A Hydrogen Framework for the East Midlands

A report prepared for *emda*

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Disclaimer

This work was by Cenex, assisted by Bryte Energy and the TBAT Innovation Limited, with funding provided by East Midlands Development Agency (emda).

The review has been carried out under the terms of contract EMX06170 with emda. The information presented is based on a combination of public domain sources, data supplied by companies and engagement with stakeholders.

While the information is provided in good faith, the ideas presented in the report must be subject to further investigation, and take into account other factors not presented here, before being taken forward. Therefore the authors disclaim liability for any investment decisions made on the basis of the review.

Executive summary

This report offers an underpinning rationale for the support of a Midlands hydrogen cluster and a Regional Hydrogen Forum by demonstrating the range of capabilities of the offering of the wider grouping of Midlands organisations in hydrogen and fuel cell technologies, and taking forward the work of the British Midlands Hydrogen Forum.

The generic case for support of hydrogen technologies – based on its use as a vector for clean renewable energy and the potential for security of energy supply – has been made by many parties, based on global market drivers and global opportunities. This study presents the case for hydrogen and fuel cells as providing *locational competitive advantage* to the Midlands, based on the presence of a regional cluster of capability plus additional unique factors offered by the Midlands region. A roadmap for development of the cluster, developed by focusing early deployment of technologies that build on the region's areas of particular strength, is proposed.

Advocacy for hydrogen and fuel cell activities has been, and will continue to be provided by national organisations. Advocacy for the interests of the region is best provided by a Regional Hydrogen Forum, building on the work of the British Midlands Hydrogen Forum, which should continue to represent the hydrogen and fuel cell interests *of the Midlands as a whole* on a national and international stage. As part of this work, it is crucial that the Forum should continue to support and nurture the developing UK-HyNet national hydrogen infrastructure project as part of its work in implementing regional project activity, specifically the Midlands Hydrogen Ring.

The Forum should aim for as wide a membership as possible, and therefore, in the short-medium term, membership fees are not recommended and funding support will be required for its operation by regional agencies. To increase the benefits offered by the Forum, it must have a long term plan to put activity, most notably deployment of hydrogen infrastructure, at the forefront of its work. Therefore the study proposes a three year work programme, whereby the Forum is funded initially by RDA support, but aims to supplement this income by seeking funding support from other national and European sources. During the three year period the Forum should transition its work from advocacy and networking to activity and project development to deliver long-term economic benefit to the region.

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1 Introduction

Cenex, together with Bryte Energy and TBAT Innovation Limited, have been commissioned by the East Midlands Development Agency (emda) to establish a technology framework to underpin current and future (East) Midlands activity in hydrogen and fuel cells.

The activity comprises two related workstreams:

- development of a Midlands Hydrogen Framework to identify regional capabilities in hydrogen and fuel cell (H2FC) technologies and project opportunities involving regional players
- establishment of an effective constitutional model and business plan for a Hydrogen Forum for the East Midlands. The forum's aim is to build on the achievements of the British Midlands Hydrogen Forum (BMHF) that was established in 2007 in order to promote the ongoing development of the hydrogen economy in the Midlands

1.1 Why hydrogen and fuel cells in the Midlands?

The Midlands is host to a cluster of technology companies and universities with world leading capabilities in hydrogen and fuel cell technologies. The development of this cluster – which includes Intelligent Energy and Rolls Royce Fuel Cells – has occurred gradually over a 20 year timeframe. Over the next five to 20 years there are three scenarios for the development of the cluster:

- The first scenario would see the cluster grow significantly (with associated GVA and employment) as the companies and universities in the region exploit the commercialisation of hydrogen and fuel cell technologies in consumer and business products and services.
- The second scenario would see region's players lose out to international competition.
- The third scenario would see hydrogen and fuel cell technologies fail to penetrate the market because macro-economic barriers to market entry (performance, cost, consumer acceptance issues, competition, etc) are not overcome.

The British Midlands Hydrogen Forum (BMHF) was formed in 2007 by a number of industry and academic organisations from across the East and West Midlands active in

H2FC development. These regional stakeholders wished to promote their capabilities and those of the region in order to demonstrate 'critical mass' and to help attract greater investment, both through government Research Development and Demonstration (RD&D) funding and from private sector investment. The BMHF was previously funded and supported by Cenex and the national Low Carbon and Fuel Cell Technology Knowledge Transfer Network (LCFC KTN). This KTN funding ceased in Q1 2009 as a result of the restructuring of the KTN portfolio by the Technology Strategy Board (TSB).

1.2 Approach

This project aims to build on the achievements of the BMHF in two ways:

- development of a 'Midlands Hydrogen Technology Framework' for future Midlands hydrogen and fuel cell activities. The resulting framework will be used to identify and broker hydrogen technology demonstration project opportunities involving regional players capable of showcasing regional strengths. The project opportunities identified will assist supply chain development for regional technology providers and academic institutions active in research, development, demonstration and deployment (RDD&D) of hydrogen technologies.
- establishment of an effective constitutional model and business plan for an East-Midlands-led Midlands Hydrogen Forum. The forum's aim is to build on the achievements of the British Midlands Hydrogen Forum (BMHF) by promoting the ongoing development of the hydrogen economy in the Midlands and defining a means of developing effective relationships with key stakeholders in other regions nationally and internationally.

1.3 Report deliverables

The report has five main aims:

- to benchmark regional capabilities in hydrogen and fuel cell technologies
- to define a set of project proposals for hydrogen technology activities capable of showcasing regional capabilities
- to develop a regional hydrogen roadmap for key business propositions associated with a hydrogen economy
- to formulate, consult on and implement a new constitutional format for a regional hydrogen forum (as a successor to the British Midlands Hydrogen Forum) to own the Hydrogen Technology Framework and to take forward the project opportunities
- establishment of a case for long-term operation of the hydrogen forum

1.4 Drivers for support

This section looks briefly at recent economic and environmental policy developments on a national and regional level that support, or promote the need for further development of, low carbon technologies including hydrogen and fuel cells.

1.4.1 National economic drivers

Prior to the 2010 general election the role of public sector policy support for innovation in low carbon technologies (via RD&D funding, public procurement, etc) was recognised by national government in its policy initiative *New Industry, New Jobs: Building Britain's Future* (BERR, 2009).

Importantly, a decision was made by the Government of the time to launch this new policy initiative in the East Midlands (at Loughborough University) on 20th April 2009 in recognition (as the Prime Minister acknowledged in his speech) of the region's positioning as hosting world-leading university and industry innovation. Hydrogen and fuel cell technologies were at the centre of this positioning, with the Prime Minister, Secretary of State for Business, Enterprise and Regulatory Reform, Secretary of State for Universities, Innovation and Skills and the Minister for the East Midlands, all visiting Intelligent Energy to learn about its hydrogen and fuel cell programmes.

Figure 1. Prime Minister Gordon Brown visiting Intelligent Energy in April 2009

At the time of writing (June 2010) the approach of the Coalition Government to strategic innovation support is yet to be completely articulated, although it is clear that initiatives requiring funding will come under intense scrutiny. Prime Minister David Cameron, in

his first major speech, has however referenced the urgent need to rebalance the UK economy and to support growing industries, including high-value manufacturing and low carbon technology and the need to support areas outside London (http://www.number10.gov.uk/news/speeches-and-transcripts/2010/05/transforming-the-british-economy-coalition-strategy-for-economic-growth-51132).

1.4.2 National environmental drivers

Since the adoption of the Kyoto protocol in 1997, there has been significant activity worldwide aimed at reducing emissions of greenhouse gases, particularly carbon dioxide. This section briefly looks at two most significant UK Government initiatives in recent times.

1.4.2.1 *Climate Change Act – November 2008*

Climate Change Act of 2008 (CCA, 2008) made the UK the first country to establish a binding long-term framework to tackle climate change. The central provisions of the act:

- Set a UK national greenhouse gas emissions reduction target of 80% by 2050 relative to 1990 levels, as discussed in 3.9 above
- Established an interim target of a 26% CO_2 reduction by 2020
- Set five yearly carbon budgets from 2008
- Launched the Committee on Climate Change

1.4.2.2 *Committee on Climate Change*

Chaired by Lord Turner, the Committee on Climate Change (CCC) is an independent body which advises the Government on emissions targets and reports on progress made in reducing GHG levels to reach the targets established by the CCA.

In its 2008 report the CCC recognises the possible future role of hydrogen in the decarbonisation of transport, but posits battery electric vehicles as a nearer term technology, citing barriers to present hydrogen vehicle uptake of infrastructure, storage and safety. It is pessimistic about the impact of hydrogen vehicles in any of the UK's carbon budgets up to 2024 (CCC, 2008, p264).

1.4.3 East Midlands regional drivers

1.4.3.1 *Emda Regional Economic Strategy*

Covering 2006-2020, emda's Regional Economic Strategy (emda, 2006) highlighted the central role of low carbon technologies in the region's future. The report notes the challenge of responding to climate change and the need to reduce energy and resource demand and the opportunities presented by the exploitation of new and growing low carbon markets.

In terms of utilising renewable energy technologies, the report focuses on the regional need to:

- create a renewables investment plan
- promote demand for and showcase renewables technologies
- support supply chain development to ensure regional economic benefit from renewables investments

With respect to exploiting low carbon market opportunities, it is relevant for this project that the strategy states the need for:

- regional awareness raising and communications campaign
- provision of dedicated low carbon business support
- creation of stronger linkages between the private sector and Higher Education Institutions active in low carbon R&D

Regional capabilities in low carbon and fuel cell technologies highlighted include Rolls-Royce and the universities of Loughborough, Nottingham and Northampton.

1.4.3.2 *Emda Regional Innovation Strategy*

Originally published by East Midlands Innovation in parallel with the regional economic strategy in 2006, the emda Regional Innovation Strategy (RIS) notes the region's 'innovation deficit': business spending on R&D was relatively 1.8% of GVA in 2002, compared to a national average of 1.4%, but only 4% of associated business turnover related to new products in the East Midlands, compared to a UK average of 9%. The strategy emphasises two critical issues for the region:

- Lack of innovation in manufacturing

- Concentration of R&D with large companies

Part of the strategy involved creation of regional iNets (innovation networks) in Transport, Food and Drink, Sustainable Construction and Healthcare and Bioscience as part of the regional innovation support programme. iNets will be discussed further in relation to the Midlands Hydrogen Forum in Part III of this report.

A revised RIS (2010-13) concentrates on four regional strengths aligned with four national Government priority areas (EMI, 2009):

- Advanced manufacturing
- Low carbon
- Life sciences
- Digital enabling technologies

The advanced manufacturing and low carbon strands are of particular relevance to the project. Considering advanced manufacturing, the report highlights the £40m Manufacturing Technology Centre near Coventry: jointly funded by AWM and emda, partners in the project include Rolls-Royce, Jaguar Land Rover, Aero Engine Controls and Airbus UK, plus the universities of Birmingham, Nottingham and Loughborough. The Centre is due to open in 2011. Turning to low carbon, the study notes that the sector supports almost 3,400 companies in the East Midlands employing over 61,000 people. Key regional players include E.ON (with its global R&D headquarters in the region), Rolls-Royce, Intelligent Energy, BAE Systems Integration, Toyota and Bombardier. Targeted innovation support for this sector is therefore a key regional priority.

Low carbon regional strengths highlighted are:

- energy and manufacturing heritages, including energy conversion and coal
- physical opportunities for the developing new energy technologies such as off-shore wind
- world class energy and low carbon research facilities, including: the Energy Technologies Institute, Loughborough University's Centre for Renewable Energy Systems Technology (CREST), The University of Nottingham's specialist facilities in the built environment and Cenex

1.4.3.3 *East midlands Regional Energy Strategy*

Published in 2004 by the East Midlands Regional Assembly (EMRA) and updated in 2007 with an action plan, the East Midlands Regional Energy Strategy (RES) aims to provide a framework for a sustainable approach to energy across the region (EMRA, 2004 and

2007). The strategy offers a number of regional policy initiatives which are of relevance to H2FC technologies, some of which are listed below – those of particular interest to the project are highlighted in bold:

ENG1 – reduction of greenhouse gases

ENG5 – **skills and knowledge development to respond to the changing energy market**

ENG 7 – promote and support energy efficiency to improve the competitiveness of the regional industrial base

ENG 10 – to ensure increasing amounts of electricity are generated from renewable sources

EMG 13 – encourage the uptake of domestic and small scale energy generation

ENG 16 – support energy generation and supply industries and promote shift to a low carbon economy

ENG 17 – **encourage research into new and emerging technologies and support mechanisms for their deployment**.

Two emda-led workstreams from the RES – economic exploitation and skills for energy (led in the region by the Skills4Energy programme) - are of particular relevance to the Midlands Hydrogen Framework and also to the regional innovation and regional economic strategies discussed above; the GOEM awareness raising work is potentially relevant to the Midlands Hydrogen Forum. A refreshed strategy will be issued in 2010.

Part I. Hydrogen Technology Framework for the Midlands

2 Introducing the technology framework

As described by emda/East Midlands Innovation a *technology framework* identifies and prioritises technologies for investment (EMI, 2008). According to the *Technology Framework for the East Midlands 2009-2011* a framework should address:

- **what our technology priority areas should be:** where we should focus investment to best develop and exploit technology for the long term economic benefit of the region
- **what our key strategic objectives should be:** the four broad aims which together will create a supportive, attractive and profitable environment for technology-based companies and individuals
- **what actions we need to take to achieve our goals:** whether that be encouraging collaborative working, attracting inward investment, promoting the region or influencing policy makers

The four strategic objectives mentioned above are to:

- Enhance and exploit East Midlands' technological strengths and opportunities
- Improve the profile and influence of the East Midlands as a technological region
- Maximise investment for technology in the East Midlands
- Develop the supportive environment for technology development and exploitation in the East Midlands

The Midlands Hydrogen Framework will be assembled in alignment with these strategic objectives as summarised in Figure 2. The remainder of this introductory section offers a brief overview of each of the areas of the framework, and acts as a summary of the main body of the report contained in Parts II and III.

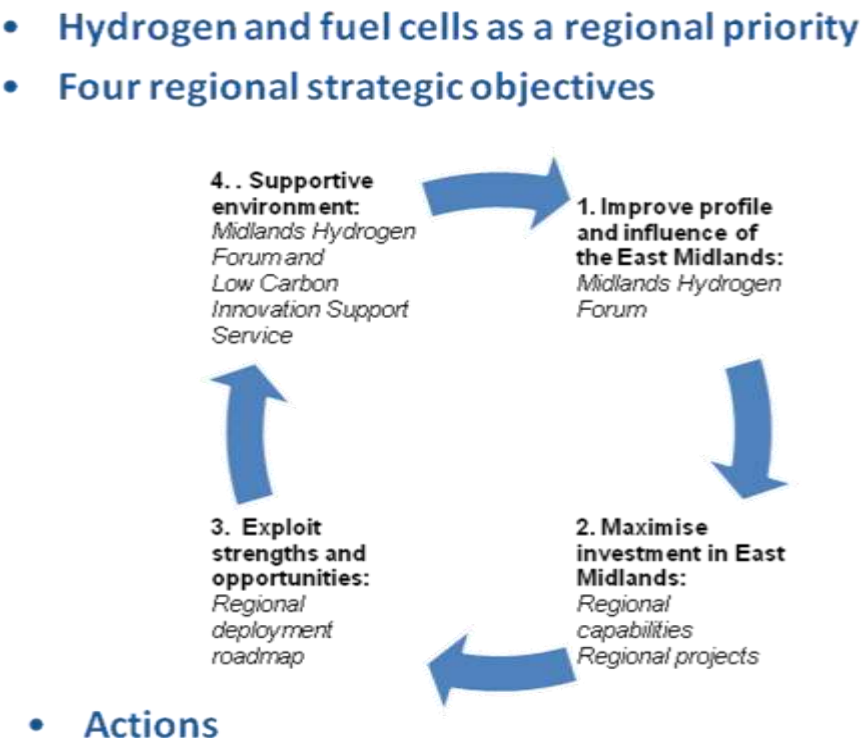


Figure 2. Midlands Hydrogen Framework

2.1 Hydrogen and fuel cells as a regional priority

Hydrogen and fuel cell (H2FC) technologies offer the potential for long-term economic and environmental benefit to the Midlands:

- economic: the Midlands is home to a UK-leading cluster of H2FC organisations with the potential to exploit the transition to a low carbon economy
- environmental: H2FC technologies offer the potential to play a leading part in helping the UK meet its climate targets for 2050

2.2 Hydrogen and fuel cells and regional strategic objectives

2.2.1 Enhance and exploit East Midlands' technological strengths and opportunities – the Midlands Hydrogen Forum

The British Midlands Hydrogen Forum was formed in 2007 with support from Cenex and the Low Carbon and Fuel Cell Technology KTN to showcase regional capabilities by raising the profile of the region and positioning the Midlands to play a leadership role in national and European agenda setting for RD&D priorities (with a particular focus on demonstration) and latterly to aid the region to win a share of available funding. Emda and Advantage West Midlands (AWM) contributed to funding tasks undertaken by the BMHF under the 'British Midlands' collaboration between the two RDAs. The RDA contributions were particularly important in taking forward the inward investment agenda. The BMHF successfully pursued its objectives through to 2009, and now has 132 members from 65 companies.

Headline achievements of the British Midlands Hydrogen Forum have included:

- *Establishing a community of H_2 & FC stakeholder*
- *Establishing a brand*
- *Initiating the Midlands Hydrogen Ring project*
- *Encouraging further collaboration within the region*
- *Encouraging collaboration beyond the region*
- *Representation with Government*
- *Raising the profile of the region on the international stage*

This work has offered a number of benefits to regional players. Without the ongoing support mechanism provided by the BMHF there is a risk that stakeholders within the region will end up chasing opportunities to participate in other regions' project proposals rather than be part of leading edge region led projects.

This project seeks to re-energise the BMHF (as an updated Forum\Community Grouping) off the back of the strategic analysis of regional resources, capabilities and opportunities presented in Part II. The process of analysing the way forward for the forum by assessing the strengths and weaknesses of potential operational models, and engaging the regional H2FC community to provide work programme for the forum driven from the 'bottom-up', is described in Part III.

2.2.2 Maximise investment in the East Midlands – regional capabilities and regional projects

The East Midlands has a number of innovative companies working in this field, such as Intelligent Energy and Rolls Royce Fuel Cells, plus significant academic strength from its universities in Loughborough and Nottingham, the combined East and West Midlands offers a package of competencies that is at least the equal to other UK areas, particularly with the inclusion of the academic strength of the University of Birmingham and the significant automotive capability offered by the West Midland cluster.

A summary of areas of particular regional strength in the production, distribution and use of hydrogen is given below – this is discussed in detail in Chapter 4:

Table 1. Summary of regional strengths in hydrogen and fuel cells (organisations from outside the Midlands, but members of the BMHF, are shown in italics)

Area of strength		Organisation
Products and technologies	Electrolysis	Bryte, *ITM*
	Solid state H_2 storage	Universities of Birmingham & Nottingham
	H_2 refuelling	Universities of Birmingham, Coventry & Loughborough, *ITM*
	Solid oxide fuel cells	Rolls Royce Fuel Cells, University of Birmingham
	Proton exchange membrane fuel cells	Intelligent Energy, Universities of Birmingham, Loughborough & Nottingham
	Systems architecture	Intelligent Energy, *ITM*
	Fuel cell vehicles	Intelligent Energy, Microcab, University of Birmingham
Services	Demonstration	Cenex, Midlands Hydrogen Ring
	Education	Midlands Energy Consortium members (Birmingham, Loughborough, Nottingham)
	Energy system integration	Bryte, ICE, *TNEI*
	Power generation	E.ON

In order to exploit these strengths, the project has continued the activities of the British Midlands Hydrogen Forum and Cenex by assisting and brokering projects aligned to

these priorities. It is particularly emphasised that the Midlands Hydrogen Ring infrastructure project should be pursued as vigorously as possible to continue to build on the region's acknowledged strength in demonstration activities and to provide competitive advantage to the region.

2.2.3 Maximise investment for technology in the Midlands – regional deployment roadmap

A number of hydrogen roadmaps, such as that of the Roads2HyCom programme, exist that anticipate an accelerated take-up of hydrogen and fuel cell technologies world wide from 2020 onwards. In the long term (2050) the consensus of all these studies is that the majority of hydrogen use will be in transport. Stationary fuel cells for combined heat and power will be common, but these will mainly use natural gas or other non-hydrogen fuels. In the Roads2HyCom scenario, the use of hydrogen builds with the use of brown (i.e., non-renewable) by-product hydrogen. From 2020 onwards decarbonised energy sources boost centralised production as mass-market uptake of hydrogen technologies takes hold.

Chapter 3 describes the introduction of hydrogen into the UK national energy system as a natural consequence of the shift to low carbon generation. The uptake of hydrogen technologies in the Midlands could mirror the UK national picture. Alternatively, the Midlands could take a proactive approach, and by adopting hydrogen as a central technology area aimed towards the early deployment of technologies that feed the areas of Midlands strength in hydrogen production, distribution and use shown in Table 1. A scenario for the proactive deployment of hydrogen technology aligned with these regional strengths is presented in Chapter 6.

2.2.4 Develop the supportive environment for technology development and exploitation in the East Midlands – Midlands Hydrogen Forum and the Low Carbon Innovation Support Service

The East Midlands Regional Innovation Strategy (RIS) offers four regional priority sectors (food and drink, transport, healthcare and bioscience and sustainable construction), each with its own dedicated innovation network or *iNet*. Hydrogen and fuel cell technologies are of significant long-term relevance to the transport sector, and of some relevance to sustainable construction; it is also true however that the Transport iNet has much to cover, particularly in addressing *current* issues in aerospace, automotive, marine, motorsport and rail. While it is possible that emda-based SMEs operating in H2FCs will be able to tap into research and development (R&D) and Innovation Support Grants through the iNet, it is less clear that the service will be able to offer the levels of tailored support and linkages/knowledge that are required by local SMEs working in the

emerging area of H2FCs, and more importantly perhaps, by SMEs wishing to enter or engage with the regional H2FC sector. The RIS recognises the need for a comprehensive Low Carbon Innovation Support Service (LCISS) to address specifically the needs of the emerging low carbon sector; support dedicated to H2FC technologies, such as the Midlands Hydrogen Forum, should therefore be designed to fit within the proposed LCISS.

2.3 Actions

A summary list of actions recommended by this study to deliver the Midlands Hydrogen Framework is presented below. The majority of actions relate to the outcomes of the work on the regional hydrogen forum described in Part III.

Action 1. Consider the region's capabilities as a Midlands proposition, not just East Midlands

Rationale: The product and technology capabilities of the region cover all aspects of production, distribution and use of hydrogen, and also cover all parts of the innovation chain from R&D to deployment. The importance of East Midlands' players such as Intelligent Energy and Rolls Royce Fuel Cells is clear, but it is equally apparent that the capabilities of the Midlands *as a whole* are more compelling than when viewed solely from an East or West Midlands' perspective.

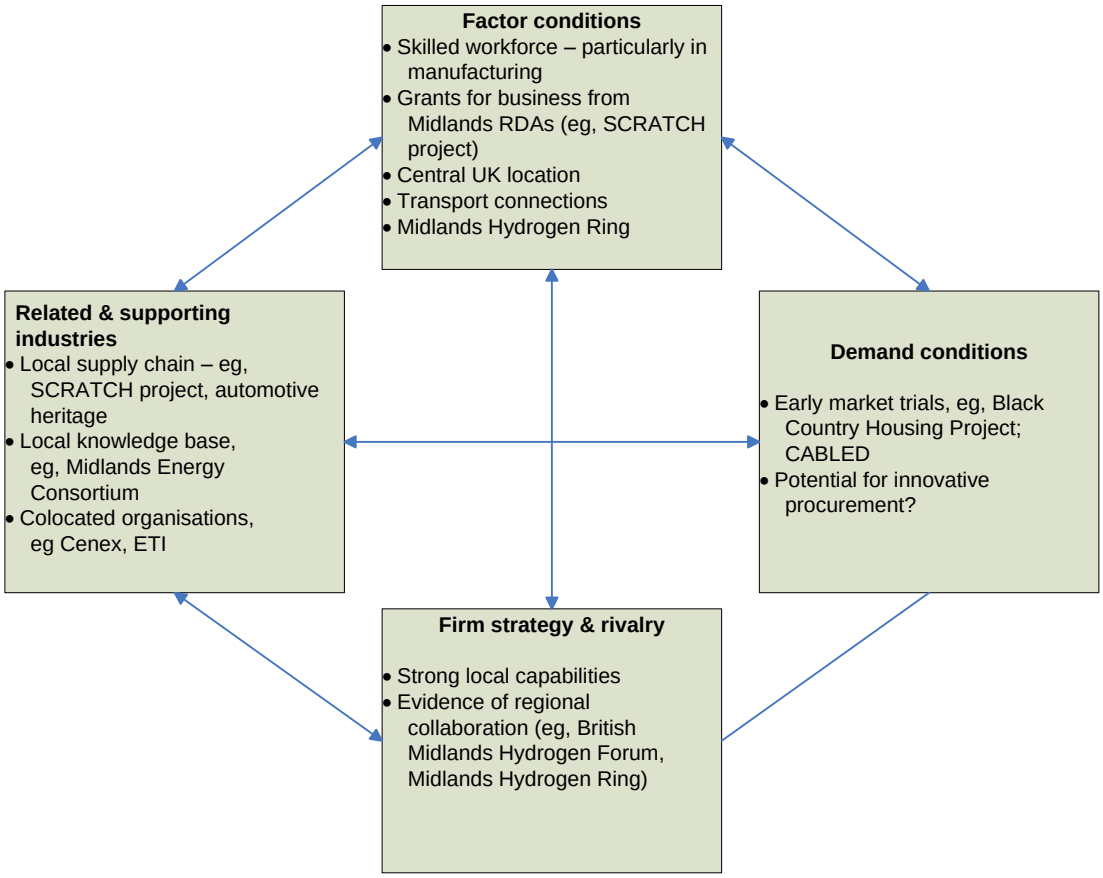


Figure 3. Competitive advantage of the Midlands (based on Porter, 1990)

That the Midlands Development Agencies and other actors, such as Inward Investment support, should work together was also a clear and consistent demand from stakeholders engaged by this study. The demise of the British Midlands collective brand has increased the perception that the regions spend more time competing than seeking areas of mutual benefit.

Stakeholder feedback

"The UK is a small country with limited resources. RDAs & other sector organisations should pool and target their resources and share knowledge in order to be more effective"

"Competition between the regions hampers development of the sector"

Action 2. RDA(s) need(s) to back the Regional Hydrogen Forum with at least three years of secure funding. The Forum should leverage all possible sources of funding – direct RDA, Inward Investment, European (eg, ERDF) – to build mass and supplement/replace its RDA funding

Rationale: The decay of activity from the British Midlands Hydrogen Forum following its loss of funding has been clear. In order to implement the long-term workplan which establishes the Forum as a central part of the UK hydrogen landscape presented in Chapter 10, and to take forward the project opportunities such as the Midlands Hydrogen Ring described in Chapter 5, long-term assured funding is required.

Action 3. Keep Hydrogen Forum membership free for at least its first three years to encourage as wide a membership as possible

Rationale: The British Midlands Hydrogen Forum (BMHF) has 132 members from 65 companies. 18 organisations are based in the West Midlands and 21 in the East Midlands, while others are involved in hydrogen and fuel cell activities in one of the Midlands regions, but are based elsewhere in the UK. Amongst the rationale for supporting the Forum for the next three years is to grow the membership beyond those companies whose main interests are in H2FC technologies in order to nurture a supply chain to satisfy the undoubtedly massive potential market for these technologies. Keeping membership free is the best way to encourage the participation of regional SMEs and to draw them into the sector.

Action 4. Hydrogen Forum should run a high-profile event every six months to grow its membership

Rationale: This action is also designed to grow membership of the Forum significantly, and to draw in players from outside of those currently in the H2FC field.

Action 5. Hydrogen Forum should publish a renewed and rebranded capability guide to sell the region's advantages

Rationale: The first guide to the hydrogen and fuel cell capabilities of the Midlands was published by the British Midlands Hydrogen Forum in October 2007 to promote the region at the internationally-renowned Grove Fuel Cell Conference in London. This study has produced a comprehensive update of the regional capabilities and activities as presented in Chapter 4. This should be used by the Forum, the Regional Development Agencies and other players to promote the region on a national and international stage.

Action 6. Hydrogen Forum should continue to engage with the national landscape to promote regional interests

Rationale: Since 2007, the Chair of the British Midlands Hydrogen Forum has worked to promote the region's interest on the national and international stage. Supported by a number of leading industrial players as well as the Regional Development Agencies, the putative UK-HyNet national hydrogen infrastructure network offers the Midlands a significant opportunity to elevate its profile nationally and internationally.

Action 7. Hydrogen Forum must take forward project activities, particularly the Midlands Hydrogen Ring, to ensure its sustainability and credibility

Rationale: The most consistent message from stakeholder consultation during the project was the need for the Forum to build on its membership base and advocacy work to achieve tangible results. In keeping with the theme of the UK-HyNet project, many of those interviewed stated that the main assistance that regional support could give to the H2FC industry is by developing a regional hydrogen fuelling infrastructure that would help attract interest and investment from international car manufacturers (OEMs). As noted in Chapter 5, the Midlands currently has the most hydrogen fuelling infrastructure in the UK. Continued development of this regional strength, plus some of the other projects identified in Chapter 5, will help build the case for further support for the Forum.

Stakeholder feedback

"The Hydrogen Ring project has not been pursued with sufficient vigour and this has diminished the forum's credibility"

"The Hydrogen Ring project is vital if the Midlands is to continue to maintain its high profile in the face of regional competition from London and Wales"

"Other activities of the forum (e.g., EU networking) must complement rather than replace proactive local networking and project work"

"Forum without project activity will simply be seen as a talking shop"

"Forum with project activity will simply be another organisation in the landscape"

Action 8. Central role for the Hydrogen Forum should be SME and supply chain development and project brokerage. This work must build on past/current emda work (e.g., low carbon supply chain mapping) to create a plan to establish a local supply chain. The Forum should play a central role in the proposed Low Carbon Innovation Support Service

Rationale: This final action underpins many of the previous actions. Emda must use the Forum to maximum advantage; the best way it can achieve that is to integrate it fully into its low carbon business support services in order to deliver maximum return on its investment.

Part II. Building the Midlands Hydrogen Framework

3 The case for hydrogen and fuel cells as a technology priority area for the Midlands

3.1 Introduction

In addressing the need for strategic support for regional hydrogen and fuel cell capabilities, it is important to understand the role of hydrogen in the current and future economy.

3.2 The market opportunity

Projecting the future market value for hydrogen and fuel cell technologies is notoriously challenging, and there have been many overly-optimistic projections published in the past.

Among recently-published figures for example, the Carbon Trust in October 2009 stated that, if fuel cell system costs could be reduced, the global market could be worth $26bn+ in 2020, rising to $180bn+ in 2050; the UK's share could be $1bn in 2020 and $9bn in 2050 (CT, 2009). In the nearer term, a recent study by the Freedonia Group states that the world fuel cell industry is currently worth $570m annually, but that demand will triple by 2013. While the main market opportunity is the near future is in portable fuel cell systems, ultimately, as discussed later in the report, the most valuable market potential is offered by transportation (http://www.freedoniagroup.com/World-Fuel-Cells.html).

3.3 Why hydrogen and fuel cells?

The two main challenges for future energy use and supply scenarios are security of energy supply and climate change (Ball, 2009). Hydrogen and fuel cells are distinct, but synergistic, technologies that offer the potential for low and ultimately zero CO_2 emissions, and improved energy security as well as other benefits including improved energy efficiency and lower urban air pollution when used as a transport fuel.

The sections below present a very brief summary of the production of hydrogen and its use in fuel cells. For a much fuller presentation, see for example Ball (2009).

3.4 Hydrogen as a fuel

Hydrogen is the lightest element. Although by far the most abundant element in the universe (constituting 75% of its visible mass), hydrogen effectively does not exist in its unbound state on earth – an indication of its reactivity. Hydrogen therefore is an energy vector – i.e., it requires a source of primary energy to make it.

Hydrogen has a boiling point of -253°C at atmospheric pressure – one reason that storage of sufficient hydrogen to act as a fuel in vehicle applications is extremely challenging.

Despite the difficulties of storing hydrogen, it offers many attractions as fuel. In its reaction with oxygen to produce water (in this case through combustion), hydrogen has the highest energy to weight ratio of any fuel – for example, hydrogen has almost three times the energy content of gasoline by weight. However, on a volumetric basis the situation is less favourable, and hydrogen only has around a quarter of the volumetric energy density of gasoline. It is interesting to note however that, even on a volumetric basis, hydrogen offers much greater energy storage capability than other energy storage devices, such as batteries and supercapacitors (Figure 4).

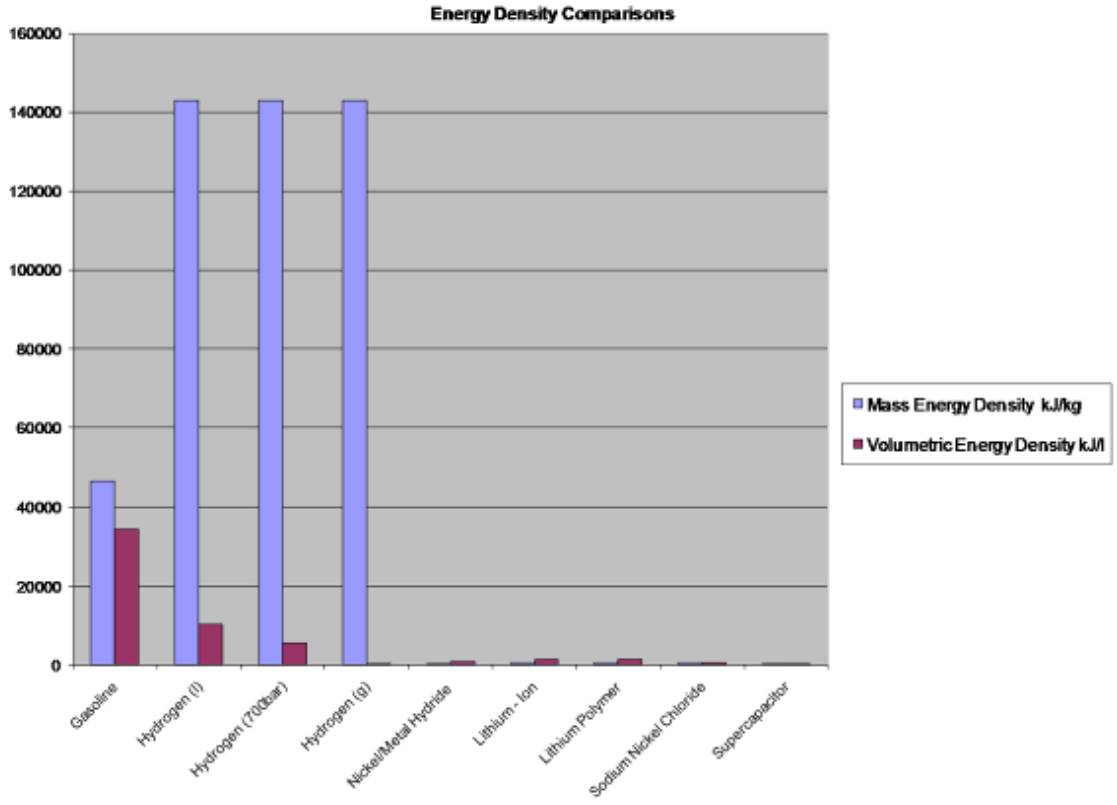


Figure 4. Energy storage comparison

3.5 Production of hydrogen

3.5.1 Hydrocarbon sources

It is estimated that over 50m tons of hydrogen are produced worldwide annually, equating to 140m tons of oil equivalent or less than 2% of the world's energy needs. Of the total, over 95% is produced from fossil fuel sources via the two reaction steps shown below:

$$\{\text{Hydrocarbon}\} \rightarrow H_2 + CO_2 + CO$$

$$CO + H_2O \rightarrow H_2 + CO_2$$

Over half of the hydrogen produced annually originates from steam reforming of methane (Olah, 2006, Figure 5).

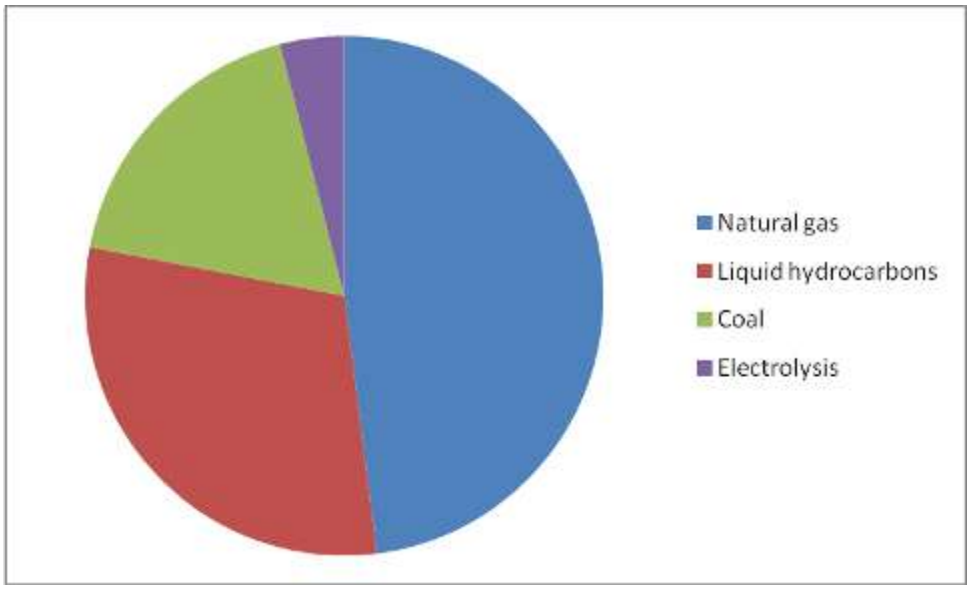


Figure 5. Production of hydrogen (source: Olah, 2006)

Methane has the highest hydrogen:carbon ratio of any hydrocarbon, and therefore releases less CO_2 per unit of hydrogen production. Coal is a particularly carbon intensive source of hydrogen. Future 'clean coal' production technologies incorporating pre-combustion carbon capture and storage offer a possible route to 'clean' fossil fuel sourced hydrogen.

All fossil fuel hydrogen production methods suffer from the fact that ultimately CO_2 is a by-product, and therefore any possible large-scale low carbon hydrogen production by such methods in the future is likely to require the use carbon capture and storage. Clean up of the hydrogen produced from hydrocarbons, and particularly coal, to a level of purity required at present for pharmaceutical or food processing purposes, or in the future for fuel cell vehicles, is also expensive.

3.5.2 Electrolysis

Electrolysis refers to the cleavage of water by electricity to produce hydrogen and oxygen. The basic reaction of electrolysis is shown below:

$$2H_2O \rightarrow 2H_2 + O_2$$

Although hydrocarbon sources of hydrogen currently dominate world production electrolysis using renewable or nuclear electricity offers the cleanest and most efficient method of generating hydrogen with respect to greenhouse gas emissions, and is also a

source of high purity hydrogen in current applications such as the food manufacturing and pharmaceutical industries. It is therefore the subject of intense research to reduce costs.

As well as the core electrolysis unit, electrolysers (like fuel cells) feature significant amounts of other equipment that make up the balance of plant (see Figure 6 for a schematic). Thus, while a number of technical challenges need to be overcome before they are ready for mass deployment, the potential rollout of significant electrolytic capacity offers a huge opportunity to UK companies to develop capability and supply chains.

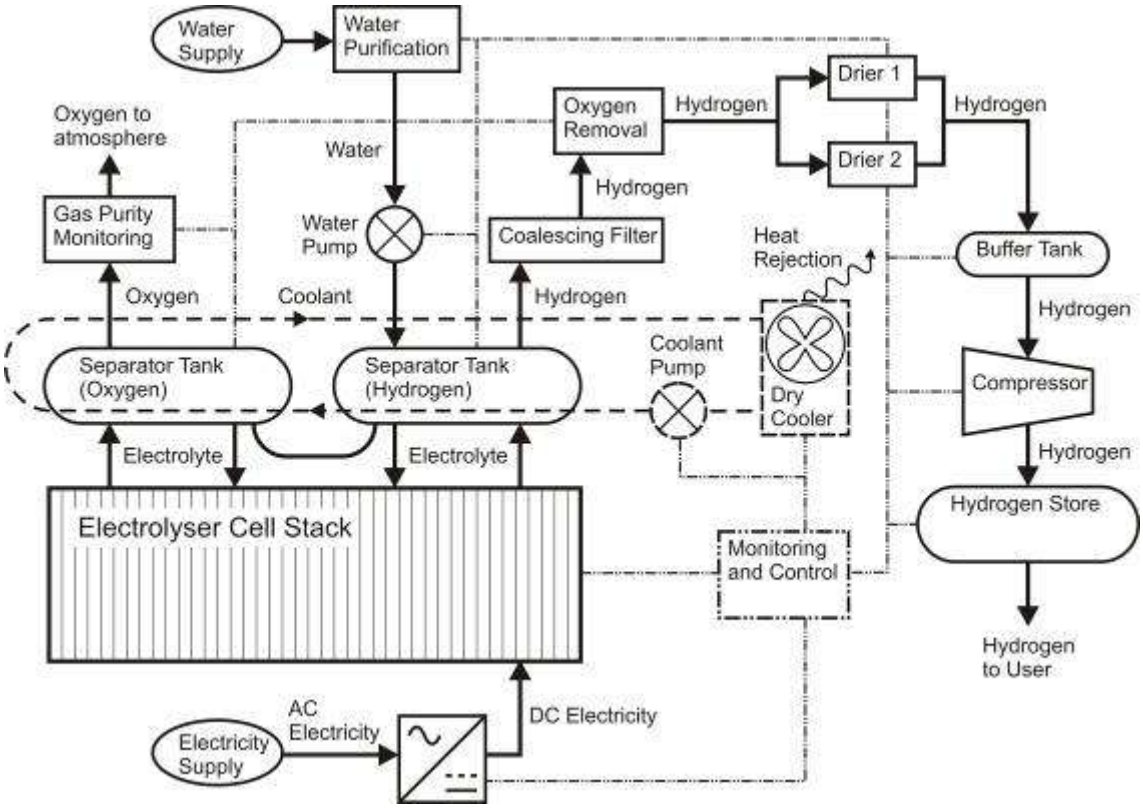


Figure 6. Electrolyser schematic (source: Bryte Energy)

3.6 Current uses of hydrogen

At present, over three quarters of the world's hydrogen production is used to make ammonia (and therefore fertilisers) and in oil refining as shown in Figure 7.

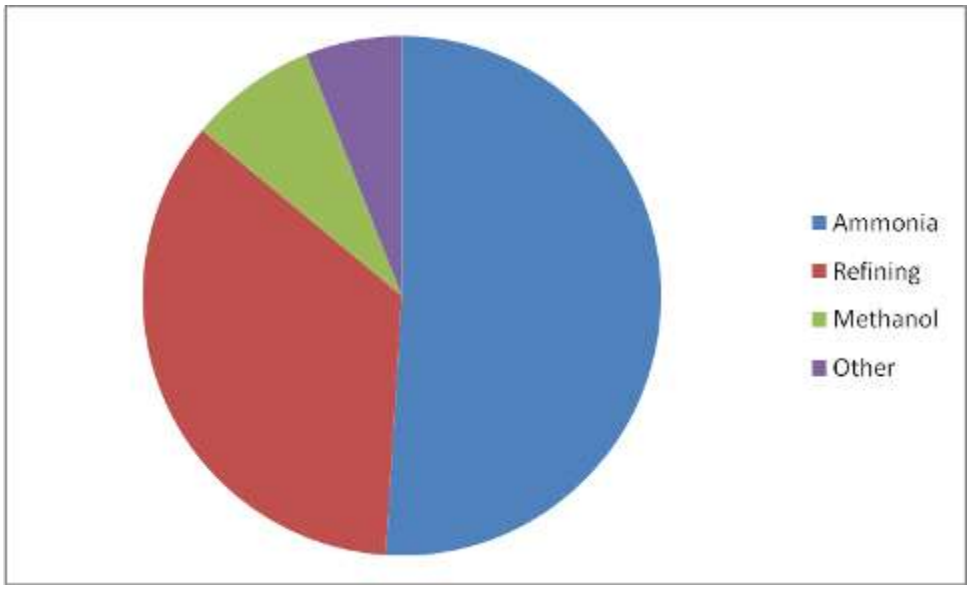


Figure 7. Current use of hydrogen (source: Olah, 2006)

3.7 Future energy use and the role of hydrogen

The hydrogen economy involves an extension of hydrogen utilisation from its current uses – in petroleum, petrochemical and other industrial applications – to its use as an energy vector providing energy for mobile, stationary and portable applications. Low carbon energy pathways in the current and future economy are summarised in Figure 8 which illustrates a number of potential pathways that use hydrogen as a sustainable energy vector. The pathways presented in the diagram will be discussed further below.

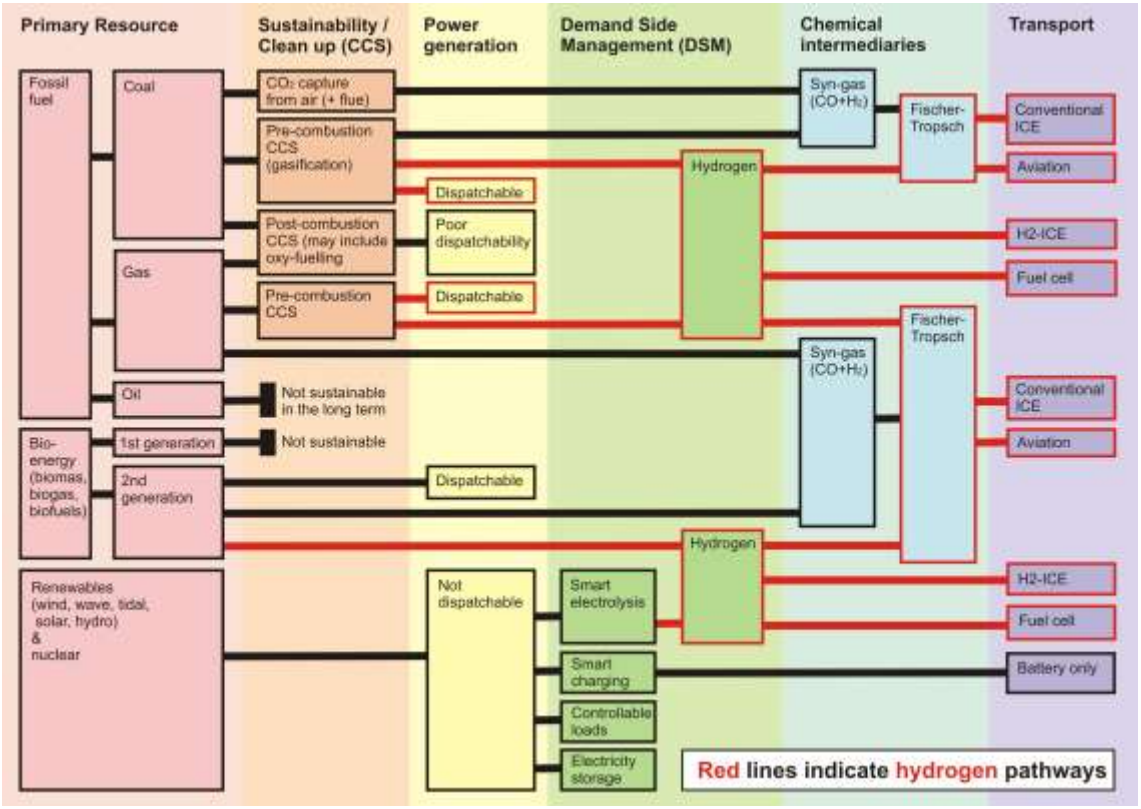


Figure 8. Low carbon energy pathways. Those involving hydrogen are shown in red (source: Bryte Energy)

3.8 Hydrogen in transport

Two means of harnessing the energy of hydrogen for in transport – the fuel cell and the internal combustion engine – are discussed very briefly below (for much fuller detail, see for example Ball, 2009; Kalhammer, 2007; Larminie, 2003 and EERE, 2001).

3.8.1 Fuel cells

A fuel cell converts the chemical energy of a fuel into electrical energy by electrochemical means. Able to operate on a variety of fuels, fuel cells are comparable to batteries, except they operate as *tertiary* cells – their fuel is continually replenished during operation and reaction products discharged – whereas batteries (whether primary or secondary) simply store and release energy by depleting their energy store.

3.8.1.1 *Operating principles*

In a fuel cell hydrogen (or a hydrogen rich stream) is reacted with oxygen to produce water and liberate heat. The proton exchange membrane (PEM) fuel cell, which is the

most promising fuel cell for transport use, is an example of a fuel cell which employs an acid electrolyte; a schematic of its operation is shown in Figure 9:

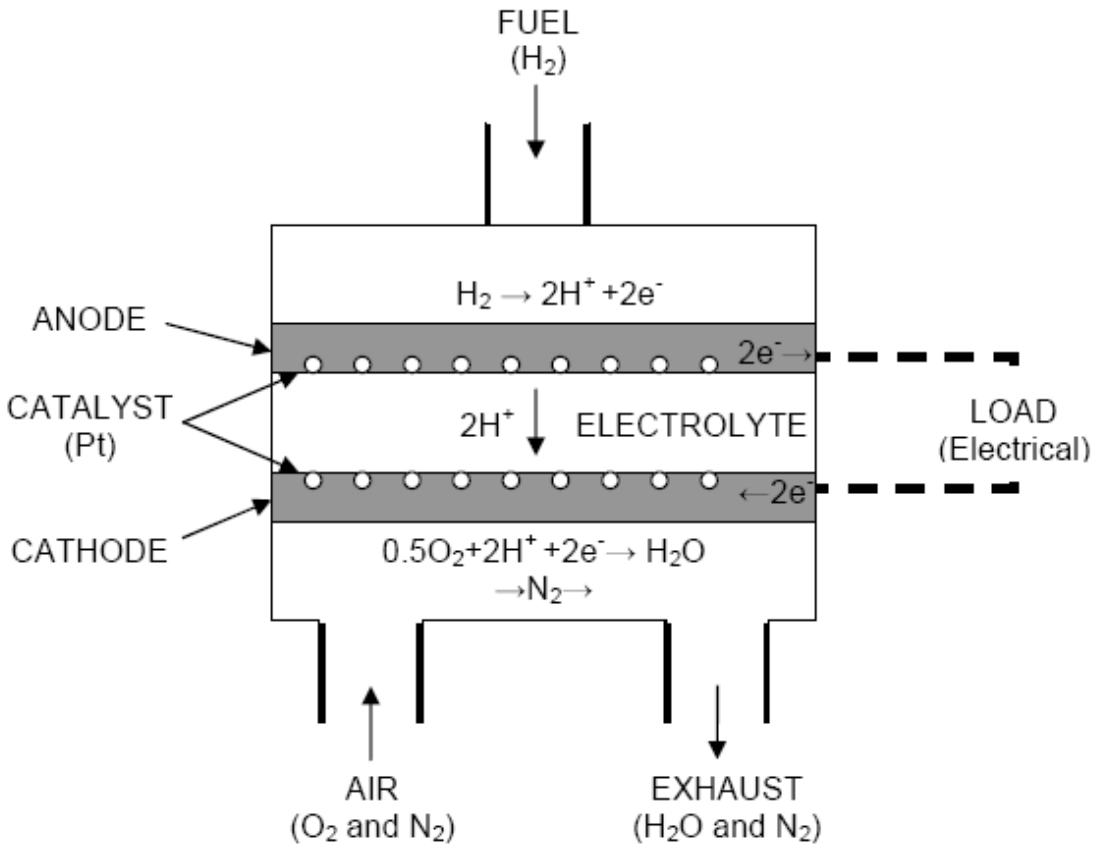


Figure 9. Principle of fuel cell operation (source: Kalhammer, 2007)

The reactions occurring in the PEM fuel cell are as follows:

At the anode, hydrogen molecules are ionised, releasing electrons:

$$2H_2 \rightarrow 4H^+ + 4e^-$$

Protons pass through the electrolyte (in the case of a PEM fuel cell the electrolyte is a polymer which allows protons to pass through), but the electrolyte does not allow electrons through, which therefore makes the anode negatively charged. These electrons pass through an external electrical circuit to the cathode, where they reduce oxygen molecules to oxygen anions, which combine with the protons that have

migrated through the electrolyte due to the potential difference between the two sides of the electrolyte:

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

So the overall reaction is:

$$2H_2 + O_2 \rightarrow 2H_2O$$

I.e., the net reaction is the same as that of hydrogen combustion. The anode and cathode reactions shown above are extremely slow at low temperatures; to speed them up the anode and cathode of a PEM fuel cell are coated on one side with a precious metal catalyst – usually platinum.

3.8.1.2 *Types of fuel cell*

Although PEM fuel cells offer the most promise for transport applications, several other types of fuel cell are available – for example, alkaline fuel cells (used in the space shuttle) and phosphoric acid fuel cells are considerably more mature technologies than PEM. The different types of fuel cells are characterised by the type of electrolyte that they employ and in turn offer different operational characteristics which lend themselves more readily to certain applications. Table 2 summarises the characteristics of the six common types of fuel cell listed in order of increasing operating temperature. As well as the different type of electrolyte, the table shows that another key variable is the temperature of operation of the fuel cell and its typical power output.

Table 2. Types of fuel cell

Fuel cell type	Operating temperature (°C)	Power range[+]	Application
Proton exchange membrane (PEM)	50-80	W-kW	Transport and micro-CHP
Direct methanol (DMFC)	50-80	W	Low power portable
Alkaline (AFC)	80-100	W-kW	Military, space
Phosphoric acid (PAFC)	200	kW	CHP
Molten carbonate (MCFC)	650	kW-MW	CHP
Solid oxide (SOFC)	600-1000	kW-MW	CHP

[+]: Key: W – Watt; kW – 1000s of Watts; MW – millions of Watts

3.8.1.3 *Fuel types*

Although this study focuses on the production and uses of hydrogen, it is important to note that fuel cells run on a variety of fuels (Table 3):

Table 3. Fuel cells and fuels

Fuel cell type	Fuel	Gas purity required
Proton exchange membrane (PEM)	Pure H_2 and O_2/air	CO < 10-100 ppm
Direct methanol (DMFC)	Methanol and O_2	Low CO
Alkaline (AFC)	Pure H_2 and O_2	No CO_2, H_2S
Phosphoric acid (PAFC)	H_2 and O_2/air	CO < 1-2% by volume, S < 50 ppm
Molten carbonate (MCFC)	H_2, CO, hydrocarbons; O_2/air	S, Cl < 1ppm
Solid oxide (SOFC)	H_2, CO, hydrocarbons; O_2/air	S, Cl < 1ppm

The variety of fuels that can be used reflects the operating principle of the fuel cell (in the case of DMFC) and the temperature of its operation. High temperature fuel cells are capable of internally reforming hydrocarbons or even waste gas streams such a methane-rich biogas to produce hydrogen, which is then consumed by the fuel cell (although less pure waste streams may need additional purification). Intolerance of impurities in fuel cells is generally due to catalyst poisoning; all fuel cells have limited tolerance of sulphur compounds, but in general, fuel cells operating at higher temperatures have a higher tolerance of impurities. Alkaline fuel cells are intolerant of carbon dioxide due to carbonation of the electrolyte.

3.8.1.4 *Advantages of fuel cells*

The main advantages of fuel cells compared to other energy conversion devices are their relatively high efficiency of fuel to energy conversion and their zero emissions at point of use. In addition, part of the efficiency of a fuel cell for transport applications lies in the direct conversion of chemical energy to electrical energy. In other systems, such as series hybrid vehicles that use internal combustion engines (ICEs), chemical energy in the form of fuel is first converted to thermal energy to mechanical energy and finally to electrical energy: even in a highly optimised systems losses will inevitably make this process less efficient than more direct conversion employed in the fuel cell.

3.8.1.5 *Fuel cell state of art*

Although fuel cells offer great promise across a range of mobile, stationary and portable applications, fuel cells remain an immature, developing technology. Significant progress is being made in H2FC technologies – in terms of performance, cost reduction, durability and operating characteristics – to bring products to market. These performance challenges are actively being addressed by focused research, however few fuel cell products are sold for profit at present, and incumbent technologies, such as internal combustion engines and domestic heating boilers are mature and highly commoditised (Roads2HyCom, 2009).

3.8.2 Internal combustion engine

3.8.2.1 *Hydrogen*

Among the vehicle manufacturers, BMW, Ford and Mazda have all been active in hydrogen spark ignition internal combustion engine (ICE) development and deployment over the last decade, along with specialist engine developers including Mahle, Roush and Pivotal. The technology of hydrogen ICEs is well understood and documented as its most common form is that of modified variants of state-of-the-art spark ignition engine technology.

Hydrogen ICEs therefore benefit from the maturity of ICE technology developed for other fuels. Hydrogen engines generate lower specific power for a given engine volume than the equivalent engine running on methane or petrol. The net effect is that either a larger engine needs to be used or vehicle performance is partially compromised. Importantly, were hydrogen to be readily available as a transport fuel and were it to be cost competitive with other transport fuels, vehicle manufacturers would be able to rapidly make available hydrogen ICE variants. In reality the widespread roll out of hydrogen is not expected to occur until fuel cell vehicles start to become commercially available, at which point the relative economics (based on fuel economy and initial capital cost) may favour fuel cells over ICE competition.

3.8.2.2 *Hydrogen-natural gas blends: HCNG*

Natural gas can be blended with hydrogen in various proportions to make HCNG. One such mixture that comprises a blend of 80% methane and 20% hydrogen is Hythane®, a patented fuel (and trademark of Eden Innovations).

The advantages of blending hydrogen with methane in an ICE are:

- reduced NO_x emissions due to the improved combustion characteristics of hydrogen compared to methane
- reduced CO_2 and CO tail pipe emissions
- addition of the increased calorific value of hydrogen
- blending allows a lower quality (and hence lower cost) hydrogen to be used when compared to a dedicated vehicle

HCNG offers a way of maximising the effectiveness of even limited volumes of hydrogen. A vehicle using HCNG would require a conversion and a minor loss in power could also be observed due to reduced volumetric efficiency.

While HCNG is subject to active evaluation by engine and vehicle manufacturers in developing markets like India, there is no major OEM interest in HCNG use for the US, Japanese or European markets.

3.9 Hydrogen and energy generation and supply

It is clear that in order to meet its renewable generation obligations, the UK must make dramatic and relatively rapid changes in the ways that it generates electricity. At present over three quarters of the UK's electricity is generated by burning fossil fuels and only 6% from renewable sources, such as hydroelectric and wind. By 2020 the UK will be obliged to generate over 30% of its electricity renewably (Figure 10, UKHA, 2010).

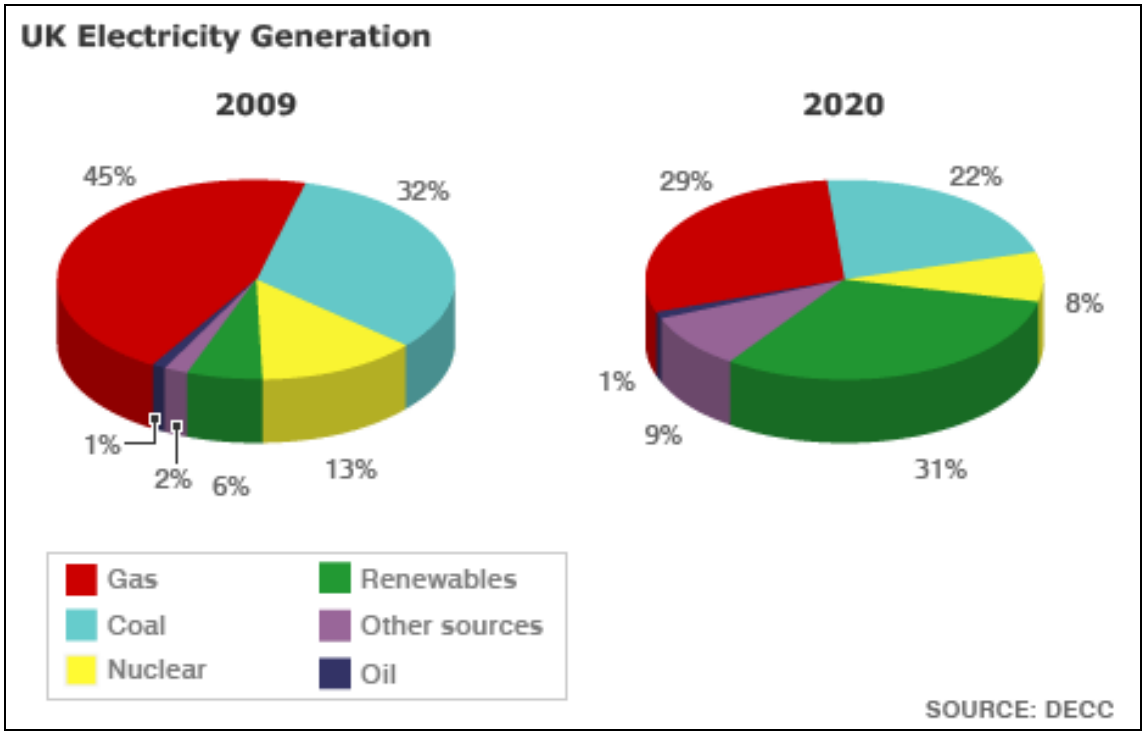


Figure 10. UK electricity generation 2009 and 2020 (source: UKHA, 2010)

In the longer term, the UK has a legal commitment to reduce its carbon dioxide (CO_2) emissions by 80% of 1990 levels by 2050 implying a massive shift in electricity generation, and the near-complete decarbonisation of transport (Figure 11).

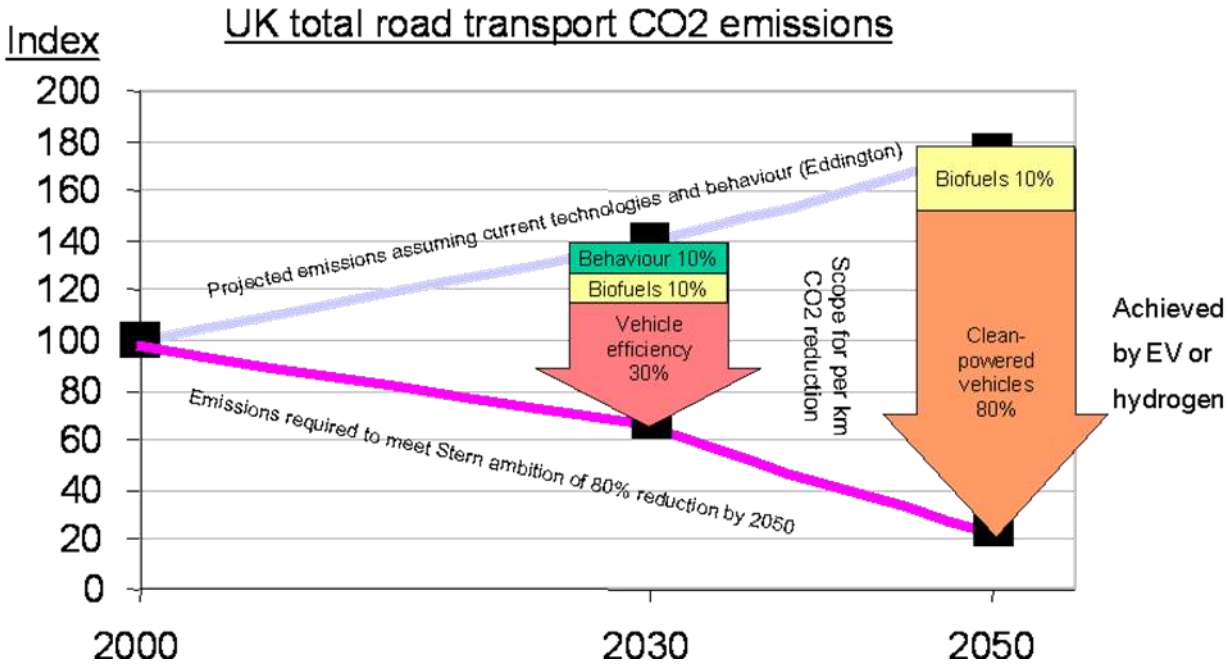


Figure 11. Pathways to the decarbonisation of transport by 2050 (King 2007)

To address the twin challenges of decarbonisation and energy security requires low carbon indigenous sources of energy (for example, see Ball, 2009). Such low carbon generators generally have poor dispatchability however (in simple terms this expresses the ability of power to be turned on and off according to demand). The key to balancing future power demand and supply lies in the implementation of a smart grid[1] and demand-side management (DSM). For example, some sources of current and future electricity demand, such as the charging of electric vehicles, are potentially controllable by demand-side measures such as price incentivisation to time-shift loads to periods of lower demand and/or energy surplus (Cenex, 2008).

Renewable energy generators, particularly wind and wave power, require time shifting over days, weeks and even inter-seasonally. At long timescales and large storage capacities, hydrogen is more economic than even the most advanced batteries. The round trip efficiency of hydrogen used for storage of grid electricity is poor compared to batteries, but the shift of the transport sector from fossil fuels will mean that energy stored as a result of DSM in the power sector will be transferred to the transport sector,

[1] One definition of a smart grid is 'an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver a sustainable, efficient and secure supply of energy' (DECC, 2010)

so there is no round trip from electricity to storage and back to electricity. Hydrogen produced in this way can also be used in industrial markets, such as fertiliser production, which are currently heavily reliant upon fossil fuels.

3.9.1 Clean fuel from smart grids – an analysis

This section presents analysis undertaken by Bryte Energy and Loughborough University on scenarios for electricity and hydrogen production in 2050. The analysis uses 2050 as a reference point because:

(i). There is a firm CO_2 reduction target upon which to base assumptions

(ii). There are many firm targets in UK Government policy set for 2020 (and some interim ones leading up to this date and spreading into the decade beyond), but there is little evidence for the emergence of significant hydrogen markets in the UK before 2020, unless a more proactive approach to market stimulation is taken (see Section 6.3.1 for further discussion)

(iii). Back-casting from 2050, with consideration of the magnitude and quantity of technical, social and economic steps that must be taken to arrive achieve the targets, highlights the urgency of initiating a strategic plan of action immediately

In 2050, the massive increase in demand for hydrogen by the transport sector is fulfilled by electrolysis, which absorbs the by-product energy from grid balancing over the longer timescales required by renewable generators. Short time shifting of loads is achieved through battery electric vehicle charging as well as opportune operation of heating, cooling and other dispatchable loads. The three energy sectors (power, heat and transport) will no longer be separated, as they are today, since they will all derive their energy from a shared set of primary generators in a mature low carbon economy. Where such generators are not dispatchable (e.g. renewables and nuclear), sectoral shift of energy to transport and heat loads enables DSM.

Dispatchable power generation from clean coal is possible; however, of the three types of clean coal technology, only the pre-combustion method makes practical and commercial sense in a mature low carbon energy system. This is because this method uses coal gasification to produce hydrogen for fuelling a generator, which is typically a gas turbine that can be highly dispatchable. Since this would run with a very low load factor, the ability to sell hydrogen to transport and industrial markets makes it economically viable. Post-combustion clean up and oxy-fuelling are clean coal

technologies that reduce dispatchability and present extremely poor return on investment in a low carbon system with high penetrations of renewables.

This scenario means that there will inevitably be large markets for hydrogen in the UK. Figure 12 shows how the balance of supply and demand would be achieved throughout the year 2050, where a reduction in CO_2 levels of 80% is achieved and the UK uses significant amounts of nuclear and renewables, but is also heavily reliant upon clean coal generation. This is called the high coal scenario.

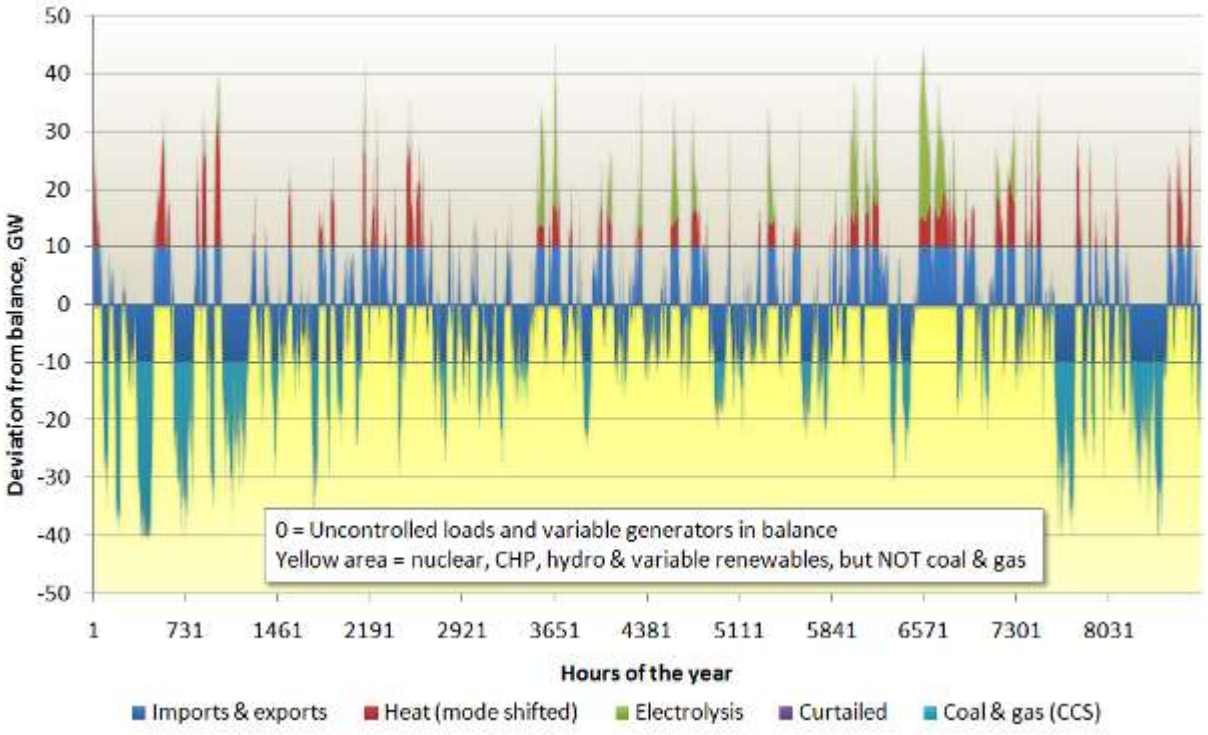


Figure 12. Grid balancing in 2050 – high coal scenario

At a value of zero, the input from non-dispatchable generators matches demand. Above zero, there is a surplus that is first taken up by trading power through interconnectors to other countries, then it is absorbed by heat loads and the remainder is taken up by hydrogen production by electrolysis. Below zero, power is imported through the interconnector and, if this is not enough, dispatchable clean coal generation is called into service.

Similarly, Figure 13 shows how the balance of supply and demand would be achieved in the High Renewables scenario, where there are high penetrations of renewables, significant amounts of nuclear and small amounts of clean coal generation.

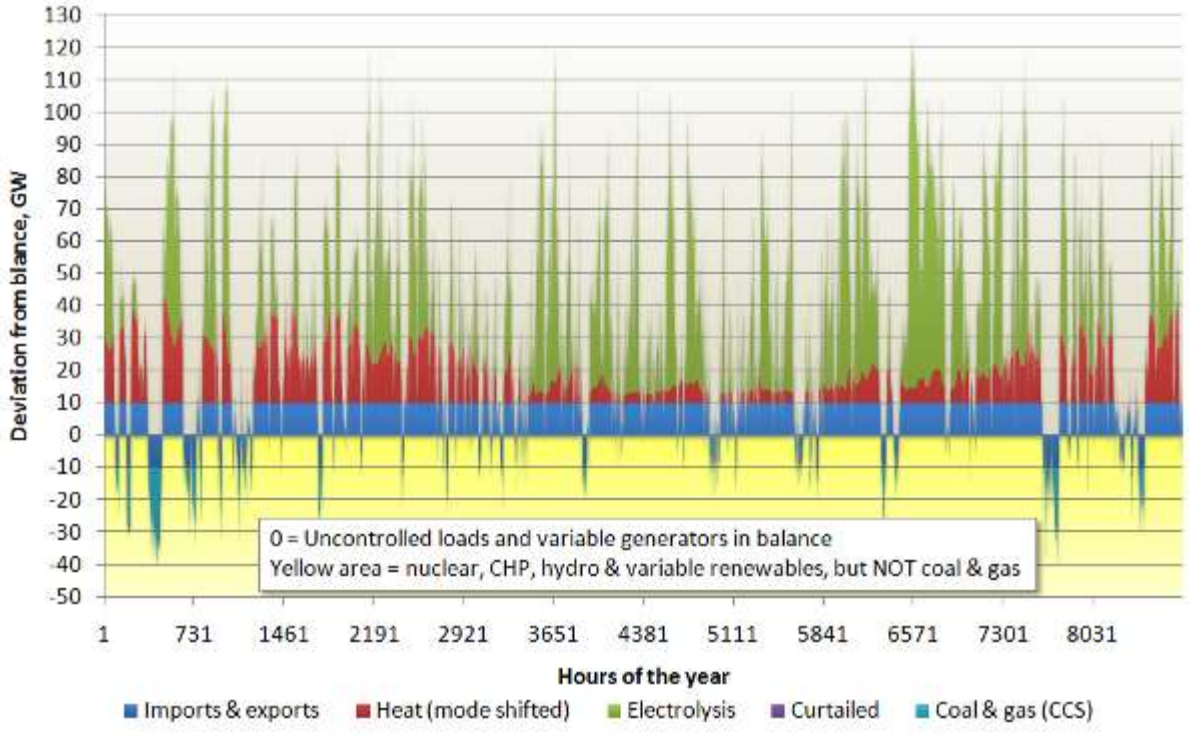


Figure 13. Grid balancing in 2050 – high renewables scenario

These two scenarios illustrate two extreme points on a spectrum of options for the UK, and the truth probably lies somewhere in between, but what is clear is that hydrogen features heavily in both. The predominance of hydrogen from clean coal sources in the high coal scenario and electrolysis in the high renewables scenario as can be seen in Figure 14 and Figure 15.

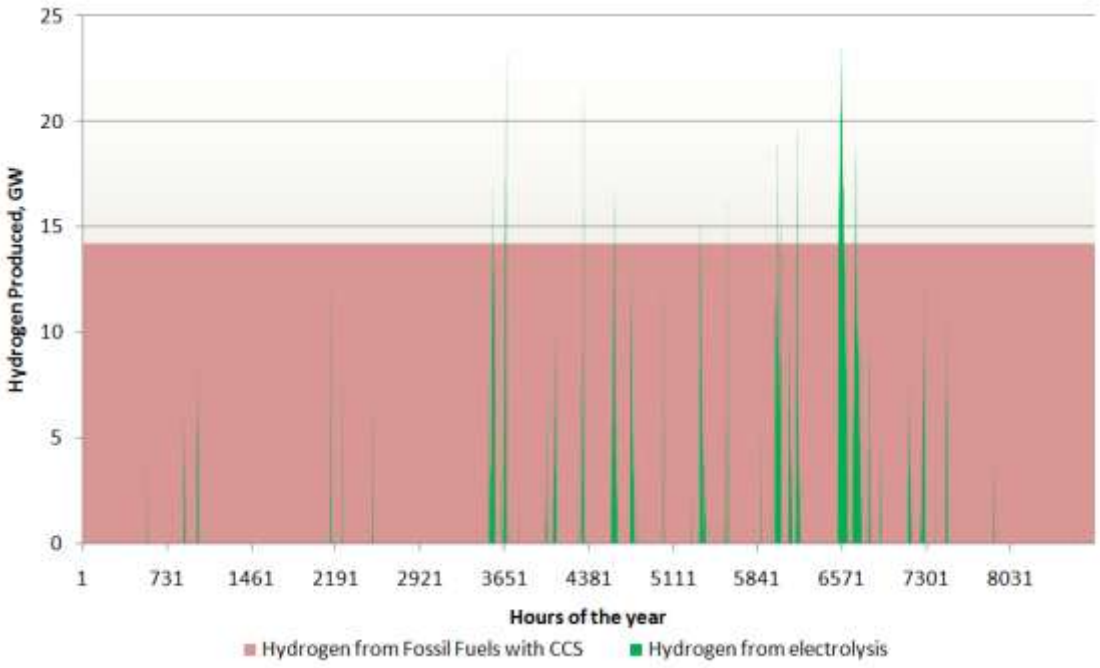


Figure 14. 2050 year round hydrogen supply - high coal scenario

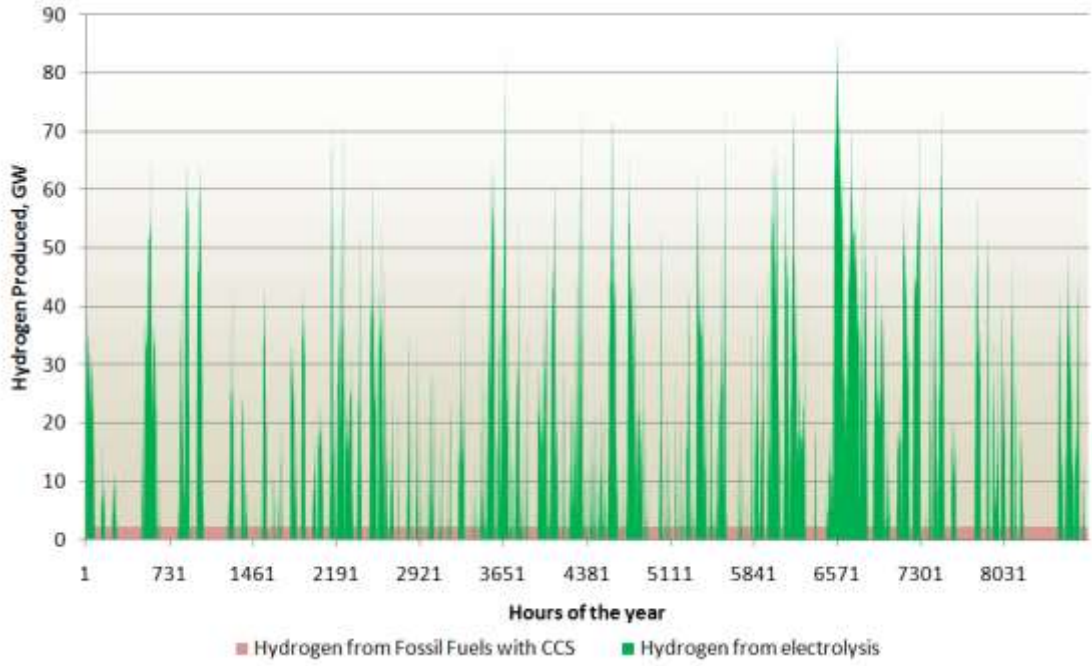


Figure 15. 2050 year round hydrogen supply - high renewables scenario

It should also be noted that these scenarios assume a complete shift from today's near monopoly of natural gas in the heat sector to it being supplied completely from grid electricity. If this modal shift is less complete, or happens slower, it increases the size and hastens the growth of hydrogen markets.

These scenarios also assume a highly reinforced grid, with no regional constraints to power flow within the UK. Again, should this be delayed, or not fully realised, it would speed up the introduction of hydrogen markets in the UK to in local markets and potentially increase their volume.

The capacity of inter-connectors with other countries is also critical to hydrogen markets and in these scenarios they are assumed to total five times the capacity of today's cross channel link with France. Intuition might suggest that the UK would wish to trade the 60% of Europe's wind resource that it owns, however the nature of weather patterns does little to make this a compelling business case and so there is good reason to doubt whether so many inter-connectors would be built. Should the interconnector capacity be less than that modelled, the hydrogen market within the UK would, once more, be larger.

In summary, the integration of hydrogen into the future energy picture is crucial, as it is arguably the only long-term way of reducing dependency on fossil fuels and enhancing security of supply. Figure 8 shows the various paths to low carbon power generation and energy provision for the transport sector. In the modelling described in this Section, dispatchability of power generation in a low carbon system is difficult to achieve and so it is the management of this that dictates the route of energy supply to the transport sector. What is particularly striking is that all pathways, except one, require the involvement of hydrogen (indicated by the red lines) on a massive scale.

4 Midlands hydrogen and fuel cell capabilities

4.1 Introduction

The Midlands is host to a cluster of technology companies and universities with world leading capabilities in hydrogen and fuel cell technologies. The development of this cluster – which includes Intelligent Energy and Rolls Royce Fuel Cells – has occurred gradually over a 20 year timeframe. Over the next five to 20 years there are three scenarios for the development of the cluster:

- The first scenario would see the cluster grow significantly (with associated GVA and employment) as the companies and universities in the region exploit the commercialisation of hydrogen and fuel cell technologies in consumer and business products and services.
- The second scenario would see region's players lose out to international competition.
- The third scenario would see hydrogen and fuel cell technologies fail to penetrate the market because macro-economic barriers to market entry (performance, cost, consumer acceptance issues, competition, etc) are not overcome.

It order to justify further support for the hydrogen and fuel cell cluster, is important to understand the degree of competitive advantage it offers the region above and beyond those offered by four priority sectors supported by the East Midlands' Regional Innovation Strategy – namely, food and drink, transport, healthcare and bioscience and sustainable construction. The study therefore undertook a detailed assessment of the region's capabilities in hydrogen and fuel cell technologies.

4.2 Mapping regional capabilities

The first guide to the hydrogen and fuel cell capabilities of the Midlands was published by the British Midlands Hydrogen Forum in October 2007 to promote the region at the Grove Fuel Cell Conference in London (BMHF, 2007). Funding and support for the activities of the BMHF was provided via Cenex, utilising funding from the Technology Strategy Board's Low Carbon and Fuel Cell Technology Knowledge Transfer Network (LCFC KTN) as discussed further in Part III.

To update the information for this study a range of regional and extra-regional players, largely drawn from the membership of the British Midlands Hydrogen Forum, were contacted between January and May 2010. Organisations were asked to provide a

profile (given in Section 4.6) and to complete a summary table describing their activities in H2FCs. Where no information was provided by the organisations, some has been extracted directly from company websites or the knowledge base built up by the BMHF. The information is summarised in Table 4.

Table 4. Capabilities of British Midlands Hydrogen Forum members

Legend:

S = Supplies
U = Uses
R = Researches

			Products / Technologies															
			H2 Production						H2 Storage				H2 Infrastructure					
			SMR	Electrolysis	Photolysis	Biological H2 and H2 from waste	Thermochemical	CCS and industrial by-product	Compressed H2 Gas	Solid state (metal hydride, etc)	Chemical	Liquid H2	Components and BOP	Process methods	Pipelines and components	H_2 refuelling
Companies		Adelan														
		Air Liquide	SU	SUR		SUR		SUR	SUR	R		SUR	SU	SR	SU	SUR
		Air Products	SU	SUR		SU		SU	S			S	SU	SR	SU	S
		Areva T&D		R												
		Baxi Potterton											U			
		Beacon Energy		U					U	U			U		U	
		Black Country Housing Group														
		BOC-Linde	SU	U					SU			SU			SU	
		Bryte Energy		UR					SU	U			UR			UR
		CENEX														R
		CERAM								R				R		
		Cryox / STFC					R		UR	UR	SUR	UR		R		
		Delta Motorsport							UR							U
		EPL Composite Solutions							SUR							U
		E-On						R								
		Energy Technologies Institute														
		FTI											S			
		Health and Safety Laboratory						R	R							R
		ICE Renewables														S
		ITM Power		SUR					SUR				UR			SUR
		Intelligent Energy	SUR	U					SUR				UR			U
		LIFECar							U				UR			U
		MERC Consulting						R								
		Microcab Industries							U							U
		Millbrook Proving Ground							U							UR
		MIRA							U							UR
		Morgan Motor Company							U				UR			U
		Nissan							U	R			UR			U
		Orion Innovations														
		Paragon Motion							U							U
		PERA														
		Precision Micro											SR			
		Revolve							UR				U			U
		Riversimple							U				U			U
		Rolls Royce					UR									
		Royal Mail										U				U
		Synnogy														
		Tata Motors							U				U			U
		Teer Coatings		SR						R						
		TNEI		U					U				U			U
		Valeswood EDT							U	U			SUR			
Universities	Birmingham	Insitute for Energy Research and Policy				R				R						
		Department of Chemical Engineering		UR		UR			U							UR
		Department of Metallurgy and Materials	R	U					U	UR	UR					
		School of Chemistry								R	R					
		Schoolof Biosciences				R										
	Leicester	Department of Engineering		R					U							
	Loughborough	Aeronautical and Automotive Engineering							U		R					U
		Department of Chemistry		R	R				U					R		
		CREST		UR					U				R			
		Department of Chemical Engineering													R	
	Nottingham	Mech., Mat. and Mfring. Engineering							U	R						
		Chemistry							U	R						
		Chemical and Environmental Engienering		R		R	R	R		R						
	Warwick	Departments of Physics and Chemistry			R		R				R					

Legend:

S = Supplies
U = Uses
R = Researches

			Products / Technologies														Services												
						Fuel Cells																							
						High Temperature		Medium Temperature	Low Temperature																				
			SOFC	MCFC	PAFC	PEMFC	DMFC	AFC	Systems architecture	Materials technology	CHP systems	FC Vehicles	H2-ICE Vehicles	Manufacturing	Consultancy	Demonstration	Economics	Education	Control & monitoring systems	Fuel cell modelling	Design & optimisation	Energy system integration	Electrode development	Power generation
Companies		Adelan	SR						SR	SR	S														
		Air Liquide				SUR										SUR			U					
		Air Products													S	S		S	U					
		Areva T&D	R							R					R					R				
		Baxi Potterton				SUR			SR		SUR			S		S			U	R	R	R		SUR
		Beacon Energy				U					U				U	S		S	U	U	U	U		U
		Black Country Housing Group													S	S		S			S	S		
		BOC-Linde				SU										S								
		Bryte Energy				U					U	U	UR		S	S	R	S	SUR		SR	SR	R	SUR
		CENEX										UR	UR		S	SR	R							
		CERAM	R							R					S								R	
		Cryox / STFC	R	R		R	R	R		SR						S		S		SR		R		R
		Delta Motorsport				U						S	R		S	S			SR		S			
		EPL Composite Solutions								R		R	R	SR										
		E-On				UR					UR				SU	SU								SUR
		Energy Technologies Institute													U		R					R		
		FTI																						
		Health and Safety Laboratory													S									
		ICE Renewables				S			S		S				S	S	S					S		S
		ITM Power				SUR			SUR	UR	SUR	R	SUR	SUR		S	R		UR	UR	UR	SUR	UR	SUR
		Intelligent Energy				SUR			SUR	UR	SUR	R		UR		SU	R		UR	UR	UR	UR	UR	UR
		LIFECar				UR			UR			SUR				SU	R		UR	UR	UR			
		MERC Consulting										R			S		S							
		Microcab Industries				U*						S				S								
		Millbrook Proving Ground										R	R		S									
		MIRA										R	R		S									
		Morgan Motor Company				UR						SUR				SU	R				UR			
		Nissan				SUR			SUR	SUR		SUR		SUR		SU	R		UR	UR	SUR		UR	
		Orion Innovations													S		R	S				R		
		Paragon Motion				U						R	R		S			R	SR					
		PERA													S	R	R				R	R		
		Precision Micro							SR						SR					UR	UR		SUR	
		Revolve				U						R	SR	SUR	S	SU			UR					
		Riversimple				U			R			SR		R			R		U	U	R	R		
		Rolls Royce	UR						UR	UR				UR	U				UR	UR	UR		UR	UR
		Royal Mail											U											
		Synnogy													S		R							
		Tata Motors				U						R		SUR			R				UR			
		Teer Coatings	R			SR				SR				S	S	S							SR	
		TNEI				U						U			S	S	R		SUR		SUR	SUR		UR
		Valeswood EDT				SU						SR			S	S			U		R	S		
Universities	Birmingham	Insitute for Energy Research and Policy								R			R				R	S						
		Department of Chemical Engineering		UR		UR			UR	UR	UR	UR			S	S		S		URS				
		Department of Metallurgy and Materials				U						UR				S		S				SR		
		School of Chemistry	R					R							R			S						
		Schoolof Biosciences																S						
	Leicester	Department of Engineering				UR							R					S				R		R
	Loughborough	Aeronautical and Automotive Engineering				R						R	R			U		S		R			R	
		Department of Chemistry								R								S					R	
		CREST				U										SU	R	S	UR		R	R		R
		Department of Chemical Engineering													S			S						
	Nottingham	Mech., Mat. and Mfring. Engineering								R								S						
		Chemistry								R								S						
		Chemical and Environmental Engienering		R						R					S	UR		S						
	Warwick	Departments of Physics and Chemistry														R		S						

* including high temperature PEMFC

4.3 Discussion of regional strengths

Table 4 offers a comprehensive picture of the H2FC capabilities of the Midlands region, supported by the individual organisational profiles in Section 4.6. Examination of the data allows areas of particular regional strength to be highlighted. These areas, and key organisations contributing to that area of strength, are summarised below in Table 5 (organisations outside the East and West Midlands region, but affiliated to the BMHF, shown in italics):

Table 5. Summary of regional strengths in hydrogen and fuel cells

Area of strength		Organisation
Products and technologies	Electrolysis	Bryte, *ITM*
	Solid state H_2 storage	Universities of Birmingham & Nottingham
	H_2 refuelling	Universities of Birmingham, Coventry & Loughborough, *ITM*
	Solid oxide fuel cells	Rolls Royce Fuel Cells, University of Birmingham
	Proton exchange membrane fuel cells	Intelligent Energy, Universities of Birmingham, Loughborough & Nottingham
	Systems architecture	Intelligent Energy, *ITM*
	Fuel cell vehicles	Intelligent Energy, Microcab, University of Birmingham
Services	Demonstration	Cenex, Midlands Hydrogen Forum
	Education	Midlands Energy Consortium members (Birmingham, Loughborough, Nottingham)
	Energy system integration	Bryte, ICE, *TNEI*
	Power generation	E.ON

The product and technology capabilities of the region cover all aspects of production, distribution and use of hydrogen, and also cover all parts of the innovation chain from R&D to deployment. The importance of East Midlands' players such as Intelligent Energy and Rolls Royce Fuel Cells is clear, but it is equally apparent that the capabilities of the Midlands *as a whole* are more compelling than when viewed solely from an East or West Midlands' perspective.

Technology demonstration is a core strength of the region. The fuelling stations at Birmingham, Coventry and Loughborough as part of the Midlands Hydrogen Ring are central to this, but other activities, such as those of Cenex, are equally significant and have given the region visibility on a national stage. Again, a holistic picture of the Midlands presents a better story than those of the individual regions. In looking forward, building upon this demonstration strength to promote showcase projects in regional centres of demonstration (along the lines of Roads2HyCom's 'Lighthouse Projects') would further build momentum for the cluster (Roads2HyCom, 2009b).

Another clear strength of the region is in education. As well as their R&D capabilities the region's universities have established a high profile, both in the UK and internationally, based on their individual merits and, significantly, using collective branding. Regional initiatives such as the Midlands Energy Consortium (key to attracting the ETI to the region) and the Doctoral Training Centre in Hydrogen, Fuel Cells and their Applications show the value of collaboration in attracting funding to the region.

4.4 Benchmarking Midlands capabilities

Section 4.2 addressed the hydrogen and fuel cell capabilities of the East Midlands, and of the Midlands region as a whole. While the East Midlands has a number of innovative companies working in this field, such as Intelligent Energy and Rolls Royce Fuel Cells, plus significant academic strength from its universities in Loughborough and Nottingham, the combined East and West Midlands offers a package of capabilities that is at least the equal of other UK areas, particularly with the inclusion of the academic strength of the University of Birmingham and the significant automotive power offered by the West Midlands cluster.

4.4.1 RDD&D activities

To build the case for the strength of the Midlands in relation to other UK, it is possible as an example to benchmark the Midlands' ability to attract R&D funding compared to other regions. A DECC-sponsored study by EA Technology published in early 2009 examined UK H2FC project activity for which information was available from public domain sources such as Technology Programme CR&D calls (EAT, 2009). Almost two thirds of the projects were R&D carried out by universities – reflecting the state of commercialisation of H2FC technology (Table 6). The report notes that much of the project activity has been focused on hydrogen storage and fuel cell development, with the study citing a significant gap in infrastructure rollout projects:

Table 6. Analysis of UK H2FC projects (Source: EAT, 2009)

Project stage	Number of projects (national)	Number of projects in the Midlands
R&D	61	16
Demonstration	26	7
Commercial	3	1
Support mechanism	3	1
Total	93	25

The Midlands had the largest number of projects in each stage of the innovation chain and therefore the largest total of any UK region (Table 7), representing public funding commitment totalling almost £12m:

Table 7. Regional distribution of projects (source: EAT, 2009)

Region	Total
East Anglia	4
London	12
Midlands	25
North East	14
North West	2
Scotland	19
South East	4
South West	4
Wales	9
Total	93

Regional clustering is cited by the EA Technology report as an important factor in attracting national funding, as is the amount of regional funding supporting the cluster. The report notes the British Midlands Hydrogen Forum and the Birmingham/Warwick SCRATCH project as case studies of how regional support has helped attract national funding. Again, it is significant that the analysis does not distinguish between East and West Midlands activities.

Looking at recent H2FC R&D project activity funded the TSB (TSB, 2009b), it is clear that both the East and West Midlands continue to obtain significant benefit from public R&D funding. The TSB had 13 projects live between July 2008 and March 2009 valued at £28.1m with grant funding of £13m. Of the 13 projects, two were led by an East Midlands SME and one by a West Midlands company; four of the 13 has significant regional involvement.

Table 8. H2FC projects funded by the TSB (source: TSB, 2009b – regional participants highlighted in bold)

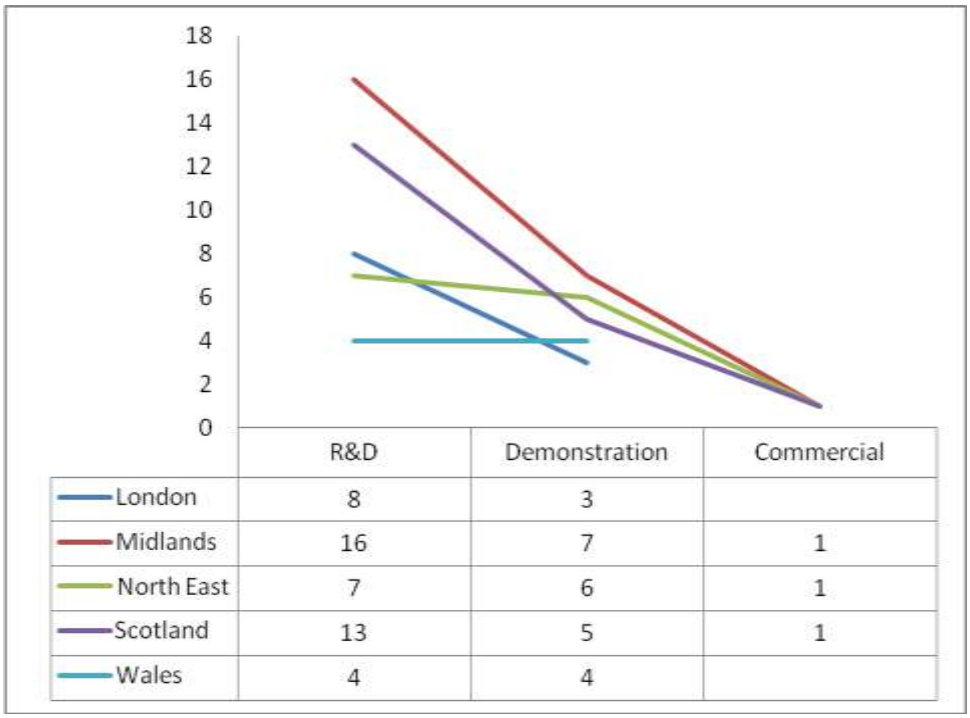
Title	Lead	Other partners
HYPNOMEM – Hydrogen Permeable Novel Membranes	**Teer Coatings Ltd (West Midlands)**	**University of Birmingham (West Midlands)**
Innovative Component Development for Low-cost PEM Stack Manufacture	**Intelligent Energy Ltd (East Midlands)**	Johnson Matthey Fuel Cells Ltd, **Primasil Silicones Ltd (West Midlands)**
Zero Emission London Taxi Commercialisation	**Intelligent Energy Ltd (East Midlands)**	Lotus Cars Ltd, LTI Ltd, **TRW Conekt Ltd (West Midlands)**
Development of a Novel Low-Cost Alkaline Hydrogen Electrolyser	ITM Power plc (BMHF member)	WH Boddingtons Ltd, **Teer Coatings Ltd (West Midlands**), **Pera Innovation (East Midlands)**, University of Southampton

Further, of the announced winners of £7m October 2009 Fuel Cells and Hydrogen Demonstration Programme, two were led by East Midlands-based Intelligent Energy, including the stationary fuel cell demonstration programme shown in Table 9:

Table 9. October 2009 TSB funding

Title	Partners	Funding
10kW fuel cell CHP demonstration	**IE CHP (lead)**, SSE, Element Energy, Logan Energy	£2.256m (£779k from TSB)

To summarise the relative strength of RD&D activity in the regions, the EA Technology study of 2009 again offers value. The data in Table 6 from across the innovation chain (research & development → demonstration → deployment) for the five 'active UK regions (see Section 4.4.2) is displayed in Figure 16.



	R&D	Demonstration	Commercial
London	8	3	
Midlands	16	7	1
North East	7	6	1
Scotland	13	5	1
Wales	4	4	

Figure 16. Regional RDD&D activity (source: EAT, 2009)

From the figure, it can be seen that the Midlands (from EA Technology's analysis based on data to early 2009) occupied a leading position of the UK regions, and that its capabilities lead across the innovation chain.

To further justify looking at the Midlands hydrogen cluster as a whole, it is instructive to note that one of the main achievements of the British Midlands Hydrogen Forum has been establishing the British Midlands as a recognised brand for the collective capabilities of the region. It bears repeating that is also significant that the Midlands Energy Consortium, a combined approach from the Universities of Birmingham, Loughborough and Nottingham was successful in winning the bid to host the Energy Technologies Institute in the region, a significant victory for a combined approach which has bred other success stories, such as the £5.5m EPSRC-funded Doctoral Training Centre hosted by the combined universities of Birmingham, Loughborough and Nottingham.

4.4.2 Closer look at regional activities

The work of the regions in the UK is important as they have taken a prominent role in progressing the H2FC agenda since the 2004 recommendation on establishing a UK national hydrogen coordination unit was not implemented (DTI, 2004 and 2005).

It is generally acknowledged that there are five regions in the UK which are 'active' in H2FC[2]:

- London
- Midlands
- North East
- Scotland
- Wales

BERR (2008) noted that most of these regions have:

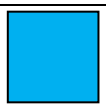
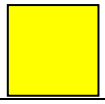
- Active stakeholder groups
- Vision and plan for establishing a 'hydrogen future'
- Programmes for coordination of RD&D
- Incubator units to assist new entrants
- Active H2FC research centres

(BERR, 2008)

A recent presentation by Helliwell (2008) outlined the H2FC capabilities of each of the regions, and highlighted a number of key initiatives for each. All of the regions have active demonstration/deployment projects; a summary of the relative strengths of the regions in hydrogen production, distribution and use – based on Helliwell's presentation – is given below (Table 10):

[2] Yorkshire is sometimes added as a sixth

Table 10. Summary of regional hydrogen activities in 2010 (modified, based on Helliwell, 2008)

	London	Midlands	North East	Scotland	Wales
Fuel production					
Fuel storage					
Fuelling infrastructure					
Fuel cell use					
Organisations					
Support					

(Revisions from the 2008 presentation include:

- Presenting fuelling infrastructure instead of 'fuel distribution'
- Support: increasing Wales' rating based on its LCEA status
- Changing 'companies' to 'organisations')

The picture in Table 10 reveals that the Midlands is favourably placed compared to other parts of the UK in most areas of hydrogen production, distribution and use. In looking at the relative strengths of the regions is important to bear in mind that this is a snapshot in time (May 2010). Potential threats to the Midlands' leading position include:

- London Hydrogen Action plan and the Olympics, which will increase its deployment of infrastructure and vehicles and renew its position as a focus of hydrogen activity
- Funding and high profile associated with Wales' hydrogen LCEA status

The UK-HyNet project (see Part III) is encouraging closer regional cooperation in the deployment of infrastructure. However it remains vital that the region builds on the evidence of capability established in this study, and the work of raising the region's

profile by the BMHF, to promote its position on the regional, national and international stage. Aggressive pursuit of the full implementation of the Midlands Hydrogen Ring and other 'Lighthouse Projects' will play a significant role in this process. Other opportunities for the region include further leverage of region's position in the low carbon vehicle landscape via the CABLED project, which is currently demonstrating electric and hydrogen vehicles in the West Midlands. That electrification of transport projects, such as CABLED, act as standard bearers for the eventual widespread rollout of hydrogen vehicles and associated fuelling infrastructure was stressed by a number of stakeholders consulted in this study. The CABLED project is unique in the current range of low carbon vehicle trials in the UK in that it is simultaneously deploying hydrogen fuel cell vehicles as well as pure electric vehicles in order to demonstrate the complementary nature of these technologies.

The activities of the regions are discussed further in relation to a Midlands Hydrogen Forum in Part III.

4.5 Other regional strengths – locational competitive advantage

In examining the effect of location on organisational competitiveness, Porter (2000) has established the principle of *locational competitive advantage*. Central to Porter's thesis is the notion of *clustering* – proximate groups of companies and institutions in a particular field, linked by commonalities and complementarities that compete, but also cooperate. Porter focuses on four aspects (the diamond) of a given region which have significant effects on its competitiveness, shown in Figure 17, and discussed briefly below:

Factor conditions: include elements such as tangible assets (e.g., regional infrastructure and location) – university research institutes being a particularly important aspect. The more specialised is the local knowledge base (i.e., in this case the more targeted towards H2FC work), the less *tradable* is this asset and the more compelling is the local cluster.

Firm strategy and rivalry: local rivalry for advanced industries, such as those involved in H2FCs, implies high investment in tangible assets (such as equipment) and in a highly educated workforce.

Demand conditions: sophisticated local markets are seen as vital in advancing clusters, by anticipating wider markets for H2FC technologies.

Related industries: the Midlands' manufacturing and automotive heritage offer the potential for building a world-leading supply chain. It is also significant that the region has been chosen as host for UK national organisations in the energy field, such as Cenex and ETI.

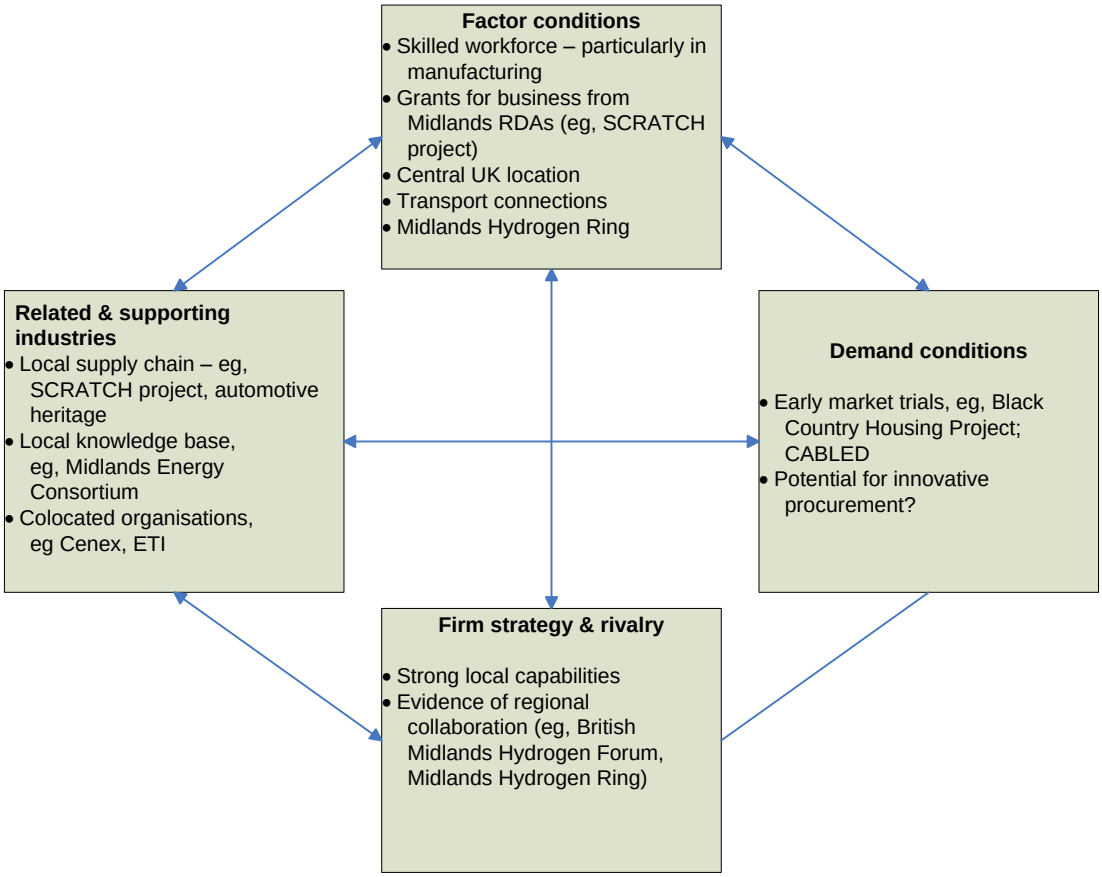


Figure 17. Competitive advantage of the Midlands (based on Porter, 1990)

The East and West Midlands possess many of the aspects of advantage shown in Figure 17. It is also apparent that in terms of H2FC expertise aspects such as the local support offered by the knowledge base and the building of supporting infrastructure are more compelling viewed from perspective of the whole Midlands rather than just the East or West of the region. Porter's argument also suggests that the more organisations that are in a cluster, the more competition and hence private investment is stimulated.

The concept of regional advantage and clustering is a further powerful argument in favour of supporting hydrogen and fuel cell technologies in the Midlands, and of discussing the capabilities offered by the Midlands region *as a whole*. Regional support

is clearly crucial in nurturing this nascent industry – as discussed in relation to potential early market development activities in Section 6.3.1.

4.6 Directory of regional players and descriptions of capabilities

4.6.1 Adelan

Contact: Dr Michaela Kendall

Address: Adelan UK Ltd Birmingham University Research Park 97 Vincent Drive Birmingham B15 2SQ

www: www.adelan.co.uk

Adelan Ltd is a small solid oxide fuel cell (SOFC) 'spin out' company which originated from the materials research developments at Birmingham and Keele Universities. Formed in 1996 with a UK Department of Trade and Industry (DTI) SMART award, Adelan is establishing itself as the UK's leading SOFC SME under the scientific guidance of Professor Kevin Kendall of the University of Birmingham.

Adelan develops and manufactures Solid Oxide Fuel Cells (SOFCs) for portable applications and is currently developing its IPR towards a range of products. The Adelan fuel cell is based upon a rapid heating tubular design which has made a particularly novel contribution to the SOFC industry. Its main advantages are the extremely low production costs per unit and unique cell design from which modular full-scale units can be built according to power requirements. This design solves two problems: (1) The fuel cell is highly resistant to cracking, and (2) Small sections of the tube (the electrodes) can be heated leaving the ends of the tubes cool for the attachment of piping and sealant materials.

Adelan aims to contribute further to SOFC technical innovation and commercialisation, developing clean energy generation devices for the 21st century by fostering strategic alliances with partner companies worldwide.

4.6.2 Air Liquide

Contact: Samantha Hughes, samantha.hughes@airliquide.com

Address: Station Road, Coleshill, Birmingham B46 1JY

www: www.airliquide.com

Over a period of more than 40 years Air Liquide has built up unique expertise in managing the entire hydrogen chain, covering not only production, distribution, and storage but also its applications right down to fuel cell level. The Group contributes to a number of European and international projects and events to encourage research and innovation, and acceptance of hydrogen as an energy vector.

Air Liquide considers that it is part of its responsibility as a world leader to open up new markets, and to introduce scientific and technological innovation into society. More recently in addition to supplying certified hydrogen fuel, Air Liquide designed, built, operates and maintains the filling station that will keep British Columbia's new fleet of green buses on the move during the 2010 Winter Games. It will be the largest hydrogen filling station in the world with the capacity to fill 23 buses per day. Over forty Air Liquide stations have been installed throughout the world to date. Some key facts which reveal the strength of Air Liquide's commitment to sustainable development and innovation are as follows:

- 36% of the revenue of the Group is directly linked to activities which contribute to protect the environment and life
- More than 60% R&D budget is dedicated to works connected to Sustainable Development and in particular to the hydrogen, clean energy carrier
- €224 million dedicated to research, innovation and technologies (2008)
- R&D: 1,000 researchers from 30 nationalities
- 8 main R&D centres (Europe, United States, Japan)
- Over 100 industrial partnerships and more than 120 international collaborations with universities and research institutes
- A dedicated division for Advanced Technologies with 750 partners in Europe and United States
- 200 to 250 patented innovations each year (a patent each day)
- 2,640 active patents

Air Liquide's activities lie at the heart of the most important challenges facing the planet. To meet these challenges, Air Liquide develops innovative technologies.

4.6.3 Air Products

Contact: Diana Raine, rained@airproducts.com

Address: Air Products plc, Hersham Place Technology Park, Molesey Road, Walton-on-Thames, Surrey KT12 4RZ

www: http://www.airproducts.co.uk/bulkgases/hydrogen_energysource.htm

With higher standards for clean air and a need for less dependence on fossil fuels, interest in alternative fuels has never been greater. Hydrogen is an important future fuel because it is renewable, abundant, efficient, and unlike other alternatives, produces no emissions.

As the world's largest supplier of merchant hydrogen, Air Products is at the forefront of the development of hydrogen energy technologies. We are working to bring safe, low-cost hydrogen production and infrastructure to the marketplace, through participation in a number of demonstration projects in Europe and around the world. Projects range from small stationary remote-power applications to multiple and varied vehicle programmes involving cars, aircraft, submarines, ship and space-rocket refuelling, as well as many industrial hydrogen solutions.

Air Products is actively involved in UK and European organisations working to make the hydrogen economy a reality. We are a member of many regional associations including the BMHF, the London Hydrogen Partnership, Scottish Hydrogen and Fuel Cell Association (SH2FCA), the UK Hydrogen Association (UKHA) and UK-HyNet. We are a founding member of the Joint Technology Initiative (JTI) Industry Group. Ian Williamson, Director of Hydrogen Energy Systems, is a board member of Cenex, the UK Centre of Excellence for Low Carbon and Fuel Cell Technologies, Vice Chair of the UK Hydrogen Association and the European Hydrogen Association.

4.6.4 Areva T&D

Contact: Paul Howard, paul.howard@areva-td.com

Address: Areva T&D Technology Centre, St Leonard's Avenue, Stafford ST17 4LX

www: www.areva-td.com

Areva T&D Ltd (a division of Areva) offers customers technological solutions for CO_2-free power generation and electricity transmission and distribution. Areva is also a world leader in nuclear power.

The Materials Technology Group has a wide-ranging know-how in materials, modelling and design of SOFC and steam electrolysis stacks (for hydrogen generation):-

- Development of glass-ceramic seals – matched expansion; high volume resistivity; steam/hydrogen corrosion resistance; application from paste or tape
- Metallic interconnects – pre-treatment; coatings; novel chemical machining
- Multiphysics mathematical modelling – all phenomena incl. electrochemistry
- Novel planar stack design – deep studies performed
- Electrical system studies – balance-of-plant; network (grid) integration
- Laboratory capability – high-purity glass melting to 1700°C; controlled-atmosphere furnacing (reducing and neutral); ageing materials in steam/hydrogen; state-of-the-art thermal analysis and dilatometry to 1550°C; volume resistivity to 700°C (Arrhenius analysis); helium mass spectrometer leak testing of sealed assemblies.

4.6.5 Baxi Potterton

Contact: Steve Hopkins, steve.hopkins@baxipotterton.co.uk

Address: Baxi Group, Stanier Way Wyvern Business Park Derby DE21 6BF

www: www.baxipotterton.co.uk

The Baxi Group (a renowned heating and boiler manufacturer), diversified into the fuel cell market in August 2002 through the acquisition of European Fuel Cell GmbH (EFC). EFC develops domestic scale CHP fuel cell systems.

It has developed the concept of the micro-combined heat and power (CHP) 'Home Energy Center', which is a 1.5 kW electrical, 3 kW thermal with further 15kW thermal from an additional integrated boiler fuel cell CHP system (PEM - Proton Exchange Membrane). This product has been specifically designed for the residential market. In

March 2005, Baxi Micro Fuel Cells, in partnership with European Fuel Cell GmbH, launched its beta system.

4.6.6 Beacon Energy

Contact: Professor Tony Marmont, tonym@beaconenergy.co.uk

Address: Baxi Beacon Energy Limited, Nanpantan, Loughborough Leicestershire LE12 9YE

www: www.beaconenergy.co.uk

Capabilities:

1. Demonstration and promotion of sustainability
2. Promotion of public awareness about global warming
3. Encouraging the reduction of CO_2 emissions

Beacon Energy is a small, non-profit making company whose premises can operate independently from fossil fuels and the national electricity grid by utilising a range of sustainable energy technologies. The state-of-the art technologies at West Beacon Farm and the Beacon Energy offices provide research opportunities for three Midlands based renewable energy centres at Loughborough University, De Montfort University and the University of Nottingham. It also hosts the HARI (Hydrogen and Renewables Integration) project.

To address some of the issues relating to personal/national perception of renewable energy, sustainability and the reluctance to implement changes, Beacon Energy offers guided tours of West Beacon Farm. The tour of the farms includes explanation of each of the technologies employed, including the lake (which provides hydro-power), photovoltaic (solar) arrays and two wind turbines. The tour also covers the hydrogen energy storage system, a rainwater collection and storage system and electric and hybrid cars.

4.6.7 Black Country Housing Group

Contact: Richard Baines, bainesr@bcha.co.uk

Address: Black Country Housing Group Limited, 134 High Street, Blackheath, West Midlands, B65 0EE

www: www.bcha.co.uk/

The Group has plans for nine more fuel cell installations in 2010; making it, indisputably, the most profligate domestic end-user fuel cell system customer in the world. This means we have the experience manufacturers and system integrators need to understand real-world applications for fuel cell based combined heat and power (CHP). We also understand automotive and portable applications of fuel cells and the full range of fuelling options in the field.

The Black Country Housing Group was instrumental in the demonstration and testing of the UK's first home to be heated and powered by a hydrogen fuel cell. The Alkaline Fuel Cell (AFC) system was supplied by Alternative Fuel Systems Ltd and had a maximum

rated nominal output of 4.4kW for electricity and 3kW for heating. The project was developed in conjunction with BOC, who provided the hydrogen in high pressure storage canisters.

The Group's next fuel cell demonstration was in partnership with BAXI and the University of Birmingham and was part of the Advantage West Midlands SCRATCH project to develop the fuel cell supply chain in the UK.

We welcome opportunities to work with all parts of the supply chain for hydrogen and fuel cells; for any application and in any part of the World. If you need to know what it is like for your product or service after you have sold it you need to speak to us.

4.6.8 BOC

Contact: Nick Rolf, nick.rolf@boc.com

Address: The Priestley Centre, 10 Priestley Road, Guildford, Surrey GU2 7XY

www: www.boconline.co.uk & www.linde.com

Internationally BOC is a member of The Linde Group, a world leading gases and engineering company with almost 50,000 employees working in around 100 countries worldwide. As a global supplier of hydrogen, BOC is able to supply a full range of purities and hydrogen mixtures to suit the most demanding of specifications. Typically, hydrogen is supplied in either compressed gas form (single cylinders or multi-cylinder packs) or as liquefied gas and BOC will work with customers to establish the most cost effective and efficient mode for their specific application.

BOC has an enviable heritage of investment in and sponsorship of a range of environmental projects and are currently actively involved with the practical application of hydrogen as a low carbon fuel source for materials handling and road vehicles. BOC has developed a range of compression, storage and dispensing technologies for use with hydrogen ICE or fuel-cell powered vehicles, some of which like the Ionic Refueller is unique to BOC. Further supporting BOC's low carbon activities is the development of the Hymera family of generator packages – the first commercially viable portable hydrogen fuel cell generators.

4.6.9 Bryte Energy

Contact: Dr Rupert Gammon, rgammon@bryte-energy.com

Address: Bryte Energy Ltd, Loughborough Innovation Centre, Epinal Way Loughborough Leicestershire LE11 3EH

www: www.bryte-energy.com

Bryte Energy offers consultancy on low carbon energy technologies, particularly in the integration of renewable energy and hydrogen systems. Services are focussed in two main areas:

- System implementation: feasibility studies, resource assessment, design, installation and operational management of energy systems
- Strategic studies: roadmapping, market analysis and technology assessment

The Bryte Energy team designed and implemented the Hydrogen and Renewables Integration (HARI) project, which was the first system of its type in the UK. The team has particular expertise in autonomous renewable energy systems and the production of hydrogen fuel by dynamically powered electrolysis, such as is required for grid balancing and management of variable output from renewable generators. Bryte Energy also has access to unique electrical distribution and control methodologies for the management of complex renewable energy systems that have been developed with its partners.

Bryte Energy has developed a unique software model, known as FESA (Future Energy Scenario Assessment), for cross-sectoral, techno-economic analysis of large scale energy networks. This is used in strategic studies on the development of low carbon energy markets and specific technologies within them, providing insight to technology developers, energy service and infrastructure providers, investors, end users, and policy makers.

Bryte Energy is the UK representative for Annex T24 of the International Energy Agency's Hydrogen Implementing Agreement, which is studying Wind Energy and Hydrogen Integration. Bryte Energy holds a Directorship of the UK Hydrogen Association and is a member of the Advisory Committee of the UK Sustainable Hydrogen Energy Consortium. The company is also involved in low carbon energy system research and technology development through Loughborough and Strathclyde Universities. The

British Midlands Hydrogen Forum was co-founded and is currently chaired by a member of the Bryte team.

4.6.10 Cenex

Contact: Robert Evans, robert.evans@cenex.co.uk

Address: CENEX Garendon Wing Holywell Park Loughborough Leicestershire LE11 3TU

www: www.cenex.co.uk

Cenex is the UK's first Centre of Excellence for low carbon and fuel cell technologies.

Cenex is a delivery agency established with support from the Department for Business, Innovation and Skills to promote UK market development and competitiveness in low carbon and fuel cell technologies for transport applications. Cenex's principal focus is on catalysing market transformation projects linking technology providers and end users. As part of this work, it runs a number of programmes for UK national and regional government, including the Low Carbon Vehicle Procurement Programme, the Alternative Fuel Infrastructure Grant Programme and the Low Carbon workstream of the Transport Knowledge Transfer Network.

Cenex is currently running a number of projects of in the hydrogen and fuel cell area, including:

- Development and demonstration of hydrogen vehicle operational and refuelling experience using two Transit vans converted for hydrogen fuel use by Revolve Technologies (formerly Roush Europe)
- Certification of hydrogen fuel cells vehicles using the Intelligent Energy EnV bike as a test case

4.6.11 CERAM

Contact: John Cotton, john.cotton@ceram.com

Address: CERAM Queens Road, Penkhull Stoke-on-Trent Staffordshire ST4 7LQ

www: www.ceram.co.uk

CERAM has been involved in the materials and systems for solid oxide fuel cells (SOFC) for 15 years. In the last 10 years, activity in this field has increased focussing in the following areas:

- Fabrication of thin section components
- Development of materials
- Component design
- Testing
- System development and evaluation

CERAM's involvement has ranged from materials and technology development to manufacture and evaluation of components in real devices e.g. multi-kW demonstrator fuel cells.

Fabrication

Fabrication of thin section ceramics for electrolyte, sealing gaskets, and interconnects has focussed on the use of tape casting and CERAM's own Viscous Plastic Processing (VPP) techniques to produce high quality planar components. The VPP technique allows the fabrication of components with thicknesses in the range 150 micron to several mm. Tape casting can produce components down to 50 microns thick, but has an upper thickness limit of approx 500 microns.

Because the VPP material is not dried on a support film problems of differential densification and warping during the drying and firing stages are minimised. In addition, the surface finish of the sheet is the same on both sides.

Several components have been manufactured using VPP ranging from 125 mm diameter discs and 100 mm square plates for electrolytes, to complex multi-bore tubular components for gas handling and heat exchange. We expect to conclude a non-exclusive license agreement for the use of VPP for the manufacture of fuel cell components with a major developer of fuel cell systems in the very near future.

Material Development

CERAM has been involved in the synthesis and development of materials for SOFC including electrolyte (both zirconia and CGO) interconnect (ceramic and metal) and

electrode (anode and cathode). Parallel studies have also focussed on other ionic conducting ceramics for sensors and electro-chemical reactors.

Testing

In addition to CERAM's extensive analytical and physical testing facilities, specialised tests for SOFC materials and components have been established which allow electrochemical characterisation in simulated operating environments. Tests include open circuit and under load measurements including V-I characterisation and AC impedance spectroscopy.

Thermomechanical testing of SOFC materials provides data for FEA modelling of the behaviour of different design configurations under operating conditions

Collaborations

We have been involved in several UK government and EU sponsored projects with leading European companies in the field, covering aspects such as component fabrication testing and device evaluation. In addition, CERAM has embarked on a number of internally funded research projects in association with prominent UK Universities. These have included:

- Development of electrode materials for high and intermediate temperature SOFC
- Design and evaluation of novel interconnect components
- Thermal stress testing of SOFC components
- Materials for direct internal reforming of hydrocarbon fuels in intermediate temperature SOFC
- Ionic conductors for electrochemical reactors.

4.6.12 Delta Motorsport

Contact: Nick Carpenter, nick@delta-motorsport.com

Address: Unit 2250, Silverstone Technology Park, Silverstone Circuit, Northants NN12 8GX

www: www.delta-motorsport.com

Delta Motorsport has been working in the field of alternatively-fuelled vehicles for over five years, including design and build support for the current Microcab hydrogen fuel cell vehicles. More recently Delta has completed the design and build of its own all-new passenger car, the E-4 Coupe (photo above). The first examples of the E-4 Coupe will be battery electric, but Delta also expects to build hydrogen hybrid versions in the near future.

Delta Motorsport is also part of the consortium undertaking the Durastor project. The main objective of the Durastor project is to develop a low cost, high pressure (350 – 700 bar) gaseous hydrogen storage vessel. The tank will offer significantly improved fatigue performance at a substantially lower cost (up to 45%) than current solutions. This step change in cost and performance will be achieved by developing monolithic thermoplastic pressure tanks, which means they will also be fully recyclable at the end of life.

4.6.13 EPL Composite Solutions

Contact: Gerry Boyce, g.boyce@eplcompositesolutions.co.uk

Address: Unit 10, Charnwood Business Park, North Road, Loughborough, Leicestershire LE11 1QJ

www: www.eplcompositesolutions.co.uk

EPL Composite Solutions is an independent company specialising in the design, development and commercialisation of advanced polymer composite materials on a global basis.

EPL spans the entire development cycle from applied research, product design, process development, product testing and certification, to setting up manufacturing plants. EPL also works with OEMs and end-users to develop and demonstrate composite solutions which provide clear technical, economic and environmental benefits over existing structures currently manufactured in traditional materials such as steel, aluminium, wood or concrete.

Having demonstrated these benefits and generated a demand, EPL then looks to identify commercial partners – either under licence or as a joint venture – to scale up and manufacture the composite solution on either a regional or global volume basis.

EPL is a consortium member in the Durastor project, which aims to develop a novel, low cost, high pressure (700bar) gaseous hydrogen storage vessel for the automotive market

that will offer improved fatigue performance at a lower cost than current solutions with the added benefit of being fully recyclable at the end of life.

4.6.14 E.ON

Contact: Dan Eyre, dan.eyre@eon-engineering.com

Address: E.ON Technology Centre, Ratcliffe on Soar, Nottingham NG11 0EE

www: www.eon.com

Competencies

- International utility company
- Supports research into hydrogen and other low-carbon energy technologies
- Power generation from renewable energy sources

E.ON is one of the UK's leading power and gas companies and is part of the E.ON Group which ranks amongst the world's largest investor-owned energy companies. E.ON UK employs over 17,000 people, many of which are located in the British Midlands, and it delivers power to over five million customers in the region through its Central Networks business.

E.ON is active along the length of the energy supply chain and is committed to achieving a low carbon future through a diverse portfolio of generating resources that are sustainable, reliable and affordable. Whilst its major R&D programme investigates low carbon technologies, it is also reducing the impacts of its fossil-fuel generation portfolio.

E.ON's R&D activities are focused through E.ON Engineering, a centre of technical and scientific excellence, which supports and develops clean energy technologies. A wide spectrum of low-carbon technologies is being developed, including renewable power, CCS, electric vehicles and micro-CHP. The role of hydrogen as a potential future energy carrier and technologies for the production, storage and utilisation of hydrogen are being supported. To help accelerate these technologies, E.ON has collaborative partnerships with government, the EU, scientific organisations, companies and universities worldwide.

4.6.15 Energy Technologies Institute, ETI

Contact: Rod Davies, rod.davies@eti.co.uk

Address: . Holywell Park Loughborough Leicestershire LE11 3EH

www: www.eti.co.uk

The Energy Technologies Institute (ETI) is a UK based company formed from global industries and the UK government. It brings together projects that create affordable, reliable, clean energy for heat, power and transport.

ETI will demonstrate technologies, develop knowledge, skills and supply-chains, inform the development of regulation, standards and policy, and so accelerate the deployment of affordable, secure low-carbon energy systems from 2020 to 2050.

ETI has current or planned projects in the following areas:

- Marine
- Offshore wind
- Carbon capture and storage
- Transport
- Energy Storage and distribution
- Distributed energy
- Buildings
- Bio-energy

4.6.16 FTI Ltd

Contact: Karl Kingston, karl@ftipv.com

Address: Unit 13, April court, Sybron Way, Jarvis Brook, East Sussex TN6 3DZ

www: www.ftipv.com/

FTI supplies high quality Ham-Let Instrumentation, Valves & Fittings. As Ham-Let UK's largest distributor, FTI offer a product that is directly interchangeable and intermixable

with Swagelok®; offering the same quality at lower prices and with a more flexible approach to business. Many of the products in the FTI range are used for hydrogen and fuel cell systems and infrastructure.

4.6.17 ICE Renewables

Contact: Laurence Duncan, laurence.duncan@icerenewables.com

Address: Crabtree Hall Business Centre, Little Holtby, Northallerton, DL7 9LN

www: www.icerenewables.com

ICE Renewables is a market leading renewable energy based solution provider working nationally in the corporate, building and agricultural sectors. Existing customers include M&S, Boots, Peel Holdings, Fisher German, Knight Frank, Northern Rail, William Davis, etc.

It is the vision of ICE Renewables to integrate existing wind and Anaerobic Digestion technology with hydrogen production and storage to allow a large number of agricultural clients to become energy independent. These clients will develop their systems to become local energy exporters so reducing demands upon the National grid.

With over 80 live projects around the UK and circa 25 new projects each month in renewable energy based electricity production this vision will shortly become reality.

4.6.18 Intelligent Energy

Contact: Dr Paul Adcock, paul.adcock@intelligent-energy.com

Address: Charnwood Building, Holywell Park, Loughborough Leicestershire LE11 3GR

www: www.intelligent-energy.com

Intelligent Energy, launched in August 2001, develops unique proprietary PEM fuel cells and hydrogen-generation technologies.

Intelligent Energy's fuel cell system combines novel fluid and thermal management techniques with metal plate architecture. The advanced PEM fuel cell stack technology provides a power to volume performance in excess of 2.5kW per litre. The integrated humidification and cooling system reduces the number of components, eliminates the conventional balance of plant to produce a smaller and more reliable power generation system.

Intelligent Energy's hydrogen generation technologies deliver pure hydrogen from a wide range of currently available fuel supplies. The current portfolio includes a compact hydrogen generator (referred to as the Meso unit) and a scalable hydrogen generator (known as the Hestia unit). These technologies have been designed to provide compact, cost-effective and scalable hydrogen generators.

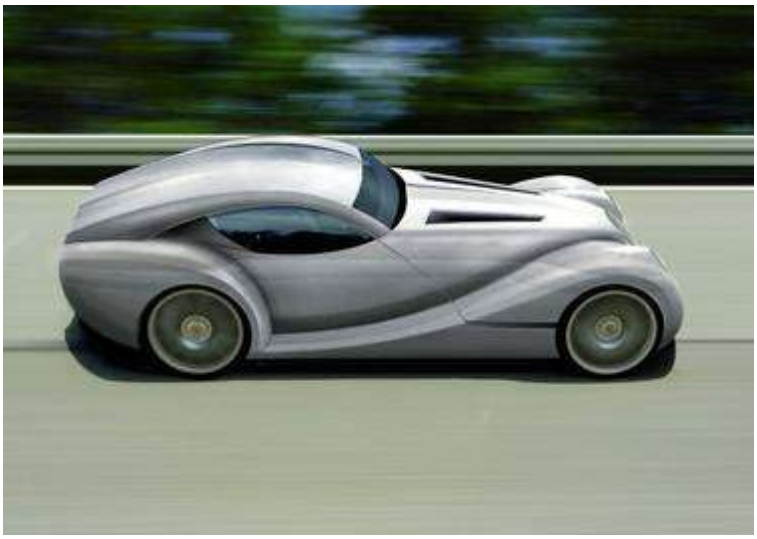
The ENV (Emissions Neutral Vehicle) bike is lightweight, virtually silent and is powered by a kW fuel cell generator. To enhance performance during peak power demand, the fuel cell has been hybridised with a battery pack which provides a 6kW peak load to the motor.

4.6.19 LIFECar

Contact: Dr Malcolm McCulloch, malcolm.mcculloch@eng.ox.ac.uk

Address: Electrical Power Group Department of Engineering Science University of Oxford Parks Road, Oxford OX1 3PJ

www: www.kron1.eng.ox.ac.uk/pages/research/life-car.php



The LIFECar project ran from 2006 to 2009 and developed an ultra-quiet, clean and economic sports car based on the Morgan Aero Eight. A QinetiQ-made Proton Exchange Membrane Fuel Cell (PEMFC) powered four separate electric motors (one at each drive wheel). Regenerative braking and surplus energy was used to charge the ultra-capacitors, which released their energy when the car was accelerating. This architecture

allowed the car to have a small fuel cell, approximately 24 kW (required to provide cruising speed), rather than 85kW typical, proposed by most competitor systems.

Project partners included:

- BOC – Hydrogen refuelling plant
- Cranfield University – Systems simulation and control of the fuel-cell hybrid powertrain
- Morgan Motor Company - Car platform and assembly of the final concept car
- Oxford University - Design and control of the electric motors and all power electronics
- OSCar - Responsible for overall system design and architecture
- QinetiQ – Developed the Proton Exchange Membrane Fuel Cell (PEMFC)

4.6.20 Loughborough University

Aeronautical & Automotive Engineering

Contact: Professor Rob Thring, r.h.thring@lboro.ac.uk

Address: Aeronautical and Automotive Engineering Stewart Miller Building Loughborough University Loughborough Leicestershire LE11 3TU

www: www.lboro.ac.uk/departments/tt/

Loughborough University has a long standing reputation for the research and development in polymer electrolyte fuel cell (PEFC) technology.

The Fuel Cell Research in the AAE Department is focussed on solid polymer technology, with a bias toward vehicle application. The research team is currently covering:

1. Fuel cell modelling from fundamentals
2. Optimisation of bi-polar plates for thermal and electrical conductivity
3. Development of PEMFC-application specific air compressors

4. Novel sodium borohydride technology for hydrogen storage

Fundamental fuel cell modelling efforts have investigated the cross over of fuel and contaminants in the membrane region and extended to analysing the degrading effect on performance given catalytic contamination. Central to optimising membrane conductivity is the water content of the membrane, given the different modes of transport in the region. Modelling multi-component transport in the membrane has been the focus of research so far.

Efforts are also being focussed on the development of injection moulds for the manufacture of rapid mechanically stable bi-polar plates using composite construction. The aim is to design for optimised thermal and electrical conductivity whilst maintaining a low cost design for mass production.

Work is also focussed on the development of air compressions systems for PEFC vehicle applications, acknowledging that current air compressors are not strictly suited to such applications. Current systems are susceptible to contaminating the compressed air, detrimental to cell performance. At the same time, the concept of an energy exchange device using compressed on-board hydrogen is being investigated.

Department of Chemistry

Contact: Professor Stephen Fletcher, stephen.fletcher@lboro.ac.uk

Address: Department of Chemistry, Loughborough University, Loughborough, Leicestershire LE11 3TU

www: http://www.lboro.ac.uk/departments/cm/staff/fletcher.html

Prof Stephen Fletcher heads an electrochemistry research group at Loughborough University, with expertise in the development and testing of novel electrodes. Typically these are printed in complex multi-layers by screen-printing techniques. A particular strength of the group is the ability to screen-print porous electrode structures. Recent clients include DERA, the US Army, the US Navy, Schlumberger plc, Morgan Fuel Cell, and National Power. The group has ongoing research in the development of lithium thionyl chloride batteries, lithium sulphur batteries, direct borohydride fuel cells, and carbon super-capacitors.

Centre for Renewable Energy Systems Technology (CREST)

Contact: Dr Simon Watson, s.j.watson@lboro.ac.uk

Address: CREST Loughborough University Loughborough Leicestershire LE11 3TU

www: www.crestuk.org

Capabilities

1. Integration of hydrogen and renewable energy systems
2. Development of electrolysers for use with intermittent power supplies
3. Renewable energy systems

As part of CREST's activities in the advancement of renewable energy, it undertakes research into the integration of renewables with other energy technologies, such as fuel cells and hydrogen systems. CREST's main activities within these fields include:

1. Contribution to the development and implementation of renewable energy through high quality research and demonstration
2. Working with research institutions, industry and related organisations world-wide to promote renewable energy
3. Provision of training and education in both theoretical and practical aspects of renewable energy systems technology.

A key challenge to accommodating the low and high frequency variability of renewable-energy sources (particularly wind and solar) is being addressed through the application of energy storage through batteries and/or hydrogen. The HARI (Hydrogen and Renewables Integration) project, located at West Beacon Farm and the offices of Beacon Energy Ltd, is and example of a novel electrical system configuration being developed by CREST in collaboration with Bryte Energy for grid-independent energy systems.

Chemical Engineering

Contact: Professor Geoff Hankinson, g.hankinson@lboro.ac.uk

Address: Department of Chemical Engineering Loughborough University Loughborough Leicestershire LE11 3TU

www: www.lboro.ac.uk/departments/cg/index.html

The NATURALHY project is a major EC funded integrated project within the Sixth Framework Programme, which is exploring the use of hydrogen as an energy carrier. Hydrogen is considered to be an essential element for global sustainable development but there are many significant challenges for implementing all the components of a complete energy system based on hydrogen.

The objectives of the NATURALHY project are to examine all the critical components of a pipeline system for the movement of hydrogen by adding hydrogen to natural gas in existing networks. A European consortium of 39 partners, including 15 from the gas industry, has been assembled. The role of Loughborough University is to undertake large-scale experimental work on gas dispersion, fires and explosions involving accidental release of hydrogen/natural gas mixtures, modelling of the consequences of such releases, assessment of the effect of hydrogen on the probability of accidental release and, ultimately, to assess the change in risk that would arise from use of the natural gas infrastructure for handling hydrogen/natural gas mixtures.

4.6.21 MERC Consulting Ltd

Contact: Ralph Hepworth, ralph@merc-consult.com

Address: 7 College Drive, Leamington Spa, CV32 6SG

www: www.merc-consult.com

MERC Consulting are specialists in the low carbon economy, especially in bridging the gap between commercial and technical issues. We have a particular interest in local energy production and distribution and see hydrogen related technologies as a key element in the emerging models for new infrastructure in this area.

Our services include:

- Techno-economic and marketing studies
- Partner searches
- Project development support
- Financial analysis

We are committed to the low carbon economy and will support selected projects on a contingency fee basis.

4.6.22 Microcab Industries

Contact: John Jostins, johnj@microcab.co.uk

Address: Bugatti Building, Coventry University, Coventry CV1 5FB

www: www.microcab.co.uk

Microcab develops innovative, environmentally-friendly vehicles for light urban transport, e.g. taxis, light deliveries, service operations, and private use. Associated with Coventry University, the company emphasises ergonomics, attractive design, and compatibility with normal urban traffic, using zero emission drive systems. Innovative concepts and light-weight materials give the required performance with very low energy use.

Microcab operates in the 'Microcab Consortium' of British Midlands SMEs with a full range of expertise in automotive engineering, lightweight vehicle structures, and low-volume vehicle manufacture.

Microcab represents a significantly different approach to that of most major vehicle manufacturers, based on innovation in vehicle design and use, rather than incremental increases in fuel economy or direct conversion to non-fossil fuels.

Experimental Microcab H4 vehicles, using hydrogen fuel cell power and in 4-seater passenger and van configurations, are in operational use on the University of Birmingham campus in a demonstration project supported by DECC. Development of an all new, upgraded version for initial production will be completed in 2010 with support from the Advantage Niche Vehicle R&D Programme, and a fleet of the first fuel cell vehicles of this type will participate in the TSB-supported Coventry & Birmingham Low Emissions Demonstrator project (CABLED).

4.6.23 MIRA

Contact: Dave Havergill, dave.havergill@mira.co.uk

Address: Watling Street, Nuneaton, Warwickshire CV10 0TU

www: www.mira.co.uk

Competencies

- Design, development, consultancy and test of automotive and defence products and vehicles.
- Research in intelligent transportation systems (ITS), Low carbon technologies and autonomous vehicles (UGVs)

MIRA is an automotive engineering centre of excellence, recognised globally as one of the leading independent vehicle engineering and test specialists.

The coupling of innovative design and integrated simulation techniques, validated in over 30 separate major development facilities, drive MIRA to deliver advanced technologies, that in turn produce class leading products

Today MIRA operates around the world and across the whole range of automotive, commercial and off highway vehicle technologies. The customer base is truly global and includes the major vehicle makers, component suppliers and other consultancies throughout the vehicle-producing world. In addition MIRA applies its vehicle expertise to the defence sector enabling safer and more efficient vehicles to be developed for ever more challenging environments.

With the case for environmentally friendly vehicles now being centre stage, MIRA is a key player in several low carbon related research projects including hybrid vehicle development, intelligent use of ITS for 'eco-driving' and energy control and management systems. The most recent of these has been the TSB funded LIMO GREEN range extended Jaguar project for which MIRA was responsible for the driveline development including the design of the battery pack, integration of an electric motor and small capacity APU and also the overall vehicle control algorithms.

MIRA Ltd is a company limited by guarantee but it has no shareholders; 100% of surplus is reinvested into the development of new techniques, technologies or facilities that will continue to assist our customers in their own vehicle development programmes.

4.6.24 Orion Innovations

Contact: Alison Cavey, alison.cavey@orioninnovations.co.uk

Address: 3 Bakers Lane, Shutlanger, Northants NN12 7RT

www: www.orioninnovations.co.uk

Orion Innovations is a specialist business consultancy that provides strategic and operational support to businesses and public sector organisations in the low carbon sector. Specifically the company works with organisations to address the strategic challenges and to realise the opportunities associated with the transition to a low carbon economy.

We work directly with developers of new technologies, offering practical solutions tailored to the needs of individual organisations, defining and understanding market dynamics and requirements and how they should be translated into practical plans to support commercialisation. This may be in the form of mentoring, interim management or consultancy support.

We also assist public sector organisations at international, national and regional levels in the identification and development of programmes in support of cleantech innovation and climate change mitigation.

Orion Innovations has particular interest and expertise in the fuel cell and hydrogen sectors, and has completed a wide range of projects for both public and private sector organisations, including long-term roadmapping, strategic assessment (e.g. cluster development); review (e.g. the SME support landscape) and commercialisation support for individual emerging technologies.

4.6.25 Paragon Motion

Contact: Dan Walmsley, dwalmsley@paragonmotion.com

Address: Silverstone Innovation Centre, Silverstone Circuit, Silverstone, Northants NN12 8GX

www: www.paragonmotion.com

Paragon Motion is primarily a Research and Development organisation with a strong background in vehicle development and chassis dynamics. It is currently engaged in

several research projects investigating the use of hydrogen in automotive applications including hydrogen fuelled internal combustion engines and hydrogen fuel cell powered vehicles.

Based at Silverstone in Northamptonshire, Paragon Motion offers its clients an extensive range of engineering development services based on a history of maximising efficiency in motorsport applications. Paragon Motion is looking to move into static energy applications and efficiency as part of its long-term strategy.

4.6.26 Pera

Contact: Phil Sheppard, phil.sheppard@pera.com

Address: Nottingham Road, Melton Mowbray, Leicestershire LE13 0PB

www: www.pera.com

Pera is one of Europe's leading innovation and business support organisations with a presence in eight European countries. Established in the UK over 60 years ago as an industry association owned by the companies it serves, we now work to improve the growth and competitiveness of industry and business in Europe by helping clients gain:

Greater access to global knowledge and markets

Helping firms and industry sectors access information, opportunities and partners on a global scale through specialist networks and business intelligence.

On behalf of national government agencies, we deliver programmes to stimulate international inward investment, technology transfer, partnering and access to high growth global markets for UK companies. We provide business intelligence and contacts to help UK firms identify and realise international opportunities. Hydrogen and fuel cells feature increasingly in these services.

Better differentiated products and services

Helping firms to implement innovation as a robust and continuous business tool to develop ideas for new products and services.

In partnership with regional, national and EC government agencies we provide access to over 10,000 scientists and engineers to develop the technology needed to realise these

ideas and helping to share the costs of innovation through partnerships with other companies. Projects include research on fuel cells.

More efficient business processes

Helping firms to optimise their manufacturing and business processes to produce lean, agile and globally competitive operations.

On behalf of regional government agencies we provide innovation, manufacturing and business improvement in addition to helping firms meet the increasing demands for innovation and sustainability within large company and public sector supply chain procurement.

More effective skills development

Helping firms to design training programmes to improve their business performance, management, leadership and use of innovation.

We provide access to hundreds of specialist trainers to help firms to compete and grow, while helping to share the costs by working in partnership with regional and national government agencies.

As a private sector company working in the public interest, Pera's not-for-profit mission enables us to reinvest operating surplus in services and facilities which benefit our clients, staff and the communities in which we work.

Environmental Management: In addition, as part of the management of our own operations, we are currently investigating the feasibility of a fuel CHP system for one of our UK sites and the potential for an associated hydrogen fuelling station.

4.6.27 Precision Micro

Contact:

Address: Nottingham 11 Vantage Way, Erdington, Birmingham B24 9GZ

www: www.precisionmicro.com

Precision Micro is a world leader in the manufacture of metallic plates and mesh for the fuel cell industry. These custom designed components can be manufactured from stainless steels, titanium, nickel and a range of exotic alloys and offer considerable benefits compared to non-metallic plates.

Although metallic plates may be machined mechanically, Photochemical Machining is a proven alternative with significant economic advantages. Precision Micro operates the largest etching plant of its kind in Europe, producing thousands of tonnes of bespoke metal fuel cell plates each year. With this flexible manufacturing technology, complexity does not come with a cost penalty.

4.6.28 Riversimple

Contact: William Cornwallis, william@riversimple.com

Address: Riversimple, Mill on the Green, The Linney, Dinham, Ludlow, Shropshire, SY8 1EG

www: www.riversimple.com

Purpose

To build and operate cars for independent use whilst systematically pursuing elimination of the environmental damage caused by personal transport

Business overview

Riversimple LLP is a UK-based business aiming to produce highly energy-efficient vehicles for personal transport.

Objective

To become a brand leader in providing personal transport solutions that meet the needs of customers, investors and the environment. Our business and manufacturing model is different from the current model – and needs to be.

Strategy

To place energy and resource efficiency at the centre of our strategy and to employ a business model that rewards such long-term efficiencies.

To lease not sell cars, maximising resource efficient use of materials and providing Riversimple with a steady revenue stream throughout the life of each vehicle.

Further, to adopt the same model upstream so that supplier, company and consumer interests are aligned around longevity and maximisation of resource efficiency – maximum utility for every unit of resource employed.

To first build urban cars that can be launched in small cities with one hydrogen refuelling facility. This strategy allows the development of a nationwide refuelling infrastructure without taking a nationwide gamble.

- To encourage global adoption of these technology standards and volume in the supply chain through open source design.
- To transform the economies of scale of vehicle manufacturing with decentralised manufacturing facilities, allowing true customisation to suit the needs of different regions and cultures.

To remain adaptable, Riversimple uses hydrogen fuel cells because they offer greater energy efficiency and lower CO_2 than any alternative for a vehicle with reasonable range, but the platform can harness any power source.

4.6.29 Rolls-Royce Fuel Cell Systems Ltd

Contact: James Logan james.logan@rrfcs.com

Address: SinA-7, PO Box 31, Derby DE24 8BJ

www: www.rrfcs.com

The Rolls-Royce fuel cell system is lower cost; more efficient; more easily distributed; more durable and maintainable than its nearest rival.

Rolls-Royce has experience in the system integration of several different types of fuel cells and believes the Solid-Oxide Fuel Cell is the best for stationary power generation applications while retaining the capability of being developed subsequently for various transportation, military and marine applications.

- Simplicity - The fuel cell is produced by screen printing on low cost ceramic type materials using proven production processes and minimal exotic materials.

- Low cost - The system uses commercial-grade materials, has few components and is low in weight.
- Efficiency - Nearly double the simple-cycle efficiency of existing power generation technologies.
- Profile - Size and weight suitable for distributed generation with potential for power densities equivalent to gas turbine systems.
- Environment - Negligible air emissions, minimal noise profile and can be entirely recycled at the end of its useful life.
- Maintainability - Unique, modular design enables field change-out without interruption of supply and enhanced support through state-of-the-art diagnostic and prognostic systems.
- Safety - System contains less than ten seconds of fuel supply at any time.
- Durability - Low parts count and the elimination of low durability components gives a realistic design target of 40,000 hours operation on a mature product and a 20-year 160,000 hour overall plant life potential.
- Fuel flexibility - System can be configured to use existing hydrocarbon-based fuels, i.e. natural gas and liquid fuels, and alternative fuels such as coal gas and bio-mass.
- Security - Suitable for connection to local distribution networks and in small, secure urban areas.

4.6.30 Royal Mail Group Ltd

Contact: Martin Blake martin.blake@royalmail.com

Address: Royal Mail, Unit 6, Ancells Court, Rye Close, Fleet GU51 2UY

www: www.royalmailgroup.com

Royal Mail Group is unique in reaching everyone in the UK through its mails, Post Office and parcels businesses – which directly employ over 176,000 people in the UK. Every working day Royal Mail processes and delivers over 75 million items to 28 million

addresses for prices that are amongst the lowest in Europe; each week we serve over 24 million customers through our network of 11,952 Post Office branches and each year our domestic and European parcels businesses – General Logistics Systems and Parcelforce Worldwide – handle some 404 million parcels.

With such an extensive social and business network and, and our presence within the UK's communities, we have a responsibility to protect and enhance the environment for current and future generations.

We recognise that the majority of our emissions are related to transport, which forms one of the key strands of our Carbon Management Programme. With a fleet of over 30,000 vehicles, we are keen to lead the drive towards operationally and commercially viable low and zero emission vehicles and solutions.

Royal Mail Group has been at the forefront of the hydrogen and fuel cell agenda over the past 3 years.

4.6.31 Science and Technology Facilities Council

Aerial view of Harwell Science and Innovation Campus with ISIS (foreground) and Diamond Light Source (back right). Credit: UKAEA

The Science and Technology Facilities Council (STFC) operates large scale scientific facilities at Rutherford Appleton Laboratory (RAL) on the Harwell Science and Innovation Campus (HSIC) near Oxford, and at Daresbury Laboratory (DL) on the Daresbury Science and Innovation Campus in Cheshire, among other sites in the UK and abroad. STFC provides peer-reviewed access to world-leading facilities such as the ISIS neutron and muon source and the Diamond Light Source. Its staff, researchers and academic collaborators have expertise in materials science, energy research, computational science and engineering, among other fields. HSIC is a potential site for a hydrogen filling station as part of the UK-HyNet infrastructure, reflecting STFC's role in hydrogen and fuel cell research.

www: www.stfc.ac.uk

ISIS neutron and muon source

Contact: Professor Bill David bill.david@stfc.ac.uk

Address: Rutherford Appleton Laboratory, Harwell Science & Innovation Campus, Didcot OX11 0QX

www: www.isis.stfc.ac.uk

At ISIS, neutron and muon beams are used to explore the atomic and molecular structure and dynamics of materials. Neutron diffraction instruments at ISIS are able to obtain real-time information on structural transitions in materials and its powerful molecular spectroscopy instruments give direct access to the binding energies and diffusion kinetics of hydrogen, methane, and other species of interest to energy conversion and storage technologies. Neutrons are one of the best ways to study molecular hydrogen, and ISIS teams conduct world-leading research into the synthesis, nanostructuring and adsorption behaviour of hydride and nanoporous storage materials, catalytic production of hydrogen, the surface chemistry, structure and ion conductivity of fuel cell membranes, and embrittlement.

Energy Research Unit (ERU)

Contact: Dr Geoff Dutton geoff.dutton@stfc.ac.uk

Address: Rutherford Appleton Laboratory, Harwell Science & Innovation Campus, Didcot OX11 0QX

www: www.eru.rl.ac.uk

ERU, based at RAL, has developed quantitative scenarios for introducing hydrogen into UK energy networks by considering the integration of electrolysis into grids with high penetration of intermittent renewables.

Computational Science and Engineering (CSE)

Contact: Professor Nic Harrison nicholas.harrison@stfc.ac.uk

Address: Daresbury Laboratory, Daresbury Science and Innovation Campus, Warrington, Cheshire WA4 4AD

www: www.cse.stfc.ac.uk

CSE, sited both at RAL and DL, develops and runs powerful simulation code for quantum mechanical, classical, mesoscale and continuum modelling of physical systems. CSE staff have the expertise to model the molecule-level behaviour of hydrogen storage, fuel cell and battery materials.

Cryox Ltd

Contact: John Vandore john.vandore@stfc.ac.uk

Address: Cryox Limited, Rutherford Appleton Laboratory, Harwell Science & Innovation Campus, Didcot OX11 0QX

www: www.cryox.co.uk

With focus on cryogenics, Cryox, a spin-out located at RAL, can provide access to technology from STFC, in storage or distribution of liquid hydrogen and in low temperature materials.

4.6.32 Tata Motors European Technical Centre plc.

Contact: Dr. Valerie Self valerie.self@tatamotors.com

Address: 4th Floor, IARC Building, University of Warwick, Coventry, CV4 7AL

www: www.tatamotors.com

Tata Motors European Technical Centre plc. (TMETC) was founded in September 2005 to provide state-of-the-art engineering competence to Tata Motors Limited (the parent company based in India) and to the global automotive engineering industry through the delivery of engineering consultancy. These third party projects are carried out with complete confidentiality and the protection of the client's Intellectual Property.

TMETC is currently involved in the following collaborative R&D programmes:

- Inclusion of the Tata Vista EV as part of the Technology Strategy Board (TSB) funded Coventry and Birmingham Low Emission Demonstrators (CABLED) demonstration programme.
- Commercial sales of Tata Vista EV will commence in 2010
- Member of the Low Carbon Vehicle Technology (LCVT) Programme funded by Advantage West Midlands (AWM) and the European Regional Development Fund (ERDF)
- Advisory Panel Member on Enhanced Fuel Cell Systems for real world commercial and passenger vehicle applications within the TSB's Energy Generation Supply: Fuel Cells & Hydrogen Technologies programme

TMETC is heavily involved in Advanced Engineering programmes in Fuel Cells and Hybrid Technology for the parent company. Details of these programmes are not yet available in the public domain.

4.6.33 Teer Coatings

Contact: Dr Glynn Dyson (Sales & Marketing Manager); Dr Kevin Cooke (Collaborative Research Coordinator) glynn.dyson@teercoatings.co.uk; kevin.cooke@teercoatings.co.uk

Address: West Stone House, Berry Hill Industrial Estate, Droitwich, Worcestershire, WR9 9AS

www: www.teercoatings.co.uk

Teer Coatings Limited (TCL) is a Droitwich-based SME with many years of experience in Physical Vapour Deposition (PVD), and in particular closed field magnetron sputtering technology. The company offers an industrial, sub-contract coating service to a world-wide customer base, but also manufactures coating equipment and test equipment, for industrial production and academic research. The company's technology has been exploited by our customers to solve problems with 1-off prototypes through to series production on millions of components per year.

TCL's coatings are used in many demanding applications, and are of increasing interest for fuels cells and the hydrogen economy. For example, to modify the surfaces of bipolar plates and similar systems, electrically conductive nitrides or carbides, and inert, high integrity and conductive carbon-based coatings can be readily deposited, as a more economic alternative to conventional noble metals (although TCL also offers an efficient and competitive capability for thin precious metal coatings too). This enabling technology has already been proven in high performance engineering environments, where adhesion, toughness, anticorrosion, longevity and coating integrity are of paramount importance.

TCL is actively involved in collaborative research in this field, with previous projects ranging from nano-clusters for catalysis to novel membranes for hydrogen purification. The company is ideally placed to assist in the development and commercialisation of fuel cell and hydrogen technology, wherever a high performance PVD thin film is required.

4.6.34 University of Birmingham

Institute for Energy Research and Policy

Contact: Professor Richard Green r.j.green@bham.ac.uk

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www: www.ierp.bham.ac.uk

The Institute for Energy Research and Policy was founded in 2005, to recognise the range of energy-related research at the University of Birmingham and the increasing importance of energy for the environment.

A number of research groups are associated with the Institute and academics with hydrogen-related research include:

1 Paul Anderson (Chemistry): Design, discovery and development of new hydrogen storage materials
2 David Book (Metallurgy and Materials): Materials for hydrogen storage and purification; Hydrogen processing of materials; Magnetic Materials
3 Richard Green (Economics): Economics of the electricity supply industry, and policy towards it
4 Rex Harris (Metallurgy): Hydrogen storage materials and permanent magnets
5 Kevin Kendall (Chemical Engineering): Fuel cells, sustainable energy, catalysts and fine particles, adhesion
6 Lynne Macaskie (Bioscience): Bio-production of clean hydrogen from waste, bionanomaterials for fuel cells, nuclear waste treatment, nanoscale platinum and palladium recovery from waste
7 Richard Palmer (Physics): Photocatalytic production of hydrogen; hydrogen storage in nanostructured materials
8 Regina Santos (Chemical Engineering): Supercritical fluids and their applications, Gasification of wet biomass for the production of hydrogen
9 Dr. Peter Slater (Chemistry): Development of new electrolyte and electrode materials for use in Solid Oxide Fuel Cells; use of alternative fuels
10 Allan Walton (Metallurgy): Hydrogen storage and purification

11 Miroslaw Wyszynski (Mechanical Engineering): New combustion and energy conversion technologies: future fuels and future engines, alternative, biomass-derived and hydrogen-enriched fuels.

Chemical Engineering

Contact: Professor Kevin Kendall K.Kendall@bham.ac.uk

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www: www.eng.bham.ac.uk/chemical/

Chemical Engineering at the University of Birmingham is involved in several projects on Hydrogen and Fuel Cells including:

DBERR project on 5 hydrogen fuel cell Microcab vehicles running on campus (£1.3million)

SCRATCH project funded by EPSRC to £1.5 million on supply chain for Hydrogen and Fuel Cells

Science City Hydrogen Energy project funded by Advantage West Midlands (£6million)

Baxi supply chain project (£1.3million)

The objective of these projects is to develop hydrogen supplies, storage media, fuel cell vehicles and CHP systems in collaboration with regional industries.

Metallurgy and Materials

Contact: Dr David Book

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Address: Department of Metallurgy and Materials School of Engineering University of Birmingham Edgbaston, Birmingham B15 2TT

www: www.hydrogen.bham.ac.uk

The Hydrogen Materials Group has a long-standing interest in the investigation and exploitation of hydrogen-materials interactions. Research areas include: production and characterisation of advanced hydrogen storage materials; novel membrane materials for hydrogen purification and separation; micro-structural processing of materials using hydrogen; and hydrogen energy demonstration systems, such as the PROTIUM hydrogen-fuel cell canal boat project. Current work includes:

EPSRC SUPERGEN UK Sustainable Hydrogen Energy Consortium, with 10 UK partners

European project on on hydrogen storage (NESSHY), with 21 partners 3EPSRC project on polymer-based hydrogen storage materials (with Universities of Cardiff and Manchester)

DBERR project on hydrogen permeable novel membranes (HYPNOMEM)

Participation in the SCRATCH project and the AWM Science City 'Hydrogen Energy Project'.

A comprehensive range of equipment includes:

Materials Synthesis: Casting (conventional and rapid quenching); ball-milling; thin-film preparation (PLD and Magnetron sputtering)

Materials Characterisation: 3 Hiden IGAs; 2 Sieverts volumetric systems; TGA and high pressure DSC; membrane test system; mass spectrometers; and a XRD and a Dispersive Raman spectrometer for in situ analysis in hydrogen.

School of Chemistry

Contact: Dr Paul Anderson p.a.anderson@bham.ac.uk

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www: www.chem.bham.ac.uk

The Hydrogen Storage Chemistry Group based in the School of Chemistry is home to an extensive ongoing programme dedicated to the discovery, synthesis and primary characterisation of new solid state hydrogen storage materials, including complex light metal hydrides and porous solids. The School also hosts research dedicated to the development of new electrolyte and electrode materials for use in Solid Oxide Fuel Cells and the use of alternative fuels. Current high profile projects include:

1. EPSRC SUPERGEN UK Sustainable Hydrogen Energy Consortium with 12 UK partners

2. IPHE approved project 'Combination of Amine Boranes with MgH2 & LiNH2 for High Capacity Reversible Hydrogen Storage' with 8 international partners

3. AWM Science City Hydrogen Energy Project

School of Biosciences

Contact: Professor Lynne Macaskie L.E.Macaskie@bham.ac.uk

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www: www.biosciences.bham.ac.uk

A number of projects to create bio-hydrogen are being conducted within the School of Biosciences. The projects include:

Bio-Hydrogen from waste confectionary

In a recent 15-month feasibility study (funded by the EPSRC), Professor Lynne Macaskie (in conjunction with C-Tech Innovation Ltd and Cadbury-Schweppes plc) has been demonstrating that hydrogen can be produced from confectionary waste. As bacteria consume high-sugar waste produced by the confectionary industry, they give off hydrogen gas. The hydrogen produced was subsequently used to generate clean electricity via a fuel-cell

Sustainable energy from urban and industrial wastes

A collaborative research project between the University of Birmingham, Cardiff University and C-Tech Innovation Ltd is using precious metals from vehicle exhausts and road dusts, food wastes and 'friendly' bacteria to create greener energy. The research team is moving towards the commercialisation phase of the project.

4.6.35 University of Leicester

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www: www.leicester.ac.uk

Over the last 15 years the Department of Engineering at the University of Leicester has been involved in work related to the production and utilisation of hydrogen through the following activities:

1. Participant in EU-funded project on 'Hydrogen generation from stand-alone wind-powered electrolysis systems' (JOU2-CT93-0413), 1994/97
2. Membership of the Steering Committee of the UK Hydrogen Network (H2NET), 2003 - 2008
3. 'Hydrogen injection in diesel engine to improve efficiency and emissions' (undergraduate BEng project), 2005/06
4. 'Development of a fuel-cell powered propulsion system for an electric vehicle' (undergraduate MEng group project), 2007/08
5. 'High-Efficiency DC-DC Converters for Fuel Cell Applications' (PhD project), 2008/11

4.6.36 University of Nottingham

Energy Technologies Research Institute - *towards a sustainable future*

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Address: Energy Technologies Research Institute, Engineering Faculty, University of Nottingham, NG7 2RD

www: www.energy.nottingham.ac.uk

Energy Technologies Research Institute (ETRI) at the University of Nottingham is a multidisciplinary institute involving researchers across Science, Engineering and socio-economic disciplines. ETRI has a £50 million portfolio of energy research activity spanning the following research priorities:

- Carbon abatement in fossil energy.
- Energy vectors and storage.
- Renewable energy.
- Low energy buildings.
- Future electrical power grids.
- Environment, policy and society.

Autumn 2011 sees the opening of the new ETRI R&D centre (part financed by the European Regional Development Fund) which is a showcase for novel alternative energy

technologies and for undertaking industrial focused R&D across the range of ETRI research priorities. The building will have a smart energy grid providing the unique opportunity for the research undertaken to feed into the energy supply and demand for the building, delivering real-time data for the use and performance of novel alternative energy technologies. The smart energy community will also have fuelling points for electric and hydrogen vehicles. The smart energy grid will also be linked to our existing Creative Energy Homes – seven occupied dwellings demonstrating novel low-carbon technologies.

Within the Energy Vectors and Storage priority area there are a number of hydrogen based research activities. These include:

1. Hydrogen generation from biomass, photocatalytic splitting of water, low-carbon reforming of fossil fuels.
2. Providing improved performance for fuel cells, electrode materials and hydrogen storage materials
3. The investigation of new catalysts and novel nanostructure membranes for fuel cell applications (both SOFC and PEMFC).
4. Microbial fuel cells
5. Integrating hydrogen systems into smart energy grids.

Mechanical, Materials and Manufacturing Engineering - Energy and Sustainability Research Division

Contact: Associate Professor Gavin Walker, gavin.walker@nottingham.ac.uk

Address: Department of Mechanical, Materials and Manufacturing Engineering University of Nottingham University Park Nottingham NG7 2RD

www: www.nottingham.ac.uk/~emzmjr/Hydrogen

Gavin Walker is currently researching solid state hydrogen storage materials, including: light metal hydrides, complex hydrides, nanostructured carbon and metal organic frameworks (MOFs). The research has yielded catalysts and accelerants to greatly reduce the operating temperature for high capacity hydrides and complex hydrides. He is also interested in carbon nanostructures as catalyst supports for PEM electrocatalysts.

Dr Walker is a partner in the UK Research Councils' Supergen hydrogen consortium UKSHEC. He is a UK expert for the International Energy Agency's Task 22 on hydrogen storage materials. Walker has a collaboration with the Kurchatov Institute investing electrocatalysts for PEM fuel cells and electrolysers and recently, a collaboration was established with Fudan University and the Institute of Metals Research (CAS) in China investigating novel high hydrogen capacity materials.

School of Chemistry

The School of Chemistry is conducting a number of projects relevant to hydrogen storage and fuel cells. The projects include:

Hydrogen storage

A research programme focussing on new hydrogen storage materials has been funded via the EPSRC SUPERGEN Initiative (Sustainable Power Generation and Supply).

Energy materials

Energy Materials encompass the School of Chemistry's research activities developing functional materials for energy generation and fuel-cells. The main research themes are:

- Metal-Organic Framework Materials
- Mesoporous Carbons
- Fuel Cell Catalysts

Department of Chemical and Environmental Engineering – Energy and Sustainability Research Division

Contact: Professor George Chen george.chen@nottingham.ac.uk

Address: Department of Chemical and Environmental Engineering, University of Nottingham University Park Nottingham NG7 2RD

www: www.nottingham.ac.uk/chemenv/

George Chen is professor of electrochemical technologies and currently engaged in a range of projects, including energy storage, energy efficiency and materials development.

Energy storage

Energy storage based research has focussed upon composites of carbon nanotubes and redox active materials (such as conducting polymers and transition metal oxides) for supercapacitors. Prof Chen's research has obtained electrode capacitance in excess of 5.0 F/cm^2 without compromising the cycle life. Prototypes are being developed in the ongoing project sponsored by E.On, aiming at developing the technology (supercapattery) for applications ranging from small (mW – W), medium (kW) to large (MW) scales.

Energy efficiency

The energy efficiency research has utilised nanoporous ion conducting membranes for fuel cells and batteries. This research has produced hybrid membranes of polymers (e.g. PVdF and PVA) and inorganic nanomaterials (TiO_2, SiO_2, Al_2O_3, etc), with the aim of adjusting the porosity and hydrophilicity of the membrane and achieving low and selective resistance passage of ions. Another more exciting development aims at new systems that are more efficient and far less problematic than those based on hydrogen.

Materials development

Materials development research has focussed upon:

The application of novel materials in electrochemical devices, including fuel cells, super-capacitors, rechargeable batteries, redox flow cells, and electrolysis cells.

Novel electrochemical processes, often with thermo- and opto- energy input, for more energy efficient and cleaner production of engineering and functional materials (metals, ceramics, polymers, nano-materials, supramolecules and composites).

4.6.37 University of Warwick

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Department of Physics

Solid State NMR Group

Contact: Professor Mark E Smith M.E.Smith.1@warwick.ac.uk

Many of the key questions relating to fuel cell technology can be better understood by applying atomic scale characterisation probes, with solid state Nuclear Magnetic Resonance (NMR) offering a number of advantages over other techniques. NMR can provide insight into problems related to components of proton exchange membrane fuel cells (PEMFC). This is a rapidly developing and key technology in new systems for energy delivery.

PEMFCs have distinct challenges associated with different components, explicitly the membrane material and the electrodes. Perfluorinated membranes are of much interest and questions relating to initial structural features, structural degradation and proton mobility could all be probed by solid state NMR. Relaxation time and other dynamic NMR measurements on 1H can be used to determine parameters governing proton motion in such materials. Carbon-supported platinum-based (e.g. Pt, PtRu, PtMo, PtRh) catalysts often act as electrode materials in such fuel cells. The materials are often poorly ordered and again difficult to characterise. 195Pt NMR can be developed, especially the use of field sweep techniques. The often heterogeneous nature of these materials means that the small particles encountered can have both metallic and oxide components. The distribution between such components and changes in these particles with processing/operation may be quantified using NMR techniques.13C NMR of catalyst support layers provides information on the interaction of the metal with the surface groupings and on the distribution of carbon species.

Other areas being developed are (1) 105Pd as a probe nucleus and (2) pulse field gradient experiments for looking at hydrogen diffusion.

Ferroelectrics and Crystallography Group

Contact: Professor Pam Thomas Department of Physics P.A.Thomas@warwick.ac.uk

The crystallography group has a dedicated x-ray diffractometer for materials research able to measure in high resolution and high brilliance for detailed structural studies (polycrystalline samples). The unit is able to measure grazing incidence and parallel beam optics for thin film samples, small angle scattering and has rapid data collection. The group is currently involved in monitoring the uptake and release of hydrogen from novel nonlinear optical phosphate storage materials.

Department of Chemistry

Contact: Professor Martin Wills Department of Chemistry M.Wills@warwick.ac.uk

Organic Chemistry

Research in the Wills group at Warwick is concerned with the development of methods for the generation of hydrogen from a variety of organic materials, including biomass. Recent research has led to the design and evaluation of several organometallic catalysts which are effective at the conversion of formic acid into hydrogen gas and carbon dioxide. We are currently examining the extension of this work to alcohols, carbohydrates and biomass as hydrogen sources.

We are also working in collaboration with Professor Kevin Kendall at Birmingham on the development of an integrated hydrogen generator/fuel cell system for energy generation. An area of rapidly developing research in our group is on hydrogen generation from water using solar energy and chemical catalysts.

4.6.38 Valeswood

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Address: Valeswood Environmental Technology Development Ltd 61 Salisbury Road Molesey Birmingham B13 8LB

www: www.valeswood.com

Valeswood Environmental Technology Development Limited supplies and installs an extensive range of hydrogen fuel cell technologies encompassing both alkaline and PEM fuel cells to cover a wide variety of applications both static and mobile. Our new 12 Volt hydrogen PEM fuel cell runs on standard commercial hydrogen gas with a purity of 99.95% at a pressure of 0.4 - 0.5 bar. It delivers a rated power of 99.6 Watts and a current of 8.3 Amps. It is suitable for powering a wide range of commercial and domestic 12 Volt appliances including computer systems.

The 24 Volt PEM cell from the same series has a rated power of 242 Watts and a current of 10.1 Amps whilst maintaining the same useful features as the 12 Volt system. This lightweight and robust fuel cell is ideal for mobile applications such as hydrogen electric bicycles and scooters. Valeswood has developed an exciting new range of bicycles and scooters using this technology which have just been launched in the UK. These vehicles use direct fuel cell power to the electric motor without the need for any batteries.

The stylish Valeswood 'Active' bicycle has a range of 60 km using a 600 litre metal hydride store and complies with all EU safety and transport requirements for on road use.

5 Regional project activity

A central aim of this work was to develop a series of project proposals involving regional players to support the evidence of cluster capability developed in Chapter 4 and therefore to further the case for ongoing support to build critical mass in the region. It is also important that the projects identified should build on regional strengths identified in Chapter 4, and, if possible, align with the present and/or future priorities identified by European and national funders.

5.1 Background

As part of the engagement established since 2007 by the British Midlands Hydrogen Forum and its Chair Dr Rupert Gammon a number of potential collaborative projects were already under discussion involving regional and extra-regional players. An example of the brokerage activities of the BMHF is the ongoing formation of the Midlands Hydrogen Ring, discussed in Section 5.3. Further project interest has arisen through the work of Cenex which has built a high level of engagement across the region in looking at the potential supply chain for hydrogen-fuelled vehicles and brokering demonstration activities.

As well as the Midlands Hydrogen Ring, other current Cenex project activity in the region includes:

Hydrogen vehicle certification (2007-

Cenex is working with Intelligent Energy and RDW to develop a reproducible process for certifying a hydrogen fuel cell powered vehicle and hydrogen storage system using the Intelligent Energy EnV motor bike as a test case.

Hydrogen vehicle operation & fuelling (2007-

Cenex funded the conversion of two transit vans by Revolve Technologies (formerly Roush Europe) to run on hydrogen. Cenex has also funded the emissions performance assessment of these internal combustion engined vehicles at Millbrook and a field trial assessment at Birmingham University. One of these vehicles is being trialled by Royal Mail at their Stornaway depot in June 2010, the other will shortly be sent to the University of Glamorgan for further trial/demonstration activities (June 2010).

CABLED vehicle trial (2010 -

Part of the UK-wide 340-vehicle Ultra Low Carbon Vehicle Demonstrator (ULCVD) trial, CABLED (www.cabled.org.uk) is a showcase demonstration of 110 ultra low carbon vehicles across Birmingham and Coventry, funded by the TSB and AWM. Cenex is managing the overall reporting of data for the trial on a national basis. CABLED is unique in the ULCVD programme because it includes Microcab hydrogen fuel cell hybrid vehicles.

This study has developed some of the proto-projects developed by the BMHF and Cenex in order to document them for further development by the future forum, as described further in the sections below.

5.2 Project listing

A listing of the 14 projects initiated or developed during this work is given below. Detail of the projects is given in the Confidential Material provided to emda with the complete study. The Midlands Hydrogen Ring is discussed separately in Section 5.3.

Table 11. Regional project opportunities developed during the study

What	Lead organisation	Type of project	Region
Midlands Hydrogen Ring	British Midlands Hydrogen Forum	Demonstration	Midlands
Fuel cell motorcycle demonstration	Intelligent Energy	Demonstration	emda
High temperature PEM fuel cell vehicle demonstrator	Loughborough University	Demonstration	emda
City to city hydrogen hybrid	Loughborough University	Demonstration	emda
Hydrogen vehicle fuelling and demonstration	University of Nottingham	Demonstration	emda
Hydrogen vehicle performance and emission optimisation	University of Nottingham	R&D	emda
Fuel cell material handling demonstration	Various - eg, East Midlands Airport	Demonstration	emda
Fuel cell auxiliary power unit (APU) for transport	Hubbard	Demonstration	emda

What	Lead organisation	Type of project	Region
Economic CO_2-to-building materials via fuel cells	University of Nottingham	R&D	emda
Fuel cell vehicle trials in the East Midlands	Leicester CC	Demonstration	emda
Hydrogen and fuel cell supply chain development – business support for SMEs	British Midlands Hydrogen Forum	Other	emda/AWM
Business models for early uptake of hydrogen and fuel cell technologies in an East Midlands context	Cenex	R&D	emda
Deployment of fuel cell CHP unit and possible hydrogen fuelling station	Pera	Deployment	emda
Fuelling and demonstration of hydrogen vehicles	Rutherford Appleton Laboratories	Demonstration	seeda

Some aspects to note from the project listing are:

- While the projects cover all parts of the innovation chain from research to deployment, the majority build on the region's identified strength in deployment
- The projects all involve at least one regional player and the majority are led by an East Midlands organisation that is a member of the BMHF. Just under half are led by the Universities of Loughborough and Nottingham

Arguably the most significant project currently underway, at least in the East Midlands, is the Midlands Hydrogen Ring deployment of hydrogen fuelling infrastructure.

5.3 Midlands Hydrogen Ring

A central justification for the formation of the BMHF, and for seeking continuation of the work of a hydrogen forum in the future, is the development of a critical mass of hydrogen fuelling infrastructure in the region. Launched in April 2008 the Midlands Hydrogen Ring is the name for a cluster of hydrogen refuelling facilities across the East and West Midlands (BMHF, 2008). Locations proposed initially for the Ring included the universities of Birmingham, Loughborough and Nottingham, plus MIRA and East Midlands Airport.

Aims of the Ring included:

- Promoting vehicle trials, initially in controlled environments and eventually on the open road between locations
- Attracting major vehicle manufacturers (OEMs) to deploy early hydrogen fuelled vehicles in the region
- Becoming a central hub in a UK hydrogen highway network

5.3.1 Current status

The first two hydrogen stations of the Ring were deployed in Birmingham and Loughborough in 2008. Further stations have opened in the Midlands and adjacent regions, assisted by initiatives such as the re-launch of the Alternative Fuel Infrastructure Grant Programme (which has 50%-funded the station at Millbrook) and the CABLED vehicle demonstration activity in the West Midlands. The current level of station deployment in the Ring is summarised in Table 12.

Table 12. Midlands Hydrogen Ring in 2010

Region	Location	Organisation(s)	Status
AWM	Birmingham	University of Birmingham	Operational 2008
emda	Loughborough	Loughborough University	Operational 2008
AWM	Coventry	Coventry University	Operational 2010
emda	Nottingham	University of Nottingham	Funded 2010
YF	Sheffield	ITM	Operational 2010
YF	Rotherham	TNEI	Operational 2010
SEEDA	Millbrook	Millbrook	Funded 2010
SEEDA	Didcot	Rutherford Appleton Lab	Funding being sought
AWM	Nuneaton	MIRA	Under discussion
emda	Donnington	EMA	Under discussion
emda	Silverstone	Delta Motors, Paragon Motion	Under discussion

Region	Location	Organisation(s)	Status
emda	Coalville	Snibston Discovery Park	Under discussion
emda	Leicester	Leicester CC	Under discussion
SEEDA	Cranfield	Nissan	Under discussion
SEEDA	Oxford	Oxford CC	Under discussion

The activities listed in Table 12 which bring the infrastructure deployments of the Midlands and adjoining regions under a single brand make the Ring a major 'Lighthouse Project' and currently give this wider Midlands grouping a unique position in the UK (Figure 18).

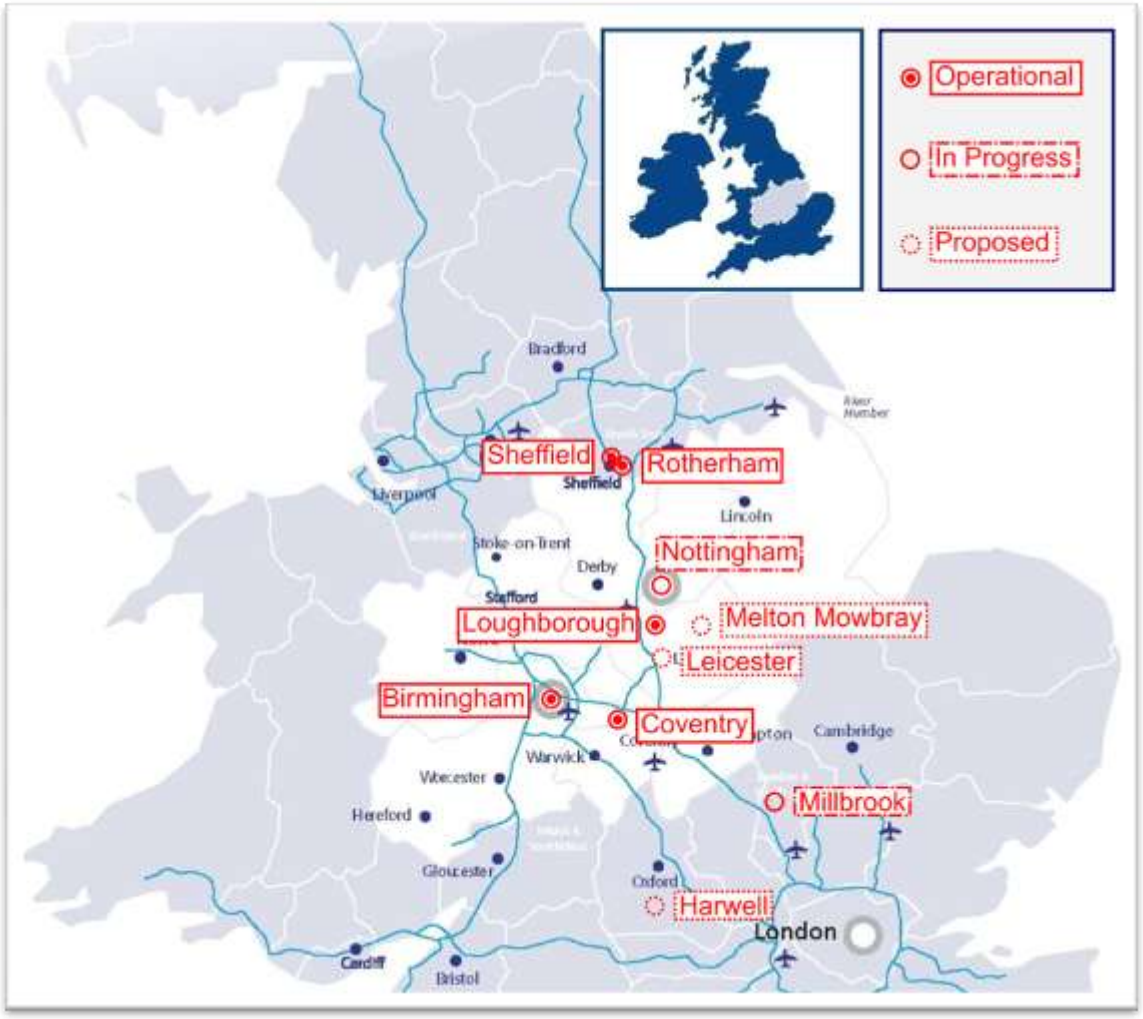


Figure 18. Midlands Hydrogen Ring

5.3.2 Midlands Hydrogen Ring and the national picture – UK-HyNet

Launched in June 2009 at Nissan Technical Centre Europe in Cranfield, the UK-HyNet project aims to create a national hydrogen infrastructure network in the UK by 2015 (Nissanpress, 2009). The Chair of the BMHF has been instrumental in driving forward the concept of UK-HyNet, which has been endorsed by many national and regional players in the UK.

Hydrogen highways or corridors – consisting of fuelling infrastructure linking strategic centres of vehicle deployment – are an enabler of the early deployment of hydrogen vehicles (see for example RoadsHyCom, 2009 and CaH2Net, 2004) and hence to unlocking the crucial hydrogen vehicle market. Such networks increase the profile of a

region as an early adopter of H2FC technology. Significant recent announcements on hydrogen highways include:

- H2 Mobility (Germany). a memorandum of understanding between a number German organisations, including Daimler, Linde and Shell, which is intended to lead to the rollout of a nationwide hydrogen fuelling network by 2015 linked to the market introduction of mass-produced fuel cell vehicles (Daimler, 2009). Germany currently has 30 hydrogen stations compared to six in the UK
- London Hydrogen Network. Led by the London Hydrogen Partnership, this plans to install at least six hydrogen fuelling stations in London by 2012 to fuel a minimum of 150 vehicles (LHP, 2010)

A putative UK national hydrogen network is shown in Figure 19. It shows that coverage of most of the major urban centres of the UK could be achieved with less than 70 hydrogen stations.

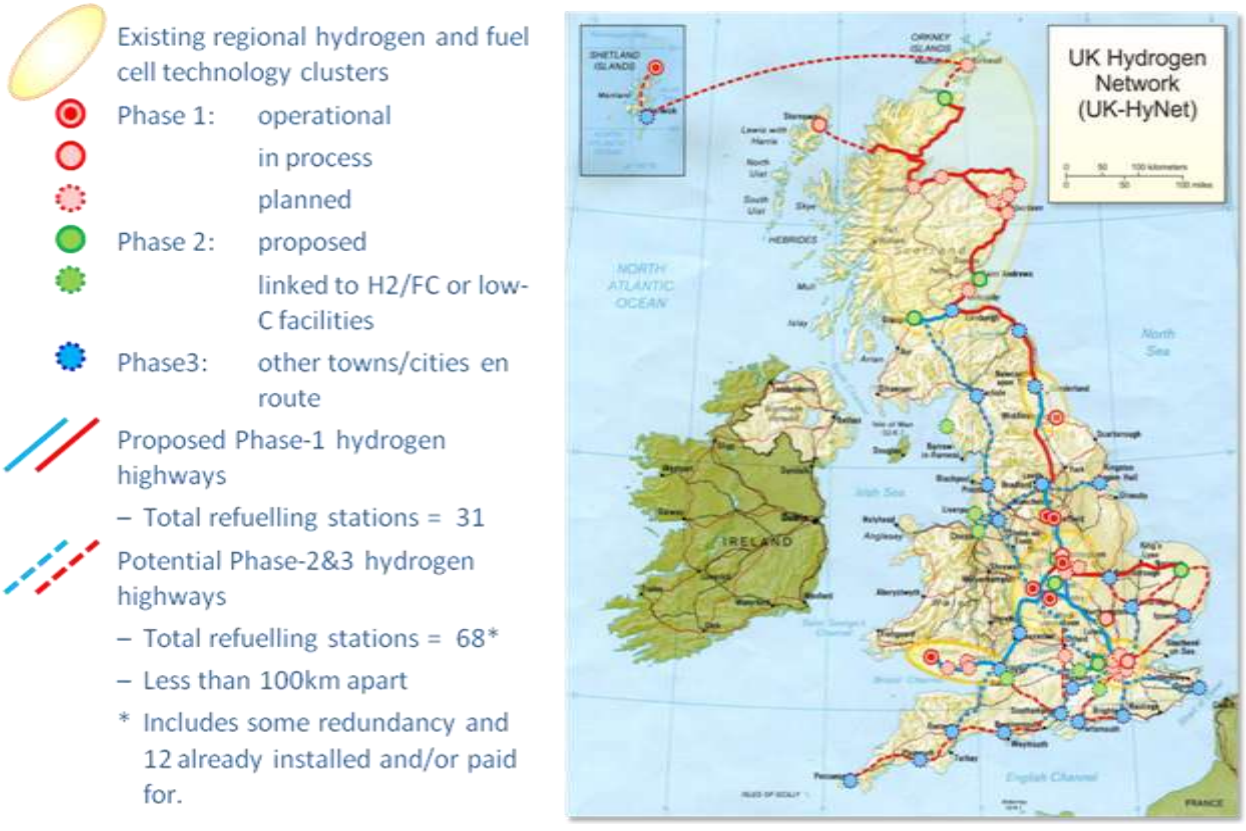


Figure 19. UK-HyNet national hydrogen highway (source: Bryte Energy)

The picture also reveals the crucial strategic position of the MHR within a future national network. For example, in linking up the highway between the Wales/South West Low Carbon Economic Area and the North East and Scotland it would be possible to travel through either the East or West Midlands. The network built up by the BMHF linking existing Midlands activity to planned stations at, for example, Rutherford Appleton Laboratory and Millbrook, will be crucial in maintaining the central position of the East Midlands and the MHR in the future network, and in the link to the London network planned for 2012.

5.4 Projects and early market opportunities

5.4.1 Roads2HyCom and NAIGT roadmaps

The Roads2HyCom study provides a summary of roadmaps from published sources, including the IEA, EU HyWays project and the Hydrogen and Fuel Cell Technology Platform (HFP), US DoE and the Japanese Strategic Technology Roadmap (Roads2HyCom, 2009).

In the long term (2050) the consensus of all these studies is that the majority of hydrogen use will be in transport. Stationary fuel cells for CHP will be common, but these will mainly use natural gas or synthetic sources as a fuel. The introduction of hydrogen begins with the use of brown, by-product hydrogen, supplemented by SMR and water electrolysis.

A crucial timeline is 2025 onwards, as decarbonised energy sources boost centralised production as mass-market uptake of hydrogen technologies takes hold. There is however no consensus on the displacement of fossil fuel hydrogen sources by renewably-fuelled sources. European hydrogen demand is projected to be between around 500,000 GWh - 1,400,000 GWh a year, corresponding to 3-7% of the EU-27's 2005 energy consumption. Clearly, these long term markets are significant – by 2050 between 30% and 75% of road vehicles are projected to be hydrogen fuelled. Roads2HyCom's 'roadmap' of the uptake of hydrogen in the EU is shown in Figure 20.

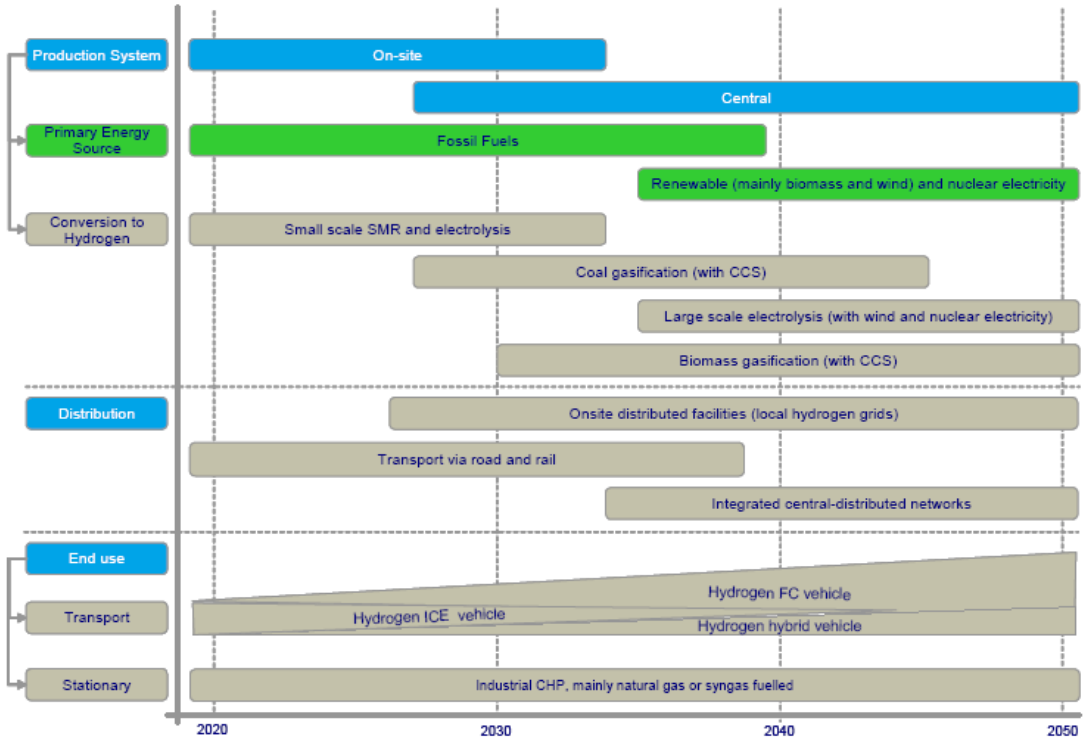


Figure 20. Roads2HyCom picture of hydrogen uptake in Europe

The recent New Automotive Innovation and Growth Team (NAIGT) product roadmap echoed the view presented by Roads2HyCom. The NAIGT picture shows the crucial role of early market demonstration of H2FC vehicles and the enabling role of infrastructure in the mass market deployment of H2FC vehicles commencing after 2020 (NAIGT, 2009). The NAIGT cautions that breakthroughs are needed in fuel cell cost, and in energy storage, including hydrogen storage, in order to reach the mass-market (Figure 21).

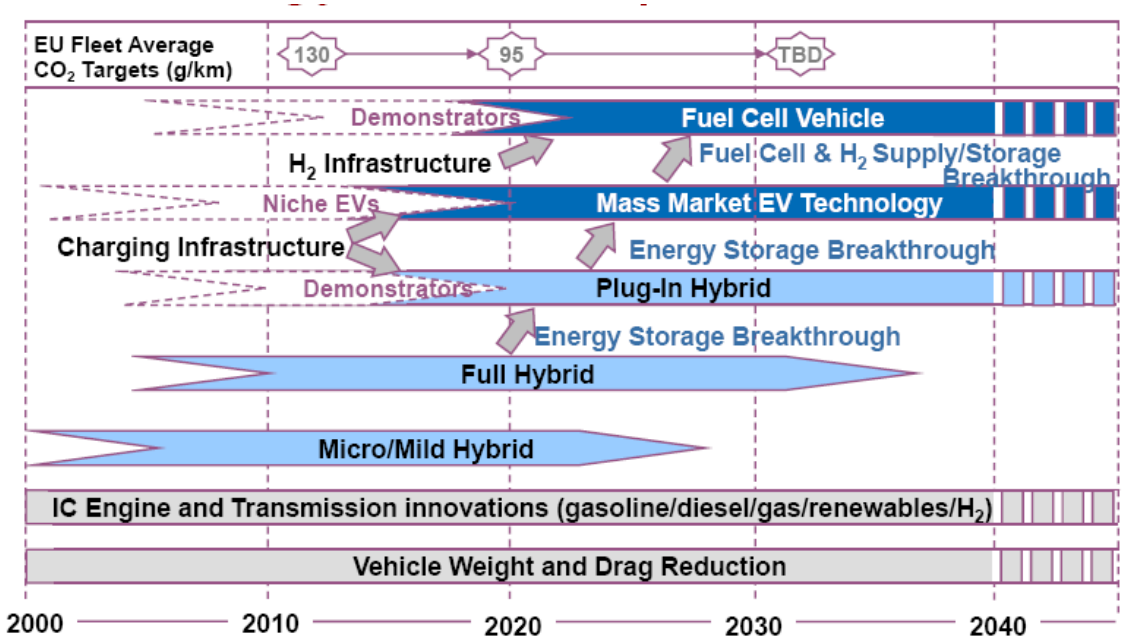


Figure 21. NAIGT roadmap (NAIGT, 2009)

There is a consensus that the biggest potential end use market for H2FC technologies is in mainstream road transport, but that many challenges remain to be overcome in areas such as renewable hydrogen production and storage, and in the cost and performance of fuel cell systems before this lucrative future market can be realised. Although there have been a number of recent announcements to indicate that mainstream automotive suppliers (OEMs) will begin to produce fuel cell vehicles in 2015, it is unlikely that significant deployments of fuel cells in transport will occur before 2020.

A number of other early market opportunities exist however where the technical requirements for H2FC technologies are not so challenging as for mainstream road transport or where the cost-benefit of new technologies is more easily realised than in competing against very mature incumbent technologies, such as the internal combustion engine.

The Roads2HyCom study offered the following summary of market opportunities in fuel cells (Roads2HyCom, 2009):

Table 13. Market opportunities for fuel cells (Roads2HyCom, 2009)

Sector	Prototypes	Product on sale	Mass production
Leisure APU	Now	2008	Limited potential
UPS*	Now (> 10 OEMs)	2010-2015?	2010?
Micro CHP	Now (> 10 OEMs)	2010-2015?	2011-12?
Industrial CHP	Now (> 10 OEMs)	2010-2015?	2010?
Fork lift	Now (5 OEMs)	2012-17?	2015-20?
Scooter/bike	Now (> 10 OEMs)	2010-2015?	2015-20?
Bus	Now (7 OEMs)	2020-25?	2015-25?
Car	Now (9 OEMs)	2015-30?	2025-35?
Small portable	Now (> 40 OEMs)	2009?	2008?

*APU = auxiliary power unit; UPS = uninterruptable power supply; CHP = combined heat & power

Table 14 below presents a modified version of Table 13 (with the limited market offered by leisure APU replaced by APUs for transport applications, which offer much greater long-term potential) with the market opportunities presented by Roads2HyCom (plus a further opportunity in remote/autonomous power) mapped against:

i. Current project activities in the emda region
ii. Current project activities in the Midlands region
iii. Potential/actual projects brokered or facilitated as part of this project

Table 14. Fuel cell market opportunities mapped against current Midlands activity, plus potential projects covered by this study

Sector	Current activities		Potential projects
	Emda	AWM	
Transport APU			+
UPS			
Micro CHP	+	+	
Industrial CHP	+		
Fork lift	+		+
Scooter/bike	+		+
Bus			
Car	+	+	+
Small portable			
Remote/autonomous power	+		+

As can be seen, the Midlands, particularly the emda region, offers activities that address many of the fuel cell market opportunities identified by Roads2HyCom. The work of this project has facilitated actual and potential projects that build on these opportunities, and has potentially extended Midlands capabilities with a potential project in auxiliary power units (APUs) for transport applications.

5.5 Projects and possible national RD&D funding

R&D

As a developing technology area, ongoing R&D is required in all areas of H2FC technologies. In its March 2009 call for H2FC funding, the Technology Strategy Board (TSB) aligned its funding priorities towards meeting the targets set by European Strategic Research Agenda of the Fuel Cell and Hydrogen Technology Platform, which covers:

- Hydrogen production
- Hydrogen storage and distribution
- Stationary applications
- Transport applications
- Portable applications
- Socio-economic aspects

In a presentation written for the BMHF stakeholder event on 22nd February 2010, the TSB noted the following interventions in H2FC in recent years (Table 15).

Table 15. UK national hydrogen projects

	number of projects	grant value (£m)	total project value (£m)	number of hydrogen projects
2008 and previous years	6	9.6	19.2	2
2009	9	8.7	17	1
2009 demo	14	7	20	4

The message from the TSB was that in 2010 it aims to review and disseminate the outcomes of its recent funding interventions, implying that additional dedicated R&D funding in 2010/11 for H2FC is unlikely; there will however be funding programmes in other low carbon areas which workers in H2FC technologies may be able to collaborate in.

Demonstration

The TSB reported in February 2010 that more funding for demonstration projects was likely to emerge from the outcomes of a workshop carried out by DECC and the TSB on roadmapping (TSB, 2009a). The workshop highlighted a number of opportunities for large-scale demonstration projects shown in Table 16 (again, these are mapped against actual and potential activities in the Midlands).

Table 16. Regional activities mapped against areas of interest from DECC/TSB roadmapping work

Sector	Current activity		Potential projects
	Emda	AWM	
Small fleet demonstrations	+	+	+
Hydrogen and CCS in large-scale power generation	+		
Hydrogen and distributed generation	+		
Hydrogen and grid balancing	+		
Hydrogen, electricity and vehicles	+	+	+

DECC is currently finalising Action Plans for Hydrogen and Fuel Cells, although at the time of writing (May 2010) these have not been published, which are likely to set out future demonstration funding possibilities for the sector aligned with some of the areas shown above. If that is the case, then the Midlands is well positioned to bid for some of the funding.

6 Hydrogen and fuel cell roadmap for the East Midlands

6.1 Introduction

There have been a number of roadmaps published charting the evolution and market deployment of hydrogen technologies. The most comprehensive recent analysis is the Roads2HyCom study which provides a summary of roadmaps from published sources, including the IEA, EU HyWays project and the Hydrogen and Fuel Cell Technology Platform (HFP), US DoE and the Japanese Strategic Technology Roadmap (Roads2HyCom, 2009).

In developing a roadmap for hydrogen and fuel cell technologies in the East Midlands it is important to consider:

1. Market drivers, which will be mainly national or global in nature
2. Regional capability to exploit the opportunities

Section 5.4.1 discussed the first point by referring to the roadmaps developed for hydrogen uptake by the Roads2HyCom and NAIGT studies in 2009 which apply on a UK-wide basis, and therefore to the Midlands. The Roads2HyCom hydrogen uptake roadmap is shown again below:

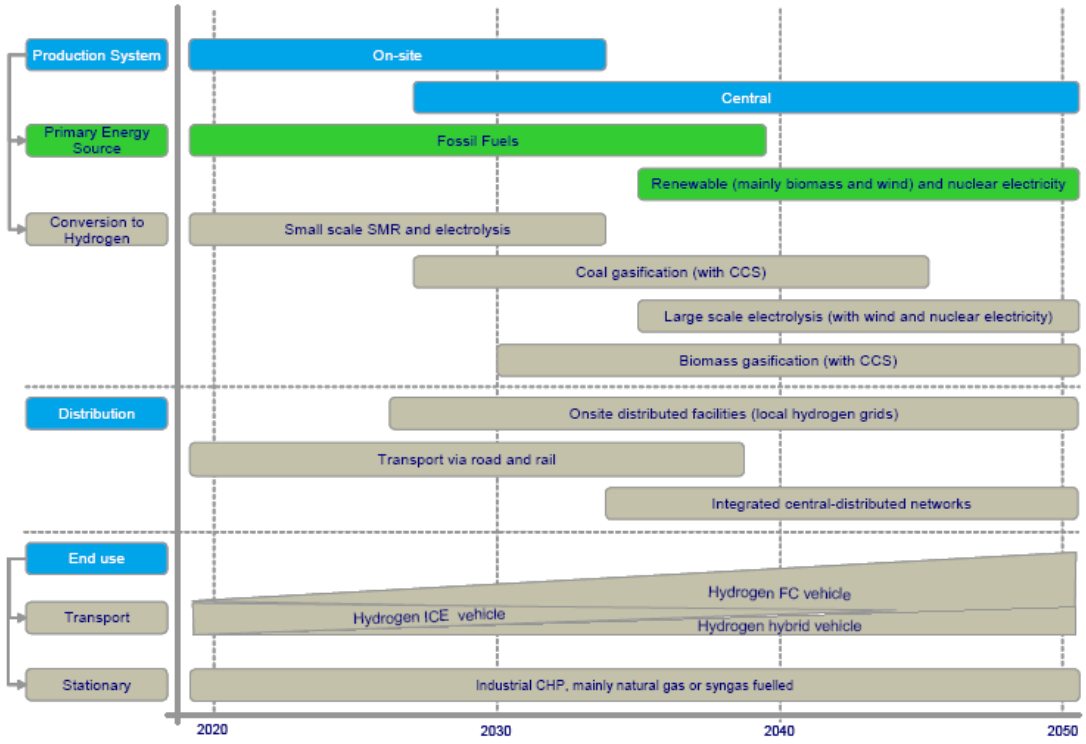


Figure 22. Roads2HyCom picture of hydrogen uptake in Europe

The remainder of this Chapter discusses the region's capacity to respond to the opportunities presented by the uptake of hydrogen technologies shown in Figure 20 and proposes areas of strength that the region should focus on.

6.2 Regional capacity to exploit opportunities

Chapter 4 presented a detailed survey of the capabilities of regional and extra-regional organisations affiliated to the British Midlands Hydrogen Forum. Analysis of these revealed strong capabilities across the following segments (Table 5, repeated below. Organisations from outside the Midlands, but members of the BMHF, are shown in italics).

Area of strength		Organisation
Products and technologies	Electrolysis	Bryte, *ITM*
	Solid state H_2 storage	Universities of Birmingham & Nottingham
	H_2 refuelling	Birmingham, Coventry, Loughborough, *ITM*
	Solid oxide fuel cells	Rolls Royce, University of Birmingham
	Proton exchange membrane fuel cells	Intelligent Energy, Universities of Birmingham, Loughborough & Nottingham
	Systems architecture	Intelligent Energy, *ITM*
	Fuel cell vehicles	Intelligent Energy, Microcab, University of Birmingham
Services	Demonstration	Midlands Hydrogen Ring
	Education	Midlands Energy Consortium members (Birmingham, Loughborough, Nottingham)
	Energy system integration	Bryte, ICE, *TNEI*
	Power generation	E.ON

Similarly, the Roads2HyCom study presented early and longer-term market opportunities for fuel cells in the following applications (Table 13, repeated below).

Sector	Prototypes	Product on sale	Mass production
Leisure APU	Now	2008	Limited potential
UPS	Now (> 10 OEMs)	2010-2015?	2010?
Micro CHP	Now (> 10 OEMs)	2010-2015?	2011-12?
Industrial CHP	Now (> 10 OEMs)	2010-2015?	2010?
Fork lift	Now (5 OEMs)	2012-17?	2015-20?
Scooter/bike	Now (> 10 OEMs)	2010-2015?	2015-20?
Bus	Now (7 OEMs)	2020-25?	2015-25?
Car	Now (9 OEMs)	2015-30?	2025-35?
Small portable	Now (> 40 OEMs)	2009?	2008?

Recent work by DECC/TSB revealed following likely early funding opportunities for hydrogen technologies (Table 16, repeated below):

Sector	Current activity		Potential projects
	Emda	AWM	
Small fleet demonstrations	+	+	+
Hydrogen and CCS in large-scale power generation	+		
Hydrogen and distributed generation	+		
Hydrogen and grid balancing	+		
Hydrogen, electricity and vehicles	+	+	+

Cross-referencing the opportunities in the tables above against the regional strengths displayed in Table 5. Summary of regional strengths in hydrogen and fuel cells leads to the statement of areas of market opportunity for the Midlands below (Table 17):

Table 17. Key hydrogen opportunities for the Midlands

Area	Technology strength of the Midlands
Hydrogen production	Electrolysers
	Precombustion carbon capture and storage
Storage and distribution	Solid state hydrogen storage
	Hydrogen fuelling stations
Use	PEMFC in vehicles
	Stationary fuel cells

As discussed in Section 4.3 a seventh area of strength, which underpins and enables the region's hydrogen and fuel cell cluster, is offered by the region's academic capabilities.

6.3 Developing an East Midlands hydrogen deployment roadmap

In assessing the potential of the six areas described in Table 17 it is important to bear in mind that, like all hydrogen technologies, they are propositions that will only shown market return in the long term. Although estimation of the future market for hydrogen technologies is challenging it is possible to offer a scenario for the UK deployment of

these technologies by backcasting from the UK's renewable energy targets for 2030 and 2050 (Barton and Gammon, 2010). As an example, the current installed base of hydrogen fuelling infrastructure and vehicles is extremely low. In order to meet the UK's targets for 2030 and 2050 huge deployments will be required, and all studies/roadmaps indicate that market take up must ramp up significantly after 2020. Based on the work of Barton and Gammon, plus other assumptions based on current and future growth in the UK markets, the UK national market deployment scenario for the deployment of the six technologies developed in the Midlands for 2010-2050 shown in Figure 23 has been created. This is a very high-level scenario, and the assumption of market share based on a broad-brush assessment of the capabilities of the region and the level of competition it may face in each area. It can be assumed that deployment in most advanced economies will follow a similar trend.

The scenario reveals significant potential for the six areas of regional strength identified. Some, such as vehicle refuelling, do not rely on technology breakthroughs. Others, such as the region's ability to exploit the growing numbers of vehicle deployments to gain a share of the on-vehicle hydrogen storage market, rely on significant breakthroughs in hydrogen storage technology – specifically solid-state storage – if it is to play to the region's major strength.

6.3.1 Local market stimulation

A central question is whether the Midlands is content to allow its industry to develop according to global market drivers or whether it is prepared to offer regional stimulus to promote early local deployment of some of the technologies that align with regional competencies. As the Roads2HyCom study notes, local funding and local political will are crucial in early deployment 'Lighthouse Projects'.

Figure 24 offers a scenario based on a proactive strategy leading to early deployment in the East Midlands of each of the technologies shown in the national picture presented in Figure 23. The model is not sophisticated, and takes no account of the link between technologies (e.g., whether the deployment of vehicles will lead or lag the deployment of infrastructure), but simply pulls forward the regional version of the supply curves shown in Figure 23.

The data from Figure 24 is tabulated in Table 18. While the deployment numbers shown are extremely challenging, and will involve significant injections of funds (whether public or private), it needs to be borne in mind that, according to Barton and Gammon's analysis, the national trend figures (shown in blue in Figure 24) are the minimum needed to meet UK national energy targets in 2030 and 2050. Enhanced regional deployment (shown in red) would help build a local market that could be supplied by

Midlands companies which could also supply the global market for these technologies. The work of Porter discussed in Section 4.5 stresses that local demand factors are crucial in building competitive advantage for the region.

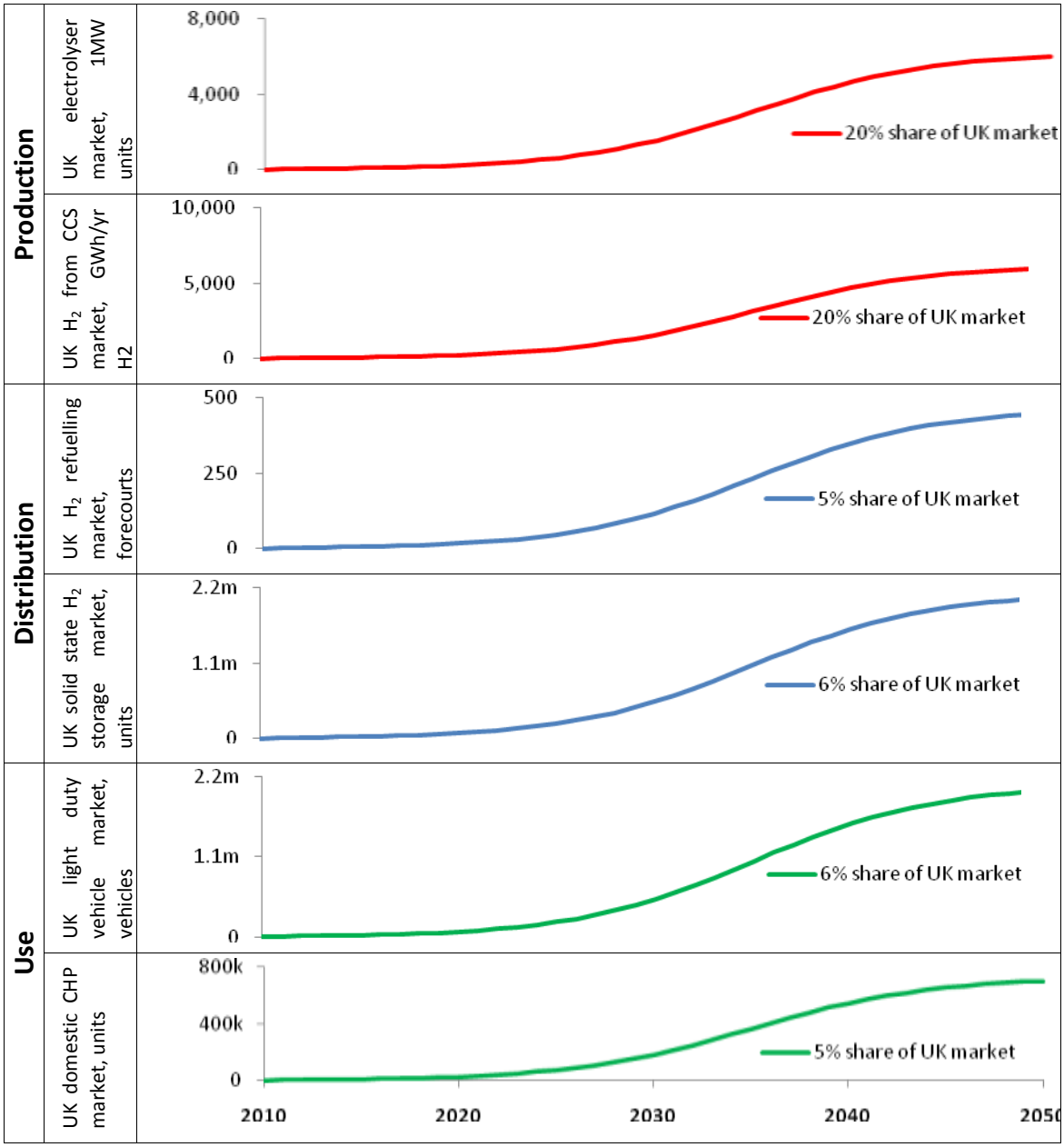


Figure 23. Deployment scenario for key Midlands hydrogen technologies to 2050

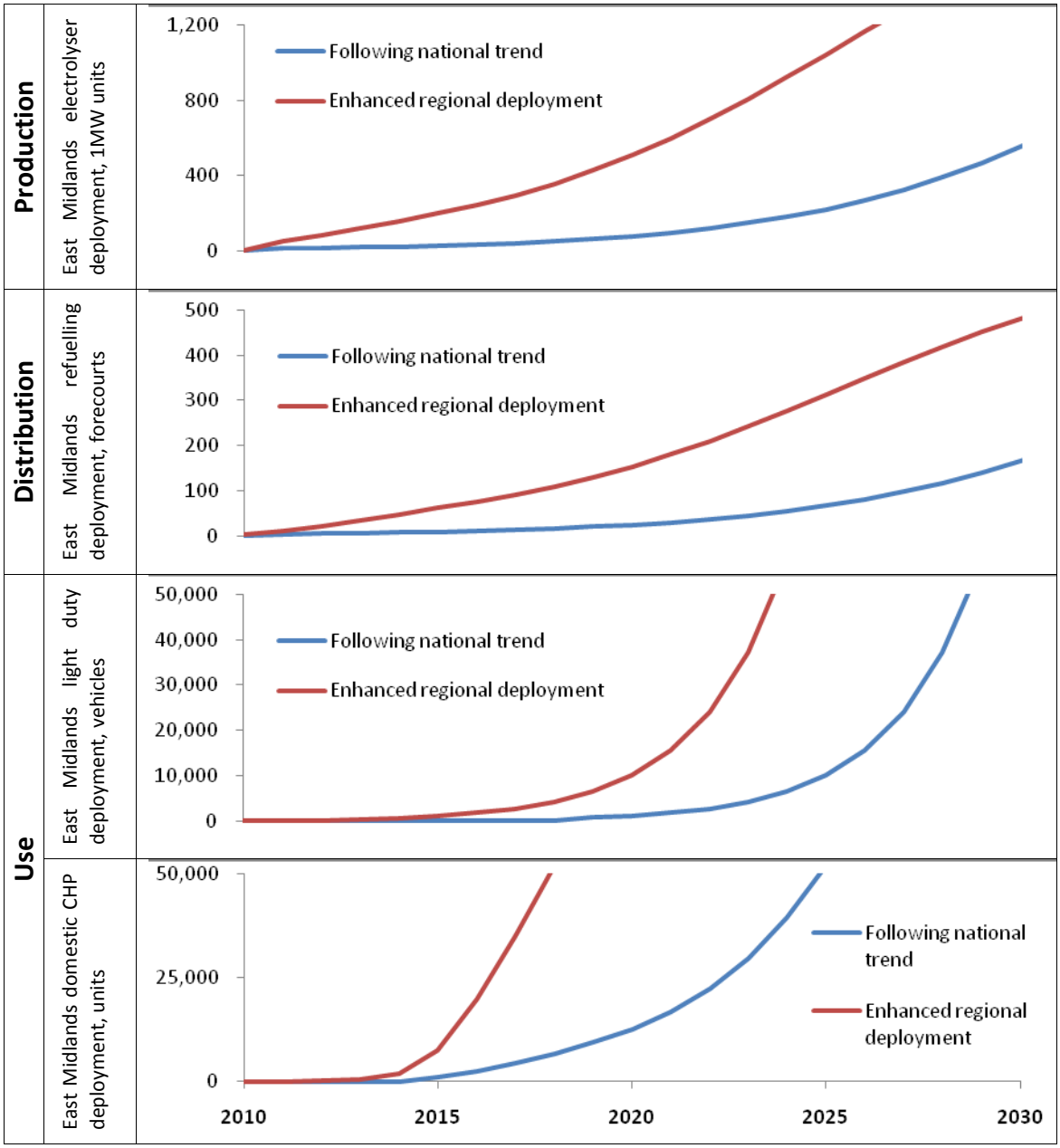


Figure 24. Scenario showing nhanced regional deployment of strategic hydrogen technologies in the Midlands to 2030

Table 18. Scenario for East Midlands deployment of regional strategic hydrogen technologies

Date	East Midlands Electrolyser Deployment, 1MW		East Midlands H2 Refueller Deployment, forecourts		East Midlands H2 Light Vehicle Deployment, vehicles		East Midlands FC Stationary Deployment, domestic CHP units	
	Following national trend	Enhanced regional deployment	Following national trend	Enhanced regional deployment	Following national trend	Enhanced regional deployment	Following national trend	Enhanced regional deployment
2010	0	0	1	2	0	10	0	0
2015	27	200	8	60	0	1,000	1,000	7,500
2020	79	508	24	152	1,126	10,093	12,549	90,110
2025	221	1,043	66	311	10,093	87,950	52,181	301,929
2030	552	1,609	165	480	87,950	615,651	193,184	661,087

6.4 The role of public procurement

In promoting regional H2FC capabilities – whether through 'Lighthouse Projects' or a fully-fledged 'Hydrogen Communities' – the role of procurement is crucial (Roads2HyCom, 2009).

The Government champions the use of the UK's £220bn annual public procurement budget to foster innovation through all its available channels, including RDAs. At the time of writing the pressure to reduce and obtain best value for this budget is increasing, nevertheless as noted by the Technology Strategy Board (TSB) the sheer size of the procurement budget makes national government uniquely placed to develop 'new technologies and services, putting the UK and in particular UK business at the forefront of innovation' (TSB, 2010). A recent example of the use of procurement to showcase hydrogen and fuel cell technologies was provided by the installation of the UK's largest fuel cell to provide CHP in Transport for London's showcase Palestra building (TfL, 2010). Funding for the £2.4m project was provided by TfL's £25m Climate Change fund.

Currently, the Department for Business, Innovation and Skills (BIS) leaves bodies such as RDAs to implement their own procurement plans. There is evidence of the beginnings of a high level strategy developing in the East Midlands. In the emda region, public procurement is estimated at £8bn per year and the region has recently published its Regional Procurement Opportunities Plan (emda, 2010) which includes the aim of reducing 'demand for energy and resources by driving change through public procurement'. Objectives of the plan include:

- Increased success for the region's private businesses and not for profit organisations in local and global public procurement markets, resulting in … benefits at all tiers in the supply chain
- Accelerated progress towards achieving regional priority objectives for the economy, society and the environment

However, it is clear from discussions with stakeholders on the outcome of this study that implementing the strategy at ground level will be challenging. Regional and local procurement initiatives are focused on obtaining value for money; they are less aimed at showcasing or stimulating new technologies with their associated risk (whether real or imagined) and higher costs.

The use of procurement to stimulate the market for innovative technologies has long been raised at a national level by Fuel Cells UK, which has pushed for the wider adoption of forward commitment procurement, tax incentives and further demonstration project support (FuelCellsUK, 2010). It is clear that there remains some way to go before green procurement becomes a daily reality in the region. It is also clear however that without the adoption of innovative procurement practices, the uptake of hydrogen and fuel cell technologies in the region will be slow, or will at least reflect the UK's national level of takeup. Some of the projects presented in this Section 5 of this report, such as the potential deployment of fuel cell vehicles in the East Midlands, offer potential exemplars of a procurement-led approach.

Part III. Midlands Hydrogen Forum

7 The British Midlands Hydrogen Forum

7.1 Introduction

As detailed in Part I of this study, the Midlands has a cluster of universities and industrial organisations with established expertise in hydrogen-related technologies including hydrogen production, storage, distribution and use in engines and fuel cells. According to *Hydrogen and Fuel Cell Capabilities of the British Midlands Region* (BMHF, 2007), over a third of the UK companies developing fuel cell technologies are located in the Midlands region. Furthermore:

In the UK, Europe and USA, it is regional activities that are leading the drive to promote and invest in the demonstration of hydrogen technologies. It might therefore be expected that early adoption will be mainly through regional initiatives. With a wealth of activity and expertise in hydrogen and fuel cell technologies that is unrivalled in the UK, the Midlands is well placed to exploit these trends. The region has a strong heritage in manufacturing, particularly in the automotive field, and in technology-based research and innovation.

The Midlands has been recognised by the European Commission (through its Hydrogen and Fuel Cell Platform Joint Undertaking – formerly known as the Joint Technology Initiative or JTI) as one of nine leading regions across Europe (the only one in the UK) developing and exploiting hydrogen and fuel cell technologies. This positions stakeholders in the region to exploit the opportunities offered by European Union and UK National Programmes for funding RD&D. However, to maintain a leading position in an increasingly competitive environment with significant pressures on funding stakeholders in the region need to operate with a common voice. From 2007-2009, the British Midlands Hydrogen Forum (BMHF) provided a voice for the region's hydrogen and fuel cell community, as described below.

7.2 Origins of the British Midlands Hydrogen Forum

The BMHF was formed in 2007 to showcase regional capabilities by raising the profile of the region and positioning the Midlands to play a leadership role in national and European agenda setting for RD&D priorities (with a particular focus on demonstration) and latterly to aid the region to win a share of available funding. Start up funding for the BMHF was provided via Cenex, utilising funding from the Technology Strategy Board's Low Carbon and Fuel Cell Technology Knowledge Transfer Network (LCFC KTN).

Both emda and Advantage West Midlands (AWM) subsequently contributed to funding tasks undertaken by the BMHF under the 'British Midlands' collaboration between the two RDAs. The RDA contributions were particularly important in taking forward the inward investment agenda. The BMHF successfully pursued its objectives through to 2009, with a highlight being the provision of a coordinated regional presence at the October 2007 Tenth Grove Fuel Cell Symposium in London.

7.3 Current constitutional model of the British Midlands Hydrogen Forum

The British Midlands Hydrogen Forum (BMHF) has 132 members from 65 companies. 18 organisations are based in the West Midlands and 21 in the East Midlands, while others are involved in hydrogen and fuel cell activities in one of the Midlands regions, but are based elsewhere in the UK.

It should be noted that the BMHF was never formally constituted; it was developed in support of the capability in the sector in the region.

7.4 Achievements of the British Midlands Hydrogen Forum 2007-2010

Chaired by Dr Rupert Gammon since 2007, the BMHF has followed a broad-based work programme aimed at promoting the region's capabilities nationally and internationally. Headline achievements in the past three years have included:

Establishing a community of H_2 & FC stakeholder

- Forum has 132 members from 65 companies

Establishing a brand

- Developed a logo
- Produced a brochure with a regional capabilities map
- Website (hosted by the Transport KTN, http://www.bmhf.org)
- Presented Annual Hydrogen and Fuel Cell Future Award at the Birmingham Hydrogen and Fuel Cell conference in March 2009 and 2010

Initiating the Midlands Hydrogen Ring project

Encouraging further collaboration within the region, e.g.:

- Valeswood test of Horizon FC at West Beacon Farm
- Road tests and refuelling of Nissan X-Trail FCV between Birmingham, Loughborough and Cranfield Universities
- Brokering collaborative funding bids

Encouraging collaboration beyond the region, e.g.:

- Linking EETC, Sheffield with Midlands Hydrogen Ring
- Hosted two workshops for the UK-HyNet project

Representation with Government

- BMHF is leading the agenda at the national level (e.g. through UK-HyNet and UKHA) , but does so with regional interests at heart
- Dialogue with RDAs

Raising the profile of the region on the international stage

- Exhibitions: Grove, Hannover Messe
- Conferences, e.g.: annual Birmingham Hydrogen and Fuel Cell Conference, All Energy, and International Hydrogen & Fuel Cells Futures
- HyRaMP (BMHF was a founding member of this regional grouping of the H2FC JU / JTI)
- Trade missions: e.g. Scandinavia, Oregon, Chile, Australia, Slovenia, China, etc
- International Energy Agency, Hydrogen Implementing Agreement: Annexes 18 & 24

7.5 Current status of the British Midlands Hydrogen Forum

Momentum for the forum has dissipated since early 2009 as a result of a loss in funding support due to LCFC KTN Programme Board's decision to reprofile spend (cutting out funding for BMHF) and ultimately as a result of the decision of the Technology Strategy Board to disband the LCFC KTN. Similarly the emda/AWM British Midlands collaboration has also ceased.

The headline work packages outlined in Section 7.4 have offered a number of benefits to regional players. Without the ongoing support mechanism provided by the BMHF

there is a risk that stakeholders within the region will end up chasing opportunities to participate in other regions' project proposals rather than be part of leading edge region led projects. It is for this reason that this project proposal seeks to re-energise the BMHF (as an updated Forum\Community Grouping) off the back of the strategic analysis of regional resources, capabilities and opportunities presented in Part I. The process of analysing the way forward for the forum by assessing the strengths and weaknesses of potential operational models, and engaging the regional H2FC community to provide work programme for the forum driven from the 'bottom-up' is described in the next chapters.

8 Models for a Midlands Hydrogen Forum

8.1 Introduction

This chapter offers an analysis of potential operational models for a future Midlands Hydrogen Forum by referring to a number of models for other organisations. The model chosen must allow the revised forum to continue and expand on the work of the BMHF outlined in 7.4, encompassing activities such as:

- realisation and ongoing refinement of the Hydrogen Technology Framework
- dialogue with Regional Development Agencies (RDAs) across all regions covered by the forum – for example emda in the East Midlands and AWM (Advantage West Midlands) in the West Midlands
- showcasing of regional capabilities on a national and international stage
- allowing the region's hydrogen community stakeholders to work together to engage effectively and constructively internally and with other regions and hydrogen and fuel cell forums and associations nationally and internationally
- effective dissemination of information to forum members about regional activities and the activities of the forum
- dissemination to forum members about funding opportunities
- cooperation on regional and national project activity
- dialogue with regions outside the UK
- establishment of demonstration projects
- facilitation and promotion of its stakeholder needs

The activities of the forum must deliver value to its members and potential funders; ultimately the longevity of the forum will be assured by demonstrating real outcomes from these activities.

8.2 Constitutional model

Firstly, it is important to define what a constitutional model is: it is a set of rules that will dictate what the forum is and how it works. The rules cover forum governance and operational aspects, including:

- Mission/focus/aim: the driver for the forum and the reason for existence

- Advocacy and Activity: what the forum will deliver, and the balance of advocacy on behalf of its members and the region with activity leading to collaborations offering tangible benefits for the region
- Structure: what form the forum will take, and how it will be governed and managed
- Staffing: the staffing requirement for the forum, and what type of staff are required
- Funding: how the forum will be financed, and what level of funding is required
- Membership: who will be encouraged to engage with the forum, what profile will they have, and what limitations will be imposed

The next section reviews possible models for the forum; they are discussed in more detail in Section 8.4.

8.3 Review of possible models for the forum

Alternative constitutional models utilised for different organisations from the UK and Europe have been investigated in order to capture best practice from previous experience so as to inform the structure and function of the forum going forward. This involved desk based research to identify suitable organisational models followed by consultation with key figures at the organisations selected in order to gather information to assess the strengths and weaknesses of each approach. The chosen models (summarised in Table 19) draw on the experience and expertise of Cenex and TBAT Innovation and are therefore predominantly related to the transport and energy sectors. A complete presentation of the information is available in Appendix 2. The constitutional models have been assessed in terms of their perceived strengths and weaknesses as discussed in the next section.

Table 19. Summary of possible Forum constitutional models

Model and example	Funding	Structure	Aim	Membership
National sector focused network with themed activity subgroups: **Foresight Vehicle**	Central funding for secretariat (and website etc) and thematic group chairmen	Central secretariat and 'figurehead' chair with five subgroups (Thematic Groups), each with a paid chairman	Promote sector interests	Free. By participation and/or invitation
National sector focused network with themed activity subgroups plus membership fees: **LowCVP**	Central funding for secretariat plus membership fees	Secretariat team (steered by a board) oversee a number of working groups focused on specific sub topics	Promote sector and member interests	Need to be involved in UK's low carbon vehicle sector and pay membership fees
National technology area focused knowledge network: **Transport KTN**	Central government funding via TSB	Central secretariat administering the networks	Promote collaboration, best practice and knowledge sharing by bringing together a variety of stakeholders	Free - open to all (national and international)
Regional sector focused network with funding support to members: **Niche Vehicle Network**	Funding from regional government for secretariat (and website etc) plus funding pot to allocate to R&D projects	Secretariat. Steering group of 15 organisations (12 private sector, three public) headed by chair	Promote sector interests and promote regional collaboration and capability building	Free. By participation and/or invitation

Model and example	Funding	Structure	Aim	Membership
Regional sector focused network with funding support to members: **North Rhine-Westphalia**	Funding from regional government, or joint funding from national & regional government, for secretariat and outreach	Funded regional offices and officers	Promote sector interests with regional focus	Free. Open to any regional, national or international players irrespective of whether core business is H_2
Trade association: **Fuel Cells UK**	Membership fees. Two levels of membership - executive (steering group) and normal, with scale of fees for SMEs, academic etc.	Funded secretariat. Chairman and executive committee to steer activities.	Promote specific aims of the association	Membership fees. Membership is open to any organisation which is interested in H2FC technology
Regional trade association: **Midlands Aerospace Alliance**	Membership fees. Two levels of membership - in region and out of region (midlands)	Paid chairman. Funded secretariat. Board of Directors to steer activities.	Promote specific aims of the association	Membership fees. Companies involved in and with the aerospace industry.
Voluntary model: **LinkedIn**	Limited seed funding; little/none after	Funding to create brand and maintain member contact mechanism - e.g., LinkedIn or similar	Build a grouping driven from the 'bottom up' around a key theme or technology	Open to all
Regional subgroup of national body: **British Marine Federation**	Membership fees	Regional subgroups and associations administered by secretariat paid by national body. Executive committee made up of volunteer organisations to steer activities.	Provide regional focus based on national objectives - allows for a UK wide solution whilst addressing regional nuances	Membership with criteria: e.g., leisure marine companies that can demonstrate a proportion of turnover in the sector.

8.4 Analysis of models for the forum

Table 20 offers a summary of the strengths and weaknesses of the constitutional models presented in Section 8.3.

Table 20. Strengths and weaknesses of reviewed constitutional models

Model and Exemplar	Strengths	Weaknesses
Funded national sector focused network with themed activity subgroups. **Example:** **Foresight Vehicle**	- Core funding allows creation of brand and ensures longevity - Initial 10 years of R&D funding meant strong engagement from community - Subgroups formed when the size of the interested community > 20 people allow focus on particular agenda and building of strong community support	- Funding required to maintain secretariat and chairs - Chairs need to be relatively senior and credible industry figures, therefore relatively expensive - Loss of funding to hand out to project activities results in gradual disengagement the community
Funded national sector focused network with themed activity subgroups, plus membership fees. **Example:** **LowCVP**	- Core funding allows creation of brand and ensures longevity - Strong engagement from community with clearly focused objectives and working groups - Provides steer on future direction of the sector to the government - Additional funding provided by membership fees allows commissioning of work packages targeted at the needs of the working groups	- Funding required to maintain secretariat. - Membership fees may exclude some participants - As an organisation primarily aimed at influencing policy there can be a perception that some groups are just 'talking shops'
National knowledge transfer networks focused on a specific field of technology or business. **Example:** **Transport KTN**	- Core funding allows creation of brand and ensures longevity - KTNs stimulate networking and collaboration leading to active projects - Funding opportunities are actively promoted via direct link to TSB and its funding streams	- Individual KTNs created for each sector group can provide a confused picture for industry - In the current national KTN picture, H2FC technologies are covered as part of a wider energy generation and supply portfolio, with a possible lack of focus on H2FC technologies and loss of contact between participants - KTNs are designed to tap into other sources of project funding rather than providing funding themselves - Engagement is difficult to maintain if there is no funding available for a particular topic - KTN metrics have been criticised for tracking input measures rather than outcomes

Model and Exemplar	Strengths	Weaknesses
Regional sector focused network with funding support to members **Example:** **Niche Vehicle Network**	- Core R&D funding for projects encourages active participation on 'enlightened self-interest' principal (participation in network has potential to improve chances of project participation and funding) - Active projects promote the success of the programme and encourage further participation and act as a regional flagship	- Funding required to maintain secretariat - Addition of R&D funding has maintained and built participation. Therefore loss of R&D funding in future may weaken engagement?
Regional sector focused network with funding support to members **Example:** **North Rhine-Westphalia**	- R&D funding means strong engagement from community. - Active projects continue momentum and impression of activity. - Strong regional branding and leverage particularly at EU level - e.g. strong presence in HyRamp project - Open membership models ensures critical mass and attracts additional engagement	- Two full time offices and full-time officers; relatively expensive - Part national funding means that local agenda is partly diluted - Regional economic focus means that H_2 must be a key economic priority for region to ensure ongoing support and commitment from the regional agency
National trade association **Example:** **Fuel Cells UK**	- Focused advocacy and lobbying for additional regional/national/European funding for H2FC - As an organisation created by the then DTI, Fuel Cells UK has the ear of national government - Provides focus and brand for heightened profile of hydrogen in public agenda	- Lack of outreach to non-members. - Level of activity varies and is limited by level of membership fee attracted. - Lack of independence - Limited to advocacy only; no associated project activity, so can be viewed as a 'talking shop'
Regional trade association **Example:** **Midlands Aerospace Alliance**	- Strong sector focus incorporating key large organisations from across the region - Provides a conduit into the industry in the region, allows dissemination of information and provides a voice for the sector - strength in numbers - good opportunity for networking and integrating synergistic members	- Still requires public sector funding, i.e. may not be commercially viable without public sector support - As the MAA covers the East and West Midlands the politics of meeting the needs of both regions can become complicated - Lack of project funding means that activities are limited to networking and advocacy; can be seen as a 'talking shop'
Voluntary model **Example:** **LinkedIn**	- Inexpensive - Openness and independence of funding stream	- Lack of funding means that there is a need for a driven moderator and community buy-in to maintain momentum - Unlikely to attract high-level participation if no self-interest - i.e., project funding. - Lack of recognised brand - Lack of funding could mean lack of credibility
Regional subgroup of national body **Example:** **British Marine Federation**	- National network with regional focus - allows flexibility on a local level whilst still linking into a national agenda - Membership fees are paid to the national body which then entitles membership to the relevant regional subgroup. This avoids confusion of paying numerous membership fees to different bodies	- Needs a credible national body - Needs all existing networking forums/bodies to come together - Activities around networking and advocacy rather than project formation

A number of important factors emerge from the summary as discussed below.

- Core funding to cover operation enables the network to become established and develop a brand identity. This is true across all the networks studied.
- Although R&D funding can initially be a strength in terms of attracting members to a network, funding must be maintained if involvement is to remain high. The Foresight Vehicle model offers a clear example of diminishing involvement and a possible loss of purpose once R&D funding is lost.
- Subgroups focusing on a specific theme or technology can offer a valuable addition to core network activity. LowCVP's Innovation Working Group is an example of an subgroup which has real credibility and buy-in from the community over and above its association with LowCVP.
- Networks that operate across a number of regions will inevitably have to balance the wishes of key regional stakeholders such as RDAs, an issue which can lead to inertia, as evidenced by the Midlands Aerospace Alliance.
- In order for a network to have credibility a suitably qualified chairperson/head is required; as this will typically be a relatively senior industry figure the associated costs will be high. This is true across all the networks studied.
- Continued engagement with the network community is essential. This can be achieved (as shown in the models reviewed) through a number of mechanisms, such as: events; promotion of collaboration; promotion of capability; focused advocacy; lobbying government etc.
- Inclusion of and buy-in from the larger organisations in that sector offers real credibility to a network. Fuel Cells UK has been effective partly because the main organisations in its space, such as Johnson Matthey, have been active in the association.
- As open a policy as possible of membership recruitment appears to be a strength as it allows the network to gain critical mass.

Membership fees can offer an additional funding stream which can be used according to the wishes of the members. Membership fees will be discussed further in Section 9.3.4.

8.5 Review of the context in which the potential forum will operate

In order to inform the direction of the project and to shape the constitutional model, an evaluation of the context within which a future forum will operate was undertaken. This considered which associations exist on a regional, national and European level that focus on H2FC technologies. The context has been mapped and has been added overleaf for reference (Figure 25). It can be seen that there are a number of

organisations that need to be considered in terms of the external environment and stakeholder landscape of the forum. The key considerations are:

- how would a future forum 'fit' with the other regional forums that already exist?
- how would the forum link into the national context?
- what could the national context look like?[3]

These points are important as they inform the form and function of the forum and how it aligns with and relates to existing hydrogen and fuel cell related bodies and organisations. A brief overview of the activity and constitutional model for each of the national and regional organisations identified has been provided in Appendix 3 for reference.

In the national context, it is acknowledged by stakeholders that there are too many organisations representing the H2FC sector. It is further acknowledged that this promotes confusion and is counter productive when interfacing with Government and other European Bodies. There have been a number of discussions held in 2009-10 between national and regional players regarding consolidation and harmonisation of activities. Following these discussions, at the time of writing (May 2010), Fuel Cells UK (FCUK) and the UK Hydrogen Association (UKHA) have announced that a Memorandum of Understanding concerning their intention to merge has been agreed. Subject to member approval, the organisations will merge from 1st July 2010.

The role and position of regional organisations (such as the Midlands Hydrogen Forum, SH2FCA and H2Wales) within this newly-formed 'hydrogen and fuel cell association' is yet to be understood. Any future Midlands regional forum must play an active, integrated and, where possible, leading role in positioning the regional bodies in the new national entity.

Prior to this development it had been suggested that UK-HyNet could have been developed into an umbrella organisation encompassing the existing national and regional bodies. UK-HyNet was originally formulated as a project to create 'a network of hydrogen infrastructure by 2015' (http://www.nissanpress.co.uk/press_site/releases/arc_2009/57999nis.htm).
Therefore, while UK-HyNet remains an important concept or brand for regional

[3] Although the remit of this project does not focus specifically on the national picture of the sector, it was felt important that this should at least be considered as forming a vital part of the landscape of any forum created.

infrastructure deployment activities, in the light of the anticipated UKHA/FCUK merger it looks highly unlikely that it will be extended to embody an overall national H2FC organisation.

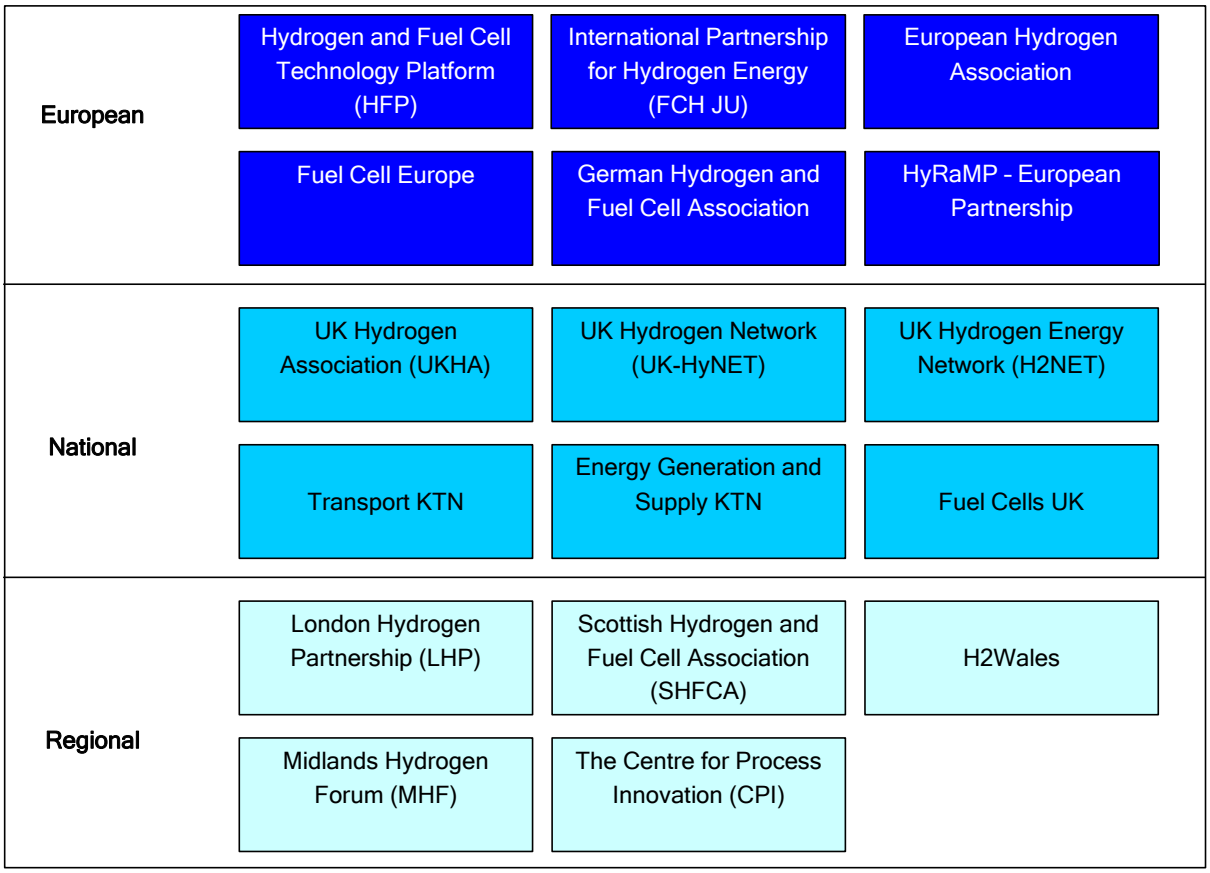


Figure 25. Landscape of hydrogen and fuel cell organisations

9 Midlands Hydrogen Forum stakeholder consultation

9.1 Introduction

As discussed in Section 7.5, engagement and activity in the BMHF has diminished since 2009 as funding for the forum was withdrawn. In order to move the forum forward, the project consulted with members of the BMHF, plus a number of extra-regional players, to encourage buy-in from the hydrogen community for renewed forum activity. The consultation process also aimed to capture lessons learnt and to establish understood best practice with regards constitutional models via a two stage process described below:

9.2 Stage one: direct stakeholder engagement

A list of stakeholders contacted is presented in the Confidential Material; this focused mainly on stakeholders from the BMHF located in the East Midlands. To support this exercise and to ensure consistency of approach for each consultation a semi-structured interview questionnaire was devised (also in the Confidential Material) with questions related to:

- level of engagement with the BMHF and review of past achievements
- role and activities of the BMHF in the future
- assessment of regional H2FC capabilities

All the responses received have been documented in the Confidential Material. Table 21 offers a summary of the responses displayed as a SWOT analysis. Key points made have been identified in bold.

Table 21. BMHF and Midlands regional SWOT from consultation with BMHF members

Strengths	**Weaknesses**
• **Unique sets of activities and capability** • **Infrastructure – Midlands Hydrogen Ring** • Brand • Lobbying • Information dissemination • Networking and facilitation	• **Limited number of members** • **Advocacy without activity: risk of the forum turning into a 'talking shop'** • Unclear objectives - what is the focus? • Lack of progress with Hydrogen Ring has damaged the forum's credibility • Lack of 'reach' to existing and future potential members - reports of difficulty in engaging with the forum • Greater activity in the West than the East Midlands; the belief that AWM has more money for supporting this sector and hence there is competition between the regions • Minimal evidence of collaboration between Universities and business
Opportunities	**Threats**
• **Provide future direction to regional activities based on a wider sector strategy** • **Enable demonstration projects – Hydrogen Ring offers a great opportunity** • Provide a link to a national body and possibly position the forum to drive a national body • Offer funding for projects • Stronger industry related chairperson • More intensive lobbying to central and regional government • Greater awareness raising • Drive the concept of working groups - for example could consider static and mobile applications as two areas of activity • Reach out to a wider audience - encourage greater membership • Increase collaboration between stakeholders • Provide links to regional knowledge base • Skills development for the sector - engineers, technicians • Promote the activity of key players – Rolls Royce, Intelligent Energy etc.	• **Large number of other forums exist - this has led to a segmentation of the sector into smaller potentially less significant groups** • **Lack of one overarching UK body for the hydrogen and fuel cells sector with which to link into; landscape is confused and positioning of the forum is critical** • Membership fees - already too many forums and associated charges - those interviewed suggested either no fees or low fees • Duplication of activity of a national and European level • Lack of understanding of the government's position on the hydrogen and fuel cell sector • Lack of funding for the forum or for projects between the forum's stakeholders • There is a perception that different regions do not want to collaborate - an issue for a cross regional forum • Increased profile of Wales through obtaining hydrogen Low Carbon Economic Areas status

The SWOT analysis shows that there are a number of strengths to build on as a result of the work undertaken by the BMHF. There is also clearly scope for development and improvement of the forum going forward to address the points detailed under 'weaknesses', 'threats' and 'opportunities'. This scope has been summarised under the following general headings (and associated descriptions):

- **Engagement**
    - Reach out to existing and new members in order to grow and develop the forum
    - Engage with and lobby central and regional government
    - Engage with other hydrogen and fuel cell bodies nationally and internationally
    - Review the chairperson role with a requirement for a higher profile person with wider industry experience to attract new members
- **Dissemination**
    - Promote the activities and capability of the forum to a wider audience
    - Publicise forum success stories
- **Positioning**
    - Clearly define the objectives and future direction of the forum
    - Provide information on the future direction of the sector
    - Position the offering of the forum to 'fit' within the existing and future context
    - Engage with the development of an overarching national body
    - Understand the government's position on the sector going forward
- **Collaboration**
    - Encourage collaboration between members
    - Encourage collaboration across regions including between Development Agencies
    - Encourage collaboration between business and the knowledge base
- **Activity**
    - Drive activity through advocacy

- Review funding options for the forum and the activities of its members
- Enable demonstration activity by informing, assisting & encouraging collaboration
- Drive the concept of working groups
- Review skills requirements for the sector going forward

The responses to the remainder of the questions posed as part of the interview questionnaire have been summarised below for reference:

How would this potentially fit/link to national schemes?

The majority of stakeholders consulted acknowledged that

1. there should be one overarching national body for hydrogen and fuel cells and
2. that the forum should be actively involved in this national body.

This would ensure that the forum (and the regions involved in the forum) would collaborate and communicate with other forums/associations/bodies nationally.

Interviews were undertaken with Fuel Cells UK and SH2FCA to discuss the point 'should there be an overarching national body' – the interview scripts for which have been added to the Confidential Material. The general feedback is that there should be one body that pulls together all other forums and associations in order to provide a single clear point of contact for potential engagement.

What would be the optimal organisational structure?

Minimal feedback was received from the forum stakeholders to this point. It was felt important that the operational delivery of the forum was overseen in some way to ensure that it delivered what it said it was going to deliver. An executive board or similar was suggested by some stakeholders as a potential solution.

What would be the criteria for joining?

The majority of stakeholders interviewed conceded that to enable any future forum to become independent of funding there is a need to significantly grow the membership. This membership however clearly has to have some form of interest in hydrogen and fuel cells - whether they are currently active or not in this field should not be a barrier. It was felt that the decision on who can join could be left to an executive board, who would judge the merits of each company on a case by case basis. This would then act as

a filter to ensure that the quality, focus and consistency of the forum membership are maintained whilst avoiding too stringent acceptance criteria.

How should the forum be funded?
What fee structure would be appropriate?
What would/could/should be the role of the Development Agency?

The general consensus was for no membership fees. A number of stakeholders consulted suggested low fees as a commitment to involvement rather than as a significant revenue stream for the forum. All stakeholders agreed that membership fees at this stage in the forum's development would not be sufficient alone to maintain its operation.

A significant number of stakeholders suggested that the most appropriate source of funding would be through Development Agencies – depending on what region and the level of membership interest.

Continuing on from the point above, it was suggested that each Development Agency providing funding would then sit on the executive board.

Would working groups be an option?

All stakeholders agreed that working groups would be a practical idea. The generally accepted concept would be for the formulation of a number of working groups centred around particular technical issues – for example hydrogen storage – or around themes – for example stationary applications of hydrogen and fuel cells. It was stressed that these groups need to be true working groups addressing real challenges faced by the industry. The definition of the rationale and focus for these groups is therefore critical to their success.

9.3 Proposed constitutional model

As a result of the work described in Section 9.2, a constitutional model was developed for review by the forum's stakeholders. This will be described below under the following headings:

- mission and aims
- activity
- structure

- staffing
- funding
- membership

An enhancement to the model was also proposed, whereby funding would be provided to collaborative projects between members to undertake research and development activity (c.f. the Advantage Niche Vehicle Programme described in Section 8.3).

It should be noted that the sections below (9.3.1 to 9.3.5) should be considered as a **proposal only** – this was presented to stakeholders at a workshop event (as detailed in Section 9.4) to act as a discussion piece. It has been outlined below to demonstrate the journey that was taken in reaching the recommendations made for the forum going forward.

9.3.1 Mission and aims

Mission

To provide value to our members by promoting research, development, demonstration, and deployment of hydrogen and fuel cell technologies.

Aims

- Increase the region's involvement in the hydrogen economy
- Develop the region's hydrogen and fuel cell capabilities
- Increase revenue into the region (via inward investment, new jobs created, etc.)
- Secure European and national funding for sustaining the forum and for supporting stakeholder projects
- Promote the region as a centre for hydrogen capability

The key to the forum will be the translation from advocacy (promotion of the forum, its message and strategy) to activity (focused projects on hydrogen and fuel cell development). This is expressed in Figure 26.

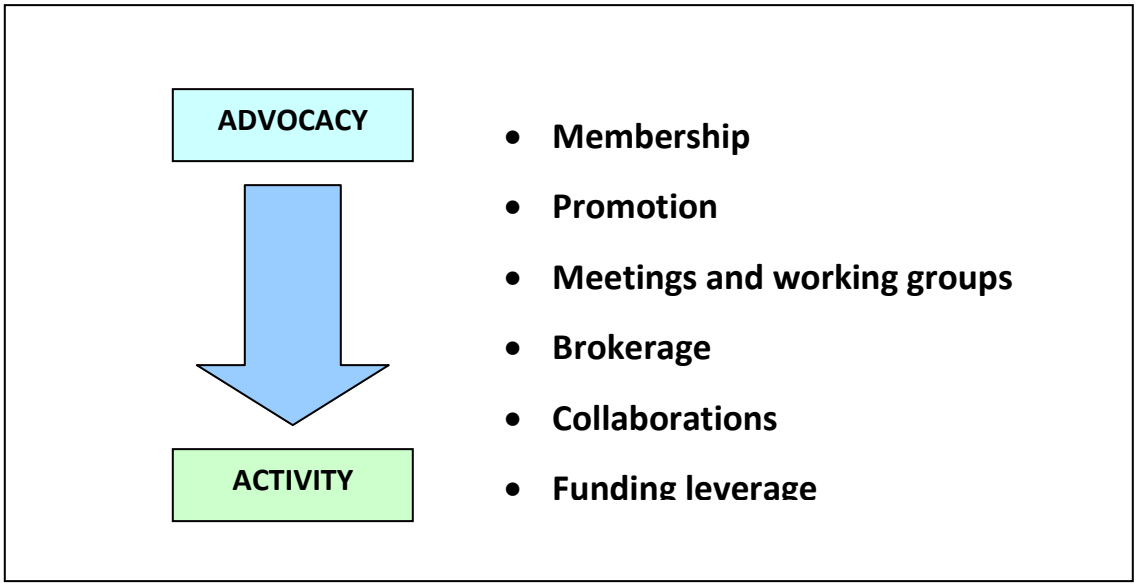


Figure 26. Forum work: from advocacy to activity

Expanding further on this crucial issue, the national Knowledge Transfer Networks (KTNs) offer a model of the transition from advocacy to activity. KTNs combine:

- A web portal providing technology, market and policy-related content on UK and international developments
- Networking events to bring together communities in order to promote technology transfer and innovation

Four sets of metrics are used to track KTN work programmes. Shown diagrammatically in Figure 27, the metrics aim to drive activity aimed at promoting a 'virtuous circle' of community engagement:

- Number of organisations that are members
- Number of meetings organised (active engagement of membership)
- Collaborations brokered
- Finance raised (public and private)

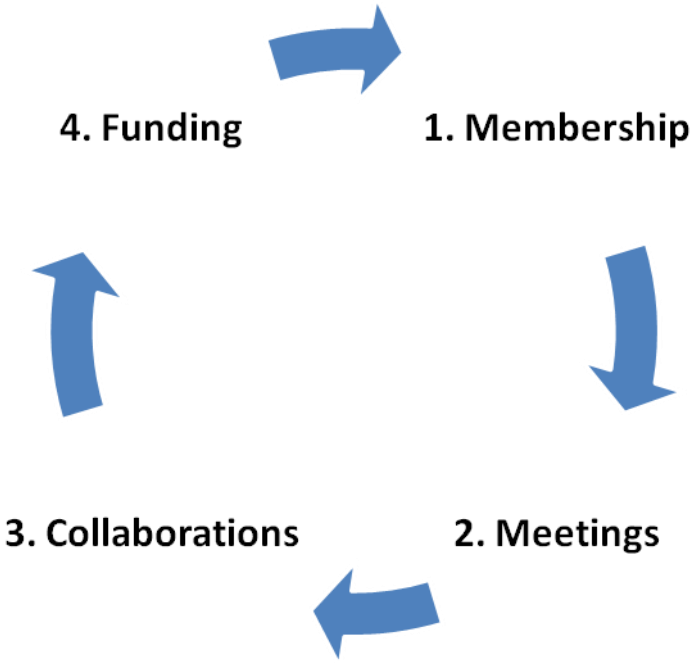


Figure 27. 'Virtuous circle' of community engagement

While the KTN metrics have been criticised for tracking input measures rather than outcomes, the model of engagement proposed is sound: growing membership and networking will lead to increased collaboration and funding for forum participants; evidence of success gained by attracting funding will serve to grow and progress the forum.

Some examples of potential and actual regional projects are:

- HARI – hydrogen energy storage and renewable energy
- SCRATCH - hydrogen from biomass; hydrogen distribution and storage; and hydrogen utilisation by fuel cell CHP
- Midlands Hydrogen Ring – hydrogen re-fuelling facilities
- Electrolyser development
- Feasibility study for fuel cell bike deployment

9.3.2 Structure

The structure proposed was for an organisation that is private, limited by guarantee and with no share capital (as is the case with the Midlands Aerospace Alliance and the British

Marine Federation, for example). A possible structure for the forum was outlined shown in Figure 28 based on that of the Midlands Aerospace Alliance.

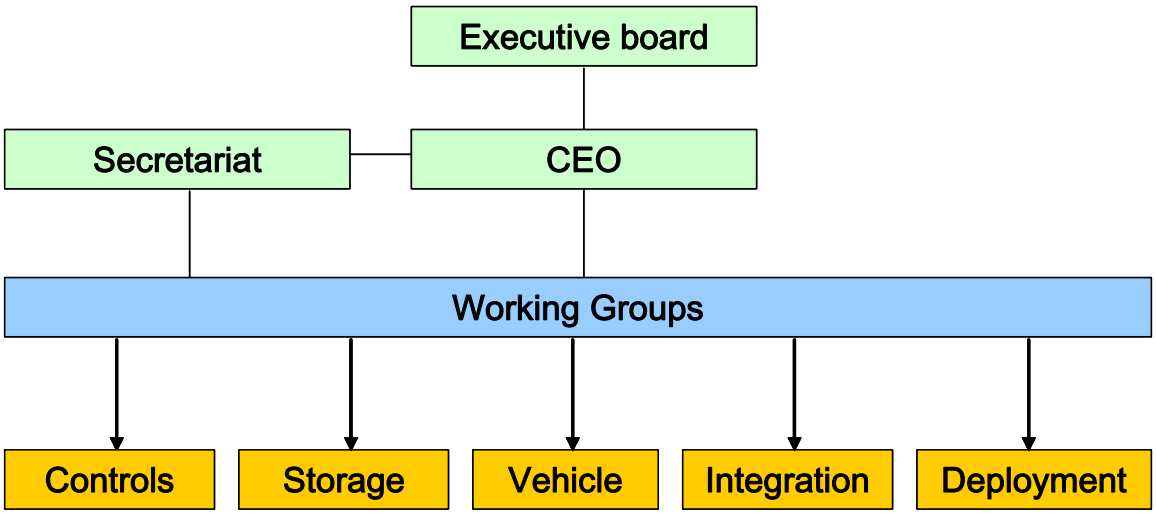


Figure 28. Possible structure for the Forum

9.3.3 Staffing

The following suggestion/proposal was put forward for discussion as a result of the investigations made for this and other similar projects:

Full time CEO (Chief Executive Officer). A salaried position, accountable to an executive board. Role responsible for promotion and delivery of forum activities, including accessing finance

Full time secretariat (x1) providing support to activities

Executive Board comprised of volunteers. Potential organisations to be invited: emda and other key regional stakeholders to act as monitors of progress for the forum

9.3.4 Funding

This investigation has shown that any forum could not be sustained by membership fees alone; indeed there is a general scepticism towards collecting any membership fees. Although there is an argument that a membership fee ensures commitment from members, evidence from other organisational models, such as KTNs, shows that any

level of fee serves as a barrier to entry to some potential participants, and the administrative overhead involved in collection and in chasing payment does not offer value for limited budget. One potential funding model is:

Three years of public funding to support the CEO and secretariat with a view to becoming at least partly self sustaining, or offering additional services at the end of two years through: membership, access to European funds etc (c.f., the current LowCVP model).

Anticipated annual funding: CEO £50k, Secretariat £20k, Sundries £24k = total £94k p.a.

9.3.5 Membership

In order to establish critical mass, membership should be open to all stakeholders (irrespective of their location) interested in hydrogen and fuel cells – i.e. it should range from providers of technology to end users and intermediaries.

9.4 Stage two. Stakeholder workshop

Stage two of the consultation process took the form of a workshop with stakeholders, structured to review the constitutional models devised for the forum and suggest the priority functions of the forum.

The workshop took place on 22nd February 2010 at the Innovation Centre on Loughborough University's campus and encompassed a presentation outlining the project undertaken, followed by a discussion workshop. The attendees at the event were split into four groups to better enable the discussions; efforts were made to ensure that there was a mix of stakeholder capability, activity and perspectives in each group to encourage a balanced discussion. A semi-structured interview script was devised in order to provide direction to the group discussions – this is shown in Appendix 4.

The feedback from the four groups is recorded in the Confidential Material and is summarised below:

9.4.1 General: constitutional model

The constitutional model proposed was well received.

On the subject of whether or not a future forum should offer funding in support of collaborative stakeholder projects, opinion was split. A number of stakeholders did not

think that the forum was the most appropriate mechanism for the distribution of monies in support of research, development and deployment projects – with designated programmes (SCRATCH was referenced for example) being the preferred alternative. Conversely, other representatives (mainly from the academic fraternity) present at the workshop intimated that any source of funding for projects should always be encouraged.

The majority of the stakeholders at the workshop anticipate either being fully involved with the forum or (as they are intermediaries to the sector) or would want to be kept informed and provide information (e.g. GOEM, HSL).

9.4.2 Mission/focus/aim

- The forum needs to assemble an evidence base for continuation of funding and activities:
    - What is the cost-benefit of participation?
    - What leverage can it show in terms of attracting funding to the region?
    - What leverage would it anticipate from continued funding?
    - How has/will it benefit SMEs?
    - What R&D funding has/will it attract?
- The direction/focus needs to be pragmatic and economically based
- The forum needs a clear proposition and focus
- A national roadmap or action plan is required - as it would help drive regional activity

Activity

- Action is the key - demonstration projects to address real challenges
- Development of technologies enabled by the forum could conceivably produce emerging businesses – to the benefit of the region
- Links to end users are required to provide targets to aim at for the sector
- Should the aim be towards a large scale demonstration, possibly focused on vehicles (as there seems to be significant support infrastructure and capability in this area – HSL also has experience in refuelling stations)?
- Forum should act as an introduction/dating agency with a view to developing collaborations in preparation for potential future funding calls

- Should fit/align to HyNET as closely as possible
- Provide visibility of European bids
- Provide links to other forums and organisations away from the sector - e.g. UK Magnetics Society
- The forum should provide a regional focal point (along the lines of a regional Centre of Excellence)
- Provide information on technology availability and technology readiness. Ability of get sight of what vehicle manufacturers are doing in hydrogen and to have potential influence
- Supply-side mapping (capabilities) and proactive demand-side mapping (potential opportunities for early deployment/demonstration projects) equally important. Midlands could become a high-profile leader in H2FC deployment and gain advantage in terms of its skills base, even if H2FC technologies are not manufactured in region. Needs proactivity and legwork to talk to potential regional deployers and to prospect along the whole innovation chain
- Activity is the desired end result but strong, proactive advocacy is still needed to achieve it
- Activity should be output orientated e.g.:
    - Coordinating funded project bids
    - Inward investment
    - Job creation
    - Wealth creation
    - Environmental / social benefits (emissions reduction)
    - Structural benefits (infrastructure development)
    - Dissemination, training, education
- The forum must help deliver funding to members, directly or indirectly
- SMEs need help/sign posting to funding and potential partners
- Need to focus on securing funding for project development (e.g. hydrogen ring). The forum can have an advocacy role in determining the scope of funding
- Role for forum is both advocacy and project development
- “It’s all about funding”

Staffing

- It was felt that if the forum was to be taken seriously and for it to move forward a full-time staff is essential
- A (full-time) professional is needed to drive this forward. Voluntary support doesn't work – no real work will get done unless there is a single paid person responsible for driving forum activities forward
- A full-time CEO and admin support was considered essential, given the amount a truly effective body would aim to achieve: RDA procurement favours tendered, project-based, service contract with clear deliverables
- Essential to get the right person in place (not full time at outset but role could grow if forum covers a larger regional scope)

Funding – membership

- Most/all would be prepared to pay a nominal fee, but none would commit to a figure. It was clear that fees alone would not be able to support the forum. It was made clear that any membership fee would have to be aligned to the perceived benefit of the forum
- Membership fees, even token, will act as a barrier to boosting membership and could be counter productive
- The costs/effort involved in collecting membership fees would be a drain on forum resources
- The LowCVP Innovation Working Group was referenced as a relevant constitutional model. It has a strong ultra low carbon vehicle and SME focus. The SMEs can't pay anything more than nominal membership fees but the SME participants are used to committing time and resources in travelling to London for meetings
- Public funding is critical – BMHF must be recognised as an 'output' (in emda terms) and so the collecting of organisation capabilities is vital. Need record of what the forum will do and has done to build an evidence based case
- Need funding for three years for start up. Can it then become self-sustaining?
- Emda inward investment would like to put additional funding in (as 'top up' not core funding) as it benefits from having experts to promote regional capabilities

Funding – projects

- The concept of providing funding to stakeholders was interesting BUT it was raised that this would fund a number of small projects whereas one large project that could benefit the whole forum community would be preferred. Therefore perhaps the identification and securing of larger pots of funding (ERDF etc.) would be more appropriate. A similar approach is currently being pursued by the London Hydrogen Partnership in its bid to the FCH JU.
- Universities wants to see funding coming out of the forum (as per niche vehicle R&D project) to fund co-operative projects
- Evidence of success would attract funding for projects (cf Niche Vehicle Network model), including possibly from VC sources – as mapped out in the Low Carbon Innovation Strategy
- Academic side (Loughborough University perspective) wants research funding from EPSRC

Membership

- It was strongly felt that 'inclusivity' was all important - that membership should be open to all that could relate to the supply chain or offer services in support of the supply chain – the application process could be one similar to that employed by the rail forum - any application is vetted by the steering group and if deemed reasonable it is allowed
- Critical mass is important and hence wider audience is better
- The Forum should focus on a local midlands agenda and expand from there (this absolutely implies regional funding for the business case)
- Midlands Aerospace Alliance provides a model for SME and University engagement via Associate Membership (shouldn't exclude others, need to keep big boys on board for credibility)

Membership – name?

- It was seen as important that the forum name involved hydrogen; less perhaps that it also included fuel cells. All endorsed the concept of a Central forum - this would allow greater involvement without the need to specify boundaries
- The consensus was for a Central Forum, as opposed to an exclusively East-West Midlands Forum. Needs a name that captures the centrality of the region, e.g. as a potential hub for the UK or central point of connection (fits with emda's Energy Connections programme), while allowing for growth and integration into (inter)national programmes: Hydrogen Heartland, Hydrogen Central, Hydrogen Hub, etc – does not need to explicitly mention fuel cells
- The forum should extent its scope beyond its Midlands base (to have a central England focus). This expansion would allow the CEO/MD to transition from a part-time to full-time role. The forum should seek to co-operate with Wales and with Sheffield (via Yorkshire Forward). Interest to draw in near regions (also Oxford, eeda, etc). The barrier between emda and AWM has been reduced through the work of the forum and this was considered to be very helpful

Membership – national linkage?

- A key consideration for the forum is how this sits in the national picture – the HyNET concept was seen as an acceptable solution as long as all parties could agree to be involved
- There is a perception that there are too many organisations and that consolidation would be a good thing.
- There is a need for a single overarching UK network with regional 'chapters', covering:
    - Scotland
    - Wales
    - North England
    - Central England
    - South (if demand is there)

- It was recognised that ultimately fund providers would drive the location and membership criteria of the forum – hard to prevent fragmentation if another regional funding body emerged
- Should the Midlands cluster take the lead? Yes, because it is important for the region that this moves forward effectively and leadership would allow stronger promotion of regional interests
- Should the Midlands lead the UK-HyNet initiative? Yes, for the same reasons as above
- The national context is that it is unsustainable to have so many organisations. A national organisation is needed to take an advice and leadership role. The forum by contrast needs to have a local and therefore an operational/delivery focus. The MD/CEO of the forum is someone that needs to prompt the formation of a national group and represent regional interests on that national group. Activities need to be joined up with or complementary but different to those in Wales

9.5 What should any future forum be called?

As part of the consultation exercise, the potential membership of any future forum was reviewed. In turn this raised the important question - what should the forum be called? This can be seen as important as it informs the perceived geographical boundary of membership for the forum and could impact on any future link between the forum and any prospective national body.

Appendix 5 shows a SWOT analysis of the three names suggested by stakeholders as part of the consultation:

- East Midlands Hydrogen Forum
- Midlands Hydrogen Forum
- Central Hydrogen Forum

Based on the SWOT analysis and feedback from key stakeholders it is proposed that any future forum should be referred to as the 'Central Hydrogen Forum' as this would deliver the following benefits and opportunities over the alternatives:

- It would enable larger numbers of organisations to become involved in the forum – thereby moving it towards a 'critical mass'

- It would potentially deliver a greater cross section of capability across the sector
- It would enable the synergy of capabilities between the regions and avoid any potential duplication of activity, thereby achieving the equivalent of economies of scale
- It completes the national picture associated with hydrogen and fuel cells – i.e. it would sit well geographically with the existing landscape

The one caveat on the change of name is that the 'British Midlands Hydrogen Forum' has become a recognised brand, both in the UK and, importantly internationally.

A discussion was also held with stakeholders as part of the direct and also the workshop consultation as to whether it was felt important that 'fuel cells' are also referenced in the title of the forum (as in the case of the Scottish Hydrogen and Fuel Cells Association, SH2FCA). The general consensus was that this was not necessary.

10 Midlands Hydrogen Forum business plan

Chapter 9 has revealed a clear desire on the part of key regional stakeholders to build a Midlands Hydrogen Forum. This chapter aims to build an evidence-based business case for the forum.

To inform the business plan, the activities that would be undertaken for the first year of the forum have been detailed along with a suggested staffing profile in order to form a realistic basis for the development of a proposition to move the forum forward.

10.1 Project plan for a Forum – timescales, activities and funding

In order to provide an insight into the potential activities of the forum a timescale has been developed which includes:

- an three year proposed workplan taking the main focus of the forum from advocacy to activity
- what level of funding support would be required
- what the expected outputs would be
- how this could be underpinned by funding streams currently available

10.1.1 Funding for the forum and forum activities

Funding for the forum is relevant from two perspectives:

- In support of the forum itself. This could be delivered from a number of sources, for example through RDA and/or European funding as is now the case with SH2FCA
- In support of forum stakeholder product and market development projects

Figure 29 below (source: Carbon Trust) provides an overview of UK national organisations and funding streams available for RDD&D activities in energy-related areas mapped against Technology Readiness Levels (TRLs). Figure 30 amplifies the role of the funders shown in Figure 29.

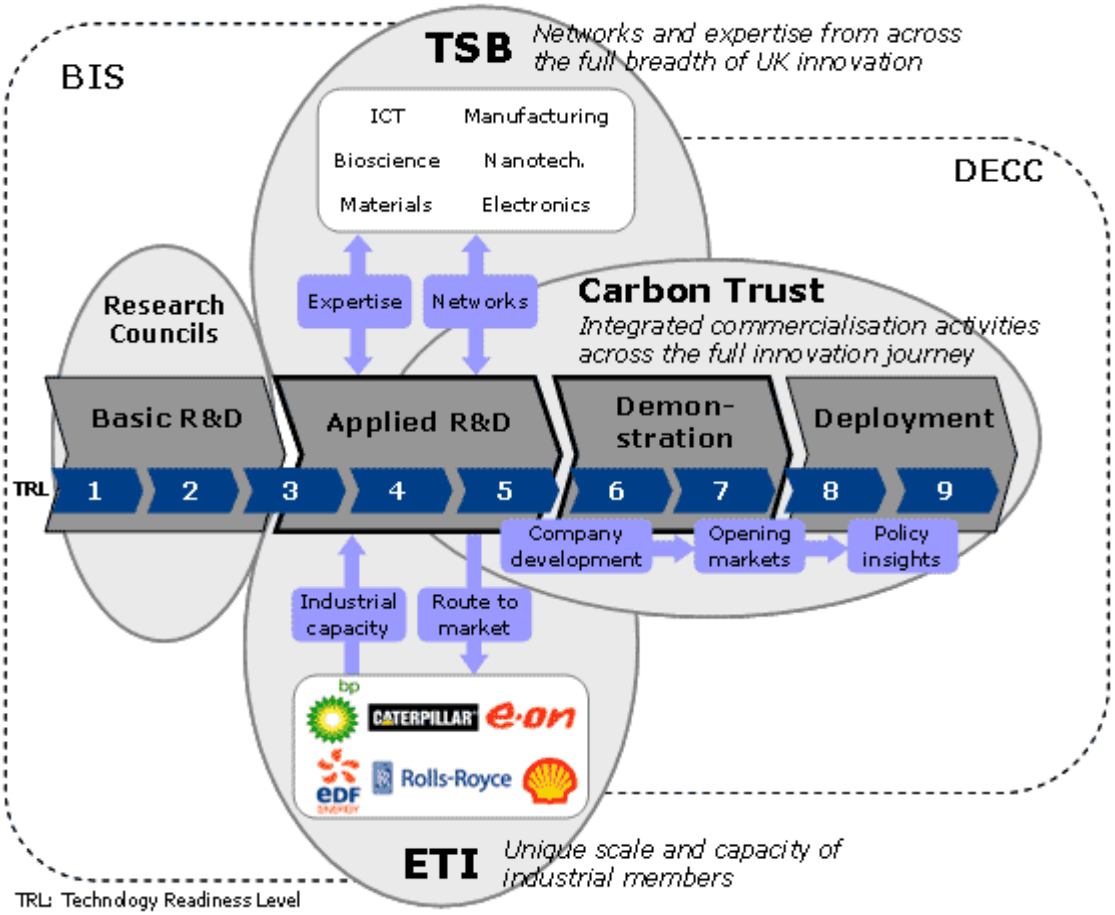


Figure 29. UK national funding streams (source: Carbon Trust)

	Research Councils	Technology Strategy Board	Energy Technologies Institute	Environmental Transformation Fund: BERR, Defra
Whom does it support?	The academic community	Business (and academics, for business-led activities)	Business (and academics)	Mainly business (and some academics and public sector)
Principal nature of research	Basic to applied research	Collaborative, applied research	Collaborative, applied research to prototype demonstration	Demonstration and early phase deployment, often single company,
Technology Readiness Level of main interest	TRL **1-3**	TRL **2-6**	TRL **3-6**	TRL **3-9** Main focus on **6-9**
What technologies does it support?	All energy technologies (and other areas)	All energy technologies (and other areas)	Low carbon energy technologies	Low carbon energy technologies
What level of funding can it offer?	Up to 100%	Typically applied research at 50%, but ranges between 25 (near market) and 75% (early stage research)	Up to 100%	Typically 25-50% depending on the project (also other types of funded incentives)
How is funding allocated?	Competitive bids into broad research	Competitive bids in response to tightly focussed calls	Directed programmes, but with open access	Mainly competitive bids in response to tightly focussed calls
Principal Government funding source	DIUS	DIUS	DIUS	BERR and Defra
Key objectives	New knowledge and capacity building	UK competitiveness	Value to partners, and Low Carbon Energy Deployment	Carbon reduction, accelerated commercialisation of technologies

Figure 30. Funders in the UK low carbon landscape - DIUS and BERR are now BIS (Source: TSB, 2008)

The following provides further details of some of the key funding streams that could be available to the regional along with the scale of possible funding:

10.1.2 National

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

EPSRC funds research and postgraduate training in engineering and the physical sciences at universities and other organisations throughout the UK. It issues calls for collaborative research projects between the knowledge base and industry under a number of themes throughout the year. According to its website, research grant expenditure was £507.3m for 2007/08 for 6,000 projects, or an average of £85k per research project.

10.1.2.2 *Technology Strategy Board*

From July 2008 to March 2009, the value of the TSB's portfolio was of £61m for 94 collaborative R&D projects in low carbon energy technologies, broken down as below:

Carbon abatement technologies	£5m
Intelligent grid management	£6m
Fuel cells and hydrogen	£13m
Bioenergy	£5m
Microgeneration and photovoltaics	£6m
Wave energy and tidal stream	£20m
Offshore wind	£7m

When business contribution is included, the value of this portfolio is £153m.

H2FC R&D projects secured £13m over this period for 13 projects (TSB, 2009b), hence the average support per project can be estimated at £1m. It is also acknowledged that this funding level is potentially for larger projects involving large organisations and that it is likely that SMEs will be involved in future collaborative projects. Therefore a reduced average project value of £500k has been assumed, based on two recent TSB applications made under the Hydrogen and Fuel Cells call involving members of the forum.

The TSB has committed nearly £9m in new projects in fuel cells and hydrogen and nearly £5m in new R&D to find innovative technology solutions to help in maximising recovery of the UK's hydrocarbon resources. Jointly with the Department of Energy and Climate Change (DECC) and The Northern Way, up to £15m is being made available to new projects in carbon abatement technologies.

Project Area	No. of projects	No. with EM participation	Summary of EM Partners
Carbon Abatement Technologies	12	8	E.ON UK plc, University of Nottingham, Visser & Smit Hannab UK, British Geological Survey Keyworth Notts, Rolls Royce Plc
Intelligent Grid Management	18	7	E.ON UK plc, National Grid Plc, University of Nottingham, Rolls Royce Plc, Loughborough University
Fuel Cells and Hydrogen	13	3	Intelligent Energy ltd, Pera Innovation
Bioenergy	10	3	Boots plc, Loughborough Innospec, Ashwell Engineering ltd, GD Strawson, University of Nottingham
Microgeneration and Photovoltaics	14	6	Romax Ltd, Pera Innovation, CREST at University of Loughborough, Loughborough University
Wave Energy and Tidal Sream	19	3	Rolls Royce Plc
Offshore Wind	8	3	Linwave Technology, Pera Innovation, University of Nottingham
Totals	**94**	**33**	

It is noted that the review of the low carbon projects undertaken in 2008/9 highlighted the significant number of projects with an East Midlands contribution (TSB, 2009b). However these were principally undertaken by regional universities, in particular Loughborough University and Nottingham University and also by the larger energy sector companies in the region such as E.ON, Rolls-Royce and Siemens. Intelligent Energy is a notable SME participant in the fuel cell and hydrogen strand. Participation from other Midlands SMEs is limited.

10.1.2.3 *Energy Technologies Institute (ETI)*

Since it was established in January 2007 as a partnership between leading international industrial companies and the UK Government, ETI has begun a number of projects aimed at accelerating the development and deployment of low-carbon technologies to help meet the UK's energy targets. By early 2010 the ETI had announced 14 projects worth over £52m and entered further contract discussions worth over £70m.

Opportunities for H2FC stakeholders exist in the across a number of elements of the programme.

- Distributed Energy (DE): novel local low carbon energy solutions including energy from waste, combined heat and power, demand and supply optimisation, stationary fuel cells, heat pumps and solar thermal systems
- Energy Networks: new electricity, gas and heat infrastructure solutions enabling a substantial deployment of low-carbon energy systems in the UK, including large-scale energy storage
- Carbon Capture & Storage (CCS): UK offshore CO_2 storage appraisal, CO_2 network modelling and low cost CO_2 capture technologies

- Transport: infrastructure demonstration for electrified light vehicles and improving heavy duty vehicle efficiency

As is the case with the TSB, Midlands' regional contribution to projects outside the key ETI investors is limited.

10.1.2.4 *Carbon Trust*

The Carbon Trust makes funding interventions in targeted areas, chosen by a process of prioritisation and industry feedback. Two of its programmes are of relevance to the project:

- Technology accelerators, which aims at opening up markets for low carbon technologies
- Research challenges aimed at commercialising promising technologies

To date over Carbon Trust has provided over £22 million of grants over seven years experience of supporting the development of low carbon technology. Of the156 projects listed on the Carbon Trust Website, only two have been led by companies in the East Midlands (Iskra £48k and Cosworth £200k). Five have been led by regional universities (Loughborough two, Leicester one and Nottingham two) and one has been led by the British Geological Society. The average grant per project is £140k.

Looking specifically at H2FC technologies, the £8m Polymer Fuel Cell Challenge initiated by the Carbon Trust in November 2009 is aimed at commercialising novel polymer fuel cell technologies that can deliver step change in system cost. At the time of writing (April 2010), five systems have been shortlisted, including one from BMHF-member ITM Power. If successful; three projects will be awarded up to £1m for further proving, and then up to £5m for commercial development (CT, 2009). The programme was targeted at advanced R&D following consultation with the TSB, which launched its demonstration-focused Fuel Cell and Hydrogen Demonstration Programme at around the same time.

The fact that the Carbon Trust is currently running a H2FC-focused funding competition may mean that it is unlikely to put further funding in this area in the short-medium term. However, funding opportunities in other energy-related fields may appear.

10.1.3 European

10.1.3.1 *Framework Programme 7 (FP7)*

The FP7 service in the region – funded by emda to promote the take up of FP7 funding in the East Midlands - has identified five potential European projects in the low carbon sectors (Source: GH Associates – a consultancy contracted by emda to encourage increased participation in FP7 funded projects in the region).

FP7 funding is released in calls that are made under specific themes throughout the year. The programme aims to promote project collaboration under these themes across Europe. To this end project teams need to comprise representation from a number of European countries. Depending on the call, there is significant financial support available for projects, however, due to the requirement for cross-Europe participation in a project, applications can be time consuming and complex. Having reviewed the membership of the BMHF, a large proportion are small enterprises that could not (at this stage in their business or product development lifecycle) afford the time input required to access and project manage FP7 funding. For this reason FP7 funding has not been considered in the project plan shown in section 6.2 below.

10.1.3.2 *The Fuel Cells and Hydrogen Joint Undertaking (FCH JU)*

JTI (Joint Technology Initiative, http://ec.europa.eu/research/fch/index_en.cfm) aims to achieve greater strategic focus by supporting common ambitious research agendas in areas that are crucial for competitiveness and growth, assembling and coordinating at European level a critical mass of research. They therefore draw on all sources of R&D investment – public or private – and couple research tightly to innovation.

The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) is a unique public private partnership supporting research, technological development and demonstration (RTD) activities in fuel cell and hydrogen energy technologies in Europe. Its aim is to accelerate the market introduction of these technologies, realising their potential as an instrument in achieving a carbon-lean energy system.

Background:

The three members of the FCH JU are the European Commission, fuel cell and hydrogen industries represented by the NEW Industry Grouping and the research community represented by Research Grouping N.ERGHY. Through the FCH JU, the three members pool resources and jointly plan activities in order to overcome barriers to the commercial deployment of fuel cell and hydrogen technologies. RTD activities are

supported by way of annual competitive calls for proposals, organised according to the strategic priorities set out in annual and multi-annual Implementation Plans.

The planning and implementation of the activities of the FCH JU is a sum of the input of a number of stakeholders represented through the governing and advisory bodies of the FCH JU. The highest decision-making body is the Governing Board with representatives of all the three members.

Funding available:

The FCH JU puts out calls for proposals. The FCH JU published its first call for proposals on 8 October 2008. The call consisted of 15 topics based on the 2008 Annual Implementation Plan. The call closed on 15 January 2009. Calls from 2010 to 2013 will be published on a yearly basis: **http://ec.europa.eu/research/fch/pdf/fch_ju_multi_annual_implement_plan.pdf#view=fit&pagemode=none**

What are the eligibility criteria?

There must be at least three 'legal entities' established in different EU member states or associated countries. The entities must be independent of each other. At least one legal entity must be a member of the Industry Grouping or the Research Grouping of the Joint Undertaking.

Is this an appropriate source of funding for a future forum or forum members?

As per the comments on FP7 funding, this funding source requires wide European collaboration which tends to exclude the majority of SME members of the forum. Some forum members are engaged with the FCH JU, but feedback has indicated that the setting up of the FCH JU has not yet speeded up access to funding. There is clearly further scope for engagement with the FCH JU, both in terms of R&D and demonstration projects, but it is not guaranteed that the FCH JU will be able to provide funding for the forum itself.

10.1.3.3 *Intelligent Energy Europe (IEE)*

The objective of the Intelligent Energy - Europe Programme (http://ec.europa.eu/energy/intelligent/call_for_proposals/index_en.htm) is to contribute to secure, sustainable and competitively priced energy for Europe, by providing for action:

- to foster energy efficiency and the rational use of energy resources
- to promote new and renewable energy sources and to support energy diversification
- to promote energy efficiency and the use of new and renewable energy sources in transport

The Programme in particular contributes to Energy Policy for Europe, including the EU action plan for energy-efficiency and the Directive on the promotion of the use of energy from renewable sources. The programme issues funding through 'calls for proposals' - each of these proposals has a different set of priorities that may or may not support a concept such as a Midlands Hydrogen Forum. For example the call for June 2010 states (key points in bold):

'In general, activities subject to call for proposals can take the form of:

- *projects*
- *or the establishment of new local and regional energy management agencies*

… However each annual work programme sets a number of more specific, action-related objectives … ***In particular, the establishment of new local and regional energy management agencies is not open for this year's call.*** *Grants will only be awarded to projects.'*

Funding available:

'Some ***€ 56 million*** *will be made available, supporting* ***up to 75% of the eligible project costs****. Any public or private organisation from the* ***EU, Iceland, Norway, Liechtenstein and Croatia*** *can apply.*

Only online applications are possible. ***Deadline for submission to the current call is 24th June****.*

The maximum duration of a project is 3 years.'

What can be funded?

IEE funding can be used for: capacity building; building and spreading of know-how, skills and methods; exchanges of experience; development of market and intelligence; policy input; awareness raising and information provision; and education and training.

What are the eligibility criteria?

- Clear objectives, high impact, European added value
- At least three partner organisations from three different eligible countries
- Budget usually between €0.5 - €2.5 million

Is this an appropriate source of funding for a future forum?

To be eligible for funding the forum would need at least two partners from two eligible countries other than the UK. The main driver for the forum is to represent and develop the capability and capacity of sector stakeholders in the Midlands. In order to be eligible for IEE funding a more European wide view would be required and hence it is felt this local/regional focus would be lost to the detriment of the forum.

Similar comments can be made to the majority of the funding sources provided on a European level - by their very nature they require European collaboration.

10.1.3.4 *European Regional Development Fund (ERDF) programme*

The European Regional Development Fund (ERDF) was set up in 1975 to stimulate economic development in less prosperous regions of the European Union (EU). As EU membership has grown, ERDF has developed into a major funding instrument to help tackle regional disparities and support regional development across the EU's Member States. ERDF provides funding for projects which contribute to economic development and regeneration, promoting competitiveness and delivering sustainable development.

Looking specifically at the East Midlands, the region is eligible for approximately 268m Euros (approx £246m subject to exchange rate fluctuations) between 2007 and 2013, which when combined with national public match funding, provides a programme value of approximately 537m Euros (approx £492m) – a significant investment in the economic development of the region.

The East Midlands qualifies as a **competitiveness and employment** region under the EU's Cohesion Policy, which aims to meet the EU objective to become 'the most competitive and dynamic knowledge based economy in the world, capable of sustainable economic growth with more and better jobs and greater social inclusion'.

The region's new ERDF Competitiveness Programme is segmented into a number of categories referred to as 'Priority Axes'. As an example; Priority Axis 1 focused on 'Innovation and Sustainable Business Practices' and sought to increase business competitiveness by increasing the rate and level of innovation and improving resource

efficiency by enabling businesses to develop and exploit new products, processes, technologies, services and markets. The East Midlands 2007-13 ERDF Competitiveness Programme officially launched a second open 'Call for Activity' under the Programme's Priority Axis 1 with up to £20m ERDF being made available under Priority Axis 1 (PA1) which sought to create a high value-added economy by supporting innovation and sustainable business practice and build on the region's key strengths. The Call for Activity invited expressions of interest from applicants that could demonstrate they can contribute significantly towards the achievement of PA1 objectives, outputs and results through eligible activities.

The report authors spoke to the ERDF team for the East Midlands region regarding funding for a regional forum:

What is the most appropriate category to apply under*?*

- The most appropriate category for any future application for a forum would be Priority Axis 1 which focuses on 'Innovation and Sustainable Business Practices'

When will the call be made?

- The next call for Priority Axis 1 is anticipated to be spring 2011. All funds available for 2010 have already been allocated and it was seen as highly unlikely that further monies would be available before this date

Who can apply?

- emda could apply on behalf of the forum, however, as emda also manages the scheme for the region it was suggested that an alternative would be more appropriate as this route would be rather bureaucratic with the need for clear demarcation between activities and departments within the Development Agency etc.
- The forum could apply under its own name provided the organisation was 'not-for-profit' – i.e. registered as private, limited by guarantee, no share capital as in the case of the Midlands Aerospace Alliance

How do you apply?

- The forum would need to register on the website: www.eastmidlandserdf.org.uk to receive notification of the next call – note, this website may be incorporated into emda's main site in the future
- All calls and the associated details are publicised on the website
- The call would detail the application process and eligibility criteria etc. – each call can be subtly different and hence it is difficult to generalise on the process
- An example of the form that needs to be filled in as part of the application can be seen at the following link, under 'ERDF only Application and Appraisal Form': http://www.eastmidlandserdf.org.uk/index.php?option=com_docman&task=cat_view&gid=133&Itemid=58

  This is a fairly standard form for public sector funding application, having the following generic headings:

  - Project Information – details of applicant, project description, project objectives, project background
  - Procurement – process to be used for procuring support
  - Equality Impact Assessment
  - Strategic Fit
  - Options Analysis - scenario planning and 'what if' assessment
  - Outputs and Results - deliverables of the project
  - Costs and Funding

The information contained in this report would therefore provide a sound basis for an application through the ERDF scheme and, as discussed below, there are already at least two examples (in Scotland and Wales) of the funding of UK regional hydrogen activities through the ERDF mechanism.

10.1.3.5 *ERDF Funding and the Scottish Hydrogen and Fuel Cell Association (SH2FCA)*

The authors spoke to Derek Mitchell of The Hydrogen Office, which offers a relevant example of a previously successful bid for ERDF funding in relation to the running of SH2FCA.

In 2009 SH2FCA successfully secured core funding from the ERDF programme administered in Scotland. The bid made focused on knowledge and technology transfer relating to hydrogen and fuel cells and was submitted by The Hydrogen Office Limited in collaboration with three Scottish Universities.

The Hydrogen Office Limited is a private, limited by guarantee organisation with no share capital. The Hydrogen Office project will demonstrate the role that energy efficiency, renewables and hydrogen can play in reducing the future impact of climate change and energy security of supply concerns.

The bid requested and secured funding over a period of 3 years for approximately £1.5m. £120K of this funding was assigned to support SH2FCA. This funding is being utilised to pay for a full-time CEO and to cover associated marketing and events costs in support of SH2FCA and its members over the 3 years.

In terms of output metrics for the ERDF funding for SH2FCA over the three years, they are believed to include:

- Safeguarding of one new job
- The holding of up to eight events per annum (i.e. 24 in total over the funded project duration) covering knowledge transfer and technology transfer - anticipated 20 to 30 attendees per event
- To provide direct support to 15 SH2FCA members (must be SMEs to qualify under ERDF) which can be delivered in a number of ways, such as supply chain development, market exploitation, funding assistance, identification of project partners, assistance to attend larger regional/national events etc.

10.1.4 Regional programmes

In addition to the schemes detailed above there are national funds which are managed and distributed regionally for product and market development for SMEs. These are awarded by Regional Development Agencies (RDAs) and are detailed below:

Grant for Research and Development (GRD) helps businesses carry out research and development work that will lead to technologically innovative products or processes. GRD is a BIS business support product managed by the Regional Development Agencies and part funded by the European Regional Development Fund.

Grant for Business Investment GBI makes discretionary grants available from Government (BIS) to support businesses with investment projects which will increase productivity, skills and employment in deprived areas in England. GBI is the BIS capital

investment grant scheme aimed at encouraging businesses to invest in land and buildings, plant and machinery to support expansion and modernisation in England's more deprived areas.

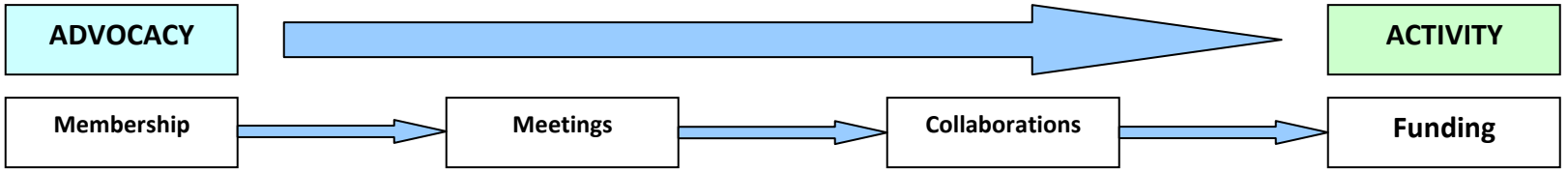
Due to the size and activity of the majority of the current membership of the BMHF it is suggested that GRD funding would be most appropriate to members in the long term. Review of the GRD supported projects shown on the emda website shows an average grant per project of £84k, (based on projects awarded from 1st April 2009 to 31st March 2010, refer to link: http://www.emda.org.uk/grd/offers.asp?nav=08&snav=0801). The GBI mechanism is clearly important however – exemplified by the £800k grant obtained by Intelligent Energy to assist with its 2010 facility move into the former Rolls Royce Fuel Cell premises on the Loughborough University campus (http://www.emda.org.uk/gbi/minisite/offers.asp).

10.2 Project plan

The analysis above reveals that are significant opportunities for the region to tap into sources of funding from key low carbon sector programmes, including those focused on H2FC technologies. Delivery of a programme that combines advocacy and activity and delivers real funding benefits to its members, and therefore the region, is a central focus of the proposed project plan for the forum's next three years, shown in Table 22.

funded by east midlands development agency

cenex



Timescale:	At 3 months	At 6 months	At 9 months	At 12 months	At 15 months	At 18 months	Totals
Actions to be undertaken	Promotion & Networking	Event		Event		Event	-
Staffing requirement	Part-time CEO	Part-time CEO	Part-time CEO and part-time Secretariat	Full-time CEO and part-time Secretariat	Full-time CEO and part-time Secretariat	Full-time CEO and part-time Secretariat	-
Funding requirement	£6.25k salary £6k sundries	£6.25k salary £6k sundries	£8.75k salary £6k sundries	£15k salary £6k sundries	£15k salary £6k sundries	£15k salary £6k sundries	£102.25k
Funding sources for projects	RDA	RDA	RDA, EPSRC , Carbon Trust	RDA(s), EPSRC, Carbon Trust, TSB	RDA(s), EPSRC, Carbon Trust, TSB	RDA(s), EPSRC Carbon Trust, TSB	-
Funding sources for forum	RDA(s)	RDA(s)	RDA(s)	RDA(s)	RDA(s), ERDF	ERDF	-
Outputs [+]	Members = 50 Projects = 0	Members = 60; Projects = 1 Funds = £84k Events = 1	Members = 70 Projects = 1 Funds = £84k	Members = 80 Projects = 2 Funds = £169k Events = 2	Members = 90 Projects = 3 Funds = £253k	Members = 100 Projects = 5 Funds = £893k Events = 3	Members = 100 Projects = 5 Funds = £893k Events = 3

Timescale:	At 21 months	At 24 months	At 27 months	At 30 months	At 33 months	At 36 months	Totals after 36 months
Actions to be undertaken		Event		Event		Event	-
Staffing requirement	Full-time CEO and part-time Secretariat	Full-time CEO and part-time Secretariat	Full-time CEO and part-time Secretariat	Full-time CEO and part-time Secretariat	Full-time CEO and part-time Secretariat	Full-time CEO and part-time Secretariat	-
Funding requirement	£15k salary £6k sundries	£15k salary £6k sundries	£15k salary £6k sundries	£15k salary £6k sundries	£15k salary £6k sundries	£15k salary £6k sundries	£228.25k
Funding sources for projects	RDA(s). EPSRC, Carbon Trust, TSB	RDA(s). EPSRC, Carbon Trust, TSB	RDA(s). EPSRC, Carbon Trust, TSB	RDA(s). EPSRC, Carbon Trust, TSB	RDA(s). EPSRC, Carbon Trust, TSB	RDA(s). EPSRC, Carbon Trust, TSB	-
Funding sources for forum	ERDF	ERDF	ERDF	ERDF	ERDF	ERDF	-
Outputs +	Members = 100 Projects = 5 Funds = £893k	Members = 105 Projects = 7 Funds = £1,117k Events = 4	Members = 110 Projects = 8 Funds = £1,202k	Members = 115 Projects = 9 Funds = £1,702k Events = 5	Members = 120 Projects = 11 Funds = £1,926k	Members = 125 Projects = 12 Funds = £2,011k Events = 6	Members = 125 Projects = 12 Funds = £2,011k Events = 6

Table 22. Three year project plan for a Midlands Hydrogen Forum

Notes:

Figures stated are per quarter - not cumulative, as detailed below:

CEO full-time salary assumed to be £50k per annum equivalent to £12.5k for each quarter above.

Part-time working is assumed to be half week working.

Part-time salary assumed therefore to be £25k per annum equivalent to £6.25k for each quarter above.

Secretariat full-time salary assumed to be £20k.

Part-time working is assumed to be half week working.

Part-time salary assumed therefore to be £10k per annum equivalent to £2.5k for each quarter above.

Sundry costs (travel, attending events etc.) estimated at £24k per annum equivalent to £6k for each quarter above.

+ Figures shown are cumulative.

'Projects' refer to collaborative projects

'Funding' refers to the anticipated funding secured from the sources identified for stakeholder projects; these sources are shown in Table 22.

'Events': it is proposed that two large scale sector focused events are delivered per annum. These should be hosted in the East Midlands with the aim of showcasing the achievements of the forum and the capabilities of its members. The purpose of these events is to raise awareness of the forum and to broaden its membership base.

10.2.1 Full time or part time CEO?

Implicit in the project plan presented in Table 22 is the assumption that the role of the CEO of the Forum will transition from a part time role to a full time position (albeit on a fixed term contract), with a concomitant increase in funding. Feedback from stakeholder workshop endorsed the view that a full time person is needed to drive the Forum forward.

Recognising the potential limitations of funding however a brief analysis of the strengths and weaknesses of employing a full time or part time CEO versus a contracted provider is presented below:

Case for an employed part-time or full-time CEO:

Strengths:

- Consistency: provides a contact point and figurehead to the forum
- Longevity: CEO has the comfort that the position has a reasonable duration which will encourage a suitably qualified individual to take the role
- Forum will be taken more seriously if it retains focused and dedicated staff
- Commitment to the forum is likely to ensure a greater focus of activity
- Stability provided through consistency
- More efficient recruitment (one off rather than multiple)

Weakness:

The main issue with taking on a permanent employee versus contract staff is reduced flexibility

Case for contract CEO:

Strengths:

- Availability of interim directors
- Flexibility
- Potential fit to forum if the plan is for a short term project

- Could potentially attract an experienced industry player to undertake a part-time role in the forum – this would obviously be beneficial if that individual had experience of and connections with a key sector such as the energy industry

Weakness:

Potentially short term contracts attract interim staff that then move on to another assignment

Summary

There are clearly pros and cons to both approaches but the main consideration has to be whether or not the forum is seen as a short term or long term proposition. It could be argued that if the Forum is to be a short term (12-18 months) support mechanism there is a case to consider a contract CEO. This could be in the form of an interim director or a secondment from a current role. The latter may provide the opportunity to enhance the networking of the forum within a given sector - for example if it was a secondment of a senior individual in the energy sector.

For the longer term proposition it can be argued that employed staff should be considered to provide longevity and consistency to the forum in order to shape and deliver activity and the membership going forward.

In order to secure suitably; qualified/experienced/connected individuals to the post of CEO it is anticipated that costs in both scenarios will be similar and cost is therefore not necessarily considered as a strength or weakness.

In the business plan it has been assumed that the role of CEO will be an employed position, as it is envisaged that for a forum to have the opportunity to deliver significant impact for the sector and region(s) a minimum duration of three years worth of activity should be planned for.

10.2.2 Project funding

Average grant values per project have been assessed and detailed above for the EPSRC, Carbon Trust, RDA and TSB. This information has been used to provide the figures for the anticipated project funding secured by the Forum over three years shown in Table 23.

Funding Source:	At 3 months	At 6 months	At 9 months	At 12 months	At 15 months	At 18 months	At 21 months	At 24 months	At 27 months	At 30 months	At 33 months	At 36 months	TOTAL
RDA (£84K/project)		1			1			1			1		4
EPSRC (£85K/project)				1					1			1	3
Carbon Trust (£140K/project)						1		1			1		3
TSB (£500K/project)						1				1			2
TOTAL	£0k	£84K	£0k	£85K	£84K	£640K	£0k	£224k	£85k	£500k	£224k	£85k	£2011K
Cumulative	£0k	£84K	£84K	£169K	£253K	£893K	£893k	£1117k	£1202k	£1702k	£1926k	£2011k	

Table 23. Possible three year project funding stream for the Hydrogen Forum

10.2.3 Fit with existing provision

Regional Context

As stated in emda's *Innovation Strategy for the East Midlands 2010-2013* known as the Regional Innovation Strategy (RIS), there is a proposal for a comprehensive Low Carbon Innovation Support Service (LCISS) to maximise the opportunities for the region associated with the low carbon economy. It is acknowledged that the low carbon economy has become a fundamental driver of economic development, and will be a prominent feature of all aspects of the RIS and regional growth. There is therefore a major focus on low carbon, in developing new technologies and helping businesses take advantage of new opportunities.

One provision of the LCISS will be targeted networking and facilitated collaboration, focused networking events with follow up support to facilitate and develop collaborative working, whether to access public funding or private sector contracts.

The region's economic strategy aims to 'transform the way we use resources and use and generate energy to ensure a sustainable economy, a high quality environment and lessen the impact on climate change'. Priority actions related to this point are:

5a. Responding to the challenge of climate change

Adaptation to Climate Change

Ensure that public and private sector leaders understand and respond to the impacts of climate change by:

- developing a regional climate change adaptation and mitigation strategy/action plan
- providing support to businesses to undertake climate change risk analysis

Reducing the demand for energy and resources

Ensure that our need for energy and resources is minimised by:

investing in better management and skills

- driving change through public procurement
- encouraging use of low carbon technologies
- stimulating clean design

5b. exploitation of new and growing low carbon markets

Utilising Renewable Energy Technologies

Maximise the economic and environmental benefits of renewable energy technologies by promoting their development and deployment through:

- creation of a regional renewables investment plan
- promote demand for and showcase renewables technologies
- support supply chain development to ensure regional economic benefit from renewables investments

Exploiting Low Carbon Technologies

Ensure that businesses are well placed to exploit the opportunities presented by the growing global marketplace for low carbon products and services through:

- regional awareness raising and communications campaign
- provision of dedicated low carbon business support
- creating stronger linkages between the private sector and Higher Education institutions active in low carbon research and development

5c. ensuring an infrastructure for a low carbon economy

Energy and Waste Capacity

Promote the development of a more secure, diverse and sustainable energy and waste infrastructure and innovative approaches to providing energy and waste services within our economy by:

- promoting and investing in renewable and low carbon energy generation
- promoting and investing in diverse and localised energy supply
- promoting and investing in diverse and localised waste management
- influencing private sector utilities and regulators concerning the capacity and longevity of existing supply and distribution and waste management infrastructure

The Hydrogen Forum will therefore directly underpin a key element of the proposed LCISS provision for the region and fits with the key strategic direction of the development agency, i.e. there is a good regional fit with existing provision for this sector.

Assuming that LCISS is created, it would seem appropriate for the CEO and any secretariat function for the future hydrogen forum for the region to be co-located with this provision. If this is not possible, then at least the role of the CEO and the functions provided by the forum should be factored into the support package offered by LCISS.

National context

For the UK to deliver energy security and accelerate the transition to a low carbon economy requires urgent and ambitious action at home and abroad to save energy; develop cleaner energy supplies and secure reliable energy supplies at prices set in competitive markets.

The UK has committed to building a low carbon economy with the announcement of the first legally binding carbon budget. The carbon budget aims to cut 34 per cent of greenhouse gas emissions by 2020. This will keep the UK on track for its long term goal of cutting emissions by 80 per cent by 2050.

The UK has also committed, as its share of the EU's 2020 targets, to 15% of energy consumed coming from renewables. This implies a significant change in the way we generate and use energy in transportation, heat and electricity. Assuming that the UK meets the EU's 10% renewable transport target and that renewable heat technologies also deliver 10%, then the UK would need renewables to provide 40% of its electricity to meet the overall EU renewable energy target – a ten-fold increase over the next decade.

Hydrogen and Fuel Cell technologies will play a part in meeting the targets outlined above and forums such as that proposed are critical to the development of collaborations and subsequent projects to address these challenges.

10.3 Concluded business plan

In the original project proposal, it was suggested that in order to gain stakeholder feedback (and ultimately their acceptance of the business plan), it was important that stakeholders be given an opportunity to provide input into the process. It was envisaged that the most appropriate and efficient way of achieving this was through the presentation of the devised business plan at a workshop attended by a selection of stakeholders from across the region's hydrogen community. The business plan could

then have been discussed by all parties present and any feedback collated with a view to its incorporation in the final document.

However, the feedback gained at the earlier workshop was felt to be conclusive and unambiguous enough to inform a final business plan. The project team were also conscious of the current apathy to attend such workshops and did not want to risk bringing together key hydrogen and fuel cell stakeholders again for what could be perceived as a non-useful meeting.

A decision was therefore taken to summarise the business plan developed and circulate this to a number of key stakeholders selected from the attendees of the workshop event detailed in Section 9.4.

11 Addendum – the potential impact of not supporting the Forum

This report has demonstrated that the Midlands is host to a cluster of technology companies and universities with world leading capabilities in hydrogen and fuel cell technologies. The development of this cluster – which includes East Midlands-based Intelligent Energy and Rolls Royce Fuel Cells – has occurred gradually over a 20 year timeframe. Over the next five to 20 years there are three scenarios for the development of the cluster:

- The first scenario would see the cluster grow significantly (with associated GVA and employment) as the companies and universities in the region exploit the commercialisation of hydrogen and fuel cell technologies in consumer and business products and services.
- The second scenario would see region's players lose out to international (or possibly national) competition.
- The third scenario would see hydrogen and fuel cell technologies fail to penetrate the market because macro-economic barriers to market entry (performance, cost, consumer acceptance issues, competition, etc) are not overcome.

While the scenarios above, particularly the third, are impacted by a number of global factors, as Porter notes regional support is crucial in creating the supporting environment for clusters to thrive (Porter, 2000). Two case studies are offered below to show the possible effect of not funding the forum on:

1. Cluster members
2. The Midlands Hydrogen forum's network:

11.1 SMEs and RDA support: Logan Energy

A number of companies, most of them SMEs with cutting edge technology and know-how, have expressed interest in either moving into the East Midlands, or if already located there, into the hydrogen and fuel cell technology space. On a less positive note, insufficient support at a crucial juncture led to the European office of Logan Energy (a member of the BMHF), which has deployed a greater capacity of fuel cell units around the world than any other company, leaving the region to locate itself in Scotland. Allowing high growth potential companies such as this to leave the region is a mistake that should not be repeated; the crucial role of RDA support in company development was echoed by stakeholder feedback during the project:

Stakeholder feedback

"RDAs need to work smart to bring hydrogen and fuel cell companies to their regions and to keep them there. There are some very brief windows when key decisions on location are made:

1. *early start-up, when the company is free to locate anywhere. RDAs should put together a simple & quick turn-key offer – a wrapper including two-year deeply subsidised facilities, investor seed-funding package etc.*
2. *scale-up stage, when the company is being tempted with financial offers to move overseas but practical hands-on help from the RDA on the logistics of setting up new facilities, as well as whatever subsidies can be made available, can be valuable and help in the making the decision to stay"*

11.2 Funding support for networks: H2Net

As discussed previously, the activity and impact of the BMHF has diminished since funding was cut in 2009, and activities have been maintained on a goodwill basis by its Chair and with ad hoc support primarily from emda's Inward Investment arm. The decay of activity by H2Net, the UK Hydrogen Energy Network, since it lost funding in 2007 offers a further example of the need for funding of network activity.

H2NET was established in April 2000 as a joint collaboration between UK industry and academia interested in the development of hydrogen as an energy vector. The network was originally funded for three years by the Engineering and Physical Sciences Research Council (EPSRC) and, from April 2003 to July 2007, was partially supported by the UK Department of Trade & Industry (DTI). Since 2007 H2NET has been looking for funding and it is currently being operated on a voluntary basis; its activities have effectively ceased.

The decay of activity of H2NET since 2007 (when it has 200 active members) when it lost support from the DTI shows that networks need funding to continue engagement and activity. There are examples of networks that have evolved from being funded to being self-supporting – Fuel Cells UK provides a good example of this (although its likely merger with UKHA in July 2010 shows that achieving and sustaining critical mass is very challenging). Discussions with Dr Geoff Dutton, H2Net's Director supported the view that the loss of funding has critically, and likely terminally, hindered H2Net. There is an argument that industry will support something, if necessary with funding, if it believes it to be worthwhile. However, it is unlikely that local SMEs will be able to offer sufficient

support to a regional Forum to enable it to operate effectively on a local, national and international stage. Therefore ongoing support for the Forum, for a minimum of three years as described in the preceding sections, is critical to continuing to progress and deliver the benefits that the H2FC cluster offers to the region.

Acknowledgements

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12 Abbreviations

AFC	Alkaline fuel cell	
APU	Auxiliary power unit	
AWM	Advantage West Midlands	West Midlands regional development agency, http://www.advantagewm.co.uk
BIS	Department for Business, Innovation and Skills	http://www.bis.gov.uk
BMHF	British Midlands Hydrogen Forum	http://www.bmhf.org
CHP	Combined heat and power	
DECC	Department of Energy and Climate Change	http://www.decc.gov.uk
DMFC	Direct Methanol Fuel Cell	
emda	East Midlands Development Agency	East Midlands regional development agency, http://www.emda.org.uk/main/
EMRA	East Midlands Regional Assembly	
FCUK	Fuel Cells UK	UK fuel cell industry trade association: http://www.fuelcellsuk.org
GOEM	Government Office for the East Midlands	
H2FC	Hydrogen and fuel cell	
HGV	Heavy goods vehicle	

LCFC KTN	Low Carbon and Fuel Cell Technology Knowledge Transfer Network	Now two bodies: Transport KTN https://ktn.innovateuk.org/web/transportktn responsible for low carbon transport activities; non-transport fuel cell responsibilities now part of Energy Generation and Supply KTN http://ktn.innovateuk.org/web/energyktn
KTN	Knowledge Transfer Network	National networks funded by the Technology Strategy Board http://www.ktnetworks.co.uk
MHR	Midlands Hydrogen Ring	
PEM	Proton Exchange membrane	
RDA	Regional development agency	
RDD&D	Research, development, demonstration & deployment	
RIS	East Midlands Regional Innovation Strategy	
SH2FCA	Scottish Hydrogen and Fuel Cell Association	http://www.sH2FCa.org.uk/
TSB	Technology Strategy Board	Executive non-departmental public body (NDPB) established by the UK Government in 2007 and sponsored by the Department for Business, Innovation and Skills (BIS) **http://www.innovateuk.org**
UKHA	UK Hydrogen Association	Membership organisation for UK hydrogen stakeholders: http://www.ukha.org
UPS	Uninterruptable power supply	

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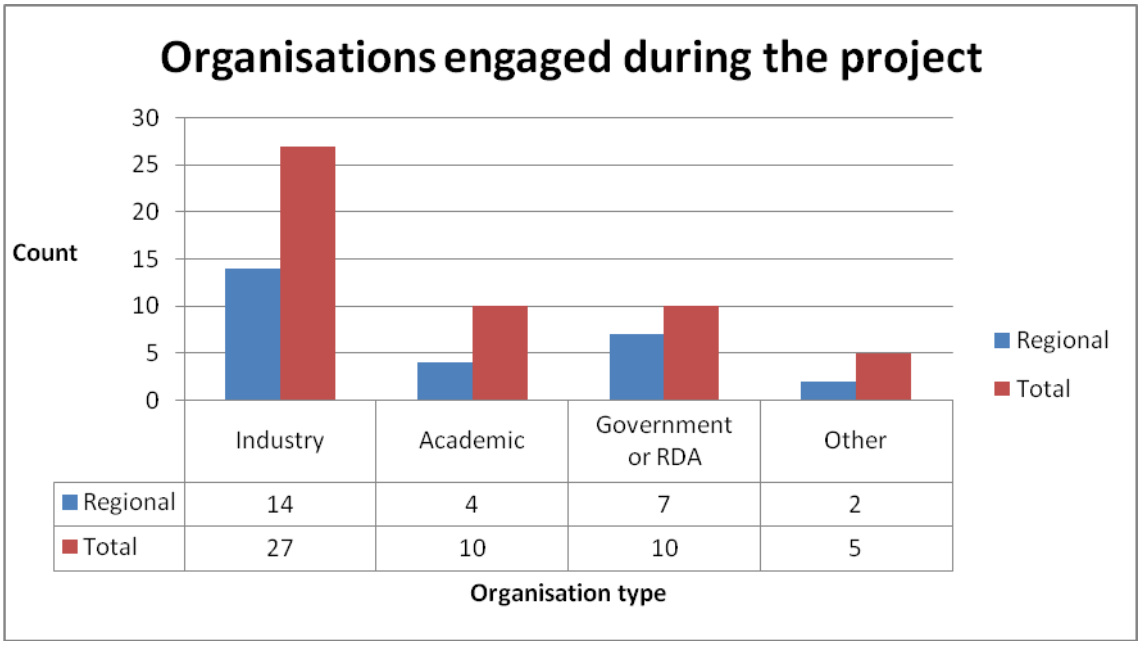
Appendices

1 Organisations engaged in producing this report



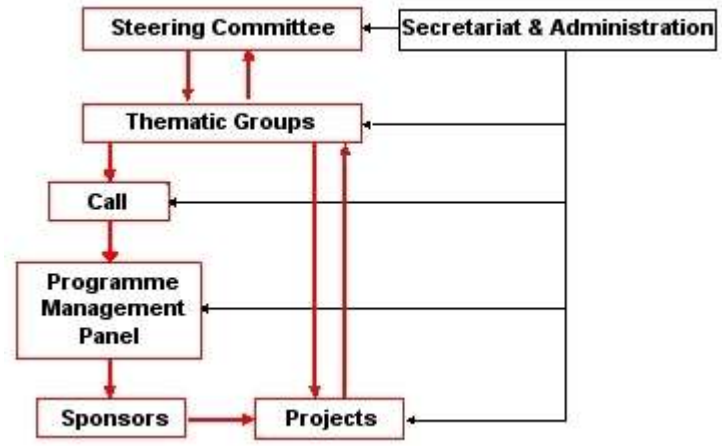
	Industry	Academic	Government or RDA	Other
Regional	14	4	7	2
Total	27	10	10	5

2 Overview of organisations and constitutional models presented in Chapter 8.3

2.1 Funded national sector focused network with themed activity subgroups: Foresight Vehicle

The Foresight Vehicle Initiative was created in 1996 by the DTI to stimulate innovation in the UK automotive industry. Between 1996 and 2006 the organisation funded research projects in the industry. Post 2006 the organisation transferred to ownership by the SMMT and thematic groups continued, with a remit to maintain the involvement of each grouping created around the specific themes to form consortia targeted to other sources of funding (TSB, FP7).

The Foresight Vehicle Steering Group was set up by the Transport Panel and the DTI and consists of representatives of vehicle manufacturers and their suppliers, independent research consultancies and university departments, government departments and user representatives such as motoring organisations. Research Projects were brought forward through five Thematic Groups, whose representatives are all expert in their chosen field. Each Thematic Group is organised around a specific area of automotive technology. The initiative is structured as follows:



The Thematic Group chair is a paid position with the responsibility for maintaining the group's agenda and to have final say over any outputs produced in the group's name.

Specific work outside of the meetings (e.g. inputs to government consultations, consortium formation and proposal writing) is done on a volunteer/self-interest basis.

2.2 Funded national sector focused network with themed activity subgroups and membership fees: *Low Carbon Vehicle Partnership*

Low Carbon Vehicle Partnership (LowCVP) is an action and advisory group, established in 2003 to take a lead in accelerating the shift to low carbon vehicles and fuels in the UK and to help ensure that UK business can benefit from that shift. It has over 350 organisations from the automotive and fuel industries, the environmental sector, government, academia, road user groups and other organisations with a stake in the low carbon vehicles and fuels agenda. The Partnership became a not-for-profit company limited by guarantee in April 2009 and introduced membership fees to supplements its central government funding. The organisation is applying for charitable status.

LowCVP's mission is "To accelerate a sustainable shift to low carbon vehicles and fuels in the UK and thereby stimulate opportunities for UK businesses". This is achieved through a programme of sector focused engagement, research and lobbying. To facilitate this, the Partnership has a secretariat team which links into a number of themed working groups, all of which are overseen by a board. The Secretariat's role is to facilitate engagement between members of the Partnership and acts as the first point of contact for organisations and individuals interested in its work. The Secretariat coordinates the work of the Board, the Steering Group and the Working Groups and represents the Partnership to internal and external audiences.

2.3 . National knowledge transfer networks focused on a specific field of technology or business: *Transport KTN*

Created in 2005 by the Department of Trade and Industry, and now funded and managed by the Technology Strategy Board (TSB), Knowledge Transfer Networks (KTNs) provide a single national overarching network for UK communities that share an interest in an area of technology development. KTNs aim to promote collaboration, best practice and knowledge sharing by bringing together a variety of stakeholders, including businesses (suppliers and customers), universities, research and technology organisations, the finance community and other intermediaries.

KTNs combine:

- A web portal providing technology, market and policy-related content on UK and international developments
- Networking events to bring together communities in order to promote technology transfer and innovation

2.4 Regional sector focused network with funding support to members: *Niche Vehicle Network*

The Niche Vehicle Network is an independent association of niche vehicle manufacturers, specialist technology companies and supply chain, based in or near to, the West Midlands. The Niche Vehicle Network was started in 2004 and was funded by AWM. The network is an association of around 25 specialist car and chassis manufacturers from around the region which is headed by a steering group made up of industry-recognised experts. This steering group decides the allocation of R&D funds.

Since 2008/9 scope has been widened by the formation of the Advantage Niche Vehicle Partnership (ANVP) again funded by AWM - which has a 'golden vote' when assigning R&D funds. The ANVP will create a competitive boost by promoting innovation through collaborative research and development and adoption of accelerated technology.

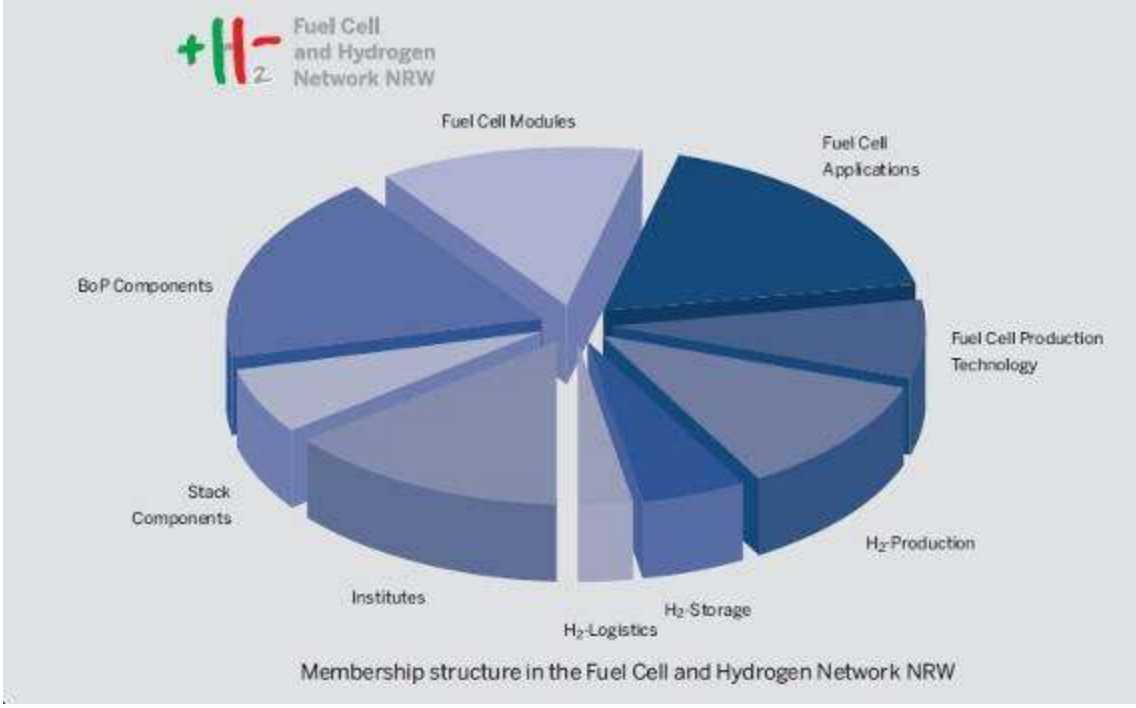
The ANVP is managed by Cenex, the Centre of Excellence for Low Carbon and Fuel Cell Technologies, and supported by Coventry University.

2.5 Regional sector focused network with funding support to members: *North Rhine-Westphalia (NRW) Grouping*

Founded in 2000, the fuel cell and hydrogen network North Rhine-Westphalia (NRW) provides networking events and has supplied funding of over €70m to over 60 Hydrogen and Fuel Cell (H2FC) projects. The group is supported by the central inward investment agenda: it operates on behalf of the state government of North Rhine-Westphalia and is part of the energy economy cluster "EnergyRegion.NRW". This cluster is made up of eight sub-groups focusing on the following areas: fuel cells and hydrogen; power plant technology; biomass; energy efficient and solar construction; geothermics; fuel and engines of the future; photovoltaics; and wind energy.

The overall aim of the H2 network element of the cluster is to position the region as an internationally recognized location for fuel cell and hydrogen technology. The network

has an estimated 375 members predominantly from industry (70%) and the knowledge base (20%) and primarily based in the region although there are some members from other states from within Germany and also overseas. The following diagram provides an illustration of the structure of the membership of the network, which is currently the largest of its kind in Europe.



Membership structure in the Fuel Cell and Hydrogen Network NRW

2.6 National trade association: *Fuel Cells UK*

Fuel Cells UK acts on behalf of its members to accelerate the development and commercialisation of fuel cells in the UK. It provides a point of contact and a clear, informed and up-to-date view on research, development and demonstration priorities for Government, other funding agencies and opinion formers.

Created with seed funding from the then DTI, Fuel Cells UK has 20+ member organisations, including the leading fuel cell companies in the UK as well as a range of other stakeholders, from energy utilities to component developers, fuel suppliers and others involved both directly and indirectly in the industry.

Membership is open to all UK registered organisations and individuals which/who support the Mission and objectives of the Fuel Cells UK Industry Association. A tiered membership structure allows Members to choose their level of participation.

Applications for membership have to be approved by the Executive Committee. Fuel Cells UK is lead by a part-time chair and deputy chair.

2.7 Regional trade association: Midlands Aerospace Alliance (MAA)

The Midlands Aerospace Alliance was formed in 2003 to support and represent the aerospace industry across the Midlands region. It became a Limited Company in 2005 and invited Midlands companies to join as formal members. Later that year it held elections to broaden board representation. It works closely with the regional development agencies as strategic partners, and shares with them the same vision for the future.

Companies involved in and with the aerospace industry in the Midlands are eligible for MAA membership at an annual subscription of £195 per year. This includes firms of all sizes active in: aircraft and systems manufacturing at all tiers, maintenance, repair and overhaul, professional services to aerospace, and testing, tooling, design and production equipment. Aerospace companies outside the Midlands region may join as Associate Members at an Annual Subscription of £390 per year.

The mission of the (MAA) is to organise more effective and efficient cooperation in the Midlands aerospace industry in order to improve the performance of all our companies and organisations.

It now has over 250 members across the East and West Midlands (it should be noted that it originally had 320 members when membership was free) . Its effectiveness was assessed in 2007 with the summary being to support the ongoing operations of the association in light of the successes it demonstrated.

The MAA Board is comprised of four permanent industry members representing industry primes and systems suppliers – Goodrich, Meggitt (Dunlop), Rolls-Royce and Smiths, six directors elected by the MAA membership, the two regional development agencies, Advantage West Midlands and the East Midlands Development Agency, and members appointed to ensure broad representation (including Amicus the Trade Union).

Four private/public working groups meet on a regular basis and report to the Board, advising on knowledge dissemination, support programmes, and strategy in their areas of expertise:

- Business development
- Innovation and technology
- Best practice management
- Skills

The Board and working groups are in turn supported by the MAA Secretariat:

2.8 Voluntary Model: *LinkedIn*

The voluntary models reviewed include Knowledge Transfer Network Special Interest Groups (SIGs) and Web2.0 communities built on sites such as LinkedIn, Facebook etc. Here the community is initiated by a 'moderator', who sets up and publicises a group based on a theme. Momentum is built and maintained by a community coming together around the theme. Membership is normally open and free with the network maintained virtually via the website (i.e. no face-to-face contact). The aim is to build a grouping driven from the 'bottom up' by a given community.

As an example, LinkedIn has over 65 million members in over 200 countries, with a new member joining approximately every second. LinkedIn's mission is to connect the world's professionals to make them more productive and successful and believes that in a global connected economy, success as a professional and competitiveness as a company depends upon faster access to insight and resources that can be trusted.

2.9 Regional subgroup of national body: *British Marine Federation (BMF)*

Regional subgroups and associations administered by secretariat paid by a national body were reviewed. Typically an executive committee is in place that is made up of volunteering organisations to steer activities. The aim is to provide regional focus based on national objectives - this allows for a UK wide solution whilst addressing regional nuances. This context becomes of interest in light of the issue of how to link any future Midlands forum with a potential overarching national body for hydrogen and fuel cells.

The British Marine Federation (BMF) is the trade association for the leisure and small commercial marine industry. It represents businesses involved in; Leisure boats - seagoing and inland, Commercial workboats, Superyachts and Hire fleets (and all the equipment and services needed for those craft). Its members come from over 4,300 businesses in today's UK leisure and small commercial marine markets. The turnover of those markets is worth £3.1 billion.

The British Marine Federation is a company limited by guarantee. Its principal trading activity is promoting the boating industry and the organisation and promotion of exhibitions. The Federation is funded from member subscriptions and from its exhibitions.

The BMF has a 50+ strong full-time executive staff which works within the policies and business strategy set by the Council of Members, (BMF Council). All of the BMF services are categorised under a three tier structure, comprising: Business Development, Member Support and External Relations.

There are 31 Group and Regional Associations. Group Associations are involved in one particular sector of the industry such as Leisure Boat Builders Association, Marine Trades Association and British Marine Equipment Association. Regional Associations encourage members across the sector to represent their geographic region such as BMF East Anglia and BMF Scotland. The business of these associations is conducted by an executive committee, elected by its members, with an elected Chairman and an appointed Secretary. Each association elects a Chairman who sits on Council. This structure allows regional representation whilst maintaining consistency of the national brand

3 Hydrogen and Fuel Cell Organisations

This section provides brief details on national and regional organisations operating in hydrogen and fuel cells. The majority of the information is taken directly from the web sites of the organisations.

3.1 National

3.1.1 UK Hydrogen Association (UKHA) http://www.ukha.org/index.php

The UKHA was created to span sector boundaries, provide a strong national voice on hydrogen energy, engage government, and drive the UK hydrogen economy. The UKHA is based in Gateshead (One North East Development Agency region).

Purpose

The UKHA will exist to provide value to its members by:

- Advocating strongly for a positive social, political and economic environment for the development of hydrogen energy in the UK
- Representing the shared interests of its members, using a collective approach to maximise impact and effectiveness
- Providing a voice to answer concerns and issues about hydrogen energy
- Giving guidance on research and deployment priorities
- Sharing up to date information and facilitating knowledge transfer
- Promoting the development of best practise and its adoption
- Influencing government and company policies in the UK to support hydrogen energy research and development
- Influencing the policies of public and private sector organisations to support hydrogen energy deployment in the UK
- Representing members' interests with European and International organisations and initiatives

Management

UKHA is managed by Technology Transition Corporation, LTD. TTC, LTD was formed in June 2003 in Gateshead, Tyne & Wear. A wholly-owned UK subsidiary of a 20 year old

US Company, TTC works to connect companies to accelerate new energy technologies. TTC understands emerging technology market introduction issues. TTC manages associations and other collaborative efforts to help companies engage with each other and with stakeholders to remove barriers and address opportunities to mainstream adoption of new products. TTC also provides consulting and management support to companies engaged in hydrogen, fuel cells, solar, electric utility and related technology areas, to address market challenges inherent in alternative energy and materials technologies (www.ttcorp.com).

The UKHA offers a variety of membership classes to potential members:

Sustaining Members

Sustaining Membership is open to all organisations that are eligible for any of the other membership classes (see below), that prefer the benefits of increased participation in all UKHA programmes and assurance of a seat on the UKHA Board of Directors, up to a limit defined in the Constitution. In addition, sustaining members are the only voting members of the UKHA Policy Committee.

Industry Members

Private companies, public or private utilities, organisations created by companies or utilities, or major buyers or users of hydrogen which already are involved or have plans to become involved in the production, storage, transportation, utilisation, or technology related to hydrogen, are eligible for membership as Industry Members. Industry Members are entitled to proportionate representation on the Board of Directors, as defined in the Constitution.

Small/Medium Enterprise Members

SME Members are organisations which, except for size, would be qualified to be Industry Members. SME businesses are those that are registered as a qualifying SME in the UK, or otherwise have fewer than 250 employees. SME Members are entitled to proportionate representation on the Board of Directors.

Related Organisations

Related Organisations include hydrogen energy and/or fuel cell projects, associations, groups and all non-profit organisations, interested or involved in hydrogen production, storage, transportation, utilisation or technologies which can benefit from information-sharing, collaboration, and the creation of a single voice to promote hydrogen energy

technologies in the United Kingdom. Related Association Members are entitled to proportionate representation on the Board of Directors.

University/Education Members

Universities, education organisations, and highly qualified individuals dedicated to education, research scholarship, or other academic or theoretical pursuits relating to hydrogen production, storage, transportation, utilisation or technologies, are eligible for membership as University/Education Members. University Members are eligible to shape UKHA policies and materials that serve to educate end-users of hydrogen technologies, as well as policies relating to Research & Development priorities. University/Education Members are entitled to proportionate representation on the Board of Directors.

Individuals

Individual membership is open to individuals who have no affiliation with organisations defined above. Individual members may participate in committee activities and receive other benefits afforded to members, but have no voting rights and no representation on the Board of Directors.

- Sustaining Member: £5,000 plus VAT
- Industry Member: £1,000 plus VAT
- Small & Medium Enterprise Member: £200 plus VAT
- Related Organisation Member: £1,000 plus VAT
- University/Education Member: £100 plus VAT
- Individual Member: £100 plus VAT

3.1.2 H2NET - The UK Hydrogen Energy Network http://www.h2net.org.uk/default.htm

The UK Hydrogen Energy Network (H2NET) was established in April 2000 as a joint collaboration between UK industry and academia interested in the development of hydrogen as an energy vector. The network was originally funded for 3 years by the Engineering and Physical Sciences Research Council (EPSRC) and, from April 2003 to July 2007, was partially supported by the UK Department of Trade & Industry (DTI). H2NET (now with approximately 200 members) is looking for new funding and is currently being operated on a voluntary basis.

Its principal aim is to promote research and discussion on issues connected with the development of the hydrogen energy economy. The formation of the Network was

prompted by wider international developments in the technologies underpinning a hydrogen energy economy.

The Network's objectives are to enhance the current profile of hydrogen energy research in the UK by:

- identifying research requirements and facilitating the development of academic/industrial collaborations in the UK
- providing a forum for the discussion of research, development, and implementation issues related to hydrogen energy exploitation
- disseminating information relating to state of the art research in the hydrogen energy economy

These objectives are addressed through a regular series of workshops and seminars, backed up by a web site and e-mail discussion group. The Network is guided by a steering committee drawn from industrial groups and university departments.

Membership of the Network is free to all those having a research or commercial interest in hydrogen energy. The network is based at the Rutherford Appleton Laboratory, Chilton, Didcot (South East of England Development Agency region).

3.1.3 Fuel Cells UK http://www.fuelcellsuk.org/

Fuel Cells UK acts on behalf of its members to accelerate the development and commercialisation of fuel cells in the UK. It provides a point of contact and an up-to-date view on research, development and demonstration priorities for Government, other funding agencies and opinion formers.

Its members include the leading fuel cell companies in the UK as well as a range of other stakeholders, from energy utilities to component developers, fuel suppliers and others involved both directly and indirectly in the industry.

Aims (taken from the website)

1. Creates the power of a collective industry voice to represent members' interests at the national and international level.
2. Promotes the advancement of public and private sector policies that encourage the development and deployment of fuel cells and associated fuels.

3. Identifies the barriers to the wider development and deployment of fuel cells and associated fuels, and facilitates action to reduce them.
4. Coordinates and promotes Members' views on current and future research, development and deployment priorities for fuel cells and associated fuels to Government and other funding agencies.
5. Works to increase the presence and influence of Members at the European and International level, to help shape the European fuel cell agenda, and enhance opportunities for Members' participation and benefit.
6. Gathers information and intelligence on fuel cells and related topics and communicates it to members. This includes informing members of funding opportunities and mechanisms, including those at European level.
7. Develops channels of communication between Members, the Government, the private sector, the European Union, other industry associations and other international organisations.
8. Undertakes targeted outreach activities to promote better understanding of fuel cells and the benefits which they bring among key stakeholders.
9. Forms links with the private and public sectors and other associations to facilitate the promotion of UK member organisations worldwide.

Achievements

- Discussions with Treasury to identify appropriate support mechanisms for fuel cells over the next 5 years;
- Working with DECC to ensure that the development of the EU Joint Technology Initiative progresses optimally and that the Environmental Transformation Fund fully recognises and builds upon the benefits which fuel cells can bring;
- Feeding into the Renewable Energy Strategy consultation, which included lobbying the Government on the introduction of feed-in tariffs for low carbon energy technologies; and
- Working with the Technology Strategy Board to optimise the scope and positioning of its £10 million collaborative R&D Call.

Membership categories, specific benefits and subscriptions are as follows:

	Executive membership	Corporate membership	Regional membership	SME membership *1	University membership	Individual membership *2
brokerage opportunities	√	√	√	√	√	
improved positioning of and opportunities for fuel cells	√	√	√	√	√	√
the opportunity to shape the direction and focus of the Association	√	√	√	√	√	√
networking through Fuel Cells UK events	√	√	√	√	√	√
improved access to and awareness of funding opportunities	√	√	√	√	√	√
being part of a shared and powerful voice to influence policy and decision making	√	√	√	√	√	√
greater awareness of development and business opportunities	√	√	√	√	√	√
marketing and promotion opportunities	√	√	√	√	√	√
Membership of Executive group	√					
Subscription (£ excluding VAT)	5,500	2,800	2,800	1,000	1,000	500

The association has a chair and deputy chair. The current Chair and Deputy Chair are Dennis Hayter, Vice President for Business Development at Intelligent Energy, and Martin Green, Strategic Development Director at Johnson Matthey respectively.

The network is hosted by Synnogy which is based in Northants (East Midlands Development Agency region).

3.1.4 Low Carbon Knowledge Transfer Network (KTN, now part of the Transport KTN) www.lowcarbonktn.org.uk

Funded by the Technology Strategy Board, the Low Carbon Knowledge Transfer Network (LC KTN) provides a single national overarching network for the UK low carbon automotive community. The LC KTN aimed to promote collaboration, best practice and

knowledge sharing by bringing together a variety of stakeholders, including businesses (suppliers and customers), universities, research and technology organisations, the finance community and other intermediaries.

The KTN combines:

- A web portal providing technology, market and policy-related content on UK and international developments
- Networking events to bring together communities in order to promote technology transfer and innovation

The Low Carbon KTN recently became part of the Transport KTN – for which Cenex is one of two current delivery partners; https://ktn.innovateuk.org/web/transportktn/overview. The Low Carbon group will continue to work with fuel cell colleagues who will become part of the new Energy Generation and Supply KTN.

3.1.5 Energy Generation and Supply Knowledge Transfer Network (KTN)

The mission of the Energy Generation and Supply Knowledge Transfer Network (EG&S KTN) is to create an integrated and dynamic network of business, technology, academic and policy stakeholders delivering strategic and effective knowledge exchange to advance the UK EG&S sector. A strong network for the sector will enable us to realise our vision of:

- Better positioning of UK business in exploiting UK/global market opportunities in accord with the Technology Strategy Board's EG&S strategy
- Improved impact and gearing of Technology Strategy Board spend in the EG&S area
- To "future-proof" the UK's activity in the EG&S area through coordinated technology & innovation

The EG&S KTN personnel are:

The Steering Group Chairman - Chris J Murray, Director UK Transmission, National Grid

The Chairman is appointed by the Technology Strategy Board and is independent of the management team.

The Steering Group

- The Steering Group advises the management team, and comprises independent representatives of organisations from large and small industrial companies as well as Government, academia and NGO bodies.

The KTN Director – Dr Brian Cane, Head of TWI Power & Energy Systems

The Director is responsible for TWI's business in fossil, nuclear and alternative energy areas.

The Management Team

Composed of the Director, a Project Manager from TWI and senior representatives from all of the consortium partners (AEA, APGTF, Synnogy, ITF and UKERC).

Role

The role of the EG&S KTN is to simplify the UK Energy Innovation landscape by providing a clear and focused vehicle for the rapid transfer of high-quality information on technologies, markets, funding and partnering opportunities. The result will be an acceleration of developing technologies up the Technology Readiness Level (TRL) ladder. It will do this by satisfying the following:

- Provide UK industry and supply chain players with the opportunities to meet and network with businesses, academia, utilities and other energy innovation stakeholders, and the private investment community, in the UK and internationally
- Provide clarity regarding the issues affecting innovative energy technology exploitation at various stages along the innovation pipeline
- Enable effective knowledge transfer between all relevant people and organisations, in particular ensuring a match between utility and industrial needs, and supply-chain technology/research capabilities
- Encourage the flow of people, knowledge and experience between policy groups, industry, the science base and the utility/generating community, with

the common aim of delivering products and services that meet a clear energy need and are commercially attractive
- Attract and optimise the various funding sources by use of roadmapping and market analysis
- Provide a forum for a coherent industry voice to inform Government policy making and the private investment community
- Provide advice on the various support mechanisms (public and private) available to the research base and industry

Fuel cells and Hydrogen is a priority area for the KTN for which there is a Fuel cells and Hydrogen Group. The fuel cell and hydrogen programme within the KTN is delivered by Synnogy.

The EG&S KTN covers the full range of fuel-cell applications and opportunities for hydrogen as an energy vector, including:

- Large stationary fuel cells, used primarily for distributed power generation and frequently deployed in combined heat and power (CHP) mode
- Small stationary fuel cells, used in residential applications, providing hot water and electricity to householders
- Transport fuel cells, for use on land, sea and air
- Portable fuel cells, primarily for deployment in consumer electronics, but also for military use
- Hydrogen production, distribution, storage and use.

In autumn 2009, the EG&S KTN launched an on-line survey aimed at identifying areas where the KTN could add greatest value to the fuel cell and hydrogen community in the UK. The main areas of interest highlighted by more than 145 respondents included information provision on funding opportunities, stationary and transport fuel-cell applications, hydrogen production, and energy conversion and storage. The survey results are helping to shape the long-term programme of fuel cell and hydrogen activities within the EG&S KTN.

3.1.6 UK Hydrogen Network

UK-HyNet is an initiative that aims to create a network of hydrogen infrastructure throughout the UK. The UK Hydrogen Network (UK-HyNet) project was launched in June

2009, and is an initiative that aims to position the UK as one of the world's leading hydrogen economies by 2015, by creating a network of hydrogen infrastructure throughout the UK.

While the UK already has clusters of world-leading knowledge and technological innovation in hydrogen, fuel cells and low-carbon energy systems, efforts have until now remained localised- and so dwarfed by national projects abroad. Under UK-HyNet, all these activities will become part of a co-ordinated national programme that can compete on the international stage.

The majority of automotive manufacturers plan to start the commercial mass deployment of hydrogen fuel cell powered vehicles (H2FCVs) in 2015. It is the intention of UK-HyNet to create the conditions by which the UK becomes the country of choice for the car makers to launch their first H2FCV fleets.

This will provide a platform for the regeneration of the UK's car industry, a showcase and test bed for its innovative technologies and a launch pad for a potentially huge and sustainable clean technology industry with enormous domestic and export market, wealth-generating and job-creation potential – in short, part of the 'green route out of recession'.

In parallel with UK-HyNet, a UK Hydrogen Roadmap is being developed which will set out a strategic plan for the emerging hydrogen industry. UK-HyNet puts in place a practical mechanism for the implementation of the strategy articulated in the UK Hydrogen Roadmap.

UK-HyNet is still very much in its formative stage and hence does not have a website as yet.

3.2 REGIONAL

3.2.1 London Hydrogen Partnership (LHP) http://www.london.gov.uk/lhp/

The London Hydrogen Partnership is working to bring hydrogen and fuel cell technology forward in the capital so as to improve energy security and air quality, reduce greenhouse gases and noise, and support London's green economy.

The LHP is sponsored by the London Development Agency (LDA) and has a secretariat for the day-to-day operations of the partnership.

The Partnership's principal objective is to work towards the establishment of a hydrogen economy for London and the UK.

It aims to:

- Establish and maintain dialogue among all sectors/actors relevant to the hydrogen economy
- Prepare and disseminate relevant materials
- Develop the London Hydrogen Action Plan as a route map for clean energy
- Provide a platform for funding bids and initiation of projects

The Partnership, set up in 2002, now consists of an Executive Committee, a Secretariat, Working Groups, numerous Associate Members and a Partnership Committee that meets annually (see diagram below).

Executive Committee

The Partnership is co-ordinated by an Executive Committee meeting quarterly chaired by a representative of the Mayor of London.

Project Groups

The Executive Committee directs the activities of a number of Project Groups to identify and enable projects under the Action Plan, and assist members to deliver Partnership objectives.

Infrastructure & Vehicles. The group is working in conjunction with the London Hydrogen Transport Plan and local Boroughs to facilitate providing six refuelling stations for the proposed 150 Hydrogen and Fuel Cell Vehicles over the next 2 years.

Stationary Applications. Identifying priority projects in portable, and small to large-scale stationary applications such as combined heat and power (CHP).

Secretariat

The Partnership is supported by a Secretariat.

Activities

In March 2009, the LHP announced its plans for a 'Hydrogen Network':

"London is set to create a 'Hydrogen network' by 2012, under plans unveiled today (Friday 26 March) to help accelerate the wider use of this zero-polluting, zero-carbon energy in the capital.

The London Hydrogen Partnership (LHP) is working with London boroughs and private landowners on plans to deliver at least six refuelling sites to run hydrogen-powered vehicles in the capital over the next two years. One is already being built in east London for the refuelling of hydrogen-fuelled buses that will begin running on the RV1 route later this year. Hydrogen vehicles emit no pollution from their tailpipes and vehicles which use hydrogen from renewable sources have no emissions at all. This could deliver huge benefits for cities in improving air quality, cutting carbon emissions and reducing dependence on fossil fuels.

The action plan published today also aims to encourage a minimum of 150 hydrogen-powered vehicles on the road in London by 2012. These could include cars, vans, taxis, motorbikes, and lorries. Fifty of the vehicles are expected to be operated by the Greater London Authority's functional bodies – Transport for London (TfL); the London Development Agency (LDA); the London Fire and Emergency Planning Authority (LFEPA); and the Metropolitan Police Authority (MPA).

The London Hydrogen Partnership and the Greater London Authority are already working with BAA on a hydrogen feasibility study to explore ways to use hydrogen and fuel cell technologies at Heathrow airport. This study could then act as a model that BAA can use in its other airports.

Hydrogen can also be used to provide cleaner, greener, low carbon energy for buildings. In February this year, Kit Malthouse opened the UK's largest in-house hydrogen fuel cell at TfL's Palestra building in Southwark. This fuel cell will provide a cheaper, local source of energy for the building, which is also the home of the LDA. By 2012 the LHP wants to see five large-scale fuel cells in London like the one at Palestra, as well as 10 fuel cell back-up systems, which can be used to keep powering essential systems such as computer data centres and lighting in the event of a power cut.

The initiatives outlined in the London Hydrogen Action Plan will aim to access funding support from the European Union, UK government and the private sector."

3.2.2 Scottish Hydrogen Fuel Cell Association http://www.sH2FCa.org.uk/

The Scottish Hydrogen and Fuel Cell Association (SH2FCA) promotes and develops Scottish expertise in fuel cells and hydrogen technologies – a global market estimated to be worth $46 billion by 2011.

SH2FCA brings together the expertise and experience of Scotland's specialised fuel cell companies, academic institutions, research and development bodies, power generation companies, energy consultants, Scottish Enterprise and local enterprise companies, and students and individuals with an interest in the subject. Membership is open to all-comers.

SH2FCA provides a coherent voice to represent, promote and develop Scottish hydrogen and fuel cell technologies. The Association engages with Scottish and UK government to create the right framework for the industry to develop. SH2FCA 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 global sustainable hydrogen and fuel cell market.

There is a very considerable opportunity for the UK to achieve a major hydrogen and fuel cell economy if significant increases in R&D support are provided in accord with investments for competitors such as Japan, US and Germany. We believe that through SH2FCA we can harness the skills and expertise available in Scotland and ensure that they are promoted on a national and international stage. We are at the dawn of the third industrial age and with a maturing oil and gas province, we must develop alternative opportunities.

The aims of SH2FCA are to:

- Be the main driver for the development of the H2FC industry in its broadest sense in Scotland
- Have an effective presence and represent the industry at Scottish, UK and EU levels
- Lobby government in Scotland and in the UK on behalf of the industry
- Identify business opportunities for members
- Provide networking opportunities for members

- Act as a vehicle for attracting funds for member companies and projects
- Propose projects in which members can participate
- Provide opportunities for collaborative working among members
- Promote member organisations' and collective capability
- Provide a forum for sharing information and raising awareness
- Advise on and create best practice for the industry
- Be a source of technical expertise

Membership costs

- Government £3000
- Corporate £1000
- SME £200
- LA £200
- Housing association £200
- University £150
- Registered Charity £75
- Student £50
- Individual £50

Previously part funded by Scottish Enterprise (understood to be in the order of £55k per annum plus additional funding for specific project deliverables - which could increase the total annual support up to approximately £100k) and part by membership fees, the Scottish Hydrogen and Fuel Cell Association (SH2FCA) has 40+ members. The association has now secured ERDF funding. Going forward the structure of the association will include a full-time chairperson role and a part-time administrative support which who will be monitored by a voluntary board of directors.

3.2.3 H2Wales http://www.h2wales.org.uk/

The H2Wales web site has been established to provide information on the transition to a hydrogen based low-carbon energy future, in general and hydrogen activities in Wales in particular. The site was originally set up as part of the Objective 1 part-funded project **"A Sustainable Energy Supply for Wales: Towards the Hydrogen Economy".** Cymru H2 Wales is a two year project, running from January 2003 to December 2004. The aim of this project is to place Wales (in particular the Objective 1 region) in a position to create wealth and employment by taking full advantage of the opportunities presented by the ongoing transition to the hydrogen economy). It continues to inform on all activities geared towards the transition to a hydrogen economy in Wales.

The **Renewable Hydrogen Research and Development Centre** is located at the Baglan Energy Park, South Wales and is one of the first of its kind. Hydrogen produced from renewable sources will be used in the building and for refuelling vehicles.

Wales' Hydrogen Energy Vision

Wales has a number of advantages that can be utilised in the transition to a hydrogen economy:

• Our abundant renewable resources provide an opportunity to clean up our energy system. However, one major part of our energy demand is still almost totally dependent on oil-based products, namely transport. Combining our renewable assets with the production of hydrogen can start to overcome the dependence of our transport sector on oil and provide significant environmental benefits.
• We possess exceptional competence in a number of industries with direct relevance to the hydrogen economy, namely the automotive, chemical, metals, and microelectronic industries as well as our long-standing expertise in agriculture. To turn this to our competitive advantage will require vision, collaboration and determination.
• The National Assembly for Wales (NAfW) has a distinctive statutory duty to promote sustainable development and has set challenging goals for the adoption of renewable energy, seeks to promote renewables to enhance industrial, rural and commercial opportunities and positions Wales as a renewable energy showcase.

It is acknowledged that a number of challenges exist in the transition to a hydrogen economy, but the Vision document ("**A Vision of the Hydrogen Economy in Wales**: **Placing Wales in a position to take full advantage of the hydrogen economy**") outlines how these challenges can be addressed and this transition can be to Wales advantage.

The team behind H2Wales mainly involves senior staff from the University of Glamorgan.

In January 2010 the establishment of the Low Carbon Economic Area (LCEA) brand in Wales was announced following a proposal to the Department for Business Innovation and Skills (BIS). The Low Carbon Economic Area (LCEA) will be centred on hydrogen technologies and Wales' ambition to build on existing skills and expertise to lead the UK in hydrogen R&D and investment.

LCEAs are being introduced across the UK to accelerate low carbon economic development activity and raise the overall UK proposition beyond those of our international competitors.

The LCEA alternative transport fuels corridor is based around the M4 initially. It builds on the investment already completed at the Renewable Energy R&D Centre Baglan, where renewably generated hydrogen and methane is available for vehicles. The Corridor will allow a test and demonstration facility for the automotive sector to develop their products and alternative fuelled vehicles in real life situations. It will be complementary to other low carbon activities such as the Heads of the Valleys low carbon zone, especially for deployment of low carbon vehicles and hydrogen fuel cells for buildings.

The LCEA concept includes:

helping regions compete on an international scale; attracting foreign investment and building collaborations (industrial and educational) to improve R&D, drive innovation and entrepreneurship

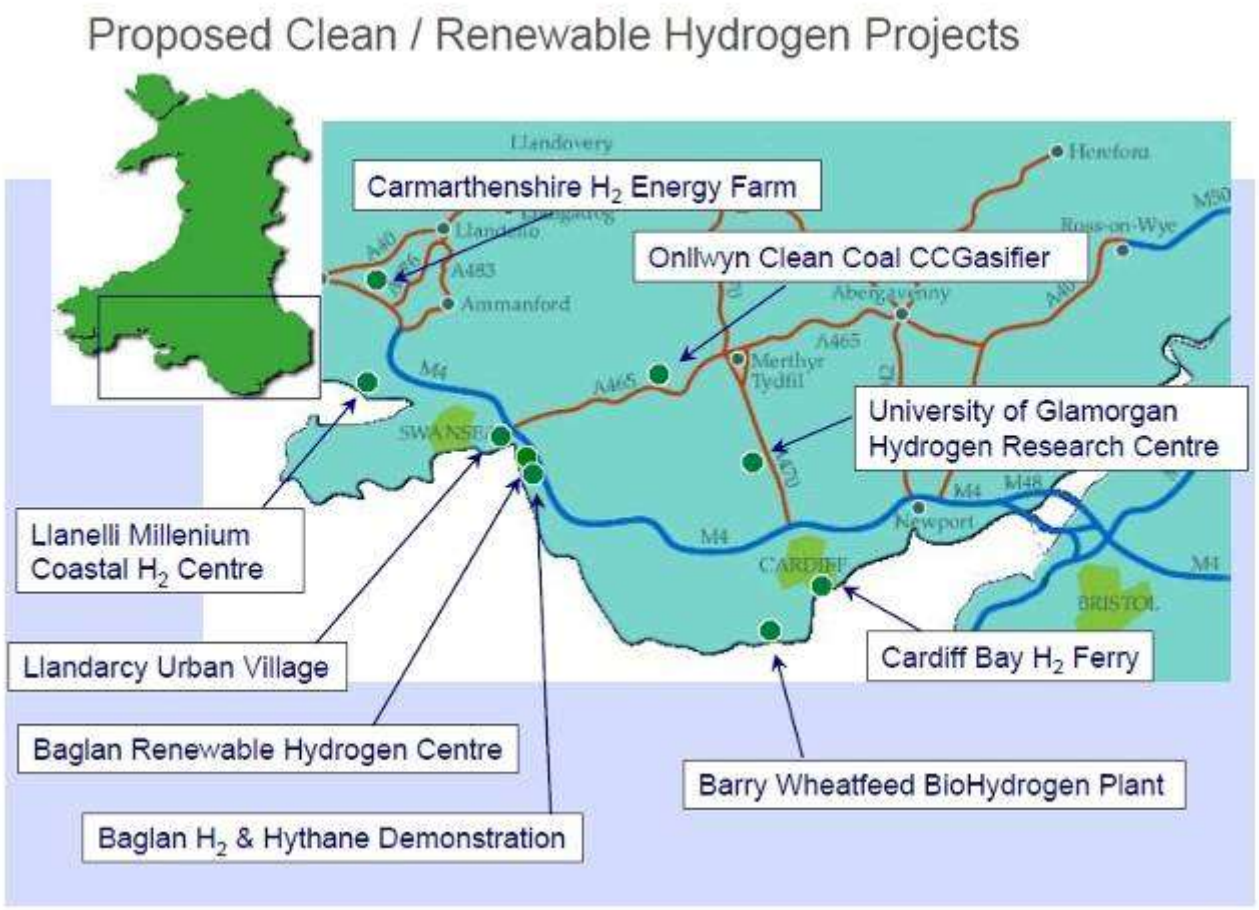
stimulating the low carbon economy based around industrial partnerships and collaboration

capitalising on distinct local and regional strengths, clustering this activity to help secure global advantage

Benefits of the LCEA in Wales will include:

- A focused and coordinated Welsh led approach to exploiting existing hydrogen expertise and automotive components industry
- A platform for growth in green jobs in the automotive sector supply chain
- A competitive advantage when attracting new investment and R&D in hydrogen technologies
- Acceleration of the growth of low carbon industries, skills base and supply chain.

The following diagram provides an overview of current activity in the area:



3.2.4 Centre for Process Innovation http://www.uk-cpi.com

The Centre for Process Innovation (CPI) was established by One NorthEast as a UK wide resource to stimulate and drive innovation within the Process Industry. Its Fuel Cell Application Facility works with the aim of establishing fuel cells as a commercially viable low carbon energy technology. To support this aim, it has established a Development Centre, designed to support all parts of the fuel cell supply chain.

The Development Centre, together with its experienced support team and extensive range of partner organisations, can offer technical support to product and project developers, OEM Systems integrators and manufacturers, reducing the risks associated with the commercialisation of the technology.

Using experience gained in a number of public demonstration projects, the Development Centre supports companies working within the fuel cell industry as well as companies considering the industry as a potential new market.

It is equipped with advanced fuel cell test stations, allowing fuel cell testing and experimentation on a wide range of fuel cells, from single cell assemblies to 15 kWe systems. Dynamic load testing can be carried out on PEM, DMFC and SOFC systems, with full data logging. The Centre offers LABVIEW capability for fuel cell testing and control and CHEMCAD capability for the design and simulation of complete fuel cell systems. Filling facilities for hydride and composite hydrogen tanks are also available.

Health and safety advice is offered to fuel cell users on fuelling systems and design, as well as the analysis, identification and quantification of sulphur species present in fuels.

Confidential and independent testing and evaluation services allow both manufacturers and consumers to evaluate the performance of their systems. Development facilities, incorporating private office space, are also available, allowing fuel cell companies to develop new systems with minimal capital risk.

The following is taken from the CPI website and aims to provide an overview of the centre:

The Centre for Process Innovation (CPI) is a lead driver of innovation in the UK's growing processing sector. We develop products, processes, services and businesses in the process and manufacturing sectors.

Structure

CPI champions three key activities supporting the process industry and delivers a unique portfolio of activity, including:

CPI Technology Development: CPI has successfully established two national technology development centres – the Printable Electronics Technology Centre (PETEC) and the Sustainable Processing Centre (SUSPROC). Each centre houses a number of unique and technology specific facilities and expertise. The centres aim to bring new low carbon industrial bio technologies and printable electronic systems and materials to market using our open access physical assets to transform research to a viable commercial process.

CPI Economic Support CPI successfully manages and delivers a number of government funded economic support projects working to bring process related low carbon energy,

environmental technologies and nano-material technologies to the North East of England and the UK.

CPI Enterprises CPI has formed new companies through spin-outs and joint ventures.

Our approach

CPI significantly reduces the risks associated with innovation. We operate a unique approach, stimulating market-led innovation, bringing together market 'pull' from industry with technology 'push' from academia, to address the real needs of the process industry in the 21st century. We work to create new and strong supply chains in the UK by instigating and developing multi-party projects.

"Energy is a global issue that puts CPI at the heart of the UK's drive to bring new sustainable energy sources into use. With Governments' increased pressure to reduce carbon footprints, CPI's work in alternative energies offers high potential to help reduce the strain on our planet.

Our fuel cell labs are up and running and technologists from around the country are taking advantage of the new facilities. We have focused on hydrogen as a fuel source and have already demonstrated the world's first hydrogen powered lighthouse. Next is a mobile hydrogen fuel station. Developments planned for the future include a move into fuel production from biomass.

The Tees Valley is an excellent base for a facility such as ours, with infrastructure and expertise in place thanks to the region's historical links with the chemical industry. Hydrogen is also produced in significant quantities, much of it as a by-product of the manufacturing activities."

4 Midlands Hydrogen Forum stakeholder workshop

The workshop consisted of a presentation outlining two potential constitutional models to an audience of key hydrogen and fuel cell stakeholders (from the East Midlands and neighbouring regions), followed by discussion in smaller sub-groups of the models proposed.

The audience was split into four sub-groups - green, yellow, blue, red.

The following structured feedback form was put in place in order to provide prompts to the participants and to provide order to the comments made to the presentations.

British Midlands Hydrogen Forum Future Workshop, 22nd February 2010

Feedback form

1. **General**
- How likely are you to get involved in this forum?
- What level of involvement would you anticipate? (High - regular contributor & attendee, Medium - occasional contributor & attendee, Low - minimal contribution or attendance)
2. **Constitutional models**
- Which constitutional model do you prefer and why?
- Do you foresee any issues with your preferred model?
- Have we missed anything?
3. **Midlands or wider**
- Should the forum involve East, East-West Midlands, or widen to a 'Central' context?
4. **Fit with the wider landscape**
- Are you involved in any other regional, national or European forums?
- What works well?
- What could be improved?
- Do you pay membership fees? How much?
- Do you think there should be one UK body for hydrogen and fuel cell activity?
5. **Funding**
- Should fulltime staff be employed to manage/run the forum?
- Would you be prepared to pay a membership fee?
6. **Forum work programme – advocacy and/or activity?**
   What should/could a new forum deliver?

5 SWOT analysis of potential forum name solutions - geographical context

5.1 1. East Midlands Hydrogen Forum/HyNet East Midlands

Strengths:

- Clear regional focus
- Public support clearly delineated - emda

Weaknesses:

- Limited number of participating organisations
- 'Island mentality' - does not consider the potential strengths associated with greater mass of organisations

5.2 2. Midlands Hydrogen Forum or HyNet Midlands

Strengths:

- Larger numbers compared with one region focus
- Greater cross section of capability
- Synergistic capabilities between the East and West Midlands - Hydrogen Ring

Weaknesses:

- If public support is required - complication of public support from two RDAs
- 'Fit' to two regions priorities and requirements

5.3 3. Central Hydrogen Forum or HyNet Central

Strengths:

- Larger numbers compared with one region focus
- Greater 'critical mass' of capability
- Synergistic capabilities between the regions
- Completes national picture associated with hydrogen and fuel cells

Weaknesses:

- If public support is required - complication of public support from multiple RDAs
- 'Fit' to three regions' priorities and requirements

5.4 Potential geographical 'fit' of the proposed forum:

Geographically then there would appear to be considerable scope for a central forum that could initially encompass the following regions:

- Yorkshire
- East of England
- West Midlands

Further, by not restricting the forum geographically through its name, the following regions could also conceivably get involved in a 'Central Hydrogen Forum':

- North West
- South East
- South West

6 Definition of Hydrogen Forum CEO role

JOB TITLE: CEO

RESPONSIBLE TO: The Hydrogen Forum Executive Board

SKILLS REQUIRED:

- Experience gained in the energy sector
- Experience of hydrogen and fuel cell technologies
- Enthusiastic
- Well organised
- Prepared to make instant decisions when necessary
- Confident at some public speaking and keeping order during meetings
- Experience of promoting a message and an image

As CEO, you will be the face of the Forum, promoting the activities of its stakeholders and encouraging its growth. You will oversee the organisation's on-going commitment to maintaining a strong brand for this sector in the region and will manage close relationships with similar forums on a national and international level. You will also need to challenge and lead the organisation, making far-reaching strategic decisions and working alongside government bodies and other interested stakeholders to make a real difference.

Such a high-profile role demands senior level experience and the ability to absorb large amounts of complex, critical information quickly. You must also possess the gravitas to operate under close public scrutiny. You are a natural strategist, politically astute and keen to prove yourself in a fascinating and challenging public policy arena. You will have a balanced approach and excellent relationship building skills honed through your background in the public or private sector.

MAIN DUTIES (General):

- Take responsibility for managing the affairs of the forum

- Oversee and guide all decisions taken by the sub committees
- Liaise with the Executive Board
- In conjunction with the secretariat, prepare and present the annual report
- Liaise with the secretariat on the agenda for each meeting and approve the minutes before they are circulated
- Be completely familiar with the constitution, procedures and the rules and regulations relating to the forum
- Liaise with the Executive Board to ensure that funds are spent properly and in the best interests of the forum
- Help to prepare and submit any statutory documents that are required (e.g. VAT, grant aid reports)

MAIN DUTIES (Specific):

- Encourage networking of the stakeholder group
- Organise events to promote the forum, enable knowledge sharing and networking
- Encourage collaboration and project development
- Develop the brand of the forum through PR
- Report activities and feedback from the forum to government
- Liaise with Regional Development Agencies
- Develop and maintain communication and collaboration with national and international hydrogen and fuel cell organisations
- Liaise with the Executive Board

TIME COMMITMENT:

Estimated to be three days per week based on current membership figures.