Benefits and Barriers of the Development of Renewable/Hydrogen Systems in Remote and Island Communities

Shannon Miles, Mary Gillie

Shannon Miles, Natural Resources Canada, Vancouver BC, Canada
Dr Mary Gillie, EA Technology Limited, Capenhurst, Chester, UK

ABSTRACT:

Under the auspices of the International Energy Agency's Hydrogen Implementing Agreement, a working group has been evaluating and documenting experiences with renewable-based hydrogen energy projects in remote and island communities. The group, Task 18, “Evaluation of Integrated Hydrogen Systems,” has considered the recent experiences in Unst and the Hebrides UK; Bella Coola BC, Canada; Utsira, Norway; Reykjavik, Iceland; Gran Canaria, Spain and the Totara Valley in New Zealand.

Part of our work is to draw out the lessons learned from existing projects and provide recommendations as to how hydrogen systems can be effectively developed. To do this we have studied some of the drivers behind the niche markets where hydrogen systems have already been developed, or are in the early development stages and how these could be expanded and modified to reach new markets. A key niche market at present is renewable-based hydrogen energy systems for remote and island communities.

The objective of this paper is to compare various aspects of the above mentioned projects. It addresses some of the general experiences of the participants in terms of benefits, objectives and barriers and also discusses future plans and recommendations for similar projects.

KEYWORDS: *refueling station, fuel cell vehicle, renewable hydrogen, hydrogen energy systems, demonstration.*

Executive Summary

The Hydrogen Implementing Agreement (HIA) of the International Energy Agency has a vision for a hydrogen future based on clean sustainable energy supply. The HIA has a mission to accelerate hydrogen implementation and widespread utilization. It has a strategy to facilitate, co-ordinate and maintain innovative research, development and demonstration activities through internal co-operation and information exchange. The HIA is comprised of research tasks, all of which are described at www.ieahia.org.

The objective of this specific study is to compare various aspects of some small or remotely-located projects which have either been operational or are just beginning in member countries over the past few years. It addresses some of the general experiences had by the participants in these projects in terms of benefits, objectives and barriers. It also discusses future plans and recommendations for similar projects and governments.

The projects selected for evaluation are:

- PURE, UK (Promoting Unst Renewable Energy)
- HARP, Bella Coola, BC, Canada (Hydrogen Assisted Renewable Power)
- Utsira Wind Hydrogen Project, Norway
- ECTOS Hydrogen Fuelling Station, Reykjavik, Iceland (Ecological City Transport System)
- Instituto Tecnológico de Canarias, Gran Canaria, Canary Islands, Spain
- Hebridean Hydrogen Park, Hebrides, UK,
- Hy-Link, Totara Valley, New Zealand

There are socio-economic benefits as well as technical reasons for developing renewable hydrogen systems in remote communities. The need for improved energy security, protection against fluctuating and/or high fuel costs, and abundant renewable energy resources are key drivers behind these projects. In addition, the need for clean air, reduced noise and community development are also good reasons. Hydrogen systems can offer jobs, tourism and engender community pride. The cost of conventional fuel and the restrictions on conventional uses of renewable resources make hydrogen more attractive.

The main barriers found are:

- the lack of mass produced, reliable, off-the shelf systems,
- funding and permitting for systems,
- challenges in design, installation and maintenance of these projects due to location and a lack of local expertise.

Distributed generation is becoming an increasingly popular approach to providing local power, and although each individual system is generally small, the number of islands or remote communities that could benefit from renewable-hydrogen systems in total represents a significant market. Some of the communities are already working to replicate their hydrogen systems, raise awareness beyond their own community and export their expertise.

A more co-ordinated approach is necessary to demonstrate the market potential and develop expertise. This would not only help local businesses expand, but also attract manufacturers to encourage suitable designs and mass production. Joint procurement of systems or components would encourage a modular design and reduce costs. Although islands and communities are different sizes and have different needs, if a modular approach could be developed this would

lead to reduced costs and enable systems to be more easily replicated, making the market more attractive to manufacturers and customers.

National and regional governments could actively support such initiatives by:

- Facilitating the development of permitting and safety codes and standards appropriate for the size of project; ensuring staff are trained to apply them correctly,
- Ensuring a holistic approach to funding which both includes and mandates education, communication and outreach and takes into account the social and indirect economic benefits,
- Encouraging partnerships and clustering in projects, rather than one-of-a-kind approaches, and ensuring this is reflected favourably in funding criteria,
- Facilitating international business opportunities for communities by actively supporting communities in exporting their systems or expertise.

Contents

1 Introduction **1**

2 Hypothesis **1**

2.1 Projects Studied 1

3 System Descriptions **2**

3.1 PURE, Unst, UK 2
3.2 HARP, Bella Coola, British Columbia Canada 2
3.3 Utsira, Norway 3
3.4 Iceland – Ecological City Transport System (ECTOS) 4
3.5 Gran Canaria, Canary Islands, Spain 4
3.6 Hebrides, UK 5
3.7 Totara Valley, New Zealand 6
3.8 Comparison Chart of the Systems 7

4 Overview of the Drivers for Projects **8**

5 Common Barriers and Opportunities **8**

5.1 Governmental 8
5.2 Economic 9
5.3 Social 10
5.4 Education and skills 10
5.5 Technical 11

6 Future Plans **12**

6.1 Raising Public Awareness 12
6.2 Expansion, replication or adaptation of systems 12

7 Conclusions and Recommendations **13**

7.1 Government Action 14

8 Acknowledgements **15**

9 Appendix 1 – Survey Questionnaire **i**

10 Appendix 2 – Endnotes **ii**

1 Introduction

The Hydrogen Implementing Agreement (HIA) of the International Energy Agency (IEA) has a vision for a hydrogen future based on clean sustainable energy supply. The HIA has a mission to accelerate hydrogen implementation and widespread utilisation. It has a strategy to facilitate, co-ordinate and maintain innovative research, development and demonstration activities through internal cooperation and information exchange. The HIA is comprised of research tasks, all of which are described at www.ieahia.org.

Task 18 is focussed on the evaluation of integrated hydrogen demonstration projects. More information can be found http://iea-hia-annex18.sharepointsite.net. Part of the work is to draw out the lessons learned from existing projects and provide recommendations as to how hydrogen systems can be effectively developed. This investigation highlights some of the drivers behind the niche markets where hydrogen systems have already been developed, or are in the early development stages and how these could be expanded and modified to reach new markets. A key niche market at present is renewable-based hydrogen energy projects for remote and island communities. We have considered the recent experiences in Unst and the Hebrides UK; Bella Coola BC, Canada; Utsira, Norway; Reykjavik, Iceland; Gran Canaria, Spain and the Totara Valley in New Zealand.

The objective of this specific study is to compare various aspects of some of these projects which have either been operational or are just beginning in member countries. This paper addresses some of the general experiences of the participants in these projects in terms of benefits, objectives and barriers. It will also discuss future plans and recommendations for similar projects. As one project manager mentioned, these small communities are microcosms of larger systems. This work was carried out through a survey questionnaire and interviews with project developers.

2 Hypothesis

As the world enter into a new energy realm, nations will be seeking new low-carbon, readily available energy solutions. The movement is away from the "one solution fits all" approach to energy into an era where a regional and most likely distributed approach will prevail. In this decentralised model, small, remote, and first-of-a-kind energy systems and their pioneer communities are evaluated.

The reasons why a particular energy system is chosen in a particular place will not simply be for technical reasons. Societal and economical pressures are playing an increasingly significant role. Some remote communities have already taken or are in the process of taking these decisions. By surveying these communities it is possible to understand not only where systems involving hydrogen are likely to be most suitable, but also to understand how these systems can be adapted and modified to be used elsewhere. If this technology is to be successful, hydrogen demonstrations will have to move from one-of-a-kind projects to systems that can be replicated and become business as usual. The questions used to survey the different projects are found in Appendix 1.

2.1 Projects Studied

The projects that selected for evaluation are:

- PURE (Promoting Unst Renewable Energy), UK
- HARP (Hydrogen Assisted Renewable Power), Bella Coola, BC, Canada
- Utsira Wind Hydrogen Project, Norway

- ECTOS (Ecological City Transport System) Hydrogen Fuelling Station, Reykjavik, Iceland
- Instituto Tecnológico de Canarias, Gran Canaria, Canary Islands, Spain
- Hebridean Hydrogen Park, Hebrides, UK
- Hy-link, Totara, New Zealand

These projects were selected because the member countries are active in this IEA working group and information was accessible. They also all have a readily available renewable energy resource. These communities are typically not able to use these resources to their full potential because of storage issues or weak grids. Hydrogen can provide a solution as demonstrated in the projects discussed in this paper.

There are many other projects that exist around the world that are doing similar work and these projects will be added to a similar follow-up study in the future.

3 System Descriptions

3.1 PURE, Unst, UK

The PURE (Promoting Unst Renewable Energy) project is situated on the island of Unst in the Shetland Islands in the most northerly part of Scotland. The area has some of the best wind and wave energy sources in Europe.[i] The project was commissioned by the Unst Partnership Ltd., a community development agency established by the Unst Community Council to support local economic development and regeneration.

The system consists of two 6kW wind turbines which provide electric power to directly heat five business units. Excess electricity from the wind turbines is used to produce hydrogen which can then be stored and is also used to fuel a fuel cell/battery hybrid vehicle and for a back-up power unit consisting of a 5kW fuel cell and an inverter (Figure 1).

Combined heat and power systems are now being developed for housing as part of the ongoing progress of the Pure Energy Centre (the business which was set up on the back of the PURE Project). The hydrogen car was a natural choice, given the high cost of petrol, but it is also a great marketing tool and is used by the team on a daily basis, raising the profile of both the business and hydrogen technologies as a whole.


Figure 1 The wind turbines and hydrogen system on Unst, the hydrogen fuelled car and the hydrogen storage facility

3.2 HARP, Bella Coola, British Columbia Canada

The HARP (Hydrogen Assisted Renewable Power) project is based in Bella Coola, British Columbia, Canada. This area is in the far west of the country and is not connected to a power grid or a gas pipeline. This community relies on power from diesel generators. This project is part of a larger initiative as part of BC Hydro's Remote Communities Electrification Initiative to provide electrical service to 17 remote communities by 2010 and up to another 50 or more communities by 2017. The overall objective is to reduce the costs and emissions associated with diesel consumption as well as to demonstrate the viability of HARP and Smart Grid Technologies for larger scale deployment in other remote communities and non-integrated areas. This project is being carried out between 2007 and 2012 in collaboration with General Electric Corporation, who will be designing and implementing Smart Grid technology.

The system will also include a 60 Nm3 H2/hr electrolyser, a 100kW hydrogen fuel cell, hydrogen storage and a 30-125 kW electrical storage system (ESS). This implementation is expected to increase the utilisation of the 2MW renewable hydro power station at nearby Clayton Falls (Figure 3) and to reduce reliance on diesel generators by 10-15% year round. In essence, this system is designed to take advantage of low load periods at the power station to produce hydrogen instead of spilling the excess water and discharging power.[ii]

A hydrogen four wheel drive truck will be delivered to Bella Coola in September 2009 to help people get used to the technology (Figure 2 Hydrogen vehicle2).

Figure 2 Hydrogen vehicle

Figure 3 Clayton Falls

3.3 Utsira, Norway

Utsira is a windswept island 20km off the west coast of Norway. The wind hydrogen demonstration project was started in 2004. The project was launched by StatoilHydro and Enercon. Local authorities, members of the local community and representatives of local trade and commerce have been involved throughout the development and operation phases and the project reports today that this was vital for achieving success. The system is designed to meet the entire energy demand of 10 households using wind energy. Using excess wind power to create hydrogen, energy can be stored for use at peak hours or when the wind is not blowing.

The system consists of a 600kW wind farm (Figure 4), a 10Nm3/h alkaline electrolyser, an 11 Nm3/h hydrogen compressor, a 2400Nm3 hydrogen gas storage at 200 bar, a 55kW hydrogen engine generator system, and 10 kW fuel cell.[iii] The plans for 2009 include a new PEM-electrolyser, integrating a new fuel cell and introducing a dispenser and a car. Further similar projects on other Norwegian islands are also planned.

Figure 4 Wind turbines at Utsira

3.4 Iceland – Ecological City Transport System (ECTOS)

Iceland is located in the North Atlantic and is famous for its geothermal renewable energy. In fact in 2008, 84% of Iceland's energy needs were met with hydro and geothermal power, with the remaining 16% coming from imported oil.[iv] Therefore, the only element of Iceland's energy use not supplied domestically is the transportation sector, but coal is imported as raw material for aluminium smelters. Iceland has a population of approximately 300,000 people and plans to be completely energy independent.

Iceland's project, the ECTOS Hydrogen Fuelling Station in Reykjavik (Figures 5 and 6), was part of Phase One of the IEA Task 18 work. This system consists of production, storage and a fuelling station and 3 FC Citaro test buses. The fuelling station has the capacity to deliver 30kg of hydrogen per day at 440bar and the total production and capacity of the station is 200kg/day (Table 1).[v] The buses had a 250kW PEM system from Ballard, 360 bar storage on the roof and an operating range of 150-240km. The station has been in continuous use since 2003. Since the conclusion of the bus test it serves private and rental vehicles and a fuel cell boat.

Figure 5 Artist impressions of the facilities in Iceland

Figure 6 Recent photo

3.5 Gran Canaria, Canary Islands, Spain

Gran Canaria is one of the Canary Islands which are located off the west coast of Africa and are a very popular tourist destination. The Canary Islands consist of 7 small island systems with only two being electrically interconnected. The rest of the islands, given the distance separating them and the depth of the ocean in this area, remain isolated electric systems. Gran Canaria has abundant solar and wind resources but has few fresh water resources and must operate desalination facilities.

The Instituto Tecnológico de Canarias (ITC) has a goal of reducing fossil fuel imports to the Canary Islands. There are two hydrogen project prototypes in operation at ITC facilities in Pozo Izquierdo, Gran Canaria: The Renewables to Hydrogen (RES2H2) project and the HYDROHYBRID project. The objective of these projects is to demonstrate hydrogen applications created with excess renewable energy. The RES2H2 system was initially designed to be able to meet electricity and water desalination demand from an isolated community through a stand-alone system. Transportation is also of interest for the Canaries in an effort to become more energy independent, and that is the objective of the HYDROHYBRID project.

There are two systems in operation at ITC. The first has been designed for stationary applications to meet electricity and water demands in stand alone operation. The system includes a 55 kW alkaline electrolyser with a nominal production of 11 Nm^3H2/hr, a 500 Nm^3H2 storage at 25 bar, six 5 kW fuel cells and inverters to supply AC power to electrical loads (Table 1). The system also includes a wind turbine and a reverse osmosis desalination plant, which takes excess electric energy from the wind turbine when the hydrogen storage tank is full (Figure 6).

The second system is a small scale hydrogen production system for transportation which consists of a 10 kW wind turbine, a 3 kWp photovoltaic system, a small PEM electrolyser (1.16 $Nm^3 H_2/hr$), a compressor, and a 5 kW fuel cell. Hydrogen produced is used to supply a small vehicle. The vehicle (Figure 7) has a 4kW fuel cell and has an estimated range of 60km. It has 7Nm^3 of hydrogen storage at 200 bar.

Figure 6 Facilities in the Canary Islands

Figure 7 Vehicle in the Canary Islands

3.6 Hebrides, UK

The Hebrides Islands are located off the west coast of Scotland. The Outer Hebrides, where the hydrogen project is based, are surrounded by some of the best natural resources, e.g. wind and wave, in Europe. Ironically they are also faced with some of the highest fuel cost in the UK[vi] and in 2003/4 imported 97% of their energy. They are connected to the UK electricity distribution network by just one 33kV link that is operating at full capacity. Only 20% of energy consumed is in the form of electricity (the rest being used for heat and transport). By creating hydrogen that can be used for heat and transport from the renewable energy resources, more of the other energy demands of the islands can be serviced from the renewable sources.

The local Council formed the Outer Hebrides Hydrogen Strategy with the aspiration to create The Hebridean Energy Park. Its aims are to develop a hydrogen skills base within the islands, establish a local renewable hydrogen production and supply infrastructure and demonstrate the opportunities and benefits of hydrogen technologies.

The Park has three phases.
Phase 1 is called the ‘Hebridean Hydrogen Lab - Capacity Building’ with aims of establishing a local skills base, building local capacity and raising community awareness of hydrogen technologies and their integration with renewable energy generation.

Phase 2 – ‘Hebridean Hydrogen Seed (H2seed) - Infrastructure and Demonstration’ will establish a hydrogen generation, storage and dispensing facility. Hydrogen is generated by water electrolysis using electricity generated by the biogas generator set at the local authority waste treatment facility. The biogas is produced by anaerobic digestion of domestic organic waste. The alkaline electrolyser’s hydrogen production capacity is 5Nm3 H2/hr. The biogas generator set operates intermittently depending on the rate of biogas production and in this sense the electrical production has some of the characteristics of other renewable electricity sources. Later, other renewable generation such as wind may be used.

Demonstrating renewable hydrogen generation is one of the key aspects of the project. Hydrogen storage will buffer approximately a week’s production while the dispenser allows the

refilling of both standard “k-type” cylinders and hydrogen vehicles.
Transport applications are viewed as the main use of hydrogen. The refuelling station required to supply the vehicles will be installed next to the hydrogen production facility (Figure 8).

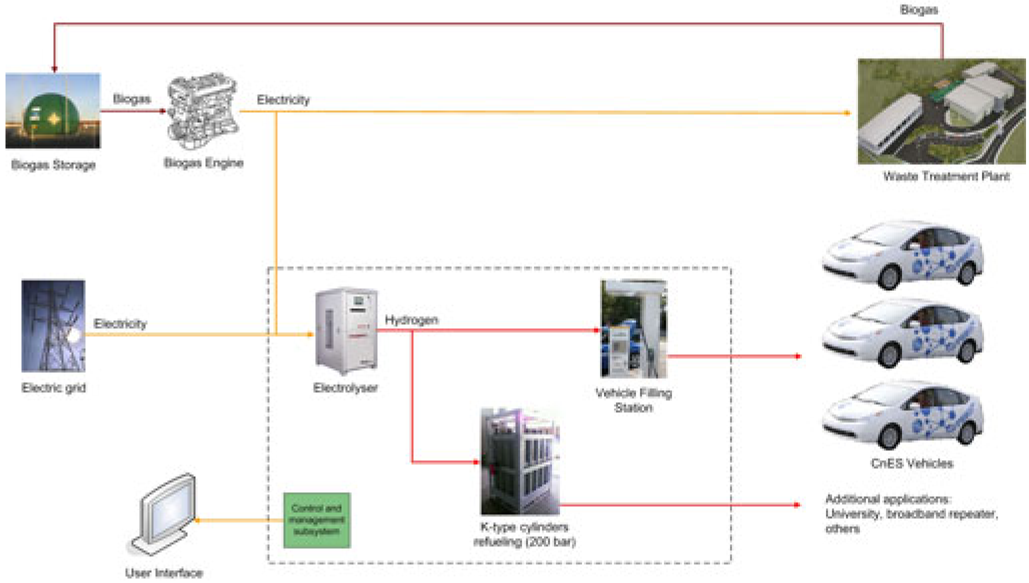


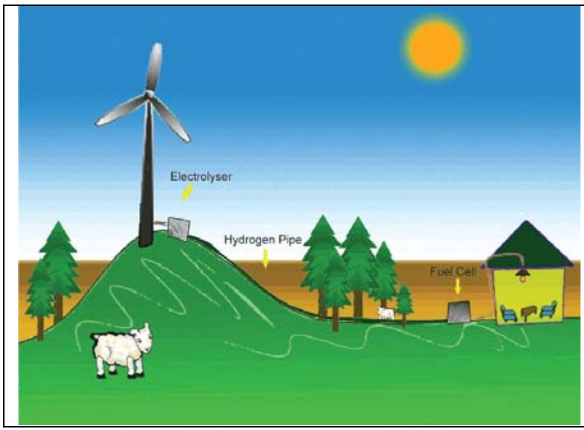
Figure 8 Diagram of the H2Seed project

Phase 3 is ‘H2 Growth.’ It is intended to expand the hydrogen infrastructure with a range of vehicles, uninterruptible power supplies and combined heat and power units. It will also develop R&D and testing services, grid balancing expertise and explore export markets for hydrogen (see section ‘Future Plans’).[vii] [vii]

3.7 Totara Valley, New Zealand

The Totara Valley site involves a small remote farming community in the Wairarapa hill country on the North Island of New Zealand. The community consists of three farms. The community expressed an interest in local renewable energy as an alternative to grid supply. Initial technologies included small roof top PV and solar hot water systems and a 1kW micro-hydro system. Unfortunately, the best wind resources were 2 km from the farms.

A small scale pilot project was then launched to demonstrate a low cost, high reliability pipeline-based hydrogen energy network. One half of the system was thus located at the wind site and the other at a farm. The system at the wind site consists of a 300W wind turbine, a supercapacitor to smooth the very fast fluctuations in the winds output, and a PEM electrolyser. The hydrogen produced is fed through a plastic polymer pipeline running 2km underground to the farm. This pipeline can also act as a store for 6kWh of hydrogen (2000 litres at 4 bar). A 1kW PEM fuel cell provides heat and power loads at the farm (Figures 9 and 10). In the future an additional hydrogen burner will also provide hot water. At the farm, there are also an inverter and buffer batteries. The combined heat and power (CHP) fuel cell and direct water heater conversion at the residences maximises the hydrogen link efficiency.



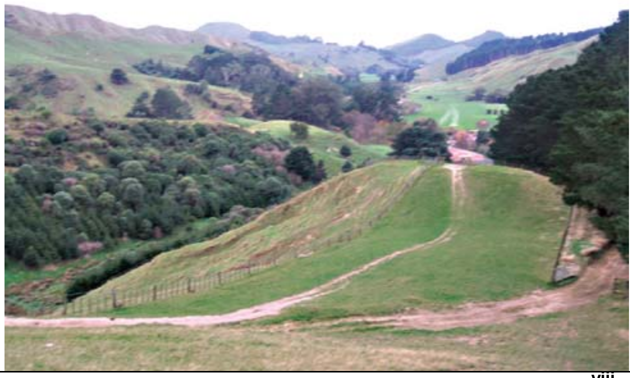


Figure 9 The Totara Valley system diagram Figure 10 Community viewed from the access track[viii]

3.8 Comparison Chart of the Systems

A summary of the technical details is given in Table 1.

Table 1 Comparison table of systems studied

Project Name	Age	Electricity Source	Electrolyser	Pressure	Compression	Storage	Use
PURE	2005	Wind 2 x 6 kW	3.55 Nm3/h Alkaline Electrolyser	30 bar	No	90Nm3 H2 @ 30 bar	Fuel Cell and Car
HARP	2008	Hydro 2MW peak 3.8MW	60 Nm3 H2/hr Electrolyser	10 bar	200 bar	H2 storage and ESS	100kW Fuel Cell H2 ICE Truck with dedicated Electrolyser
Utsira	2004	600kW Wind (restricted to 150 kW)	10 Nm3/h alkaline Electrolyser	12-200 bar,	11 Nm3/h 2 stage	2400 Nm3	55 kW H2 Engine and a 10 kW Fuel Cell
Iceland	2003	Hydro and Geothermal	60 Nm3/hr at 1.5 MPa	440bar	15-440 bar	Station can supply max 200kg per day	Buses
Canary Islands #1	2007	Wind	5.5 kW Alkaline Electrolyser 11 Nm3/ H2/ hr	25 bar	No	500Nm2 H2@25 bar	Reverse osmosis desalination plant 6x 5kW Fuel Cell
Canary Islands #2	2007	3kWP Solar, Low wind Turbine	1.16 Nm3 H2/hr PEM Electrolyser	15 bar	Yes 200 bar	50Nm3 H2 @200 bar	1x5kW Fuel Cell and a small vehicle
Hebrides	Install ation 2008/9	Biogas plus potentially other renewable energy projects	Alkaline Electrolyser 5Nm3 H2/hr	200 bar	N/A	k-type cylinders	Transport
Totara	Install ation 2007/8	Wind 300W	PEM electrolyser	4 bar	No (pressure electrolyser)	Only in pipe line	CHP

4 Overview of the Drivers for Projects

All of the communities are in remote locations or on islands with weak or no electrical connection to the mainland. The main drivers for such communities to develop renewable energy systems are often straightforward. These are primarily energy security, including the high cost of transporting fuel to their community and related logistical issues, and making full use of an abundant local renewable energy resource.

With the cost of energy high and increasingly difficult to predict, known supplies dwindling, insecurity of supply, etc., communities are becoming innovative. The other common theme is pollution. Many communities do not have grid access and for example, in Canada rely on diesel power, which is typically polluting and noisy. Anecdotal evidence shows that in addition to energy security, using renewable energy to reduce pollution and noise is a significant factor for most communities as well. It is no coincidence that the projects have arisen in areas with excellent renewable energy resources. In Iceland, they have also given rise to visions of connecting know-how and hydrogen excellence with the international leadership on geothermal systems.

There is also a desire for more local control, local economic development and increasing environmental awareness. Many remote communities are concerned about 'brain drain'. By developing local energy systems they provide jobs that range from those needing hands-on mechanical skills to low-carbon professional engineering and business roles. In addition, this engenders community pride.

The drivers above apply equally to purely renewable energy projects or other community development projects. The additional drivers to include hydrogen are the benefits of energy storage and clean economic fuel for transportation. Some communities, like Iceland, are looking for total energy independence, while others are looking for partial energy independence. Some are interested in hydrogen solely for stationary power.

As well as energy security, reduction in fuel bills is also a significant driver as energy prices tend to be much higher in remote communities, whilst incomes are often lower than the national average. The following statistics are examples of this:

- In Unst over 50% of people spend over 20% of their household income on energy.[ix]
- The cost of fuel in the Western Isles (or Hebrides) is 13% higher than in Scotland's mainland urban areas.[x]
- In the Western Isles of Scotland, 34% of households spend more than 10% of their household income on fuel costs.[xi]
- The Canary Islands have the lowest average wages in Spain.[xii]

5 Common Barriers and Opportunities

Even in projects using more common or mature renewable energy technologies, there are many barriers and challenges that must be overcome. The results of this survey show that hydrogen projects are no exception. It is interesting to note that many of the opportunities for remote and island communities arise out of finding solutions to these barriers.

5.1 Governmental

Project participants felt that politicians often believe that new technology is not ready or are unfamiliar with the technology. Many politicians managing funds for remote communities are used to providing finance for 'bread and butter' projects, for example fishing or agriculture. Many are naturally quite conservative and lack technical understanding and in some cases this leads them to assume that a new technology is not yet ready. As a result, communities have to educate the funders at the same time as applying for funding.

Other communities reported that they have to deal with unsubstantiated claims relating to safety and reliability that could undermine projects. This requires careful handling as people can be suspicious of what is new. It can be exacerbated by experts who do not want to engage with the general public or do not operate openly. In the Hebrides this has been tackled in a practical manner. At least two hydrogen fuelled internal combustion engine (ICE) cars will be used in the first demonstration project and driven as pool vehicles by employees of the local Council. As many people use or see these vehicles, to allow many people will become comfortable with the technology using only two vehicles. Such demonstrations can quantify the reduction of CO2 emissions as well as the reduction in operational costs so that future decisions can be made on facts rather than hearsay.

Waning popularity in government for long term solutions whose benefits may not be apparent within the duration of an election cycle has been raised as a concern from many of the projects. This is especially problematic when some projects have a long lead time to get off the ground. Having different parties in power nationally and at the municipal level was identified as a problem in Iceland. However, they emphasised the important role that local government can play, particularly in ensuring active participation and supporting entrepreneurship. [XV]

Government can play a leading role in permitting, as negotiating permits and safety standards can be difficult for small communities. Often standards are not available, vague or inappropriate for small systems. The Hebrides gave the example of the British Compressed Gas Association CP33 guideline that only applies to pressures of up to 200bar not the 420bar considered in the current project. This results in municipalities or permitting agencies taking a very conservative approach.

5.2 Economic

Although hydrogen systems can reduce running cost for communities, the initial capital and installation costs are often high. Furthermore with one-of-a-kind projects, commercially available technology solutions are difficult to obtain. The Hebrides have found that procurement contracts can be inflexible making raising the funds even more difficult. Furthermore, they found that few companies were interested in working on a small project when other larger developments were available.

In the case of PURE, some of the community was initially not that enthusiatic to the project until they could see its potential for the island. PURE sees its objectives as delivering social as well as economic benefits. By using indigenous renewable resources, direct household bills are not only cut, but the communities are less vulnerable to rapid fluctuations in energy prices. As the price of conventional fuels increased during the ECTOS project, the local population in Iceland became more enthusiastic about hydrogen.[XV]

Expensive logistical issues for fuel delivery in remote and island location make indigenous sources of energy more favourable. For example, in some remote communities in Canada, ice roads have been known to collapse and sea ice can strand fuel deliveries. In island communities, high seas can delay delivery and overall small price increases for oil can mean large price increases for remote communities.

This review has found that hydrogen systems can add economic value to a community via tourism. In many cases these new energy systems have created a tourist attraction. This brings income directly from show-casing the technology and also from the associated increased demand for accommodation and catering. In the case of PURE, this is further increased by people coming to their training centre. For Utsira, the track to the wind turbines has the additional benefit that it allows disabled visitors to get around and enjoy more of the island, especially useful as it is popular for bird watching. They estimate that there have been 500-1000 more visitors to the island as a result of the system. In Iceland, the fuelling station has had thousands of visitors and further established themselves as eco-tourist destination.[xiii] In extending the hydrogen network in Iceland, two areas of focus are car rentals and tourist whale watching boats through 'Smart-H2'.[xiv] NORDSESIL, a network developing sustainable energy in remote communities in the Nordic region is actively investigating the opportunities for 'green tourism'.[xv]

5.3 Social

Small communities can have an advantage in these types of projects in that they can more easily co-ordinate and contact all those who will be affected. Many people want to 'do their bit' to reduce the impact of climate change. Remote and island communities are likely to be severely affected by climate change and the impact may well be sooner than in other areas of the globe. This concern can be used to drive projects.

It was hard to find any adverse affects on society of hydrogen systems. Systems that have such a direct impact on people's day to day lives are an excellent means to get children enthusiastic about science and using it responsibly. As Elizabeth Johnson of PURE commented "it makes school children think science 'is cool'." It gives people a sense of pride and ownership and a reason for collaboration.

A lgreat deal of awareness-raising and general information provision is needed. This is built into programmes such as those on the Canary Islands, PURE, Iceland and in the Hebrides. ITC engages with large numbers of school children with site visits to their research centre. PURE's training centre also offers residential courses on hydrogen systems. Training, awareness-raising, public acceptance and job creation are an integral part of the Hebridean project. This is driven by an aspiration to create an economy around R&D and demonstration and the export of technical expertise. Hydrogen fuelled vehicles will have a high visibility throughout the Outer Hebrides and therefore are ideal as an initial demonstration project. This will help to raise local public awareness to the potential benefits of hydrogen use in conjunction with comprehensive public relations and marketing programme.

Developing innovative projects can be easier within smaller communities where there is a greater level of trust. In remote close-knit communities, everyone has to rely on each other each and every day. People know each other better and can discuss and talk through issues face to face. Moreover, local government is often less remote from the people it serves.

5.4 Education and skills

Initially there may not be sufficient people with the appropriate skills to start a project. Remote communities where transport is sparse can struggle to attract experts to visit them. Nevertheless, renewable and hydrogen systems offer job creation opportunities. The skills required range from skilled manual jobs through to engineering and business expertise. This helps to prevent 'brain drain' from remote areas.

An initial lack of skills was recognised in the Hebrides and therefore the first part of the project was focused on training. A schools programme started to raise awareness of the emerging hydrogen market and career opportunities in the context of sustainable energy consumption. This includes practical demonstration sessions. The Hebridean Hydrogen Lab is a teaching and research facility to develop the practical skills base that will be required in future phases of the

Hebridean Hydrogen Park plan at a local level. Training is integrated into existing pre- and post-eighteen engineering qualifications. Research and development activities will increase economic development and job creation from the plan. In Phase 2, the project will train the facility operators, emergency response service personnel and users in safe working practices and develop appropriate incident response protocols.

There is also an opportunity for relatively small communities that have developed hydrogen systems to develop a business in passing on their know-how to other communities. As PURE commented, "we are in a particularly good position, we understand from first hand experience the problems faced by remote communities."

In the Canary Islands ITC is planning to build a training and maintenance program as part of their initiative. Iceland reports opportunities for education and an increase in awareness and 'enlightened discussion about energy and hydrogen projects across the globe.[xvi]

5.5 Technical

Even though hydrogen has been used for decades in the petroleum and chemical industries, use in small scale projects like these for energy storage is still emerging. One of the main problems for hydrogen systems is that it is still difficult to buy 'off the shelf' systems. As a result, a lot of custom modelling and design is required for each project. Much of hydrogen technology does not have a long track record, which is a particular problem for remote communities where the time for delivery of replacement parts may be lengthy. Furthermore, the lifetime of components and vehicles are sometimes uncertain, thus putting together a business case is often a challenge. Iceland highlighted the fact that as other communities have not yet adopted the technology, it is not yet mass produced and therefore expensive.

Whilst transport fuel is a key driver in remote communities, it is generally difficult and or costly for communities to obtain vehicles or design their own at this stage because hydrogen fuelled transport technology is primarily being developed inside major automotive and bus manufacturers. However, Iceland has identified the fact it has the advantage that it only requires 20 filling stations to service the whole of the population.[xvii]

However, despite these problems, hydrogen is still useful to remote communities. Island communities that have developed hydrogen projects such as in the UK either have no electrical link to the mainland or a weak link. As a result they cannot exploit exceptionally good renewable resources by transmitting power to the mainland and the large load centres. In the case of the Canary Islands they have a very high load due to the need for desalination for drinking water. However, their weak networks make connecting renewables very difficult without compromising power quality. Using hydrogen as an energy storage medium to absorb excess renewable power is one way of connecting more capacity. Storage as hydrogen offers the possibility of using the energy as heat, power or transport. As the Canary Islands commented,

"*The energy paradox regarding an almost total dependence of the Canary Islands on imported fossil fuels, and the important potential of wind (average speed of 7,5 m/s, with yields of wind farms in the range of 3,000 – 4,500 equiv. hours) and solar energy (sun hours > 2,500 – 3,000 h/year, with radiation of 5 - 6 kWh/m2-day) energy. If technical barriers were to be overcome, the Canary Islands could be in a position to self supply an important part of its energy needs."*

The Totara Valley has overcome some of the difficulties of the complexities of hydrogen systems by using a low pressure plastic pipeline to transport hydrogen, a simple, low-cost solution compared to a new 11kV power line. The technical challenges that New Zealand has experienced thus far have been a result of adverse weather conditions hampering installation due to the remote location and not the hydrogen technology.

While there are few systems to compare and unknowns still exist in terms of how systems will perform in different climates, the general principle of using hydrogen and renewables is established as a feasible energy system.

6 Future Plans

Hydrogen systems are yet to become mainstream but some of the communities are using their experience to engage in public awareness and/or expansion or replication of these systems.

6.1 Raising Public Awareness

PURE is concentrating on training, providing skills for hydrogen communities, and on travel, using their hydrogen powered car for general awareness. ITC in the Canary Islands is working on general public awareness to encourage adoption of hydrogen systems. British Columbia is trying to tie the project into the overall BC Provincial strategy and the utility is doing a lot of community consultations over 2 years. Iceland is collecting driving performance information across different drive trains such as battery cars, methane cars and hydrogen cars to map the possibilities to use local fuel to run the transport before a public policy is finally set. Companies that receive subsidised alternative vehicles turn in measured data and report on their experience until 2010, and discussions of social issues are collected via questionnaires, focus group discussions and semi-constructed interviews. In its follow-on project 'Smart-H2', Iceland has included public consultation and involved 20 different organisations.[xviii]

6.2 Expansion, replication or adaptation of systems

British Colombia has identified energy storage as a part of the advanced power distribution networks that power companies are interested in. The Bella Coola project is therefore aligned with additional interests. First of all British Colombia is concentrating on one community and comparing hydrogen with the use of a vanadium redox battery (VRB) electrical storage system. After accumulating the learning from this project the plan is to then expand to many other communities. In the future they would also like to replicate their systems abroad.

Norwegians associated with the Utsira project are working with StatoilHydro and are considering a number of other island projects. PURE has set up a company to provide consultancy and design expertise for other hydrogen systems.

ITC plans to expand its hydrogen capacity and add new projects. If the first project is successful, they can expand to other communities in the area. Both PURE and ITC are developing designs or applications for the developing world and/or emergency applications.

There are further plans for hydrogen projects in the Outer Hebrides. One aim is to expand the hydrogen systems with a range of vehicles, uninterruptible power supplies and combined heat and power units to increase the proportion of energy supplied from local sources. Other areas of work will be in using hydrogen for grid management, providing field tests, evaluating research and development, and exploring commercial opportunities for vehicles and tourism. Export markets will also include non-energy sectors such as hydrogen for the manufacture of fertiliser. Thus, their export markets focus is on more mainstream uses of hydrogen rather than replication to islands in other regions.

New Zealand would like to demonstrate their system on a large scale in a remote area. They expect that the system will be scalable for sizes between 10kW and 100kW. The rugged, easy to install, low cost plastic piping is ideal for harsh, remote environments.

7 Conclusions and Recommendations

There are socio-economic benefits as well as technical reasons for developing renewable hydrogen systems in remote communities. The need for improved energy security, protection against high fuel costs, and the availability of abundant renewable energy resources are key drivers behind these projects. Although their locations can make design, installation and maintenance of projects difficult, the cost of conventional fuel and the constraints on conventional uses of renewable resources make hydrogen more attractive. Hydrogen can offer jobs, tourism and engender community pride. This niche market could also be a springboard to more mainstream markets.

The main barriers found are

- the lack of mass produced, reliable, off-the shelf systems;
- funding and permitting for systems;
- challenges in design, installation and maintenance of these projects due to location and a lack of local expertise.

Although each individual system is small and insignificant alone, the number of islands or remote communities that could benefit from renewable-hydrogen systems in total represents a significant market. None of the barriers to hydrogen developing to its full potential are insurmountable, but they require co-ordinated action from government, industry and communities.

A more co-ordinated approach is therefore needed to demonstrate the market potential and develop expertise. This would not only help local businesses expand but also attract manufacturers to encourage suitable designs and mass production. There are already developments in this direction:

- The British Columbia project is aiming to replicate successful technologies in 30 communities, aligning itself with the needs of power companies and highlighting the possible market size.
- The European REislands project (www.europeanreislands.net) aims to produce and disseminate information on sustainable energy with the goal of providing the information for island communities to use 100% renewable energy.
- The European Islands Network on Energy and Environment 'Islenet' (www.Islenet.net) is a network concentrating on the development on sustainable energy resources for Islands. The projects are mainly R&D or lobbying for climate change legislation.
- The Nordic Network for Sustainable Energy Systems in Isolated Locations is working to improve the capability of energy-using communities in isolated areas of the Nordic region to share knowledge, skills and access to funding. It acts as a link between local and international efforts. Some of the research projects include hydrogen including:
    - The Utsira project
    - A wind hydrogen and PV project in Antarctica
    - A wind/diesel/hydrogen project focusing on two islands: Nolsoy and Nanortalik

  In the long term there are plans to use the results in other areas.

Many of the islands surveyed are members of these networks. These initiatives could be expanded to provide, for example, more training and safety advice.

A further area for consideration could be joint procurement of systems or components to encourage a modular design and to reduce costs. Although islands and communities are different sizes and have different needs, if a modular approach could be developed this would lead to reduced costs and enable systems to be more easily replicated, making the market more attractive to manufacturers. Existing forums may be the place for investigating these proposals.

7.1 Government Action

National and regional governments could actively support such initiatives by:

- Facilitating permitting, safety and codes and standards development appropriate for the size of project, ensuring staff are trained to apply them correctly,
- Ensuring a holistic approach to funding which includes and mandates education, communication and outreach, and takes into account the social and indirect economic benefits,
- Encouraging partnerships and clustering in projects rather than one-off approaches, ensuring this is reflected favourably in funding criteria,
- Facilitating international business opportunities for communities by actively supporting communities in exporting their systems or expertise.

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9 Appendix 1 – Survey Questionnaire

Questions for Renewable and Hydrogen Energy Projects in Remote Communities

Task 18 of the International Energy Agency's Hydrogen Implementing Agreement is an international collaborative project evaluating hydrogen demonstration projects. Part of the remit is to draw out the lessons learned from existing projects and provide recommendations as to how hydrogen systems can be effectively developed.

To do this we are studying the drivers behind the niche markets where hydrogen systems have already been developed and how they could be expanded and modified to reach new markets. A key niche market at present is renewable and hydrogen energy projects for remote communities.

We would therefore be grateful if you could answer the following questions regarding the development of your project.

1. What were the drivers for developing a renewable energy system in your community? If possible please 'paint a picture' or give statistics of the situation before and after the installation of the system.
   (For example: fuel costs, reliable energy supply, job creation, environment)

2. What were the drivers for including hydrogen and/or fuel cells in your system? If possible please 'paint a picture' or give statistics of the situation before and after the installation of the system.

3. What were the barriers/ challenges for the installation?

4. Please briefly describe your system and the reasons behind any of the key features.

5. Did you account for transport in your decision making?

6. What plans do you have to replicate or expand your system?

7. How could the system/technology you have, be modified for different situations? (for example: in different climates or geographic locations or for different applications)

8. Have there been any unexpected benefits for the community since the project was started? (for example: increased tourism, retaining qualified citizens, job creation etc)

9. What have been the barriers to success/ challenges on your project?

Many thanks for your time.

10 Appendix 2 – Endnotes

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[xi] Ibid.

[xii] http://canarias24horas.com/index.php/2008031546733/canarias/economia/los-sueldos-canarios-de-los-peores-de-espana.html accessed 29th October 2009

[xiii] Schoenung, S., Riddell, B., Maack, M., Miles, S., His, S. A Comparative Study of Hydrogen Refueling Station Experience. Proceedings of the 17th World Hydrogen Energy Conference.

[xiv] Smart H2 available at http://www.newenergy.is/en/projects/current_projects/smart_h2

[xv] NORDSESIL Nordic Network for Sustainable Energy Systems in Isolated Locations. http://nordsesil.net

[xvi] ECTOS Ecological City Transport System, Deliverable no.17, Total Impact Assessment, Responsible Party: UNI. (http://www.newenergy.is/newenergy/upload/files/utgefid_efni/ectos_17-total_impact_assessment_.pdf)

[xvii] Smart H2 (http://www.newenergy.is/en/projects/current_projects/smart_h2/)

xviii Ibid.