



Fuel Cell Today Portable Survey 2008

Dr. Mike Hugh, April 2008



Summary

2007 saw a number of important developments in the portable fuel cell industry. Perhaps most important was the International Civil Aviation Organisation's (ICAO) ruling in January allowing the carriage of fuel cells and a limited number of methanol refuelling cartridges into aircraft cabins. This was followed some months later by the US bringing its equivalent legislation into line with that of the ICAO. One of the main hurdles for early portable fuel cell markets has thus been removed, and although others remain, these are viewed as wholly positive developments by those working in the sector.

Remaining technical challenges for portable fuel cells include increasing the longevity of stacks, the miniaturisation of stack and BoP, increasing power density, and improving the reliability of passive DMFC which are currently favoured by developers of mobile phones.

Though nearer to market than other fuel cell prospects such as cars, the portable fuel cell sector has yet to see the establishment its first mass-fabrication facilities.

However several indicators suggest that the prospect of a portable product being launched on the wider public within the next two years is well within the bounds of possibility.

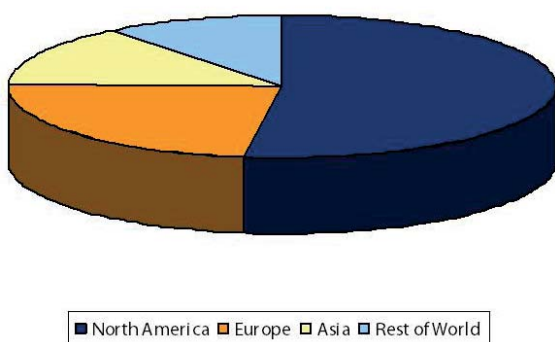
This Survey is a summarised version of a more in-depth report available to FCT's Syndicated Research subscribers, which contains greater depth of analysis and 10-year market development forecasts.

1. Market developments over the last 12 months

Portable fuel cell development by region

The following graph shows the proportions of the number companies involved in portable fuel cell development by geographical region. North America accounts for just over half of all companies involved with the development of fuel cells for portable applications worldwide, leading Europe, and Japan.

Graph 1: Geographical distribution of companies involved with portable development activity in 2007



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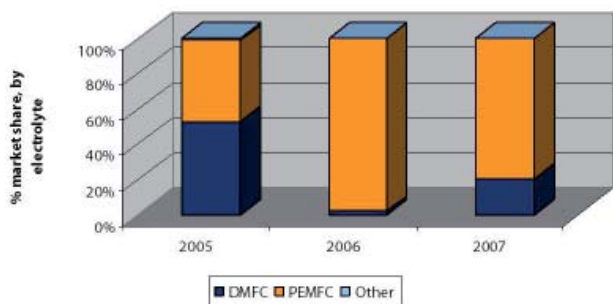
This distribution may partly reflect the wider economic truths of the various regions. For example the North American segment has seen the highest growth, possibly not only due to the availability of military funding (one of the few examples of governmental support for portable fuel cells found anywhere in the world) but also because of the US's traditionally strong provision of high risk venture capital. The growth of new companies in the US contrasts with that of Japan, whose economy (and fuel cell development base) is not only dominated by large corporations but where access to early-stage investment is more limited, representing a formidable barrier to entry for SMEs.

Within Europe, France, Italy and Germany continue to lead the way in terms of number of companies involved whilst the Asia region includes activity from Japan, China, Korea and Taiwan.

Portable fuel cell development by electrolyte

It is worth briefly noting that since the advent of the hugely successful PEMFC 'h-racer' toy car by Horizon Fuel Cell Technologies, more PEMFC portable fuel cells than DMFC have been shipped over the last two years. But the h-racer phenomenon is likely to be anomalous in the long run as far as portable fuel cells are concerned. The great majority of portable fuel cell developers for the mainstream CE markets are focussing on DMFC formats, be they active DMFC (for laptops and other relatively large portable products) or passive (for smaller products such as mobile phones). When one of the major CE OEMs start to retail its first (DMFC) fuel cell product, the sheer numbers associated with these markets will ensure DMFC quickly reassumes its position as the fuel cell type of choice for all but niche portable applications, where PEMFC (including Direct Hydrogen Fuel Cells – see comment by Dr. Charles Stone in Section 3) and SOFC will take some small share of the market.

Graph 2: Relative proportions of portable fuel cell types shipped worldwide, by electrolyte.



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Notable portable fuel cell news stories in 2007/08

The following news stories are selected highlights of developments in the portable fuel cell sector internationally over the last 12 months. This list is non-exhaustive.

- 19th Nov 2007 Fuel cartridges given green light for international air transport
The International Civil Aviation Organisation (ICAO) revises its rules to allow portable fuel cell systems as well as fuel cartridges to be carried on to planes as hand luggage. The guidelines will come into force worldwide by January 2009.
- 18th Nov 2007 Samsung develops fuel cell mobile device which 'runs on water'
Samsung unveil a PDA which produces hydrogen on demand from a metal/water reaction. The device can produce up to 3 W of electricity, and Samsung claim that the cartridge would have to be changed once every five days based on usage of around four hours per day.
- 3rd Oct 2007 Toshiba DMFC media player unveiled
Toshiba unveiled a prototype version of its 'Gigabeat' media payer at the Ceatec exhibition in Japan. The unit can run for 10 hours on 10 ml of methanol, and Toshiba say it will be launched commercially in 2008.
- 6th Mar 2007 MTI MicroFuel Cells receives \$500,000 funding from US Department of Energy
MTI MicroFuel Cells announce that the US Department of Energy (DOE) released \$500,000 of funding in order to develop MTI Micro's 'Mobion' technology platform. With this latest commitment, the DOE brought its total commitment to MTI up to \$1.5m in under a year.
- 11th Jan 2008 Horizon joins with Corgi to develop fuel cell toys
Horizon Fuel Cell Technologies and Corgi International entered into a strategic partnership which will allow Corgi to utilise Horizon's fuel cell background for a range of hydrogen-powered toy cars. This relationship builds on the success of Horizon's h-racer toy car and its manufacturing agreement with the Wah Shing toy company of China.
- 25th Feb 2008 Voller Energy enters offers period
Voller Energy is considered as being in an offer period as defined in the City Code on Takeovers and Mergers following the decision of the company's board to ask Deloitte Corporate Finance to conduct a strategic review as part of an attempt to maximise shareholder value.

2. Market dynamics

This section explores some of the developing market dynamics of the emerging portable fuel cells sector. It is intended to place Section 1 'Market developments' into context.

The nature of development incentives

Portable fuel cells have not benefited from the same level of governmental support as have other applications, such as transport and small stationary. The reason for this is that policy makers do not see portable markets as having the ability to meet wider policy objectives, such as CO₂ reduction, or energy security. As such, in the main part the burden of portable fuel cell development is left entirely to the private sector. Spotting apparently clear market demand for longer run-time in increasingly power-hungry electronic devices, the private sector has duly invested heavily in fuel cells, and it is likely that it will succeed in bringing portable products to market before the fuel cells types that have received government support. An exception to this observation is in the US, where the military continues to fund a number of programmes which call for the development of novel battlefield power sources.

Codes and standard

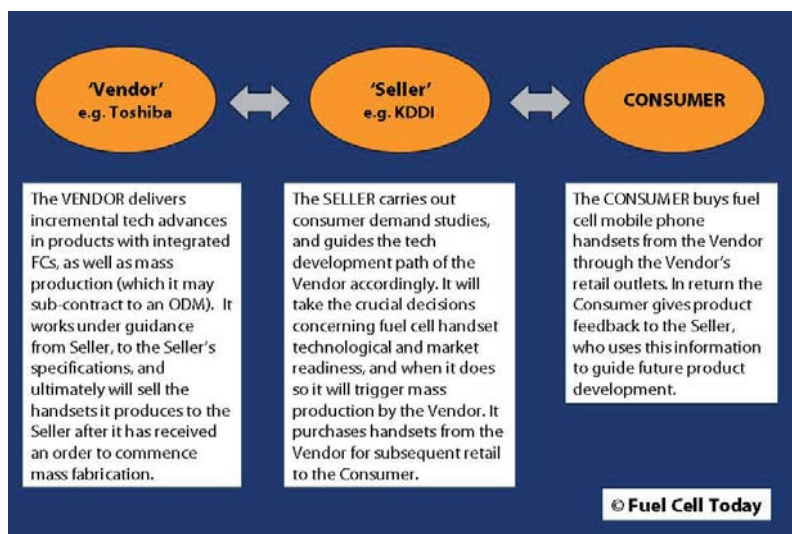
In the field of codes and standards there are essentially two competitions to be won. First is the competition to establish national and international codes (C&S) – where the winner may be able to export C&S internationally. Second, the private sector is involved in a competition to establish a range of industry-standard formats, an area with clear first mover advantages.

Supply chain development

Given the complexity of 'conventional' portable electronic products, especially portable CE products, it is reasonable to assume that the supply chains for portable fuel cells will be correspondingly complex. Indeed, the landscape of potential markets for portable fuel cells is still evolving, and developers have had to adjust their operations as previous market penetration strategies have failed.

An understanding of the wider supply chains for any single product is crucial when speculating when markets might emerge. In the case of mobile phones, it is not actually the developers of fuel cell products that will take the decision to bring fuel cell products to market; this decision rests in the hands of the telecoms companies (or 'sellers') - see Graph 3. So, when considering timetables for market introduction of fuel cell mobile phones, it is as (or more) useful to talk to telecoms companies than it is to talk to technology developers.

Graph 3: Simplified structure of the emerging fuel cell mobile phone supply chain, showing the central importance of the 'Seller'.



3. Guest Comment – Dr. Charles Stone

As part of the 2008 Portable Fuel Cells Survey we are pleased to include a guest comment from Dr. Charles Stone. Dr. Stone is a world renowned expert in PEM fuel cell technology. He began his career with Ballard Power Systems in 1990 and was appointed Vice President of Research and Development in 2002. Dr. Stone left Ballard in March 2007 to start up his own consulting firm (Eon Consultants) in the area of Green Energy.

Fuel Cells Technologies Powering Up Electronic Devices of the Future

"Consumers today are becoming increasingly dissatisfied with the run-time available from even advanced lithium-ion rechargeable batteries for both mobile phone and laptop applications. It is a rarely publicised fact that lithium ion batteries can permanently lose 35% of their energy capacity over 12 months if exposed to 40°C when charged to 100% capacity – the usual state a lithium battery is exposed to in an operating laptop.(1) This insatiable

hunger for increased power and run-times from hand-held and portable electronic devices is a problem that demands a solution, or more likely a set of solutions. On the lithium ion battery side, Panasonic recently announced that they have developed a battery with an almost two-fold increase in energy density, 740 Wh/L, relative to convention lithium ion batteries.(2) While this is a truly impressive achievement, the US Department of Energy's 2010 target is for a fuel cell system of less than 50 W to demonstrate an energy density of 1000 Wh/L as a power source for consumer electronics.(3)

As researchers strive for alternatives to battery technology, the most advanced opportunity is surely direct methanol fuel cells (DMFC). There are almost twenty companies,(4) small and large, that are heavily promoting the potential of this technology to challenge batteries as the future power source in hand-held and portable electronic devices. Yet today, beyond some niche military applications, the technology seems to be stuck in the demonstration program phase. The key challenges most often cited for DMFC are in the areas of cost and power density, associated with such issues as system complexity, relatively high catalyst loadings, fuel utilization due to methanol permeating across the membrane, and the fact that carbon dioxide and small amounts of methanol are emitted from the fuel cells.(5) While recognizing that these issues require further resolution, significant advances have been made by companies like MTI Micro Fuel Cells, Toshiba, Hitachi, LG Chem and Neah Power Systems and others which undoubtedly bring the technology closer to commercialization. In a February 2007 announcement by PolyFuel Inc., a developer of advanced membranes for DMFC, they confirmed that commercialization of battery replacement DMFC products should begin in 2008/9.(6) In a more recent announcement in September 2007, the same company released information on an in-house DMFC stack, built with PolyFuel's proprietary hydrocarbon membrane, which demonstrated power density of 500 W/L.(7)

Although not often discussed as a power source for electronic devices, an alternative fuel cell technology to DMFC is direct hydrogen fuel cells (DHFC). Recent advances in both metal hydride and chemical hydride storage, as well as advances in DHFC stack technology have elevated the potential of this technology to also compete as an alternative to lithium ion batteries. At the spearhead of this development is Angstrom Power Inc., a private company located in North Vancouver, Canada. Angstrom has already developed demonstration products with their micro DHFC technology and has developed key strategic relationships with Motorola and Heliocentris to help bring its technology to market. Angstrom and others are also working closely with regulatory authorities to see hydrogen approved as a fuel for on-board use in airplanes, hopefully as early as 2009.(8) On the chemical hydride storage side, Millennium Cell Inc., a NASDAQ-listed company in Eatontown, New Jersey is the clear leader with direct application of their hydrogen storage technology in hydrogen batteries.(9) More recently, a private company in Australia, Oreion, announced that it is actively evaluating DHFC, amongst other fuel cell related technologies, developed by Australia's world renowned Commonwealth Scientific and Industrial Research Organisation (CSIRO).(10) It appears that the longer DMFC technology takes to find true commercial application in micro power devices, the more interest is being generated in DHFC as an alternative technology. Given the market opportunity for high energy density power devices, with the top three Chinese manufacturer alone produced more than 600 million lithium ion batteries last year,(11) there will be lots of room for both fuel cell technologies to capture significant value.

Given the substantial financial investments already expended on DMFC and its near commercial status, why should the market invest further in DHFC technology? DHFC possesses a number of advantages over DMFC that secure its role as a viable fuel cell alternative as a battery replacement technology. Most fundamentally, due to the near two orders of magnitude higher kinetics of hydrogen oxidation over methanol oxidation, the energy conversion efficiency is higher and the use of precious metal catalysts is much lower,(12) leading to higher power density, lower cost devices. Further, DHFCs are capable of near complete fuel utilization with essentially passive operation, obviating the need for micro mechanics and sensors which add cost, volume and complexity which could in turn negatively impact durability and reliability. However, it would be naive to assume that the use of hydrogen as a fuel in DHFC is fully solved, both on a technical as well as an emotive level.

Micro fuel cells, whether based on DMFC or DHFC are the best alternative to the lithium battery technologies which many believe have reached the limit of their ability to provide the required power and run-time to the new generation of electronic devices. The key advantage of fuel cells is that, unlike batteries, they can provide essentially continuous power as long as a fuel source is provided. Here, finally, is a fuel cell application with real customer pull, as opposed to technology push - a necessary and valuable driver for OEM and consumer adoption.

From an investment perspective, micro fuel cell technologies offer substantial operational advantages to existing technology at a competitive price and within the required parameters for durability. The remaining issues of fuel storage and supply are more of a regulatory issue than a technology issue. Consumer demand will be the final determinant that ensures the success and acceptance of both DMFC and DHFC technologies as competitive alternatives to batteries."

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4. Company Profiles

In this section we focus on a small number of fuel cell developers that have seen noteworthy developments over the past 12 months. This list is non-exhaustive.

Name: Antig

Technology: DMFC

Taiwan-based Antig have developed a number of new systems solutions products over the past year, including the 5W 'Blade', the 25W 'Cube', and the 50W 'Brick'. This is a new line of attack for them – they previously focused on stacks (which they still do – ranging from 3W to 50W). At the core of these systems is Antig's H2PowerChip, building on an innovative architecture that leverages printed circuit board (PCB) technologies. Antig sells their stacks to system makers, who then build their own power systems which they sell directly to end users or other companies. Antig also produces so-called 'white box' solutions, ready made fuel cell systems to companies looking to market the systems under their own brand. Lastly, Antig provides stack and system customisation services to companies looking for a specific type of fuel cell solution. In April 2008, Antig announced it had received Underwriters Laboratories (UL) approval for its H2PowerChip Stack. Antig claims its H2PowerChip Stack is the first of its kind to receive UL certification covering the use of methanol based micro fuel cells for use in portable electronic equipment.



Name: CMR Fuel Cells

Technology: DMFC

CMR Fuel Cells is a UK-based developer of high-power density fuel cell stacks for portable electronics applications, focusing on DMFCs. CMR is developing low-cost, high power density DMFC stacks for longer-run-time portable power applications such as notebooks and off-grid chargers. CMR has a technology portfolio offering conventional stacks as well as CMR's patented mixed-reactant, flow-through architecture.

In July 2007 CMR announced that it had entered into a non-exclusive joint development agreement (JDA) with Samsung SDI, allowing the two firms to work together in the manufacturing of a DMFC system demonstrator. CMR also entered into a non-exclusive collaboration with Xaar and Solvay to jointly develop a single-step production process for the mass-manufacture of entire fuel cell stacks. CMR exhibited a working DMFC system at the FC Expo in Tokyo in February 2008. In March, CMR announced that it had entered into a Joint Collaboration Agreement with Acta to accelerate development of alkaline membrane fuel cells. The Agreement will initially coordinate the activity of the two companies and is expected to lead to further joint development activities in which Acta catalysts and products would be engineered into CMR stacks.



Name: Horizon Fuel Cell Technologies

Technology: PEMFC

Horizon are a developer of small PEMFC systems, registered in Singapore but based in Shanghai, China. The company had a commercial hit with its 'h-racer' fuel cell toy car and miniature hydrogen filling station, and have since teamed up with the Wah Shing toy company of China, to which they will sell the fuel cell systems (Wah Shing will integrate them into the toy car's body). In January 2008, Horizon announced another strategic partnership, this time with Corgi International, to develop and market a new PEMFC toy car. Horizon have developed their product range, and presented their new 'HydroPak' portable power generator in January 2008, which delivers 25W continuous power and 50W peak. This is a water-activated cartridge system which makes use of both Horizon's fuel cells and Millennium Cell's hydrogen on demand storage technology. The retail price of the system is \$400, with the disposable cartridges - which can provide enough energy to recharge the average notebook computer eight to ten times - costing \$20 each. Horizon has also been involved in two consortia developing high performance unmanned aerial vehicles (UAVs).

**Name: IdaTech**

Technology: PEMFC

Small stationary and portable PEMFC developer IdaTech has enjoyed a particularly eventful twelve months. The highlight was the successful flotation of the company on London's Alternate Investment Market (AIM) in August 2007. Other noteworthy events were the award of a second contract from the U.S. Army's Communications Electronics Research Development and Engineering Center, worth \$2.55 million, to further develop its 3 kW tactical fuel cell generator using jet and diesel fuel; the realisation of distribution deals with three companies in Latin America and Southeast Asia; the development of a large-scale hydrogen purification system with Japanese partners, following the signing of a multi-year contract; and the construction of a new production facility in Tijuana, Mexico, which has a capacity of 3,000 units per year (note: not all of this capacity will be used for the production of portable fuel cells; IdaTech also make a range of larger stationary fuel cells aimed at the telecommunications and back-up power markets).

Name: Jadoo Power Systems

Technology: PEMFC

Jadoo Power Systems' N-Gen Fuel Cell Power Unit was named 'product of the year' by an Electronic Products magazine in January 2007. In March, it was awarded a joint contract with Millennium Cell by the US Air Force to develop a fuel cell-based power system designed for use in aeromedical evacuation flights. In August 2007, the company announced that Velocity Venture Capital had acquired a stake in it. While the exact size of the investment was not reported, it is understood to be the largest ever made by Velocity, which normally invests between \$100,000 (£50,750) and \$1 million (£507,500) into firms. The funding will be used by Jadoo to increase production. Also in August, Jadoo co-founder and CEO Larry Bawden left the company (though he remains chairman of the company's directors), and Leonard Devanna has assumed the post, following a brief spell by interim CEO Lee Arikara.

Name: Millennium Cell

Technology: Hydrogen on Demand

New Jersey-based Millennium Cell continued to develop its 'Hydrogen on Demand' (HoD) technology. Perhaps the most significant development of the past year has been a tie-up with Horizon Fuel Cell Technologies (including an equity exchange in the region of \$5m) which has resulted in the joint development of the HydroPak portable power system. Other developments include: the securing of funding from the National Centre for Manufacturing Sciences (NCMS), as well as a contract with the U.S. Air Force Research Laboratory (AFRL) to extend the capabilities and performance of Millennium's HoD fuel cartridges for current and future soldier power systems; the formation of a relationship with Kuchera Defense Systems (KDS) with a view to integrating Millennium Cell's fuel cell technology into KDS systems; the establishment of a manufacturing facility for its Hydrogen on Demand fuel cartridges developed in collaboration with the Dow Chemical Company and the Edison Welding Institute; and the completion of a full acquisition of Gecko Energy Technologies through a merger with one of its subsidiaries.

Name: MTI MicroFuel Cells

Technology: DMFC

In March 2007 it was reported by Reuters that MTI was to suspend its military fuel cell product programme due to a lack of funding and sales opportunities. In addition, MTI would cut a full 20 per cent of its fuel cell business workforce and eliminate the unit's post of chief operating officer, thereby allowing the company to commit more resources to its consumer fuel cell programme. However this news was followed in April 2007 by the US Department of Energy (DoE) reinstating funding for MTI that formed part of a cost-shared programme temporarily suspended in 2006. Other highlights include: the formation of a partnership with Trident Systems (makers of military ground sensors) as part of an attempt to push MTI Micro's consumer market platform into low-power military markets; the establishment of a new pilot production line at the company's Albany headquarters; notification from the NASDAQ stock exchange that the company had failed to comply with the minimum bid price rule; and the unveiling of a new Mobion-powered digital camera grip and cell phone concept at the FC Expo in Tokyo in February 2008.

Name: Neah Power Systems

Technology: DMFC

Neah Power Systems develops micro fuel cells for lap top computers, military and civilian portable electronic communications equipment. The company has undertaken initial testing of the fuel cell stack architecture that is targeted for inclusion in its fuel cell prototype development programme. In 2007, the company announced that it was to have its shares of common stock quoted on the OTC Bulletin Board (OTCBB), after receiving a notice of approval for trading. In other news, Neah agreed a \$1.55m bridge loan from six institutional investors to help secure its debt; Dr. Buzz Aldrin joined the Neah Power board of directors; two retired US Marines with experience of military research, development and acquisition joined the strategic advisory board; and Dr Gerard C D' Couto was appointed as the new CEO.

Name: Polyfuel

Technology: DMFC

In April 2007, portable membrane developer Polyfuel was issued two broad patents by the US Patent and Trademark Office for what is described as 'fundamental fuel cell technology'. The two patents related to the chemistry behind PolyFuel's hydrocarbon-based polymer fuel cell membranes. In other news, Polyfuel received \$2 million (£1.01 million) in funding from the US Department of Energy (DOE), which formed part of an existing \$3 million (£1.52 million), three-year contract announced in late 2004 to facilitate the development of fuel cell power supplies for mobile phones but which was suspended in late 2006 due to a tightening of the DOE budget. Other significant developments include: the award in October 2007 of \$2m over two years by the US National Institute of Standards and Technology (NIST) to develop a new, ultra-low crossover membrane for portable fuel cells; the accomplishment of fourth of the company's five step roadmap to the production of a fully functioning laptop PC power module, relating to water management.

Name: SFC Smart Fuel Cell

Technology: DMFC

SFC Smart Fuel Cell reported an increase in sales of more than 100 per cent over the past 12 months. The German company, which provides mobile power solutions based on fuel cell technologies, saw sales increase to Euros 14.3m (£10.7 million) over 2007, in comparison to the 2006 total of Euros 7m (£5.24m). The increase in sales was driven largely by a solid uptake of the company's EFOY fuel cell systems, with 29 motor home manufacturers now having adopted the technology. In addition, the company was also awarded a number of new development contracts with German and US defence organisations for its Power Manager portable power systems. The company has received several orders from Europe in November and December 2007 for 1,100 EFOY fuel cells in total. Of these, 300 fuel cells were delivered in Q4 of 2007, 800 fuel cell systems will be relevant to 2008 sales. The total value of these major orders amounts to approximately Euros 1.8m.

Name: Toshiba

Technology: DMFC

Japanese electronics giant Toshiba continues its development of DMFC portable consumer electronic products. In February 2007 the company unveiled a headphone-style prototype which featured a DMFC and methanol fuel tank built in to one of the ear-phones which, according to Toshiba, could achieve continuous music playback for over ten hours on five ml of methanol. In October, Toshiba displayed a DMFC version of its 'Gigabeat' media unit (see picture on the cover page of this Survey) at the Ceatec electronics exhibition in Tokyo. Toshiba claim the product can run for 10 hours on 10 ml of methanol, making it more efficient than a conventional battery of a similar size. Furthermore, they say that the prototype version shown at Ceatec is not far from the planned commercial version, which is due to be launched in 2008. Toshiba have also spent considerable efforts designing a methanol refueling flask which they say will be compatible with all of their planned portable devices, so the same methanol flask could be used to refuel DMFC laptops, mobile phones, media units etc.

About the author

Dr. Mike Hugh works as a Senior Analyst, Asia, for Fuel Cell Today. His main areas of interest are fuel cell markets in the Far East, and fuel cell companies as investment propositions for the financial sector. Mike can be contacted at mikehugh@fuelcelltoday.com.

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