forum for
RENEWABLE ENERGY
development in Scotland

HYDROGEN AND FUEL CELL OPPORTUNITIES FOR SCOTLAND

THE HYDROGEN ENERGY GROUP REPORT

SCOTTISH EXECUTIVE

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ISBN: 0-7559-5148-4

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St Andrew's House
Edinburgh
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Produced for the Scottish Executive by Astron B47326 08/06

Published by the Scottish Executive, August, 2006

Further copies are available from
Blackwell's Bookshop
53 South Bridge
Edinburgh
EH1 1YS

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EXECUTIVE SUMMARY

The Forum for Renewable Energy Development in Scotland (FREDS) has established the Hydrogen Energy Group (HEG) to examine and report on the potential and opportunities that hydrogen and fuel cell technology represents for Scotland in the short and long term. The conclusions of HEG are expressed in a number of future visions and achievable goals. The potential is immense and well recognised.

Less well documented is the comparatively negligible investment in hydrogen and fuel cell technology in Scotland and the UK in stark contrast to some of our European neighbours, North America and Japan.

To redress the balance and ensure that Scotland, with its unique resources, takes a lead in selected market sectors, HEG have articulated two pressing investment requirements. The first is a series of tactical short-term measures to 2010 that urgently need pump-priming finance in the order of the £2.5 million per annum over the next 3 years. These short-term measures are a re-statement of the HEG interim report recommendations which are now further supported and justified by independent work undertaken by IPA Consulting. They are:

1. Support for further demonstration projects involving hydrogen use in remote or off-grid communities in Scotland.
2. Projects are funded to support unique Scottish technology that involves fuel cell design or production.
3. Projects are funded to enable applications of hydrogen technologies and fuel cells, which are currently at the research or development stage, to be demonstrated commercially and value engineered for future market entry.
4. An inter-university research centre be established in Scotland to create fuel cell and hydrogen-based intellectual property for future exploitation within Scotland.

The second series of recommendations are longer-term measures in support of strategic goals that can be achieved up to 2020 within a policy framework using increased levels of fiscal incentives and substantive programme improvements.

HEG conclude that 10,000 jobs and GVA to Scotland's economy of £500 million per annum are the potential benefits available from such an approach. In order for Scotland to achieve its 40% renewable target by 2020 it will almost certainly require hydrogen and fuel cell systems to balance and integrate many diverse and intermittent sources of energy.

CHAPTER 1 – INTRODUCTION

1. The Forum for Renewable Energy Development in Scotland (FREDS) established the Hydrogen Energy Group (HEG) to examine and report on the potential and opportunities that hydrogen and fuel cell technology represents for Scotland in the short and long term. This report draws together the conclusions of HEG and recommends an action plan that will kick-start long-term development of an indigenous hydrogen and fuel cell industry in Scotland geared towards an integrated policy for renewable and green energy.

2. The membership of HEG is drawn from industry, academia and government agencies. Those participating are listed in Appendix 1. Their unanimously agreed vision is as follows:

To create a political, fiscal, business, educational and social environment within which hydrogen and fuel cell technologies can be developed to greatly enhance a robust and sustainable renewable energy economy in Scotland.

3. To support their work HEG commissioned IPA Energy Consultants to examine current funding mechanisms in response to a belief by the members of HEG that there are funding gaps for hydrogen and fuel cell projects due to their perceived long-term, high-risk nature. IPA's funding report is in two parts, the second of which supports HEG recommendations and outlines mechanisms designed to overcome barriers. IPA have also reported on storage technologies as an enabler for a totally renewable remote, or off-grid, energy network. High-level modelling suggests the economics of this may be approaching break even.

AIMS AND OBJECTIVES

4. The Scottish Executive believes that significant opportunities for Scotland exist within the development of the hydrogen and fuel cells sectors. The Forum for Renewable Energy Development in Scotland decided to establish a hydrogen sub-group to scope current activity and support within the hydrogen and fuel cell sectors and to consider how Scotland might best support, influence and develop this work.

The hydrogen sub-group has considered:

- What opportunities exist for Scotland within progress towards a hydrogen economy.

In particular, the sub-group has:

- assessed existing national and international activity within the hydrogen and fuel cells sectors;
- identified the key opportunities for hydrogen and fuel cell technologies in Scotland;
- suggested measures to overcome the barriers from moving from research to demonstration and accelerating the commercial deployment of hydrogen and fuel cell technologies;

- identified possible opportunities for Scotland within the hydrogen and fuel cell technologies supply chain;
- assessed the potential for hydrogen and fuel cell technologies to improve the supply of energy in remote areas of Scotland;
- assessed what role the Energy Intermediary Technology Institute might play in driving forward the hydrogen agenda in Scotland.

5. In addition, the group has suggested intervention measures that will overcome barriers, close funding gaps and stimulate a new world-class industry that can flourish in a global market estimated to reach $50 billion per annum by 2020.

BACKGROUND AND CONTEXT

6. The need for renewables, hydrogen and fuel cell technologies is clear as the problems associated with the decline of hydrocarbons become apparent. What took nature millions of years to create under the North Sea has been exploited and depleted by man in less than three decades. Even without considering the fast increasing need of the developing nations, the demand for hydrocarbon from the developed world is forecast to outstrip discovery and supply within a decade.

7. The Scottish Executive has already recognised the importance of taking action to address the central issues of energy policy, i.e. energy security, climate change and fuel poverty. The commitment to produce 40% of Scotland's energy from renewable sources by 2020 is examined in the FREDS report "Scotland's Renewable Energy Potential: Realising the 2020 Target".[1] The target takes account of the intermittency of some renewable generation sources and the associated problems of matching consumer demand patterns with reality of renewable energy production. This results in some 6GW of installed renewable generation capacity being required to meet the 2020 target. This still leaves the issue of periods of high pressure, with little wind or waves, which suggests a continuing commitment to hydrocarbon fuelled capacity to meet back-up for peak demand.

8. Another option is to use excess production from renewable systems, during times of low consumer demand, to produce hydrogen that is stored for peak demand generation. The European Union has undertaken much work to develop a hydrogen and fuel cell platform with a vision of a hydrogen economy linked to renewables. This vision puts hydrogen and fuel cells at the core of energy storage, distribution and smoothing. This point is illustrated in Appendix 2 by an abstract from a presentation on the European Union Hydrogen and Fuel Cell Platform Joint Technology Initiative.[2]

[1] *Scotland's Renewable Energy Potential: Realising the 2020 Target,* a report by FREDS, 2005
[2] *Hydrogen Energy and Fuel Cells - A vision of our future,* European Hydrogen and Fuel Cell Technology Platform, 2005

9. Biogas and biofuels are also very important renewable sources that can be utilised more effectively with the aid of fuel cell technology. Furthermore, hydrogen produced by the full range of primary renewable sources, using electrolysis of water for example, provides clean energy conversion that can substitute current hydrocarbon resources with emerging renewable resources. Scotland is particularly rich in renewable resources and hydrogen and fuel cell technology is a means by which we can harvest its full potential. This concept is analysed in detail in the IPA report 'Hydrogen Technology Systems' which is discussed in paragraph 61.

10. Investment in renewables worldwide has reached $30 billion per annum and 1.7 million people are directly employed. 160 GW of installed renewables represents 4% of global capacity and all the trends show a steeply increasing commitment by governments with large commercial and investment banks beginning to take notice. World investment in hydrogen and fuel cell technology is estimated at $4 billion in 2004, rising rapidly and impacting on both static generation and transport applications.

11. HEG is convinced that a hydrogen and fuel cell infrastructure in Scotland will happen in concert with the rest of the UK, Europe and the World. It is not a question of "if" it is a question of "when". Anyone in any doubt about this statement only needs to read the "Deployment Strategy" report published in August 2005 by the European Hydrogen and Fuel Cell Technology Platform.

12. HEG believes that hydrogen and fuel cell technology is an issue of prime importance to Scotland and warrants well-focussed public funding support to stimulate market opportunity. HEG also believes that the Scottish Executive should use the whole range of its fiscal, planning, and policy powers to leverage economic, social and environmental returns that will impact on the long-term prosperity of the nation.

THE HYDROGEN ENERGY GROUP'S VISION

13. HEG has gathered evidence that hydrogen and fuel cell technology, and significant areas of emerging renewables technology, in Scotland are encountering serious investment barriers due to the perception that it is high risk with long-term return. Investment patterns are generally viewed as short-term profit orientated. It is therefore seen as imperative that public sector support is available to the emerging hydrogen and fuel cell industries. With strong support from national and local government, HEG believes that private sector funding will follow as opportunities become nearer to market. Other countries such as Canada, USA, Japan and Germany already have a longer-term view and are building their expertise and capability and preparing their economies for a fast evolving industrial revolution, essentially driven by large-scale public support.

14. HEG believes that if government and industry work in partnership, to create the right policy and financial framework, then the following visions are deliverable and align with the Scottish Executive's key targets for renewable energy.

HEG BELIEVES THAT BY 2010:

Scotland will have around 50 leading demonstration projects that encompass transport and static power generation applications. This will promote Scotland to the premier league in hydrogen and fuel cell technology in Europe. A range of actions will be required, including, the encouragement of community-led schemes, public procurement, targeted support for SME development and planning support for renewable energy downstream storage and smoothing facilities.

Research and Development activity associated with hydrogen and fuel cells will have been enhanced at Scotland's leading universities and will have created highly-qualified people, new expertise and greatly enhanced intellectual property. Education and training all the way from schools to universities, and especially at college level will have created the technologists required to implement this new energy structure. All of this will be providing feedstock for the emerging industry.

The number of people directly employed in hydrogen and fuel cell technologies will have increased from a current estimate of around 100 people to 1000. Education, research and development, and industry will be sharing this employment. Equally important will be community-led employment resulting from installation, operation and aftercare of hydrogen and fuel cell applications.

Scotland will be at the centre of UK and European Fuel Cell and Hydrogen research, development, demonstration and commercialisation activities. This will have levered substantial inward investment and funding from sources external to Scotland.

Scotland will have bid and achieved at least one European "Lighthouse" hydrogen and fuel cell project because it is the richest and most diverse source of renewable resources in Europe.

HEG BELIEVES THAT BY 2020:

Of the 40% of energy created by renewable resources at least half will have downstream hydrogen production, storage and fuel cell facilities.

20% of Scotland's total electrical power generation will be decentralised with a significant fuel cell component.

20% of Scotland's homes will have fuel-cell-based micro-combined heat and power systems, increasing at a rate of 10MWe per year.

10% of all vehicular transport, road and rail, will be powered by fuel cells operating on renewably produced fuels.

ECONOMIC OUTCOMES

The number of people directly employed in hydrogen and fuel cell technologies will increase from an estimate of around 1000 people in 2010 to 10,000 in 2020. Education, R&D and industry will share some of this employment, but, as important, is the potential for community-led employment that will be the dividend from installation, operation and aftercare of hydrogen and fuel cell applications. To sustain this level of employment Scotland will have to become a net exporter of hydrogen and fuel cell skills and technology very similar to the level of expertise in the offshore oil industry that is in high demand from developing countries.

As a result of achieving the above employment goals, it is estimated that the resultant hydrogen and fuel-cell environment will contribute £500 million per annum to Scottish GVA.

15. These visions have been assembled against a background of credible achievement elsewhere in the world. Recent Canadian experience is summarised below.

EXAMPLE OF ACHIEVEMENT

Canada's Fuel Cell and Hydrogen Industry: Summary of Capabilities Guide 2004/05

The 2004 sector profile shows strong growth in many key indicators for the period 2002-2003:

- Revenue grew 40% from $134 million in 2002 to $188 million in 2003.
- R&D expenditures increased 5% from $276 million in 2002 to $290 million in 2003.
- Employment reached 2,671, an increase of 40% from 2001.
- Participation in demonstration projects increased by 232%, to 262 in 2003 from 79 in 2002.
- Patent holdings up by 34% to 581 in 2003.

CHAPTER 2 – BACKGROUND

BACKGROUND TO THE TECHNOLOGY, ROLE AND ECONOMICS OF HYDROGEN AND FUEL CELLS

16. To fulfil the visions described in chapter 1 rapid development of fledgling fuel cells and hydrogen infrastructure is an absolute requirement. This chapter describes the technologies involved and their current status worldwide.

THE ROLE OF HYDROGEN

17. When hydrogen is burned, the product of combustion is water creating the impression of a clean, pollution-free fuel. However, hydrogen, like electricity, is not an energy source in its own right, and it can only be as environmentally friendly as the primary energy used to produce it.

18. If renewable electricity is used to produce hydrogen by electrolysis then this provides a virtuous circle and a totally green application. The most likely renewable sources would be wind and marine systems that have spare capacity at times of low demand. Biomass is unlikely to be a suitable renewable source as any excess fuel would preferably be converted into liquid biofuels.

19. The utilisation of hydrogen can be achieved in three principal ways – standard combustion (i.e. in conventional internal combustion engines), gas turbine and fuel cell. Of these methods, fuel cells are the most attractive for renewable energy applications due to the high efficiency (potentially 90%) that is possible over a wide range of application scales as well as the avoidance of pollutants such as Nitrogen Oxide(NOx). Another possibility is to provide public gas supplies based on mixtures of hydrogen, methane and carbon monoxide, largely from renewable resources. Such a product could be used in current equipment for homes and industry.

20. At present, production of hydrogen from renewables is up to three times as costly as from fossil fuel and so sustainably produced hydrogen is not economic. HEG believe that public funds should be used to support demonstrations of systems using renewably produced hydrogen as explained later in this report. This will provide the basis for economic investments by the private sector as changing fuel economics close the current cost disparity gap.

21. To illustrate this latter point, current economics of fossil fuelled hydrogen production are escalating due to rising energy prices but little attention is paid to associated carbon dioxide emissions. Suggestions are now being made to combine such large-scale production processes with sequestration of the carbon dioxide produced. This will demand centralisation near suitable sequestration sites; it will increase cost and the extensive associated hydrogen distribution system would lead to significant energy losses. Under such circumstances the renewably produced hydrogen alternatives would look more attractive.

22. Scotland already has experience and skills associated with large-scale hydrogen production at the Mossmorran and Grangemouth facilities, which are linked with major companies like Shell and BP. In addition, Scottish and Southern Energy has joined with BP, Shell and others to evaluate the world's first full-scale hydrogen production – gas-fired generation – carbon sequestration project at Peterhead in Scotland.

23. These existing and future large-scale hydrogen facilities offer Scotland a building block on which to develop the infrastructure to produce hydrogen from renewable/zero emission sources for onward distribution and utilisation by, for example, urban consumers located at a distance from the initial source of energy production (such as a wind farm in, say, the Solway Firth or a marine power station in the Pentland Firth). These urban consumers are likely, initially, to be within Scotland, such as the conurbations of the Central Belt. In the longer term there may well be export opportunities of the hydrogen to other parts of the UK and beyond.

24. In the transport sector, liquefied or compressed hydrogen is inferior to oil and petrol in terms of stored energy density. However, the redeeming feature of renewably produced hydrogen for transport applications is its pollution-free conversion.

25. The benefits of hydrogen storage and use are discussed in detail in IPA's report entitled "Hydrogen Technology Systems". This demonstrates the economics associated with hydrogen use to provide peak power management and intermittency smoothing for networks with a high proportion of renewable generation. The following diagram illustrates how the EU thinking currently projects the development of sources for hydrogen production.

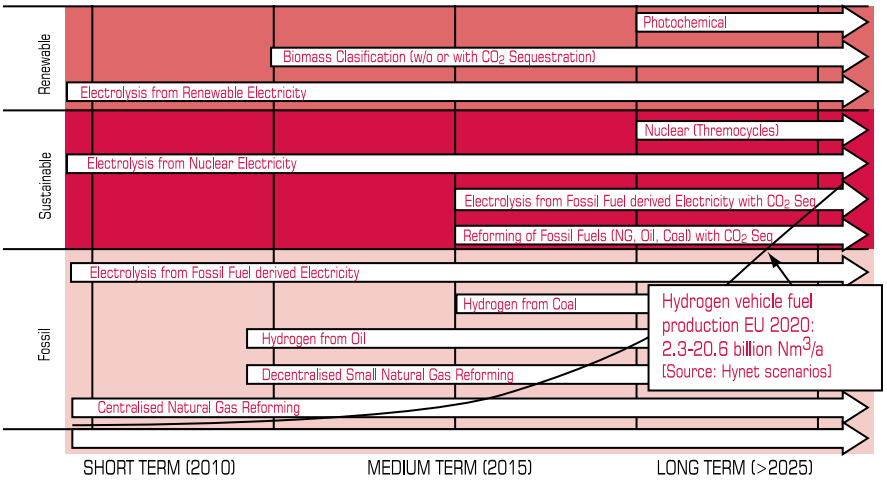


Figure 1: Maturation of hydrogen production pathways from HyNet Roadmap Executive Report[3]

[3] "Towards a European Hydrogen Energy Roadmap" Hynet Partners, May 2004

THE ROLE OF FUEL CELLS

26. Fuel cells are in essence batteries with an external source of fuel; they have one very important characteristic, they offer very high chemical to electrical conversion efficiencies over a wide range of system sizes. This arises from the absence of mechanical work in fuel cell conversion, and means that only the most advanced and largest thermal power stations come close to the efficiency that can be expected from a fuel cell system of much smaller scale. Hydrogen is an ideal fuel for fuel cells although other fuels such as natural gas, biofuels and biogases are also attractive and Scotland has specialist skills in the utilisation of such fuels in fuel cells.

27. Stationary fuel cell systems can be either connected to the power grid or stand-alone. Such systems are likely to be fuelled by natural gas or liquefiable hydrocarbon fuels in the first applications with biofuels and hydrogen becoming more important as the technology matures. The expected stationary fuel cell technology development track is for decentralised power applications with a gradual transition from fossil fuels to CO_2 neutral fuels; however much early deployment will be in premium power applications particularly in the defence sector where fuel cells can achieve early competitiveness.

28. As time progresses, the load centres of the power network will become largely self-contained consisting of renewables supported by decentralised fuel cell systems. The advantages of a decentralised system arise from lower transmission losses, higher total energy efficiency and improved energy security. A high value national transmission network, powered by advanced thermal or nuclear generation, hydropower, buffered wind power and large-scale fuel cell systems will support these load centres and provide back-up and balancing power.

29. Stationary deployment is expected to involve both high- and low-temperature fuel cells. High-temperature fuel cells will be applied where carbon-containing fuels, including less pure hydrogen, is available and for large-scale systems, particularly when high value heat is demanded. Low-temperature fuel cells will be applied where clean hydrogen is available and where early application is facilitated by technologies developed primarily for transport applications. There are major programmes of investment in fuel cells for transport applications in many countries, and this is being combined with development of new pilot infrastructures for hydrogen in California, Canada and Germany.

30. Fuel cells and hydrogen can enable the introduction of renewables on a much larger scale, especially through the increased availability and reliability of decentralised generation. They will play an essential role in the conversion of biofuels to electricity at a high efficiency and low emissions. There are many different kinds of gaseous and liquid biofuels. These can be produced from waste or through agricultural production. Biofuels can be used directly in high-temperature fuel cells at a high efficiency and benefiting from the fuel flexibility of these systems.

CHAPTER 3 – INTERNATIONAL PERSPECTIVE

INTERNATIONAL PERSPECTIVES AND EU ROADMAP FOR HYDROGEN AND FUEL CELLS

31. In this report regular reference is made to the "European Union roadmap". This is a significant document from which Scotland can benefit. This chapter will explain the background to it and also highlight other international experience.

32. At the moment fuel cells are not economically competitive with other sources of generation, although fuel cell systems out-perform their competitive products in conversion efficiencies and environmental benefits. The reason for this economic disadvantage is entirely due to the lack of economies of scale and continuous cost improvements in the technology. Once fuel cell systems move from prototype to large-scale production, the potential market is enormous. The European Hydrogen and Fuel Cell Technology Platform, has been developed by a pan-European group of experts of whom HEG group member, Professor John Irvine, is a member. They have developed the diagram below to explain the progress towards economic competitiveness.

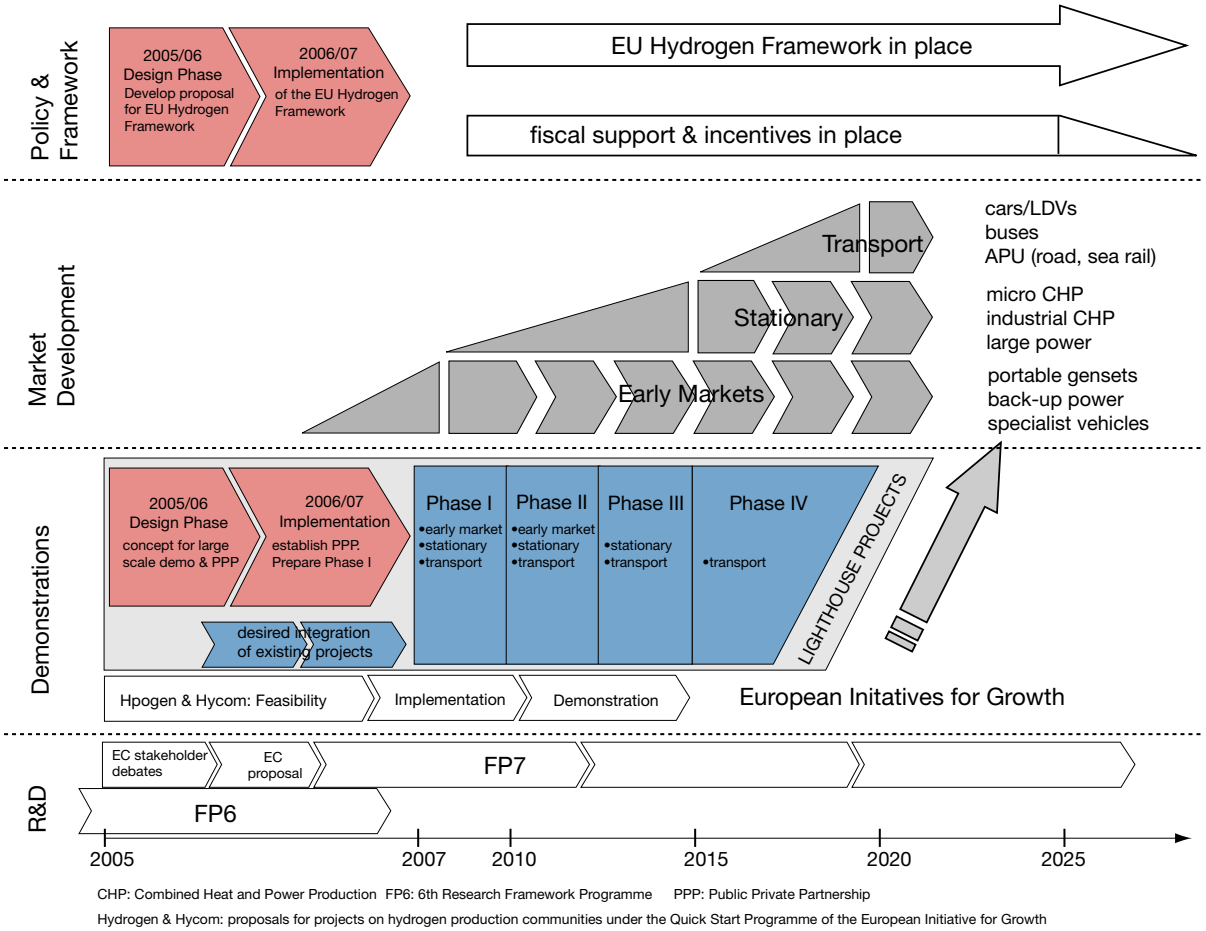


Figure 2: European Hydrogen and Fuel Cell Technology Platform, "Deployment Strategy Report", Snapshot 2020

33. HEG's vision for Scotland draws heavily on the EU 2020 vision. By 2020, conventional oil supply is unlikely to be able to meet demand. Certainly, Europe's oil import dependence will be in excess of 70%, far higher than the 50% it is today. Hydrogen is therefore expected to become an important alternative energy vector. However, any major change in the energy industry is likely to require several decades to implement effectively, owing to the high capital intensity and long asset lives involved.

34. In pursuit of the long-term goals, a set of milestones, known as "Snapshot 2020", have been set by the European platform. 2020 has been chosen because it encourages challenging targets, whilst helping to test for practicality and feasibility. It also reflects requirements on the application side, corresponding with the findings of the Strategic Research Agenda (SRA). Accounting for a lead-time from research to mass market roll-out, 2015 has been chosen for the SRA milestones, allowing 5 years for serial development and commercialisation activities.

35. The Table below indicates the deployment status for applications by 2020, expressed in numbers of sold units per year and cumulative sales projections respectively.

	Portable Fuel Cells (FCs) for handheld electronic devices	Portable Generators & Early Markets	Stationary FCs Combined Heat and Power (CHP)	Road Transport
EU Hydrogen (H2)/FC units sold per year Projection 2020	~ 250 million	~ 100,000 (~ 1 GWe)	100,000 to 200,000 (2-4 GWe)	0.4 million to 1.8 million
EU cumulative Sales projections until 2020 EU Expected 2020	n/a	~600,000 (~ 6 GWe)	400,000 to 800,000 (8-16 GWe)	n/a
Market Status	Established	Established	Growth	Mass market roll-out
Average power FC system	15W	10kW	3kW (Micro CHP) 350 kW (industrial CHP)	
FC system cost Target *	1-2 /W	500 /kW	2,000 /kW (Micro) 1,000-1,500 /kW (industrial CHP)	< 100 /kW (for 150,000 units per year)

Figure 3: Key Assumptions on Hydrogen & Fuel Cell Applications for a 2020 Scenario

36. There are a number of countries that are investing significant funds in hydrogen energy and fuel cell technology. The most significant economic impacts have been in Canada, Germany, Japan and the United States of America where federal and state governments have led the development of these technologies and which are now reaching the next major challenge – commercialisation of the technology. In terms of the economic impacts that these countries have experienced, the major employment and value added impacts to date have been in manufacturing and R&D.

37. The US Department of Energy has adopted a different approach. It is committed to a 10-year research, development and demonstration programme in order to achieve demanding performance and cost targets which will enable industry and government to commit to a full commercialisation decision in 2015. The milestone for 2012 is to deploy around 100,000 units with a total installed capacity of 500 MWe capacity.

38. In both the USA and Japan, firm plans are supported by substantial public funds. Japan has set aside a budget in 2005 equivalent to 260 million. The US 2005 Federal Appropriation equalled 235 million plus equivalent funding from individual states. China, India and S Korea have also now entered the race.

39. In particular HEG has been alerted to the funding level of two-hundred-and-fifty-million euros per annum that may be committed by EU Framework Programmes targeted specifically at Hydrogen and Fuel Cell technologies. HEG sees this as a prime target for cross-national programmes that can accelerate and enhance Scotland's involvement in hydrogen and fuel cell technologies.

RELEVANCE TO SCOTLAND

40. In the Scottish context, hydrogen and fuel cell technologies match well with Scottish capabilities in engineering of energy systems, technological development and manufacture. This is greatly reinforced by a wealth of renewable resources and the associated opportunities for clean energy export that presents a very real possibility that must be enabled. Furthermore, Scotland has some uniquely suitable development grounds to prove the feasibility of these new technologies and to showcase Scottish technology.

41. In essence, hydrogen and fuel cell technologies have an important role to play in Scotland becoming a 'centre of excellence' for sustainable energy. Scotland has over 25% of Europe's renewable resource impinging upon its shores, with the Pentland Firth alone predicted to supply 15TWhr per annum, which would equate with more than 0.25% of the 15 country EU's electricity production.

42. Scotland's renewable resource is primarily located in the Highlands and Islands whilst our skills in technology development are reinforced by extensive industrial capabilities in engineering for energy systems in the West of Scotland, high technology manufacturing in the Central Belt and oil and gas expertise in Grampian.

43. Several new Scottish companies; such as Fuel Cells (Scotland) Ltd, St Andrews Fuel Cells Ltd, Smart Energy and SiGEN; are already operating to develop and manufacture new fuel cell technologies as well as enhancing the systems integration for hydrogen and fuel cell technologies. The Scottish Hydrogen and Fuel Cell Association (SHFCA) is already the leading UK industry association and is providing an excellent focus for these new industries in Scotland. On a UK level, Fuel Cells UK is promoting the development and commercialisation of fuel cells.

44. The Scottish academic base is strong with world-leading activities in fuel cell materials development, integration of fuel cells and hydrogen, and key activities in hydrogen production and storage. St Andrews and Strathclyde are International Centres of Excellence respectively in Fuel Cell Development and Integration with developing activities in Heriot Watt, Napier, Aberdeen and RGU.

45. Profiles of the above active organisations are attached in Appendix 3.

46. A study commissioned by Scottish Enterprise showed that, dependent on the market penetration of hydrogen and fuel cell technologies, up to 1000 full-time jobs in Scotland could be created from the hydrogen and fuel cell industry in the relatively short term with a net additional GVA of £39 million per annum. Additional jobs and GVA could be created from, e.g. setting up of major manufacturing plants.

47. This independent assessment aligns with the HEG 2010 vision and underlines the need for Government support.

CHAPTER 4 – INPUT FROM IPA CONSULTANTS

48. This final report from HEG was preceded by an interim presentation to the FREDS group in May 2005. This provided four short-term recommendations which are still retained and discussed in chapter 5.

49. Discussion with FREDS at this stage highlighted gaps in the groups ability to quantify and justify some arguments for investment in hydrogen and fuel cells, particularly in relation to grant support. Subsequently, work was commissioned from IPA Consultants to assist the group finalise their report.

50. Three main reports have now been delivered as follows:

- "Interim Report – The potential for Hydrogen and Fuel Cell Development in Scotland", published in August, 2005. The main topic in this report is a review of sources of funding.
- "Hydrogen Technology Systems" published in November, 2005. The main topics in this report are a technology review of energy storage devices and an island renewable system model.
- "Final Report – The potential for Hydrogen and Fuel Cell Development in Scotland", published in December 2005. The main focus in this report is proposed mechanisms to support HEG's recommendations.

51. All three reports are on the FREDS website www.scotland.gov.uk/enterprise/energy

HEG RESPONSE TO IPA INTERIM REPORT: THE POTENTIAL FOR HYDROGEN AND FUEL CELL DEVELOPMENT IN SCOTLAND

52. The main focus of the IPA report centres on "Assessment of Existing Support Schemes". This is a thorough piece of desk research on the diverse sources of grant, loan and equity that may be accessed by players in the hydrogen and fuel cell sector. The diagram attached as Appendix No. 4 is a graphical summary of their findings. However, HEG is aware of anecdotal evidence that the seemingly unlimited promise of financial support outlined in the report is in reality much more difficult to access. The following has been accumulated from currently active Scottish hydrogen and fuel cell organisations from the public and private sector.

COMPETITIVE BIDDING, TRANSPARENCY AND TIME

53. For competitive bids submitted for financial support the chances of success are rarely better than 1 in 4, often less than 1 in 10. The reality is that the resources needed to complete application forms and prepare fully justified business plans is a significant barrier for SMEs. Many of the processes which applicants must go through when applying for funding can be exhausting with agencies asking for more and more information. Whilst large companies can stay this pace, SMEs tend to fail. It is accepted that there has to be due diligence and public accountability, but several bad experiences for a busy SME executive are likely to deter them from attempting to make future application for public funds.

54. Funding body transparency is important. One Scottish fund recently encouraged an application, completed the structuring of the grant, offered an indication that everything was in place for a straightforward sign-off, only to state two months later that there was no funding left available for investment.

55. Time taken to secure funding from the public sector is also a factor and most SMEs cannot endure the delay. Such problems are particularly serious for new technologies offering high potential returns in the longer term. Such investment returns are typical for renewable and clean energy technologies and the risk/reward perception by public and private sector investors leads to protracted analysis of opportunities.

HEG recommends that the Scottish Executive considers setting up a funding applications unit for the area of renewable energies. The purpose of the unit would be both to search for funding opportunities that match the capability of Scottish private and public sector bodies and to support applications for these funds. Professionals would be employed to gather together suitable partners, at home and abroad if appropriate, formulate applications according to bid criteria, create the necessary documentation and make submissions. Past experience in the Republic of Ireland shows that this type of approach encourages companies and universities to participate with a cost of no more than 10% of grant award but a greatly enhanced strike rate. Appendix 4 demonstrates the complexity of the funding opportunities available.

PROVISION OF BALANCE OF FUNDING WHEN GRANTS ARE AWARDED

56. A quite separate issue is the attitude of Scotland's financial community to hydrogen and fuel cell investment which influences the provision of balance of funding when grants are awarded. Private sector funds for long-term, high-risk investment are almost non-existent in the UK. Most innovative companies are initially very small with highly qualified and dedicated people struggling to exist. Even when they are successful in gaining public funding grants, they often fail to find sufficient balance of funding.

HEG recommends that the Scottish Executive considers introducing "Proof of Concept and Commercialisation" funding for SMEs that can prove they have innovative technology. The mechanism for SMART & SPUR has shown itself to be robust and should be extended to allow 75% cash support for follow up projects. The Scottish Executive might also consider repayable Innovation Loans of up to £250,000 directed towards emerging strategic industries that could have a major impact on the Scottish Economy.

PUBLIC PROCUREMENT DIRECTION

57. A third group of concerns involves the lack of public procurement direction to secure early utilisation of new technologies. Local and national government in other EU countries, especially in the US close market failure gaps and stimulate commercialisation using public procurement. There is, as yet no apparent equivalent in Scotland or the UK. When compared to other EU countries, the UK seems to fail to interpret EU funding rules in as generous a way. These areas of public policy are not only barriers to economic development in Scotland but also discourage SMEs from trying to access EU funds.

58. HEG recognises that in considering any new support, government must weigh the balance of emerging technology risk against the public sector duty to minimise risk. Emerging technologies by their very nature carry higher levels of risk than established technologies.

59. However, if emerging technologies are to break into the commercial market they need publicly-funded transitional bridges. Scotland needs to be proactive in putting in place the necessary requirements that would enable public funding in projects to be increased to the higher limits of intervention currently legislated for within the European Union (re state aid) under environmental exclusion.

HEG recommends that the Scottish Executive encourage local and national public sector procurement in order to drive the development of regional low carbon emission applications. Although these procurements would have to conform to all EU procurement rules, local requirements with proximity to service and repair facilities would favour employment and deployment in Scotland.

100% COST RECOVERY

60. In some community-led project applications it may be appropriate to consider the creation of community-owned companies that would be, not for profit, limited by guarantee organisations, whose memorandum and articles of association would be designed to qualify for charitable status. The business model pioneered by the PURE project in Unst can, in principle, access 100% funding from the public sector for any development project. This is a route which could be used to establish further demonstration projects.

HEG RESPONSE TO IPA REPORT: HYDROGEN TECHNOLOGY SYSTEMS

61. Whilst the first IPA Report considered funding sources, to support fulfilment of the four recommendations put forward by the HEG, the second report reviews technology capable of storing renewable energy and reusing it in a hydrogen economy.

62. This is particularly important in relation to HEG's first main recommendation, which proposes extra financial support for demonstration projects involving hydrogen use in remote or "off-grid" communities in Scotland.

63. The report makes a compelling, albeit high-level case, for bringing together a group of technologies including wind generation, batteries, electrolysers, hydrogen storage, fuel cells, gas-turbine generation and hydrogen-powered transport, to demonstrate how a large island economy could be completely self supporting in energy terms using only renewable sources. The model takes account of intermittency issues that are often seen as the Achilles heel of wind and wave-based solutions for remote locations.

64. Given the wealth of renewable resource in Scotland's island communities, the concept of fulfilling this vision could be undertaken as a pan-European "Lighthouse" project aimed at providing a Scottish-based exemplar, funded in large part from EU sources, ultimately for wider exploitation throughout the world.

65. Moreover, IPA suggests that with current gas-oil prices of around $600/t, an island requirement similar to that of Shetland (50MW electrical demand) could be economic. Other attractive features are that ITI Energy are already investing £9.3 million in advanced battery systems which the concept requires, and a successful community-based funding mechanism has already been demonstrated for the smaller Unst based "PURE" hydrogen and fuel cell demonstration scheme.

66. To quote from IPA's paper, "These demonstration projects have the potential to provide added value to Scotland's economy in terms of skills development, job creation, technology innovation, reducing reliance on imported fossil fuels as well as the associated environmental improvements that could result."

HEG recommends that funding be provided to develop the island renewable model in greater depth and to bring forward a fully justified investment proposal.

HEG RESPONSE TO IPA FINAL REPORT: THE POTENTIAL FOR HYDROGEN AND FUEL CELL DEVELOPMENT IN SCOTLAND

67. Continued dialogue and iteration between HEG and IPA has created a consultant's report that is truly reflective and encompasses all of the diverse interests represented by the membership of HEG. Hydrogen and fuel cells is so different from other single industry renewable groups that have reported to FREDS; it is an emerging group of technologies that are in the very early stage of development; its applications range from transport to static and include everything from hydrogen production through storage, distribution, and end with a myriad of applications.

68. The four proposals that were formulated by HEG in its interim report to FREDS have now been refined and are restated in the next chapter of the report incorporating the guidance and added value provided by the IPA report.

CHAPTER 5 – RECOMMENDATIONS

RECOMMENDATIONS AND PROPOSALS

69. The development of the hydrogen and fuel cell sector cannot fall to any one organisation in Scotland. It will require a co-ordinated approach by both government and industry.

70. HEG believes the following action should be taken to improve the short- and long-term funding environment and many of the mechanisms already in place.

SHORT-TERM RECOMMENDATIONS

71. HEG have concluded that by implementing the following four recommendations over the next 3 – 5 years a strong bedrock will be provided for the hydrogen and fuel cell sectors to grow. HEG estimate the four recommendations will require funding of £2.5 million per annum.

72. These recommendations were previously presented in HEG's interim report to FREDS in May 2005. However, the consultation work carried out by IPA has enhanced and developed them further.

73. No direct financial apportionment for each of the recommendations has been defined. HEG feels that they should not be prescriptive at this early stage but should rely on the mechanisms outlined in chapter 6 to prioritise applications which broadly support all four recommendations given that the bids received meet the required criteria. However, each of the recommendations are directly aligned to the vision articulated by HEG in paragraph 13.

RECOMMENDATION ONE – SUPPORT FOR FURTHER DEMONSTRATION PROJECTS INVOLVING HYDROGEN USE IN REMOTE OR OFF-GRID COMMUNITIES IN SCOTLAND.

74. Scotland's renewable resource will perform a pivotal role in the development of the Scottish energy economy and should play a major role in any demonstration projects involving hydrogen and fuel cells.

75. The PURE project has provided a model of how communities can lever renewable investments to create jobs and renewed economic activity. Scaling-up and extending such experience will be important if Scotland is to become a world leader in deploying these technologies. HEG suggest that dedicated public funds should be made available to support the development of off-grid demonstration schemes in Scotland.

76. As funding for first and second generation demonstration projects is only likely to be required in the short term (3- to 5-year horizon), HEG recommend that public funding is provided via a dedicated grant-based scheme. HEG suggest that the tender process for obtaining funding should be competitive and that there should be a series of calls for proposals that ensure an incremental range of projects rather than multiples of the same project model in different geographical locations.

77. Further funding may also be required for subsequent demonstration schemes, however, the requirements, and hence funding mechanism, of these schemes may be somewhat different. Securing a European "Lighthouse" project under this measure might be possible.

HEG considers that this recommendation could support up to 10 demonstration projects per annum over a period of 3 years.

RECOMMENDATION TWO – PROJECTS ARE FUNDED TO SUPPORT UNIQUE SCOTTISH TECHNOLOGY WHICH INVOLVES FUEL CELL DESIGN OR PRODUCTION.

78. Additional public support directly aimed at the development of indigenous hydrogen and fuel cell technology would increase funding opportunities; however, "match" funding will still be required to complement the public support. IPA investigated how other EU countries implement support mechanisms for hydrogen and fuel cell industries and achieve leverage from other sources.

79. Of the EU countries the German public sector seems to be the most successful in providing funding through both national and regional initiatives – in aggregate total public financing is said to approach 100 million a year.

80. Experience shows that a well-funded and directed public programme, with specific aims and objectives, provides considerable incentives for commercial organisations to become more active in developing and demonstrating technologies in the region. This, in turn, supports innovative SMEs, stimulates the creation of new SMEs, encourages spin-out of novel and advanced technologies from universities and spin-in from advanced technologies from other countries through inward investment.

81. A key aspect of the development of hydrogen and fuel cell technologies in other EU countries, is the significant contribution being made by large industrial, engineering and chemical firms as well as utilities, not to mention the auto industries in Germany, France and Spain.

82. In order for Scotland, and the UK, to make a significant contribution to the hydrogen and fuel cell market, and to share in the economic benefits that result, it will be important for the UK's manufacturing and engineering base to collaborate and co-invest with government.

HEG considers that targeted public sector support that encourages greater industrial involvement will enhance the creation and application of indigenous intellectual property resulting in sponsorship of at least five new fuel cell developments per annum.

RECOMMENDATION THREE – PROJECTS ARE FUNDED TO ENABLE APPLICATIONS OF HYDROGEN TECHNOLOGIES AND FUEL CELLS, WHICH ARE CURRENTLY AT THE RESEARCH OR DEVELOPMENT STAGE, TO BE DEMONSTRATED COMMERCIALLY AND VALUE ENGINEERED FOR FUTURE MARKET ENTRY.

83. It is vital that hydrogen and fuel cell technologies are demonstrated in real world situations. Demand for such demonstrations is an important factor in bringing on new technologies, both from the public sector and community-based groups as well as private enterprises.

84. It is also likely that larger organisations would provide funding for trials of their own technologies and so it will be important to create an environment that will be favourable to developing these technologies in Scotland.

85. In order ensure the availability of matched funding for any public sector grants, it will be important to create a market pull for the products of the technology under development. This can be addressed to ensure a market for the end product. Types of mechanism which could be used include:

- Mandatory/Voluntary Procurement Schemes for Public Sector organisations. Government policy could support and (be supported to) promote hydrogen and fuel cell applications in central and local government organisations for applications such as space heating, embedded generation and emergency power supply systems. This may be mandatory or voluntary procurement of the necessary technology.
- Auctions/Tenders – This would be likely to be initiated from publicly-funded organisations and would help create a demand for "new" technologies. The current SBRI scheme (Small Business Research and Innovation) scheme adopted by Ministry of Defence and the Research Councils could be embraced by the Scottish Executive with positive discrimination towards Hydrogen and Fuel Cell technologies.
- Voluntary Schemes on businesses. The Energy Savings Trust and the Carbon Trust can both have a positive impact on the adoption of new energy technologies by business and commerce.
- Capital Grants – an extension of the Scottish Community and Householder Renewables Initiative (SCHRI) to encourage the take up of hydrogen and fuel cell technologies in communities and households. To date, the Warm Deal programme run by the Scottish Executive has installed over 60,000 central heating systems for pensioners. HEG firmly believe that hydrogen and fuel cell technologies could contribute to these fuel poverty policies.
- Influencing instruments such as education and training, information provision, and social recognition schemes.

86. It is not for any one individual organisation to further develop Scottish-based technologies, but a number of different stakeholders (both public and private) need to work together to create a demand for such projects and support them financially. HEG fully endorses and supports the work of the Scottish Hydrogen & Fuel Cell Association (SHFCA), which was set up in 2004 to represent the hydrogen and fuel sectors in Scotland, embracing commercial, industrial and academic activities. Current membership of SHFCA is detailed in Appendix 5.

87. In supporting these projects Scotland should commit to medium - and long-term goals to both attract organisations to develop their technologies in Scotland and also provide investors with the confidence to invest in Scottish based technologies. SHFCA must be repositioned and adequately resourced to become an effective instrument of economic development in hydrogen and fuel cells.

HEG consider that a wide-ranging and long-term series of programmes and activities must be developed to promote hydrogen and fuel cell awareness and use. The socio-economic impact of these future platform technologies and their integration in to a new sustainable clean energy infrastructure will require considerable effort and support from every sector of our community, as opposed to individual project support, to implement this recommendation.

RECOMMENDATION FOUR – AN INTER-UNIVERSITY RESEARCH CENTRE BE ESTABLISHED IN SCOTLAND TO CREATE FUEL CELL AND HYDROGEN-BASED INTELLECTUAL PROPERTY FOR FUTURE EXPLOITATION WITHIN SCOTLAND.

88. The hydrogen and fuel cell community is well established through its industry association, SHFCA, which provides focus for the development of the industries in Scotland.

89. In view of the considerable strengths in Scotland in different aspects of hydrogen and fuel cell research, combined with our industrial capabilities and our renewable energy potential, it is important to provide a Scottish collaborative research centre in Renewable Hydrogen and Fuel Cell Technology to complement SHFCA's industry development role.

90. Critical mass is becoming ever-more important in securing strategic research and development funding, especially in the European context. If Scotland is to maintain and grow its current level of excellence in this important area of energy technology, it is essential to support high-level interdisciplinary collaborative activities. Bringing together fundamental science with systems engineering would provide a unique focused collaboration able to compete with international Research Centres. This would provide high-level support for industrial and SME development activities, enhance university-driven commercialisation and attract inward investment.

91. It is recognised that Scotland has several leading research institutes involved in hydrogen and fuel cell development. The focus of this Renewable Hydrogen and Fuel Cell Technology Centre would be on research to produce, store and transport hydrogen, to stabilise dynamic renewables, to utilise biomass in fuel cells, to provide hydrogen and fuel cell tertiary education and training and to explain and promote these new technologies to schools, society and decision-makers. Funding would be utilised to strengthen the complement of Senior Researchers, to establish world-leading facilities, for research training and for outreach activities to companies and society.

92. The Scottish Higher Education Funding Council (SHEFC) provides financial support for teaching, research and associated activities in Scottish higher education institutions. A number of centres have already been funded by the SHEFC with the aim of developing Scotland's research base. It is therefore accepted that to ensure open competition and transparency any new centre as described above would be developed in collaboration with the SHEFC.

MEDIUM- TO LONG-TERM PROPOSALS

93. HEG recommends that an approach similar to that employed to develop and provide market support for renewable energy be instigated to develop and provide medium- and long-term support for the hydrogen and fuel cell sectors. These recommendations are as follows:

FUEL CELL OBLIGATION

94. Renewable energy has been supported in the UK since 1990 through the Renewables Obligations (NFFO in England, Wales and Northern Ireland, and SRO in Scotland). This offered fixed-price, long-term (15-year) generation contracts to renewable developers, and were specific to stated renewable technologies, e.g. wind, landfill gas, biomass, etc. This "kick-started" the renewables sector. This support then changed to a market led obligation on electricity suppliers under the existing Renewables Obligation and issue of Renewable Obligation Certificates (ROCs).

95. Hydrogen and fuel cells are now at the stage of early renewable energy technologies in the late 1980s: they require to be demonstrated in scale in practical industrial/commercial applications. To this end it is recommended that an "SRO-like" obligation for the early entry of hydrogen and fuel cell technologies is created, allowing a prescriptive, competitive tendering process offering fixed-price, long-term contracts for the supply of grid electricity from fuel cell units. This would be enacted under the existing Electricity Act in a similar fashion to the previous SRO/NFFO process. Ultimately, this process would migrate to direct competition of fuel cell technologies in the electricity market.

MULTIPLE RENEWABLES OBLIGATION CERTIFICATES FOR RENEWABLE HYDROGEN

96. The use of hydrogen produced from primary renewable driven electrolysis, to generate electricity via a grid connected fuel cell, should be allowed to claim multiple ROCs until a "threshold" level is reached in terms of a) either a generating capacity limit of grid connected fuel cell units or b) an energy supplied limit is reached.

97. This would stimulate the early adoption and field testing/demonstration of such systems or units. The "2005/6 Review of the Renewables Obligation Statutory Consultation Document" of October 2005, prevented the "multiple counting" of ROCs being claimed from the generation of electricity from hydrogen (e.g. via a fuel cell) where the hydrogen in question has been manufactured from renewable sources.

98. Some of the **industry representatives** from HEG wish to note their disagreement to this and recommend that multiple ROCs should be permitted for renewably produced hydrogen.

FUEL CELL 'POWERSHIFT' PROGRAMME

99. The use of fuel cells in vehicles should continue to be supported via a "Powershift" mechanism, administered by Energy Savings Trust. Further, the use of renewably produced hydrogen as a vehicle fuel should be zero rated until a capacity limit is reached then duty introduced (at a growing rate but still ultimately with a lower rate than hydrocarbon fuels).

HYDROGEN WITHIN A RENEWABLE TRANSPORT FUEL OBLIGATION

100. In the 2004 Pre-Budget Report the UK Government announced that it would look at the possibility of a Renewable Transport Fuel Obligation (RTFO), along the lines of the Renewables Obligation which exists in the power generation sector. The RTFO would require 5% of all UK fuel sold on UK forecourts to come from a renewable source by 2010. This equates to an annual market for renewables fuels of some 200 million litres (44 million gallons). It is recommended that renewably produced hydrogen be named as a qualifying renewable fuel under an RTFO mechanism.

101. An RTFO would enable the transport sector to play a more active part in carbon emissions reductions. The Government study behind the RTFO finds that an RTFO could be introduced by April 2008. The benefits in 2010 would be around 1 million tonnes of carbon per annum at 5% of all road fuel sales from the transport sector – between 2 and 3% of transport emissions.

102. According to figures from the Scottish Executive "Scottish Renewable Resource Study 2001"[3] there is vast potential renewable electrical energy available at a generation cost below 5p/kWh.

103. Hence, Scotland has significant potential to use its indigenous renewable resource to produce hydrogen as a vehicle fuel, and to address the significant market (200 million litres of diesel equivalent or 660 million Nm^3 Hydrogen).

104. HEG also recommend that appropriate support is given to renewably produced hydrogen (such as an initial zero fuel duty rate proposed earlier) and to developing fuel cell technology for transport applications. This would include a separate Scottish-funded programme (via Scottish Executive or Scottish Enterprise) to develop: electrolyser technology (hydrogen production); hydrogen storage (building on existing ITI Energy success); refuelling techniques and equipment (from oil and gas connection expertise); fuel cell development and electric vehicle technology/integration.

[3] "Scotland's Renewable Resource" Garrad Hassan, 2001

CHAPTER 6 – FUNDING MECHANISM AND EDUCATION

FUNDING MECHANISM

105. In terms of how recurrent funding could be allocated in a fair and transparent way, HEG are mindful that mechanisms for allocating funds from public sources have been developed at both the EU and UK level. Common features of these mechanisms are (a) clear Aims and Objectives for each "Call for Proposals", (b) a set of fixed criteria against which every application will be judged to have met these Aims and Objectives and (c) an independent body to judge how each application meets the criteria.

106. The public body providing the funding would set the Aims and Objectives for each "Call for Proposals" as well as the criteria for judging. They would also appoint the panel of independent experts in accordance with Norton Committee recommendations on standards in public life. The panel would judge each application in terms of meeting these aims and objectives on the basis of the judgement criteria. It would seem appropriate that the panel of independent experts is drawn from across the stakeholder community including the academic, industry and public sectors.

107. In respect of the judgement criteria, a number of factors are considered essential:

i) does the Application align with the Aims and Objectives;

ii) what is innovative about the Application;

iii) why is funding from the State required?

iv) what are the expected results, and how do they align with industrial and commercial needs;

v) what are the economic benefits of this Application and who is likely to benefit;

vi) how will the results be exploited;

vii) what are the environmental and social impacts of undertaking the project, and how significant are they relative to the economic benefits;

viii) what are the specific risks with regard to the successful outcome of the project;

ix) how will the project be organised and managed;

x) what is the financial commitment required for this Application.

108. The Scottish Executive Business Growth and Innovation Division within the Enterprise and Lifelong Learning Department currently administer the SMART, SPUR, SEEKIT and SCORE programmes. They work with a wide range of the innovation community in Scotland that encompasses universities, SMEs, Large Companies, the private sector Financial Community and other public bodies. They use selection panels for project evaluation, have a variety of due diligence mechanisms at their disposal and are well practised in taking projects forward through implementation and completion. HEG propose that this team should administer the funding of all project-based activity. The members of HEG would welcome the opportunity to serve on selection panels given their wide knowledge and experience of the technology. Any conflict of interest would be dealt with by declaration.

109. HEG further recommends that the most appropriate Scottish Enterprise unit be asked to set up a team dedicated to making application for funding from a variety of public and private sources throughout the world. In the first 3 years pump-priming funding of £500k per annum is envisaged on the basis that this team will create applications for at least £20 million and achieve a success ratio of one in four. Depending on the success of the team during its first 3 years, the continued existence of the team would be secured by a levy on funding raised at a level of around 5%. With EU funds of around £150 million per annum committed to the development of hydrogen and fuel cells technology there is every reason to believe that a dedicated team of skilled writers could greatly enhance Scotland's penetration of funding mechanisms. HEG also envisages that no specific restrictions would be placed upon the team making application for hydrogen and fuel cells funding alone. There may well be projects that involve a wider base of renewable technologies that incorporate hydrogen and fuel cells as part of the overall project.

110. HEG recognises that stimulation of effective market mechanisms is as important as direct fiscal incentives. Encouraging early stage adoption of hydrogen and fuel cell technology through a variety of public procurement initiatives would bridge the initial gap. HEG also recommends that consumer demand side organisations such as Scottish Community and Householder Renewables Initiative (SHCRI) be directed to encourage adoption of hydrogen and fuel cells applications and provide consumer grants equal to those available for other renewable technologies.

EDUCATION AND TRAINING

111. For disruptive technologies such as fuel cell and hydrogen technologies, education and training are key barriers to implementation. Currently, the following items are taught in Scottish schools:

- Energy (including renewable energy) within the Standard Grade Technological Studies module;
- Basic hydrogen fuel cell electrochemistry and an overview of the 'hydrogen economy' (including production and storage) within Higher Chemistry.

112. Further, there are no current college/SNVQ level qualifications covering hydrogen and fuel cell technologies. The two most appropriate courses where this should be introduced are:

- Gas Appliances Installation and Maintenance (Level 2);
- Vehicle Maintenance and Repair (Levels 1 and 2). This would also be required to take recognition of electric vehicle technology.

113. These courses could cover the basic installation of both stationary and vehicular systems. The electrical installation aspects of fuel cell devices would be covered by existing electrical courses: the specific nature of hydrogen and fuel cell devices require further training in combustible gas and high pressure systems not directly in the electrical connection/installation sector.

114. Additionally, the hydrogen and fuel cell sector requires to liaise with the planning authorities in Scotland. Fundamentally, this requires recognition of hydrogen and fuel cell developments within both Structural and Local Plans (produced by Local Authorities) for, for example, use of land for local electrolysis plants for transport use. Further, the sector requires to liaise with the Scottish Building Standards Agency regarding the future regulation/certification of fuel cell units for building integrated use.

115. At university postgraduate level, there are elements of taught modules dealing with hydrogen and fuel cell technology at both the University of St Andrews and the University of Strathclyde.

116. Scotland is world renowned for the standard of its education and should take a lead in this area. It is very important to address these new technologies in the Schools curriculum and to enhance the very highest levels of education that are available at some of the universities; however, perhaps the most important gaps exist between these levels. It is absolutely essential to develop training programmes at college and basic university levels. We cannot create a new Industry without training the specialists who will implement these new technologies.

CHAPTER 7 – CONCLUSIONS AND CHAIRMAN'S STATEMENT

117. This report demonstrates the wide support for hydrogen applications and associated fuel cell developments as part of a Europe-wide initiative to use these technologies to drive towards more sustainable energy systems with low carbon impacts.

118. The UK generally has been slow to play a substantial part in this work, and has not seen itself as a major innovator or investor in this sector. However, this report highlights the special attributes that Scotland possesses, which make it a prime candidate to benefit from a more aggressive attitude.

119. First, Scotland's ambition to generate 40% of its electricity from renewable sources by 2020 requires the integration of many intermittent sources, particularly wind. As the proportion of wind grows, the situation will arise where useable output is below production capability unless storage systems are developed. This will be particularly true of embedded systems.

120. The EU views hydrogen storage and fuel cells as a method of increasing yield, and balancing energy demand with production, and this is key to delivering an integrated, low carbon, energy economy. Scotland is unique in Europe for the quality and quantity of its renewable sources of energy and, as such, it should take a lead in demonstrating the value of hydrogen storage and distribution systems coupled with fuel cells.

121. Secondly, Scotland has indigenous intellectual property in specific parts of the fuel cell market. Work in the area of solid oxide devices is recognised as world class and is already seen to be moving towards substantial reductions in the cost of production. This work must be properly funded and driven hard for success.

122. Finally, the activities, associated with the two issues already described, offer the potential of new Scottish jobs, both in academia and through the strong growth of new companies associated with emerging fuel cell and hydrogen applications.

123. For all these reasons, the FREDS HEG Sub-Group recommend the Scottish Executive considers carefully the requests for selective support contained in this report, as well as reviewing the need for specific energy policy development to ensure its success.

124. HEG has endeavoured to create imaginative solutions that provide the Scottish Executive with the exciting prospect of developing a range of completely new industries in Scotland. The financial and non-financial actions it proposes promise enormous social and economic dividends with a large multiplier effect many times the size of the initial investment.

Extract from European Hydrogen and Fuel Cell Technology Platform

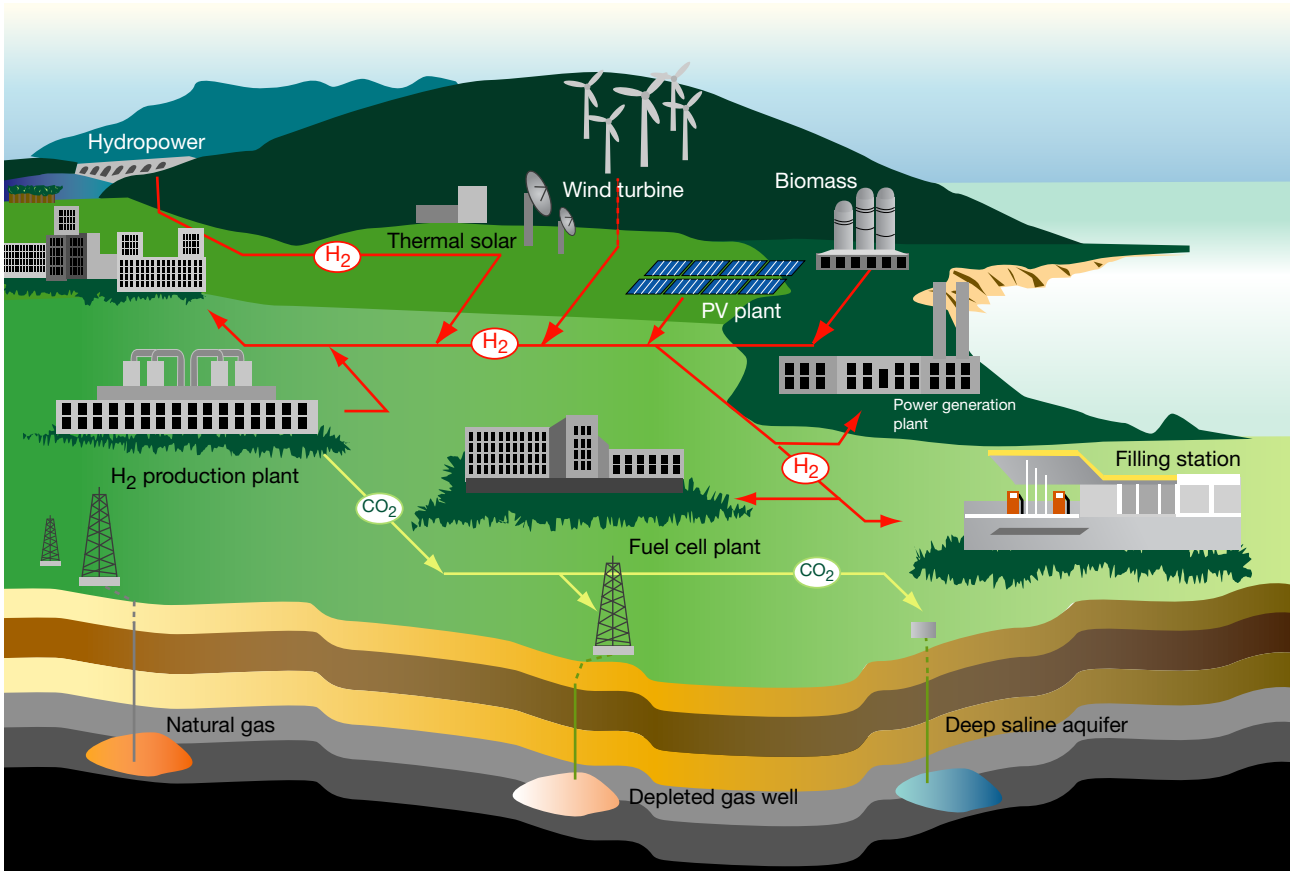
Deployment Strategy Report – August 2005

The state aid issue has to be carefully considered by the European Commission. The possibility for governments and public administrations to support private initiatives in the field of new technologies is often limited by the rules on market competition. The strategic priority of hydrogen and fuel cells technologies as defined by the European Commission should be reflected in some way in the state aid approach: in fact, at present these technologies are clearly not competitive with conventional energy technologies, similarly to the situation with renewable energies. This requires the possibility of public support even in the form of public funding or fiscal incentives in order to speed up transition from the research and innovation phase towards market introduction, growth and maturity.

APPENDIX 1: LIST OF HYDROGEN ENERGY SUB-GROUP MEMBERS

David Sigsworth Group Chairman	Scottish and Southern Energy
Dr. Andrew Cruden	Institute for Energy and Environment University of Strathclyde
Celia Greaves	Director Synnogy
Edward Angus MBE	Business Director Fuel Cells (Scotland) Ltd.
Ray Eaton	Technical Director Fuel Cells and Hydrogen Department of Trade and Industry
Professor John Irvine	Centre for Advanced Materials School of Chemistry University of St Andrews
Sandy Macaulay	PURE Project Director
Garth Graham	Group Contingency Planning Manager Scottish and Southern Energy
James Ferguson	Highland Alternative Energy
Nial McCollam	Director, Technology and Markets ITI Energy
Melanie Hay	Senior Executive Scottish Enterprise Energy Team
Alan Laird	Director Group Engineering and Technology Scottish Power
Alan Wilson	Technical Services Manager Scottish Power
Tom Read	Chief Executive Scottish Hydrogen and Fuel Cell Association
James P Thomson Secretariat	Policy Officer Energy and Telecommunications Division Scottish Executive

APPENDIX 2: EXTRACT FROM HYDROGEN AND FUEL CELL PLATFORM–JOINT TECHNOLOGY INITIATIVE



APPENDIX 3: COMPANY PROFILES

Scottish and Southern Energy plc is involved in the generation, transmission, distribution and supply of electricity and in the storage, distribution and supply of gas. It is the third largest supplier of electricity and gas in the UK, providing energy to over 6 million customers and the second largest generator of electricity (the largest from both non-nuclear and renewable sources). It owns/operates almost 10,000MW (megawatts) of electricity generating capacity (including around 4,300MW of gas-fired, 4,000MW of coal-fired and around 1,400MW of hydro-electric and wind farm capacity). In addition, it has interests/investments in initiatives to generate electricity from biomass, "micro" wind turbines, deep-water offshore wind turbines, tidal power and solar photovoltaics. It has joined with BP, Shell and others to evaluate the world's first full scale hydrogen production – gas-fired generation – carbon sequestration project (at Peterhead in Scotland).

siGEN Ltd. is widely recognised for its expertise in hydrogen and fuel cells across the UK, EC and is well known and recognised as a systems integrator across N America. siGEN has laid down more fuel cell systems across the UK than any other company. It is used to working with partners to deliver best advice and best value to the client. Some examples of successful system delivery. siGEN were also one of the founder members of the SHFCA.

- First commercial combined heat and power system for domestic property installed and commissioned in Eyemouth in November 2005. siGEN are also approved service contractors for Baxi/European Fuel cells and Ceramic Fuel Cells.
- Provided all of the hydrogen and fuel cell systems to the Shetland PURE wind-hydrogen project and acted as host to PURE project engineer Ross Gazey for the Knowledge Transfer Programme.
- Launched the schools "Fuel Cell Challenge" education initiative in October 2005 as part of a public outreach programme to raise awareness of fuel cell and hydrogen technologies.
- Reva electric Hybrid car conversion, supported under the SCEDS programme and supplied to the PURE project.
- Deployed five of 5kW fuel cell systems at Beacon, Acklam, Aberdeen, PURE, and the London Hydrogen partnership Trafalgar Square Christmas tree lights in 2004.
- Awarded two SMART awards (although siGEN declined to pursue one of them after award was made) for fuel cell product development.
- Design of hydrogen and fuel cell systems for three Eco-marathon vehicle teams, 2003-2005. The 2005 event was in conjunction with Mackie Academy, Stonehaven, who were the only school team entry in the fuel cell class in the UK.
- Tested and characterised two differing fuel cell systems (Relion and Plug Power) under a Dti programme and tested four other fuel cell systems, (Voller, Ballard, P21 and Heliocentris).
- Delivered first industrial fuel cell UPS system for commercial duty to AMEC. Unit now transferring to the HSE for further evaluation jointly with siGEN and AMEC.
- Contractor for the first two FC and Hydrogen projects in the Western Isles, begin January 2006.

Fuel Cells (Scotland) Limited is a designer, builder and manufacturer of modular seal-less solid oxide fuel cell stacks. The company has its laboratories at Rosedale House, Rosewell, Midlothian. Its Website is www.fuelcellscotland.com. FCS has been awarded SMART1, SMART2 and SPUR funding for the development of full size prototype stacks following the successful working demonstration of a 10-cell stack with all peripherals in 2004. A total of 4,500 hours of proof of concept operation has reaffirmed our conviction that the Fuel Cells (Scotland) Ltd stack design is ahead of most other solid oxide concepts. When taken to market as "the engine" for a standard Combined Heat & Power (CHP) device, we look forward to demonstrating the functionality, the efficiency and the cost effectiveness of our technology.

The **PURE Project** has delivered a zero emissions, off-grid renewable hydrogen hybrid power supply to an industrial estate on Unst, the most northerly island in the UK. The project incorporates high- and low-cost stored energy (hydrogen and thermal) as well as a fuelling for the UK's only road licensed renewable H2 fuel cell car. Building on the success of the project, the PURE Energy Centre is being established on Unst to investigate and commercialise the many R&D opportunities arising out of this unique project. The core products of the PURE Energy Centre are training, consultancy, a "pay-as-you-go R&D facility" and the supply of PURE Energy Systems. Its Website is www.pure.shetland.co.uk/

The **Hydrogen Office Project** is working to develop a zero-carbon emission, self-sufficient office building within Midlothian, Scotland, to prove that innovative renewable and hydrogen energy technologies can safely and reliably meet the needs of a modern office building. The project will support the development of the hydrogen and fuel cell industry in Scotland, improve the skills and technology needed to significantly reduce carbon dioxide emissions within the building sector and facilitate ongoing research and development. Its Website is www.thebep.org.uk/hydrogenoffice/background.asp

The **Scottish Hydrogen & Fuel Cell Association** (SHFCA) was formed in March 2004 by the hydrogen and fuel cell industry and academia in Scotland with the support of Scottish Enterprise through the Scottish Energy Industries Group (SEIG). SHFCA was the first formally constituted fuel cell and hydrogen industry body in the UK and remains the only UK industry body representing both fuel cells and hydrogen industries. A list of current and prospective members is also attached.

The Scottish Hydrogen & Fuel Cell Association:

- Brings together the expertise and experience of Scotland's specialised fuel cell companies, academic, teaching, research and development bodies, methane generation companies, a variety of consultants, Scottish Enterprise and local enterprise companies, and students and individuals with an interest in the subject.
- Provides a coherent voice to represent, promote and develop Scottish hydrogen and fuel cell technologies.
- Engages with Scottish, UK and EU government bodies to create the right framework for the industry to develop.

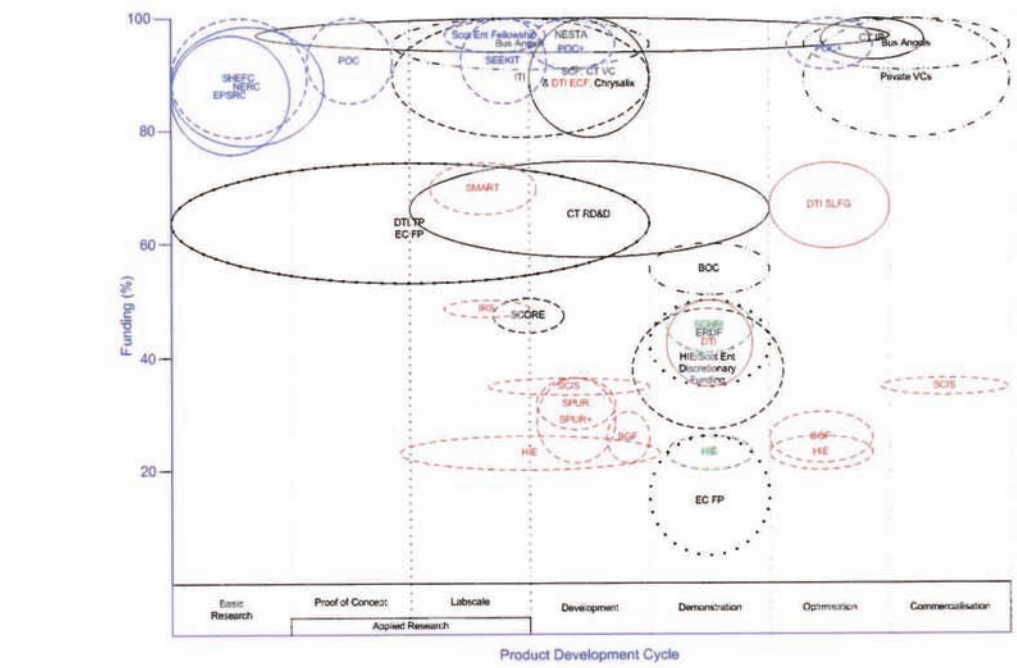
- Is developing relationships with other national and international hydrogen and fuel cell bodies, to work together to evolve a mutually beneficial strategy to create and develop a sustainable hydrogen and fuel cell market.
- Is a non-profit membership-based organisation. Membership has grown organically and currently stands at 40 organisations and 80 named representatives.
- Participates in, and represents members' interests in, national and international events, for, conferences and exhibitions.
- Holds regular open meetings dealing with a wide range of fuel cell and hydrogen topics.

St Andrews Fuel Cells Ltd is a privately owned company, spun out from the University of St Andrews and incorporated in February 2005. The company is based on the SOFCroll, an exciting new geometry for solid oxide fuel cells (SOFCs). This patent protected design promises a simpler manufacturing process and hence reduced costs, the main problem for the commercialisation of SOFCs at present. The Intellectual Property for the SOFCRoll design is very distinct, unlike the generic planar and tubular designs for which there is very complicated and competing IP

The company has had a careful and disciplined genesis, which was spurred by the patent application. The initial background development was assisted by Scottish Enterprise funding, to produce the working fuel cells, as proof of viability. The financial footings of the company have been enhanced by the award of a Royal Society of Edinburgh Enterprise Fellowship to Dr. Alan Feighery to produce a sound business plan for the commercial development of the SOFCRoll. The company has also received a Scottish Enterprise SMART:SCOTLAND award for the production of new and improved versions of the cell design. The company was accepted into the Carbon Trust Incubator Scheme and has recently received Carbon Trust R&D support and has Venture support. The company has a website, www.standrewsfuelcells.com, which contains further information on both the company and the technology.

APPENDIX 4: FUNDING FOR HYDROGEN AND FUEL CELLS

The diagram below is from a report commissioned by the Scottish Executive[4] and shows a diagrammatic representation of the various funding schemes applicable over the product development cycle. This demonstrates that there is a wide variety of funding and funding bodies, particularly during the early stages of product development, however, there is no dedicated grant assistance scheme primarily targeting the development of Scottish- (or UK-) based fuel cell and hydrogen activities.



The following key provides a description of the graph's features:

- Black – funding may support a variety of actors
- Blue – funding support for research organisations and universities
- Red – funding support for SMEs
- Green – funding support for community-based organisations
- Dashed Line – funding support from Scottish-based organisations
- Bold Line – funding support from UK-based organisations
- Dotted Line – funding support from European organisations
- Dash-Dot Line – funding support from private organisations

The greater the height of the bubble the greater the funding that could be available to an individual project. For example, the IRS (Investment Readiness Support from the Scottish Enterprise) is in the grouping for up to £25,000 whereas the EC FP and Private VCs is in the grouping for greater than £500,000. The bubbles also represent the maximum percentage of funding available from any one scheme as well as the maximum funding amount.

[4] *The Potential for Hydrogen and Fuel Cell Development in Scotland,* Revised Interim Report, October 2005, IPA Energy Consulting

APPENDIX 5: CURRENT SHFCA MEMBERS

- B2M Ltd.
- Berwickshire Housing Association
- Business Environment Partnership
- Cenergie plc
- Ceramic Fuel Cells Ltd.
- Charles Peterson (individual)
- CMR Fuel Cells Ltd.
- Coastal Resources Ltd.
- Delta Energy & Environment
- Fife Energy Ltd.
- Fuel Cell Markets Ltd.
- Fuel Cells (Scotland) Ltd.
- Greenheat Systems Ltd.
- Heriot-Watt University
- Highlands & Islands Enterprise
- Intelligent Energy
- ITI Energy
- Luichart Technology
- Micro Power Energy Ltd.
- Mike Kettle (individual)
- Napier University
- Nigel Holmes (individual)
- P-21 GmbH
- Paul Murphy (individual)
- Peak Scientific Ltd.
- Read Associates
- Robert Gordon's University
- SBG Lanarkshire
- Scottish Power plc
- Sgurr Energy
- siGen Ltd.
- TUV-NEL
- University of Edinburgh
- University of Glasgow

- University of St Andrews
- University of Strathclyde (2 depts)
- Unst Partnership
- AREG (tbc)
- Energy Institute (tbc)
- Air Products (prospect)
- UTC (prospect)
- Onsite Power Systems (prospect)
- Scottish & Southern Energy (prospect)
- BP (prospect)
- Scottish Coal (prospect)

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ISBN 0-7559-5148-4

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