Draft Final Report

Feasibility Report for Hydrogen Energy Study Centre In Shetland

to

Shetland Renewable Energy Forum (SREF)

November 2004

IPA Energy Consulting

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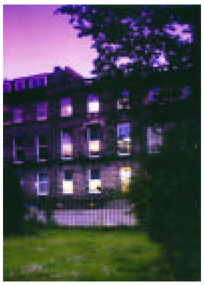

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ACRONYMS AND ABBREVIATIONS

To be finalised

1. EXECUTIVE SUMMARY

IPA Energy Consulting were commissioned by the Shetland Renewable Energy Forum (SREF) to undertake a study to determine the feasibility of a hydrogen energy study centre on Shetland. A positive feasibility should allow others to prepare a detailed business plan and progress this through to implementation in the knowledge that such a facility is, in principle, viable. A negative feasibility should indicate why such a facility would not be viable, and why it would not be worth developing in Shetland. The study was conducted in several stages with a report provided at the conclusion of each stage.

1.1 Identification of Stakeholders and Potential Users

An identification survey was undertaken to provide an overview of the current activities in the hydrogen sector. The survey covered 6 different jurisdictions; UK & Eire, Europe, US & North America, Asia and Australasia. It also provided a representation of activities of organisations located in several jurisdictions. The survey showed that there are significant activities and interest in hydrogen related activities with the automotive industry leading the way, as well as a number of demonstration projects and future commitments for the development of dedicated centres such as the Hydrogen Energy Research Centre in Turkey and the Hydrogen Park project in Italy. There are a significant number of academic institutions involved in the research, development and demonstration of hydrogen related technologies worldwide. In the UK for example, 13 academic institutions were identified as having a strong interest in hydrogen related activities such as hydrogen production, storage, end use and systems.

There are a number of Non-academic institutions that have shown a keen interest in undertaking hydrogen related activities such as the Regional Development Agencies in the UK, as well as activities in existing energy centres. There has also been strong collaboration on projects within Europe such as the Clean Urban Transport for Europe project (CUTE) and the Development and Demonstration of Infrastructure Systems for Hydrogen as an Alternative Motor Fuel. The majority of centres and projects having close ties to both universities and industry with funding coming from a mix of industry and national government as well as donor agencies within the European Commission and the United Nations. Of particular interest are the activities that are occurring in Iceland, Hawaii, Utsira in Norway, Vanuatu in the South Pacific and Islay in North West Scotland where they are pursuing hydrogen based economies.

As well as the traditional 'hydrogen companies' which are linked to industries such as in the production processes of the chemicals industry, there are a number of new start ups and existing companies exploring the opportunities relating to the use of hydrogen in energy systems, automotive applications, small scale devices such as mobile communications etc. The leading organisations are mainly based in the US and Japan, with extensive research into fuel cells and their applications.

1.2 Consultation

The purpose of the consultation was to get the views of key stakeholders on the feasibility of a hydrogen energy study centre on Shetland. The number of respondents to the consultation was 32 covering 6 different countries and a broad spectrum of activities as shown below:

- Public Bodies;
- Universities;
- Consultancies;
- Commercial Organisations ; and
- Centres of Expertise.

In general the consultees were very positive towards a hydrogen energy centre on Shetland, with a number showing an interest to be involved with activities both in terms of providing support to a centre and undertaking collaborative ventures. Knowledge transfer between different organisations is seen key in finding solutions to technical problems and in disseminating information and a centre on Shetland could play a key role in bringing about the development of hydrogen technologies and systems.

It is clear from the interview responses that the main emphasis is currently moving towards "real life" demonstration projects in "real world" conditions. This is clearly what is required to help move the industry forward and prove technologies to the general public, investors and governments to give them confidence and show that hydrogen is a viable alternative to conventional energy carriers and it is with demonstration projects that the majority of respondents believe Shetland can play a key role.

However, what is not required is a "talking shop" but a centre that can provide for testing and development of products in real world conditions. It is the view that in order to attract organisations to Shetland and use its facilities it will require something novel or unique and which cannot be obtained elsewhere. If this can be achieved then the disadvantage of Shetland's location will not be an issue as organisations will look to use these facilities and learn from the acquired expertise.

1.3 Appraisal of Exploratory Work

An appraisal of all of the exploratory work undertaken by the Unst Partnership in developing a case for a hydrogen energy study centre on Shetland was undertaken. Whilst playing close attention to the objectives of the Unst Partnership the key themes underpinning the development of a hydrogen energy centre on Shetland were explored.

The conclusion that hydrogen is not an appropriate storage media for electricity does not invalidate its nearer term use as a transport fuel. As production from the East Shetland Basin declines, it will be inevitable that the importance of the oil terminal at Sullum Voe will also decline. Shetland is rich in renewable power potential. There is no good reason why Shetland should not become the first area in the UK to convert from an almost complete reliance on transport hydrocarbons to the first place in the World that relies upon its own, renewable, energy resources for transport.

Given focus and sufficient funds, it may be possible to develop Unst as a prototype for shifting the whole of Shetland to renewable energy. If this were to be the case, wind and hydraulic power, moderated by energy storage, would make Shetland a primarily renewable electric economy. Surplus renewable power could be used to generate transport hydrogen that would reduce the 100% dependence of the transport sector on hydrocarbon transport.

The marketing of a “life sized laboratory” could be the distinctive factor that attracts both organisations looking to use such facilities but also organisations looking at other aspects of a hydrogen economy - such as the social and environmental impacts. It will be important, however, at an early stage that the local community buy in to the plans and are made aware and kept fully abreast of any activities that are likely to occur. Organisations are more likely to be attracted to areas that have the backing and support of the local community and where there is less likely to be opposition to schemes.

1.4 Identification and Assessment of Business Opportunities

Potential business opportunities for a Hydrogen Energy Centre in Shetland were identified in part from our consultation with key stakeholders, and in part from our own expert assessment of the opportunities. The following table summarises the potential opportunities, from a high level perspective, in terms of:

a. Opportunity – High (strong case for pursuing), Medium (possible opportunities) and Low (unlikely to be a sustainable opportunity); and

b. Time frame to realise opportunity – short (0-5 years), Medium (5-10 years) and Long (>15 years).

Area	Description	Opportunity	Timeframe for commencement of services
Demonstration	Exploiting the Renewable Resource	High	Short
	Hydrogen for Transport	High	Short
Education & Training	Undergraduate & Post Graduate Learning	High/Medium	Short
	Courses	High/Medium	Short/Medium
	Vocational Qualifications	Low/Medium	Long/Medium
	Schools, Colleges & Visitors	High	Short/Medium
Research	Internal (relating to demonstration projects on Shetland)	High	Short/medium
	External (other research opportunities)	Medium/Low	Short
Testing			
	Long term testing (weeks to months)	Medium/high	Medium/Short
	Short term testing (~1-2 days)	Low	Medium/Short
	Market Testing of Devices (i.e fuel cell phones/computers etc)	Medium/Low	Short/Medium

Certification	Medium/Low	Medium/Short

1.5 Identification of Potential Funding Streams

There are a number of possible funding streams which may be beneficial to a centre on Shetland both in terms of its establishment costs and also in supporting projects.

Possible funding sources identified include:

1.5.1 Scotland

- Highlands & Islands Enterprise (HIE)
- Scottish Energy Environment Fund
- Community and Householders Renewables Initiative (SCHRI)
- Energy Intermediary Technology Institute (ITI Energy)

1.5.2 UK

- Department of Trade & Industry
- The Carbon Trust
- Engineering and Physical Sciences Research Council (EPSRC)
- Natural Environment Research Council (NERC)
- Enhanced Capital Allowances (Inland Revenue)

1.5.3 EU

- ALTENER
- EU hydrogen and fuel cell Quick Start Initiative
- EU Sixth Framework Programme: Sustainable Development, Global Change and Ecosystems

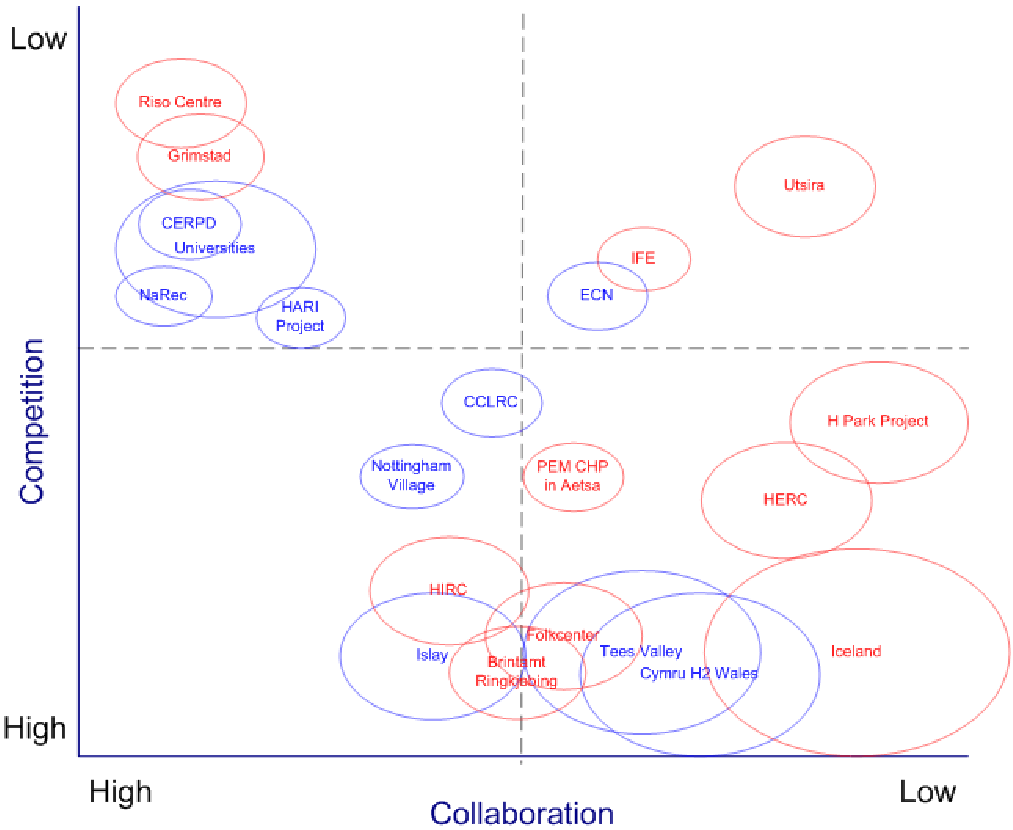
1.6 Identification of Competition and Opportunities for Collaboration

The potential competition to a centre on Shetland will depend upon the "uniqueness" of the experience that it will be able to offer compared to the services or facilities offered by other centres and organisations elsewhere. Whilst there is some likelihood of competition with established centres of expertise it is more likely, however, in the longer term that the main competition to Shetland will come from other areas that have a similar climate - significant renewable resources, islanded grid network (or potential for), space for demonstration projects, etc.

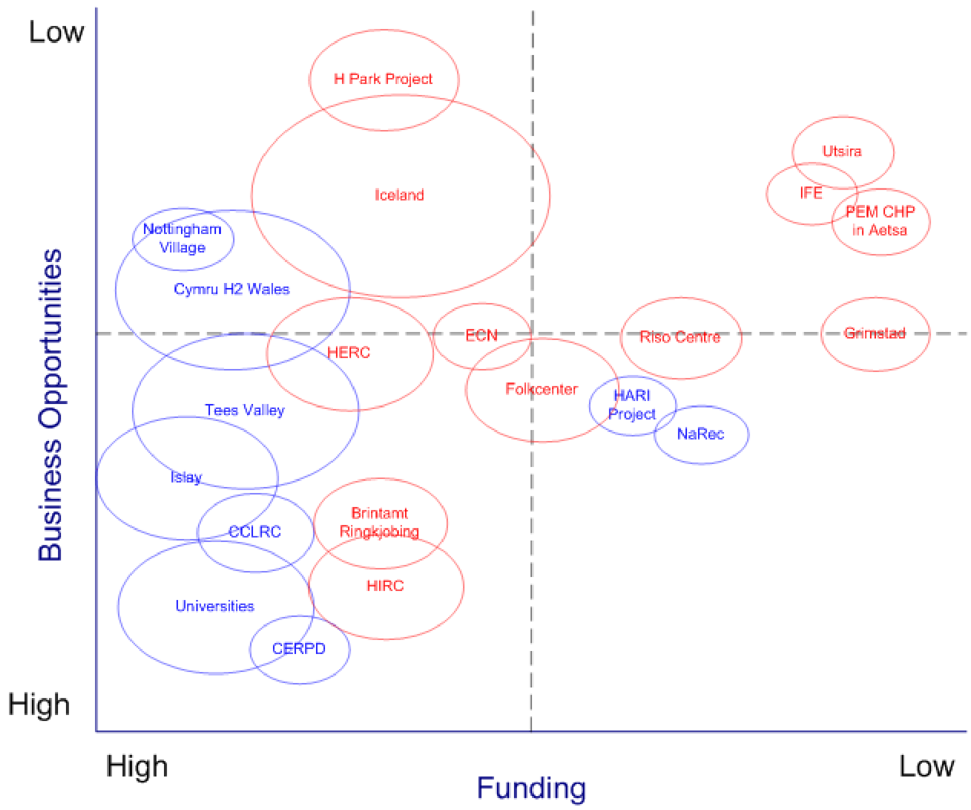
There will also be opportunities for collaboration both within the UK and further afield in undertaking demonstration projects, testing and the transfer of know how. It will be important, however, that a centre does not try to directly mimic activities that are being performed elsewhere but provides additionality to the market it is aiming to both develop and exploit.

The following two figures provide a high level subjective analysis of the potential competition and collaboration opportunities and the potential business opportunities and the rivalry for funding sources respectively. Organisations occupying a larger area represent a larger impact or footprint in terms of competition and collaboration opportunities. Organisations highlighted in blue are from the UK, whereas organisations highlighted in red are from the rest of Europe.

Competition and Collaboration Prospects



Business Opportunities and Funding Competition



1.7 Identification of Marketing Opportunities

There are a number of companies and institutions that would be potentially interested in using the services that a centre could provide. It will be important that the marketing aspects of a centre are not merely promoted as a study centre but as somewhere which is actively developing hydrogen energy and the application of hydrogen energy on a particular site. For example, the instigation of demonstration projects such as the development of hydrogen powered transport for Unst and potentially for other parts of Shetland and beyond. The marketing of a centre should focus on its own skills, experience and abilities but also promote the skills and expertise in renewable and hydrogen energy which also exist on Shetland. The centre as part of its marketing strategy should emphasise its strong linkages with other centres of excellence in hydrogen and renewable energy in Scotland, other parts of the UK, Europe, North America, Asia, Africa and potentially in other parts of the World.

Marketing opportunities will depend upon the different business areas that a centre pursues and will exist at a number different levels:

- Shetland
- Scotland
- The rest of the UK
- EU countries
- Internationally

The main market segments are:

- University and R & D centres
- Public sector institutions – DTI, Scottish Executive, Department of Energy, Scottish and Highlands and Islands Enterprise, ITI Energy etc.
- Private sector companies involved in renewable energy engineering and management
- Financial institutions with interests in renewable and hydrogen energy (renewable energy funds for example)
- Regional institutions – European Environmental Agency, the EU Directorates on Research and Innovation and the Environment and Transport
- International institutions and networks in economic and social development and renewable energy – UNEP, Small Islands Developing States (SIDS) network, the World Bank and other international financial institutions as well as national and international hydrogen and renewable energy associations.

1.8 Potential for a Hydrogen Centre in Shetland

The development of a centre on Shetland would be a unique development in Scotland, the rest of the UK and internationally, because of:

- Its remote island location
- Its focus on local applications for hydrogen energy.

Most science parks and technopoles that have been developed in the UK and Europe are located near a critical mass of university and private sector based R & D. While there is no critical mass of universities and R & D centres in Shetland, a centre on Shetland could build on its existing networks and linkages and develop a real and virtual centre of excellence for the hydrogen (and renewable energy), linking with other HEIs and R & D centres in Scotland and beyond through telemetric and personal linkages.

1.8.1 Location and Planning

It is our view that if a centre is to be developed on Shetland then it would be pragmatic to build on the site of the PURE project at the Hagdale Industrial Estate in Baltasound, Unst.
While it is recommended that the Unst site at Hagdale be developed as the core development of a centre on Shetland, subsequent developments could include hydrogen storage (for example) on Yell and a liaison office which could be located within say NAFC in Scalloway or Shetland College on the Gremista site.

For the development of a Centre it is our understanding that existing buildings could be rented or purchased for the project and therefore planning regulations would not be an issue. If there was new build either on the Hagdale site or nearby, then planning submissions and consents might need to be obtained.

1.8.2 Structure and Staffing

Once a centre has been established it is envisaged that, as a minimum, it would have a core staff of 4 with the following:

- Centre Manager, also responsible for marketing and liaison with other institutions
- 2 project engineers (one with specific responsibility for training)
- 1 PA/Secretary

It would also be recommended that the existing staff working at Hagdale on a partial basis could work on an occasional consultancy basis with the Centre Management team to ensure the transfer of knowledge and continuity during the initial stages.

1.8.3 Establishment and Operating Costs

The estimates of additional capital expenditure for the development of a centre and operational expenditures given in the tables below are based on our estimates of what the incremental costs for the development and operation of a Centre would be.

Requirements	**Costs**
Equipment for hydrogen energy development including hydrogen storage	£100,000
Office furniture equipment and computers	£20,000
Workshop benches, shelving, instrumentation etc	£15,000
Equipment of training area – furniture, audio visual equipment	£20,000
Design and legal costs	£7,000
Sub-Total	£162,000
Contingencies	10%
Total	**£177,000**

Estimated CAPEX Requirements

Any new build for offices would cost around £1,400/square metre with services but no internal equipment.

Requirements	**Costs**
Rental of offices and buildings	£7,000
Staffing	£130,000
Marketing and Accountancy	£8,000
Office consumables	£2,000

Telecoms	£3,000
Travel	£4,000
Sundry/contingencies	£4,000
Total	**£158,000**

Estimated OPEX Requirements

1.9 Economic Impacts – Employment, Linkages and Value Added

Shetland has a medium term target of producing 25MW or 50% of its current energy supplies from renewable energy sources. If this was to be achieved as many as 250 jobs could be directly created in the renewable energy sector in Shetland. Taking an employment multiplier for 1.3 the construction sector, maintenance and other supply chain linkages and allowing for leakage within the Shetland economy as many as 325 FTE jobs could be created in the long term.

If the hydrogen economy accounted for 20% of energy production in Shetland it would be equivalent to 65 FTE jobs directly and indirectly created. These 65 FTE jobs in the hydrogen economy with a GVA/FTE job of £50K would give a value added for the hydrogen sector in Shetland of £3.3 million.

The development of a centre would bring other benefits to Unst and Shetland from its business activities. This would in part benefit the Shetland economy through direct, indirect and induced multiplier impacts. For example, the creation of employment in the service sector such as hoteliers and transport.

In addition to employment creation and the development of supply chain linkages on Shetland in the renewable and hydrogen energy sector, the potential for hydrogen energy is to reduce the dependence on imported supplies of energy. In the longer term the gradual replacement of traditional hydrocarbon based energy sources with a cleaner fuel such as hydrogen will have other economic impacts including reduced atmospheric pollution and the associated impacts of human health, health and treatment costs. These benefits will not merely be on Shetland but with the increasing use of hydrogen energy will be transferred elsewhere in Scotland, the UK and beyond.

1.10 Recommendations

Based on our analysis it is clear that a hydrogen energy study centre by itself would not be a realistic or viable venture for Shetland in isolation from other activities such as testing, research and development related to commercial opportunities. It is therefore recommended that a centre markets itself as a “Hydrogen Energy Centre” rather than a “Hydrogen Energy Study Centre”.

1.10.1 Core Functions of a Centre

It is recommended that a centre is built on the foundations of the PURE project, with the development of training courses relating to its activities seen as its first priority. The initial development of a centre could then include activities, based on the PURE project, such as

- Providing consultancy expertise in the conversion of energy to hydrogen
- An independent testing and certification capability (fuel cells, electronics)
- Demonstration for the safety management of hydrogen facilities (Health and Safety Issues)

The further development of demonstration projects is seen as key to the longevity and successfulness of a centre. It is therefore recommended that rather than establishing an "all-embracing" centre at the outset it would be more pragmatic to develop a centre over a period of time in tandem with the development of projects. Particular emphasis should be given to those projects that could potentially be self-sustaining and benefit Shetland as a whole, such as exploiting Shetlands renewable resource for hydrogen production and using hydrogen in transportation applications. A further study would be required to determine the viability of these projects.

The core functions of a centre should be the applied development of hydrogen technology to the benefit of the economy of Shetland and Scotland. This could include:

- The development of the wind energy/hydrogen fuel cell work on Unst including an expanded workshop and store, an office and a demonstration and training area
- Demonstration projects such as the development of a hydrogen based transport system on Unst
- The construction of an area for training in hydrogen energy and fuel cell technology.
- The development of the research and training network on Shetland involving the PURE project and a centre on Unst, Shetlands College (renewable energy management), North Atlantic Fisheries College (engineering) and involving other key centres of the University of the Highlands and Islands network, while maintaining the strong links developed with Robert Gordon University and private sector partners in Shetland, Scotland and elsewhere in Europe and the UK.
- Testing and accreditation facilities

1.10.2 Concluding Remarks

It is apparent that other countries are developing hydrogen energy and applications and therefore if Scotland wants to maintain its competitive position in the development of this technology the importance of a centre as a focal point within a Scotland/UK renewable energy/hydrogen network is apparent. In addition there is an opportunity for one community, namely Unst to have most of its energy provided from renewable energy resources, including hydrogen. Such an achievement would act as a beacon for Scottish and UK renewable energy technology.

2. INTRODUCTION

The purpose of this report is to provide the Shetland Renewable Energy Forum (SREF) with a view of the potential viability of a Hydrogen Energy Study Centre on Shetland. The study commenced on the 27th of July 2004 and concluded on the 15th of December 2004 with the delivery of the Final report and presentation to the SREF, Shetland Enterprise and the Shetland Islands Council Development Department.

The study has been undertaken in several distinct yet interrelated stages with a report after the conclusion of each stage:

- Identification of Stakeholders and Potential Users
- Consultation
- Appraisal & Identification of market for centre
- Final Report & Presentation

2.1 Background to the Project

The principal aim of SREF is '*to ensure that Shetland maximises the economic and community benefit of developing its renewable energy resources while minimising the impact on the environmental, social and visual amenity of the islands*'. The island of Unst in Shetland is hosting the first community owned hydrogen production facility in Europe and symbolises the potential for this fuel of the future to be generated anywhere. The PURE Project has attracted a great deal of interest worldwide from academic institutions, politicians and the business community. This interest has highlighted the potential to attract contracts for field trials, testing and research, as well as more general learning and study opportunities. There is now interest in a more permanent hydrogen energy study centre in Shetland.

SREF commissioned IPA Energy Consulting to undertake a feasibility study to identify, clarify and quantify the need and opportunity for a Hydrogen Energy Study Centre in Shetland to support the development of the emerging hydrogen renewables sector.

2.2 Objectives of the Project

The overall objective of the study is to determine the potential viability of a Hydrogen Energy Study Centre on Shetland. The study considers the economic viability of a hydrogen energy study centre but only so far as to determine broad establishment costs and potential income streams.

A positive feasibility should allow others to prepare a detailed business plan and progress this through to implementation in the knowledge that such a facility is, in principle, viable. A negative feasibility should indicate why such a facility would not be viable, and why it would not be worth developing in Shetland.

The full terms of reference for the study are provided in Annex A

2.3 Structure of the Remainder of the Report

Section 2 provides an overview of the existing hydrogen centres, centres of excellence, hydrogen R&D facilities and academic facilities worldwide.

Section 3 provides a summary of the consultation exercise which was carried out to get the views of key stakeholders on the feasibility of a hydrogen energy study centre on Shetland

Section 4 provides an appraisal of the exploratory work undertaken by the Unst Partnership in developing a case for a hydrogen energy study centre on Shetland.

Section 5 identifies and assesses the possible business opportunities for a hydrogen energy centre on Shetland.

Section 6 identifies the current range of funding opportunities and financial support that might be available for a centre.

Section 7 identifies possible competition and collaboration opportunities.

Section 8 identifies possible Marketing opportunities.

Section 9 highlights the potential for a hydrogen centre in Shetland including the economic impacts.

Section 10 provides the summary and recommendations

In addition to these main sections of this report there are several annexes as described below.

Annex A – Terms of Reference

Annex B – Identification Survey

Annex C – Questionnaire

Annex D – List of Respondents to the Consultation

Annex E – Summary of Consultee responses

Annex F – Background Information on the Economy of Shetland

Annex G – HEI Linkages on Shetland

Annex H – Planning and the Energy Sector

Annex I – Data Register

3. IDENTIFICATION OF STAKEHOLDERS AND POTENTIAL USERS

An identification survey was undertaken to provide an overview of the existing hydrogen centres, centres of excellence, hydrogen R&D facilities and academic facilities worldwide. The survey was conducted as a desk based study with the main source of information being the World Wide Web. The survey is not exhaustive in terms of identifying all of the stakeholders in the hydrogen field but provides an impression of the type of activities, centres and commercial organisations that have been established to undertake research and pursue opportunities within the hydrogen sector.

The survey covered 6 different jurisdictions; UK & Eire, Europe, US & North America, Asia, Australasia & International. The "International" survey provides a representation of the activities of those organisations that are active in several jurisdictions, for example Shell Hydrogen and DuPont.

An overview of the results of the Identification survey for the UK & EIRE and Europe are provided in the following section. A summary of the results of all the jurisdictions can be found in Annex B. The full results of the survey are provided in the Stage 2 report to this assignment.

3.1 UK & Eire

This survey was the most detailed in identifying the key players in the hydrogen sector as these organisations are deemed to have potentially the most influence, in terms of competition and collaboration opportunities, in determining whether a hydrogen study centre on Shetland is feasible.

3.1.1 Academic Institutions

There are a large number of academic institutions undertaking projects in the hydrogen field. The majority of activities are performed within existing departmental groups although the University of Glamorgan has set up a separate Hydrogen Research Unit within its Sustainable Environment Research Centre. Another centre that has just recently been established is the UK Energy Research Centre (UKERC), although its current remit does not cover hydrogen technologies it may do in the near future. Its aim is to provide energy research in the UK, and for cooperation between the UK and researches from other countries with its head offices at Imperial College in London and subsidiary offices at other Universities throughout the UK. A list of the Academic institutions identified are provided below in Table 2 - 1.

Organisation Name	Area of Interest
Sustainable Environment Research Centre (SERC) – Hydrogen Research Unit	Research
Inter University Centre for Economic Renewable Power Delivery (CERPD)	Research
Imperial College	Hydrogen Production
University College Cork	Hydrogen Production & Storage
University of Birmingham	Hydrogen Storage & End Use
University of London, Queens Mary College	Hydrogen Storage
University of Nottingham	Hydrogen Storage & Systems
University of Oxford	Hydrogen Storage
Loughborough University, CREST	Hydrogen Systems
University of Leicestershire	Hydrogen Systems
UMIST (UMIST Ventures Ltd)	Hydrogen Systems
University of Cambridge	Hydrogen Systems
The Robert Gordon University & University of St Andrews	Hydrogen Systems
The Robert Gordon University	Hydrogen End Use

Table 2 - 1: Identified Academic Organisations active in Hydrogen Related Activities

3.2 Non-Academic Institutions

As well as the centres and projects highlighted here the 9 Regional Development Agencies are and have developed regional strategies for the economic growth in their localities, with some covering hydrogen where it is realistic to do so (i.e. due to technical excellence, resource, business appetite etc). Some are more developed than others such as the Tees Valley Hydrogen project as highlighted below and others have undertaken feasibility studies in looking at the development of a hydrogen economy such as in the West Midlands (Advantage West Midlands) where they are also trialling a three wheeled vehicle powered by fuel cells (developed in collaboration between industry and academia at Coventry University). A list of the Non-Academic institutions identified is provided below in Table 2 - 2.

Organisation/Project Name	Area of Interest
CCLRC Rutherford Appleton Laboratory, Energy Research Unit (ERU).	Research
NaREC (New and Renewable Energy Centre)	Research
Tees Valley Hydrogen Project – linked to the Centre for Process Innovation	Development & Demonstration
The Islay Hydrogen Project	Hydrogen Systems
A Sustainable Energy Supply for Wales: Towards the Hydrogen Economy	Hydrogen End Use

Table 2 - 2- Identified Non-Academic organisations/projects active in Hydrogen Related Activities

3.3 Commercial

We have identified a number of UK organisations who are either active or have interests in hydrogen and its technologies. A list of the commercial organisations identified is provided below in Table 2 - 3.

Organisation Name	Area of Interest
Accentus plc	Hydrogen Storage & Production
Hydrogen Solar	Hydrogen Production & Storage
Anglesey Wind and Energy (Wind Hydrogen Limited)	Hydrogen Systems
Electrochemical Technology Business	Hydrogen End Use
Advantica	Hydrogen End Use
Voller Energy	Hydrogen End Use
SiGEN	Hydrogen End Use, production & storage)

Table 2 - 3 – Identified Commercial Organisations active in Hydrogen Related Activities

IPA
IPA Energy Consulting

3.4 Europe

The identification survey looked to provide examples of both centres of excellence and projects being run by academic and non-academic organisations as well as those commercial organisations active in the Hydrogen field

3.4.1 Academic Institutions

Within the academic institutions no centres of excellences dedicated to hydrogen activities have been identified, although a number of Universities have been active in non-academic centres such as the Grimstad Renewable Energy Park in Norway and the Risø centre in Denmark. There are, however, a number of Universities active in various projects within the hydrogen field, in particular in Northern Europe. A list of the Academic institutions identified is provided below in Table 2 - 4 below.

Organisation Name	Area of Interest
University of Stuttgart, Germany, Department of Lifecycle Engineering	Hydrogen Production
Roskilde University, Denmark – Energy & Environmental Group	Hydrogen Systems
University of Cassino, Italy, Department of Industrial Engineering	Hydrogen Systems
University of Oslo, Norway	Hydrogen Storage & Systems analysis

Table 2 - 4 – Identified Academic organisations active in Hydrogen Related Activities

3.4.2 Non-Academic Institutions

There are a significant number of Non-Academic Institutions active in the hydrogen field with the majority of centres and projects having close ties to both universities and industry. Funding of these centres and projects comes from a mix of industry and national government as well as the donor agencies within the European Commission and the United Nations. A list of the Non-Academic institutions identified is provided below in Table 2 – 5 below.

Organisation/Project Name	Area of Interest
Institute for Energy Technology (IFE), Norway	Research & Development
Folkcenter, Denmark	Development & Demonstration
Risø Centre, Denmark	Research, Development & Demonstration
Hydrogen Energy Research Centre (HERC), Turkey	Research & Development
Hydrogen Park Project, Italy	Research & Development
Energy Research Centre of the Netherlands (ECN)	Research & Development
Centre for Solar Energy and Hydrogen Research (ZSW), Germany	Research & Development
Grimstad Renewable Energy Park, Norway	Demonstration
Hydrogen Innovation and Research Center (HIRC), Denmark	Research, Development & Demonstration
ECTOS (Ecological City Transport System) Project – Iceland	Hydrogen End Use
Development and Demonstration of Infrastructure Systems for Hydrogen as an Alternative Motor Fuel - Italy, Germany, Sweden & Denmark	Hydrogen End Use, Development & Demonstration
Cryoplane – Liquid Hydrogen Fuelled Aircraft: System Analysis	Hydrogen End Use
RES2H2 - Integration of Renewable Energy Sources with the Hydrogen Vector – Spain & Greece	Hydrogen Systems, Production & Storage
H2 MUC - Hydrogen Project at Munich Airport, Germany	Hydrogen Systems
CEP (Clean Energy Partnership), Germany	Hydrogen Systems
Hydrogen Competence Centre, Germany	Hydrogen Systems
Scandinavia's First Hydrogen Fuelling Station. Sweden	Hydrogen Systems
Wind Hydrogen System Utsira, Norway	Hydrogen Systems
CUTE (Clean Urban Transport for Europe) Project	Hydrogen Systems
Brintamt Ringkjobing Amt, Denmark	Hydrogen Systems
PEM CHP in Aetsa, Finland	Hydrogen Systems

Table 2 – 5 – Identified Non-Academic organisations/projects active in Hydrogen Related Activities

3.4.3 Commercial

We have identified a number of European organisations who are either active or have interests in hydrogen and its technologies. A list of the commercial organisations identified is provided below in Table 2 - 6. This list is not meant to be exhaustive but provide an indication of the types of activities commercial organisation are pursuing.

Organisation Name	Area of Interest
Corporación Energía Hidroeléctrica de Navarra (EHN), Spain	Hydrogen Production
SRE (Soluções Racionais de Energia, SA), Portugal	Hydrogen End Use/Systems
Norsk Hydro Electrolysers AS (NHEL), Norway	Hydrogen Production & Storage
ELT (Elektrolyse Technik), Germany	Hydrogen Production
IRD Fuel Cells A/S. Denmark	Hydrogen End Use

Table 2 - 6 – Identified Commercial Organisations active in Hydrogen Related Activities

4. CONSULTATION

The purpose of the consultation was to get the views of key stakeholders on the feasibility of a hydrogen energy study centre on Shetland. Where it was not possible to directly interview the stakeholders a questionnaire was sent to them. The interview questions are provided in Annex C. A list of prospective interviewees was provided by Sandy Macaulay of the SREF to which the Consultants expanded. The number of respondents to the consultation was 32 covering 6 different countries and a broad spectrum of activities as shown below:

- Public Bodies;
- Universities;
- Consultancies;
- Commercial Organisations ; and
- Centres of Expertise.

Of those who were interviewed 7 were from the Academic arena, 9 were Non-Academics and 16 were commercial organisations. A list of consultees is provided in Annex D.

The questionnaire covered broadly 6 areas:

- Hydrogen Markets;
- Study Centre;
- Financing the Centre;
- Education;
- Final Question ; and
- Other information.

The main themes underlying the consultation responses are provided below. The views of the respondents are summarised in Annex E. Full interview responses are provided in the Stage 3 report to this assignment.

4.1 Hydrogen Markets

The interviewees were asked questions relating to hydrogen markets. In particular details of their activities relating to hydrogen, how they saw the potential markets developing and what they considered would be required to stimulate the growth of these markets/activities.

There are a number of organisations active in areas relating to a hydrogen market. In particular in fundamental research and some demonstration projects, as well as organisations providing services to and looking to be leaders in hydrogen technologies and systems in order to get a competitive edge in the market place. There are also a number of "funding" bodies, public and private, looking to invest both in project ideas and Intellectual Property rights as well as a number of organisations looking to actively support an industry in promoting and disseminating information. Knowledge transfer between different organisations is seen key in finding solutions to technical problems and in disseminating information and this can be seen by the number of collaborative projects between academia and commercial organisations. Within the UK (and further a field), Shetland has the opportunity to collaborate with other centres of excellence, academia and commercial ventures in bringing about the development of hydrogen technologies and systems.

It is clear from the interview responses that the main emphasis is currently moving towards "real life" demonstration projects in "real world" conditions. This is clearly what is required to help move the industry forward and prove technologies to the general public, investors and governments to give them confidence and show that hydrogen is a viable alternative to conventional energy carriers. There are already a limited number of demonstration projects such as the integration of hydrogen for use in transportation and the use of hydrogen in electricity generation and it is with demonstration projects that the majority of respondents believe Shetland can play a key role.

Hydrogen technologies such as fuel cells and storage solutions are still a long way off from being commercial let alone being competitive with current forms of energy carriers. Due to the higher costs of transport fuel compared to other forms of energy use, however, hydrogen has the potential within the medium term (5-15 years), to become a realistic option for use within the transportation sector provided the infrastructure and expertise is developed. Parallel to this hydrogen could become a realistic opportunity for islanded communities where fuel costs are generally higher, such as is the case of Shetland. There is therefore potential for Shetland to become a "hydrogen island" and with this obtain the knowledge and expertise that will be able to be exported globally.

4.2 Study Centre

The interviewees were asked questions relating to a proposed study centre on Shetland and in particular the advantages and disadvantages of having a centre on Shetland as opposed to another location.

It is clear that what is not required is a "talking shop" but a centre that can provide testing and development of products in real world conditions. It is the view that in order to attract organisations to Shetland and use its facilities it will require something novel or unique and which cannot be obtained elsewhere. If this can be achieved then the disadvantage of Shetland's location will not be an issue as organisations will look to use these facilities and learn from the acquired expertise.

For hydrogen to be attractive it needs to be produced from renewable sources of energy such as wind turbines and marine devices. The conditions on Shetland mean that its renewables resource (both on and offshore) is significant but in order for it to take advantage of the resource it requires some form of storage media to make it a viable opportunity, due to the lack of load on the Island. The use of hydrogen storage could therefore be a realistic option. Shetland should aim to make use of its renewable resources and demonstrate how this would tie in with hydrogen, rather than looking at tailoring a centre towards a specific activity as this would require a critical mass to become successful. There is clear demand for demonstration projects, from which a study centre could follow and capitalise, and if Shetland is able to deal with real life applications and look at the problems associated with these then it would be a big attraction, not only from being able to see real life applications but the knowledge and experience gained of the people involved with the demonstration projects. Building on the work of the Pure Project and providing further demonstration projects will make Shetland attractive to both research and commercial organisations alike.

Once a centre was established there are a number of organisations that would be interested in providing support for and services to a centre as well as organisations that would consider collaborative ventures. It will be important, however, that a centre does not try and mimic work that is currently being done elsewhere as this will only antagonise other institutions who have or are developing an expertise.

The community has an important role to play in the successfulness of a "hydrogen base" on Shetland both in terms of acceptance of the technologies and upheaval that a change could bring about due to changes in infrastructure (i.e. demonstration projects, move to a hydrogen economy etc) but also in the knowledge and understanding of how these technologies work and integrate within their community. A very positive attitude of the community will give organisations confidence in the ability of Shetland to embrace change, but also and more importantly not to oppose developments.

4.3 Financing the Centre

The interviewees were asked questions relating to the financing of a centre. In particular they were asked whether they would look to collaborate with a centre, whether they would consider becoming a partner in a centre and how they would look to assist a centre financially.

There are a number of public bodies within the UK that could provide grants for the initialisation of a centre, whether this was a new building or expanding the existing facilities on Unst. There may also be possible collaborative opportunities with industry whereby start up costs could be funded by a public-private partnership. A number of organisations have also shown an interest in being associated with a centre on Shetland.

The key to the successfulness of a centre, however, is whether it will be able to attract the interest and use over a sustained period of time. For it to succeed it will need to attract finance from external sources. The majority of organisations would pay to use the centre on an "as and when" basis, and so it will be important that a centre is offering organisations a unique experience to entice them to use the facilities over a sustained and long period of time. If a centre is competing against another centre then the costs of getting to Shetland, both in terms of travel costs and man-days lost due to travel time, would be a detriment factor to using a centre on Shetland.

4.4 Education

The interviewees were asked whether they would want a centre to offer research opportunities and education facilities for graduates and employees. They were also asked whether they would use a centre and what would entice them to use it.

Most Universities would collaborate with a centre on Shetland providing it had something on offer that the Universities could not themselves facilitate. This may be for example providing practical experience for post-graduate students in hydrogen technologies and systems. Having such collaborations with Universities would also be to the advantage of a centre in that a centre could use other research facilities, gain from external expertise and benefit from academic links. Besides academia both non-academic and commercial organisations would look to benefit from the knowledge that a centre would accumulate and whether this would be as part of bespoke training courses, exchange of teaching and research between centres or helping with the education and development of renewable – hydrogen systems in other jurisdictions. Knowledge transfer is seen as key for the emerging hydrogen markets and with the experience and expertise that Shetland could gain from demonstration projects it could play a pivotal role in this area.

4.5 Final Question

Each of the respondents was asked whether they thought it was realistic or feasible for Shetland to have a Hydrogen Energy Study Centre. In general all respondents were favourable to the idea of having a hydrogen energy study centre on Shetland on the condition that a number of factors were met such as:

- Accessibility Issues need to be overcome
- Contingent on a centre/Shetland having a uniqueness to offer
- It needs to be sure of its market for services and whether people would be willing to travel to Shetland to use the facilities
- A centre should form part of a wider network of UK centres rather than trying to become the centre where all hydrogen activities are carried out
- It should not become over ambitious and try to do everything related to hydrogen
- A centre should start off small and be allowed to grow organically
- It needs to be focused and specific
- A centre will need to have something to offer or demonstrate and therefore it will be important for Shetland to have a number of activities.

4.6 Other Information Provided

Finally the interviewees were asked of they had add any further comments as to the feasibility of a hydrogen energy study centre on Shetland. There was a general feel that Shetland should not be the only hydrogen centre but part of a network of centres around the UK each sharing their expertise and knowledge.

5. APPRAISAL OF EXPLORATORY WORK

Within this section we appraise all of the exploratory work undertaken by the Unst Partnership in developing a case for a hydrogen energy study centre on Shetland. In analysing this work we paid close attention to three key objectives of the Unst Partnership namely;

- To relieve poverty and unemployment amongst the resident of Unst;
- To promote and/or provide skills training of all kinds, particularly such skills as will assist residents of Unst in obtaining paid employment; and
- To promote trade and industry for the benefit for the general public.

A list of the documents provided by the SREF highlighting the work undertaken by the Unst Partnership is shown in Annex I. In reviewing these documents we have explored the key themes underpinning the development of a hydrogen energy centre on Shetland.

5.1 "The Potential for Hydrogen in Scotland" – Forum for Renewable Energy Development in Scotland (FREDS), 2004.

This document begins by providing three key issues:

2. *Hydrogen has a significant potential as the basis of an energy system with low carbon dioxide emissions; it can be used as a fuel for road transport, distributed heat and power generation and for energy storage.*
3. *Hydrogen has the potential to be produced from diverse and distributed sources, thereby providing opportunities for the regeneration and development of sustainable communities in Scotland. As a means of storage, hydrogen also has the potential to make a significant contribution to balancing electricity produced from primarily intermittent renewable sources and to supporting security of supply.*
4. *The market for hydrogen fuel cells is embryonic but potentially huge. There may be potential for Scotland to build on existing strengths within industry and academia to provide opportunities for job creation within the hydrogen and fuel cells sectors*

The assumptions in this document seem to be a constant theme underlying all the other documents provided by the SREF and appear to form the basis for the developments of hydrogen activities on Shetland and so it is worth critically examining the validity of the claims. It is well known that hydrogen is an energy carrier not an energy source. Every kg of hydrogen has to be manufactured from another energy source. The second law of thermodynamics states that when such energy transformations occur, there will be a loss of primary energy. Such losses will occur whether the hydrogen is manufactured from electricity, fossil fuels or biomass. The primary energy losses are quite considerable, thus a greater amount of primary energy must be available to deliver any energy used in the form of hydrogen.
As an example, one of the most energy efficient electrolyser that can be commercially purchased today is *Norsk Hydro*'s HP-30, which produces hydrogen at 30 bars. The

various power transformations from mains grid through the transformer and rectifier to the electrolyser cells result in power losses of about 5% before any electrolysis takes place. The electric energy consumption of the whole electricity system is 4.35 kWh (or 15.660 MJ of energy) per Nm^3 hydrogen. The energy value of the hydrogen is 10.78 MJ/nm^3 (LHV)[1] and 12.74 MJ/nm^3 (HHV). So this transformation, involving 4.35 kWh of primary (electric) energy is just 68.6% efficient based on the LHV. If the hydrogen is to be used in transport, it will be required to be compressed to at least 300 bars so as to give the vehicle range and thus reducing the efficiency even further. The figure below shows the Power Supply System to an Electrolyser Plant.

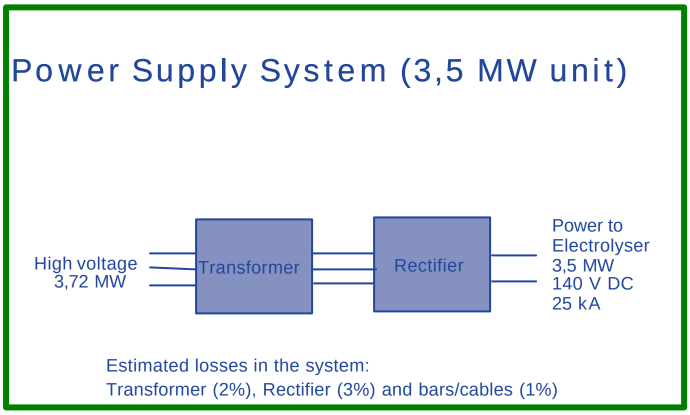


Figure 4 – 1 – Representation of a Power Supply System to an Electrolyser Plant

Of course, it is possible, in a well-integrated energy scheme, to use most of the heat generated by electrolysis and compression in pre-heating or directly in space heating. That could result in primary energy utilisation close to 90%. But heat has a much lower "thermodynamic value" than either electricity or hydrogen so cannot be valued in the same way. That is to say that the low grade heat captured in this way cannot be transformed to make electricity or hydrogen.

A similar conundrum occurs when hydrogen is made from biomass or wastes. Hydrogen is already widely made by the gasification of oil and coal and by the steam reformation of natural gas or naptha. These processes are between 70% (gasification of coke or anthracite) and 82% (reformation of natural gas) efficient. The gasification of biomass and waste - neither primary sources being high in fuel quality - is likely to require even more primary energy loss in the transformation to hydrogen than is required by fossil fuels. In all cases, some of the waste heat generated by the process can be captured and used in some low grade application thus raising total energy utilisation.

All this becomes more problematic when the use of hydrogen as a method of storing electricity is considered. All solutions for doing this result in some of the energy from the input hydrogen being transformed back to electricity while the remainder is transformed into low grade heat.

[1] Heating values express how much energy is released on combustion of a given quantity of fuel, for example, joules per kilogram, or Btu per gallon. A "high heating value" (HHV) includes the heat that can be obtained by condensing the water vapour produced by combustion. A "low heating value" (LHV) does not include this heat. The appropriateness of using LHV or HHV when comparing fuels depends on the application. For stationary combustion where exhaust gases are cooled before discharging (e.g. central heating boilers), HHV is more appropriate. Where no attempts to extract useful work from hot exhaust gases (e.g. motor vehicles), the LHV is more suitable.

The losses from hydrogen to electricity are even greater than the losses from electricity to hydrogen. The theoretical efficiency of transforming hydrogen to electricity exceeds 80%. However, the actual conversion efficiency of commercially delivered, proton exchange membrane (or PEM) fuel cells on the market is around 40%, hydrogen to electricity[2]. Of course, the heat generated can also be captured to give a greater overall fuel utilisation rate, but clearly there is a need for further research in improving the efficiencies of the fuel cells.

But the key question is whether the combination of electrolysers, hydrogen store and hydrogen powered PEM fuel cells can transform intermittent energy sources like wind power into power systems that can supply reliable and economic power according to demand. It looks as if this goal is distant and further research is required in improving the efficiencies of the process.

A representation of the total energy flows of such a system are sketched below:

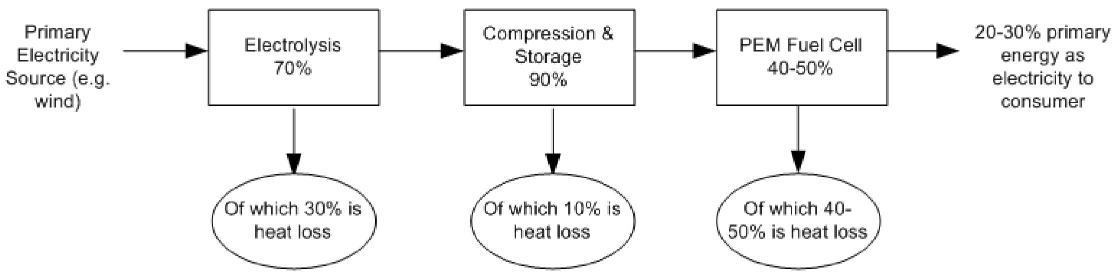


Figure 4 – 2 – Representation of the Total Energy Flows of a Hydrogen System

It is essential that the arithmetical balances of all the hydrogen processes are well defined so that, however attractive they may appear to be, their limitations are also understood. In fact, gas motors have a higher efficiency than PEM fuel cells and they cost considerably less. The conclusion is that, for the foreseeable future, hydrogen is neither an efficient nor an economic way to store electricity. Other, better, methods of storing power exist, including pumped hydro storage (up to 80% efficient), compressed air energy storage (>60% efficient) and various forms of batteries (up to 80% efficient).

5.2 Discussion paper "Hydrogen in Shetland – International Context"

This paper lists a number of projects against which the potential opportunities for Shetland in the development of a hydrogen economy may be measuring itself. Therefore it is worthwhile to take a step back and review the situation in the places mentioned.
It is axiomatic that to develop a CO_2-free, hydrogen economy firstly requires the existence of a surplus of renewable energy. In the whole World, there is only one economy where such a surplus exists, the Western half of Denmark.

The USA is the World's largest single consumer of hydrocarbons. Its plans to reduce its reliance upon hydrocarbons are still being considered. While it will undoubtedly lead the

[2] www.ird.dk & www.sigen.co.uk

World in technology development, from which Shetland can benefit, it will be many, many decades before hydrogen, from renewable sources, contributes any more than the tiniest fraction of its energy needs.

Iceland has proposed to transform itself into a "hydrogen society". Its main achievement to date, with considerable assistance from the EU, is a single hydrogen dispenser at a Shell filling station in Reykjavik and two hydrogen buses. Although blessed with abundant renewable energy in the form of hydropower and geothermal energy, effectively all of Iceland's generating capacity is dedicated to existing customers. To transform the transport sector from 100% dependence upon hydrocarbons to renewable hydrogen will require either that existing customers, like the two aluminium smelters, will have to be re-powered or closed. Or alternatively massive, new, investments are made in new, renewable power installations, at a huge cost and against that country's environmental lobby which is resistant to new dams or geothermal power stations. Without those new energy generators, the hydrogen cannot be manufactured.

The same applies to Hawaii where the application to build every new geothermal power plant is hard-fought. The reliance of this economy on hydrocarbons is so complete that ideas of building sufficient new generation equipment simply to replace local hydrocarbon consumption do not appear to be realistic, let alone the idea that sufficient renewable energy could be generated to allow the export of hydrogen to California.

As regards Vanuatu, which has outlined its vision for a 100% hydrogen economy by 2010, the following statement was taken from Vanuats's vision for a 100% Renewable Energy Economy[3];

- *"2010 is the target date to stop importation of petroleum fuels and become a hydrogen based economy. By 2020 we will eliminate any remaining internal combustion engine vehicles and all machinery, vehicles and electrical generation will be done using fuel cells and renewable energy systems such as hydroelectric, geothermal, wind and solar.*
- *In this initiative, all components must be modular and designed to integrate into one system that works together"*

Clearly here there is a political will but the reality of converting the island to a hydrogen based economy by 2010 is going to be an expensive and technically challenging process.

5.3 Letter from EA Technology (J N Baker) to Sandy McCaulay

This letter raises the fundamental question of whether the SREF needs the interest of the IEA more than the IEA needs the interest of the SREF, located in one of the most inaccessible and remote areas of Europe. The obligations of participation in Task 18 may be onerous in terms of costs and time for a relatively small organisation and the requirement that EA Technology would receive "free and open access to all relevant information and data in relation to the PURE project for the purpose of Task 18 case study analysis" may even become unacceptable.

[3] http://www.vanuatugovernment.gov.vu/energy%20statement.html

However, this might be a way of attracting grant funding and academic activity and also bring with it the benefits of networking with colleagues on an international basis.

5.4 "Community Hydrogen Opportunities in Clean Energy Solutions" and a letter from Cameroon

Depending on the expectations of the PURE project regarding hydrogen generation and use, if the recommendations from the "Community Hydrogen Opportunities in Clean Energy Solutions" are accepted, it is possible that the PURE project will see very few practical, near commercial outlets for hydrogen. All of these will be high cost and high technology in nature. Hydrogen generation and use can be not only expensive but in the wrong hands, hazardous.

A low-level interaction with community-based renewable energy efforts elsewhere in the World is always productive, socially as well as technically. However, there is always a danger that efforts to address the needs of organisations in completely different economic, social and geographic circumstances could detract from the main efforts of the PURE project.

5.5 Email correspondence between Tohoku University, Japan and Sandy McCaulay & "Exploiting the Learning Potential of the PURE Project", a briefing paper for Shetland Enterprise

The interest of the outside World in the PURE project will depend mostly on its ambitions. A large project, focused mostly in its own backyard but doing something not tried anywhere else in the World, is likely to attract respect and attention World-wide.

No sophisticated, fully functioning, renewable energy based system at a significant scale has yet been established anywhere. Given focus and sufficient funds, it may be possible to develop Unst as a prototype for shifting the whole of Shetland to renewable energy. If this were to be the case, wind and hydraulic power, moderated by energy storage, would make Shetland a primarily renewable electric economy. Surplus renewable power could be used to generate transport hydrogen that would reduce the 100% dependence of the transport sector on hydrocarbon transport.
This will require that the Shetland Council and other funding agencies can first see that the plans developed by the SREF, at the very modest scale presently being built, can be expanded to cover the entire island of Unst at an acceptable cost and with a high degree of reliability. In turn, if this is achieved, the same technologies could be applied to reduce the other Shetland Islands' dependence on hydrocarbons. As this takes place, the SREF will develop skills and attract know how that will be unique. This would attract attention from all over the World which in turn would draw in talent, attracted by the sheer excitement of the project.

5.6 Summary

The conclusion that hydrogen is not an appropriate storage media for electricity does not invalidate its nearer term use as a transport fuel. As production from the East Shetland

Basin declines, it will be inevitable that the importance of the oil terminal at Sullum Voe will also decline. It is an irony that while Shetland remains an important transit point for most of the UK's crude oil, refined hydro-carbons are more expensive in Shetland than anywhere else.

The decline of the Shetland Basin oil resource is coinciding with a World peak in oil (as depicted in Figure 4 - 3 below) production that will see the UK, for the first time since the industrial revolution, at the end of a long energy supply chain rather than at its top.

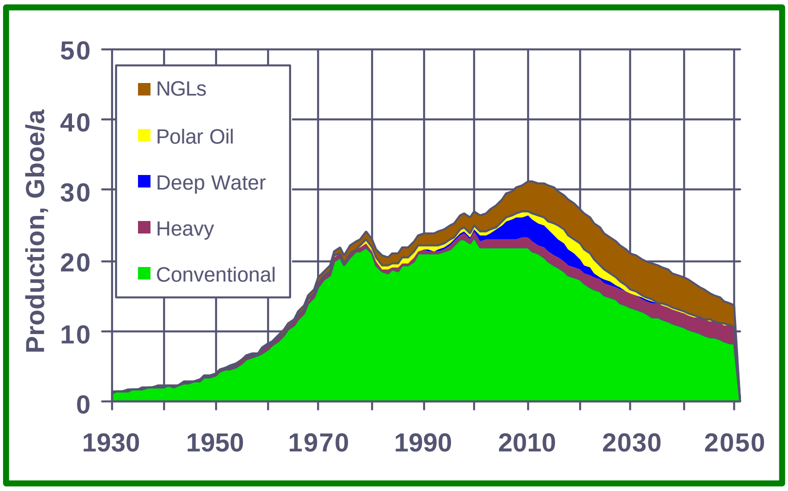


Figure 4 - 3 Oil Production to 2050[4]

Shetland is rich in renewable power potential. There is no good reason why Shetland should not become the first area in the UK to convert from an almost complete reliance on transport hydrocarbons to the first place in the World that relies upon its own, renewable, energy resources for transport.

The marketing of a "life sized laboratory" could be the distinctive factor that attracts both organisations looking to use such facilities but also organisations looking at other aspects of a hydrogen economy - such as the social and environmental impacts. It will be important, however, at an early stage that the local community buy in to the plans and are made aware and kept fully abreast of any activities that are likely to occur. Organisations are more likely to be attracted to areas that have the backing and support of the local community and where there is less likely to be opposition to schemes.

Demonstration projects are likely to cause disturbance and upheaval to the local community both in terms of the establishment and installation of projects but also during their operation. It will therefore be important to explain the benefits to the local community in terms of the advantages to the local economy.

[4] From the Association for the Study of Peak Oil, 2004

6. IDENTIFICATION AND ASSESSMENT OF BUSINESS OPPORTUNITIES

Once a hydrogen energy centre is established it could provide a number of different services and in this section we look to identify the potential business opportunities related to developing hydrogen energy technologies.

6.1 Potential Business Opportunities

Potential business opportunities for a Hydrogen Energy Study Centre in Shetland were identified in part from our consultation with key stakeholders, and in part from our own expert assessment of the opportunities.

The key needs and opportunities identified from the consultation with key stakeholders were as follows:

- There is a need for hydrogen R&D projects to move to 'real world' demonstration projects operating under realistic conditions;
- There is potential for Shetland to become a 'hydrogen island', and to export the knowledge that this would bring in terms of technology, system integration, and hydrogen utilisation;
- There is a need for test centres in all regions to test and certify products, and to develop codes and standards for both static and portable devices;
- Shetland should make use of its renewable energy resources; and
- There is also a need for working systems to facilitate social science studies on the effects of hydrogen on the local population.

A number of comments were also made on what the Centre should *not* be:

- A 'talking shop';
- Undertaking fundamental research; or
- Duplicating efforts made elsewhere.

The following table summarises the potential opportunities, from a high level perspective, in terms of:

a. Opportunity – High (strong case for pursuing), Medium (possible opportunities) and Low (unlikely to be a sustainable opportunity); and

b. Time frame to realise opportunity – short (0-5 years), Medium (5-10 years) and Long (>15 years).

Area	Description	Opportunity	Timeframe for commencement of services
Demonstration	Exploiting the Renewable Resource	High	Short
	Hydrogen for Transport	High	Short
Education & Training	Undergraduate & Post Graduate Learning	High/Medium	Short
	Courses	High/Medium	Short/Medium
	Vocational Qualifications	Low/Medium	Long/Medium
	Schools, Colleges & Visitors	High	Short/Medium
Research	Internal (relating to demonstration projects on Shetland)	High	Short/medium
	External (other research opportunities)	Medium/Low	Short
Testing			
	Long term testing (weeks to months)	Medium/high	Medium/Short
	Short term testing (~1-2 days)	Low	Medium/Short
	Market Testing of Devices (i.e fuel cell phones/computers etc)	Medium/Low	Short/Medium
Certification		Medium/Low	Medium/Short

Table 5 – 1 Potential Business Opportunities

6.2 Demonstration Schemes

The PURE project is potentially the first of many demonstration projects that could occur on Shetland. As well as providing benefits to the "hydrogen world" in the development and understanding of hydrogen technologies and systems, demonstration projects on Shetland have the ability to benefit the local community by bringing about employment, increase in local economic activity, lower fuel costs as well as environmental benefits.

Funding for demonstration projects is usually via a mixture of capital grants and private contributions. These funds are usually hard fought for and for every success there are usually a number of failures. Demonstration projects tend be finite in duration, the project on Utsira for example is only expected to be run for 2-3 years. It is therefore important in order to help sustain and build up a centre that funding is able to be secured on a regular basis. As well as competing for capital grants Shetland should also look towards its own resources and the possible revenue that can be generated to support a centre. The following provides such examples.

- **Exploiting the Renewable Resource**

  Shetland has some of the best wind, wave and tidal resources in Europe, but utilisation is presently constrained by the lack of load on the isolated Shetland grid[5]. Generating hydrogen by electrolysis of water, although at present a very inefficient process, could provide the necessary load. According to modelling undertaken by IPA for the Highland Council in 2003, a 10% increase in the capacity factor of a wind turbine results in an 18.8% increase in profits after interest and tax. Expected capacity factors for wind turbines in Shetland may easily be 10% higher than capacity factors for equivalent plant on the UK mainland, due to the better wind resource. Therefore the additional profits from a Shetland wind turbine may be sufficient to offset the additional cost of electrolysis equipment, thereby producing hydrogen at very low cost (potentially a negative cost, if the value of Renewable Obligation Certificates (ROC)[6] outweighs the additional capital costs of creating demand through electrolysis). The hydrogen produced could be sold for use on-site by demonstration projects, and any excess could potentially be sold into the conventional hydrogen market (although the storage and export costs would need to be considered).

  However, the value of ROCs is the main driver of profitability of renewable energy projects, and this value is uncertain, as it depends on a combination of future policy decisions and the total number of projects going ahead which in turn dictate the price of the ROC's. Basing capital decisions on estimates of future wind speeds is also inherently risky. There may also be constraints in terms of the siting of wind turbines and electrolysis equipment, and constraints on the ability of the grid to transfer power between these two elements, if they are not co-located. The ability of demonstration project developers to pay for on-site hydrogen consumption may be limited, and the market may be small in size or constrained over time. Finally, the conventional hydrogen market is highly competitive, with hydrogen being produced by a small number of powerful players such as oil refineries, and it would not be advisable to rely on sales into this market to bolster the economics of the scheme without further careful market analysis.

  Further analysis of this opportunity is required to determine whether the increased generation of Renewable Obligation Certificates from Shetland renewables would offset the additional cost of the electrolysis equipment.

- **Hydrogen for Transport**

  Many $ billions are being spent by the major vehicle manufacturers on the development of fuel cells that are supposed to deliver more efficient power trains

[5] This is not the "only" reason, however. Scottish and Southern Energy (SSE) have obligations to customers regarding the quality and security of supply they provide. In order to ensure that they are best able to meet these obligations SSE require certain characteristics from the generation plant that is available. These characteristics are not presently offered by the majority of wind generators.

[6] The renewables obligation is an obligation on licensed electricity suppliers to supply a proportion of their energy from renewable sources of energy. A ROC is equivalent to 1 MWh of electricity generated.

for transport vehicles. Notwithstanding the existence of the *SiGen*'s "Ghost" special vehicle in Shetland, it is doubtful that resources can ever be developed in Shetland that will be able to compete with the major fuel cell manufacturers or contribute in a meaningful global or even local way to the development of fuel cell transport. However, hydrogen can and does power internal combustion engines. Ford, especially, has chosen the hydrogen internal combustion engine as a key component of its strategy in developing vehicles powered by hydrogen[7]. Most vehicles on Shetland for many years are likely to be powered with internal combustion engines. There may therefore be an opportunity for a centre to convert some existing vehicles to operate on hydrogen, thus creating a local centre of excellence in what could be the "hydrogen capital" of the UK. Such entrepreneurs already exist in California[8].

The scale of this transition in Shetland is manageable by comparison with the rest of the UK. The amount of power needed to replace transport hydrocarbons in the UK economy is immense. Recently a study by Warwick University calculated that in order to satisfy the demands for transport hydrogen at today's level, about 100 nuclear power stations would have to be built, or 100,000 3MW, wind generators[9].

The problem is more tractable on Shetland, a small landmass where the problems of the limited range of hydrogen vehicles, a big problem for US or UK consumers, is less of an issue for Shetland Islanders. The following calculation provides an example of the case in point;

Example

- *Assumptions*

  Number of Shetland vehicles = 13,000[10]
  Demand for fuel per vehicle (say) = 30 litres/week
  Gasoline, SG (specific gravity)[11] = 0.74[12] litres/kilogramme
  Gross Calorific Value Fuel Oil[13] = 43.5 GJ/tonne
  One cu m of hydrogen (LHV) has energy value 10.8 MJ
  Using the Norsk Hydro HP-30 electrolyser, then, electricity needed for 1 cu m hydrogen = 4.35 kWh

- *Calculation*

  Vehicle Consumption (litres per year) = 13,000 * 30 l = 20,280,000 litres per year.
  Which is equivalent to 20,280,000 l/y * 0.74 l/kg = 15,007,200 kg or (say) 15,000 tonnes

7 http://www.ford.com/en/innovation/engineFuelTechnology/hydrogenInternalCombustion.htm
8 http://www.h2carco.com/Drive_cars_suvs.html
9 http://www.oswald.co.uk/ocl/windaccountancy04.pdf
10 Shetland in Statistics, 30th Edition
11 The specific gravity of a substance is a comparison of its density to that of water
12 Handbook of Petroleum Refining Processes (La Fleur, Pennwell Books)
13 http://www.dti.gov.uk/energy_prices/

Total energy, 15,000 t * 43.5 GJ/t = 652,500 GJ = 652,500,000 MJ
Energy equivalent is: 652,500,000 MJ/10.8 MJ = 60,416,667 Nm3 hydrogen
Power needed to make hydrogen = 4.35kWh * 60,416,667Nm3 = 262,812,501 kWh or (say) 263,000 MWh

Therefore Shetland's 13,000 vehicles, require approximately 263,000 MWh per year. If we assume that this power is to met by wind generators and each wind generator has an annual load factor of 35%, then the power to supply all the transport hydrogen of the Shetland Islands can be provided by 43, 2 MW turbines. For reference purposes, it is worth noting that in 2002, the electricity generated for the electrical requirements of Shetland was 231,000 MWh.

6.3 Education

Exploiting the Learning Potential of the PURE Project is a paper published by Glenarder Ltd for the Shetland Enterprise. It highlights some of the potential "learning" activities and collaborative opportunities with academic centres for a centre on Shetland. The paper highlights four areas for learning potential; short course development, undergraduate and post graduate learning, vocational qualifications and flexible schools curriculum. It also highlights the potential for Academic collaboration and in particular with Robert Gordon University (RGU).

Clearly, if a centre on Shetland is to be involved in education activities it will need to be recognised by academic and most importantly University Institutions both within the UK and further afield. We do not, however, believe that a centre on Shetland should be focussed purely on providing learning facilities. Whilst it will be important for a centre to provide these activities there will not be sufficient demand to maintain a centre over the short to medium term.

- **Undergraduate and Postgraduate learning**

From the consultation with key stakeholders a number of academic institutions highlighted that they would consider using a centre to provide both undergraduate and post graduate students with practical hands-on experience of hydrogen technologies and systems. Depending on the type of courses or research being undertaking would determine the duration and length of time students would use a centre. For example, a Masters programme would normally consist of two modules of taught courses at the University and then a third project based module which could either be taken within industry, at the University or other research establishment. Although, this would not bring any significant financial income to a centre it could provide a centre with extra resource to undertake projects relating to its own activities. This is similarly the case with PhD students, who would be more inclined to use a centre over a longer period of time.

As well as students visiting a centre it may also be possible to collaborate with Universities in providing lectures to undergraduate and postgraduate students relating to the centres expertise. However, for this to occur it will be important that the centre offers expertise that the university does not itself have. It is unlikely, however, that these courses will be undertaken at a centre on Shetland until a sufficient critical mass of activities has developed and would more likely involve the centres staff lecturing at Universities.

- **Courses**

A centre could offer a number of recurring or bespoke training or education packages to both non-academic and commercial organisations. These could be aimed at delivering both theoretical and practical workshops. Workshops/seminars could also be undertaken at other venues both within the UK and elsewhere. As well as providing supplementary income for a centre it would also help with the dissemination of activities of the centre.

Recently the Unst Partnership undertook an exercise to gauge the interest in attending training courses in Unst on hydrogen systems. The course is aimed at £850 per person, including travel from Aberdeen, accommodation costs and is to be run over 4 days. If we assume that this course is run twice a year with attendance of 15[14] per group then the total income would be expected to be of the order of £25,500. However, this does not take into account the expenditure to run the courses and so if we assume that:

- Accommodation Costs – £42 per person staying at the Baltasound Hotel on Unst – Total of 3 nights.
- Travel Costs from Aberdeen (NorthLink ferry) - £160 return for 2 berth cabin in peak season with North Link ferries based on one person occupancy; and
- Income to expenditure ratio is 69% - Salaries, equipment etc (based on the 2002 Annual Review from the Centre for Alternative Technology (CAT) for courses)

Then, the total income to a centre after expenditure is approximately £5,245 annually or £175 per person. The demand and longevity for such courses will depend on the centres activities and its ability to provide subject matter that cannot be obtained elsewhere.

- **Vocational Qualifications**

From the consultation the Health & Safety Executive stated that one of the major problems that is going to occur in the industry is a lack of skilled workers able to install and trouble shoot hydrogen installations. When a mass "hydrogen" market is developed there will be a need to retrain for a variety of different skills and consequently there will be a major shortage of workers and trainers. This is clearly a long way off from being commercial reality and it is likely that if hydrogen technologies are used in every day items such as in domestic appliances and transport a number of such centres will be set up around the UK to fill the skills gap. However, there could be an advantage of becoming the first accredited centre to offer such qualifications in both training professionals and the trainers themselves.

[14] Thus far between 30 and 40 people have shown an interest in the course.

- **Schools & Colleges**

Another area of opportunity for a centre would be to run courses and activities that form part of the schools curriculum (i.e. technology, science etc). A centre would therefore need to provide an experience that is going to be worthwhile, like at the Centre for Alternative Technology (CAT) in Wales. A centre could be set up to facilitate for both day visits (from local schools) and for longer term visits so that the costs and time of travel do not become a prohibitive factor. It may also be appropriate to set up links with the other activities on Shetland – Fisheries College, Archaeology etc in order to offer students different experiences. If we model a centre on Shetland on the CAT centre (£3.75 entrance fee per pupil on day visits) then the maximum possible income available from local schools for day courses/visits based on students in schooling in Shetland[15] would be as follows;

Schooling	Student Numbers	Income	Expenditure[16]	Total Revenue
Secondary	1589	£5959	£655	£5304
Primary	2097	£7864	£865	£6999
		£13,823		**£12,303**

Table 5 – 2 Potential Revenue from Schools & Colleges (Short term Courses)

The analysis above assumes that each student will attend the centre once a year, whereas in reality a centre could provide a number of courses. However, to maintain this interest a centre will need to offer experiences that target the different age groups and curriculum activities.

A similar analysis can be undertaken for week long courses and assuming that:

- Courses are run for 6 months of the year – 26 weeks;
- Entrance fee - £3.75 (no charge for teachers);
- 3 out of the 5 days are spent at the centre, with the other 2 days undertaking other activities on Shetland – which are charged at £3.75 per day;
- Number of group visits is 52 (assuming 2 groups per week) – In Comparison 200 schools and further education colleges visited CAT in 2002.
- 24 students per group;
- Accommodation Costs – £8 per student per night staying at the Gardiesfauld Youth Hostel on Unst – Total of 4 nights.
- Travel Costs from Aberdeen via ferry[17] - £140 return per 4 berth cabin in peak season with North Link ferries;

[15] 2002 Student figures obtained from Shetland in Statistics, 30th Edition.
[16] Based on Income to Expenditure ratio from the CAT Annual Review 2002 for Education.
[17] Costs include 10% concessions for full time students.

- No allowance has been made for meals, travel whilst on Shetland and travel to and from the ferry link terminals; and
- Income to Expenditure ratio is 69% - Salaries, equipment etc (based on the 2002 Annual Review from the CAT for courses)

Student Numbers	1296
Cost per Student	£86
Centre's Income	£14,040
Centre's Expenditure	£9,688
Centre Revenue	**£4,352**

Table 5 – 3 Potential Revenue from Schools & Colleges (Long term Courses)

Another opportunity could be for the centres staff to run courses at schools and colleges. Depending on the content, structure and appetite for these courses several schools and colleges could be visited during one tour.

- **Other Income Streams**

As well as the potential income streams from academic institutions it is likely that a centre would attract other visitors such as those on holiday. The total number of visitors to Shetland in the year 2000 was 47,719[18] which included people on business (21,231), holiday (16,040), visiting friends and relatives (8,492) and other (1,416). The table below shows the different income to a centre depending on the number of visitors to a centre. The analysis is undertaken on the following assumptions:

- Entrance charge of £7.90 for adults and £4.50 for children (this is representative of the charges at the CAT centre in the summer months);
- 50% of visitors are adults and 50% of visitors are children; and
- No expenditure for maintenance of activities at a centre is determined[19].

Percentage of total visitors to Shetland visiting centre	Total Visitors	Total Revenue
1%	470	£2,914
5%	2,360	£14,632
10%	4,720	£29,264
15%	7,080	£43,896

Table 5 – 4 Potential Revenue from Visitors

The figures presented in this section provide an illustration of the potential income that a centre is likely to achieve, based upon a number of assumptions. It will be important for a centre to provide sufficient interest and facilities to attract visitors to a centre.

[18] Shetland in Statistics, 30th edition
[19] Note, the income to expenditure ratio for CAT is 234% for day visits.

6.4 Research

Most research that is undertaken is normally supported by specialist laboratories and facilities either run by the organisation or used in collaboration with several parties and backed up by a vast information resource on which to draw upon. It is therefore, unlikely that organisations would use a centre on Shetland for pure research.

We do not foresee a centre on Shetland competing against these types of facilities but rather providing a supporting role where specific expertise is required. For example, where technical expertise is required or in facilitating research into the social science aspects of hydrogen systems - here a centre could be used as a base for these activities. It will be important, as with the education opportunities, that a centre affiliates itself with Universities and other centres of excellence such as the Rutherford Appleton Laboratories and the Hydrogen and Innovation Research Centre (HIRC) in Denmark.

There then may be opportunities to collaborate with organisations to obtain funding via the various capital grant schemes as highlighted in chapter 5, however, it is most likely that the research activities at a centre will be closely linked to the demonstration project(s) on Shetland. This activity will therefore be dependent on the number and types of demonstration projects occurring as well as the ability to raise the required funding. Funding for this research is likely to come from the various capital grant schemes or be self-generated by a centre through its other activities.

6.5 Testing

Having facilities to undertake the testing of products has the potential to form a major component of work at a centre. However, a centre would need to provide a distinctive selling point and provide services that cannot be obtained elsewhere in order to entice organisations to Shetland. It is in the provision of test facilities where this could occur and in particular in testing devices in real world applications and conditions.

It will be important that a centre builds upon the skills and facilities developed as a result of the demonstration projects in providing testing services to organisations, rather than providing one off facilities to a limited market over a finite timeframe. These could include but not be limited to;

- Generating hydrogen from Shetlands significant renewable resource. Providing a clean, sustainable and reliable source of hydrogen that is cost competitive with other sources of hydrogen will be a major attraction to organisations looking to test their devices.
- Storage systems could be tested in relative isolation compared to other more densely populated areas.
- Testing devices on an islanded grid system offers a full range of conditions that may be experienced at some point on more conventional grid connected networks. Under the more challenging conditions manufacturers will be able to analyse the impact of voltage and frequency fluctuations on their equipment when connected to a real network and over an extended period of time. The characteristics of demand also affords the opportunity to test any load following

capability that a manufacturer may wish to offer for a device. By developing and testing products on a system that offers a range of characteristics that may be only rarely encountered on the mainland, but under which conditions the equipment is required to be able to function correctly, Shetland offers an ideal opportunity for the development of hydrogen based energy devices for manufactures to gain confidence in their equipment. The conditions in Shetland will also provide an excellent demonstration facility for other network operators to assess the suitability of hydrogen projects on their networks. A logical starting point would be the provision of a number of connection points for grid-connected technologies.

- The ability to "plug and play" devices in real conditions will not only assist organisations in the development of products but also allow other stakeholders to see technologies in real life conditions.
- Market Testing Devices. As hydrogen technologies become better established and proven in real world conditions the take up and use of devices would be expected to grow as external factors such as market conditions and the availability of devices become more conducive to the commercialisation of hydrogen technologies. For example, in the utilisation of hydrogen for use in a variety of products such as cookers, fuel cells for mobile phones/laptops etc. There are a number of manufacturers currently developing fuel cells for use in smaller applications such as mobile phones and laptops. These include NTT DoCoMo and Fujitsu of Japan who have stated that fuel cell phones powered by methanol will be commercial by 2006 and Toshiba who have stated the fuel cell laptops will be made available in 2004/5. In order to attract manufacturers to market test devices in Shetland a centre could form the focal point to orchestrate these activities. However, it may have to compete against other organisations offering similar services at more convenient locations and so a centre on Shetland must ensure that it keeps ahead of its competitors by providing better facilities and expertise.

It is unlikely, however, that there will be a demand for testing of devices over a short time period (1-2 days), unless a manufacturer/developer moves its base to Shetland and so it will be important that a centre markets itself appropriately. Depending on the duration and the services an organisation will require will dictate the costs that a centre will accrue and consequently the fee it charges out for use of its facilities. For example, EMEC currently charge £150,000 per annum for use of its facilities. This includes all consents, sub sea infrastructure, insurance, electrical connection, power purchase agreements etc as well as some data gathering relating to the devices.

Another example is the New and Renewable Energy Centre (NaRec) in the North East of England. It is aiming to set up a number of facilities including a blade test facility and electrical laboratory. It is anticipated that the blade testing facility would be used over a 4-5 month period and cost in the order of £200,000 for its use. For this facility, there is only a very limited market (only 13 European manufacturers) and so it is crucial to have good client based relations in order to understand their needs. The electrical laboratory is to be smaller in scale and will vary from a few hours of testing to several weeks. The costs for these services will depend very much on the facilities and expertise required. An interesting diversion, however, is that NaRec has the ability not to charge for use of its facilities but instead take a share in the company so that the Intellectual Property rights are kept within the North East. Whether or not they will be able to do this once the initial funding from the Regional Development Agency (One North East) for the development of the facilities have been used up is yet to be determined as the costs of running the centres activities will need to be covered.

6.6 Certification

A further development of the Test Centre concept would be to provide certification services for near-market technologies. This relies on the fact that new technologies such as grid-connected electricity generation require certification against a number of standards (health and safety, grid connection and performance standards), before they are ready for mass-market implementation. The Centre could also be involved in the initial development of standards for the industry. Whilst it is likely that the majority of certification services will start in the medium term it is debateable whether sufficient critical mass will develop for a centre on Shetland to make it successful compared to other more recognised certification services.

Types of certification could include CE marking and ISO accreditation. CE marking on a product is a manufacturer's declaration that the product complies with the essential requirements of the relevant European health, safety and environmental protection legislations. There are essentially two options available to the manufacture to certify their product and affix the CE Marking;

- Minimal Risk – which entails self-certification by the manufacturer; and
- Greater Risk – where products/systems are required to be independently certified.

If a centre were to offer services in the "greater risk" category then it would need to become a "Notified Body," which is achieved via nomination from the government. A Notified Body is usually able to offer the following services:

- product testing
- type examination certificate issue
- Technical File and design dossier evaluation
- surveillance of product and quality system
- identification of standards

ISO accreditation is an international standard covering a wide variety of products and processes. The vast majority of ISO standards are highly specific to a particular product, material, or process. However, the standards that have earned the ISO 9000 and ISO 14000 families a worldwide reputation are known as "generic management system standards". ISO 9000 is concerned with "quality management". ISO 14000 is primarily concerned with "environmental management".

ISO certification tends to take only a couple of days but it depends on the product/system being certified and the number of people within an organisation that are involved. Therefore, organisations providing ISO certification tend to charge out on a daily fee rate and normally provide the services on site. As an example, International Certification Services (ICS) is a leading ISO certification body and currently charges £550 per day plus

VAT. CE marking, however, can take the manufacturer several months to achieve depending on the number of applicable directives. Costs that it will be able to command will therefore depend on the duration and services it was providing. For example, the ATEX directive, which covers equipment and protective systems intended for use in potentially explosive atmospheres (which is applicable to all hydrogen applications), can take several weeks depending on the number of components within the device.

In the short to medium term manufacturers' of devices such as fuel cells and electrolysis equipment are most likely to use their own facilities in order to achieve the appropriate certification. It will not be until hydrogen technologies become more established and utilised for use in domestic and other industrial applications that sufficient market demand will be created for certification services.

6.7 Summary

There are a number of potential business opportunities that a centre on Shetland could take advantage of, as highlighted above. However, in order to attract organisations to use a centre on Shetland for a sustained period and use its facilities and expertise it will be required to provide experiences that cannot be obtained elsewhere. This could take the form of one large project, such as converting Unst (say) into a hydrogen economy or replacing fossil fuelled based transport with hydrogen, or several smaller demonstration projects providing different experiences. By generating this interest or "distinctive factor" and developing a centre in tandem which could provide organisations/individuals with the ability to see these projects first hand, the ability to develop/test devices and also facilitating educational activities a centre on Shetland has the potential for being a viable and realistic opportunity.

7. IDENTIFICATION OF POTENTIAL FUNDING STREAMS.

This section identifies the current range of funding opportunities and financial support that might be available for a centre. We have highlighted those non-governmental organisations and public bodies that may be able to provide assistance both in terms of the development of a centre and its activities. The different institutions are presented within the locality in which the support is targeted towards.

7.1 Scotland

- **Highlands & Islands Enterprise (HIE)**

  HIE provides financial support for a wide range of community-based projects, including:

  - HIE Network Financial Assistance for Community Projects, ranging from feasibility studies and the purchase of equipment through to the refurbishment of buildings. The average grant size is 25%, depending on location and size of the project.
  - Innovation Advice, and in some cases financial assistance for new product and process development. The aims of the programme are to increase commercialisation of research and innovation and to enhance involvement in global markets.
  - The Community Development Project Initiative, which entails direct grant assistance for community-led economic development projects that aid economic regeneration and employment opportunities in the Highlands & Islands. To be eligible for support, the project must demonstrate:
    - genuine community support
    - contribute to an economic benefit in the area in which it is located
    - priority will be given to projects that can show that support will result in the establishment of new employment opportunities.

  Applications are limited to a maximum of £10,000.

  Further information can be found at: www.hie.co.uk/Financial-assistance.html

- **Scottish Energy Environment Fund**

  With its academic and government partners, SEEF assists Scottish industry to take advantage of the radical changes occurring in the energy market in the UK through identification of market opportunities; free evaluation of new and novel energy system technologies and promoting collaborative projects which promote the deployment and up-take of clean and energy efficient devices.

  Further information can be found at: www.seef.org.uk

- **Community and Householders Renewables Initiative (SCHRI)**

The Community and Householders Renewables Initiative (SCHRI) of the Scottish Executive is operated by the Highlands and Islands Enterprise and the Energy Saving Trust. It is aimed promoting community renewables, providing expertise and developing networks. There are two funding areas:

- Capital Grants - Capital grants pay for a contribution to the capital costs of projects, with funding of up to 100% of the project costs. The maximum grant is £100,000; and
- Technical Grants/Assistance - Technical assistance funding of up to 100% is available to support non-capital projects, such as feasibility or scoping studies and capacity building within a community. The maximum grant is £10,000 and applicants are required to outline contributions from other sources (public or private).

Applications for funding under Technical Assistance and Capital Grants are assessed against the following criteria.

- Community benefit, involvement and a good level of local support for the project.
- Technical viability and capacity to produce renewable energy within 2 years of funding being granted
- Maintenance and management plan for the project once installed
- Cost-effectiveness
- Larger capital projects may also be subject to independent technical assessment, prior to grants being offered.

Further information can be found at: www.est.org.uk/schri/

- **Energy Intermediary Technology Institute (ITI Energy)**

ITI Energy is aimed at identifying R&D requirements for the energy sector by collaborating closely with Scottish academic and business institutions. It will, among other things, exploit and commercialise intellectual property, releasing technology quickly through new start-ups and/or to existing SMEs or larger companies, and create new business opportunities. ITI Energy will spend £450 million over the next 10 years for new technology matchmaking. In order to access the pre-competition research funds, it is necessary to become a member of the ITI; this costs £400 per annum. Additional information on procurement and research commissioning is expected to be published at the end of 2004.

Further information can be found at: www.itienergy.com/

7.2 UK

- **Department of Trade and Industry (DTI)**

The Department of Trade and Industry provides financial assistance to hydrogen energy initiatives through the New and Renewable Energy Programme. One of the themes of the Programme is Fuel Cells. Funding can be obtained through the Collaborative Research and Development scheme, which provides 25%-75% of project costs and targets industry-industry or industry-academia collaborations. Partnerships with EU counterparts (through the EUREKA network, www.eureka.be) are accepted. The selection process is competitive.

Further information can be found at: www.dti.gov.uk/crd/

- **The Carbon Trust**

The Carbon Trust is an independent company funded by Government; one of its aims is to help businesses and the public sector capture the commercial opportunities of low carbon technologies. Its Venture Capital Programme has hydrogen infrastructure, production, transportation, storage, and distribution as one of its priority areas. Under this scheme the Carbon Trust typically invests between £250k-£1.5m per deal as a minority stakeholder alongside private sector investors on the same terms. The selection is based on the following criteria:

- Financial position
- Management experience
- Market research
- Competitive advantage
- Identified funding
- Technical and innovative evidence
- Confirmation of intellectual property protection and
- Additionality.

Further information can be found at: www.thecarbontrust.co.uk/

- **Engineering and Physical Sciences Research Council (EPSRC)**

The Engineering and Physical Sciences Research Council, through its Infrastructure and Environment Programme operates the SUPERGEN initiatives in cooperation with the Carbon Trust. The Supergen III initiative funds:

- Energy storage and recovery systems – Maintaining an uninterrupted supply from intermittent sources.
- Distributed power systems and devices – Exploring networks and control of small-scale generating systems.

EPSRC funds collaborative partnerships between industries and universities. The selection process entails the review of the project proposal by an independent panel of experts.

Further information can be found at: www.supergen.co.uk.

- **Natural Environment Research Council (NERC)**

The Natural Environment Research Council promotes hydrogen research as one of the priority themes for the Sustainable Energy Economy Programme. The funding schemes include a new Energy Centre and a research programme that applies to universities only. However, NERC also operates the CONNECT scheme, which is aimed at facilitating and promoting new interactions between researchers and those who can make use of the results of research e.g. industry, commerce, business or public sector agencies. In particular, the CONNECT B scheme is aimed at research applications on which a public sector partner agrees to commit 50% of the funds. The assessment criteria include

- the degree of partner involvement
- novelty of the proposal
- cost effectiveness of approach
- need, urgency and inability of other schemes to respond.

The application process is held annually; in 2004 pre-selection took place in August.

Further information can be found at:
www.nerc.ac.uk/funding/grants/grants.shtml

- **Enhanced Capital Allowances (Inland Revenue)**

Enhanced Capital Allowances for - Cars with Low CO_2 Emissions Scheme. These are 100% first year allowances, which are claimed in the business's income or corporation tax return. The scheme applies to expenditure on new plant and machinery installed at gas refuelling stations to refuel vehicles with natural gas or hydrogen fuel. The refuelling station does not need to be open to the public, or used for cars. Eligible equipment can include:

- storage tanks;
- compressors;
- controls and meters;
- gas connections; and
- filling equipment.

The expenditure must be incurred between 17 April 2002 and 31 March 2008. Further information can be found at:

http://www.inlandrevenue.gov.uk/capital_allowances/cars.htm#4 or http://www.eca.gov.uk/

7.3 EU

- **ALTENER**

ALTENER is part of the "Intelligent Energy - Europe" (EIE), the community's support programme for non-technological actions in the field of energy efficiency and renewable energy sources. The duration of the programme is from 2003 to 2006. ALTENER promotes new and renewable energy sources for centralised and decentralised production of electricity and heat and their integration into the local environment and the energy systems. Competitive funding opportunities are advertised through calls for proposals advertised on:

http://europa.eu.int/comm/energy/intelligent/call_for_proposal_2003/index_en.htm. The next call for proposals are expected to be announced in the Autumn of 2004.

Further information can be found at:
http://europa.eu.int/comm/energy/intelligent/index_en.html

- **EU hydrogen and fuel cell Quick Start initiative**

The Quick Start Initiative is an EU scheme aimed at boosting EU economic development by encouraging the creation of public/private partnerships in co-operation with the industry, the research community, and other partners, including notably the European Investment Bank to leverage finance. Within this scheme there is a specific funding source for hydrogen and fuel cell projects. A further €150 million will be available in 2004-2005 from the EU for hydrogen economy projects. The selection of projects involves a competitive tender. Information on calls for proposal can be obtained from the Electronic Daily Official Journal of the European Community.

Further information can be found at: www.europa.eu

- **EU Sixth Framework Programme: Sustainable Development, Global Change and Ecosystems**

A call for proposals in the area of 'Sustainable energy systems - research activities having an impact in the medium and longer term' was published in September 2004 (reference number OJ C224 of 08.09.2004). The areas covered by this call are:

- fuel cells
- new technologies for energy carriers
- renewable energy technologies

- capture and sequestration of CO_2
- socio-economic tools and concepts.

The total indicative budget for this call is €190 million, with €124 million being made available for Integrated Projects and Networks of Excellence and € 66 million available for Specific Targeted Research Projects and Coordination Actions.

The closing date for applications is the 4th December, 2004.

Further information available at http://fp6.cordis.lu/fp6/

8. IDENTIFICATION OF COMPETITION AND OPPORTUNITIES FOR COLLABORATION

The potential competition to a centre on Shetland will depend upon the "uniqueness" of the experience that it will be able to offer compared to the services or facilities offered by other centres and organisations elsewhere. There will also be opportunities for collaboration both within the UK and further afield in undertaking demonstration projects, testing and the transfer of know how. It will be important, however, that a centre does not try to directly mimic activities that are being performed elsewhere but provides additionality to the market it is aiming to both develop and exploit.

The identification survey showed that there are a significant number of organisations currently involved in hydrogen related activities. These range from commercial organisations such as vehicle manufacturers researching, developing and demonstrating the use of hydrogen to organisations developing hydrogen production and storage technologies. As well as in-house specialist facilities to support these activities there are also established centres pursuing hydrogen activities, such as the Centre for Process Industries (CPI) and the Centre for Renewable Energy Systems Technology (CREST). Centres dedicated to hydrogen activities tend to be located in North America whereas within Europe, hydrogen activities tend to be attached to established facilities with only a small number of dedicated hydrogen centres such as the recently established Hydrogen Innovation and Research Centre (HIRC) in Denmark.

Whilst there is some likelihood of competition with these centres it is more likely, however, in the longer term that the main competition to Shetland will come from other areas that have a similar climate - significant renewable resources, islanded grid network (or potential for), space for demonstration projects, etc. These include the neighbouring islands to Shetland such as Orkney and Islay – which has already undertaken a feasibility study for the creation of a hydrogen economy.

There is also potential for competition from Scandanavia such as from the Folkecenter in Denmark which has a number of demonstration and testing facilities as well in Iceland which is at the early stages of establishing a decade long experiment in which the whole country will, in effect, serve as a laboratory. Other localities looking at the potential of establishing an expertise in hydrogen systems and technologies based on their own "uniqueness" include the Tees Valley Hydrogen Project, which already has an existing hydrogen infrastructure and the international hydrogen centre in Turkey where it has significant resources of both boron, which can be used as hydrogen carrying material in fuel cells, and hydrogen sulphur.

Whilst these centres and activities can be viewed as competition a centre should aim to establish links with these and other research organisations to exchange knowledge, experience and expertise. Figure 7 - 1 below provides a high level analysis of the potential competition and collaboration opportunities. We have included only those Academic and Non-Academic organisations identified from Stage 2 of the report that are based within Europe, as it is not anticipated that organisations from other jurisdictions will provide direct competition to a centre on Shetland although there may be opportunities for collaborative ventures. The analysis of the competition and possible collaboration opportunities is based upon the following methodology:

- ***Potential for Competition***
    - An identified "uniqueness" (i.e. renewable resource, existing hydrogen infrastructure, expertise etc);
    - Potential for several demonstration projects;
    - Testing facilities; and
    - Progress of developments

- ***Collaboration Opportunities***
    - Education based organisations offering post graduate qualifications in hydrogen related activities;
    - Opportunity for the transfer of experience and expertise between organisations;
    - Pooling resources to obtain funding for projects; and
    - Undertaking joint projects.

Organisations occupying a larger area represent a larger impact or footprint in terms of competition and collaboration opportunities. Organisations highlighted in blue are from the UK, whereas organisations highlighted in red are from the rest of Europe.

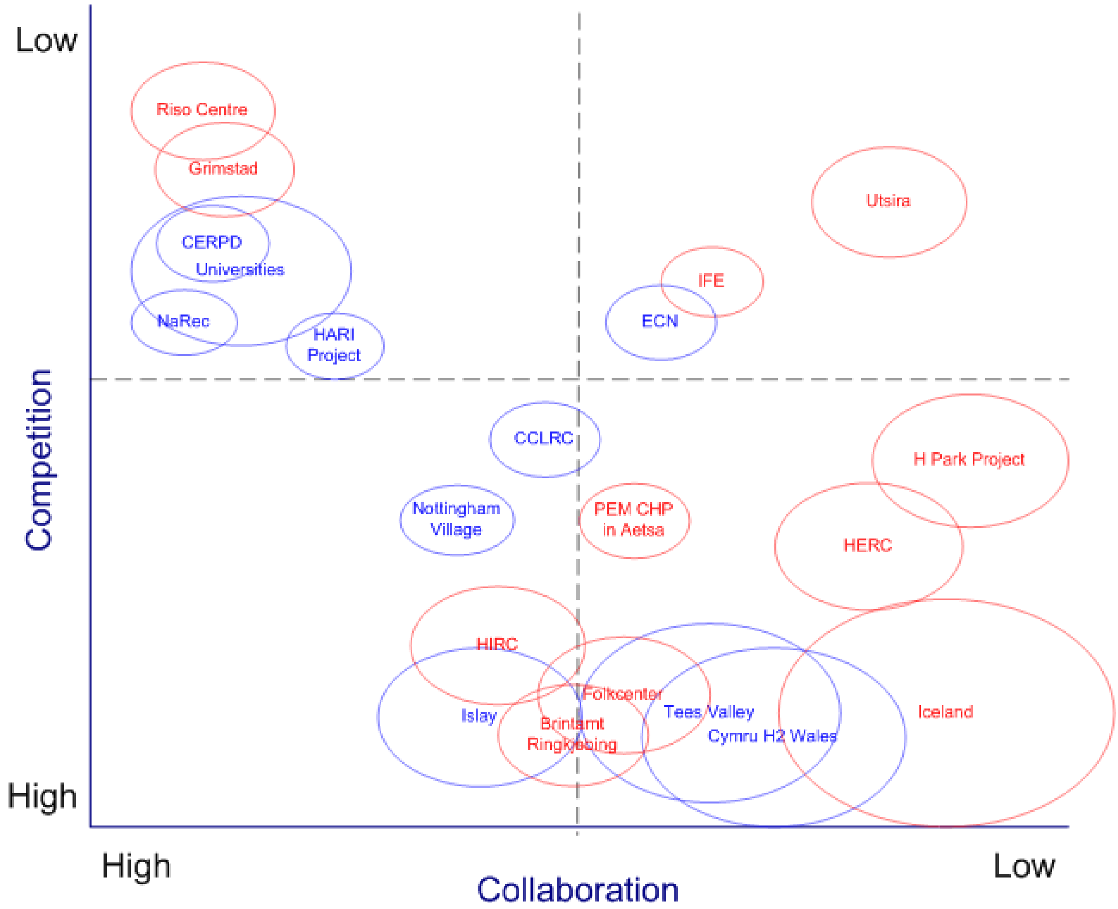


Figure 7 - 1 Competition and Collaboration Prospects

Figure 7 - 2 below provides a different high level view in terms of the potential for business opportunities for a centre and the rivalry for funding sources. As with the previous figure, we have included only those Academic and Non-Academic organisations identified from Stage 2 of the report that are based within Europe.

The analysis presented is based upon the following methodology:

- ***Competition for Funding***
  - o Duration of funding requirements; and
  - o Funding sources (i.e. organisations that are chasing the same funding sources)

- ***Business Opportunities***
  - o Number of potential opportunities (i.e. one off projects or a series of schemes);
  - o Duration of opportunity (i.e. short undertakings or longer term projects);
  - o Consistency of opportunity (i.e. for how long and for how often)

Organisations occupying a larger area represent a larger impact or footprint in terms of the funding requirements and business opportunities. Organisations highlighted in blue are from the UK, whereas organisations highlighted in red are from the rest of Europe.

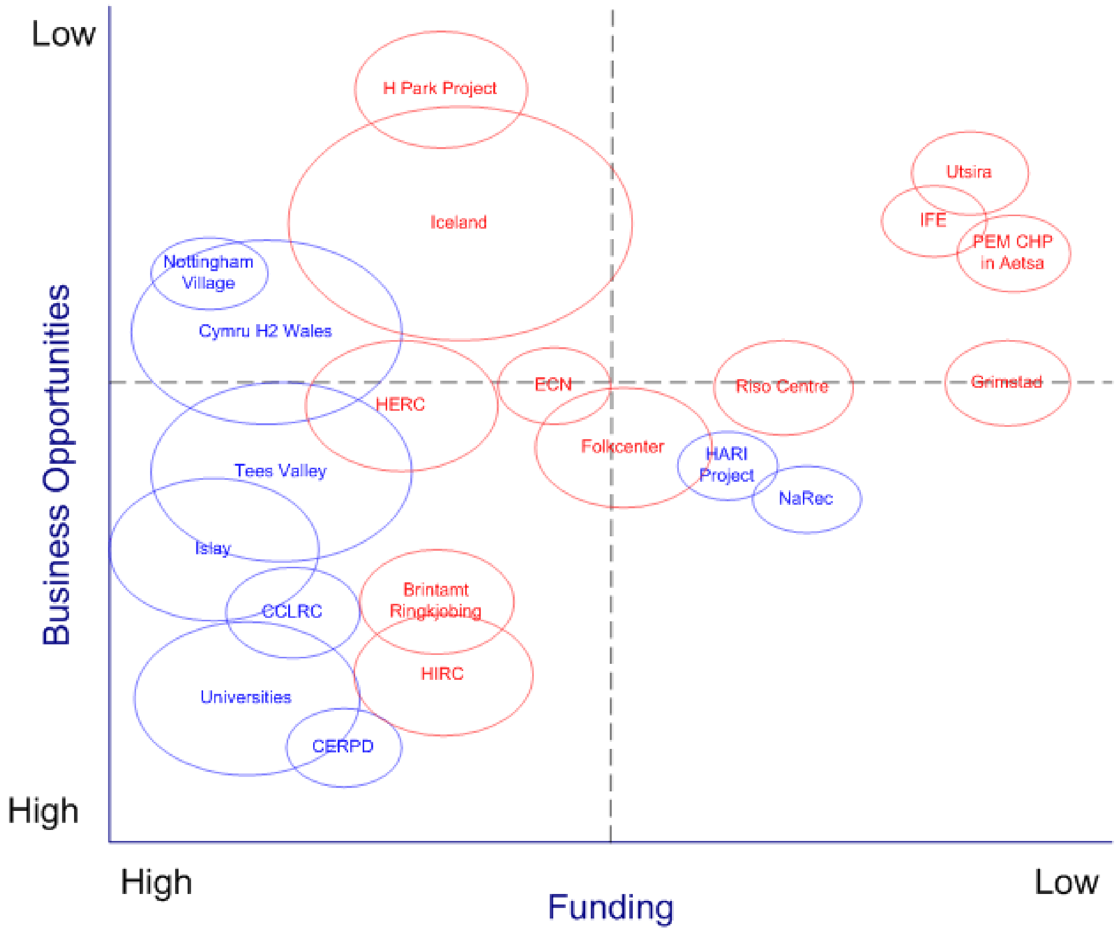


Figure 7 - 2 Business Opportunities and Funding Competition

The analysis above provides a high level representation of where the different organisations sit with respect to a centre on Shetland. Clearly these figures are dynamic in that each of the "bubbles" may expand, contract or move location depending on how a centre would fit in with other organisations as a result of its activities. The following section (7.1) provides a more detailed description of the potential competition and collaboration opportunities.

8.1 Competition

The Hydrogen Islay Project – The project is now seeking assistance from the DTI and other sources, including the enterprise network. Providing the funding is realised it is anticipated that a demonstration project could be up and running in 2 years. Although there could be collaboration between a centre on Shetland and possibly one on Islay there is a clear rivalry in obtaining funding for demonstration projects, through the EU and UK schemes but also from Scottish funding sources.

Cymru H2 Wales – The project "A Sustainable Energy Supply for Wales: Towards the Hydrogen Economy" is due to be completed by December 2004, after running for 2 years. The project, which is being run by the University of Glamorgan, is researching the social economic and technical implications of moving to a hydrogen economy in the region and will deliver a framework through which it can be achieved. The report will identify the most viable demonstration projects and sources of funding including costs for a second phase. As with the hydrogen Islay project there will be competition for funding of schemes from both the UK and EU but also there is a clear drive to undertake several demonstration projects and create both experience and expertise in hydrogen and its technologies in the local economy.

Tees Valley Hydrogen Project – From its existing assets (30km hydrogen distribution system) and skill base it is aiming to undertake the following;

- A Series of Hydrogen Demonstrator Projects;
- The Fuel Cells Application Facility;
- The Middlehaven Macro CHP Project;
- The Fleet & Fuelling Project; and
- Green Hydrogen

Primary funding has been from the regional development agency and ONE North East but plans to increasingly diversify into a mixture of commercial, industrial and public funding in which Shetland could be in direct competition. As with Cymru Wales there is a drive to undertake several activities thereby establishing a further expertise and knowledge base in hydrogen applications.

Hydrogen Park Project (Italy) – As with the Tees Valley Project, the Hydrogen Park Project has significant hydrogen infrastructure linked to the production processes of the chemicals industry. Although the concept is at a very early stage it has the potential for becoming one of the major areas for testing and developing hydrogen technologies. Although potentially a much larger scale to a centre on Shetland, there could be possible competition in obtaining funding for projects and attracting organisations for the testing and demonstration of their technologies.

Hydrogen Innovation Research Centre, HIRC (Denmark) - One of the main goals for HIRC is to start a series of demonstration projects, which will show the usage of hydrogen for different purposes and on the longer view create a basis for the new technology to be exploited commercially by companies of the area. Different demonstrations installations are already in the process of being prepared. For instance, there is currently a hydrogen-driven truck. They are also aiming to establish a unique knowledge environment (including areas for research and production applications), which will enable the development and production of a range of commercial hydrogen applications. As well as the direct competition (funding, business opportunities) with a centre on Shetland there may also be opportunities to collaborate as the HIRC centre visualises itself as a Danish counterpart with the transfer of expertise and experiences between the two centres.

Brintamt Ringkjobing Amt – The Danish County of Ringkjobing Amt is aiming to become a leading international region for sustainable energy sources. It is actively pursuing a number of hydrogen demonstration projects mainly around the transportation sector (trains, ships, small vehicles). The project has affiliations with the HIRC.

Wind Hydrogen System Utsira (Norway) – The project was officially opened on the 1st of July 2004, with the aim of proving the technical viability of a wind-hydrogen system to supply all the electricity requirements of 10 homes. It is expected that the project has a finite timescale of between 2-3 years and so there is unlikely to be any direct competition to a centre on Shetland, both in terms of seeking capital grants for funding (as Norway is not a member of the EU) and looking to exploit business opportunities resulting from the demonstration project. However, it is possible that the demonstration project is further expanded to supply the whole of Utsira (~250 inhabitants) once the current project has been completed. Organisations undertaken social research into the effects of hydrogen on local communities will clearly be interested in performing research on Utsira.

Hydrogen Energy Research Centre, HERC (Turkey) – The “uniqueness” of the proposed centre is the locality to Boron reserves (which can be used in fuel cells as a hydrogen carrying material) and hydrogen resource (from hydrogen sulphur from the black sea). It is unclear as to the current status of the project but it has the ability of becoming a major centre for testing and demonstrating technologies.

Folkecenter (Denmark) – Has established renewable energy and hydrogen testing and demonstrating facilities including 10 different types of windmills; 12 solar cell installations; 10 different solar heating plants; wind-hydrogen production and filling station; plant oil laboratory for transport; 4 green wastewater treatment plants; dike pond system; cars running on plant oil or hydrogen produced from wind energy.

Iceland “Hydrogen Economy” – Iceland aims to be the world’s first hydrogen economy and has already taken steps with the ECTOS project towards its vision. It is therefore in an excellent position to demonstrate technologies in real world conditions and therefore be at the forefront of hydrogen developments. It will also be in competition with a centre on Shetland for obtaining funding sources from the EU for assistance with its vision.

8.2 Collaboration

Universities

These include, but not limited to, Birmingham, Loughborough, Imperial College, UMIST, RGU, St Andrews etc, as well as international institutions within Europe and further a field. Shetland is at a disadvantage in that it does not have its own University and so it will be important for a centre on Shetland to be recognised and form affiliations and collaborations with Universities. This work has already started in establishing firm links with RGU, but only so far as supporting the training and research opportunities surrounding the operation of the PURE project. This should be further expanded with the development of a centre with the aim of becoming a demonstration and testing site for hydrogen research applications. By becoming part of the "academia network" it will bring with it further expertise and credibility to a centre as well as the potential for collaborating on various activities including the sourcing of funding through capital grant schemes.

Centres

There may also be possibilities for collaboration with other centres of expertise within the UK and further a field. In the UK a centre could form part of a network of "regional centres" each addressing issues that are relevant to their own locality. Centres for collaboration could include the New and Renewable Energy Centre (NaRec), who have yet to undertake any hydrogen activities and the Inter University Centre for Economic Renewable Power Delivery (CERPD) which is run by the University of Strathclyde and Glasgow. This could also be extended to Europe with centres such as the Grimstad Renewable Energy Park in Norway and the Riso Centre in Denmark forming an association with a centre on Shetland in both sourcing funding (although Grimstad would not be eligible for EU funds) for activities but also in the transfer of experiences and expertise. The dissemination of activities to industry, general public and government will be a key feature of these collaboration activities in order to promote the benefits of hydrogen technologies.

8.3 Summary

The competition and collaboration opportunities identified provide an overview of the current state of play. Competition to a centre on Shetland can only be directly assessed once a business plan has been developed that will determine the role(s) of a centre and that of Shetland in developing a hydrogen based expertise. The activities/centres identified may not materialise or centres that are already established may look to change their focus and new players may enter the market.

Although there is significant activity within the hydrogen arena, there are no centres or non-commercial activities that are leaps and bounds above everyone else in terms of the progress they have made so far. Commercial activities are somewhat different, however, with rapid progress being made by the automotive manufacturers and also the fuel cell industries in developing fuel cells for portable applications. Most centres/non-commercial activities within Europe can be represented by the following 3 categories;

- Early stages of development;

- Just starting out; or
- Vision on the "drawing board".

Whilst a centre should aim to be self supportive, there are distinctive merits in looking to collaborate with other centres in sharing know how and collaborating on projects. In order for a centre to gain "academic credibility" it needs to associate itself with a recognised University. The foundations of this work have already been established with RGU University in Aberdeen and it would be recommended that these links are kept strong particularly in the early years of developing a centre. Whether a centre should become part of a network of centres within the UK is outside the realms of this study, however, the key criteria for a centre on Shetland is that it should be able to stand on its own two feet – being a hub for all hydrogen activities on Shetland - irrespective of activities elsewhere.

9. IDENTIFICATION OF MARKETING OPPORTUNITIES

The Identification survey and consultation exercise identified a number of key players in the hydrogen market. This included higher education institutions, research and development centres, private sector companies and public sector institutions. The overall response to the consultation exercise was very positive and has been summarised in Section 4 of this report. Marketing (and business) Opportunities may be seen at different levels:

- Academic Institutions
- Non academic institutions, including public institutions such as the Scottish Executive, DTI, HIRC etc
- Commercial/private sector companies

The general consensus is that the development of a Hydrogen Centre on Shetland would attract a lot of interest and potentially financial support and in the medium to long term investment. The main problems perceived with the establishment of a centre on Shetland is the relatively remoteness of the location and the costs of travel. The development of renewable and hydrogen research and development networks, backed by telecommunications linkages should however, overcome some of these perceived disadvantages. For the majority of institutions and companies contacted there was awareness regarding the potential for renewable energy development on Shetland and the work on hydrogen in particular.

Meetings and discussions in Shetland with members of the SREF, SMPower, Economic Development and Planning Departments of the Shetland Islands Council (SIC), Shetland Enterprise and the North Atlantic Fisheries College (NAFC) and Shetland College indicate an interest in becoming involved in training, research and development on renewable and hydrogen energy. Shetland renewable energy interests have established good links with other research centres on hydrogen and renewable energy in Scotland, the rest of the UK, Europe and internationally.

Hydrogen energy development is already being promoted by a number of institutions and private sector companies both nationally and internationally. It will be important that the marketing aspects of a Hydrogen Centre be not merely promoted as a study centre but as somewhere which is actively developing hydrogen energy and the application of hydrogen energy on a particular site. This could be the marketing of demonstration projects such as the development of hydrogen powered transport (terrestrial and seaborne) for Unst and potentially for other parts of Shetland.

9.1 Marketing of a Centre

The marketing of a centre should focus on its skills, experience and abilities but also promote the skills and expertise in renewable and hydrogen energy which exist on Shetland. This includes design, engineering, materials, planning and implementation skills in a number of different economic sectors. A centre as part of its marketing strategy should emphasise its strong linkages with other centres of excellence in hydrogen and renewable energy in Scotland, other parts of the UK, Europe, North America, Asia, Africa and potentially in other parts of the World. There has already been the creation of a strong network on renewable energy, the SREF which represents different aspects of the sector on Shetland – the SIC, engineering and materials, economics and management, economic development and other public and private sector partners. This provides the basis for the development of a renewable energy and hydrogen energy cluster on Shetland.

There will be a need to market the different services and expertise at a centre. The key components of expertise, as identified in Chapter 6, could be as follows:

- Accreditation and testing of hydrogen technologies such as fuel cells and storage equipment
- Specialised training courses in hydrogen energy including design, engineering and applications
- More generic courses on the management and economic aspects of renewable and hydrogen energy
- Consultancy expertise such as providing technical advice on hydrogen energy/systems.

In addition the Centre should promote its function as a unique Centre with opportunities for visitors – school pupils, college and university students, the public and tourists. The centre could develop a web portal for hydrogen energy and technology on Shetland but with linkages with other relevant websites in the private sector, public R & D institutions and universities in Scotland, the UK, Europe and internationally. It is suggested that the portal be developed in key international languages including English, Spanish, French, Chinese and Arabic.

The marketing opportunities for a centre exist at a number of different levels:

- Shetland
- Scotland
- The rest of the UK
- EU countries
- Internationally

The main market segments are:

- University and R & D centres
- Public sector institutions – DTI, Scottish Executive, Department of Energy, Scottish and Highlands and Islands Enterprise, ITI Energy etc.
- Private sector companies involved in renewable energy engineering and management
- Financial institutions with interests in renewable and hydrogen energy (renewable energy funds for example)

- Regional institutions – European Environmental Agency, the EU Directorates on Research and Innovation and the Environment and Transport
- International institutions and networks in economic and social development and renewable energy – UNEP, Small Islands Developing States (SIDS) network, the World Bank and other international financial institutions as well as national and international hydrogen and renewable energy associations.

9.1.1 Public Sector, HEI & R&D Linkages

A number of government offices, public sector R & D establishments and higher education institutions (HEIs) in Scotland, England, Wales and beyond were contacted as part of the consultation exercise. There was a general awareness of the Shetland initiatives on hydrogen and renewable energy. The PURE project and Unst Partnership have already developed valuable contacts and collaboration with a number of these, most notably with Robert Gordon University in Aberdeen which is working on hydrogen and renewable energy. Conversations with North Atlantic Fisheries College (NAFC) in Scalloway and Shetland College indicate that they may offer complementary skills to those of the Hydrogen Energy Study Centre and their staff and students could benefit from the presence of a study and research facility which provides valuable training and R & D skills. Annex F provides further details of the HEI linkages on Shetland. Collaboration with key public sector institutions including FREDS, the Scottish Executive, university and public sector R & D centres could also widen the scope for promoting and marketing a centre. NGO's such as the US Hydrogen Association will also be key in the promotion of activities at a centre into international markets.

9.1.2 Private Sector Linkages

A number of Shetland based and Scottish companies as well as international companies have developed initiatives and interests in renewable energy and potentially hydrogen energy as well as having experience and skills in marine engineering and materials they include:

- AMEC
- BP Energy
- Delta Marine, Lerwick
- European Marine Energy Centre, Orkneys
- Malakoff Limited
- Ocean Kinetics
- Scottish and Southern Energy (which has a major interest in renewable energy)
- Shetland Composites
- Shetland Windpower Limited

- SiGEN, Aberdeen
- Unst Inshore Services
- Unst Partnership (PURE)
- Wavegen

Some of the Shetland based companies are already members of the SREF and this provides a cluster of expertise that already has links with the centre's initiative. SREF and PURE and other key players in the renewable energy sector in Shetland have already developed lnkages with companies and institutions in Europe (Denmark and other Scandinavian countries, Germany), North America, Asia (Japan) and Africa (Cameroon).

PURE has already established contacts with research and private sector networks throughout the world and these could be built on through using a hydrogen and renewable energy portal specific to Shetland and island economies. There are other opportunities to link with international organisations which have interests in renewable and hydrogen energy and developing countries, particularly SIDS. Such organisations include:

- OECD, Paris
- IEA, Vienna
- Environmental Agencies (SEA, EA, EEA)
- UNDP, UNEP, UN Habitat
- International financial institutions – the World Bank, Asian Development Bank, EBRD, European Investment Bank, African Development Bank
- The European Union and its specialised agencies

9.1.3 Summary

There are a number of marketing opportunities that have been identified from the consultation exercise. These show that a number of companies and institutions would be potentially interested in using the services that a centre could provide – testing, accreditation, undergraduate and postgraduate training, training for industry as well as possibilities for collaboration in R & D which would also be a method of levering money for R & D funding and training. In addition a consortium of producers and technology/R & D centres including the centre on Shetland could market its capabilities internationally – this may provide a stronger presence with greater expertise and experience than a single centre could provide. The experience of renewable energy and hydrogen development on Shetland would also provide a model for other island communities which have a dependence on imported hydrocarbon energy but which also have access to renewable energy sources from wind, wave and tidal power

The development of marketing opportunities for hydrogen energy and technologies will be dependent on a number of different factors. These include:

- The pricing and supply of alternative energy sources
- Taxation of energy sources
- Government incentives to encourage the use of new energy sources (renewable energy obligations, tax and other incentives)
- The regulatory regime for energy products and markets.
- The level and pace of commercialisation of equipment which produces and uses hydrogen.

10. POTENTIAL FOR A HYDROGEN CENTRE IN SHETLAND

This chapter looks at the potential for a hydrogen centre in Shetland in the context of other science and technology centres in the UK and provides an estimate of the establishment costs and the possible physical structure and management of the Centre as well as the potential employment generation and economic development impacts of the Centre, by itself and also to Shetland as a whole.

10.1 Comparators – Science Parks, Technopoles and Discovery Centres

The development of a centre on Shetland would be a unique development in Scotland, the rest of the UK and internationally, because of:

- Its remote island location
- Its focus on local applications for hydrogen energy.

Most science parks and technopoles that have been developed in the UK and Europe are located near a critical mass of university and private sector based R & D. In general they provide an opportunity for knowledge transfer and commercialisation from universities and public sector R & D centres either directly through spin off or spin in companies and through partnerships with large private sector organisations. In some cases science parks have developed as university and private sector initiatives in a relatively unplanned fashion e.g. Cambridge and Oxford Universities, in other cases they have been planned and have involved public sector and regional development expenditure, sometimes with the support of EU regional development funds.

Examples of the latter are to be found in Scotland (West of Scotland), Aberdeen, Manchester, Salford, Sheffield, Warwick etc. In countries such as France and Italy there has been major support and funding from central government, regional and sub – regional finance. In some cases science parks and technopoles consist of a mixture of activities – R & D, consultancy, commercialisation, commercial and social activities and associated infrastructure. Some science parks are more specialised e.g. agriculture, IT and medicine at the Montpellier Technopole in France, Biotechnology in Dundee, Manchester and Strasbourg.

While there is no critical mass of universities and R & D centres in Shetland, a centre on Shetland could build on its existing networks and linkages and develop a real and virtual centre of excellence for the hydrogen (and renewable energy), linking with other HEIs and R & D centres in Scotland and beyond through telemetric and personal linkages. A centre could provide an example of how to combine R & D, demonstration and pilot projects in hydrogen energy, while combining this with other activities (education, visitor attraction, accreditation etc).

10.2 Location, Facilities and Planning Aspects

The survey results from the consultation do not give a general consensus that the Centre should be on one location, but rather a split site with linkages to other private and public sector R & D centres of excellence.

It would seem logical, however, that given the existing PURE project, its office, demonstration project and site which is currently occupied by the Unst Partnership, the SREF and other community organisations, that a centre be developed on this existing site. There is further room for building development, including space for offices, laboratories and a demonstration/training centre. The site is located on the Hagdale Industrial Estate on Unst and is connected to all major utilities. There would need to be a survey of the net area available for development, including existing buildings which may become available on the site. It should be noted adjacent to the site (to the east) is a SSSI. The land to the south of the estate (on which the wind turbines and hydrogen plant room are located) is owned by the Unst Community Council, and would be available for development subject to their approval.

It is therefore our view that a centre should be developed at the Hagdale Industrial Estate at Baltasound, Unst where the existing PURE project is based. The PURE project currently has one office, combined with a workshop. Adjacent to this is a larger office and training rooms of Telecroft2000. This has provided IT Training and Business Services on Unst since 1990, and contains a well-appointed video-conferencing suite, and a robust computer network. Telecroft2000 intends to transfer this facility to the Unst Partnership in March 2005. As well as the above, there will need to be additional space in order that a centre has:

- Store and workshop facilities
- A demonstration area

One option for the above is that the Unst Partnership and the centre take over the Hagdale Industrial Estate refurbishing those buildings that they need and renting out space which is superfluous to their requirements. Accommodation for students and visitors could be provided at the Baltasound Hotel, the Unst Youth Hostel and possibly through the rental of MOD housing.

While it is recommended that the Unst site at Hagdale be developed as the core development of a centre on Shetland, subsequent developments could include hydrogen storage (for example) on Yell and a liaison office which could be located within say NAFC in Scalloway or Shetland College on the Gremista site.

On the issue of planning aspects for the development of the Centre it is our understanding that existing buildings could be rented or purchased for the project and that therefore planning regulations would not be an issue. If there was new build either on the Hagdale site or nearby, then planning submissions and consents might need to be obtained. Issues of planning are however beyond the scope of this feasibility study and would need to be confirmed with the relevant planning authorities. Annex G provides an overview of planning developments relating to the energy sector on Shetland.

10.3 Structure and Staffing

Once a centre has been established it is envisaged that as a minimum a centre would have a core staff of 4 with the following:

- Centre Manager, also responsible for marketing and liaison with other institutions
- 2 project engineers (one with specific responsibility for training)
- 1 PA/Secretary

The responsibilities of the Centre Manager would be the overall coordination and management of the functions of the centre and liaison with other private sector, R & D and training centres in the fields of hydrogen energy. The Manager will also have a responsibility (which s/he may share with one of the project engineers) for marketing the centre and the services and capabilities that it will provide. The Centre Manager may have a background in engineering and/or economic development but should have experience in managing and developing renewable energy projects and preferably hydrogen energy projects. We would expect the Centre Manager to be recruited in Project Year 1 and to be a full time appointment.

We propose the recruitment of 2 project engineers with graduate qualifications in engineering and experience in renewable energy and hydrogen energy technology. One project engineer would be recruited in Project Year 1 and the second project engineer would be recruited in Project Year 2, when training and other similar functions would commence. The PA/Secretary as with other staff would be a full time appointment. There are existing staff working at Hagdale on a partial basis and it would be useful at least in the initial stages if they could work on an occasional consultancy basis with the Centre Management team to ensure the transfer of knowledge and continuity.

10.4 Establishment and Operating Costs

The PURE project has already been allocated a budget of £300,000 for project development. The estimates of additional CAPEX and OPEX given below are based on our estimates of what the incremental costs for the development and operation of a Centre would be. Additional capital expenditure (CAPEX) has been estimated as follows:

- Equipment for hydrogen energy development including hydrogen storage (£100,000)
- Office furniture equipment and computers (£20,000)
- Workshop benches, shelving, instrumentation etc (£15,000)
- Equipment of training area – furniture, audio visual equipment etc (£20,000)
- Design and legal costs (£7,000)

TOTAL CAPITAL EXPENDITURE = £162,000 + contingencies of 10% = £177,000

Any new build for offices would cost around £1,400/square metre[20] with services but no internal equipment. No allowance has been made for the refurbishment of the existing buildings.

The main items for operating expenditure (OPEX) would be:

- Rental of offices and buildings (say £7,000 per year)
- Staffing (£130,000 per year, including social and pension costs)
- Marketing and Accountancy (£8,000 per year)
- Office consumables (£2,000/year)
- Telecoms (£3,000/year)
- Travel (£4,000/year)
- Sundry/contingencies (£4,000/year)

TOTAL OPERATING COSTS = £ 158,000/year

These CAPEX and OPEX provide an estimate of the likely capital and operational costs of a centre based on the above assumptions.

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10.4.1 The Organisational Structure for a centre

There are a number of options for the management and ownership of a centre as shown below. It is not the objective of this study to determine the most appropriate, but only to highlight the possible options. These could include:

- A partnership – an example being the existing Unst Partnership[21]
- A Not for Profit Company Limited by Guarantee (public + private equity)
- A Community Owned Company or Enterprise (Development Trust, Social Enterprise, Co – operative or other form)
- A Private Limited Company with equity shares from different partners. These might include Shetland Isles Council, Shetland Enterprise, the Community and private sector.

It will be important in assessing the most suitable legal form of ownership to take account of the registration and formation costs (legal, accounting and other), the issue of director liabilities and the implications of different forms of ownership for the raising of finance and equity for investment, future capital growth and development. . It would also be worth assessing the appropriateness of existing organisational structures of parties interested in taking on the development of the Hydrogen Centre.

[20] Information given by a chartered surveyor in Lerwick

[21] The existing Unst Partnership was set up in response to the economic decline of Unst linked to the downsizing of the RAF base on the island. It has a broad membership including Unst Community Council, Shetland Islands Council, Shetland Enterprise, Shetland Tourism, Shetland Amenity Trust, NAFC, Shetland College, Defence Housing Executive, the Scottish Executive, Highland & Islands Enterprise and others. Its aims are economic development and diversification with the aim of the slowing the economic decline of Unst.

10.5 Economic Impacts – Employment, Linkages and Value Added

Annex H provides background information to the economy of Shetland, including the overall economy, economic development initiatives and planning issues. It also provides the position of renewable energy in the context of Scotland and Shetland.

Employment generation is crucial for the economy of Unst where there has been a loss of around 200 jobs and a 33% reduction in population, since 1996. For Shetland as a whole the gradual decline of Sullom Voe and fisheries means that new employment opportunities must be created if viable communities are to be maintained.

On the 24th November 2004, Shetland Islands Council outlined a proposal to invest in a 300 MW community owned wind farm. Together with a similar proposal by Scottish and Southern Energy it emphasises the need for an interconnector to the UK mainland. The prospect of an interconnector, however, if approved is along way off and so if Shetland is to develop its renewable resource in the meantime it will require the development of energy storage and improved demand management to accommodate unpredictable renewable forms of energy production. There is a specific interest in replacing imported oil fuels in Shetland as these are already costing over £1 per litre in rural areas[22].

Shetland has a medium term target of producing 25MW or 50% of its current energy supplies from renewable energy sources. If this was to be achieved as many as 250 jobs could be directly created in the renewable energy sector in Shetland[23]. This would include jobs in the construction phase as well as operating and maintenance. However one would expect employment after construction to fall considerably. Taking an employment multiplier for 1.3 the construction sector, maintenance and other supply chain linkages and allowing for leakage within the Shetland economy as many as 325 FTE jobs could be created in the long term.

If the hydrogen economy accounted for 20% of energy production, say, in Shetland that would be equivalent to 65 FTE jobs directly and indirectly created. Of these one might assume that 70% would be on Unst i.e. 45 FTE jobs, including project staffing at a centre. Other jobs may be created in the supply chain, maintenance and teaching and training sectors in Lerwick and Scalloway. Value added per FTE is difficult to estimate but it is typically £40 – 60K in the marine and environmental technology sectors (SWRDA: 2004[24]) i.e. 65 FTE jobs in the hydrogen economy with an GVA/FTE job of £50K would give an value added for the hydrogen sector in Shetland of £3.3 million. . It should be noted that Unst already has skilled engineers, technicians, electricians and mechanics who have experience in renewable energy. This resource could contribute to and benefit from the development of the Centre.

The development of a centre would bring other benefits to Unst and Shetland. This could include:

[22] Sandy Macaulay 28th November 2004.
[23] This is on the basis of estimates of employment for wind energy made in an EU commissioned report – 'Prospects for Offshore Wind Energy, EU Report Alterner XVII/4.1030/Z/98-395 by the British Wind Energy Association.
[24] We have used data which was collected as part of a study of the Key Sectors of the South West economy in England which also has interests in renewable energy, including wind and marine energy. The study looked at the economic performance of a number of key sectors, including environmental and marine technology. It also looked at comparator regions in the UK including Scotland and Wales.

- Income from testing and accreditation
- Training income
- Seminar and Conference income
- Spend by students, private and public sector and other visitors to the centre
- Spend by the centre on construction, maintenance, equipment and consumables

This spend would in part benefit the Shetland economy through direct, indirect and induced multiplier impacts. For example an annual spend by the Centre plus students and visitors of say £200,000 per year and assuming that £30,000 spend creates 1 direct FTE job per year, would suggest that spend at a centre could create 7 FTE jobs which with a multiplier of say 1.3[25] would be equivalent to 9 FTE jobs over and above those in the renewable energy/hydrogen sector.

In addition to employment creation and the development of supply chain linkages on Shetland in the renewable and hydrogen energy sector, the potential for hydrogen energy is to reduce the dependence on imported supplies of energy, notably hydrocarbons which are increasingly likely to be vulnerable to geopolitical considerations such as political and security problems in the major production areas of hydrocarbons – the Middle East and North Africa and some of the West African states. In the longer term the gradual replacement of traditional hydrocarbon based energy sources with a cleaner fuel such as hydrogen will have other economic impacts including reduced atmospheric pollution and the associated impacts of human health, health and treatment costs. These benefits will not merely be on Shetland but with the increasing use of hydrogen energy will be transferred elsewhere in Scotland, the UK and beyond.

[25] These figures are based on estimates from other project studies for regional development agencies in the UK.

11. SUMMARY & RECOMMENDATIONS

The objective of the study is to determine the potential viability of a Hydrogen Energy Study Centre on Shetland. Based on our analysis it is clear that a Hydrogen Energy Study Centre by itself would not be a realistic or viable venture for Shetland in isolation from other activities such as testing, research and development related to commercial opportunities. It has also been shown that there is a requirement for demonstration projects showing hydrogen and its technologies in real world conditions. Continuing and building on the work of the PURE project, Shetland has the ability to offer the hydrogen market real life projects showcasing hydrogen technologies, systems and expertise and, almost more importantly to governments and the general public, showing hydrogen being used safely and proficiently in real world applications and conditions.

In order for a centre to be viable on Shetland and ensure its longevity it needs to develop a critical mass of projects, providing unique experiences that cannot be gained elsewhere and enticing people to come to Shetland because of its development expertise. Rather than establishing an “all-embracing” centre at the outset it would be more pragmatic to develop a centre over a period of time in tandem with the development of projects. Once Shetland creates a critical mass of projects it will present a unique selling point by allowing organisations to experience hydrogen technologies working in different environments.

Regardless of whether these projects are at the smaller end of demonstration or significantly larger such as the potential for introducing renewable energy/hydrogen economy on one the islands, a centre should form the hub of activities on Shetland in association with the range of engineering and other technical skills on the islands which include renewable energy and marine engineering. The experience and expertise gained from demonstration projects could then form the basis of expertise for further developing a centre. In the short term, therefore, it is clearly sensible to build on the foundations of the PURE project on Unst in developing a centre. While it is recommended that the Unst site at Hagdale be developed as the core development of a centre on Shetland, subsequent developments/demonstration projects could include other areas on Shetland, for example hydrogen storage on Yell and a liaison office which could be located within NAFC in Scalloway or Shetland College on the Gremista site.

It is also interesting to note that from the consultation exercise the responses from organisations were very positive, as shown in the figure below, when asked whether they had an awareness of, interest in and views on the feasibility of Hydrogen Energy Centre in Shetland.

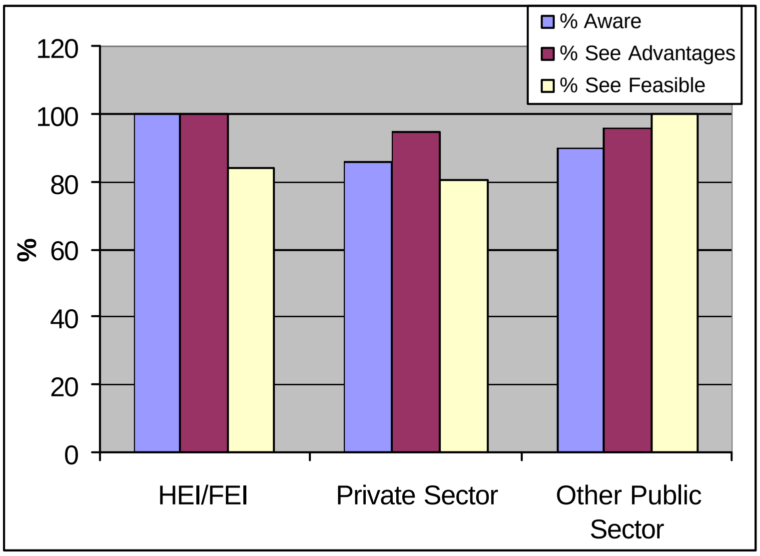

Figure 10 - 1 Summary of Reponses to Survey on the Hydrogen Energy Research Centre

It should be noted, however, that while the percentage seeing the advantages of the centre was high, this did not mean that they did not in some cases perceive that there were disadvantages – notably the remote location of Shetland and the costs of access to a Centre.

11.1 Functions of a Centre

A centre should be built on the foundations of the PURE project. It is our understanding that training courses have and are being developed. This would seem a logical progression for the initial development of a centre. Specialist training on the Unst site could be provided at a centre for visitors and students, including students from NAFC and Shetland College who are undertaking courses in renewable energy engineering and management. Given the specialised expertise and experience which the Unst centre could provide, it could also offer practical training and workshops on hydrogen energy and fuel cell technology, which stems from the work of the PURE project, for undergraduate and postgraduate students from other UK, European and international universities. The PURE project has already developed close relations with Robert Gordon University School of Engineering in Aberdeen and this will be crucial in establishing both the credentials and networking opportunities for disseminating details of the training occurring at a centre on Unst.

Once the initial foundations of a centre has been developed it could aim to include a range of potential activities on which to further expand, based on the PURE project, such as

- Providing Consultancy expertise in the conversion of energy to hydrogen
- An independent testing and certification capability (fuel cells, electronics)
- Demonstration for the safety management of hydrogen facilities (Health and Safety Issues)

With the development of demonstration projects a centre will be able to expand and provide greater services to the hydrogen and renewables community. Shetland is rich in renewable power potential. There is no good reason why Shetland should not become the first area in the UK to convert from an almost complete reliance on transport hydrocarbons to the first place in the world that relies upon its own, renewable, energy resources for transport. Particular emphasis should be given to those projects that could potentially be self-sustaining such as "Exploiting the Renewable Resource and Hydrogen for Transport" as identified in Chapter 5. We would therefore recommend that a further study is carried out to model the financial and economic viability of these projects.

The development of a centre could also offer a resource – featuring a new and exciting technology which could be visited at certain times by school parties from other parts of Shetland, Orkney, Scotland and beyond as well as being a tourist attraction on Unst.

The core functions of a centre should be the applied development of hydrogen technology to the benefit of the economy of Shetland and Scotland. This could include:

- The development of the wind energy/hydrogen fuel cell work on Unst including an expanded workshop and store, an office and a demonstration and training area
- Demonstration projects such as the development of a hydrogen based transport system on Unst
- The construction of an area for training in hydrogen energy and fuel cell technology.
- The development of the research and training network on Shetland involving the PURE project and a centre on Unst, Shetlands College (renewable energy management), NAFC (engineering) and involving other key centres of the UHI network, while maintaining the strong links developed with Robert Gordon University and private sector partners in Shetland, Scotland and elsewhere in Europe and the UK.
- Testing and accreditation facilities

It is important to reiterate that a centre should not merely be a study centre but actually undertake testing and development work related to applications on Unst and potentially elsewhere in Shetland. A centre should therefore market itself as a "Hydrogen Energy Centre" rather than a "Hydrogen Energy Study Centre". Whether a centre should become part of a network of centres within the UK is outside the realms of this study, however, the key criteria for a centre on Shetland is that it should be able to stand on its own two feet financially – being a hub for all hydrogen activities on Shetland - irrespective of activities elsewhere.

11.2 Concluding Remarks

It is apparent that other countries are developing hydrogen energy and applications and therefore if Scotland wants to maintain its competitive position in the development of this technology the importance of a centre as a focal point within a Scotland/UK renewable energy/hydrogen network is apparent. In addition there is an opportunity for one community, namely Unst to have most of its energy provided from renewable energy resources, including hydrogen. Such an achievement would act as a beacon for Scottish and UK renewable energy technology.

ANNEX A – TERMS OF REFERENCE

Shetland Renewable Energy Forum
Unst Partnership Office
Hagdale Industrial Estate
Baltasound, Unst
Shetland
ZE2 9DS

Tel: 01957 711838
Fax: 01957 711685
up@unst.shetland.co.uk
www.sref.co.uk

FEASIBILITY REPORT FOR HYDROGEN ENERGY STUDY CENTRE IN SHETLAND

Invitation to Tender

Background
Shetland Renewable Energy Forum was formed in December 2002 and represents the growing renewables industry in Shetland. The principal aim of SREF is "To ensure that Shetland maximises the economic and community benefit of developing its renewable energy resources while minimising the impact on the environmental, social and visual amenity of the islands".

The island of Unst in Shetland will host the first community owned hydrogen production facility in Europe and symbolises the potential for this fuel of the future to be generated anywhere. The PURE Project has attracted a great deal of interest worldwide from academic institutions, politicians and the business community. This interest has highlighted the potential to attract contracts for field trials, testing and research, as well as more general learning and study opportunities. There is now interest in a more permanent hydrogen energy study centre in Shetland.

Feasibility Study
SREF wishes to commission a feasibility study to identify, clarify and quantify the need and opportunity for a Hydrogen Energy Study Centre in Shetland to support the development of the emerging hydrogen renewables sector. The study should consider the economic viability of a hydrogen energy study centre but only so far as to determine broad establishment costs and potential income streams.

A positive feasibility should allow others to prepare a detailed business plan and progress this through to implementation in the knowledge that such a facility is, in principle, viable.

A negative feasibility should indicate why such a facility would not be viable, and why it would not be worth developing in Shetland.

SREF would like to be able to provide the Feasibility Study to third parties to assist in the development of business case proposals for Shetland.

Appointment and Scope of Works
SREF will appoint a single company to undertake the Feasibility Study.

The exact extent of the study is negotiable but will be expected to include the following responsibilities:

- Consultation with SREF to finalise the study parameters.
- Consultation with industry involved companies and organisations (see appendix A).
- Identification of existing Hydrogen Centres in United Kingdom, Europe, North America and
- Japan including centres of excellence, specific hydrogen R&D facilities, academic facilities, etc.
- Appraisal of all exploratory work already undertaken by the Unst Partnership in developing the case for a hydrogen centre in Shetland.
- Identification of business opportunities in testing, demonstrating, studying, comparing and other possible activities related to supporting the developing hydrogen energy technologies.
- Identification of possible establishment costs for any centre in Shetland including all accommodation, equipment and resources (taking account of existing hydrogen producing facilities such as the PURE project in Unst).
- Identification of potential income streams relating to above-identified business opportunities.
- Identification of potential employment opportunities.
- Identification of research and academic partnership opportunities.
- Identification of possible ongoing operating costs.
- Identification of known marketing opportunities and requirements.
- Assessment of the most suitable location within Shetland for such a facility.
- Assessment of existing and future potential competition and resultant impacts on above feasibilities.
- Typewritten report to SREF with conclusions.

A presentation in Shetland on the final study conclusions will probably be requested. Tendering organisations should provide a price for such a presentation separate to the main fee.

Timescale
The timescale for this study should be no more than 4 months from appointment. Tenderers may suggest or request longer and said suggestion or request will be considered by SREF.

Submission
Proposals are sought from interested companies willing to undertake this study.

Submissions should include the following information:

- Details of previous relevant experience including knowledge of the renewable energy industry, knowledge of further education and familiarity with the Shetlands Islands.
- Details of intended resource application.
- Details of any proposed partners.
- Study Cost with breakdown itemising fees, expenses and third party costs.
- Final Presentation Cost
- Timing Plan(s) for the work including proposed completion target dates.
- Any other information or proposals.

Submissions will be assessed on the following priority basis:
- Quality of proposed study.
- Cost of proposed study.
- Timeliness of proposed study
- Quality of experience and knowledge presented.

Submissions should be made in two copies to:

David Thomson - Chairman
Shetland Renewable Energy Forum
Unst Partnership Office
Hagdale Industrial Estate
Baltasound
Unst
Shetland
ZE2 9DS
No later than **Friday 30th April 2004**

Appendix A.

Provisional List of Companies and Organisations for Consultation

3E Engineering
AMEC
Ballard
BMW
BOC
BP
DTi
Ford Motor Company Ltd
Fuel Cells Scotland Ltd.
Highland & Islands Enterprise
Health & Safety Executive
Imperial College, London
Institutes of Electrical, Chemical and Mechanical Engineers
Loughborough University
Promoting Unst Renewable Energy
The Robert Gordon University
Scottish and Southern Energy plc
Shell
SHFCA
siGEN
St. Andrews University
Strathclyde University
Toyota
University of the Highlands and Islands

Plus

Japanese research institutions to be named
Any other relevant company or organisation

ANNEX B - IDENTIFICATION SURVEY

UK & EIRE

Academic Institutions

A summary of the Academic centres and projects being undertaken are shown in Table B - 1 and Table B - 2 respectively

Centres

Centre Name	Type of Centre	Activities
Sustainable Environment Research Centre (SERC) – Hydrogen Research Unit	Research	Hydrogen Research Unit, working on a range of sustainable environmental technologies, particularly biological hydrogen production implementation
Inter University Centre for Economic Renewable Power Delivery (CERPD)	Research	In the field of hydrogen technologies CERPD activities include: • Active in the use of biotechnology as a fuel source (production of H_2) • Use of Fuel Cells for transport and static power generation • Fuel Cell systems

Table B - 1 Academic Centres

Projects

University Name	Type of Projects	Project Activities
Imperial College	Hydrogen Production	Primary research interest is light induced electron transfer reactions, and in particular processes which convert solar energy to useful chemical or electrical energy.
University College Cork	Hydrogen Production	Wind Energy producing hydrogen for fuel cells.
University College Cork	Hydrogen Storage	Wind Energy forecasting and Hydrogen Storage and Fuel Cell applications. The objective of the project is to research the feasibility of small scale, grid-linked power supply systems based on wind generation input together with an integrated hydrogen gas generation and storage facility
University of Birmingham	Hydrogen Storage	Research in Magnetic and Hydrogen Storage Materials mainly for transport applications
University of London,	Hydrogen Storage	Non Synthesis and Predictive

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Queens Mary College		modelling of New Hydrogen storage Materials. The research is aimed to clarify the effects of chemical modification and processing on H storage characteristics of selected materials.
University of Nottingham	Hydrogen Storage	Researching materials for hydrogen storage
University of Oxford	Hydrogen Storage	Research into materials for hydrogen storage.
Loughborough University, CREST	Hydrogen Systems	HARI project. Hydrogen production, storage and usage equipment has been added to an existing renewable energy system, which feeds commercial and domestic loads on a local mini-grid at West Beacon Farm.
University of Leicestershire,	Hydrogen Systems	Renewable energy conversion, storage and integration projects. Recent projects include: • Hydrogen generation from stand alone wind powered electrolysis systems.
UMIST (UMIST Ventures Ltd)	Hydrogen Systems	Projects include: • Fuel cells and hydrogen • Solid oxide fuel cells • Development of a novel redox battery • Management of hydrogen, methanol and ammonia plants
University of Nottingham	Hydrogen Systems	Proposals for a Nottingham Hydrogen Village on a site adjacent to the University's Jubilee Campus.
University of Cambridge	Hydrogen Systems	USHER Project. Demonstrate large scale building integrated PV, production of hydrogen from the solar energy by electrolysis, storage and dispensing for a fuel cell to operate a bus in an urban area. Project is currently abandoned due to insufficient funding.
The Robert Gordon University & University of St Andrews	Hydrogen Systems	The objective of the project is to design and build a tidal power generation system with good responsive capability. This will be achieved by mounting a reversible electrolyser/fuel cell unit onto a tidal stream generator, delivering an integrated system
University of Birmingham	Hydrogen End Use	Researches new combustion and energy conversion technologies, alternative fuels and hydrogen for sustainable power sources for propulsion and stationary use. It is

		particularly known for its development of the engine-based fuel reforming technology
The Robert Gordon University	Hydrogen End Use	High density hydrogen production at 100% purity using a reconfigured multi metallic composite membrane reactor. Ultimately the aim of the project is to produce a reactor design that is cost-effective, low maintenance and flexible to operate.

Table B - 2 Academic Projects

Non-Academic Institutions

A summary of the Non-Academic centres and projects being undertaken are shown in Table B - 3 and Table B - 4 respectively

Centres

Centre Name	Type of Centre	Activities
CCLRC Rutherford Appleton Laboratory, Energy Research Unit (ERU).	Research	The ERU maintains and operates the ERU Test site facility on behalf of the Engineering and Physical Sciences Research Council (EPSRC) for use by UK-based academic researchers and students. The site boasts a wide range of equipment including two wind turbines, two diesel generators, two flywheels, battery storage, a photovoltaic panel and three meteorological masts. *Projects in Hydrogen include;* • Hydrogen generation from stand-alone wind power electrolysis systems • Network co-ordinators for the H2NET (UK Hydrogen Energy Network),; • Hydrogen's role in reducing greenhouse gases (2001-04), • Fuel Cells: providing heat and power in the urban environment
NaREC (New and Renewable Energy Centre)	Research	Is one of 5 centres of excellence set up by One North East as part of the Strategy for Success program. NaRec is to take forward proposals in the field of new and renewable energy through a partnership between Industry and Academia

		Its facilities include: • Wave and Tidal dock facilities • Conference facilities • Blade test facility (Oct 2004) • Electric Power Laboratory (started Jan 2004)
Tees Valley Hydrogen Project – linked to the Centre for Process Innovation	Development & Demonstration	The aim of the Tees Valley Hydrogen Project is to develop industries related to the hydrogen economy and low carbon technologies from an existing assets and skill base (particularly relating to hydrogen). It is doing this through a series of 5 major projects: • A Series of Hydrogen Demonstrator Projects • The Fuel Cells Application Facility • The Middlehaven Macro CHP Project • The Fleet & Fuelling Project • Green Hydrogen The Tees Valley has a unique asset consisting of a 30 km hydrogen distribution system incorporating an underground hydrogen storage facility of nearly 1000 Te located within an urban environment.

Table B - 3 Non-Academic Centres

Projects

Project Name	Type of Projects	Project Activities
The Islay Hydrogen Project	Hydrogen Systems	Looking to identify how the resources on Islay can be utilised to create a large scale hydrogen demonstration project. .
A Sustainable Energy Supply for Wales: Towards the Hydrogen Economy	Hydrogen End Use	The objective of this project is to place Wales in a position to create wealth and employment by taking full advantage of the opportunities presented by the ongoing transition to a hydrogen economy.

Table B - 4 Non-Academic Projects

Commercial

A summary of the commercial organisations are shown in Table B - 5.

Organisation Name	Type of Projects	Project Activities
Accentus plc	Hydrogen Storage & Production	Focuses on developing Intellectual Property (IP) and new products for licensing
Hydrogen Solar	Hydrogen Production & Storage	Portfolio of hydrogen technologies and Intellectual Property aimed at the hydrogen economy.
Anglesey Wind and Energy (Wind Hydrogen Limited)	Hydrogen Systems	Current Projects: • Shetland Wind • Teesside Hydrogen Balancing Scheme • One third owner of Hunterston Hydrogen (HH), which has been formed to develop a 90MW wind-hydrogen scheme in Ayrshire.
Electrochemical Technology Business	Hydrogen End Use	Development of Fuel Cell coatings
Advantica	Hydrogen End Use	Activities include investigating the transition to hydrogen economy via natural gas and fuel cell systems.
Voller Energy	Hydrogen End Use	Development of a range of portable power packs, battery chargers and mobile generators
SiGEN	Hydrogen End Use (as well as production & storage)	Design and implementation of commercial Fuel Cell power solutions. Services include: • Fuel Cell Systems • Hydrogen Production Systems • Hydrogen Compression and Storage

Table B - 5 Commercial Activities

Europe

Academic Institutions

A summary of the Academic projects being undertaken are shown in Table B - 6.

Projects

University Name	Type of Projects	Project Activities
University of Stuttgart, Germany, Department of Lifecycle Engineering	Hydrogen Production	The research was into the production of hydrogen and methanol for use in Fuel Cell Vehicles and was completed in 1999
Roskilde University, Denmark – Energy & Environmental Group	Hydrogen Systems	A number of projects relating to the introduction of hydrogen as an energy carrier in Denmark. Testing of fuel cell vehicles and systems analysis has also been undertaken.
University of Cassino, Italy, Department of Industrial Engineering	Hydrogen Systems	The department focuses its work on energy analysis of systems with high temperature fuel cells, cooling layout for MCFC, energy analysis for microbial and PEM fuel cells, energy storage (hydrogen), hydrogen in cogeneration and the production and distribution of hydrogen.
University of Oslo, Norway	Hydrogen Storage (& Systems analysis)	Research includes: • Hydrogen Storage Materials • Hydrogen as an Energy Carrier • Experimental Design of a solar-hydrogen control system

Table B - 6 Academic Projects

Other projects that have been identified but not included in the above table include hydrogen research taking place at the Centre for Renewable Energy at the Norwegian University of Science and Technology and also a comparative study of fuels for on-board hydrogen production for PEM fuel cell applications in the automotive Sector at the Yildiz Technical University in Istanbul.

Non-Academic Institutions

A summary of the Non-Academic centres and projects being undertaken are shown in table Table B - 7 and Table B - 8 respectively

Centres

Centre Name	Type of Centre	Activities
Institute for Energy Technology (IFE), Norway	Research & Development	IFE is an international research centre for nuclear and energy technology. IFE is involved in a

		number of hydrogen projects - within hydrogen production, energy systems, hydrogen storage and market analysis for hydrogen energy
Folkcenter, Denmark	Development & Demonstration	Developing, testing, and demonstrating renewable energy technologies which are designed for manufacturing in small and medium scale industries.
Risø Centre, Denmark	Research, Development & Demonstration	Carries out research in science and technology, providing Danish society new opportunities for technological development. Risø collaborates with universities, research institutes, technological institutes and the industrial sector on a national, European as well as on an international basis. Risø employs over 700 staff.
Hydrogen Energy Research Centre (HERC), Turkey	Research & Development	International Hydrogen Technologies Centre to be based in Istanbul, Turkey. *Reasons for location of Centre* About 64% of boron reserves in the World are in Turkey. Boron can be used commercially as hydrogen carrying material in fuel cells. The black sea has a huge amount of hydrogen sulphur at 60M depths, which can be evaluated as a hydrogen resource
Hydrogen Park Project, Italy	Research & Development	The goal is to turn Porto Marghera (Venice) into one of the most important world centres for the production and use of hydrogen, and for the promotion of studies and projects aimed at the development of the energy source. Porto Marghera is one of the few industrial areas in the world with existing and substantial hydrogen production, linked to the production processes of the chemical's industry.
Energy Research Centre of the Netherlands (ECN)	Research & Development	It is the largest research centre in the Netherlands in the field of energy with approximately 900 employees. Within their hydrogen remit ECN Fuel Cell Technology develops materials, components, stacks and system components for

		stationary and automotive applications of fuel cells
Centre for Solar Energy and Hydrogen Research (ZSW), Germany	Research & Development	Offer facilities for Research and development of environmentally sound technologies for providing power, heat, and fuels.
Grimstad Renewable Energy Park, Norway	Demonstration	The main activities of the centre are to provide information to the public, teaching and research. The centre encompasses a broad spectrum of different renewable energy technologies; solar cells, biomass cells, electrolyser for production of hydrogen, fuel cells, heat pumps, solar thermal systems as well as ground wells.
Hydrogen Innovation and Research Center, Denmark	Research, Development & Demonstration	The goal of the new Hydrogen Innovation and Research Centre (HIRC) is to generate jobs as well as groundbreaking research in the field of sustainable energy. HIRC will conduct technical research into the commercialisation of hydrogen technology, and hopes to stage a number of demonstrational projects highlighting the commercial possibilities afforded by hydrogen technology in the future. Projects already in development include a hydrogen-fuelled truck. Announcement was made on the 30th August 2004

Table B - 7 Non-Academic Centres

Projects

Project Name	Type of Projects	Project Activities
ECTOS (Ecological City Transport System) Project - Iceland	Hydrogen End Use	Demonstration project to investigate the potential for eventually replacing the use of fossil fuels in Iceland with hydrogen and create the world's first hydrogen economy. *Activities* • Three DaimlerChrysler hydrogen-powered buses are to be tested for two years in Reykjavik. • The next phases will be the

		introduction of private vehicles using hydrogen-based fuels, and • a gradual introduction of vessels (fishing fleet) at first using fuel cells for their auxiliary equipment and later for their main propulsion. The vessel project started in Oct 2003 and is called New-H-Ship
Zero Regio - Lombardia & Rhine -Main towards Zero Emission: Development and Demonstration of Infrastructure Systems for Hydrogen as an Alternative Motor Fuel - Italy, Germany, Sweden & Denmark	Hydrogen End Use	Overall objective of developing low-emission transport systems for European cities
Cryoplane – Liquid Hydrogen Fuelled Aircraft: System Analysis	Hydrogen End Use	The project will assess the technical feasibility, safety, environmental compatibility and economic viability of using liquid hydrogen as an aviation fuel
RES2H2 - Integration of Renewable Energy Sources with the Hydrogen Vector – Spain & Greece	Hydrogen Systems (Production & Storage)	The objective of this project is the clean production of hydrogen while exploiting a renewable energy source, such as wind power, to overcome, on one hand, the problem of storing surplus energy and, on the other hand, the production of clean hydrogen that effectively meets the demands of an energy vector that is compatible with sustainable development.
H2 MUC - Hydrogen Project at Munich Airport, Germany	Hydrogen Systems	Fully automatic refuelling and operation of hydrogen vehicles. The system comprises two parallel hydrogen supply paths, one for the refuelling of three apron buses with ICE H2-engines with gaseous hydrogen (GH2) and one for the refuelling of passenger cars with liquid hydrogen (LH2).
CEP (Clean Energy Partnership), Germany	Hydrogen Systems	A public hydrogen filling station is currently under construction at the Messedamm in Berlin. On site, hydrogen will be derived from water by electrolysis and stored as pressurized gas. Additionally, cryogenic liquid hydrogen will be delivered and stored. The hydrogen will be used in vehicles powered either by a modified internal

		combustion engine or by fuel cell propulsion systems
Hydrogen Competence Centre, Germany	Hydrogen Systems	A hydrogen filling station has been installed by TOTAL in the BVG bus depot located Usedomer Strasse in Berlin Mitte in October 2002. The project aims at: • Gathering technical and economical data on the whole hydrogen supply chain in a real field experiment • Establishing safety management procedures for service stations • Promoting the practical use of hydrogen fuel (public acceptance, education)
Scandinavia's First Hydrogen Fuelling Station. Sweden	Hydrogen Systems	The filling station will provide customers with two filling alternatives - either pure hydrogen or a mixture of natural gas and hydrogen. The production of hydrogen gas is local and completely renewable. The electricity used in the electrolysis process is generated by wind power.
Wind Hydrogen System Utsira, Norway	Hydrogen Systems	To demonstrate how wind power and hydrogen together may provide a reliable and efficient source of electricity, and to be able to design a complete energy system that is cost efficient under today's economic and political environment
CUTE (Clean Urban Transport for Europe) Project	Hydrogen Systems	The CUTE project is an initiative to use hydrogen fuel in the public transportation system of nine European cities and is evaluating 27 hydrogen powered buses in a variety of conditions – 4 of the 9 hydrogen stations will supply hydrogen produced through water electrolysis.
Brintamt Ringkjobing Amt, Denmark	Hydrogen Systems	The goal of the project is to come through as a leading international region for sustainable energy sources via a number of different activit ies,
PEM CHP in Aetsa, Finland	Hydrogen Systems	The project demonstrates decentralized CHP production in a local energy system. Demonstration comprises a residential PEM fuel cell micro-CHP production of approx. 4kW in size

Table B - 8 Non-Academic Projects

Commercial

A summary of the commercial organisations are shown in Table B - 9

Organisation Name	Type of Projects	Project Activities
Corporación Energía Hidroeléctrica de Navarra (EHN), Spain	Hydrogen Production	Producing Hydrogen from Wind Power. In collaboration with the Universidad Pública de Navarra (UPNA) and Smart Energy Systems, this project consists of simulating the electric power generation conditions of a wind farm in a laboratory and analysing the effects in an electrolyser. An experimental laboratory has been installed in the Universidad Pública de Navarra to carry out the research
SRE (Soluções Racionais de Energia, SA), Portugal	Hydrogen End Use/Systems	**EDEN Project (Endogenize the Development of Novel Energies).** The Project's purpose is to develop a national technological basis enabling the scientific, technological and business community to intervene / participate actively in the mutation process from the present energy paradigms to a new one in which hydrogen will play the main role
Norsk Hydro Electrolysers AS (NHEL), Norway	Hydrogen Production & Storage	Supplier of water electrolysis equipment and complete compression, purification, storage and gas handling systems for industrial applications, hydrogen fuelling stations and distributed energy systems
ELT (Elektrolyse Technik), Germany	Hydrogen Production	Expertise is based on atmospheric electrolysers (System BAMAG®) and pressure electrolysers (System LURGI®)
IRD Fuel Cells A/S. Denmark	Hydrogen End Use	Research, Development & Production of Fuel cell materials, cells and systems

Table B - 9 Commercial Activities

US & North America

Academic Institutions

There are a large number of academic institutions active in the field of hydrogen from the point of regional and national centres of excellence to individual research projects. Examples of the academic centres and projects being undertaken are shown in Table B - 10 and Table B - 11 respectively

Centres

Centre Name	Type of Centre	Activities
Hydrogen Technology Learning Centres	Education	Establish learning centres in the states of California, Florida and New York
Maryland Hydrogen Technology Education Center (H2TEC)	Education	Establish undergraduate course in hydrogen technology as well as graduate study and short courses.
Development of a Regional Hydrogen Technology Education Consortium (HyTEC)	Education	4 universities from 4 states to provide education and training for students, professionals, and the public. Centres at each university will be established to develop courses, workshops and disseminate materials
Oregon Institute of Technology (OREC), Oregon University	Education, Research & Development	Provides specialized course work, curriculum, and laboratory training to educate and train students and industry personnel in the understanding, application, design, installation and development of renewable energy sources and related technologies.
Hawaii Fuel Cell Test Facility (HFCTF) at the University of Hawaii	Research & Development	Testing of fuel cells for commercial and military applications. Focuses mostly on finding ways of making fuel cell technology more commercially practical.
Center for Electrochemical Systems and Hydrogen Research (CESHR), Texas A & M University	Research & Development	CESHR's main interest is in developing proton-exchange-membrane fuel cells (PEMFCs) for aerospace and military and terrestrial applications.
Hydrogen Research Institute (HRI), Université de Québec à Trois-Rivières	Research	Design, fabrication and simulation of fuel cells using a solid polymer membrane are HRI's prime objectives.
Hydrogen Energy (H2E) Center at Penn State University (PSU)	Research	Formed to serve as a focal point for multi-investigator activities at PSU on hydrogen production, storage and utilization systems.
Argonne National Laboratory, University of	Research	Current R&D programmes are investigating Hydrogen production,

Chicago	storage, Fuel cell development and testing, Fuel and power systems, Vehicle simulation and testing, Economic and technical analysis, Infrastructure assurance, Environmental research & Technology validation projects

Table B - 10 Academic Centres

Projects

Project Name	Type of Project	Project Activities
Hawaii Hydrogen Project (HHP) and Hawaii Hydrogen from Rene wable Resource Program (HHRRP) at the University of Hawaii.	Hydrogen Production	Funded since 1986. Set up both HHP & HHRRP. Project of interest include: • Photo-electrochemical Hydrogen Production • Biological Hydrogen Production • Gasification of Biomass in Supercritical Water (a process for hydrogen production by the catalytic gasification of biomass in supercritical water).
Clean Air Now Solar Hydrogen Project at the University of California	Hydrogen Production & End Use	Design, construction, and analysis of photovoltaic hydrogen production and vehicle refuelling station.
The Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project at the University of California	Hydrogen End Use	Five-year study of hydrogen fuel cell-powered vehicles - looking to address issues such as fuels and fuelling infrastructure, and the promotion of the technology.
Hydrogen Fuel for Transportation at the University of California	Hydrogen End Use	Three-phase program to demonstrate hydrogen fuel for use in transportation applications.
Fuel Cell Bus Programme, Georgetown University	Support development and commercialisation of fuel cell buses	Active since 1983 in developing and testing Fuel Cell Buses. They are now developing the third generation of buses – with the aim of developing non-hybrid fuel cells using liquid fuel.
University of Missouri-Rolla	Research & Development	Projects to: • develop a stronger solid oxide fuel cell sealant from glass-ceramic materials. • develop improved fuel cell electrolyte and electrode materials • develop novel approaches for processing fuel cell components

Table B - 11 Academic Projects

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Non-Academic Institutions

There are a number of non-academic organisations active within the hydrogen field. Of note are the activities in Hawaii which could be considered to have similar circumstance to that of Shetland. Examples of the types of non-academic centres and projects being undertaken are shown in Table B - 12 and Table B - 13 respectively

Centres

Centre Name	Type of Centre	Activities
National Renewable Energy Laboratory (NREL)	Research, Development & Demonstration	The operation of the program is divided into several tasks: • Hydrogen Production and Delivery • Hydrogen Storage • Fuel Cells • Analysis • Technology Validation • Education • Safety, Codes and Standards NREL's hydrogen and fuel cells research efforts are organised to support the US DOE's Hydrogen, Fuel Cells & Infrastructure Technologies Program
Center for Fuel Cell Research and Applications	Demonstration	The primary activity of the Centre involves evaluating the performance of near-commercial fuel cell systems and related equipment for the benefit of technology consumers and investors.
The Hydrogen Energy Center (HEC)	Demonstration	Aims to: • make renewable hydrogen and offer electric vehicle recharging at a site in southern Maine • promote hydrogen-fuelled domestic power production
Hawaii Hydrogen Center for Development and Deployment of Distributed Energy Systems	Research & development	Hydrogen production and infrastructure research and testing. Providing a venue for technology development, testing, applied research, demonstration, information dissemination, and technology transfer.
Hydrogen Research and Application Center	Research & Demonstration	Activities commenced in 1999. Research to produce, store and apply hydrogen for both space and Earth applications.

Table B - 12 Non-Academic Centres

Projects

Project Name	Type of Projects	Project Activities
Fuel Cell Demonstration Program (FCDP)	Hydrogen End Use	Demonstration of PEM Fuel Cells ranging from 1-20kW.
National Fuel Cell Research and Innovation Initiative (NRC – IFCI)	Hydrogen End Use	Working with partners from industry, universities and other government agencies to build fuel cell technology clusters across Canada
Hydrogen Village	Hydrogen Systems	The Hydrogen Village will deploy and demonstrate in a geographically defined setting, numerous technologies that support the integration and production of hydrogen to generate clean, reliable, and efficient energy.
The Chewonki Renewable Hydrogen Project	Hydrogen Systems	Design, installation, and operation of a hydrogen energy system fuelled by renewable energy.
Hawaii Hydrogen Power Park[26]	Hydrogen Systems	The project will demonstrate an integrated hydrogen production, storage and fuel-cell system.
Schatz Solar Hydrogen Project	Hydrogen Systems	Developed a full-time, automated, stand-alone energy system that demonstrates that hydrogen can be used to store solar energy.

Table B - 13 Non-Academic Projects

Commercial

Examples of the organisations active in the hydrogen field are shown below in Table B - 14. There are many organisations in the US & North America active in the hydrogen field– in particular in the area of fuel cells. The results of this survey identify only a small number of those organisations – as to list them all would be to numerous.

Organisation Name	Type of Projects	Project Activities
Texaco Ovonic Hydrogen Systems LLC	Hydrogen Storage	Aims to bring metal hydride hydrogen storage systems into full commercial production for emerging fuel cell markets

[26] The state of Hawaii has much higher electricity cost than the rest of the US and this is mostly due to the lack of interconnection with the mainland which:

- requires high reserve margins,
- requires extra efforts to maintain reliability and power quality, and
- poses challenges to connect renewable energy sources on the grid.

In addition, with its total dependence for energy on imported fossil fuel, Hawaii is particularly vulnerable to dislocations in the global energy market. Due to all of the above mentioned, the Hawaii Natural Energy Institute (HNEI) was established a few months after an oil embargo in 1974. The institute was established to meet the following goals:
(1) diminish Hawaii's total dependence on imported fossil fuels;
(2) meet the state's increasing energy demands with little or no environmental degradation; and
(3) contribute to the technology base for finding solutions to the national and global energy shortage.

FuelCell Energy	Hydrogen End Use	Development, manufacture and commercialisation of high temperature hydrogen fuel cells for stationary electric power generation
UTC Fuel Cells	Hydrogen End Use	Development of PEM fuel cells and fuel processor technologies for transportation, commercial power, portable power, and space and defence applications.
Fuel Cell Technologies Ltd.	Hydrogen End Use	Commercialising of fuel cell systems
Ballard	Hydrogen End Use	Developing, manufacturing and marketing proton exchange membrane (PEM) fuel cell products
Solar Hydrogen Energy Corporation (SHEC)	Hydrogen Production	Research and development company that was incorporated in 1996 and has developed a number of technologies for the solar thermo catalytic production of hydrogen
Proton Energy Systems	Hydrogen Production	Major electrolysis manufacturer.

Table B - 14 Commercial Activities

Asia

The survey looked to provide examples of both centres of excellence and projects being run by academic and non-academic organisations as well as those commercial organisations active in the hydrogen field. Of the different regions, hydrogen activities within Asia have been the most difficult to identify. This has been in part due to the lack of information in English on web based sites.

Academic Institutions

Examples of the types of academic centres and projects being undertaken are shown in Table B - 15 and Table B - 16 respectively

Centres

Centre Name	Type of Centre	Activities
Hydrogen Research Centre	Research & Development	Opened in 2004, the centre will develop technologies to produce hydrogen by resolving water through the utilization of intense heat from nuclear reactors. China
HESS (Hydrogen Energy Systems Society)	Research & Development	HESS (operating since 1973) is a centre for research and development for ideal hydrogen energy systems utilizing renewable energy sources. Japan

Table B - 15 Academic Centres

Projects

Project Name	Type of Project	Project Activities
Malaysia's Eco-House	Hydrogen Systems	Solar-Hydrogen powered home sited at the University Kebangsaan Malaysia (UKM)
Tohoko University – Research Activities	Hydrogen Storage & Production	Research activities include: • Hydrogen Storage Materials • Ceramics Membranes for Hydrogen Production

Table B - 16 Academic Projects

Non-Academic Institutions

Of those Asian countries surveyed Japan is by far the most active in the hydrogen field. The Ministry of Economy, Trade and Industry, is continually funding the technological development and infrastructure for practical use of Fuel cells – in 2002 22 billion yen was allocated to this area. In 2005 demonstration tests are to be started by the Agency for Natural Resources and Energy, to determine whether large volumes of high-purity, high-pressure hydrogen can be obtained from refineries in order to supply a futures society based on hydrogen energy. The Institute of Applied Energy has also performed research on Hydrogen Energy Systems. So far no centres have been identified, however, organisations such as the Railway Technical Research Center (RTRI) in Japan are undertaking research and testing of fuel cells for train applications. Examples of the non-academic centres and projects being undertaken are shown in Table B - 17 and Table B - 18 respectively.

Centres

Centre Name	Type of Centre	Activities
Hydrogen Energy System Research Group, National Institute of Advanced Industrial Science and Technology, Japan	Research and Development	Research and development of hydrogen production technology by using ion exchange membranes and of new hydrogen storage materials with high capacity and storage technology applicable to hydrogen supply stations or to hydrogen storage tank for automobiles.

Table B - 17 Non-academic Centres

Projects

Project Name	Type of Project	Project Activities
Japanese Hydrogen and Fuel Cell Demonstration Project (JHFC)	Hydrogen Systems	Operating since 2000 to investigate the energy effectiveness, environmental burden and other aspects of fuel cell vehicle use. Automobile manufacturers are participating to collect basic data through fuel cell vehicle trials on public roads. Also participating are fuel producers who are supplying hydrogen in either gas or liquid form at fuelling stations.
International Clean Energy Network Using Hydrogen Conversion, Japan	Hydrogen Storage	▪ Building a worldwide clean energy utilisation system. ▪ Hydrogen utilisation technology ▪ Electrolytic process to manufacture hydrogen ▪ Hydrogen liquefaction equipment ▪ R & D for Hydrogen transportation and storage at the consumption site to be utilised for power generation or as an alternative fuel etc.

Table B - 18 Non-Academic Projects

Commercial

The main types of activities are in the development of fuel cells and hydrogen infrastructure for automotive use. For example, DaimlerChrysler’s SIM Technology research and development centre in Shanghai is helping the Chinese Central Government with the electronics components of the first Chinese fuel cell vehicle. Also, Hino Motors and Musashi Institute of Technology (Japan) have already jointly-developed a refrigerator lorry with a hydrogen engine. In Singapore BP are looking to develop a hydrogen refuelling station. The station, expected to be up and running by the first quarter of next year, will produce its own hydrogen gas via electrolysis (using electricity from the grid). Other examples, of commercial organisations active in the hydrogen field are shown below in Table B - 19.

Organisation Name	Type of Project	Project Activities
Toyota[27]	Hydrogen End Use	Developing fuel cells for automotive and residential markets.
Tokyo Gas	Hydrogen End Use	Market entry and penetration of Fuel Cells for stationary use

Table B - 19 Commercial Activities

[27] As well as Toyota, Mazda, Nissan, Honda and Mitsubishi are also developing fuel cells for automotive use.

Australasia

The survey looked to provide examples of both centres of excellence and projects being run by academic and non-academic organisations as well as those commercial organisations active in the Hydrogen field. Hydrogen activities are not as well developed in Australasia compared to the other jurisdictions identified in this report. However, the small island of Vanuatu is aiming to become the first country in the South Pacific region to base its entire economy on renewable energy with hydrogen at its fore. The aim of the island is to become completely oil free by 2030.

Academic Institutions

The University of Tasmania is the only academic institution identified thus far that is active in the hydrogen field. The University has been active in two hydrogen related projects and is looking to set up a research centre. Examples of the academic centres and projects being undertaken are shown in Table B - 20 and Table B - 21respectively

Centres

Centre Name	Type of Centre	Activities
The Hydro Tasmania Hydrogen Energy Research Facility	Research	The facility will investigate potential Hydrogen applications in automotive technology and electrical engineering in collaboration with German and Danish research teams.

Table B - 20 Academic Centres

Projects

Project Name	Type of Project	Project Activities
Hydrogen Powered Scooter, University of Tasmania	Hydrogen End Use	Development of a hydrogen-powered scooter. Applying the technology to cars is the group's next task.
Hydrogen Energy Systems in Antarctica (H2ESA) program, University of Tasmania	Hydrogen Systems	The broad and long-term objectives are to Identify, Analyse and Overcome the challenges to using hydrogen as a means of storing and supplying renewable energy in remote, harsh and pristine environments.

Table B - 21 Academic Projects

Non-Academic Institutions

As with the academic organisations there are only a few organisations active within the hydrogen field. Examples of the non-academic centres and projects being undertaken are shown in Table B - 22 and Table B - 23 respectively

Centres

Centre Name	Type of Centre	Activities
Fuel Cell Manufacturing Facility	Manufacturing	Idea for a Fuel cell manufacturing base as part of a project to rejuvenate an area of NSW.

Table B - 22 Non-Academic Centres

Projects

Project Name	Type of Project	Project Activities
Perth Fuel Cell Bus Trial	Hydrogen End Use	Evaluation program looking to inform and educate key stakeholders.
Hydrogen Fuel Cell SMART House, NSW (Australia)	Hydrogen Systems	The purpose and aim of this project is to demonstrate that electrical power generated by using hydrogen Driven Solid Oxide Fuel Cells and P.E.M. (Proton Exchange Membrane) Fuel Cells, can provide reliability and cost- effective power generation, and that it is feasible to commercialise hydrogen fuel cell applications in niche markets such as housing.
Hydrogen Energy for the New Millennium, Christchurch (New Zealand)	Hydrogen Production (as well as storage and end use)	The programme has two main themes: 1. Development of technology to deliver distributed electricity supply from New Zealand coal, through hydrogen production and fuel cells 2. Development of a capability for production of distributed hydrogen by electrolysis from renewable energy

Table B - 23 Non-Academic Projects

Commercial

No commercial organisations have been found to be significantly involved in hydrogen related activities.

International

This section looks to provide examples of those organisations active in several jurisdictions. This list is not meant to be exhaustive (for example, BP have similar activities as Shell - production, distribution and retailing of hydrogen) but provides an indication of the type of activities organisations are pursuing.

Organisation Name	Type of Activities	Project Activities
Qinetiq Ltd	Hydrogen End Use	Experience in the design and application of PEM fuel cells, while also working on solid oxide, liquid feed fuel cells and hydrogen storage technologies.
DuPont	Hydrogen End Use	DuPont has over 30 years of experience in fuel cell system development.
Rolls Royce	Hydrogen End Use	Fuel Cell manufacture
BMW[28]	Hydrogen Car Development and Production	Production of BMW's first hydrogen car, BMW 750hL shown at Expo 2000
Stuart Energy	Hydrogen Production, Storage & Supply	Design, build, integrate, sell and service Energy Stations to produce, store and deliver hydrogen on-site for high-value, emission-free fuel and power applications
BOC	Hydrogen Supplier	BOC operates almost a hundred hydrogen plants around the world ranging from large-scale steam methane reformers to small electrolytic plants
Linde Gas AG	Hydrogen Supplier	Large hydrogen manufacturer and supplier. Activities involved in: • 10.000 PSI / 700 bar Filling Station • H2-Filling Stations from Munich to Tokyo • Mobile applications • Clean-Energy Partnership • CUTE • Zero Regio • EIHP • HyWays • Hynet • StorHy • LH2 Fuel Station Munich Airport
Shell Hydrogen	Various	Set up in 1999 to pursue and develop business opportunities related to hydrogen and fuel cells

Table B - 24 International Activities

[28] As also highlighted in the Asia chapter, most automobile manufacturers are actively pursuing fuel cells for transport.

ANNEX C - QUESTIONNAIRE

Name of Organisation	
Contact Name	
Contact Details	
Organisation Activities – Overview	
Activities Relating to Hydrogen	Production Storage End Use Systems Other
Business locations	
Number of people employed.	Within organisation Relating to hydrogen activities

Hydrogen Markets

What is your market?	
Where do you see the potential markets in the near term, 5 years, 10 years? What are the needs?	
What do you think will be required in order to stimulate these activities?	
Of these what are important to you?	

Study Centre

Are you aware of the activities that are occurring on Shetland with respect to hydrogen?	
Do you see any advantages or disadvantages of having a centre on Shetland compared to an alternate location?	
What would be your preferred location?	
What facilities, if any, do you currently use.? Good and bad points about these facilities.	
How often do you use these facilities?	
What would you like a centre to offer in terms of facilities? (hydrogen supply, storage, load, ISO accreditation, education etc)	
Shetland has an excellent engineering base (outside of the centre) – would you look to take advantage of this or would you bring your own expertise.	
Would you provide you own engineer/expertise to run and operate the	

activity or would you want the centre to provide this service?	
Besides your own expertise what other expertise would be beneficial to you in terms of your activity?	
For how long and how often would you use a centre if it offered the facilities you require?	
Over what period would this be? (i.e. for the next 5 years only).	

Financing the Centre

There have been examples of other centres being set up in collaboration with both university and industry organisations – for example, **Grimstad Renewable Energy Park in Norway** as well as a number in the US. Would this be something that you would consider?	
If so, how would you support/collaborate with the centre? • Set up costs • Grants • Minimum guarantee of work etc	
Would you become a partner in such a centre? (i.e. becoming a shareholder/taking partial liability for the centre etc)	
How would you want to pay for services? (daily rates/annual retention fee etc)	
Do you have a budget for Research, development & Demonstration?	

Education

One thing that the centre could offer is to facilitate PhD/Msc Students/employees in hydrogen research. Is this something your organisation would be interested in?	
Would your organisation use the centres facilities ?, or would it look to other institutions that could accommodate?	
What would entice your organisation to use a centre on Shetland?	

Final question

Do you think that it is realistic or feasible for Shetland to have a Hydrogen Energy Study Centre

Other Information
Any other information provided by the interviewee

ANNEX D – LIST OF RESPONDENTS TO THE CONSULTATION

Academic

Name	Business	Potential Interest in Shetland Hydrogen Centre and/or hydrogen related activities
Joe Irvine	University of the Highlands & Islands (Shetland based)	Involvement of UHI in applied hydrogen research and training in Shetland.
Samantha Cherryman	School of Technology, University of Glamorgan	Training / learning / advice related to developing a similar renewables-hydrogen demonstration project in Wales.
Salman K. Salman	School of Electrical Engineering, RGU, Aberdeen	PURE & related projects for academic study and research opportunities.
Patrick Devine-Wright	Institute of Energy and Sustainable Development,De Montfort University, Leicester	The use of Unst as a study centre for undergraduate, post-graduate and specialist research students enrolled at de Montfort Uni - focused on the community ownership and acceptability of local hydrogen production for local consumption.
Ian Bryden	School of engineering, RGU, Aberdeen	Testing of hydrogen systems powered by marine renewables.
Rupert Gammon	Loughborough University	Collaborative research & development of low cost, low pressure electrolyser and hydrogen storage for integration with a renewable energy supply – HARI Project.
Hugh Middleton	Agder University College, Denmark	Active in electrolysis, compressed gas storage and fuel cells.

Non-Academic

Name	Business	Potential Interest in Shetland Hydrogen Centre and/or hydrogen related activities
Colin Raftery	Scottish Executive	Support for developing a Scottish industry in hydrogen and renewable energy, and promoting projects which extract community benefit from both.
Ian Edwards	ITI Energy	Support for R&D hydrogen projects which will lead to production and demonstration of patentable new systems, components or products.
Elaine Hanton	Highlands & Islands Enterprise	Strategic interest in supporting the development of a hydrogen industry linked to the emerging renewables sector in the Highlands & Islands.

Gordon Newsholme	Health & Safety Executive, Technology Division, Bootle	Ability to test plant, processes & systems and conduct field trials, under safe, tightly controlled conditions & to scrupulously monitor & report on the results; ability to accurately profile performance of h2 plant in operation.
Jens Christian Møller	Hydrogen Innovation & Research Center (HIRC)	HIRC will conduct technical research into the commercialisation of hydrogen technology, and hopes to stage a number of demonstrational projects highlighting the commercial possibilities afforded by hydrogen technology in the future. Projects already in development include a hydrogen-fuelled truck.
Tanto Hycinth Ndikilar	CAT Cameroon	Learning and training in skills related to integrating hydrogen production & storage with solar power.
Karen Hall (UK based)	(US) National Hydrogen Association	A community hydrogen production model which can be replicated. The value to the US (where oil is still very cheap) of conducting field trials of H2 production systems in a location where oil is expensive and small scale H2 production can soon be a viable alternative.
Richard Court	New and Renewable Energy Centre (NaRec)	Research & Development in wet, wind and solar renewables
John Autherson	Centre for Process Industries	Promoting innovation on process industries by using existing chemical industry infrastructure. They are building a Fuel Cell Applications Facility to support uses of hydrogen and are involved in a number of hydrogen related projects in the North East of England

Commercial

Name	Business	Potential Interest in Shetland Hydrogen Centre and/or hydrogen related activities.
Mikael Sloth	H2 Logic	Hydrogen and fuel cell development company
John Baker	EA Technology	Sharing knowledge and encouraging international collaboration relating to hydrogen demonstration projects. Support for renewable energy storage research and development.
Jonathan Hill	Econnect	Field trials and practical demonstrations of hydrogen production, storage and re-use for balancing islanded electricity networks supplied by intermittent renewable energy.
Mike Zelinski	Texaco Ovonic Hydrogen Systems LLC, USA	Field trials and out-of-lab product testing for the European certification and commercialisation of hydrogen storage systems.

Gordon Proven	Proven Engineering	The integration of hydrogen into renewable energy systems. Testing and field trials for integrated small scale h2 systems.
Fred Gibson	Shetland Composites	Consortium R&D Projects (like Ghost) involving prototype vehicles or boats made from composite materials; mouldings for H2 plant
David McGrath	SiGen	Installing & demonstrating working H2 systems; renewable / hydrogen system integration; undertaking innovative collaborative projects.
Jack Barclay	Unst Inshore Services	Building Europe's first H2 boat certified for marine use, based on the UIS patented boat design; R&D around H2 inboard & outboard engines & fuel systems for boats.
Ben Yates	Wavegen	Integration of wave power devices with hydrogen production and storage.
Gareth Davies	Aquaterra, Orkney	Interest in developing partner community research and development institute, focused on marine renewables, with formal links to a Shetland hydrogen centre.
Ed Angus	Fuel Cell Scotland	Opportunities for extended testing and field trials of fuel cells under controlled and monitored conditions; activities related to commercialisation of fuel cell.
Jana Hutt	Glanarder Ltd.	Developing training and skills development around the PURE Project in Unst.
Declan Pritchard	Wind Hydrogen Ltd.	Practical demonstration of principles of wind to hydrogen systems to help promote & encourage development of larger grid connected systems.
Alastair Rennie	AMEC	Corporate interest in developing a wind-hydrogen power station in Shetland (potentially built by AMEC). Provided technical advice and information for the PURE feasibility study from the AMEC engineering team.
Tony Marmott	Beacon Energy	Support for developing cost-effective hydrogen plant powered by renewable energy. Support for field trials of hydrogen applications - eg. hydrogen vehicles.
Peter Gray	Johnson Matthey	Field trials and out-of-lab product testing for the mass commercial market in fuel cells.

ANNEX E – SUMMARY OF CONSULTEE RESPONSES

Hydrogen Markets

Academic

- ***Market***

The University of Glamorgan has been involved in hydrogen production research for the past 10 years and are hoping to develop an industrial scale hydrogen production plant in Wales. Their main area of work is in the production of hydrogen via biological processes as well as the socio economic impacts of hydrogen. They are also closely linked to the regional development agency which is looking to entice hydrogen businesses to the area.

DeMontfort University are involved in ESPRC funded research looking at a more sustainable electricity system in the UK, which includes the integration of hydrogen. Research is also being undertaken within the social science arena in looking at the transition to hydrogen systems.

Robert Gordon University are working with St Andrews University on an integrated tidal current and hydrogen system (funded by Scottish Enterprise, proof of concept scheme) and also working on the PURE project (as part of the Knowledge Transfer Programme).

The University of the Highlands & Islands activities in relation to hydrogen have yet to be determined. However, in October of this year a decision on what area to be pursued is going to be made.

The Centre for Renewable Energy Systems Technology (CREST) at Loughborough University is undertaking a Hydrogen and Renewables Integration demonstration project. The aim of the project is to disconnect from the grid and become totally autonomous.

Agder University College in Denmark is involved in Electrolysis, compressed gas storage and fuel cells.

- ***Potential markets in the near term, 5 years, 10 years and what are the needs?***

The majority of academic institutions agreed that hydrogen was realistic to be a major energy carrier in the future (>15 years), although a lot of work is required in getting it to this point. Ian Bryden of Robert Gordon University said that hydrogen could become a major part in the longer term but major technical breakthroughs will be required. He provided an example of the conversion of electricity to hydrogen and then to electricity and that the process is currently very inefficient (~30%) and requires to be at least doubled before it becomes economic. Hydrogen for transport, however, could occur sooner but again problems associated with storage and distribution needs to be resolved. Dr Devine-Wright of DeMontford University also saw the potential for hydrogen in transportation and acting as a storage buffer for renewables. The key theme was that a series of demonstration project are required in different situations to prove the robustness of the technology.

- ***Requirements to stimulate activities***

  There were a variety of different views on what would be required to stimulate the hydrogen market. These views are summarised below:

  - Build a research capability and thus create experience and qualifications;
  - Raw materials for Renewables;
  - Better Storage technologies;
  - Hydrogen distribution network;
  - Cheaper manufacturing;
  - Improved lifetimes of technology (i.e. Fuel cells and electrolysers);
  - Links to local companies to develop suitable technologies;
  - Encouragement of market take up through education of the general public;
  - Central point of contact coordinating the whole process and driving this forward;
  - Funding – via research councils, government or other funding bodies; and
  - Removal of cost and technology barriers and raising of awareness of hydrogen;

Non Academic

- ***Market***

  The Non-Academic institutions based in Scotland are looking to promote, support and develop opportunities in Scotland within the Energy industry. The US National Hydrogen Association (NHA) is looking to provide technology and management services to alternative energies including hydrogen and fuel cells. They would also look to disseminate information on the activities in Shetland

  The Scottish Executive is providing support for developing a Scottish industry in hydrogen and renewable energy and in particular promoting projects which extract community benefit from both. The Highlands & Islands Enterprise has a strategic interest in supporting the development of a hydrogen industry linked to the renewables sector in the Highlands & Islands. The role of the Energy Intermediary Technology Institute (ITI Energy) is to become a centre of excellence for research and development of new energy technologies, recognised and respected internationally as a source of high calibre expertise, of focused investment funding, and of unswerving, collaborative commitment to successful market entry and commercialisation.

  The role of the Hydrogen Innovation and Research Centre (HIRC) is in facilitating. It aims to conduct technical research into the commercialisation of hydrogen technology, and hopes to stage a number of demonstrational projects highlighting the commercial possibilities afforded by hydrogen technology in the future. Projects already in development include a hydrogen-fuelled truck.

  CAT Cameroon is a Non-Profit Making grassroots NGO created in 2001 with the main aim to help eradicate poverty and improve environmental quality in Cameroon through the development and use of appropriate technology, by demonstrating results, building skills and influencing people".

Currently the New and Renewable Energy Centre (NaRec) are not involved in hydrogen activities but may get involved in storage technologies for renewable energy systems. They would look to provide support and funding for research projects.

The Centre for Process Industries (CPI) promotes innovation on process industries by using existing chemical industry infrastructure. They focus on the delivery of hydrogen production, systems and usages not on research. They also have good links with organisations, both public and private, on hydrogen related issues.

- ***Potential markets in the near term, 5 years, 10 years and what are the needs?***

The NHA believe that there will be no commercial systems in the next 5 years but lots of demonstration systems for static and portable applications. These will help the creation of code standards. In 10 years they foresee some commercial portable systems such as fleet applications. For the near term the HSE thought it would be useful to have "standards," as the DTI finds it problematic to give products "CE/ISO" marks because there are no specific standards to compare against. At present any new technologies would be certified against the fundamental regulations of the HSE, but this is fiddly and costly. CAT Cameroon also saw the potential of hydrogen technologies in Africa.

- ***Requirements to stimulate activities***

The NHA said that outside funding is required as is awareness of the safety issues. Public confidence is also required. Policy pushes are needed so that policy makers and decision makers understand the benefits of the technology. Training on installation and maintenance of systems is also required. The HSE stated that demonstration projects are required so that devices can be seen to operate in the real world to facilitate learning and understanding of the issues. For example, how to solve the retro-fitting problems and scalability. It is relatively straight forward to store hydrogen in wide open spaces for example, but how are these devices put into urban areas? CAT Cameroon also agreed with the HSE in that demonstration projects are required especially in Africa in order to help expand the energy base for rural industrialisation and employment generation. NaRec said that improving the efficiencies of fuel cells and systems was required as is a reduction in the cost of producing and using hydrogen.

The CPI said that Government support is essential. They would like the UK government to send clear signals, as is happening in the US where hydrogen activities are occurring and with momentum. It will also be important that the tax free status of hydrogen should remain.

Commercial

- ***Market***

Information on the activities and markets of those commercial organisations interviewed is summarised below.

- H2 Logic ApS — Danish organisation specialising in Systems and market integration of hydrogen and fuel cell technology

- EA Technology — Energy technology Services company. Over the last 12 years have been involved in fuel cell assignments – field trials, analytical services for power utilities, governments etc.

  More recently (last 5 years) have become more aware of hydrogen systems and their hydrogen work has run in parallel with its fuel cell work.

  They also have a strong interest in transport and renewable fields.

- Econnect — Have been involved in the HSAPS (Hydrogen stand alone power systems) market analysis project. The project aimed to establish realistic market development projections for hydrogen and fuel cell technologies in small to medium sized remote power applications.

- Texaco Ovonic Hydrogen Systems — Develop and manufacture hydrogen storage systems for portable, motive, and stationary applications – both fuel cell and internal combustion engine

- Fuel Cell Scotland — Developers of solid oxide Fuel Cell Stacks (fuel to electricity).

- Shetland Composites — Composite manufacturer provides services to the hydrogen/renewables market. They would hope to be a supplier of services to a hydrogen centre.

- SiGen — Design and commission fuel cell systems.

- Unst Inshore Services — Boat builder looking to pursue opportunities with hydrogen transport (boat, car). Also considering hydrogen production as a business opportunity.

- Wavegen — Wave Power generators. Devices include the Limpet Oscillating Water Column (OWC) on Isla, have funding for offshore floating structures and currently developing a near-shore OWC wave device.

- Aquaterra — Not currently active in the hydrogen market but follow it with keen interest. However, they are currently looking to undertake feasibility studies on Orkney to explore how to integrate the technology. This work is dependent upon the DTI's/Carbon Trust decision on whether to fund the projects.

- Proven — Small scale Renewable Energy Systems and Wind

	Engineering	Turbine manufacturer. Have been involved in European research into high speed fly wheels (kinetic energy), but have avoided hydrogen until recently due to the poor input-output efficiency. Has done some research into losses and efficiency in hydrogen storage. Also looked at using waste heat from hydrogen production for hydrogen CHP system.
•	Glenarder Ltd	Consultancy specialising in Training, Education and Workforce development.
•	Wind Hydrogen Ltd	They have teamed with AMEC and intend to make Shetland the 1st hydrogen economy in the world, using IC engines and not Fuel Cells (as they are too expensive just now).
•	Beacon Energy	Beacon Energy are involved in the HARI project along with CREST to produce hydrogen in a 34 kW electrolyser using renewables such as wind, hydro and PV.
•	AMEC	Production and use of Hydrogen.
•	Johnson Matthey	Make components for Fuel Cell systems (catalytic electrode parts and membrane electrode parts)

- ***Potential markets in the near term, 5 years, 10 years and what are the needs?***

There were a number of differing responses of where these organisations saw the potential markets. These views are summarised below.

- Portable use of fuel cells;
- Micro fuel cell CHP on natural gas and hydrogen;
- Hydrogen in transportation sector;
- Renewable energy generation combined with hydrogen systems;
- Telecoms – mobile masts using wind hydrogen storage systems;
- Domestic Heating Applications;
- Near term will be demonstration projects only;
- Near term – hydrogen produced and used to produce power locally;
- Predominantly the chemicals market over the next 10 years;
- Longer term - roles of fuel and electricity are reversed. Electrical energy, whether derived from renewables or nuclear technology will generate the quantities of hydrogen needed by society. Hydrogen electrolysis plants will be sited at railway yards, harbours, airports and motorway forecourts and will operate in harmony with the electricity industry.
- Longer term (~2050) the hydrogen market could have a turnover of about £50bn/year; and
- Longer term – use hydrogen as fuel to overcome the load problem associated with cooking.

Wind Hydrogen also commented that they are ready to roll out their patented wind – hydrogen systems which will ;

- Provide a balancing service to licensed electricity suppliers with an increasing number of wind plant in their generation portfolio.
- Provide a sustainable, clean source of hydrogen fuel for the "zero emissions" transport sector.

- ***Requirements to stimulate activities***

There was a clear consensus that for the near term what is required are demonstration projects. Other requirements to stimulate activities are summarised below.

- Government (local and national) intervention (and support) either in the form of funding programs, incentives for clean energy or mandates for lower emissions/use of alternative energy. Funding programs need to be sustained – not just for one off demonstrations;
- Development of standards;
- Greater perception of demand;
- Technology being right
- Further research activities - make hydrogen conversion more efficient, improvement of operating fuel cells at high temperatures (120 C) for Hydrogen CHP, compressibility and storage of hydrogen in urban areas;
- Cheap source of hydrogen as currently consumption of hydrogen in meaningful volumes is prohibitively expensive – a hydrogen power plant;
- Test centres required across all regions to help test and provide certification for products;
- Public access so that the public can see these devices actually working;
- Industry awareness; and
- Good Academic links as they carry out fundamental research on fundamental science.

A number of respondents also stated that Shetland could be at the forefront of these activities by setting up a number of demonstrations of complete working systems, due to its circumstances – community support, renewable resource, relative ease of integration, islanded network etc. Econnect also stated that the public's perception of hydrogen – its "street cred," needs to be addressed.

Johnson Matthey also stated that the UK government has been proactive in developments with legislation, codes and standards, as have the Carbon Trust. However, the technology is currently very expensive and costs need to be brought down so that they are affordable. This will not happen until there are many units. This is the "Chicken & Egg" scenario. Without any subsidies or support from the government the costs will come down very slowly. Niche applications, such as mobile phone base stations and computer centres are prepared to pay large amounts for reliable systems (premium power systems, uninterruptible systems). Companies charge between 2,000 – 10,000/kW for reliable systems.

Stationary systems need costs to come down to around 500/kW and transport systems need around 50/kW. They also stated that developments in Japan are funded by the Japanese government on a competitive basis, but this could not happen in Europe due to anti-competitive laws.

Study Centre

Academic

- ***Are you aware of the activities that are occurring on Shetland with respect to hydrogen?***

  All of the academic institutions contacted were aware of the activities on Shetland.

- ***Advantages and disadvantages of having a centre on Shetland.***

  - *Advantages:*

    The advantages foreseen by the academic institutions are summarised below.

    - Excellent renewable resource (highest wind resource in Europe);
    - Small scale demonstration projects are more easily set up;
    - Cost of fossil fuels is high on Shetland and therefore there is a need to reduce these costs; and
    - Can build on the current hydrogen projects and infrastructure.

  - *Disadvantages*

    The general consensus was that the only disadvantage of having a study centre on Shetland was its location due to the costs and time taken of travel. The University of the Highlands & Islands also stated that due to its location it would be difficult to build a critical mass and attract the best scientists to relocate. Agder University commented that its location may restrict access to potential investors.

- ***Preferred location.***

  Of those academic institutions interviewed none said that they would prefer an alternate location to that of Shetland, although the University of Glamorgan are hoping to set up a centre within their own vicinity. DeMontford University stated that for social research it would be useful if a centre was located near a local community where hydrogen was being used practically. Ian Bryden of RGU stated that a centre should ideally be located near to Lerwick or Sumburgh airport to cut down on travel time and costs while the University of the Highlands & Islands said it would prefer a centre to be located near one of its academic partners. CREST also commented that if there is technology or another activity on Shetland then a centre should also be based there to build a centre of gravity.

- ***Facilities currently using***

  Of those academic institutions interviewed only the School of Engineering at RGU are using external facilities. They use the laboratory facilities at Edinburgh University for testing marine devices. For the most part, however, tidal is field related. They are also involved with the marine centre on Orkney, where the facilities and staff are excellent although the transportation costs of getting to Orkney are high.

- ***Centre facilities***

There was no clear consensus as to what type of facilities a centre should offer as it was dependent on the universities interests and activities. Although a couple of respondents stated that it would require IT support and internet access. The responses are summarised below.

- DeMontford University would require working systems so that it could facilitate its studies in the social science arena in looking at the effects on the population. For this it would be useful to have interview rooms available.

- RGU (school of engineering) would like to see open instrumental sites where concepts could be tested out – i.e. large building area, with utilities, hydrogen supply, safe environment etc. They would also require technician support.

- RGU (clean technology team), stated that a centre should be involved in all types of hydrogen related activities (production, storage, using hydrogen to generate power, cars) as they are complimentary to one another. Specifically, they would like other renewables such as tidal power used to produce hydrogen for storage

The University of Glamorgan, however, did not believe that a centre could offer anything that they do not have already and would need novel things to be happening in Shetland to get them to go there.

- ***Shetlands Engineering Base***

In answering this question academic institutions were in general agreement that they would both take advantage of the engineering expertise on Shetland as well as using their own expertise.

- ***Centres expertise***

There was no clear consensus as to what extent the academic institutions would use the expertise of the centres staff to operate projects/activities. The responses are summarised below.

- RGU (school of engineering) would use their own expertise, but for longer term projects may use the centres staff.

- RGU (clean technology team), said that the ideal situation would be to have a collaborative link between a centre and the university. This would be an opportunity to promote the centre. Engineers and scientists may spend time on Shetland and at the university. Therefore no real “here” or “there” distinction.

- CREST said that besides their own expertise an electronics base would be useful as would electrochemical, economics, business support and marketing expertise. Providing a centre could offer the required facilities they could see using the centre on a regular basis.

- Providing the centre had something to offer the University of Glamorgan it would be inclined 95% of time to use the centre’s expertise.

- ***Demand for a Centre***

  The general view is that the academic institutions would use a centre providing it had something unique to offer and it tallied up with their own research activities. The use of the centre would then be dependent on their own activities. RGU (clean technology team) also stated that it would be reliant upon the relationship between the University and centre whilst the University of the Highlands & Islands said that ideally a centre would be a permanent research facility with teaching.

Non Academic

- ***Are you aware of the activities that are occurring on Shetland with respect to hydrogen?***

  All of the Non-Academic institutions, with the exception of the HIRC and NaRec, were aware of the activities on Shetland. CAT Cameroon first heard of the activities on Shetland at the Renewables 2004 conference in Bonn.

- ***Advantages and disadvantages of having a centre on Shetland.***

  - *Advantages:*

    The advantages foreseen by the Non-Academic institutions are summarised below.

    - Grid independency;
    - Good renewable resources;
    - Good potential applications for hydrogen – energy storage/CHP/transport etc
    - Ideal place to run prototypes on a small scale;
    - High fuel costs and therefore hydrogen economy makes sense;
    - Good industry base;
    - Isolated test bed;
    - Community is keen to embrace new technologies – local commitment ; and
    - Build on the work currently being done by the PURE project as well as the other hydrogen activities.

    The Scottish Executive also stated that all these factors together provide a strong case for having a study centre on Shetland. The hydrogen economy is also likely to take off first in Shetland compared to other places within the UK (due to isolation from grid, fuel costs etc). By having a hydrogen economy the community would be involved in terms of getting the expertise/using hydrogen related products etc, and so create a good knowledge base.

  - *Disadvantages*

    The general consensus was that the main disadvantage of having a study centre on Shetland was its location due to the costs, time taken and frequency of travel. Although the HSE believed that this was not a large disincentive as long as there was something to see in Shetland it would attract people. The Highlands &

Islands Enterprise also said that this is a common problem with most projects they are involved in and the key is to get people to come and see what is occurring and show them how accessible it is.

The Scottish Executive said that location is not really an issue but it could be a constraint if the centre is competing against other centres in the UK but Shetland has other attributes that favour it. Another disadvantage was that Shetland had no direct links to academic institutions (although there is potential for collaboration with other Scottish Universities). The NHA said that if wishing to showcase the technology it is a long way from the large population areas.

NaRec stated a number of disadvantages such as:

- Limited market in Shetland; and
- Isolated site may not translate well to bigger market;
- Distance to current science and technology research; and
- If company needed to take equipment to Shetland, they would ship it which could be prohibitive.

- ***Preferred location.***

  There was no strong preference of the preferred location for a hydrogen study centre. Although ITI Energy stated that it depends on what technology is being demonstrated. For example, hydrogen for transport would be best demonstrated in a city centre location. Renewable energy for electricity storage would need to be demonstrated where there is a demand/load. The HSE also said that what is on offer is the key. NaRec stated that it would need to be sited where there was infrastructure and support. The CPI did say, however, that the North East of England would be an ideal location for such a centre.

- ***Facilities currently using***

  The HSE have specialist laboratories that are used to test products if they are found faulty or dangerous. In the first instance, however, it is the responsibility of the manufacturer to prove that their product is safe. The HIRC uses Universities and research centres in Denmark.

- ***Centre facilities & Expertise***

  There was no clear consensus as to what type of facilities or expertise a centre should offer. A summary of the responses are provided below.

  - ITI Energy stated that a better aim for Shetland would be to make use of their renewable resources and demonstrating how this would tie in with hydrogen, rather than looking at certification/accreditation opportunities say, as this type of work would need critical mass to be successful and there are already companies active in this area with a track record.

  - The HSE has an established expertise and knows as much as anyone in this field. However, they would look to learn from the leaders in the field. What would be most beneficial to the HSE would be seeing real projects and the associated problems in order to develop a better understanding.

- The HIRC said that laboratory scale solutions are in the past and what is important now is to see the technology at commercial scale. They would also look to use their own staff for the operation of projects but also said that besides their own expertise they would see expanding contacts and coordination of activities beneficial to their own activities.

- CAT Cameroon said that it would like a centre to provide training and accreditation and have production, storage and use of hydrogen expertise available. They would also want their own expertise to run and operate the activity but with training and collaboration with a centre on Shetland and would look to use the engineering base outside of the centre.

- The NHA said that it would like a centre to offer expertise to other centres or facilities.

- NaRec said that it would use both the expertise on Shetland and its own and it would particularly welcome electrical, chemists, physicists and engineering support.

- The CPI said that there would be a natural interaction with Shetland especially in knowledge transfer and expertise. It would like to see further research in efficient storage capability (low pressure and small scale), efficient electrolysis and practical applications.

▪ ***Demand for a Centre***

ITI energy stated that there is a demand for demonstration projects rather than a study centre and the HSE said that if Shetland is able to deal with real life hydrogen applications and look at the problems associated with these then it would be a big attraction. CAT Cameroon said that they would have continuous collaboration with the centre as this shall be necessary for the exchange of information and experience as did HIRC who said that they would like to cooperate with a centre as they are the Danish counterpart.

Commercial

▪ ***Are you aware of the activities that are occurring on Shetland with respect to hydrogen?***

All of the Commercial institutions, except for Texaco Ovonic Hydrogen Systems, were aware of the activities on Shetland.

▪ ***Advantages and disadvantages of having a centre on Shetland.***

- *Advantages:*

    - Renewables Resource (especially wind and ocean);

- Islanded grid network;
- Established expertise;
- Has space for projects, especially storage;
- High Fuel prices - the technology would be acceptable sooner due to higher costs of present infrastructure;
- Good engineering support in Shetl; and
- Good links to Scandinavia;
- Positive community attitude to renewable developments;
- Good for small scale "real world" trials;
- Able to demonstrate hydrogen systems in remote "island" communities;
- Systems can filter out in the community faster than in other locations due to low population/housing density – i.e. less issues with hydrogen storage;
- Able to address problems with technologies/systems etc from a rural perspective (in more extreme conditions) as being more isolated will prove the robustness of the technology and also make it easier to change and adapt the systems. Essentially it will be like a life sized laboratory;
- Takes the organisations using a centre out of their everyday environment - especially due to Shetlands location. This will allow organisations to concentrate more on the activity in question – not distracted by other things;
- Adds strengths to network of organisations in the region. A centre can draw on the strengths of others in the region and others can draw on the strength of a centre ; and
- Would have greater profile in Shetland as may get "lost" in places like Glasgow.

- *Disadvantages*

  - Remote location/accessibility;
  - Cost/time of travel;
  - Distance from corridors of power (i.e. where the funding is coming from and other research activities);
  - Limited market if not globally expanded;
  - Difficult to attract permanent expertise;
  - Having concentration of expertise on small number of people;
  - Not enough knowledge in the region ; and
  - Environment - Shetland is a good place to be in the summer, but in winter months the weather can be harsh and there are only a few daylight hours.

Fuel Cell Scotland stated that there are no advantages of having a centre on Shetland as it is too far away from the main energy consumption areas. Aquaterra said that the advantages outweigh the disadvantages, and especially in working in small communities where there is local support and able to integrate the technologies more easily.

- ***Preferred location.***

There was no general consensus to a preferred location for a study centre. Two organisations preferred a location other than Shetland with H2 logic of Denmark saying that it should be centrally placed in Europe in a region with great hydrogen potential such as the Western part of Denmark and Fuel Cell Scotland said it should be near the large consumption areas and in Scotland this would be the central belt.

The other respondent's views are summarised below

- Shetland Composites said that a centre should not be contained at just one location but multiple locations on Shetland – For example, Unst for demonstration projects, Yell for storage (in conjunction with Sullom Voe), and also Lerwick during the winter months because as well as being the location of the port it will provide year round entertainment for visiting engineers/students.

- Wavegen would like facilities close to a wave resource (preferable Atlantic waves)

- EA technology said that Unst would be preferable as it has the experience but as long as there was not a significant increase in travel time, than going to Lerwick.

- SiGen said that if a centre goes ahead then the outer isles and western periphery are more ready and able, then the main conurbations.

Econnect said that it would be sensible for Shetland to tie in with one of the other major centres such as the NaRec or possibly a centre in Aberdeen. Shetland could then be an offshoot from one of these centres. Aquaterra said that location is not the issue. It is the people (expertise) that is behind the venture that is important. This expertise and drive will determine the success of the centre

▪ ***Facilities currently using***

Four of the organisations interviewed use facilities which are described below. Fuel cell Scotland does not use any facilities but buys hydrogen in cylinders.

- H2 logic – Will be looking to use the HIRC (Hydrogen Innovation and Research Centre) in Denmark. They would use the facilities as a network source in many projects and would be in weekly contact with them.

- EA Technology have there own small scale test beds for Fuel Cell work. They tend to do work at customers premises as this is what the customers prefer.

- SiGen use their own test facilities.

- Johnson Matthey have their own facilities in the US, UK and Japan.

▪ ***Centre facilities***

There was no general consensus of what facilities those organisations interviewed would require from a study centre. Below provides a list of facilities that were discussed.

- Expertise in the conversion of energy to hydrogen;
- Independent testing and certification capability;
- Facilities to test any products – in the longer term the ability to test combustion products (i.e. cookers) as well as Fuel Cells;
- Test Centre for larger fuel cells and electronics;
- Direct thermo electrolyser for sewerage and biomass;

- Safety management infrastructure i.e. laboratory set up with hydrogen detections systems, flame proof lighting etc. The costs of this though often outweigh the costs of the trial;
- Practical orientated facilities – a place where they can access information and bounce ideas off them to develop products;
- Lobby work;
- Scientific, standards, safety and funding knowledge;
- Conference centre and technology centre/museum so that it becomes a focus for both business people and the public;
- Familiarisation with production cycle – how it works, demonstration, hands on experience ; and
- People (expertise) involved in whole process – track record of experience, able to share expertise.

Shetland Composites also raised an issue of where is a small research centre going to fit in compared to the multi billion dollar investments currently being made in hydrogen with fuel cells, transport etc. They could see a centre working for HSE issues, but not for pure research.

- ***Shetlands Engineering Base***

In answering this question most of the commercial institutions were in general agreement that they would both take advantage of the engineering expertise on Shetland as well as using their own expertise. Proven Energy would use their own expertise as they have years of experience and feel confident in their own vision. Wind Hydrogen said that they are hoping to set up a large complex on Shetland with storage tanks, genset bands, offices etc. There would be 24hr operation of the complex as they would be looking to balance the system and they would look to have an association with the centre perhaps using the centre's engineers and expertise on their own problems.

- ***Centres expertise***

In general organisations would look to use the centres expertise for the running and operation of projects. Initially the organisations would use their own engineers to set up the project and depending on the duration of the projects would use the centres staff. Wavegen also stated that it would provide its own expertise for the design, construction and installation of wave generators but would want expertise from the centre on the electrolysis side of things and the integration of power generation to hydrogen production. Unst Inshore Services said that they would use their own engineers for the production of general equipment, but would develop specific equipment in tandem with the centre. They would also require expertise on fuel cell systems and hydrogen producing equipment.

H2 logic would also like access to professional sub-suppliers, delivering cheap, safe and powerful components, e.g. fuel cells, hydrogen storage. Fuel Cell Scotland said that it would require the expertise of an Electro-chemical engineer. Beacon Energy said that it would like metal hydride storage and cascade metal hydride compressor facilities.

- ***Demand for a Centre***

Econnect said that the problem is accessibility with having a centre on Shetland but if it was to tie in with another centre on the UK mainland and work in collaboration then there would benefits for both parties. They also have a R&D arm and one of the areas is load controllers specifically for renewable technologies. They could see an advantage of working with Shetland on a demonstration project where the load controllers could be used to put the surplus electricity through electrolysis to produce hydrogen.

Aquaterra are completely behind a centre and would look to collaborate in research projects and programmes, including demonstration projects. They would also propose a joint approach in attracting industrial partners (the likes of BP/Shell etc). Aquaterra's links could be used to compliment the links of the Unst Partnership.

Proven Energy said that if the centre was co-operative then they would think about using it. They also said that hydrogen has a battle to show that it is useful as in storage for example, and so would need to see some positive moves forward before they would use such a centre.

SiGen intend to have strong links with the centre and would look to use a centre on a continual basis over the next 4-5 years for development purposes. Johnson Matthey would not use the centre directly but would be interested in being involved through collaboration with system integrators. Their components could be used in the Fuel Cells being tested.

Financing the Centre

Academic

For funding the University of Glamorgan use contacts within business, objective 1 EU Funding, research councils and industrial sponsorship. RGU (clean technology team) also suggested that funding be sought from bodies such as the DTI and Scottish Enterprise and then build on this to become self-sufficient.

Non Academic

The Scottish Executive would be keen to be involved in the hydrogen sector and in conjunction with a number of other public bodies, such as the DTI/Shetland council etc, would consider providing grants for the establishment of such a centre. The Scottish Executive would also look to use its powers to promote and disseminate information on the centre both nationally and internationally. They would use Ministers and other contacts to promote the activities. The NHA would also look to support a centre by increasing its visibility and enhancing capabilities by bringing in outside expertise and would consider becoming a partner in a centre..

The Highlands & Islands Enterprise supports projects financially by providing funding for start up costs. Each scheme is judged on its own merits and the idea of a hydrogen energy study centre seems to fit in well with its current policy of supporting renewables in the Highlands & Islands. As well as financial assistance they could help to establish links with other key centres. For example, they have helped with the setup of the Marine Energy Test Centre in Orkney and are also working alongside to promote it.

ITI Energy would look to fund specific projects (rather than a centre as a whole). They have a budget of £15 million, which is guaranteed for 10 years and funding would be on a project by project basis. ITI fund development to control IP and must show an advantage to the Scottish economy. They are interested in the technology underpinning projects.

CAT Cameroon would look to collaborate and work with the centre to demonstrate the viability of hydrogen in their own region through their grassroots network. They would also look to receive training from a centre in Shetland on Renewable Hydrogen Systems and look to integrate this knowledge into their own society.

Commercial

- ***Financial Collaboration***

  The majority of respondents would consider setting up a centre in collaboration with a number of other bodies, although Unst Inshore Services would wait until the centre is up and running to see what the benefits would be before committing. EA Technology said that they do not have sufficient resources for projects of this sort. Proven Energy and Johnson Matthey would not consider financial collaboration. Johnson Matthey said that it would be difficult for them to justify financing the centre themselves as they have their own facilities and there would be duplication of work.

- ***Involvement in Centre***

The majority of respondents said that they would buy services from a centre on an "as and when" required basis. Fuel Cell Scotland said that they would have to gauge on a competitive basis and see what is in it for them before determining the best way to get involved in a centre. SiGen said that it was impossible to say just now on how it would look to get involved in a centre but would perhaps offer to run the centre, and would more than likely be prepared to invest in the centre and be involved in skills transfer to the local engineers.

Shetland Composites stated that to make the centre a success external funding sources are required. Set up costs etc could be funded within Shetland/UK but an external means is required for the longevity of a study centre. Wind Hydrogen said that they would hope to be actively involved provided they can fund it from the commercial side of their business.

AMEC would be interested in becoming a partner in a centre and would look for collaboration where the centre could provide them with small scale test and demonstrations and AMEC would offer access to larger scale facilities for bigger devices.

Education

Academic

- ***Facilitating Students***

  There was a general agreement, with the exception of the University of Glamorgan and CREST who already facilitates PhD students in this area, that those Universities interviewed would look to use a centre for facilitating its students. The University of the Highlands & Islands said that this would be the major reason for them to use a centre. RGU (school of engineering) were positive and said that this is something that is currently being looked at with the marine test centre on Orkney, although the demand for taught courses is still a long way off. CREST did, however, say that it may be more appropriate for MSc students to use the facilities as there projects usually last for about 3-4 months.

- ***Using the Centres facilities***

  The University of the Highlands & Islands would use the centre, but also foresee collaborations with other universities. In using a centre they would look to seek financial support and would expect top grade facilities and people with the appropriate knowledge and expertise. RGU (clean technology team) is trying to establish its own facilities in research but if there is collaboration then both parties would have access to the universities research facilities and library. RGU (school of engineering) said it would depend on the individual research and what the centre was offering.

  DeMontford University said that a centre would need to offer some unique application/research into practical hydrogen storage and use from renewables along with facilities to conduct interviews. The University of Glamorgan said that a centre would need to offer novel aspects of hydrogen use/production as a few universities already have expertise in this area. This was also the feeling at CREST where a centre would have to offer something that they could not do. Agder University said that the promotion of fuel cells would entice them to use a centre on Shetland.

Non Academic

The HSE is involved in research projects (mainly EU funded through the 6th framework). It collaborates with a number of institutions and would consider collaborating with a centre on Shetland.

One of the major problems that is going to occur in the industry is a lack of skilled workers able to install and trouble shoot hydrogen installations. When a mass "hydrogen" market is developed there will be a need to retrain for a variety of different skills and consequently there will be a major shortage of workers and trainers. A study centre could therefore offer training packages (of which the HSE would be interested).

The HIRC would be interested in the exchange of teaching and research and depending on the facilities that are offered would use a centre. Although they did sight low cost renewable energy as being a good incentive.

CAT Cameroon currently network with Universities and Schools in Cameroon and these would very much welcome such cooperation with a centre on Shetland. In such as partnership programme, the universities, schools and CAT Cameroon would use the Centre's facilities, since the centre would be the mother institution to such training programme in Cameroon. Renewable Energy training is a major need in Cameroon and in the sub region. The Shetland project on renewable hydrogen system is very appropriate for Cameroon and the sub region. Initial collaborations with Shetland project would ensure a lasting partnership and Shetland will surely have to supervise the development of this programme by sending experts to Cameroon and visiting professors to the Universities.

Commercial

- ***Facilitating Students/employees***

  H2 Logic has a number of projects that could be useful to have PhD students involved in. Therefore, if a centre were to collaborate with a University there could be some form of collaboration between parties. If the centre is leading on an area then it would entice them to use the centre.

  Glenarder said that for a university to use the centre it would have to be something cost effective and something that is not or cannot be offered on campus.

  Aquaterra said that on Orkney there are a number of MSc and PHd students researching/studying Renewable and Environmental issues. They therefore could see a collaboration whereby students go to Shetland to undertake a Module/study/research in hydrogen related issues. Currently they receive students from Heriot Watt University but are also looking to set up links with RGU, Aberdeen and Edinburgh Universities.

  Johnson Matthey sponsor PhD and Masters students. They may be interested in using the centre to provide education to the students in H2 related matters or perhaps using the centre if they have a particular research area.

Final Question

Academic

Respondent	Feasible?	Comments
University of the Highlands & Islands	**Yes**	**Will need to be as attractive to commercial research as possible. Accessibility issues also need to be overcome.** **Could be a field studies centre where research students undertake experimentation and then return to write up results etc at their university.**
University of Glamorgan	**Yes**	**More feasible for universities in Scotland and the North of England than elsewhere in the UK to use such a centre due to distances.**
RGU (clean technology team)	**Yes**	
DeMontford University	**Unsure**	**Contingent on Shetland having a unique hydrogen installation on offer as in Iceland.**
RGU (school of engineering)	**Yes**	**As long as it is part of a network. It should not try and become the centre where all hydrogen activities are to take place as this won't work. For example, in Scotland, St Andrews University is where most of the hydrogen research is being undertaken and will continue to be so. Shetland could provide a "field facility" as part of a wider network. It is important that any faculties developed on Shetland are not duplicating facilities elsewhere .**
Centre for Renewable Energy Systems Technology (CREST)	**Yes**	**However, the size of the centre would be critical in terms of how many customers it can serve. He suggests that it should start small and have a strategy to allow it to grow and for growth to happen organically.**
Agder University, Denmark	**Yes**	

Non Academic

Respondent	Feasible?	Comments
Scottish Executive	**Yes**	**The executive is positive and would be keen to promote a new initiative such as this. Having demonstration projects would boost the interest in the centre**
ITI Energy	**Yes**	**Providing it is pitched in the correct way. People have to be convinced that there is a definite reason to go to Shetland – the "uniqueness."**
Highlands & Islands Enterprise	**Yes**	
Health & Safety Executive	**Yes**	**However, before setting up a centre it needs to have something to offer/demonstrate. It will therefore be important for Shetland to have a number of activities in operating and demonstrating differing technologies – a hydrogen economy would be ideal. There needs to be something unique to see, where this experience cannot be gained anywhere else so that people will travel to Shetland. It would make sense then to follow with a study centre**
Hydrogen Innovation Research Centre (HIRC)	**Yes**	
CAT Cameroon	**Yes**	**It is very realistic and feasible.**
US National Hydrogen Association	**Yes**	**Shetland has the drive to succeed and is not limited by red tape such as in the US and has the opportunity to try things out,**
New and Renewable Energy Centre (NaRec)	**Unsure**	**Less than 50% of succeeding. There are a number of barriers that need to be overcome to make it attractive. This does not mean that it is not possible but it needs to do it right.**
Centre for Process Industries	**Yes**	**It needs to be focussed and specific.**

Commercial

Respondent	Feasible?	Comments
H2 Logic	**Yes**	**Because of the special energy conditions in the region. But I think the region itself will have to pay for the establishment of the centre. This will make it possible for the centre to build up a knowledge that afterwards can be sold outside the region, securing the continuation of the centre.**
EA Technology	**Unsure**	**SREF should be quite sure of their market for services and whether people would be willing to travel to Shetland to use the Centre, given that time costs are often greater than the raw travel costs.**
Econnect	**Yes**	**Can see a centre working, providing it has synergies with other centres on the UK mainland. There would need to be a number of activities on Shetland to support a centre.**
Texaco Ovonic Hydrogen Systems	**Yes**	
Fuel Cell Scotland	**No**	
Proven Energy	**Unsure**	**Initially thought against being in Shetland but as an afterthought felt that it may be possible to get on with the work in Shetland without too much interference from committees and meetings.**
Shetland Composites	**Unsure**	**If it can find a niche market then YES if it cant then NO**
SiGen	**Yes**	
Unst Inshore Services	**Yes**	
Wavegen	**Yes**	**Definitely, very impressed with SREF.**
Aquaterra	**Unsure**	**There is definitely scope for such a centre but need to get their market right, whether they have to create their own or not. The key will be the right people (expertise) behind a centre.**
Glenarder Ltd	**Unsure**	**Need to ensure that they are not over ambitious and try to do everything related to hydrogen – should have some specialisation and be able to offer what business/ universities want**
Wind Hydrogen Ltd	**Yes**	**There is the potential for the hydrogen economy to take over from the Hydrocarbon activities on Shetland. Expertise will be required for refuelling vehicles and in the maintenance of the pumps and tanks. If the centre was to be a Research Lab with a tourist attraction, then the closer to commercial activity the better.**
Beacon Energy	**Yes**	**Shetland could be one of only a few hydrogen operating units in the UK besides themselves.**
AMEC	**Yes**	
Johnson Matthey	**Yes**	

Other Information Provided

Academic

- ***University of Glamorgan***

  There is the possibility of having three such centres working in collaboration that are connected to share information that are close to the marketplace. Shetland would have to offer a novel concept/facilities/operations – different from the standard work that is already being done – for it to work and to get people to go there.

- ***Centre for Renewable Energy Systems Technology (CREST)***

  The Tees Valley imitative was mentioned where they are developing a centre alongside two projects. Hydrogen infrastructure on an industrial scale already exists in the Tees Valley. There are thoughts of having a centre where young companies can develop new products using the existing infrastructure and hydrogen friendly environment. He feels that there is room to have a number of centres in the UK and such a centre on Shetland could serve the Scottish market.

Non Academic

- ***Fuel Cell Scotland***

  Scotland has the resources to be a massive exporter of clean energy with renewable resources of around 60GW and a demand of around 4GW. What is required is to look on a macro level and Scotland has a place to play. However, it needs to be supported by government and the big utilities. If Scotland is to become a leader in hydrogen then at least 20 "Unsts" are required and activity in areas of high population density is a must.

- ***CAT Cameroon***

  Cameroon is a developing country with its economy dependent mostly on natural resources and the introduction of renewable energy technologies is gaining grounds in the country as Government is developing favourable policies for renewables. It's therefore very necessary to demonstrate a wide variety of renewable energy options including renewable hydrogen systems, so as to create higher awareness, acceptance and the choosing of appropriate solutions.

- ***US National Hydrogen Association***

  From their visits to other facilities many people have voiced an interest in seeing H2 from wind. Here Shetland has a leadership opportunity. Also if the SREF produce a newsletter they would like to receive it. They produce newsletters and would be keen to raise awareness of the Shetland project by passing on the newsletter.

- ***Centre for Process Industries (CPI)***

  Believes that there is potential for collaboration on a number of fronts. They are interested in the European Lighthouse Project (€2.8 billion) and with this they need European linkages and so could consider a link to what happens in Shetland.

Commercial

- ***Econnect***

  Very impressed with the attitude of Shetlanders in embracing Renewable technologies. This should be emphasised in any venture as it will give comfort to those people who would go to Shetland to test products/use facilities etc. Econnect would be happy to be associated with such a venture to promote renewable technologies.

- ***Proven Energy***

  A centre would need to listen and be co-operative. They have had problems with organisations not listening and so ended activities with them. This has resulted in them going to Italy for certain products. Their view was that if you get people who listen and are willing to co-operate that distance issues may become secondary.

- ***Sigen***

  Once the public is aware of the technologies then demonstration projects will be scaled up. This needs to be part of a National Strategy. There needs to be local, regional and national government support for the centres. Currently USA, Canada, Japan and China are much further forward with respect to investment. Also regional development agencies in E&W are funding hydrogen studies, but not in Scotland.

- ***Wavegen***

  Wavegen are definitely interested in a Hydrogen Energy Centre on Shetland as it could be used as a test site for Wave-Hydrogen demonstration project

- ***AMEC***

  For the hydrogen economy to evolve there needs to be policy interaction between the DTI and the SE. They need to work together to express what the UK wants in terms of the hydrogen economy. There needs to be a coherent approach between the DTI and the Treasury.

- ***Johnson Matthey***

  It is important for Shetland to tap in to European wide activities and funding. Also important to keep informed about other islands aiming to do the same things as themselves. Johnson Matthey are involved in lobbying on hydrogen and Fuel

Cell activities in the UK on the commercial side with government and car manufacturers. They may be interested in lobbying for support of the Shetland centre if asked.

ANNEX F – HEI LINKAGES ON SHETLAND

The North Atlantic Fisheries College (NAFC) and Shetland College are well networked with public and private sector stakeholders in the renewable energy sector. In particular, NAFC can offer courses and skills in:

- Engineering practice (HNC)
- Mechanical, Electrical and Production Engineering (modern apprenticeships and SVQ Level 3)
- Workshop Skills training

NAFC also has accommodation, catering, library and social facilities in Scalloway. Complementary to the NAFC's capabilities are those of Shetland College on its Germista campus just outside Lerwick. Shetland College has a course unit on renewable energy and is planning to launch a HNC on Renewable Energy Management after agreement by the EU.

Both NAFC and Shetland College are part of the University of Highlands and Islands (UHI) Millennium Institute. UHI includes renewable energy and power generation on a number of courses including the following;

- BSc Mechanical Engineering (North Highland College; Inverness College)
- MSc, diploma and certificate courses in Managing Sustainable Development (Lewis Castle College)
- BSc (Hons) Natural Science(Inverness College, Moray College, Orkney College, SAMs)
- BSc (Hons) in Sustainable Development and Environmental Management (Orkney College)
- BSc Rural Development Studies (Argyll College, Lews Castle College, Lochaber College, Moray College and selected Learning Centres

The capabilities of NAFC and Shetland College together with their UHI network linkages and the linkages that the PURE project has developed with other HEIs and research centres – Robert Gordon University, the University of St. Andrews, Loughborough University and others[29] provides a solid base for the development of training and technology training modules at a proposed centre. Shetland College has q 34Mb broadband connection via a microwave link and ISDN connections with its learning centres, including the one at Unst. This would allow for teleconferencing.

A feasibility study carried out for Shetland College with respect to the establishment of small scale renewable energy training facility identified a number of factors which indicate private sector interest in renewable energy in Shetland. These include:

[29] There are a number of Scottish, UK and European universities working on renewable and hydrogen energy and fuel cell technology. They include Aberdeen, Abertay, Dundee, Glasgow, Heriot Watt and Strathclyde universities in Scotland as well as the University of Glamorgan in Wales and Birmingham. Loughborough and Nottingham universities in England.

- Strong interest from 26 employers with 126 employees and 36 individuals
- A strong demand for accredited installers courses in the different renewable energy technologies

ANNEX G – PLANNING AND THE ENERGY SECTOR

On the planning side, the policy recommendations for energy are contained in Chapter 7 of the Shetland Structure Plan (2000) which is currently being updated. The Topic Goal under Chapter 7 is 'to promote the sustainable and efficient use of energy resources to maximise social, environmental and economic benefit within Shetland.' The Structure Plan recognises that reliance on oil and waste gas to the extent of 93% of energy production is not sustainable. Policy SP ENG3 states that 'proposals for the generation of power from *renewable energy resources will be encouraged* subject to other relevant policies in the structure plans'.

The Shetland Energy Unit published the Shetland Energy Plan in 1998 which aimed at a more strategic and coordinated approach to energy management in Shetland. The aim of the Plan was to reduce dependence on hydrocarbon fuels and maximise the use of local resources, including renewable technologies. Policy SP ENG 4 states that '*energy related developments that take into account the objectives and strategies set out in the Shetland Energy Plan and comply with environmental and other provisions of the Structure and Local Plan will be considered favourably.*' The Structure Plan includes amongst its Plan Performance Indicators the number of applications for renewable energy projects approved/refused over the plan period.

ANNEX H - BACKGROUND INFORMATION ON THE ECONOMY OF SHETLAND

This annex provides background information on the economy of Shetland, including the overall economy, economic development initiatives and planning issues. It also provides the position of renewable energy in the context of Scotland and Shetland.

Context

The total population of Shetland was 21,988 in 2001 and census figures over the period 1931 – 2001 show some variation in population which is linked to net migration, itself influenced by levels of investment on the islands (Shetland in Statistics: 2003). The economic state of the oil sector and the Sullom Voe Terminal is an important influence on the resident population. Total employment expressed in full time equivalent jobs was estimated at 12,248 in 2003 (Economic Development Unit, Shetland Island Council). Employment levels vary and are linked to the state of the oil sector, fisheries and service personnel in particular. The rate of unemployment in 2002 was 1.8% which is low relative to Scotland and the rest of the UK. Unemployment figures are kept down by out migration in search of work.

One key factor for the current and future economic development of Shetland is its dependence on imported energy supplies in various forms – oil, petrol, diesel and bottled gas. Shetland 2012 sets out the economic development strategy for Shetland (Shetland Local Economic Forum: 2003). This document presents the main economic sectors and identifies the key issues which are likely to affect that sector up to 2012. Based on our analysis of Shetland, there area a number of strengths and opportunities which are identified with respect to the development of renewable energy and community development, such as:

- A rich and clean natural environment
- A strong community spirit
- The opportunity to develop renewable energy
- Scope for developing industry/education partnerships and skills development.

Employment and Energy

The Shetlands economy is built on two main pillars – the oil sector and fisheries. More than 52% of the workforce is directly dependent on these two sectors, which suggests that an even higher proportion of the population is dependent on these sectors. With respect to the oil sector, most of which are related to the operations of the Sullom Voe Oil Terminal, 19% of private sector jobs are directly related to the oil sector, with the highest dependency being in the manufacturing sector (30% of jobs), followed by the services sector (23%), the construction sector (15%) and the primary sector (2%) (Shetlands Islands Council Employers Survey: 2003). The total number of jobs dependent on the oil sector is 2,200. In addition the council receives revenues as a result of the Sullom Voe operations.

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However Shetland is a net importer of energy[30], the oil transhipped at Sullom Voe goes to refineries elsewhere in the UK. Many other activities in the manufacturing, services, transport are based on imported diesel which is the main supplier of electricity to the islands from the Lerwick power station[31]. Other sources of fuels – petrol, diesel and fuel oils for transport, heating and manufacturing are all imported. There is a limited production of heat from waste at an incinerator plant in Lerwick which goes into a district heating scheme and some electricity is generated from gas turbine plant at Sullom Voe. It is fair to say that many other economic activities in manufacturing, fishing, the oil sector, transport, commerce and services are dependent on the importation of relatively expensive imported hydrocarbon energy.

This means that employment across the islands is also linked in part to imported energy and the impact which energy prices have on the costs of production. There are in the islands a number of major consumers of electricity, these include fish processing companies such as Shetland Catch and other companies in Lerwick, ice making factories and defence facilities such as the RAF radar facility on Unst. Direct and indirect employment in the renewable energy sector is limited – to wind farms, wave and tidal energy initiatives, education and training and the PURE project at Hagdale on Unst. These produce for off grid requirements.

Planning

The Structure Plan for Shetland considers that sustainable development is a main aim of Shetlands Islands Council and goes on to state that sustainable development is at the heart of the Structure Plan. The Plan emphasises partnership between communities, the Council and the private sector. The Sustainable Vision for 2016 (Chapter 2 of the Structure Plan – General Development Strategy) states that by 2016, '*the consumption of resources has been dramatically reduced with the development of waste minimisation and the recycling of all our recyclable waste, where practicable. Renewable energy projects are commonplace.*'

Economic Development – Key Players

At the regional level, economic and social development is coordinated by the Highlands and Islands Enterprise (HIE) which has a network of economic development and enterprise agencies across the region, including the Shetland Enterprise. The development of renewable energy is a priority for HIE and in 2002, the HIE established a community energy unit (CEU) as part of the Scottish Executive's Scottish Community and Household Renewables Initiative (SCHRI). This unit has supported the development of the hydrogen fuel project in Unst.

On Shetland, the Economic Development department of the Shetland Isles Council and the Shetland Enterprise are the key players in the public sector. Shetland Isles Council

[30] One estimate by SM Energy is that Shetland uses the equivalent of £30.5 million of energy per year, of which electricity sales account for £19.3 million. Most on grid electricity generation on Shetland is generated by the Lerwick power station which is oil based.
[31] This is distributed around the Shetland Islands by a 33KV main grid and a secondary 11KV network by Scottish and Southern Energy.

has a strong commitment to the development of renewable energy in Shetland as shown in the Vision for the Economic Development of Shetland to 2015.

Shetland Enterprise which is part of the HIE network has supported several companies and community organisations that have become involved in renewable energy. These include the PURE project on Unst and Shetland Composites which has a number of projects including solar powered navigation lights.

In addition, Shetland Enterprise[32] has been supporting the Unst Partnership with the creation of a renewable skills unit and delivering a schools renewable energy project. Shetland Enterprise also supports the transfer of skills from traditional sectors in the Shetland Islands – the oil, fishing and marine technology sectors to the renewable energy sector through the appointment of a manager to design a range of courses for local companies to benefit from the development of the renewables sector.

Other associations with a keen interest in the promotion of renewable energy include the Shetland Renewable Energy Forum, the Unst Partnership, Community Councils and importantly a number of private sector companies and specialists, some of whom are represented on the Shetland Renewable Energy Forum.

Renewable Energy in the Context of Scotland

Scotland has set ambitious targets for energy production from renewable sources. It has natural conditions, wind, wave and tidal power resources which favour the development of renewable energy. The aim is for 40% energy requirements of the country to be met by renewable energy by 2020. There is a considerable degree of commitment to the development of renewable energy in Scotland supported by the Scottish Executive, Scottish Enterprise, Highlands and Islands Enterprise, Scottish Renewables, Forum for Renewable Energy Developments in Scotland (FREDS), the power sector, university and other research centres, the private sector, community groups and NGOs.

Scotland already produces a substantial proportion of its electricity needs from renewable resources, notably hydro – electric power (12% of total electricity). The Scottish Executive estimates that 1,940 jobs are sustained by the renewable energy sector in Scotland and that 10 FTE jobs may be created for each additional Megawatt of renewable energy produced. Taking into account indirect and induced employment creation through expenditure by individuals in the sector (induced multiplier) and supply chain impacts (indirect multiplier), current and potential job creation linked to the renewable energy sector will be even higher.

The development of the renewable energy in Scotland has the potential to reduce economic dependence on imported fossil fuels as well as contributing to the reduction of global warming and atmospheric pollution from CO2, CO, particulate and NOx emissions. The latter will bring economic benefits through improved mortality and morbidity, health and treatment costs.

[32] Highlands & Islands Enterprise (2004). *Thirteenth network report 2003-2004*.

Renewable Energy in the Context of Scotland

Economic development and planning guidelines for Shetland emphasis the need to develop renewable energy as a way of reducing dependence on hydrocarbon fuels and as a logical step in the exploitation of the islands primary renewable energy resources – wind, wave and tidal energy. If the target of 50% of Shetland energy is to come from renewable resources for electricity generation alone, (on the basis of current maximum demand 49.0 megawatts according to Scottish and Southern Energy) then this will mean the production of around 25 megawatts from renewable sources. In addition if all the energy consumption on Shetland is included, then additional energy production will be necessary for transport (hydrogen energy for cars, fishing vessels, public transport), replacement of other sources of energy, including bottled gas (propane). These are clearly ambitious targets and they will need to take into account:

- Energy pricing for electricity and hydrogen generated by wind power
- Energy demand projection
- The existing infrastructure for energy production and distribution in Shetland, including the Lerwick power station, petrol stations, bottled gas distribution, oil distribution networks.

The arguments for the development of renewable energy in Scotland apply to Shetland, with Shetland being even favoured by renewable energy sources than the Scottish mainland and the remainder of the United Kingdom. Indeed, Shetland's renewable energy resources compare favourably with many other parts of the Europe and the World.

A renewable resource assessment study for Orkney and Shetland provides estimates of the potential renewable energy resources for Shetland (Aquaterra et al: 2004). Using the category of 'an acceptable energy development strategy' with 80% likelihood, taking into planning and other constraints (land ownership, MoD interests and wildlife value), the study estimates the Shetland has a potential for 2,000 GWh annually (allowing for the replacement of current energy use of 1,100 GWh, of which the majority would be produced from offshore wave power. Onshore energy generation potential would be provided by onshore wind power (70 GWh), micro renewables[33] and energy from waste. These estimates are made for the period to 2020.

The Economic Impacts of Hydrogen and Renewable Energy

The economic impacts of renewable energy and hydrogen are likely to become increasingly important in the future in Scotland, the rest of the UK, Europe and internationally. A reduction in the demand for hydrocarbon based energy sources (coal, natural gas, oil and its derivatives) will have, depending on supply conditions impacts on oil and gas market prices. This in turn will have impacts on oil and gas exporting states which in some cases are already seeking to diversify their economic base.

[33] These include hydrogen power and bio - diesel. The Aquatera report suggests that between 10% and 15% of energy needs could be produced from micro – renewables.

The development of renewable and hydrogen energy will depend on a number of factors – the cost of the technology, energy pricing, regulation and of course demand. The development of the Renewable/Hydrogen sector will have a number of impacts:

- The development of new businesses based on the development of such technology
- Supply chain linkages for companies which provide goods and services to these businesses
- Increased employment in the Renewable/hydrogen energy and linked sectors of the economy
- Savings in import costs for hydrocarbon and non renewable sources of energy.
- Improvements in ambient air quality with the replacement of hydrocarbon based energy. This will have impacts on mortality and morbidity, notably from respiratory diseases, heart disease and cancers which are related to atmospheric pollution caused by hydrocarbon based pollutants – particulates, CO, CO_2 and NOx.
- A contribution in the long term that renewable energy and hydrogen energy might make to global warming and the projected negative economic impacts of global warming – flood and other catastrophic events, disease, desertification.

In the longer term as the supply of hydrocarbon energy decreases relatively to demand, prices will rise and this may well have a negative impact of the economic growth of individual states as well as on world economic growth. Rising energy costs will have knock on effects of the costs of production, the profitability of companies and employment. The development of renewable energy, including hydrogen will therefore potentially have positive impacts for global energy security and economic growth. One would also expect that the negative impacts of the volatility of oil and gas prices on economic growth and social development would be alleviated.

ANNEX I – DATA REGISTER

Document Title, Author & Date	Received From	Document Type	Date
Hydrogen Developments in Shetland – Spring/Summer 2004	Sandy Macaulay	Word doc.	28/07/2004
Community Hydrogen Opportunities in Clean Energy Solutions (CHOICES) Programme, 18/07/2004 (email correspondence)	Sandy Macaulay	Word overview & email correspondence (from CAT Cameroon)	28/07/2004
International Action Programme, International Conference for Renewable Energies Bonn, 30/06/2004	Sandy Macaulay	Word doc	28/07/2004
International Energy Agency (IEA) Hydrogen Implementing Agreement Task 18 (Demonstration Systems)/The Pure Project, EA technology, 09/06/2004	Sandy Macaulay	Letter	28/07/2004
Exploiting the Learning Potential of the Pure Project – a briefing paper for Shetland enterprise, Glenarder Ltd	Sandy Macaulay	Word doc	28/07/2004
The Potential for Hydrogen in Scotland, FREDS Secretariat, May 2004.	Sandy Macaulay	Word doc	28/07/2004
Developing Shetlands Hydrogen Economy – International Context (discussion paper)	Sandy Macaulay	Word doc	28/07/2004
Hydrogen Community Research, email correspondence with De Montfort University and Sandy Macaulay, 27/07/2004	Sandy Macaulay	Email correspondence	28/07/2004
A Shetland Wide Opportunity	Ross Gazey	Presentation (ppt)	27/07/2004
Fuel Cell Research Meeting – delegate list, 18th March	Sandy Macaulay	Word doc	28/07/2004
Potential Hydrogen Collaboration with Japanese firms.	Sandy Macaulay	Email correspondence	28/07/2004
Towards a sustainable future development of a Fuel Cell and Hydrogen energy economy in Scotland – contents page.	Sandy Macaulay	Word doc	28/07/2004
A list of contacts for Interview Stage	Sandy Macaulay	Excel doc	25/08/2004
Wavegen Sustainable Value Proposal – Transportable Energy from Renewables	Sandy Macaulay	Hard Copy	19/09/2004
National Hydrogen Association (NHA), Summer 04, Quarterly Newsletter.	Sandy Macaulay	Hard Copy	19/09/2004
Shetland in Statistics	Elizabeth Johnson	Pdf version	14/10/2004