FuelCellToday
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event report

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Rome's iconic Colosseum (Source: Jonathan Wing)

Rome's spectacular Fontana di Trevi Conference Centre played host to this year's European Fuel Cell Piero Lunghi Conference – the fourth addition in the biennial series. Scientifically focused, the conference ran in three parallel parts: PEMFC materials, design and modelling; SOFC materials, design and modelling; and research grouped across prevalent themes in the wider fuel cell community.

Such themes included: the diverse roles that fuel cells can play in carbon strategies – particularly in the use of molten carbonate fuel cells (MCFC) for carbon capture and storage; managing the costs of early market fuel cell electric vehicle (FCEV) deployment; fuel cells in niche transportation; securing continuing funding for basic and applied research; and the need for education of professionals and the public. Although technical by nature, the above sessions gave a more acute insight into some of the major issues and opportunities the industry faces as well as introducing new issues and opportunities of their own.

This report summarises and explores themes raised in the conference plenaries – *Policies: world roadmaps and new horizons* and *Market: fuel cells and hydrogen, customer outreach and investment returns* – as well as the pertinent insights from the diverse range of parallel sessions the conference offered.

Policies: world roadmaps and new horizons

Europe

The first presentation of the conference came from Bert De Colvenaer, Director of the Fuel Cell and Hydrogen Joint Undertaking (FCH JU) – the public-private partnership between the European Commission, research and industry that supports fuel cell and hydrogen energy technologies in Europe. 43% of the projects evaluated by the JU get funded and De Colvenaer drew attention to a recent project, NEXPEL. A consortium of seven European partners, the project has received a €1.3 million grant from the JU and aims to develop and generate next-generation higher efficiency PEM electrolysers over a three year period to improve the establishment of hydrogen as a renewable energy storage medium. The project's outcomes will also be integrated into a refuelling station model.

With reference to the popular McKinsey *A Portfolio of power-trains for Europe* report, De Colvenaer predicted that the total cost of ownership of a hybrid electric vehicle should level with that of a conventional vehicle by 2020. It will be longer before FCEV costs level and the deployment of a European hydrogen refuelling infrastructure would cost somewhere in the region of €30 billion – a large, but not unobtainable level of investment but one that certainly raises questions of how best to incentivise investment and avoid the perennial chicken and egg conundrum that plagues FCEV commercialisation.

The European Commission funding for the JU comes from the SET (Strategic Energy Technology) Plan under the Seventh Framework Programme (FP7) which runs from 2007 to 2013. The Eighth Framework Programme, Horizon 2020, will determine the future funding of the JU from 2014 to 2020. The Framework Programme has a total budget of €80 billion, but the division of this is yet to be decided. Regardless, De Colvenaer is confident that the JU will receive an equal, if not greater, amount of funding than it has under FP7.

United States

The US Department of Energy's (DoE) Joe Stanford opened by speaking of the challenge of communicating the benefits of fuel cells to stakeholders and the public. It is harder for the average person to see where and how fuel cells fit into the green picture – the technology does not enjoy the same instinctive understanding that wind turbines and solar panels do. As such Stanford advocates that an emphasis on education, particularly for politicians, is needed for a successful future for fuel cells.

On the automotive front, Stanford admits the DoE has leaned focus towards battery electric vehicles, though merely because they can offer immediate benefits – fuel cells are still the preferred future solution. This is a notion that Fuel Cell Today has seen reflected through several parties, including automakers such as Hyundai. In its Fuel Cell Program, the DoE had historically focused on FCEV – undoubtedly the most alluring of fuel cell applications, but has widened its scope and spawned several successes, most notably the emergence of a viable fuel cell forklift market that the DoE stimulated interest in with funding from the 2009 American Recovery and Reinvestment Act (ARRA). ARRA funding removed parts of the first mover concern of materials handling site operators by putting the technology in their hands; with successful demonstrations there is now tangible industrial interest and investment. With the boom in interest, forklift fuel cell manufacturer Plug Power expects to turn a profit within the next year.

In 2011, the cost of PEMFC was approximately $49/kW – very close to the DoE's target and a positive indication of the increasing maturity of the technology. Electrolyser technology has not advanced as rapidly, and indeed has missed some of its DoE targets, so more work must be applied in this field as well as into the further development of regulations, codes and standards to support the new technologies as they reach the market.

There have been worries about continuing cuts to the Fuel Cell Program, but Stanford reassured the audience that activities will continue regardless of budget, in part due to a separate basic energy sciences budget of approximately $35 million. The budget supports ongoing research for breakthroughs and is far more stable than many others; as such technological advancement should continue.

South Korea

Korea is the world's tenth largest energy consumer yet imports 97% of its primary energy – a huge energy security worry and the driver behind the nation's aggressive green energy activities. Seong-Ahn Hong of the Korea Institute of Science and Technology spoke of the launch of the Green Growth Initiative three years ago – 'a new national development paradigm'. Operated by the Presidential Committee on Green Growth – a partnership of 36 civil experts and 14 politicians – the initiative has three objectives: climate change mitigation; new engines for growth; increasing quality of life and showing international leadership.

As part of the initiative a new Renewable Portfolio Standard (RPS) will supersede the nation's feed-in tariff scheme from next year; the RPS commands a move towards renewables with the following stringent goals for percentage of renewables in total energy generation:

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2020
%	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	10

The nation is showing an increasing favourability for fuel cells with sixteen MCFC power plants constructed in the last three years totalling 51.2 MW. Under the RPS fuel cells receive double credit and domestic utility POSCO Power has placed a two year order with US manufacturer FuelCell Energy totalling 140 MW of MCFC, the first 2.8 MW of which shipped in October. POSCO has demonstrated significant adoption of MCFC for prime power plants and is now looking to market a 100 kW system for home use, further capitalising on the benefits fuel cells will receive under the RPS.

Korea is also home to thirteen hydrogen stations and one of the world's most proactive FCEV manufacturers, Hyundai, which plays a central role in Korea's ongoing FCEV demonstrations. The automaker will be producing 1,000 FCEV annually from 2012 to 2014 and 10,000 annually from 2015 with sales starting in its home territory.

Japan

Yokohama National Laboratory's Ken-Ichiro Ota spoke of an ongoing Japanese debate that started six years ago on the future of primary energy production. At present there are three broad contenders: fossil fuels, nuclear energy, and renewable energy. There are limited Japanese resources for fossil fuels and, due to the small size of the islands, no place where CCS (carbon capture and storage) is feasible on a large scale. Nuclear energy has fallen out of favour after the recent Fukushima disaster with concerns of plant safety and waste treatment amongst

stakeholders and the public. One consequence of the disaster has been a stronger drive towards cleaner renewable solutions.

ENE-FARM is a brand created by the Fuel Cell Commercialisation council of Japan (FCCJ) under which several gas utilities and fuel cell manufacturers are jointly marketing fuel cell micro-CHP systems for home use with the support of an ongoing government subsidy. Thousands of units have been installed since the scheme began in 2009, including one at Ota-san's house. The Great East Japan Earthquake caused widespread power disruptions and in its aftermath, there is an increasing desire amongst the Japanese for distributed uninterruptable power supplies. This has led to a surge in interest for ENE-FARM units so strong that the subsidy scheme is struggling to meet demand.

Several major automakers are members of the FCCJ and a 2015 commercialisation date for FCEV was cemented back in January by a memorandum of understanding between Toyota, Nissan, Honda, JX Nippon Oil & Energy Corp., Tokyo Gas and others. The agreement includes the construction of one hundred hydrogen refuelling stations to support the influx of FCEV from 2015 including the development of a hydrogen highway around Tokyo and up to the Kyushu region (home to Osaka and Nagoya) – a distance of approximately 800 km. Japan has marked the decade 2015–2025 as early commercialisation; during this period focus will be given to expanding sales channels and reducing costs of hydrogen infrastructure and fuel through economies of scale and technological advancements.

China

With prime power coming from an ever-expanding series of coal-fired power stations Chinese fuel cell development focuses strongly on transportation – an area of exponential growth as the population continues to urbanise at speed. Despite the republic's reliance on unsustainable fuels for prime power generation there is a strong drive for emissions reduction in transport – 60% of Chinese city pollutants are a result of vehicle emissions.

Huamin Zhang of the Dalian Institute of Chemical Physics (DICP) explained China's three step strategy for 'new energy vehicles':

1. 2006 – Demonstrations of various vehicles for public services
2. 2012 – New energy buses, light-duty hybrid cars, light-duty electric vehicles
3. 2015 – Homogeneous charge compression ignition engine cars, plug-in hybrid electric vehicles and FCEV

This strategy follows a goal in the 2011–2016 governmental five year plan to see one thousand new energy vehicles in at least twenty cities. DICP operates a fuel cell spinout business, Sunrise Power, which has been developing fuel cell stacks for bus demonstrations since 2006, including for buses used during the 2008 Olympics. Fuel Cell Today will be releasing a detailed report on Chinese fuel cell developments early next year.

Market: fuel cells and hydrogen, customer outreach and investor returns

Pierre-Etienne Franc, head of the NEW-IG, opened the session with a weary note that this year's Eurozone debt crisis had taken emphasis away from environmental concerns; these concerns are continuously pertinent and globally we cannot afford to turn our focus for too prolonged a period.

Regardless, volume deployments of fuel cells in various applications have begun. At present there are: approximately 200 hydrogen refuelling stations, 50 fuel cell buses and 300 FCEV worldwide; more than 2,000 fuel cell forklift solutions deployed across the United States; and many thousands of fuel cell micro-CHP units installed in Japan. Franc says technology has now reached 'the valley of death' – the area of first-mover risk between research/demonstration and full commercialisation. The next few years will be critical in determining the success of fuel cells for the foreseeable future.

Franc estimates that €18 billion worth of investment will be needed to reach full commercialisation. Industry, European Commission and member state commitments will be needed to reach the required level of funding and the NEW-IG is working towards subsidisation strategies in a similar vein to how ARRA supported fuel cell forklifts in the US. In most instances consumers don't want to pay a premium for clean technology, something only exacerbated by recent global financial worries.

With the technology now well grounded, research is leaning towards the fuel. As Christian Sattler of FCH JU research grouping N.ERGHY explained, fuel cells are merely transformers and education to outsiders should focus on why the fuel, rather than the technology, is viable.

Sattler also drew attention to the under-representation of hydrogen production and distribution in FP7 as well as prohibitive research funding regulations – he is hoping both will change under Horizon 2020. Continuing research is needed to support a fast and cost-effective market introduction of fuel cell technologies but there also needs to be the room to undertake research that isn't necessarily linked to any end market, as this is the true space for innovation – this is a capacity met by the basic energy sciences fund in the US, but that has no equal in the EU.

Every gigawatt of energy production capacity creates 3,000–6,000 jobs, and installed capacity creates 1,500–3,000 jobs – new energy solutions are beneficial on many fronts. But before large-scale deployment can occur grid parity and market visibility are needed says Alberto Ravagni, chairman of stationary power at the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), a forum for governments to discuss and promote hydrogen and fuel cell technologies.

Ravagni believes, as do many, that stationary applications are where fuel cells will truly excel. The performance of the technology has surpassed expectations; McKinsey has been commissioned to write a report on distributed power generation in a similar vein to its popular *A Portfolio of power-trains for Europe* report that should demonstrate the technology's strength against alternatives. Fuel cells in stationary applications have a key advantage over those in automotive applications: they do not require a new fuel infrastructure to be deployed before they can be used, making them a more affordable and approachable investment.

Educating Europe: HyProfessionals

HyProfessionals is a new two year project between nine partners under the FCH JU. It aims to educate future professionals on fuel cell and hydrogen technologies – a critical step towards widespread acceptance – through the following:

- Identification and mapping of existing programmes in the EU
- Development of specific initiatives, proposals and guidelines for technical training at different levels
- Increasing understanding amongst state and local government representatives
- Open exchanges of experiences, project results, training initiatives, etc
- Encouragement of social change
- Facilitation of access to education and training systems
- Launching of a comprehensive public education campaign about hydrogen economies and fuel cell technologies to overcome public lack of knowledge

A 2009 EU project, FC-HyGuide, has produced a freely available guidance document on making good life cycle assessments (LCA) in order for European researchers and producers to develop a product declaration – a necessary step before commercialising their product. LCA is a technique for assessing the environmental aspects of, and potential impacts associated with, a product. Manufacture, operation and end of life must all be taken into account in the assessment.

Transportation: European developments and applications

Reducing market introduction costs through use of a universal FCEV stack

The CEA (Commissariat à l'energie atomique et aux energies alternatives) is conducting a comprehensive analysis of stack designs to determine the viability of a universal fuel cell stack for use in FCEV during the early market introduction phase.

FCEV currently come at a significant price premium to conventional vehicles, primarily through the cost of the fuel cell stack. Automakers are working to reduce the cost of these vehicles before commercial sales begin in 2015, but tentative prices are still at least a £10,000 premium over conventional models, and often much more.

The CEA project, AUTOSTACK, brings together automakers – Daimler, Volkswagen, Volvo, Fiat – and component suppliers – Solvay, Umicore, Powercell, and more – to gain data from both the top down (automakers) and the bottom up (component suppliers) to develop stack designs. The CEA found that, contrary to common belief, platinum is only a small part of stack cost, as are all other raw materials. The vast majority of cost comes from process: the specific development and manufacturing tools and operations needed for stack production.

If the automotive OEMs were to unify on a stack design and pool manufacturing for early market FCEV entry prices could be decreased dramatically, increasing market capture potential and leading to faster profits for those involved. The lingering question is, would they?

Hydrogen at sea: a fuel cell sailboat

Another CEA project is the sailboat *Zero CO_2*. With a budget of approximately €2 million, the project aims to raise climate change awareness amongst sailors and the Mediterranean population whilst proving the viability of low-carbon technologies at sea.

The boat's electric motor is powered by a combination of a 25 kW hydrogen-fuelled PEMFC of CEA's own design and batteries charged both conventionally and through a small on-board wind turbine and photovoltaic panel; the vessel travels at a speed of four knots. Unfortunately such boats demand local hydrogen production and portside refuelling – this damages their feasibility for near-future use.

Photos: Marie Czamanski

Blue sky thinking: fuel cell aircraft

ENFICA-FC was an EU–funded project for the development of a lightweight aircraft powered by a 20 kW Intelligent Energy PEMFC with a 1.2 kg, 350 bar hydrogen tank. The system was certified by the International Civil Aviation Organisation (ICAO) before use and the plane undertook a total of three flights at (sequentially) two, eleven and forty minute durations. Although largely successful the project has not been awarded extended funding and has now closed. Whilst this is a shame, recreational aviation is a niche market that fuel cells do not necessarily yet suit.

More immediate applications of fuel cells in aviation are in the form of UAV (unmanned aerial vehicle) and motive power for commercial jet landing gear. The former in particular is proving popular and has significant market potential in military surveillance use.

Fuel cell hybrid buses in Brazil

As a developing country, Brazil relies heavily on its public transport as car ownership is still comparatively low. Uniquely, 92% of Brazil's electricity is renewable thanks to expansive wind, hydroelectricity and biomass schemes, but only 26% of its transport fuel is renewable. The combination of these aspects makes Brazil a perfect test bed for fuel cell public transport. A project supported by the World Bank will see from January a demonstration of buses powered by a 120 kW PEMFC hybridised with a 108 kW battery operating on a 44 km Brazilian bus corridor that carries more than six million passengers a month.

Photo: EMTU

Fuel cells for carbon capture and storage

Traditionally power generation leads directly to carbon emissions, turning this on its head is an exciting notion. MCFC can fully separate CO_2 from a fuel stream making it available for sequestration and avoiding any atmospheric carbon emissions. Perugia's FCLAB suggests the use of MCFC at existing cogeneration power plants for instantaneous carbon capture and additional power generation that can be used to power, or partially power, the facility.

One drawback of the solution is that CO_2 content at the cathode, where CO_2 is removed for CCS, is directly linked to cell efficiency. However this is not an issue when using the MCFC as an addition to an existing power plant; at the 1 MW cogeneration plant FCLAB trialled at the MCFC added an additional 26% power to the plant's output.

There are limitations in applying MCFC to existing power plants, particularly as scale increases. For example, researchers at Università degli Studi di Genova developed a way to remove many of the standalone components of an MCFC and have it sit between the open cycle and steam cycle of a natural gas combined cycle (NGCC) power plant taking flue gas from the plant and returning it decarbonised. However, a typical NGCC plant has a nominal output of around 950 MW – requiring an MCFC solution of 150 MW. This is an enormous technical and financial constraint.

Scalability issues aside, there are many power plants at which fuel cell solutions can readily be applied for CCS. Fuel cells can also be used as independent distributed power plants with full CCS. MCFC is the dominant technology in this arena, with utilities such as Korea's POSCO Power leading the way. SOFC also has the potential to outperform conventional power cycles under a variety of fuels.

Fuel cells are ready for commercial exploitation in these stationary CCS applications but there are substantial cost barriers to be overcome before they are feasible for widespread use. Carbon taxes and other rewards for CCS can offset some cost but by no means make the solutions affordable.

Biofuels and the utilisation of waste

The use of biofuel, whether biogas from anaerobic digestion or biowaste at wastewater processing facilities, in MCFC is increasing in popularity; a previous analyst view *Bioenergy and the Hydrogen Economy* also looks at this trend. The use of these biofuels can pose a threat to MCFC in the form of hydrogen sulphide. It is found at a volume of around 0.2% in most biogas feeds and can poison MCFC catalysts. This can be abated through catalyst strengthening and by cleaning of the biogas feed. The Università la sapienza has seen positive results using activated carbons to clean the fuel stream. This does not affect CO_2 or CH_4 so are of no detriment to MCFC performance.

Microbial fuel cells (MFC) have the potential to play important roles in cleansing landfill leachate and in wastewater treatment facilities. As Bristol Robotics Laboratory's Ioannis Ieropoulos explained to EFC, the nitrogen, phosphorous and potassium in urine are traditionally difficult to treat but microbial fuel cells may be used to process them effectively on-site.

40% of the methane in wastewater is lost before it can reach a conventional MCFC; microbial fuel cells can be used directly in the plant to process the wastewater as it arrives. MFC are not as well developed or as large as traditional fuel cell technologies so Ieropoulos suggests an effective solution would be to have MFC followed by a MCFC, thus maximising the waste stream's energy potential.

Fontana di Trevi (Source: Jonathan Wing)

The conference will return to Rome in two years' time under a slightly modified guise: European Fuel Cell and Hydrogen 2013: Technology & Application. It will be interesting to see how the fuel cell and hydrogen landscape changes in that time.

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