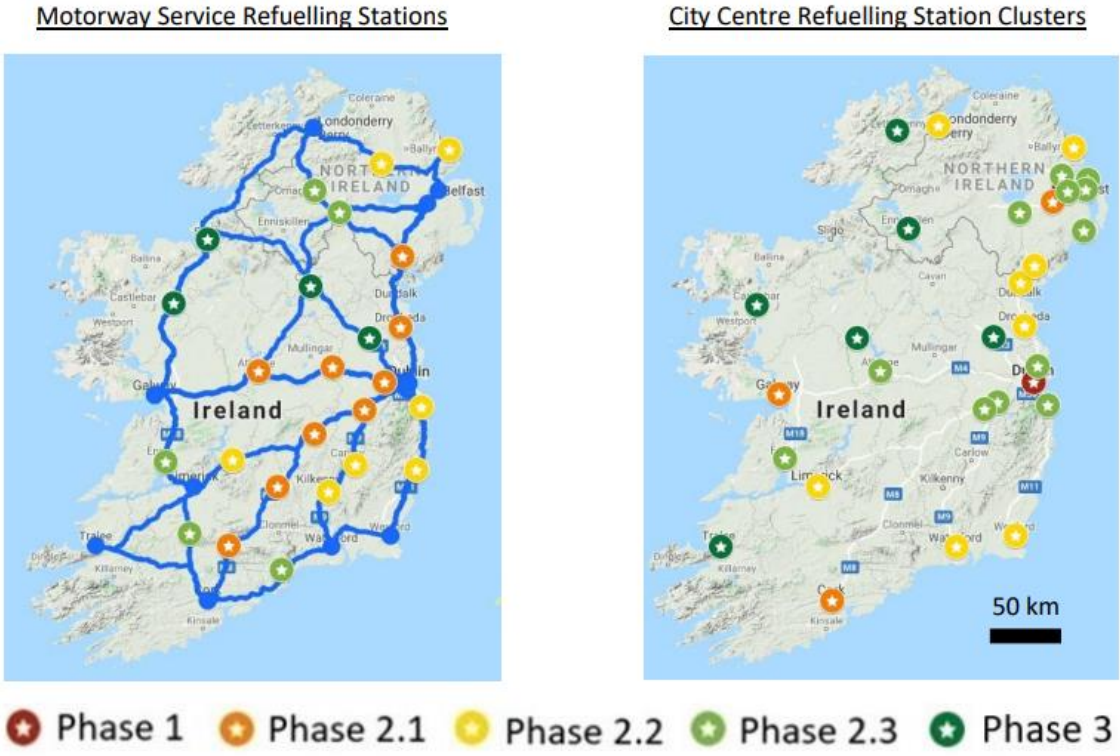

Figure 7.3 Hydrogen Ireland's Map Showing Roll Out of Refuelling Stations

The Hydrogen Ireland Roadmap envisages:

'An investment of €350 million is required for all aspects of the hydrogen production chain to fulfil the strategy by 2030. This covers all costs of production equipment, compression, distribution trailers and hydrogen fuelling stations.

An acceptable investment per company can create the hydrogen mobility industry: This investment can be financed by industry whilst delivering an affordable hydrogen price ***<u>(<<€10/kg</u>*)** [our emphasis] to customers and an attractive rate of return for investors.'

It is significant and worth repeating that the unsupported break-even cost per kg H2 in Case 2 was as follows:

	E1	**E2**
Cost per kg delivered LOW	**€12.47**	**€9.00**
Cost per kg delivered HIGH	**€15.22**	**€11.50**

Table76.3 Unsubsidised Breakeven costs of H2 per kg

The business case modelling (Section 7.4 below) will show that there could be a very promising opportunity for VIDCO and the community of Valentia if we follow the assumptions of Hydrogen Ireland's report.

7.4 Business Case

Capital Cost	**E1**	**E2**
Electrolyser Cost	€1,080,000	€1,350,000
Cooling	€52,500	incl
Enclosure	€96,000	incl
Install	€11,400	incl
Parts	€29,100	incl
Civils	€20,000	€20,000
Compressor	€294,000	€294,000
Dispenser	€127,000	€127,000
Storage	€150,000	€150,000
Delivery	€1,000,000	€1,000,000
Total	€2,860,000	€2,941,000
WITH GRANT SUPPORT[73]	**€1,430,000**	**€1,470,500**
Life Span Yrs	7	10
Annualized Capital Cost	**€204,286**	**€147,050**
O&M Costs		
Maintenance/y	€25,000	€7,000
Operation/y	€20,000	€15,000
Admin	€5,000	€5,000
Insurance/y	€3,000	€3,000
Total O&M/y	**€53,000**	**€30,000**
Total Non-Power Annual Costs	**€257,286**	**€177,050**
kWh electricity per kg H2	55	50
Power Price	0.07	per kWh
Total Power Requirement kWh/y	7,227,000	6,570,000
Total Cost electricity: low scenario	€505,890	€459,900
Total Energy Costs Delivered	**€763,176**	**€636,950**
Cost per kg delivered LOW	**€5.81**	**€4.85**

Table 7.4 Business Case for 1MW H2 Electrolysers and 3MW Offshore Wind Turbine

This price for H2 delivered to the forecourt of a dispensing station is in line with the H2 Ireland projections. However, this is a breakeven scenario.

[73] It is assumed here that H2 Ireland's proposed 50% support to capital spend is put into policy.

The power price identified here is €0.07. It is at the level of average wholesale price for power. The opportunity here is for VIDCO to generate the electricity needed itself with an offshore turbine.

The power price here could give a payback period for such a turbine of between 8.8 and 10.8 years.

Therefore, the profitability for the opportunity is marginal in the sale and distribution of the H2 but could be substantial through the sale of the electricity.

The wind turbine component of the opportunity could generate a return of between 4.65% and 6.7% which would be substantial.

It is critical to note that **this power sale opportunity does not exist in a non-H2 Ireland scenario**: the grid upgrades required to connect a >3MW turbine in South West Kerry would be very substantial (Section 3.2.1.3). There would also be significant public acceptance issues to overcome in large scale grid upgrades. In addition, as suggested by the consultants in their grid assessment, the authors of this report consulted the CRU as to grid upgrade issues and were advised that the local production of H2 off-gird was preferable to and more feasible than grid upgrade.

The Electrolyser and H2 Distribution infrastructure proposed here is negligible in comparison. The footprint of the entire H2 generation site would be in the 50m square range and would have effectively no negative landscape or biodiversity impacts. The H2 Distribution would also be insignificant. A single Linde 500 bar trailer can transport 1,100kg of H2 in a single load: the production of the electrolysers here is 505kg/d.

Figure 7.4 Linde H2 Tanker
Source[74]

The opportunity in Case Study 3 to produce H2 for distribution from an off-grid offshore wind turbine in Valentia could be, in the policy scenario outlined by H2 Ireland, considered highly feasible.

[74] https://www.the-linde-group.com/en/clean_technology/clean_technology_portfolio/hydrogen_energy_h2/h2_one_stop_shop/h2_distribution_and_storage/index.html

7.5 Benefits

The opportunity may ultimately be feasible and profitable. The opportunity also is in line with VIDCO's local employment and innovation aims.

There may also be a number of secondary benefits and opportunities that could make the project even more viable. These would be:

- Oxygen Bi-product Sales
- Ionized Water bi-product sales
- Research and Engineering employment benefits to the community
- Negotiating lower Capex costs
- Second Stage Economies of Scale
- Sale of knowledge and expertise developed to other communities
- Establishing partnerships with funders
- Establishment of a profitable flagship H2 research centre will bring with it high-value visitor catering/accommodation opportunities
- Protection of the health and heritage of the island and it's people

7.6 Risk Analysis

The issue of acquiring foreshore licences must be addressed at an early stage.

There will be significant planning issues for a project of this scale. It will almost certainly be closely scrutinised by interested parties at a national level.

The project requires very significant capital investment

The project is complex and will require considerable management skills at the legal, administrative and the project management level.

7.6.1 Risk mitigation measures

Preparation in advance of spending commitments is key to avoiding these risks. VIDCO could gain the required personnel and experience through participating in Case Study 2 research as a means of improving likelihood of success in Case Study 3.

It may also investigate participating as a work package leader with offshore demonstration projects that require a community organisation partner. As it has no technical expertise built up yet, it should probably aim to assist an established academic partner in exploitation, dissemination, business plan –modelling H2020 or INTERREG project work package.

VIDCO should build alliances with policymakers and stakeholders now to prepare the ground for applying for the necessary permissions and licenses.

VICO's participation in Case Study 2 would likely build understanding and support in the wider community and nationally which can support the offshore planning application process.

Carrying out Case Study 2 would put in place the necessary admin and management structures to overcome any management risks in this complex project

7.7 Proposed Next Steps

As for Case Study 2, Section 6.6, but with the addition of two more tasks:

1. Join H2 Ireland and keep in touch with policy changes
2. Establish the necessary personnel and management resources

8.0 Conclusions

The switch from fossil fuels to renewably sourced H2 as a significant energy carrier for transport in rural Ireland is essential: battery technologies are potentially environmentally costly, the extension of range has limits, and they will always have longer re-powering times than FCVs.

The challenge for Valentia Island is to find a way of participating in the radical restructuring of our social and economic systems which the transition from oil to H2 will bring in a manner which is self-determined and protects the heritage and environment of the Island.

This challenge can be met and can be turned to the advantage of the community through increased employment and revenue opportunities.

However, it would be naive to think that Valentia Island is living in a vacuum. The prospect of the transformation that is ahead of us is apparent to every community in Ireland. There is therefore urgency to this challenge: will Valentia be a leader in this sphere in Ireland or will it be the recipient of the innovative technologies and strategies of others.