Sustainable Road Transport: a future perspective

The role for hydrogen and how it will be achieved

Chris McAtominey. Intelligent Energy.

17th July, 2013
Intelligent Energy

- UK based international power technology company
- Commercialising our leading fuel cell technologies with our global business partners
- Substantial and growing intellectual property portfolio of over 440 patents (granted and pending)
- Focus on: Consumer Electronics, Stationary Power and Motive Sector markets
- Established in 2001, but with a history of 25 years fuel cell innovation from a Loughborough base
- 350 personnel in UK (HQ), Japan, India, USA
Commercialisation Through Partnerships

• Blue Chip customers with understood & scalable commercialisation route

• Business model: from licensing to equity participations

• Scalability, cost reduction and manufacturing risks mitigated

• Accelerated and de-risked go-to-market plans
Commercial Application Across Sectors

- Intelligent Energy fuel cell systems are applied across sectors and markets:
  - **Consumer Electronics**: portable & extended operating power
  - **Stationary Power**: CHP, on-demand, telecommunications, backup power, emergency power
  - **Motive Power**: Two-wheeled vehicles, automotive, commercial vehicles
Intelligent Energy Zero Emission World Firsts
A long history of world firsts in hydrogen fuel cell technology

First purpose built fuel cell motorbike

First manned fuel cell aircraft

First fully road approved fuel cell scooter

First PEM fuel cell black cab
Working with OEMs across selected markets: ‘design once, deploy many times’

Portable power

Stationary power

Powered Two Wheelers

Air Cooled systems

CHP systems

Aerospace

Passenger Cars / LCVs

EC systems
Full Range Personal Mobility up to 100kW

We offer our partners rapid access to power technology markets, combining their well-established channels to mass markets with our field-proven technologies and integration knowledge.

US$1 - 2bn
Reported estimated average cost to develop a fuel cell automotive system.
Intelligent Energy and Suzuki Motor Corporation SMILE FC Announce Completion of Ready-to-Scale Fuel Cell Production Line
Two principal focus areas:

- Design for series production at low cost
- Substantial power density superiority
Stationary Power & Combined Heat and Power

• Unreliable base load a feature across many addressable emerging markets for clean, reliable power

• Rapidly growing demand for clean, reliable power in mobile telecommunications, particularly in India

• The number of mobile phone subscribers in India will reach 1.24 billion in 2015

• The number of cell towers will reach over 500,000 by 2015

• 70% of cell towers in India subject to 8 hours or more of outages per day
On-Demand and Backup Power for Telecoms

- Proven in the field
- Lower life cycle costs compared to diesel
- Remote monitoring capability
- Quiet
- Zero emissions
Consumer Electronics

- Fuel cell systems can provide much longer operating life than a conventional battery, in packages of lighter or equal weight per unit of power output.

- With a strong background in system engineering we can develop innovative, modular power systems tailored to our partners’ needs

- Intelligent Energy can provide the experience and know-how to integrate our proprietary fuel cell technology into consumer electronic products
Perspective:
Pathway to Hydrogen Vehicles and Hydrogen Refilling Infrastructure and the UK H2Mobility Programme
Hydrogen increasing in importance: Energy storage and the ‘Intelligent Grid’

Sources of Hydrogen

- Natural gas, biogas, coal, biomass
- By-product from the petrochemical industries
- Renewable generation, storage and ‘buffering’

Uses of Hydrogen

- Industry
- Transport
- Domestic
In order to achieve EU/G8 CO$_2$ reduction goal of 80% by 2050, road transport must:

- Achieve 95% decarbonisation....
- Potentially, zero CO$_2$ for all new vehicles from 2040
Leading to growing forecasts for FCEVs

Light Duty Vehicle Scenario 2050

Passenger Vehicle Sales to 2050

Vehicular Hydrogen Demand to 2020

Pike Research forecasts more than 5,200 hydrogen fuelling stations to be operational worldwide by 2020.
There is no ‘silver bullet’ zero or low carbon future powertrain option: FCEVs address the fundamental shortcomings of BEVs

BEV and FCEV technology well suited to:
Small cars which don’t drive far (today ~ 25% of EU CO2 emissions)

FCEV technology also well suited to:
Medium and larger cars, driving further (today ~ 75% of EU CO2 emissions)
Fuel cell electric vehicles – compelling benefits

Superior vehicle attributes:
- Strong (EV) acceleration
- High levels of refinement
- Low levels of occupant fatigue

Convenient operating experience:
- Full-range capability (elimination of ‘range anxiety’)
- Fast refilling at conventional stations

Low CO₂ emissions:
- Zero CO₂ from vehicle (‘tailpipe’)
- Potentially zero CO₂ ‘well to wheel’ with hydrogen from renewable sources
Developing a rollout strategy for hydrogen transport in the UK
UK H₂Mobility: a joint industry-government project evaluating the potential and developing a rollout strategy for H₂ transport in the UK

**Goal**

- Evaluate the potential for **hydrogen as a transport fuel** and develop a rollout strategy that will contribute towards
- Decarbonising surface transport
- Creating new economic opportunities
- Diversifying energy supply
- Reducing local environmental impacts

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**Companies interviewed in Phase 1A**

- Fuel retailers
- Fleet operators and lease companies
- Valuation companies
- Grid operator

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**UK Government departments**

- Car OEMs

**Hydrogen providers/producers and utilities**

**Technology providers**

**Public-private partnerships**

**Fuel retailers**
Key achievements of Phase 1 of UK H₂Mobility

- Assembled a **comprehensive fact base**, specific to the UK, covering FCEVs, HRS and the means of hydrogen production and distribution

- Gained **novel insights into consumer perceptions** of FCEVs and the factors influencing purchasing decisions through primary market research

- Developed a **roll-out plan for a national network of HRS** and quantified the cost of building the HRS network

- Investigated a broad range of **hydrogen production** methods and quantified, for the first time, the **benefits that hydrogen production by water electrolysis** can have on the broader UK energy system

- Combined all elements into a **roadmap** showing that **hydrogen mobility** can be a **credible solution** to decarbonising road transport in the UK

- Identified the **challenges that must be overcome** in order to deliver the roadmap
The UK H$_2$Mobility analysis provides a long-term vision for a hydrogen rollout strategy for the UK along six dimensions:

1. Consumer perspective
2. Fuel cell electric vehicle (FCEV) demand
3. Hydrogen refuelling station (HRS) network
4. Hydrogen production mix
5. Economics & sustainability
6. Benefits of hydrogen mobility

Now is the right time for FCEVs to be available from 2015. Several international markets have started to develop strategies for the roll-out of hydrogen as transport fuel.
1 The market research identified 7 statistically different consumer segments, 2 of which are likely early adopter groups

<table>
<thead>
<tr>
<th>Segment number</th>
<th>Potential early adopters</th>
<th>Probable late adopters</th>
<th>Probable rejecters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Well-off enthusiasts</td>
<td>High mileage luxury</td>
<td>Single car value</td>
</tr>
<tr>
<td>2</td>
<td>Innovative greens</td>
<td>Cautious pragmatists</td>
<td>Younger sceptics</td>
</tr>
<tr>
<td>3</td>
<td>High mileage luxury</td>
<td>Cautious pragmatists</td>
<td>Uninterested rejecters</td>
</tr>
<tr>
<td>4</td>
<td>Cautious pragmatists</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Probable rejecters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Probable rejecters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Uninterested rejecters</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Attitudes to infrastructure
- **High willingness to drive to find H₂**
- **Medium concern over 1 HRS per city**
- **Strongest willingness to sacrifice convenience**
- **Below average willingness to drive to HRS**
- **Strong concern over 1 HRS**
- **Medium willingness to drive to HRS**
- **Limited willingness to sacrifice convenience**
- **Limited willingness to sacrifice convenience**
- **Will only drive short distance to find H₂**

### Tech attitudes
- **Strong tech enthusiast**
- **Willing to pay for new tech**
- **Wants and might pay for new tech**
- **Low innovativeness**
- **Well informed on car tech**
- **Not interested in new tech**
- **Very low interest in tech**
- **Low interest in new technology**
- **Low interest in technology**

### Green attitudes
- **WTP¹ for green**
- **Tailpipe more important than WTW²**
- **Strongest green attitude**
- **Green hydrogen important**
- **Weak green motivation**
- **Not willing to pay**
- **Slight green, but no sacrifices**
- **Some concern about pollution, but not WTP for green cars**
- **Some concern about pollution, but not WTP**
- **Lowest environmental concern**

### Cost sensitivity
- **Payback not important**
- **WTP for green and new tech**
- **Payback of low importance**
- **WTP for green and new tech**
- **Payback important for new/green tech**
- **Low running costs important**
- **No WTP for green/new tech**
- **Low running costs important**
- **Value buyer**
- **No WTP for green/new tech**
- **No WTP for green/new tech**
- **Capital cost primary factor**

### Proportion in sample
- **~ 10%**
- **~ 40%**
- **~ 50%**

1 WTP = willingness to pay
2 WTW = well-to-wheel
Demand forecast shows that a cumulative FCEV fleet of ~1.6 million FCEVs could be reached by 2030 as ownership costs decline over time.

**FCEV ramp-up**

- Demand projections based on **FCEV price estimates** provided by OEMs through a **Clean Team**
- **First series-produced FCEVs** will come to market in 2015
- **Early phase might require support** in order to increase demand for FCEV when TCO is high and infrastructure low
- **Mass market deployment during 2020s** as competitive TCO is reached

**FCEV car parc (cumulative)**

<table>
<thead>
<tr>
<th>Years</th>
<th>Thousands</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>0</td>
</tr>
<tr>
<td>2020</td>
<td>500</td>
</tr>
<tr>
<td>2025</td>
<td>1,000</td>
</tr>
<tr>
<td>2030</td>
<td>2,000</td>
</tr>
</tbody>
</table>

**FCEV ownership cost premium (illustrative)**

**Annual FCEV sales**

<table>
<thead>
<tr>
<th>Years</th>
<th>Thousands</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>~10</td>
</tr>
<tr>
<td>2020</td>
<td>&gt;100</td>
</tr>
<tr>
<td>2025</td>
<td>&gt;300</td>
</tr>
</tbody>
</table>
HRS deployment will cover metropolitan areas and connecting roads from 2015, with large-scale rollout after 2020.

Seeding of Tier 1 regions\(^1\) – major cities and connecting roads in 2015

- Initial seeding in major population centres
- \(~65\) HRS

Coverage extended to Tier 2 regions and all major roads <2025

- Extend coverage to enable close-to-home refuelling to \(50\%\) of the population and long distance travel
- \(~330\) HRS

Full population coverage by 2030

- Extend close-to-home refuelling to the whole of the UK, including less populated regions
- \(~1,150\) HRS

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1 Defined as most attractive regions for FCEV deployment based on vehicle density and per capita income
The H₂ production mix could provide a 60 - 75% reduction in WTW¹ CO₂ emissions of FCEVs compared to diesel vehicles

**CO₂ emissions of FCEVs**

- The agreed **H₂ production mix** provides CO₂ emissions similar to Plug-in hybrids/range extended EVs
- FCEVs achieve **ultra-low emissions** (< 50g TTW²-equivalent) by 2020
- **Emissions of FCEVs** 60% to 75% lower than a comparable diesel vehicle during 2020s

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1 Well-to-wheel
2 Tank-to-wheel
3 WTW emissions of an average new car in respective year

Source: EEA, SMMT, Low carbon vehicle partnership, UK H₂ Mobility
The production mix includes water electrolysis (WE), steam methane reforming (SMR)

**Production mix**

- **Existing capacities** could provide sufficient H₂ until approx. 2018
- **SMR¹ and WE²** dominate the production mix in the long run
- **On-site water electrolysis** is included in production mix to avoid technology lock-in and reduce distribution costs to remote stations
- This mix can deliver **H₂ at a cost competitive with diesel**
- **Additional production technologies** (e.g. biogas SMR, waste gasification and CCS) could be included if they become technologically viable on large scale

### H₂ production and supply

<table>
<thead>
<tr>
<th>Year</th>
<th>SMR</th>
<th>WE</th>
<th>Existing capacities</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>95</td>
<td>0</td>
<td></td>
<td>95</td>
</tr>
<tr>
<td>2020</td>
<td>49</td>
<td>51</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>2025</td>
<td>50</td>
<td>9</td>
<td></td>
<td>59</td>
</tr>
<tr>
<td>2030</td>
<td>51</td>
<td>2</td>
<td></td>
<td>53</td>
</tr>
</tbody>
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1 Steam Methane Reforming  
2 Water Electrolysis

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¹ Steam Methane Reforming  
² Water Electrolysis
5 Analysis suggests that a financing need of GBP ~ 400mn needs to be covered to establish a HRS infrastructure in the UK

Illustrative free cash flow development from HRS investments and operations

GBP millions

**Key results**

- In short term, HRS likely to be underutilised
- Analysis suggests new hydrogen stations could be profitable from ~2020
- Market-led rollout of stations is possible during 2020s

**Operational break-even in early 2020s:** Revenues cover OPEX but not CAPEX

**Cashflow break-even in mid-late 2020s:** Revenues cover OPEX and CAPEX

Likely low FCEV sales before 2020 present challenge for cost-effective infrastructure rollout in short term

Financing need\(^1\): ~ 400 mn GBP (thereof ~60 mn GBP before 2020)

1 Sum of undiscounted, negative cashflows before cashflow break-even
Hydrogen transport is able to provide several important benefits to the UK

Long-term benefits of hydrogen infrastructure

<table>
<thead>
<tr>
<th>A</th>
<th>CO₂ emissions</th>
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<tbody>
<tr>
<td>▪ FCEV CO₂ emissions ~75% less than equivalent diesel car in 2030</td>
<td></td>
</tr>
<tr>
<td>▪ CO₂ abatement between ~10 mn and ~30 mn tonnes of CO₂/year possible by 2050</td>
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</table>

<table>
<thead>
<tr>
<th>B</th>
<th>Local emissions</th>
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<tbody>
<tr>
<td>▪ FCEVs have no harmful tailpipe emission and could lead to significant health benefits</td>
<td></td>
</tr>
<tr>
<td>▪ Air quality damage costs could be reduced by ~100-200 mn GBP/year in 2050¹</td>
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<table>
<thead>
<tr>
<th>C</th>
<th>Energy security</th>
</tr>
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<tbody>
<tr>
<td>▪ Domestic energy production activities could increase by up to 1.3bn GBP/year by 2030, improving the UK’s balance of payments</td>
<td></td>
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</table>

Wider benefits

- Setting up FCEV and H₂ production in the UK could provide high-skilled jobs and additional value creation
- UK could become international lead market for hydrogen transport if skill base and competitiveness develops
- Hydrogen transport could provide additional benefits to society such as reduced noise levels, reduced health care cost due to reduction of ultrafine particles and reduced cost for cleaning public places from exhaust emissions, etc.

¹ Based on calculations using Defra’s Air Quality Damage Cost Guidance
Phase 2 of UK H₂Mobility is focusing on overcoming the most important barriers and market failures and creating a business case for a UK hydrogen infrastructure

Objectives UK H₂Mobility

Evaluate the potential for **hydrogen as a transport fuel** and develop a **rollout strategy** that will contribute towards

- Decarbonising surface transport
- Creating new economic opportunities
- Diversifying energy supply
- Reducing local environmental impacts

Phase 2

- Developing a **detailed business case** and overarching framework for how the UK H₂Mobility rollout will be implemented
- Defining a joint **risk mitigation and action plan** to overcome initial market hurdles
Appendix
Intelligent Energy reports highest power densities yet for automotive fuel cells

Published on Tuesday 26th March, 2013

London, March 26: Intelligent Energy today announced that its proprietary fuel cell technology is providing leading levels of power output and performance for a number of its automotive customers, with the company’s fuel cell stacks demonstrating continuous volumetric and gravimetric power densities of 3.7 kW/L and 2.5 kW/kg, respectively.

“We believe that our fuel cell stack technology has achieved industry leading power density performance. These interim results are only part way along our technology roadmap and much more is still to come with further improvements in the pipeline”, Intelligent Energy’s Motive Division Managing Director, James Batchelor commented. "Importantly, we deliver these benchmark performance levels using our own patented technology which has been designed for high volume, low-cost manufacturing. We provide our technology to existing clients as they progress towards series production and continue to work with new automotive customers and OEMs under a variety of commercial arrangements” he added.

Intelligent Energy is a global leader in fuel cell design and development, with a range of high performance, compact, cost-effective and scalable technology focused on its target market sectors. In 2012, the company formed a joint venture in Japan with the Suzuki Motor Corporation to manufacture fuel cells for a range of automotive and other sectors. In February of this year, within 12 months of its incorporation, the joint venture, SMILE FC System, announced the completion of the first ready-to-scale production line.

Dr Henri Winand, Chief Executive at Intelligent Energy, said: “Power-dense power sources are critical in a range of applications across our automotive, consumer electronics and stationary power markets. In particular, fuel cell electric vehicles provide one of the most practical and efficient means of reducing road transport carbon emissions, where powerful, yet efficient, power systems are much needed. Developing class-leading technology, designed for series manufacture, offers our customers both reduced time-to-market and lower commercialisation scale-up risks. It clearly demonstrates that our fuel cells are ready for the automotive industry and other mass markets.”

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Intelligent Energy Announces Energy Device Collaboration with Global Telecom

Intelligent Energy’s consumer electronics division selected by Cable & Wireless Communications for energy on the move

27 February 2013, London (UK) — Intelligent Energy, the global power technology company, today announced a collaboration with Cable & Wireless Communications, and in particular its Sure brand. The companies will work together to test personal energy devices powered by Intelligent Energy’s cutting-edge fuel cell technology to power various mobile devices across their market sectors. The companies will commence a user trial of an Intelligent Energy portable power device during the summer of 2013.

Intelligent Energy and Etisalat Announce Energy Device Collaboration

Intelligent Energy’s consumer electronics division selected by telecom, Etisalat for user trial

21 May 2013, London (UK) — Intelligent Energy, the global power technology company, today announced a collaboration with world-leading telecommunications company, Etisalat Nigeria, starting immediately. The companies will work together to test personal energy devices powered by Intelligent Energy’s proven fuel cell technology, with an Etisalat user trial to commence in this quarter. The scope of the Etisalat trial will include in-field testing of a new, cutting-edge solution, based on Intelligent Energy’s clean energy technology with selected customers across various devices.