FuelCellToday
The leading authority on fuel cells

The Fuel Cell Industry Review 2013

ACKNOWLEDGEMENTS

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The Fuel Cell Today Industry Review 2013 is based for the most part on information available up to July 2013.

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GLOSSARY

AFC – Alkaline Fuel Cell.
APFCT – Asia Pacific Fuel Cell Technology (Taiwan).
APU – Auxiliary Power Unit.
ARRA – American Recovery and Reinvestment Act.
Bar – The bar is a unit of pressure defined in SI units as 100 kilopascals.
CARB – California Air Resources Board.
CE – Conformité Européenne.
CHIC – Clean Hydrogen In European Cities.
CHP – Combined Heat and Power.
DMFC – Direct Methanol Fuel Cell.
DOE – Department of Energy (USA).
EU – European Union.
FCEV – Fuel Cell Electric Vehicle.
FCE – FuelCell Energy (USA).
FCH JU – Fuel Cells and Hydrogen Joint Undertaking (Europe).
HRS – Hydrogen Refuelling Station.
HT PEMFC – High Temperature Proton Exchange Membrane Fuel Cell.
kW – Kilowatt.
LPG – Liquefied Petroleum Gas.
MEA – Membrane Electrode Assembly.
MCFC – Molten Carbonate Fuel Cell.
MHV – Materials Handling Vehicles.
MoU – Memorandum of Understanding.
MW – Megawatt.
OEM – Original Equipment Manufacturer.
PAFC – Phosphoric Acid Fuel Cell.
PEMFC – Proton Exchange Membrane Fuel Cell.
Recovery Act – American Recovery and Reinvestment Act.
RoW – Rest of the World.
SGIP – Self Generation Incentive Program (California).
SOFC – Solid Oxide Fuel Cell.
UPS – Uninterruptible Power Supply.
USB – Universal Serial Bus.
W – Watt.

September 2013

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Executive Summary

Overall fuel cell system shipments (excluding toys and education kits) in 2012 were 45,700 – growing by 86% compared to 2011, again led by increases in the stationary sector. Annual megawatts shipped exceeded 150 MW for the first time in 2012, reaching a total of 166.7 MW.

Shipments of fuel cell systems for stationary power continued to grow from 2011 to 2012, over all categories. Our revised full-year data for 2012 put systems shipped at over 24,100 units and approaching 125 MW, increases of 50% and 53% respectively over 2011.

Transport system shipments recovered from a disappointing year in 2011 to reach 2,700 units in 2012. Increases were seen in all categories including materials handling, light duty vehicles, buses and aerospace.

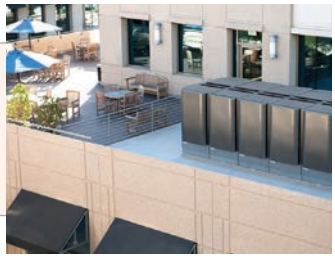
Portable system shipments almost tripled between 2011 and 2012, growing by 174% to reach 18,900 units. A minor sales decline in the APU sector for the second year running was more than offset by significant increases in small and micro fuel cell systems.

27 new hydrogen refuelling stations were opened worldwide in 2012, bringing the total number of stations in operation to 208. The stations are located in Europe (80), North America (76), Asia (49) and the Rest of the World (3).

Regionally, Asia continues to dominate the fuel cell industry in terms of system shipments with 28,000 in 2012 or 61% of the global market. Asia also overtook North America to lead the 2012 megawatt count with 86.1 MW, or 52% of the total; North America now follows second with 37%.

By electrolyte, system shipments in 2012 were dominated by PEMFC (88%), which is used in the widest range of markets globally. In terms of megawatts, MCFC has grown to rival PEMFC through its use in large prime power installations; both exceeded 60 MW in 2012.

In 2013 we forecast that annual shipments of fuel cell systems will increase by 46% to reach a total of over 66,800 for the full year. Annual megawatts shipped are expected to grow by 29%, to reach 215.3 MW. The bulk of this increase is expected from the stationary sector.



The bulk of the growth in system shipments will also be in the stationary sector, with shipments expected to more than double year-on-year. The widespread commercial release of fuel cell chargers for consumer electronics we expected last year did not come to fruition.

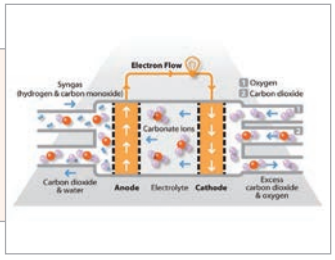
Growth in small stationary fuel cell systems, particularly from the Ene-Farm scheme in Japan, is expected in 2013. Numerous deployments of large stationary prime power plants in South Korea are expected to significantly boost the annual megawatt figure.

We anticipate that transport shipments will decrease marginally in 2013, with fewer fuel cell vehicle, bus and niche transport shipments. However the materials handling vehicle sector continues to thrive, now focusing on airports and ports for its next phase of deployments.

Hydrogen refuelling stations will continue to be added in 2013 as a number of regions prepare for the commercial release of fuel cell electric vehicles in 2015. Countries in Europe, North America and Asia have all launched hydrogen infrastructure programmes in 2012 and 2013 to facilitate this.

The number of systems shipped in 2013 is forecast to increase in North America and Asia, with Asia accounting for the bulk (76%) of these units. Annual megawatts shipped are also expected to increase in these two regions, with Europe remaining flat year-on-year.

PEMFC will remain the dominant electrolyte (88%) in system shipments in 2013 but growth will also be seen in SOFC through increases in stationary power applications. MCFC is expected to overtake PEMFC in 2013 for the first time in terms of annual megawatts shipped with 43% of the annual total.



Introduction

Overview

Fuel Cell Today is the leading source of information and analysis covering the global market for fuel cells. The Fuel Cell Industry Review 2013 is the third edition of our annual publication, which presents a global summary of developments in the fuel cell industry during the past four years, a forecast for the current year and an outlook for the future.

The Current State of the Industry chapter covers developments during 2012 and the first half of 2013, discussing each sub-application in turn, followed by regional developments and the latest update for each main fuel cell type. As discussed in this chapter, fuel cells are an extremely versatile technology, with systems ranging from single watts up to megawatts – a million times larger. For this reason we report both the number of systems shipped and the megawatts they generate. Viewing this information together for each of the market sectors provides the best view of the industry.

The Current State of the Industry also contains a special feature analysing the influence of California's Self Generation Incentive Program (SGIP). SGIP has been in operation since 2001 and has provided financial support for a range of stationary fuel cell installations since 2002.

The Outlook chapter discusses our expectations for the full year 2013 and also includes commentary for each of the three main applications covering high profile global developments taking place in the next three to five years.

Tables of data can be found at the back of this Review, including historical information dating back to 2009. Data are presented for each year in terms of annual system shipments and the sum total of those systems in megawatts, both divided by application, region and fuel cell type as described in the section below.

Fuel Cell Applications and Technologies

Fuel Cell Today categorises the use of fuel cells into three broad areas, defined as follows:

Application Type	Portable	Stationary	Transport
Definition	Units that are built into, or charge up, products that are designed to be moved, including auxiliary power units (APU)	Units that provide electricity (and sometimes heat) but are not designed to be moved	Units that provide propulsive power or range extension to a vehicle
Typical power range	5 W to 20 kW	0.5 kW to 400 kW	1 kW to 100 kW
Typical technology	PEMFC DMFC	MCFC PAFC PEMFC SOFC	PEMFC DMFC
Examples	- Non-motive APU (campervans, boats, lighting) - Military applications (portable soldier-borne power, skid-mounted generators) - Portable products (torches, battery chargers), small personal electronics (mp3 players, cameras)	- Large stationary combined heat and power (CHP) - Small stationary micro-CHP - Uninterruptible power supplies (UPS)	- Materials handling vehicles - Fuel cell electric vehicles (FCEV) - Trucks and buses

Portable fuel cells encompass those designed to be moved, including auxiliary power units (APU);

Stationary power fuel cells are units designed to provide power to a fixed location;

Transport fuel cells provide either primary propulsion or range-extending capability for vehicles.

Fuel Cell Today also considers fuel and infrastructure, relating to the production, storage and distribution of fuels for fuel cells. Each of these topics is discussed in more detail in the Current State of the Industry chapter.

Shipments by electrolyte refer to the six main fuel cell technology types: proton exchange membrane fuel cells (PEMFC), direct methanol fuel cells (DMFC), phosphoric acid fuel cells (PAFC), molten carbonate fuel cells (MCFC), solid oxide fuel cells (SOFC) and alkaline fuel cells (AFC). High temperature PEMFC and low temperature PEMFC are shown together as PEMFC.

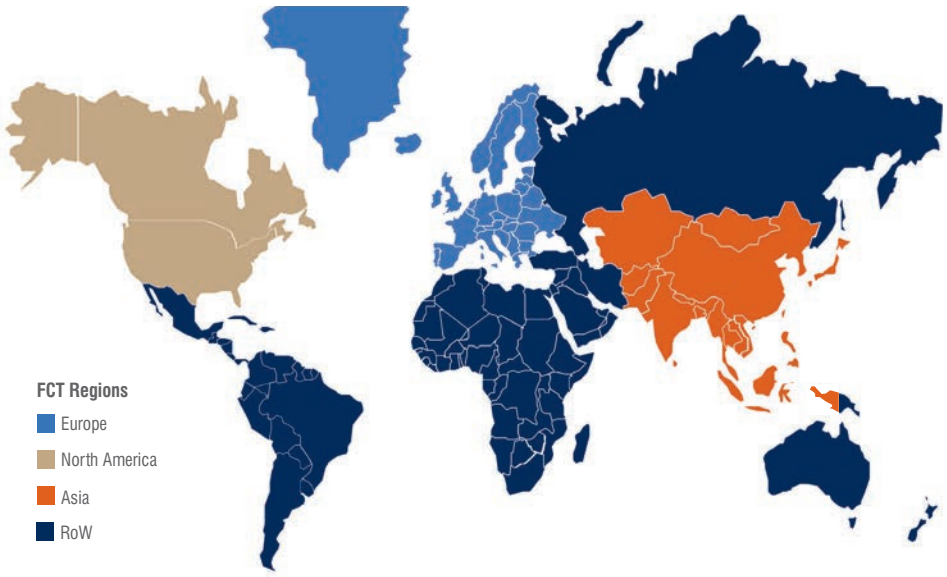
For an explanation of the six main types of fuel cell available on the market today, including their advantages and disadvantages, visit our website (www.fuelcelltoday.com).

Geographical Regions

Fuel Cell Today identifies four main geographical regions: Asia, Europe, North America and the Rest of the World (RoW).

Data Reporting

Shipments are reported by numbers of units (systems) and by total megawatts shipped annually. We report shipments from the final manufacturer, usually the system integrator. These finished systems are then shipped to the final region of adoption, used in our shipment by region classification.



We do not include data for toys and educational kits from the portable sector in order to highlight growth in industrial fuel cell use; there is still a commentary on this market in the chapter on portable fuel cells, but shipment figures now reflect end-uses of fuel cells generating electricity for a specific purpose. The overall dataset has also been updated in the light of new information and full year 2012 data. The data presented here may differ from those previously published by Fuel Cell Today.

The data presented here are based on interviews between Fuel Cell Today and key industry players, publicly available sources such as company statements, press releases or stock market filings, and planned demonstration programmes by companies and governments. Shipment numbers are rounded to the nearest 100 units and megawatt (MW) data to the nearest 0.1 MW. Where power ratings are quoted, these refer to electrical output unless stated otherwise. Our 2013 figures are a forecast for the full year.

Current State of the Industry

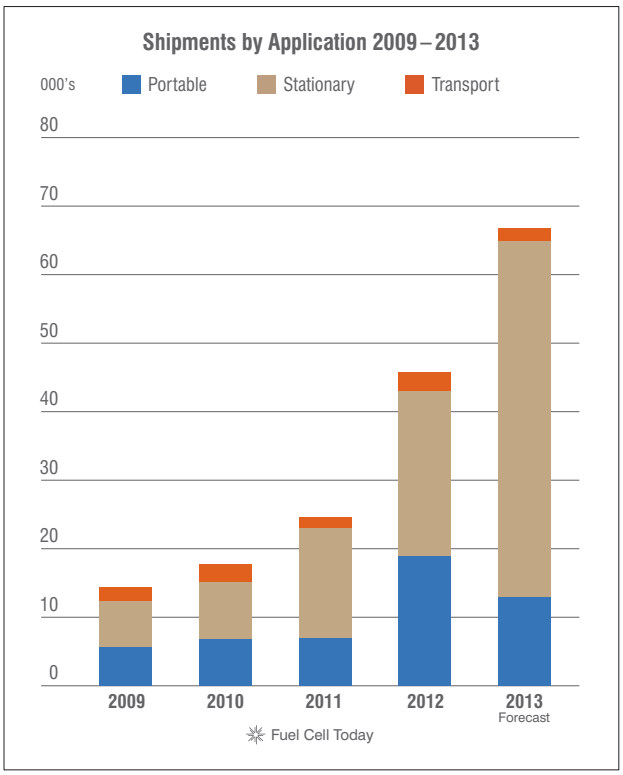
Introduction

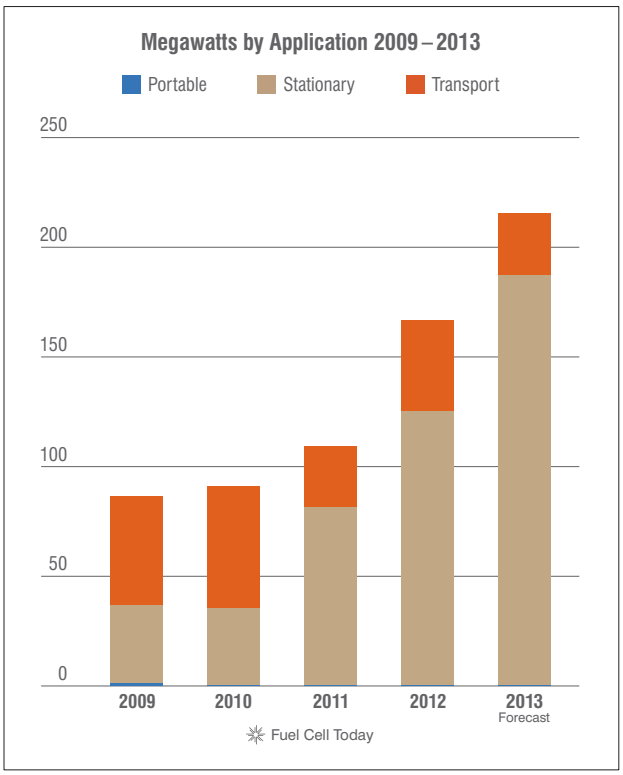
Shipments of fuel cell systems in 2012 almost doubled versus 2011 to reach a total of 45,700 units

Fuel cells are becoming well established in a number of markets where they are now recognised as a better technology option than conventional internal combustion engine generators or batteries. As such, shipments of fuel cell systems in 2012 continued to grow, almost doubling versus the previous year to reach a total of 45,700 units. The first half of 2013 has continued the momentum in new orders for fuel cell systems and we expect this to continue throughout the year with 2013 again showing growth for the industry, this time of 46%, with shipments approaching 67,000 units.

Last year our expectations for the full year of 2012 included a significant increase in the shipment of portable fuel cell systems aimed at the consumer electronics market. While several of these systems were successfully launched during the year, a number of setbacks were also experienced which meant that overall around 30,000 fewer systems were shipped than we had anticipated. More detail on the portable sector's performance can be found on page 8.

Despite this shortfall in expectations from the portable sector, continued growth in unit shipments of fuel cells for transportation and a significant increase in unit shipments of stationary fuel cells led to an increase overall. The stationary sector is by far the stand-out performer for fuel cell technology, finding application across all scales: from small-scale grid-connected micro combined heat and power units for residential use, to off-grid backup power systems providing uninterruptible power supplies to critical infrastructure, to prime power for buildings and even to megawatt-scale installations designed as grid-connected power stations.





In terms of megawatts shipped, the stationary sector continued to lead the fuel cell industry in 2012 thanks to the large size of individual units. In our 2012 Industry Review we forecast that the total megawatts shipped for the full year of 2012 would reach 175.8 MW; with only a small number of projects cancelled that significantly affected the total, the industry ended the year within 95% of that estimate, with 166.7 MW shipped. Further growth in megawatts shipped by the stationary sector is expected through 2013 and boosts our forecast for the year by 30%, with the industry as a whole exceeding 215 MW.

Asia has been the dominant region adopting fuel cell technology during the past five years,

Regionally, Asia has been the dominant adopter of fuel cell technology during the past five years, and this dominance has grown each year – 61% of units shipped in 2012 went to the region. This is not expected to change in 2013; in fact, we expect Asia's dominance to increase further, exceeding 75% of shipments for the full year. In terms of megawatts, the dominance is not so pronounced thanks to the sizeable market for large stationary fuel cells in North America. Nevertheless, Asia still accounted for 52% of megawatts shipped in 2012, and our expectations are for this to grow to 57% in 2013.

PEM fuel cell technology continues to prove the most popular type of fuel cell with regards to unit shipments. This can be attributed to its wide application across all applications, unlike other fuel cell types, and its suitability for use at both small and large scales. In terms of megawatts the picture is distributed more evenly between PEMFC, MCFC and SOFC. The contribution from the latter two is thanks to their use in the stationary sector for large-scale prime power deployments.

PEM fuel cell technology is the most popular type with regards to unit shipments

Interest in fuel cell technology has never been stronger – in the last year several high-level partnerships were forged, particularly in the automotive sector, and significant technology acquisitions took place. The fuel cell industry continues to consolidate as it progresses from an investment-led technology industry to a market-led commercial industry. We saw several companies cease trading during the past year, but in a number of instances other businesses stepped in to acquire technology assets and strengthen their own positions within the industry. Mergers and acquisitions (M&A) are a positive indicator of an industry streamlining itself for success with successful technologies thriving, companies improving their technology portfolios and less feasible ideas being discarded. We expect to see an increasing amount of M&A activity in the future.

We are witnessing the beginning of an extremely exciting time for fuel cell and hydrogen technologies, driven primarily by three forces: the recognition of hydrogen as an attractive and important energy storage platform by energy utilities; the interest of major global telecoms in fuel cell backup power; and the commercialisation of fuel cell electric vehicles (FCEV) by the world's major automakers. With an increasing number of truly global companies utilising and investing in fuel cell technology and with the supply chain improvements and technology recognition that will come with the mass-manufacture of passenger vehicles, the fuel cell industry is becoming increasingly well-aligned for global success.

The following sections of this chapter look at the year's developments in each major application (portable, stationary, and transport), world region and fuel cell technology type, as well as an overview of developments in fuel and infrastructure and a special feature on the Californian Self-Generation Incentive Program.

Developments by Application

Portable

In our 2012 Industry Review we had high expectations for significant growth in shipments for portable fuel cells in 2012 led by the anticipated launch of three fuel cell chargers for consumer electronics. In the end, two of those three systems (by myFC and Aquafairy) failed to launch as planned and while the third, by Horizon Fuel Cells, did reach the consumer market, adoption was significantly lower than expected. As such we have revised our final full-year 2012 figure for fuel cell shipments down by around 30,000 units, to 18,900 units shipped. This is still an increase of 174% on 2011 and reflects the potential in this sector. Horizon and myFC are continuing their efforts to commercialise their systems in 2013, but Aquafairy has changed its focus to developing fuel cells for emergency backup power instead, so is no longer concentrating on the consumer electronics sector. We expect continued interest in portable fuel cells for consumer electronics in 2013, but at a slightly reduced level than before as the technology establishes itself against competing batteries. As such, unit shipments are forecast to end the year slightly lower than in 2012, at around 13,000 units.

Our final full-year 2012 figure for portable fuel cell shipments is around 30,000 units lower than we forecast last year

In terms of megawatts, the figure for portable fuel cells is small in comparison to other applications, due to the small size of the fuel cell units. Our data for megawatts shipped is rounded to the nearest 100 kW and the full year for 2012 ended 25% up on 2011 at 0.5 MW. The decreased shipment levels expected for 2013 mean this figure drops to 0.3 MW in our forecast.

Educational Fuel Cells and Toys

Fuel cells for educational purposes continue to sell well and new products have launched that refine the concept. Despite Fuel Cell Today not including toys and educational kits in our dataset, they form an important source of cash for many companies and educate future engineers and scientists about the concept.

Horizon Fuel Cell Technologies is one of the largest suppliers of these systems and has improved its offering over the years, producing more and more advanced products. Its latest fuel cell powered remote control car is designed to be controlled by a smartphone, with the standard controls replaced by an app where users can control the car by tilting their phone. The car comes with its own refuelling station, which can be powered either by a solar panel or through a USB connection, thereby avoiding the perennial 'chicken-and-egg' problem.

Auxiliary Power Units

BOC launched a version of its Hymera product that includes a packaged lighting solution in October 2012. The product uses high-efficiency bulbs, with the output equivalent to two 300 W halogen bulbs. This fuel cell lighting package boasts benefits over diesel generators with silent operation and no particulate, CO_2 or NOx emissions at point of use. It can also provide longer runtimes than batteries, providing up to 24 hours of operation from a single 10 kg hydrogen cylinder.

The Advanced Manufacturing Research Institute (AIST) in Japan announced the release of a portable solid oxide fuel

cell (SOFC) unit in March 2013 that can operate on a range of liquid fuels. AIST intends for the unit to be used in disaster and emergency situations, or for outdoor use. Based on microtubular SOFC technology, the system can directly use general-purpose hydrocarbon fuels, including liquefied petroleum gas (LPG).

There is a strong interest in portable power in Japan and environmental technology company Bio Coke Lab Co. has developed a 33 W portable fuel cell system that will be marketed as an emergency power supply. The company will initially target municipal governments, office buildings and families and it is hoping to commercialise the product for a price of around ¥450,000 (~£3,050/$4,700). The fuel cell system utilises the company's proprietary magnesium hydride hydrogen storage alloy in combination with a Horizon Fuel Cell Technologies stack. The prototype system weighs 8.5 kg and each 40 Wh fuel cartridge can supply 72 minutes of power, but the company is aiming to increase the device's capacity by 20% whilst reducing weight by 30% before its planned launch at the end of 2013.

Shipments of charging units for consumer electronics suffered a few setbacks in 2012

Consumer Electronics

In the 2012 Fuel Cell Industry Review we forecast tens of thousands of charging units for consumer electronics would be shipped from a number of companies and we can confirm that the majority of these units were sold, but this application did suffer a few setbacks. Swedish manufacturer myFC had planned to launch its fuel cell charging unit in a staggered manner from July 2012, but a fire at its manufacturing facility hindered progress and launch plans have been delayed. At present the PowerTrekk unit is available in the USA from outdoor supplies retailer REI, and is also on sale in China and Japan.

Horizon Fuel Cell Technologies has continued the global rollout of its MiniPak portable charging device and is now offering customisation options for retail partners and bulk buyers. In the USA a ruggedised, longer lasting version is now being sold through outdoor retailer Brunton, which is adding the fuel cell to its existing range of off-grid power solutions, whilst the standard version continues to be sold by REI. Production runs of branded MiniPaks have also been manufactured for internal business promotional activities by companies such as Air Liquide to promote its Blue Hydrogen concept.

Lilliputian Systems, Inc. (LSI) has continued development of its silicon-chip-based fuel cell electronics charger, the Nectar™ Mobile Power System, which is planned for sale in the near future through US-based gadget retailer Brookstone. LSI has financial backing from electronics giant Intel, whose chip manufacturing facilities are used in the construction of its stacks, and in September 2012 LSI announced it had secured $40 million (£25.9 million) during an equity financing round. The Nectar was debuted at the 2013 Consumer Electronics Show in Las Vegas and won a number of awards including the CES Innovations Award for Engineering & Design in the Portable Power category. It was selected as one of fifteen products (out of over a thousand) to win the Popular Science Product of the Future Award, and was also one of twelve products given the Gotta be Mobile Best of CES Award. LSI claims each cartridge can provide ten 0–100% charges of an average smartphone and will retail from Brookstone in packs of two for $19.99 (£13). Brookstone will sell the fuel cell itself for $299 (£194) at its 300+ retail locations across the USA and nationwide through its website and catalogue.

Neah Power Systems, Inc. is still developing its PowerPlay™ consumer-oriented fuel cell recharging solution which was originally slated for release in the spring of 2013. The company announced it is working with a Fortune 110 company on this development, although at the time of going to press its identity had not yet been revealed.

Aquafairy joined forces with Rohm in 2012 to further develop its portable fuel cell technology. The companies were developing electronics chargers and emergency power systems in a range of styles, including a case design where a smartphone is docked into the fuel cell charger. One 3 g calcium carbonate laminate sheet can generate 4.5 litres of hydrogen and fully charge a smart phone within two hours. Currently there has been no date set for commercialisation of these products.

Military organisations around the world continue to show interest in fuel cell technology

Military

Military organisations around the world continue to show interest in fuel cell technology, evaluating it as a means to significantly reduce the weight carried by soldiers in the field.

Californian micro fuel cell developer UltraCell had its XX55 fuel cell and CliC-It methanol filling station evaluated by the New Zealand Defence Forces (NZDF) Battle Lab, starting in 2012 and culminating in May 2013. The XX55 and filling station were both deployed during Exercise Alam Halfa, a multi-lateral field exercise also involving US Army & Marine Corps and the Australian Army. During the trials, the XX55 was used to power mission-critical communications equipment, including radios, laptops and other devices compatible with the 5 V USB, 12 V DC cigarette lighter and 24 V DC outputs the unit offers. The NZDF was able to locally source the methanol fuel, which it mixed with deionised water in the CliC-It system to refuel the fuel cells.

UltraCell is continuing development of its systems and received a grant of $1 million (£648,000) to test solid acid fuel cell stacks from SAFCell. The fuel cells operate at around 250°C and can therefore tolerate greater levels of impurities in the fuel than low-temperature fuel cell technologies. They can also run on both gaseous and liquid fuels, including propane, methane, methanol and diesel. Initial testing is scheduled for 2014.

Privately owned military fuel cell developer Protonex has also reported continued success and in early 2013 secured a $2 million (£1.3 million) credit facility to expand its sales activities. The company's fuel cells have been field tested for the past three years, and are now entering production and deployment.

SFC Energy (SFC) has a long history of developing methanol-powered fuel cells for military applications and its JENNY and EMILY systems continue to enjoy success. SFC has been awarded $1 million (£648,000) to qualify its 50 W JENNY system for the US Air Force and bring the fuel cell to production readiness. A new version of its big sister, the EMILY, was also launched boasting a 35% power increase over the previous model up to a maximum of 125 W, but contained within the same form factor. The unit is fully ruggedised and is designed to be vehicle-mounted to provide power for communications, night vision, navigation and any additional requirements.

Other

Some applications of portable fuel cell technology are not ones that would instantly come to mind when thinking of portable power solutions, and CEKAtec AG has found one such niche with its fuel cell powered drinks trolley. The unit was designed to provide power to the trolley's coffee machine for long-distance train journeys where the conventional battery-powered trolleys run out of power, and the system has begun a trial on Swiss Federal Railways' Zurich–Berne route. By replacing the batteries with CEKAtec's IHPoS fuel cell and low-pressure hydrogen storage, the trolley's runtime is doubled – providing enough power for around 120 espressos. Furthermore the fuel cell solution is smaller than, and half the weight of, the conventional system.

Stationary

Unit shipments of stationary fuel cells showed a continued increase in 2012, with support from both large and small-scale applications, to finish the year 50% higher than in 2011. Our revised full year data for 2012 was 98% of that forecasted in the 2012 Industry Review, underlining the robustness of this sector and demonstrating its continued delivery of commercial orders. In terms of megawatts the full-year data also delivered on our expectations at 97% of our forecast from last year. The stationary sector is by far the biggest contributor to the annual megawatts shipped figure with 124.9 MW shipped in 2012, accounting for 75% of the total for that year.

2013 is expected to continue this trend of growth and dominance for the stationary sector. New regional markets are opening for both telecommunications backup power and residential micro-CHP, and support is continuing for installations of large megawatt-scale fuel cells.

Unit shipments of stationary fuel cells finished 2012 50% higher than in 2011

Prime Power

Fuel cells for prime power applications continue to be dominated by three companies: FuelCell Energy (MCFC, 300 kW+), Bloom Energy (SOFC, 200 kW) and ClearEdge Power (PAFC, 400 kW ex-UTC Power technology) and their major markets continue to be the USA and Korea. Somewhat surprisingly in comparison to other markets for fuel cells, five of the six types of fuel cell are all vying for position in this space – normally only one or two different technologies compete in any single market.

Ballard continues to sell a small number of its PEMFC ClearGen™ units per year and the company commissioned a 1 MW system at the headquarters of Toyota USA at the end of 2012. In early 2013 it also announced the sale of a smaller 175 kW system to the Blue Lake Rancheria Tribe of Humboldt County, California; this system will run using hydrogen produced from biomass gasification. Potentially of greater interest is the sale of another 175 kW ClearGen™ system to its Chinese partner Azure Hydrogen (Azure). Ballard has worked with Azure on projects for smaller telecoms backup fuel cells, but there is also potential to install large numbers of prime power fuel cells in China, and across Asia.

AFC Energy announced its biggest project to date and is planning to install a 1 MW alkaline fuel cell system at the Essex facility of UK chemicals company Industrial Chemicals Limited. ICL currently has AFC's Beta fuel cell system on test, and subject to a successful trial will install the larger system over time. This project has been funded by the EU with a grant of up to €6 million (£5.1 million, $7.9 million).

Fuel cell industry veteran United Technologies Corporation (UTC) finalised the sale of its fuel cell business (UTC Power) to ClearEdge Power (CEP) early in 2013 and UTC now no longer has any involvement in the fuel cell sector; this is discussed in more detail in the Development by Electrolyte section on page 33.

Despite the obvious distractions and uncertainty surrounding the future of its fuel cell business, a number of sales were made to North American and Asian customers during the past year. Korean interest in large fuel cell systems remains strong, with Samsung Everland purchasing a number of units to install in prominent buildings, such as the Busan International Finance Center (0.4 MW) and the Lotte World Tower (0.8 MW) along with a further seven systems destined for a 3 MW facility owned by public utility KOSEP.

United Technologies Corporation finalised the sale of its fuel cell business to ClearEdge Power early in 2013

The newly acquired business unit continues to attract high-profile domestic customers, with US broadband and telecommunications company Verizon launching a $100 million (£65 million) fuel cell and solar power project which will install fuel cell units at up to nineteen of its facilities in seven states across the USA. Californian customers include rocket-maker Pratt & Whitney Rocketdyne and the State Air Quality Agency, who are both installing 400 kW units.

Bloom Energy continued to progress in the US market with limited orders now being met from its new East Coast manufacturing facility under construction in Delaware. This new facility was part-funded by $16.5 million (£10.7 million) in direct incentives from the State of Delaware and, once complete, it is hoped it will create around 900 jobs in the area. The first systems to be manufactured at the new facility are for Delmarva Power, who is constructing two large fuel cell power stations in the state which together will supply around 30 MW to the electricity grid. Attracting this facility to the state has not been without controversy however, because the deal relied upon mandatory rate increases for Delmarva customers, something which has not been universally welcomed by those customers footing the bill.

Bloom's West Coast manufacturing facility in California has been kept occupied during the year with continued strong purchasing from a range of customers. Target Corporation, the second largest retailer in the USA, purchased two Energy Servers to power stores in San Francisco and Pasadena as part of a trial. If successful the company could install fuel cells at its East Coast stores, where power outages have been increasingly common in recent years. AT&T placed an order for 9.6 MW of Bloom's fuel cells, stating a desire for greater predictability in electricity pricing. Despite producing higher cost electricity than the grid, the price is fixed in a power purchase agreement, the Energy Servers provide reliable and uninterruptible power that negates the need for further backup power. 1 MW of Bloom Energy Servers will power the offices of American Honda Motor Co. and 600 kW of Bloom boxes will be used to power a new building which claims it will be America's largest carbon-neutral office building when it is completed in 2014; to achieve this goal, the building's fuel cells will use directed biogas.

Bloom Energy is "halfway there" on the path to breakeven financials according to its CFO

Bloom's CFO, Bill Kurtz, in an interview with GigaOM in August 2012, claimed the company is "halfway there" on its road to breakeven financials. Kurtz said the company is doubling revenues every six months and with each increase in installed fuel cell systems it is reducing costs. In another

statement to Fortune magazine later in 2012, Kurtz added that Bloom had become "gross margin positive" in 2012 and was on track "to be profitable in 2013".

Fuel Cell Today expects to see profitability for larger companies in the fuel cell industry within the next three years

Profitability is something Fuel Cell Today expects to see for larger companies in the fuel cell industry within the next three years, but the question for Bloom is how long it will need, or what size of IPO will be required, to pay back its existing investors to the tune of $1.2 billion (£778 million)?

The final player in this market, FuelCell Energy (FCE), is also probably the most successful to date, and this momentum continued through 2012 and into 2013. The company has increased its production capacity in the USA whilst at the same time entering into an agreement with its Korean partner, POSCO Energy, for it to manufacture full fuel cell systems in Korea from 2014. Thus far POSCO has taken delivery of fuel cell kits from FCE and has added the necessary balance of plant in order to install full systems; this deal will open up new Asian markets for FCE and provide valuable licencing revenue in the future. As a continuation of its existing partnership with POSCO, FCE announced its biggest order to date in November 2012, for 121.8 MW of fuel cell kits; this is also the largest single order in the history of the fuel cell industry. Shipments were expected to begin in May 2013 after completion of deliveries under previous orders.

FCE broke ground on a 14.9 MW fuel cell power station in Bridgeport, CT; to be the largest fuel cell power station in North America

The use of FCE's fuel cells in power plants in Korea is now being replicated in its domestic market, the USA. Ground was broken in April 2013 on a 14.9 MW fuel cell power station situated in Bridgeport, Connecticut. Once complete, this installation will be the largest fuel cell power station in North America.

Outside of Korea and the USA a small number of deployments are underway in Europe through its German subsidiary, FuelCell Energy Solutions (FCES), and another in Canada. London's Walkie-Talkie building on Fenchurch Street will be powered by a 300 kW fuel cell to provide electricity, hot water and air conditioning *via* adsorption chillers. German construction company BAM Deutschland is installing 300 kW at a federal research facility and, early in 2013, FCES entered into a ten-year service agreement with electric utility Elektrizitaetswerke Zurich to maintain an existing FCE installation operational in the country since 2010. In Canada, FCE is installing a fuel cell at a landfill site to run on gas produced at the site. Successful demonstration in this application could lead to further deployments at landfill sites, providing valuable electricity and heat and utilising gas that is often otherwise flared, providing no revenue.

Micro-Combined Heat and Power

According to energy consultants Delta-ee, fuel cell micro-combined heat and power (micro-CHP) systems outsold conventional engine-based micro-CHP systems for the first time in 2012, accounting for 64% of global sales. This emergence as the dominant technology for micro-CHP is led entirely by uptake under the Japanese Ene-Farm scheme, which should install around 50,000 systems in 2013.

Since the commercial launch of Ene-Farm in May 2009 continued development and optimisation has resulted in greater efficiencies and durability while at the same time lowering cost. The latest PEMFC models on the market have an electrical output of between 700 W and 750 W and boast

overall efficiencies of 95%. They also provide a size reduction of 17% in depth, which makes them less intrusive in terms of installation space, and now retail for less than ¥2 million ($21,000, £13,500) before subsidies. After financial incentives have been applied the cost reduces further, by more than 25% in some cases.

With the success of fuel cell micro-CHP in Japan, it is not surprising to see new companies showing an interest in getting involved with this market. In September 2012, Honda's President, Takanobu Ito, announced his company's intent to develop a residential SOFC micro-CHP system in partnership with NGK Spark Plug Co. Ltd.

Existing Ene-Farm manufacturers in Japan are also looking to replicate their domestic successes abroad with Panasonic collaborating with Viessmann to bring its fuel cell technology to Europe.

Taking second place to Japan is Germany, where 350 systems have been installed between September 2008 and the end of 2012 under the Callux project. Callux is scheduled to run until 2015 and recently shared its experiences thus far with representatives of the new European-wide micro-CHP field demonstration scheme called ene.field. Launched in October 2012, ene.field brings together 27 project partners including nine European fuel cell manufacturers and aims to install around 1,000 fuel cell micro-CHP systems across twelve Member States over the next five years. ene.field is expected to cost €53 million ($69.5 million, £45 million), with €26 million ($34 million, £22 million) coming directly from the European Union under the Seventh Framework Programme. Elcore announced in July 2013 that it would be installing 135 of its 300 W systems during the course of the project, with the first installations expected in Germany imminently. Each set of manufacturer trials will last for three years, with start dates and geographies largely decided by the manufacturers themselves. The project will be the first time that Ceres Power will deploy appreciable numbers of its technology; after several years of setbacks the company is now focusing on its fuel cell stack technology and is actively seeking integration partners for Europe. In July 2013 it was announced that Ceres had partnered with South Korea's largest boiler manufacturer, KD Navien, for product testing and the initial development of a micro-CHP product for the Korean market. KD Navien is a major exporter of boilers to the USA, so if the collaboration is successful the market opportunities for Ceres are substantial.

A new European micro-CHP field trial launched in 2012 called ene.field

Also enjoying continued success in the German market, following a series of successful installations under the European SOFT-PACT project, is Ceramic Fuel Cells Limited (CFCL). The SOFT-PACT project runs until 2014 and sees CFCL partnering with utility E.ON, heating system manufacturer Ideal and software control company HOMA to deploy up to 100 fuel cell micro-CHP systems in various configurations in Germany and the UK. The company runs a dedicated BlueGen manufacturing facility in Heinsburg, Germany with a potential production capacity of 1,000 systems per year. In April 2013 CFCL received an order from German energy provider EWE for 60 units to be shipped by the end of the year in the final stage of a development and demonstration agreement that began between the two companies in 2010.

The Government of the North Rhine-Westphalia region began offering subsidies for highly-efficient micro-CHP units to offset their capital cost. The scheme is to run until 2017 and up to 45% of the *additional* capital cost of a CFCL BlueGen fuel cell micro-CHP, compared to conventional technologies, could be covered providing a saving of around €10,000 ($13,120, £8,500) to customers. CFCL sold its first unit under the scheme in March 2013 and has plans to install up to 600 units across the country by 2015.

In summer 2013, CFCL launched a scheme in the UK offering fully financed BlueGen units for social housing, schools and small businesses. Taking advantage of favourable feed-in tariff rates in the UK, CFCL has pre-arranged the necessary finance to cover the capital cost of the units, whereby customers can take advantage of a free fuel cell system and reduced electricity costs by signing a ten-year contract. Financiers recoup their capital investment through feed-in tariff payments; a 6-9% return on investment is expected by the end of the contract, after which ownership of the fuel cell passes to the customer.

Grid-Support and Off-Grid Power

Using fuel cells as backup power systems in the telecoms market gained prominence as an application thanks to the US Government and its 2009 Recovery Act funding. Since then, customers around the world have experienced the benefits and cost savings that can be achieved through using fuel cell backup power.

In our 2012 Fuel Cell Industry Review we said that 2013 was set to be a pivotal year for fuel cell backup power systems servicing the telecoms sector after an increase in orders seen in 2012. This seems to be proving true with momentum being sustained through the early part of the year. Ballard Power Systems has reported that orders for its ElectraGen™ systems from customers in Asia and Africa exceeded 400 units through December and into January.

Ballard offers both hydrogen-fuelled and methanol-fuelled backup power systems after acquiring IdaTech's business assets in August 2012. The methanol-fuelled systems are proving especially popular and in the eight months since it acquired the technology, Ballard had sold more than 500 methanol-fuelled systems. The benefits of methanol as a fuel are discussed further in the Fuel and Infrastructure section on page 22.

Hurricane Sandy passed over the East Coast of the USA in October 2012 with devastating effect, but during this time fuel cell powered cell phone towers remained in operation for extended periods for customers in New York, New Jersey and Connecticut. Altergy has more than 60 fuel cell systems installed in the disaster area and all were reported to function normally during and immediately after the storm. The more frequently fuel cells are seen to provide reliable power during similar events, the more interest there will be from around the world in utilising the technology.

Asia, and in particular China, represents a huge potential market for fuel cell technology as mobile phone adoption increases at an exponential rate. Here a number of companies, including VN Technologies, ReliOn, FutureE and Ballard, are involved in trials with major telecommunications providers. Trials in the USA eventually led to large-scale customer orders and it is hoped that the same will happen in China, home to two of the three largest mobile network providers in the world, China Mobile and China Telecom, both of whom are trialling fuel cells.

China is a huge potential market for telecoms backup fuel cells

In March 2013 Ballard received an investment of $2 million (£1.3 million) from its Chinese partner Azure in its Dantherm Power subsidiary, which acts as a development centre for Ballard's telecoms backup fuel cell systems. Through this deal Azure has bought a 10% stake in Dantherm and plans to assist Ballard with entering the Chinese market; the companies are both working on backup power trials for China Mobile.

One of the aspects of fuel cell technology that appealed to telecoms customers was the replacement of widely used fuels such as diesel, which historically have been prone to theft. One telecom provider in the Philippines had installed methanol-fuelled systems, but was finding that, in some instances, even the methanol was being stolen. In response to this the company is trialling a new product from Acta, known as Acta Power. The Acta Power is a self-regenerating backup power system which incorporates a fuel cell and an electrolyser meaning the unit can operate in backup mode autonomously without the need for refuelling. During operation when grid power has failed the unit provides power using its on-board store of hydrogen. When grid power resumes, the unit replenishes its fuel supply using water electrolysis. Acta is involved in a project to develop rainwater harvesting capability for the Acta Power which would mean that the unit could even ensure its water supplies were replenished, further minimising the need for maintenance visits.

Transport

Stringent greenhouse gas (GHG) emissions reduction targets are commonplace across the world and transportation is one of the most critical areas to be addressed if these targets are to be met. In the European Union a commitment has been made to reduce GHG emissions by 80% (from 1990 levels) by 2050, which would require a 95% reduction in emissions from road transport. Two broad objectives are key to facilitating this: increasing the use of public transport and promoting the use of low-to-zero-emission vehicles.

Repeat customers are purchasing fuel cell systems for materials handling without subsidies in North America

Fuel cells in transportation applications are coming of age. Repeat customers are purchasing systems for materials handling applications without government subsidies in North America, an increasing number of fuel cell buses are operating in cities across the world and, for the first time, fuel cell cars are rolling off a series production line.

The significance of commercial-scale vehicle production for the fuel cell sector as a whole cannot be overstated. The volumes associated with mainstream automotive manufacture will bring into play beneficial economies of scale across the entire supply chain, leading to components of higher quality and lower cost. The automakers' approach to cost reduction will be aggressive as they seek total cost of ownership parity with internal combustion engine vehicles, particularly in the reduction of expensive catalyst materials such as platinum – the eventual aim being that a fuel cell electric vehicle (FCEV) should contain no more platinum than is found in the catalytic converters fitted to the exhausts of diesel cars. The implications of such thrifting efforts will strongly benefit those who manufacture and sell PEMFC, the dominant fuel cell technology today, accounting for 88% of units shipped in 2012, but since they tend to be of a smaller size this represents only 41% of the total installed power.

Light Duty Vehicles

2012 saw the automotive industry further align itself towards mass production

2012 saw the automotive industry further realign itself away from fuel cell demonstration and towards mass production in a period that shipments-wise could be described as the quiet before the storm, with one notable exception. An increase in shipments of 21% between 2011 and 2012 coincided with a flurry of activity from automakers, industries and governments, seen during 2012 and into 2013, as all parties readied themselves for the market introduction of FCEV.

Collaborations have been the most notable theme in this industry shift as automakers look to pool their resources to accelerate cost reduction and ease mass manufacture of fuel cell systems. Within the first seven months of 2013 three alliances formed: BMW with Toyota, Renault-Nissan with the Automotive Fuel Cell Cooperation (AFCC – Daimler and Ford), and General Motors (GM) with Honda.

BMW and Toyota jointly announced in January 2013 that they would be sharing a number of technologies and co-developing a fundamental fuel cell vehicle platform by 2020 – including not only a fuel cell system, but also a hydrogen tank, electric motor and supporting battery system. Germany is an important early market for FCEV and Toyota can lend to BMW years of experience and expertise in the development of fuel cell and battery powered drivetrains. This development was a substantial leap forward for BMW, who had previously concentrated on hydrogen internal combustion engine (HICE) vehicles but had largely avoided fuel cells, and is reaffirmation of the globally held view that FCEV are a critical part of zero-emissions motoring.

Toyota, however, will not be waiting until 2020 to release a fuel cell vehicle. It is signatory to a 2011 agreement amongst Japanese automakers and oil and energy companies to popularise FCEV and work together to build a network of approximately 100 hydrogen stations across four major metropolitan areas by 2015. In September 2012 Toyota announced a new fuel cell stack with twice the power density of the stack used in its 2008 FCHV-adv vehicle at approximately half the size and weight. It is understood that Toyota plans to begin series production of an FCEV, possibly under the umbrella of the Prius brand, in 2014 for market launch in Japan, the USA and Europe from 2015. A pre-production version of the vehicle is expected to be revealed at the 2013 Tokyo Motor Show in November, exactly two years after the unveiling of the FCV-R concept at the 2011 show.

Daimler and Ford have been developing fuel cell technology for decades and created a joint venture at the end of 2007, the AFCC, to purchase Ballard Power System's automotive fuel cell assets and continue development. In January 2013 the Renault-Nissan Alliance joined the Cooperation as a technology partner under an agreement to jointly develop a common fuel cell system for use in separate mass-market cars from 2017. This timeframe comes hand-in-hand with a decision by Daimler to forego its limited production run of second-generation B-Class F-CELL pre-commercial vehicles planned for 2013/2014 and instead focus on a more affordable vehicle for launch in 2017, when infrastructure in Germany and elsewhere will be more developed. The company shipped its last batch of B-Class F-CELL vehicles in 2012 for German projects through the Clean Energy Partnership (CEP) and for lease in California. Under the Californian lease scheme, customers pay $599 (£388) per month (including fuel, maintenance and insurance) for a three-year term or $849 (£550) per month for a two-year term.

Collaborations have been the most notable theme in the automotive sector

Ford still has no immediate-term plans to release a commercial FCEV but its deep involvement in the AFCC keeps the automaker at the technological forefront. In September 2012 Nissan showcased its TeRRa concept – a design study for a zero-emission evolution of its popular Juke and Qashqai SUV crossovers and an indicator of the company's direction for commercial FCEV.

In early July 2013 Honda and General Motors announced that they have signed a co-development agreement to collaborate on next-generation fuel cell systems and hydrogen storage technologies. The companies will benefit from shared expertise and economies of scale in manufacturing once they enter the production phase. Honda plans to launch a successor to the FCX Clarity in Japan and the USA from 2015, with a European rollout to follow later, although this vehicle will likely implement current-generation fuel cell technology.

Volkswagen, the world's second largest automaker (2011, by unit production), whose last fuel cell demonstrator was a version of the 2008 Tiguan, recently signed a four-year engineering services

agreement with Ballard Power Systems to advance the development of fuel cells for use in its demonstration programme. This marks a swift return to automotive fuel cells for Ballard following the end of a five-year non-competition period stipulated during the creation of the AFCC. Shortly after the agreement was signed it was reported that Volkswagen is to begin trials of a fuel cell powered Audi A7 later in 2013.

One automaker has decided to go it alone in pursuit of an early market advantage in the FCEV arena. Following a series of demonstrations throughout 2011 and 2012, in September 2012 Hyundai revealed its intention to take the ix35 Fuel Cell into series production for a production run of 1,000 vehicles between 2013 and 2015 before entering mass production of up to 10,000 units per annum dependent on demand. The vehicles are being targeted at public and private fleet operators, predominantly in Europe, with the majority to be built and delivered in 2014. The first fifteen vehicles were delivered to the Municipality of Copenhagen in June 2013. Hyundai is signatory to an October 2012 memorandum of understanding (MoU) with Honda, Toyota, Nissan, infrastructure builders and Nordic NGOs agreeing to bring FCEV and hydrogen infrastructure to Scandinavia between 2014 and 2017.

By providing these 1,000 vehicles Hyundai is hoping to encourage infrastructure builders to construct stations in preparation for the wider introduction of FCEV, thus breaking the perennial 'chicken and egg' problem that plagues FCEV commercialisation. This was a bold move by the Korean automaker at a time when its contemporaries are scaling back demonstrations. The belief that fuel cells are Hyundai's future is evident across the company as it looks to become a world leader in this next generation of passenger vehicles.

Buses

Fuel cell buses can provide tangible air quality improvements to cities and they continue to be the way in which the majority of the public first encounter fuel cell transportation. By operating on conventional routes in major cities, passengers are boarding the buses as part of their existing routine; once aboard, they experience the benefits of the technology and a positive impression is created. This familiarity encourages customers to consider fuel cells as they emerge in consumer markets. European projects are placing increasing numbers of buses into regular service in prominent cities and across the Atlantic, CT Transit has commercially procured the world's first unsubsidised fuel cell bus.

Fuel cell buses can provide tangible air quality improvements to cities

Positive developments though these may be, the bus industry is slow-moving and it must be remembered that fuel cell buses are only just emerging from the demonstration phase. The CT Transit procurement is an important step in the transition to a commercial market ahead of widespread adoption, which we last year said could happen as early as 2014 thanks to increased demonstrations and the cost reduction targets of the fuel cell manufacturers.

Overall, we saw a 86% increase in bus shipments between 2011 and 2012 thanks in large part to a number of EU-backed demonstration projects as well as ongoing projects across the USA.

The majority of fuel cell buses shipped in 2012 were destined for European locations, thanks to demonstration projects initiated with funding allocated by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) – the public-private entity responsible for the distribution of EU Framework Programme funding for hydrogen and fuel cells. In December 2012 the FCH JU published 'Urban buses: alternative powertrains for Europe'. The report, which was created in a similar manner to the 2010 light-duty vehicle report 'A portfolio of power-trains for Europe: a fact-based analysis', collates findings from 40 companies and government organisations on eight powertrain technologies available to urban buses from 2012 to 2030. Data includes comparative well-to-wheel analyses and focuses on environmental impact, performance and total cost of ownership (TCO). The report finds that it is unlikely that the diesel engine will be able to meet tightening heavy-duty vehicle emissions legislation beyond 2015 and that the hydrogen fuel cell bus is the only articulated bus expected to decrease in TCO until 2030 – from a current price premium of 125% to just 15–20%. Hydrogen fuel cell buses also compare best to conventional powertrains, offering similar performance, flexibility of route selection and a low infrastructure cost per kilometre whilst offering low emissions and noise. Following the report's publication the FCH JU and its partners are now working to create a roadmap for the commercial deployment of HFC buses in Europe.

Following on from two previous European fuel cell demonstration programmes, CHIC (Clean Hydrogen in European Cities) began in 2010 with a goal of integrating 26 fuel cell buses into daily public transport operations in bus routes across five European locations: Aargau, Switzerland; Bolzano, Italy; London, UK; Milan, Italy; and Oslo, Norway. Fuel cell buses are now in operation in all five cities and the project runs until 2016. High V.LO-City, which began in early 2012, complements CHIC and aims to rapidly deploy the very latest fuel cell buses in transport fleets in three different European regions: Brussels, Belgium; Imperia, Italy; and Aberdeen, Scotland. The High V.LO-City project aims to look at the entire fuel cell bus value proposition, including maintenance and hydrogen infrastructure build-up. Five buses for Brussels will be delivered by the end of 2013 and ten Ballard-powered Van Hool buses are set to arrive in Aberdeen in early 2014. Once in operation, the Aberdeen fleet will be the largest of any European city and is one part of a much wider initiative for the city, which is famed for its offshore oil drilling activity, to transition from a fossil-based energy city to a renewable-based one, capitalising on the abundant wind potential in the region.

Once in operation, the Aberdeen fuel cell bus fleet will be the largest of any European city

In North America the non-profit Center for Transportation and the Environment (CTE) in Georgia finalised a contract with CT Transit in April 2013 for the delivery of a fuel cell powered 40-foot heavy-duty transit bus in partnership with bus manufacturer ElDorado National, systems integrator BAE Systems and Ballard Power Systems. The bus and its extended operations support were procured under a standard request for proposal (RFP) process using industry-defined specifications and terms that drive contractor accountability. This procedure mirrors the procurement of a standard bus and is an important step towards full commercialisation of fuel cell buses in the USA. The vast majority of existing buses operating in the USA have been procured and built under federally funded research programmes, most notably the Federal Transit Administration's (FTA's) National Fuel Cell Bus Program (NFCBP). CTE expects to deliver the bus in 2014 and is also involved in a project to integrate next-generation Hydrogenics fuel cell modules into a new Proterra bus design, although this project is NFCBP funded. The bus will use 30 kW modules, which feature reduced numbers of components and simplified integration requirements, improving overall affordability.

In May 2013 Ballard signed a non-binding MoU with its Chinese partner Azure Hydrogen to extend the scope of their collaboration to include fuel cell buses. Azure plans to develop fuel cell bus capabilities in China with Ballard's technical support and domestic funding from various private and government sources. If successful, Azure would be producing China's first fuel cell buses since a previous United Nations Development Programme (UNDP) project with the Chinese Ministry of Science and Technology (MOST) that ran from 2002 to 2010 and saw six SAIC fuel cell buses used at the 2008 Olympic Games and 2010 World Expo.

Tata Motors has a clear interest in fuel cells

Tata Motors, India's largest automaker and the world's third largest bus manufacturer, and the Indian Space Research Organisation (ISRO) have been joined in a fuel cell bus development MoU since 2006 and in July 2013 it was reported that the first fuel cell bus from this effort was undergoing testing at an ISRO facility. The fuel cells used in the all-Indian vehicle have been developed using experiences gained from ISRO's development of cryogenic technologies and the organisation is also experienced in the production, storage and handling of gaseous and liquid hydrogen. Tata Motors has a clear interest in fuel cells; having shown off its Starbus fuel cell concept at the 2012 New Delhi Auto Expo, the company is currently accepting delivery of twelve Ballard fuel cell bus modules for integration into demonstration buses to be used across a number of Indian cities.

With Hydrogenics' next-generation fuel cell bus module now available and Ballard's seventh-generation module, the FCvelocity-HD7, in development, we expect to see the arrival of increasingly cost-competitive fuel cell buses over the coming months. These next-generation modules also begin to bring lifetimes closer to those of conventional buses, all improving the value proposition and lessening the need for capital funding support.

Materials Handling Vehicles

Materials handling vehicles (MHV) continue to be an important niche market for the fuel cell industry. This application was popularised in 2009 thanks to funding allocated from the American Recovery and Reinvestment Act, which saw the subsidised sale of fuel cell equipped forklifts deployed at the warehouses of many high-profile American brands, including BMW Manufacturing, Coca-Cola, FedEx and Walmart. In 2011 we began to see unsubsidised repeat orders for fuel cell forklifts and this trend continued throughout 2012.

BMW's manufacturing plant in Spartanburg, South Carolina is now operating North America's largest fuel cell forklift fleet, with over 275 units being used in the assembly halls for the company's X3, X5 and X6 vehicles. Hydrogen for the forklifts is currently supplied by Linde, although BMW is looking at producing hydrogen on-site using methane from a nearby landfill site. Methane from the same site is already used to provide approximately 50% of the site's energy needs and is part of BMW's ambition to become the most sustainable car manufacturer in North America.

Data from the World Industrial Truck Statistics indicates that the European market for MHV is 56% larger than the American market. Efforts to translate the success of fuel cell forklifts in North America to Europe have begun. Plug Power and Air Liquide's European fuel cell forklift joint venture, HyPulsion, was created in November 2011. Its first major order has been with Ikea, with twenty forklifts and a hydrogen station installed at Ikea's logistics platform near Lyon, France in May 2013. In the same month Air Liquide invested a total of €5 million ($6.6 million, £4.3 million) in Plug Power including a preferred stock purchase, increased ownership of HyPulsion (now 80% Air Liquide, 20% Plug Power) and an engineering services contract.

Infintium continues to work with ITM Power in bringing its MHV products to Europe and in January 2013 the partners announced that Infintium's product range had been successfully CE certified, allowing European sales to begin.

Demonstration projects such as HyLIFT are showcasing MHV in Europe but without a strong funding programme in place for widespread trials at large customers we expect growth in this market to be slow but steady. Individual government support may stimulate pockets of growth: funding from Austria's Federal Ministry for Transport, Innovation and Technology led to the delivery of ten Linde/Fronius fuel cell pallet trucks and accompanying refuelling infrastructure at global logistics provider DB Schenker.

An application where fuel cell MHV can bring a particular benefit is at airports. Airports are emissions hotspots, in large part thanks to the many planes taking off and taxiing. There is no easy solution to substantially lower these emissions in the short term; however another significant contributor to airport emissions comes from the ground support equipment (GSE) – the tow tractors and other vehicles that service aircraft before and after flight. At London Heathrow, for example, 37% of the total NOx emissions come from GSE. Batteries have become a popular powertrain option for this reason but the same limitations are suffered here as with battery forklifts and fuel cells can offer the same benefits of range, weight, and infrastructure reduction. In September 2012 it was announced that Vision Industries and Balqon had entered into a joint development agreement to build a fuel cell hybrid terminal tractor, the Zero-TT, and in November 2012 Plug Power received a $2.5 million (£1.6 million) DOE award to retrofit fifteen electric tow tractors with GenDrive fuel cells for use at two of FedEx's domestic airports in Tennessee and California.

Fuel cell MHV can bring particular benefits at ports and airports

Other

One of the fundamental appeals of fuel cell technology is its applicability to a wide range of markets and applications, both mainstream and niche. For fuel cell personal mobility, light duty vehicles only tell part of the tale. In October 2012 the EU project SWARM (demonstration of Small 4-Wheel fuel cell passenger vehicle Applications in Regional and Municipal transport) began. The project will run until September 2016 and will see the deployment of 90 small, lightweight passenger vehicles designed for city and regional use across the British Midlands, Brussels and Bremen in Germany. The locations have been chosen as areas that can link existing hydrogen stations to form a highway in the three countries; Air Liquide will install a 200 kg/day, 700 bar hydrogen station in each area by the end of 2013 with vehicles to follow afterwards. The vehicles, which will be provided by Riversimple, Microcab and H2O e-mobile, will be put into the hands of real users for testing over a three year period. This marks the first demonstration of Riversimple vehicles following several years of delays and a step up in activity for Microcab, the fuel cell mobility spinout of the University of Coventry.

Another lightweight city car is the QBEAK by the Danish automotive company ECOmove. The QBEAK is a plug-in electric car with a sandwich floor that allows the interchange of six powertrain modules for the four in-wheel electric motors. In mid-2012 it was announced that a consortium of Danish partners including the HT-PEMFC manufacturer Serenergy had been granted funding by the Danish government to develop a version of the QBEAK range-extended by a biomethanol-fed fuel cell. The basic version would see a 2.5 kW fuel cell and methanol tank occupy two of the car's six slots; different combinations of batteries, fuel cells and fuel tanks can be deployed to suit the customer and the vehicle has a range of up to 800 km. OK, one of Denmark's largest fuel distributors, is interested in methanol as a clean fuel that does not

entirely obviate its existing liquid fuel infrastructure, as gaseous hydrogen would, and is working with partners including ECOmove and Serenergy to develop a methanol filling station; declarations of intent for a methanol filling station and several QBEAK vehicles have been received from the municipalities of Aarhus, Horsens and Mariagerfjord.

In Taiwan, APFCT's progress with its fuel cell scooter programme continued throughout 2012. In July, the Taiwanese Ministry of Economic Affairs released a safety and reliability standard for hydrogen fuel cell motorcycles allowing APFCT to begin mass production. In November, the company held a public ride and drive of a fleet of 80 scooters in Pingtung County. Twenty of the scooters will remain in the county for local government use and the remaining 60 will be distributed amongst seventeen hotels in the Kenting region for rental by guests. Each site will be equipped with a hydrogen canister exchange machine that APFCT has co-developed with Acta; the system uses a solar-driven electrolyser to refill the metal hydride canisters, two of which are used in each scooter for a range of 50 miles. APFCT has also been working to export the scooter to Hawaii, where it installed a solar canister exchange machine and demonstrated scooters in late 2012. Hawaii is 90% dependent on imported oil so hydrogen transportation fuelled by solar electrolysis is a particularly attractive proposition. The company is now actively seeking partnerships with motorcycle manufacturers globally to take part in a prospective 3,000-strong fuel cell scooter demonstration in order to help the technology reach mass production.

Tightening heavy-duty diesel vehicle legislation in the USA is beginning to create a demand for zero-emissions solutions

Tightening heavy-duty diesel vehicle legislation in the USA is beginning to create a demand for zero-emissions solutions in this sector. Last year Total Transportation Services signed a letter for the purchase of 100 fuel cell Tyrano Class 8 heavy-duty trucks from Vision Industries and in March 2013 the DOE awarded a $3.4 million grant to fund the demonstration of twenty of the vehicles with the Houston Galveston Area Council in Texas. The project aims to measure the operational cost-effectiveness of the technology, with fuel coming from local natural gas. It is hoped the trucks will displace 200,000 gallons of diesel, 39 tons of NOx and 0.8 tons of particulate matter per year. Four more trucks are to be used at the Ports of Los Angeles and Long Beach for drayage operations.

Fuel and Infrastructure

Hydrogen Refuelling Stations

27 new HRS opened worldwide in 2012, bringing the total number in service to 208

27 new hydrogen refuelling stations (HRS) were opened worldwide in 2012, bringing the total number of HRS in service to 208 as of March 2013, according to the LBST and TÜV SÜD information website H2stations.org – 80 in Europe, 76 in North America, 49 in Asia, and three elsewhere. Of the 27 new stations, sixteen are in Europe (of which five are in Germany), eight are in North America, and three are in Asia. Comparing against a total of twelve new HRS opened in the previous year gives an annual increase in new HRS openings of 225%, indicative of the market preparation for the impending commercialisation of FCEV.

With 2015 now less than two years away it is unsurprising that country-wide initiatives are emerging to support the rollout of HRS in key launch markets. More information on the various public-private hydrogen mobility initiatives that are underway is available in Developments by Region on page 28.

New funding is emerging in several areas to support the large capital outlay required for hydrogen stations and a number of incremental innovations and improvements to the refuelling technology are becoming available as the window for station construction opens.

As users of hydrogen stations transition from a small number of trained users to large numbers of the general public, it will be important to ensure that the systems are easy to use. In June 2013, Air Products released its new SmartFuel H70/H35 retail hydrogen dispenser. The dispenser has been developed with conventional fuel dispensing equipment manufacturer Bennett Pump Company and as well as including components to meet the requirements of SAE J2601 Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles it has also been designed with consumer-friendliness at the forefront. The product includes a traditional debit/credit card payment system and a 5.7" LED screen with on-screen training for first-time users. The new dispenser will be installed at ten new hydrogen stations due to be installed in California starting this year.

California has long been a hotspot for FCEV and low-emission motoring in general thanks to the progressive air quality legislation imposed by the California Air Resources Board (CARB), which can and does set more stringent targets than federal equivalents. In June 2013 the California Energy Commission awarded $18.69 million in grants for projects that will expand the state's hydrogen refuelling infrastructure. The funding covers the costs of construction of seven new hydrogen stations in the state as well as the evaluation and upgrading of existing publicly-accessible stations. Of the seven new stations, one will produce 100% renewable fuel thanks to its use of an ITM Power electrolyser and purchased renewable electricity. This station is a rebuild project at Hyundai's proving ground in Chino and will produce at least 100 kg hydrogen per day when it opens in October 2014; it will also be the first publicly-accessible HRS in San Bernardino County.

In 2013 the California Energy Commission awarded $18.69 million in grants to expand the state's hydrogen infrastructure

Japan's first dual-purpose hydrogen and gasoline refuelling station opened in Ebina in April 2013. The station is the result of a joint project between JX Nippon Oil & Energy Corp. and NEDO and demonstrates the commercial hydrogen station standard developed by the Research Association of Hydrogen Supply/Utilization Technology (HySUT). The ability to install hydrogen pumps at existing petrol stations offers an advantageous infrastructure build-up model as these are already situated in strategic locations across the country. Unclear and over-compensative hydrogen setback distances have been a hindrance to this model in the past, particularly in Japan, where domestic standards can lean towards the overcautious.

London's position as a leading city for hydrogen transport is to be further secured thanks to the London Hydrogen Network Expansion (LHNE) project, which will see Air Products build two new hydrogen stations in the city, including one in Central London, and upgrade all existing sites to 700 bar to facilitate FCEV refuelling.

On-site hydrogen generation

On-site generation of hydrogen, whether through water electrolysis or natural gas reformation, is an exciting alternative to the bulk delivery of hydrogen by tanker to refuelling sites – a model that is not far removed from the conventional fuel distribution system. In June 2013 Air Products introduced a new high-output offering to its PRISM line of on-site hydrogen generation systems. Running on natural gas, the system combines proprietary reformer technology with pressure swing adsorption and can produce 4,500 standard cubic metres of hydrogen per hour.

HyGear offers an on-site hydrogen generation system that utilises a scaled-down version of the steam methane reforming (SMR) process that is currently used at an industrial scale to produce the vast majority of hydrogen used today. HyGear claims that the downscaling does not affect the efficiency of the process and the technology was the winner of Mercedes-Benz fourth BlueEFFICIENCY award, which credits innovations in sustainable mobility.

Although reforming natural gas on-site incurs carbon emissions, the lack of additional transport significantly reduces the overall carbon footprint and cost. In the case of on-demand systems such as HyGear's there is an additional financial saving to be had in negating the need for significant on-site hydrogen storage.

Electrolysis

Coupled with renewable electricity, water electrolysis can offer truly clean hydrogen

Of all existing hydrogen production methods, water electrolysis is the most favourable. When coupled with a renewable electricity source, water electrolysis can offer truly clean hydrogen. Electrolysers can be applied at any scale, from large centralised systems to small distributed systems at individual refuelling sites. Electrolysis can also complement renewable electricity as an energy storage mechanism to balance the variability inherent with renewable sources. Large centralised electrolysers can take the role of dispatchable power plants to aid supply-side management, ramping up to meet peaks in supply. Small distributed electrolysers could also enable demand-side management, dependent on the capability of the grid to transport excess electricity and the amount of hydrogen storage available at the sites.

Even without its use as a transport fuel, hydrogen is rapidly becoming recognised as an important energy storage medium. As PEM electrolyser technology reaches the megawatt scale the power-to-gas concept is now being embraced by utilities with a number of high-profile projects launching in the last year. E.ON has been a particularly prominent supporter of the concept with its Falkenhagen demonstration plant successfully injecting gas into the natural gas grid for the first time in June 2013. Hydrogenics is installing the world's first 1 MW PEM electrolyser stack at an E.ON power-to-gas facility in the City of Hamburg. With permissive legislation Germany is a hotspot for power-to-gas: ITM Power and RWE are also building pilot plants in Frankfurt and Ibbenbüren, respectively. The Hamburg installation paves the way for multi-megawatt systems, key to the technology's success at the utility level. In November 2012 NEL Hydrogen launched its P•60 electrolyser, designed specifically for energy applications with a 10–100% operational range and an output of 60 Nm^3/hr of hydrogen per stack at 15 bar pressure. ITM Power offers a modular megawatt-scale system and Proton OnSite will be launching megawatt-scale systems next year.

Electrolysis and its interplay with renewables and the silos of electricity, heat and transportation is explored in more detail in our recent report 'Water Electrolysis & Renewable Energy Systems', available free of charge online.

Liquid fuels

Liquid fuels offer a compelling alternative to compressed gaseous hydrogen, particularly when considering fuel distribution and ease of use. As the name suggests, direct methanol fuel cells use the fuel as is – SFC Energy's range of products continue to be the most successful commercially

available DMFC systems and are popular in a number of auxiliary power applications. DMFC technology is not suited to larger-scale applications but a fuel processor can be used to reform methanol into hydrogen onsite for use with a conventional PEMFC system. This style of deployment has soared in popularity recently, most notably for telecoms backup power systems.

Fuel cells for telecoms backup power have traditionally been supplied with hydrogen, through either packaged hydrogen cylinders or the refilling of fixed tanks by a trailer. The latter is obviously impractical in both remote areas and those where hydrogen is not commonly delivered for any other purpose. Systems with methanol processors are offered by companies including Ballard, ReliOn and Altergy and have quickly become popular: Ballard reported in April 2013 that sales of methanol-fuelled ElectraGen systems are outstripping those of the hydrogen-fuelled version. Hy9, who provides methanol reformers for the likes of ReliOn and Altergy, in January 2013 announced a collaboration with leading Japanese telecoms equipment supplier Sankosha Corporation to further develop the market for methanol-fuelled telecoms backup solutions in Asia.

Sales of methanol-fuelled ElectraGen systems are outstripping the hydrogen-fuelled alternative

Other

Fuel theft can be a common problem in certain regions where fuel cell backup power systems are deployed and there is a growing customer desire for alternative solutions. Diverse Energy, which had been developing an ammonia-based system targeted at telecoms sites in Africa, entered into administration in October 2012 after a failed funding round. Its core technology was acquired by AFC Energy as part of an EU-funded project, Alkammonia, which supports the development of ammonia-fed alkaline fuel cell systems.

With any fuel type, replenishment is a consideration; for more remote sites with little surrounding infrastructure this can be a burden. Further considerations include fuel shipping and value. Aiming to address some of these considerations, Horizon Fuel Cell Technologies is developing a new product line, AquiGen, which is fed with a food-grade-acid–water mix. The acid can be distributed in powdered form and mixed with water at the point of use, vastly simplifying fuel supply logistics. There is an obvious financial and environmental benefit in shipping powdered fuels; furthermore the powder is unlikely to face any restrictions in terms of the carriage of dangerous goods. Products in the line are expected to launch later this year and will be available in 150–500 W configurations for APU applications and 1–5 kW for stationary backup power applications.

But what if a fuel cell system didn't require any fuel at all? Acta in March 2013 signed a distribution agreement with MVS Energy Solutions, a new business division of MVS Engineering Ltd, India's largest supplier of industrial gas equipment and solutions, for the distribution of fuel cell backup power solutions with on-site hydrogen generation. The appeal, in particular for remote areas, is obvious: electricity from solar panels or small wind-turbines (or grid electricity if available) is used by an electrolyser to generate hydrogen from a water supply, continuously replenishing the fuel cell's store of fuel and allowing for an entirely autonomous system.

Some telecoms backup fuel cells generate their own hydrogen using water electrolysis

Technologies are now advanced enough for such systems to be sold in cabinet form and an increasing number of fuel cell and electrolyser manufacturers are introducing such offerings. Acta launched its Acta Power system at the Group Exhibit Hydrogen + Fuel Cells at the Hannover Messe in April 2013 and the first system sold is being sent to Africa. A particular selling point of the system is its collection and storage of rainwater for electrolysis. Acta also supplies electrolyser modules to Germany's FutureE, whose Jupiter Independence system was revealed a year earlier at 2012's Hannover Messe. The first commercial system of this type was Electro Power Systems' ElectroSelf, which was launched in February 2010; the concept has now gained traction and is becoming an increasingly feasible solution for backup power applications.

Special Feature

Self-Generation Incentive Program: Funding

Financial support for fuel cell technology has been an important factor during the past few years, encouraging the increasing adoption of the technology in a number of areas. Stationary fuel cell adoption has grown significantly in the USA and the Republic of Korea, led by strong financial incentives. In the USA, California and Connecticut have been the dominant states in terms of their incentives for fuel cells, and this Special Feature focuses on the Californian Self Generation Incentive Program (SGIP).

History

The SGIP was established in 2001 in response to the energy crisis experienced the previous year, during which electrical outages were experienced across California. Legislation was drafted directing the California Public Utilities Commission (CPUC) to offer financial incentives to electricity consumers of the major investor-owned utilities that offset all, or a portion of, their energy needs. In 2009, its remit was changed such that it no longer supported projects based solely on peak load reduction but instead shifted its focus to concentrate on reducing greenhouse gas emissions.

Current status

Today the SGIP is recognised as one of the longest running distributed generation (DG) incentive programs in the USA and it encourages the development of both renewable and non-renewable DG technologies. The programme has been extended to run until January 1st 2016 and currently allocates a budget of $83 million (£53.8 million) per year. The budget is divided into two categories: 75% of the incentive budget will be dedicated to the renewable and emerging technology category (which includes fuel cells), and 25% will be dedicated to the non-renewable category. The maximum incentive available per project is $5 million (£3.2 million) and applicants must pay a minimum of 40% of eligible project costs. If the applicant is eligible for the 30% Federal Investment Tax Credit, this means that the incentive may cover up to 30% of total project costs.

While there are no minimum or maximum size restrictions on installations, certain criteria must be met for eligibility: self-generation equipment must be installed on the customer's side of the electric utility meter; the installation must meet some portion of the electrical load at the site; and projects must beat an on-site emission rate of 379 kg CO_2/MWh. Qualifying technologies include wind turbines,

Stationary Fuel Cell Deployments in the USA

fuel cells, combined heat and power (CHP) gas turbines, micro turbines and internal combustion engines, organic Rankine cycle/waste heat capture, advanced energy storage (AES) and pressure reduction turbines.

2013 Incentive Levels for Eligible Technologies[1]

Technology Type	Incentive ($/W)
Renewable and Waste Energy Recovery	
Wind Turbine	$1.19
Waste Heat to Power	$1.19
Pressure Reduction Turbine	$1.19
Non-Renewable Conventional CHP	
Internal Combustion Engine - CHP	$0.48
Microturbine - CHP	$0.48
Gas Turbine - CHP	$0.48
Emerging Technologies	
Advanced Energy Storage[2]	$1.80
Fuel Cell - CHP or Electric-Only	$1.80
Biogas[3]	$2.03

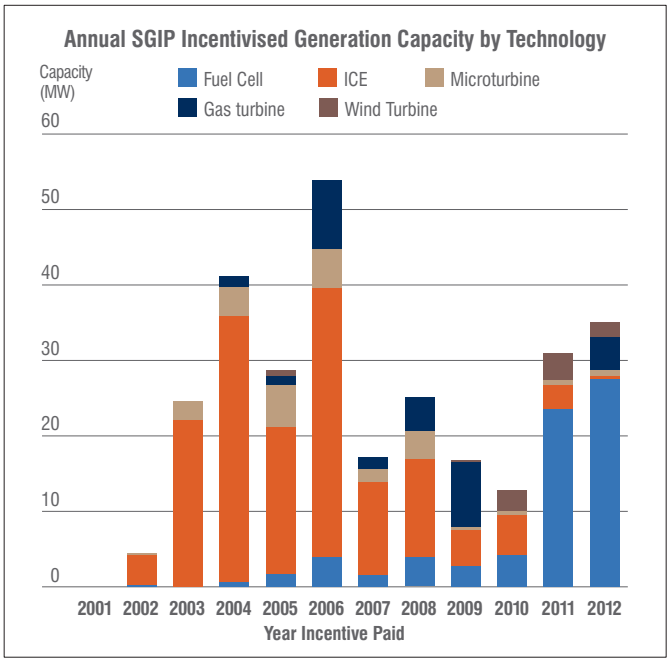
Table Notes

1. An additional incentive of 20% will be provided for the installation of eligible technologies from a California Supplier.
2. Stand-alone as well as coupled with solar PV or another SGIP-eligible technology.
3. The biogas incentive is an additional contribution that may be used in conjunction with fuel cells (or any conventional CHP technology).

Applications for installations including fuel cells began from the outset and reasonably steady capacity additions were seen each year until 2008. Since 2009, strong growth in applications has been seen and this is a trend which will continue, as explained below. In terms of total capacity since 2001, fuel cells only account for 23%, compared to more than 53% for internal combustion engines (ICE).

In terms of incentives paid however, fuel cells have enjoyed a much larger percentage of the available funds, taking almost 65%, compared to less than 20% for ICE. This highlights the relatively high cost of newer technologies such as fuel cells when compared to the more mature ICE.

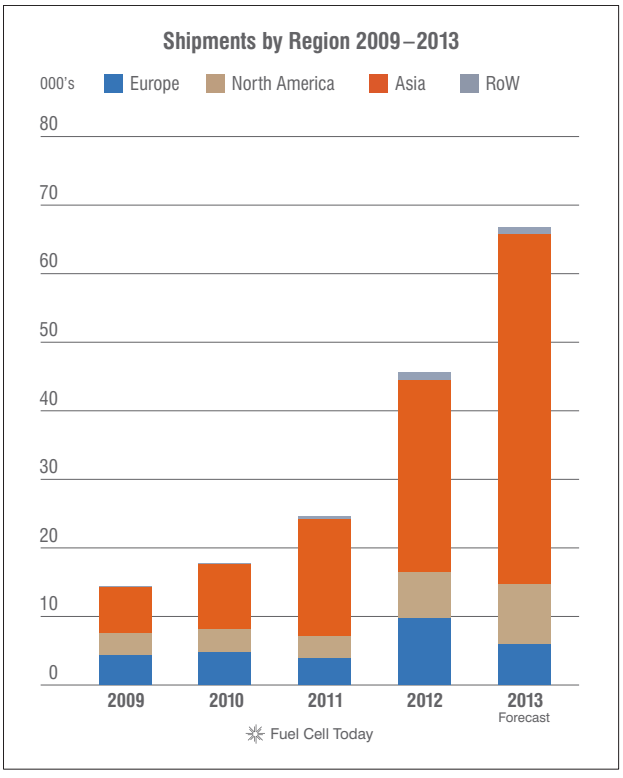
From 2011, there has been a significant shift in the choice of technology that applicants to the programme have submitted. During 2011 and 2012 the vast majority of completed payments have been for fuel cell installations, accounting for 90% of projects and 76% of installed capacity. This shift in technology choice towards fuel cells (solar PV is not included in the SGIP) has been taking place progressively and looking at the breakdown of new applications implies that the trend is set to continue.

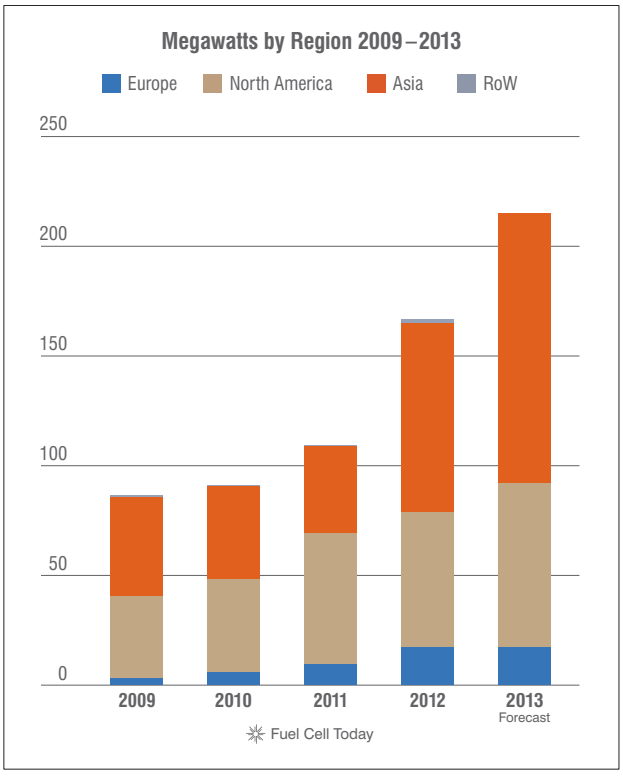


Developments by Region

Regionally, unit shipments of fuel cell systems in 2012 followed a similar trend to the previous year, with Asia dominating adoption of the technology. 61% of all units shipped (28,000 units) went to the region in 2012, a slightly smaller percentage than in 2011. With Japan, Korea and a number of other countries actively installing fuel cells for backup power and micro-CHP, and with fleets of fuel cell cars, scooters and buses on the roads as well as growing interest from new players, we expect this dominance to continue in the years to come.

In particular, Korea is the leading country of adoption for large stationary fuel cell systems, and as a result the Asia region also dominates in terms of megawatts shipped in 2012 with 86.1 MW or 52% of the total. North America is another significant contributor to annual megawatts shipped due to a combination of its support for domestically-manufactured large stationary fuel cells and its adoption of fuel cells for materials handling equipment.





Korea is the leading country of adoption for large stationary fuel cell systems

Inter-regional efforts to collaborate on fuel cell technology also continued to grow throughout 2012 and the fourth EU–US Energy Council met in Brussels in December 2012 to reaffirm the importance of EU–US cooperation in energy research and innovation. The Energy Council oversees work to guide cooperation through joint research, twinning of projects and exchange of researchers focused on four priority areas, one of which is hydrogen and fuel cells.

Hydrogen and fuel cell associations also continued to collaborate during 2012 and into 2013, forming strategic partnerships to advance the adoption of fuel cell technology. The Canadian Hydrogen

and Fuel Cell Association was particularly active, signing a memorandum of understanding with the Scottish Hydrogen and Fuel Cell Association and a partnership agreement with the Spanish Hydrogen Association. These agreements are intended to promote relationships and technology transfer between the different countries to mutual benefit.

Hydrogen and fuel cell associations continued to collaborate in 2012 and into 2013

Europe

In Europe, 2013 marks the final year of the European Union's (EU) current funding programme and the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), and much effort has been focused on what form its next iteration will take and how much funding should be allocated. The eighth iteration of the EU Framework Programme for Reseach and Innovation is called Horizon 2020 and current proposals are to reincarnate the existing public–private partnership as FCH JU 2, with special focus on sustainable transport and energy security. The total budget is €1.4 billion ($1.8 billion, £1.2 billion), between 2014 and 2020, supplied in equal share between private sector companies and the European Union.

Also at a European level, the European Commission (EC) published a proposal including measures aimed at supporting the development of alternative fuels in its Member States. The proposal includes a set of binding targets for hydrogen infrastructure, including the introduction of common standards for fuel hoses and the linking of existing and planned hydrogen stations to create a network across Europe. This would apply to the 14 Member States with existing hydrogen networks. Also relating to European standards for hydrogen vehicles, the EU published Commission Regulation (EU) No. 630/2012, which includes emissions requirements for vehicles using pure hydrogen or a mixture of hydrogen and natural gas (H2NG). This is an amendment to its Euro 5/6 light duty regulations and includes new definitions for hydrogen fuel cell electric vehicles (FCEV) and electric powertrains, and a hydrogen reference fuel specification for FCEV (minimum 99.99% H_2) was also added.

The 8th iteration of the EU Framework Programme for Reseach and Innovation is Horizon 2020

The provision of hydrogen as a fuel for vehicles has been a topic that has been discussed in detail at a regional level resulting in the creation of a number of national 'hydrogen mobility' groups. In the United Kingdom, the UK H_2Mobility project presented the findings from its first year early in 2013. The project identified three phases were needed for the rollout of hydrogen refuelling stations (HRS) in the UK. Initially 65 HRS would be deployed by 2015 which would be sufficient to service the major population centres and connecting roads. Before 2025, this network would need to be expanded to 330 HRS to provide close-to-home refuelling for 50% of the UK population. By 2030, full coverage could be achieved with the deployment of 1,500 HRS. Also during this time, the mix of technologies used to produce hydrogen is expected to change from existing methods (mainly steam methane reforming) to a mix containing more than 50% water electrolysis; this would give a carbon dioxide emissions reduction of 75% by 2030 when compared with diesel engines.

Finland published its Hydrogen Roadmap in April 2013, which found that a changeover to hydrogen-fuelled transportation would result in a significant saving to Finland's balance of payments for fuel imports, even when the hydrogen was produced from natural gas. If hydrogen could then be

The French have launched a hydrogen infrastructure programme: Mobilité Hydrogène France

produced from domestic renewable raw material the country's car and bus traffic could eventually become self-sufficient and it could also significantly reduce its carbon footprint.

France is the latest country to announce the launch of a hydrogen infrastructure programme with Mobilité Hydrogène France launching in July 2013. A consortium of twenty partner members including gas production, storage, energy utilities and government departments, its aim is to formulate an economically competitive deployment plan for a private and public hydrogen refuelling infrastructure in France between 2015 and 2030, including an analysis of cost-effectiveness.

In the stationary sector, the ene.field European field trial for fuel cell residential micro-CHP was launched in September 2012 and brings together 27 project partners, including nine European fuel cell manufacturers, with plans to install around 1,000 fuel cell micro-CHP systems over the next five years. Project participants have also held meetings with members of the Callux project to gain experience from Germany's biggest demonstration to date of fuel cell heating systems for domestic use.

Feed-in tariffs are an important mechanism to support the introduction of residential cleantech in Europe, as has been seen with the introduction and soaring popularity of solar PV. The North-Rhine Westphalia Government launched its capital subsidy scheme for highly efficient CHP (including fuel cells) in late 2012. The scheme will run until 2017 and is expected to cover around half the capital cost of micro-CHP fuel cells. In the UK, the Government has increased the feed-in tariff applicable to fuel cells from 14.2 p/kWh up to 17 p/kWh in order to encourage adoption of the micro-CHP technologies.

North America

In North America there is strong support for fuel cells and hydrogen technologies, led by the US Government and the activities of the US Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE). In late 2012 EERE published an update on the commercial successes of its Fuel Cell Technologies Program, identifying 36 commercial technologies relating to fuel cells and hydrogen that have entered the market since 2000; all but one of these technologies was still available when the report was published, highlighting the success of the programme.

Support for fuel cell technology in the USA reaches to the highest levels with members of the US Senate launching a new bipartisan fuel cell and hydrogen caucus in summer 2012. The caucus is intended to promote the continued development and commercialisation of hydrogen and fuel cell technologies in the United States and, in April 2013, 27 Representatives signed a letter requesting $147.8 million (£95.8 million) in funding for the fuel cell and hydrogen energy program and $50 million (£32.4 million) for the solid state energy conversion alliance (SECA) solid oxide fuel cell program as part of the FY 2014 Energy and Water Appropriations Bill. The President is also supportive of fuel cell technology, including it as part of his 'all of the above' energy strategy and he called on Congress to establish an Energy Security Trust, which would divert revenue from oil and gas exploitation on the US outer continental shelf. He proposes to set aside $2 billion (£1.3 billion) to develop technologies, including fuel cells, which will wean the USA off fossil fuels.

Following in the footsteps of other regions, the USA launched its own hydrogen infrastructure project in May 2013, H2USA. California has typically led the USA in terms of automotive legislation to reduce emissions, and has done so for automotive fuel cells too, installing a number of hydrogen

refuelling stations across the state. H2USA is looking to build upon this existing base, but across the whole country, advancing the development of a hydrogen infrastructure and preparing the USA for the imminent introduction of fuel cell electric vehicles.

Asia

Japanese support for fuel cells has always been strong and is continuing apace, with the continuation of capital subsidies for domestic fuel cells and Japanese automakers announcing international collaborations aimed at sharing expertise and maximising market opportunities when they begin to commercially launch fuel cell vehicles from 2015. Infrastructure development is also continuing, and HySUT continues to coordinate this effort. Commitments have been secured from JX Nippon Oil & Energy Corp. to build 40 hydrogen stations by 2015 and Iwatani has committed to build 20 stations, which puts Japan well on its way to its current target of 100 hydrogen refuelling stations by 2015.

The Ene-Farm residential micro-CHP scheme is expecting its highest ever level of annual sales to date in 2013, following the rapid depletion of several subsidy grants in 2012. Japanese companies are also now collaborating with foreign companies to modify their systems for use abroad, especially in the European market. Panasonic's £2.5 million ($3.8 million) fuel cell research and development centre in Cardiff, Wales opened in September 2012 and will adapt and modify the company's Japanese domestic fuel cells for the UK and further European markets.

Japan is well on its way to building 100 hydrogen refuelling stations by 2015

In October 2012 the Chinese Central Government pledged to provide funding for technological innovation projects in the auto industry, although the level of funding was not disclosed. The funding is intended to speed up commercialisation of 'new energy vehicles' including battery electric, plug-in hybrid and fuel cell vehicles.

In Taiwan, a fleet of fuel cell scooters is already on the road, fuelled by hydrogen stored in easily exchangeable canisters, as explained on page 22. The country's Ministry of Economic Affairs is working to create a global version of the safety and reliability standard for hydrogen fuel cell motorcycles, which APFCT's fuel cell scooters were assessed against and passed. APFCT's fleet has accumulated more than 120,000 kilometres (three times the circumference of the Earth) in cities, mountain and seaside areas; the first such test for fuel cell motorbikes in the world.

Rest of World

The Rest of World region is highly disparate, with pockets of significant fuel cell interest, but when assessed as a whole it is not as well developed as the other world regions we analyse. Despite a modest decrease in annual shipments to the region, fuel cells continue to globalise and there is a growing interest in their use for power-support applications in emerging markets.

Fuel cells continue to globalise and there is a growing interest for power-support applications in emerging markets

In South Africa, the Government has announced its support for a project to trial residential fuel cells. As part of the Government's beneficiation strategy and its drive to develop additional uses of platinum it will partner with Ballard Power Systems and Anglo American Platinum on field trials of a methanol-fuelled residential fuel cell system. The home generator product is being developed as

a means of addressing the many households in rural South African communities that are currently unable to economically access the grid as a result of distance or terrain. Households that are more than 14 km from the nearest grid connection are currently the most economically suitable for fuel cell deployment.

There has been a noticeable rise in interest for fuel cell backup power in telecoms

The use of mobile telephony in emerging economies is booming and the increasing dependency on electronics for economic growth is at odds with the underdeveloped electricity grid infrastructures in many of these countries. As such, there has been a noticeable rise in interest for long-lasting and reliable fuel cell backup power and uninterruptible power supply systems in these countries. In May 2013, Oorja Protonics executed a multi-party memorandum of understanding for the evaluation and demonstration of its DMFC systems for the South African telecom tower market.

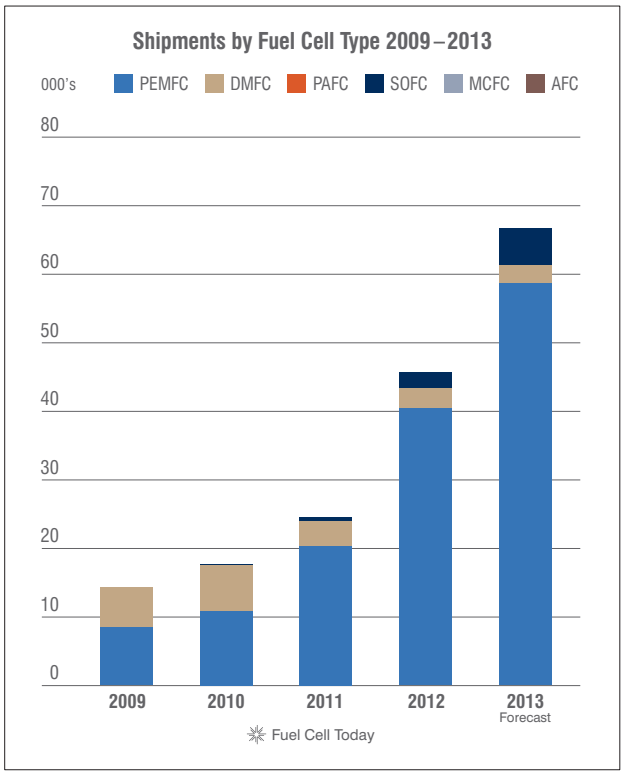
As discussed in the Fuel and Infrastructure section of this report on page 22, methanol is an extremely popular fuel for use in remote locations and countries that do not have existing hydrogen consuming industries. As of May 2013, more than 270 Ballard ElectraGen-ME methanol fuel cell backup systems have been deployed in sixteen Carribbean and Latin American telecommunications networks. Electrical grids in this region are particularly susceptible to damage from extreme weather conditions and the demand for reliable backup power systems in these challenging environments is strong. In Indonesia, wireless operator XL has selected methanol-fuelled fuel cells from Cascadiant to provide backup power for critical sites on the island of Kalimantan.

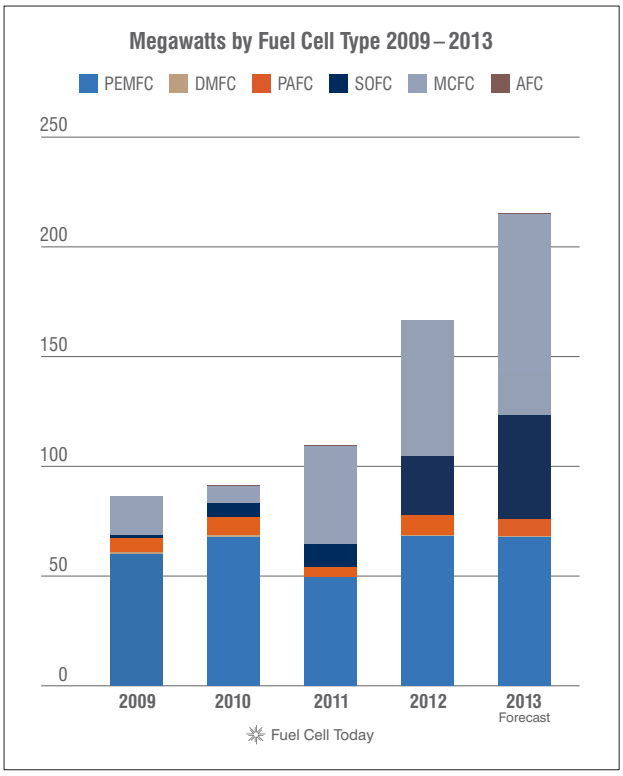
In September 2012, Victoria became the first State in Australia to provide a feed-in tariff for which fuel cells are eligible. The Victorian Government has accepted the recommendations of the Victorian Competition and Efficiency Commission (VCEC), which began a review into feed-in tariffs in January 2012. Ceramic Fuel Cells, the Australia-headquartered company that develops fuel cell systems for homes and other buildings, was involved in the consultation process with VCEC.

Victoria's solar power feed-in tariff will be broadened to include all low-emissions and renewable technologies of less than 100 kilowatts. From 1 January 2013, the new tariff has initially provided a minimum of 8 Australian cents per kilowatt hour of electricity exported to the grid, which is based on the adjusted wholesale price of electricity. The rate will be updated each year in line with the adjusted wholesale electricity rate. The feed-in tariff will be available for electricity generators whose technology produces 50% or less of the emissions intensity of conventional electricity generation in Australia: Ceramic Fuel Cells' BlueGen fuel cell unit will thus be eligible for this feed-in tariff.

Developments by Electrolyte

The dominance of PEMFC technology in recent years continued throughout 2012 in terms of the number of fuel cell units shipped. PEMFC technology is well suited to a range of sizes and is also used with a variety of different fuel types, when suitably processed to generate hydrogen. As such it finds application from the small, sub-watt scale, right through to the megawatt scale. 88% of total fuel cell shipments in 2012 were PEMFC, and this trend is expected to continue for the future as this type of fuel cell is the preferred choice for automotive applications.





Nonetheless, the other five types of commercially available fuel cells also saw growth in 2012, and this can clearly be seen in the chart of megawatts shipped by fuel cell type. During the past two years, MCFC technology has established itself on an equal footing with PEMFC in terms of megawatts shipped and this is largely due to adoption of large stationary power plants in the United States and in Korea. This trend is expected to continue and in 2013 we forecast that more megawatts of MCFC will be shipped than any other fuel cell type. SOFC technology is also firmly established, with an increasing penetration of residential micro-CHP in Japan, and megawatt-scale installations in the USA by Bloom Energy.

During the past two years, MCFC has established itself on an equal footing with PEMFC in terms of megawatts shipped

Polymer Electrolyte Fuel Cells

Polymer electrolyte membrane fuel cells have been the most popular and versatile of the six fuel cell technologies on the market. Systems have ranged in size from tiny educational kits and watt-scale chargers for consumer electronics, right up to 1 MW stationary power generators. The sheer diversity of applications from cars and buses to backup power devices and residential micro-CHP can be considered both a blessing and a curse. On the positive side, the popularity of PEMFC has encouraged intensive research and development, by both industry and academia alike, leading to improvements in lifetimes, durability and cost reduction. On the negative side, these various applications have resulted in the development of unique designs in each case meaning standardisation is not commonplace; the relatively small numbers of fuel cells produced each year for the different applications has also meant economies of scale for manufacturing have not been realised.

The image of fuel cells that captures the hearts of the public has always been that of fuel cell vehicles driving on our streets producing water vapour as their only emission. As we mention in the Transport section of this Review on page 16, the global automakers are now gearing up for commercialisation with Hyundai leading the industry with series production of its ix35 Fuel Cell vehicle already underway. Automotive fuel cells all use PEMFC technology, and to produce hundreds or even thousands of cars, manual assembly of fuel cell components can no longer be an option. Automated coating, assembly of membrane electrode assemblies (MEA) and stacking will all need to be improved in the next two years in order for these vehicles to arrive on our roads.

The benefits of automated production are not simply cost reduction through economies of scale. When you are manufacturing hundreds of thousands of MEA it is most cost-effective to encourage customers to adopt common electrode platforms, because manufacturers can run the equipment without changing the raw materials feeding it; changing the size and dimensions of components can be more flexible, by simply programming different parameters into the equipment. Removing the human aspect also improves overall quality, with the same results achievable for every component. These areas are where the real improvements in PEMFC will be seen in the coming years, led by the automotive industry. The standardisation of electrochemistry and automation leading to quality improvements will both combine to enable mass manufacture on a scale never before seen for fuel cells. If the other market applications currently using fuel cell technology align themselves with this process, they will inevitably reap the rewards which the automakers require in order to commercialise.

Automated manufacture of MEA and stacks will need to be improved for fuel cell vehicles to arrive on our roads

Component suppliers to the PEMFC market are focusing their efforts in this area. Tanaka Kikinzoku Kogyo K.K. (Tanaka) has constructed a dedicated plant for the manufacture of fuel cell catalysts. This new facility will allow Tanaka to quickly increase production capacity to meet future fuel cell catalyst demand for the residential micro-CHP sector; the plant is expected to be in full operation by October 2013.

Johnson Matthey Fuel Cells is also investing in manufacturing techniques that automate the production of membrane electrode assemblies. As explained above, this is an essential next step in the evolution of PEM technology gearing up to the widespread launch of fuel cell cars in the coming years.

Another established supplier to the PEMFC market, BASF, announced a restructuring of its fuel cell activities in early August 2013 and is exiting the manufacture of membrane electrode assemblies (it predominantly focused on HT-PEMFC technology). In the future BASF will focus on catalysts and adsorbents for fuel cells, managing these products through its Catalysts division. Other companies who manufacture HT-PEMFC MEAs including Advent Technologies and Danish Power Systems intend to increase their market share as a result of BASF's exit.

Platinum is almost uniquely stable under fuel cell operating conditions

Platinum remains a focal point for many, who say its cost and perceived limits to its availability will cause issues for the long-term viability of PEMFC. Substitute catalysts for PEMFC are always under development and in some instances claims are made based upon laboratory experiments, which in certain cases do not relate to the real-world conditions under which PEMFC operate. Base metal or graphene-based systems have all been suggested as possible alternatives, not only for hydrogen PEMFC, but also for those operating with reformed natural gas and even methanol fuel cells, but care must be taken to note the conditions under which testing takes place. Often alkaline conditions are used, which are not representative of the acidic conditions of PEMFC or DMFC. A reasonable proxy for the likelihood of eliminating platinum can be seen in the automotive industry, where precious metals are used in catalytic converters to abate diesel emissions. After decades of research and development, platinum is still the metal of choice for this reaction, simply because it offers the best performance. Improvements are made to the catalysts enabling progressively reduced platinum loadings and the same is true for platinum-containing fuel cells. The working environment inside a fuel cell is highly aggressive and corrosive, with heat, water, acidity and electrochemistry all conspiring to destabilise the vast majority of metal catalysts which could otherwise perform the same chemical transformations. Platinum is almost uniquely stable under these conditions, and so the most likely way to reduce platinum loadings is to improve catalyst dispersion and stability to enable less metal to meet the durability and lifetimes expected.

The US DOE is targetting platinum loading reductions of 61% in terms of cost per kilowatt

One potential alternative that appears to be gathering momentum is the approach taken by ACAL Energy (ACAL). It has replaced the cathode side of the fuel cell with a system similar to a redox flow battery. This means that no platinum is required on the cathode side of the fuel cell, reducing overall loadings by up to 80%. ACAL still requires platinum for the anode side of the fuel cell, where the fuel is processed, but the replacement of the cathode is said to offer cost reductions of close to 25%. Durability testing of its fuel cell under a standard automotive drive cycle has reached 10,000 hours, equivalent to 300,000 miles and the company is in talks with major automotive OEMs. The US DOE has published targets for platinum loading reductions, in terms of cost per kilowatt, which it believes are necessary for the widespread global commercialisation of PEMFC in automotive

applications. Currently a 61% reduction would be required by 2017, versus 2011 loadings, so if ACAL's technology is proven commercially it could offer an attractive way to reach this target.

Direct Methanol Fuel Cells

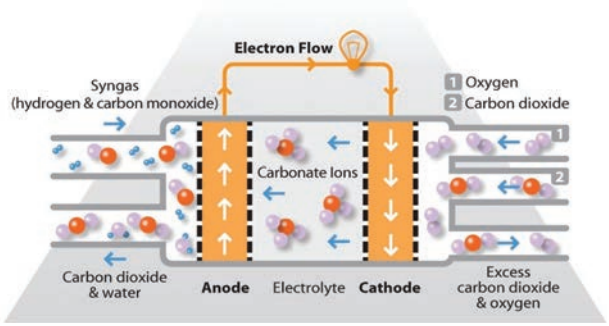
The market for direct methanol fuel cells continues to be led by German company SFC Energy (SFC). Its product range targets auxiliary power and off-grid applications and the company also develops units for military operations. SFC has entered into a number of partnerships during the past year in order to expand its regional reach both in terms of fuel cell sales, and also the necessary fuel.

In July 2013 SFC acquired Simark Controls, a Canadian distributing company with product integration and manufacturing expertise for power products, instrumentation and automation that serves the oil and gas industry as well as the mining, forestry and community supply markets. SFC hopes this purchase will expand the market for its existing fuel cell products to include the oil and gas sector.

Molten Carbonate Fuel Cells

The sole commercial developer of molten carbonate fuel cells (MCFC) is US-based FuelCell Energy (FCE) which manufactures large stationary systems in sizes of 300 kW, 1.4 MW and 2.8 MW. It is currently enjoying success in the Democratic Republic of Korea market through its manufacturing partnership with utility POSCO Energy. FCE ships 1.4 MW fuel cell kits to Korea which POSCO assembles at its balance of plant facility to make the products from FCE's range. In November 2012, POSCO placed the largest order FCE had ever received, for a total of 121.8 MW of fuel cell kits, leading FCE to increase its manufacturing capacity in order to meet the additional demand; FCE's manufacturing capacity is expected to reach 70 MW in 2013, above the level at which the company believes it can achieve positive quarterly gross margins. The two companies have also entered into a licensing agreement whereby POSCO will manufacture full fuel cell systems at an upgraded facility in Pohang from late 2014 or early 2015. The upgraded facility will provide fuel cell systems for the wider Asian market and under the agreement POSCO will pay FCE a royalty of 3% on every system it sells for the next fifteen years.

POSCO placed the largest MCFC order ever, for a total of 121.8 MW of fuel cell kits



FCE's domestic market in the USA is also continuing to grow, and with full-scale manufacture taking place in Korea within two years, FCE will be looking to expand the markets serviced from its US facility. Tri-generation facilities are still of interest and further to its installation at the water treatment facility in Orange County FCE has installed a demonstration unit at a landfill site in Vancouver. The unit will process landfill gas to produce electricity, heat and also hydrogen. Successful demonstration could lead to an expansion in deployments at landfill sites, turning a source of waste into a potential revenue stream. The company also announced it would build a 14.9 MW fuel cell park in its home state of Connecticut, providing enough power for 15,000 US homes. FCE will own and operate the plant and sell the electricity to utility Connecticut Light and Power under a fifteen year power purchase agreement.

MCFC could potentially mitigate the emissions of fossil-fuelled power plants

Another development that is unique to this fuel cell type is a DOE funded project looking to use FCE's MCFC technology for carbon capture. The project aims to demonstrate that directing the relatively dilute CO_2 exhaust from coal-fired power plants into the air intake of an MCFC will allow the fuel cell to operate as usual, producing a concentrated CO_2 output. MCFC technology requires a source of CO_2 in order to operate, so this could be a potential solution to mitigating the emissions of existing fossil-fuelled power plants if suitable sequestration techniques can be found for the carbon.

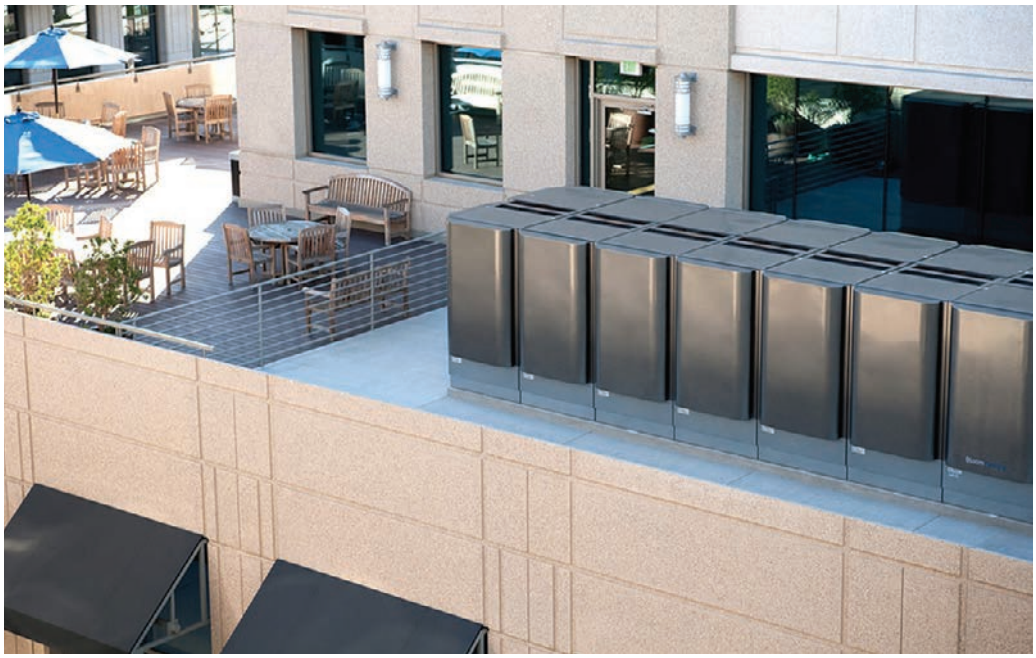
Solid Oxide Fuel Cells

Solid oxide fuel cells (SOFC) remain a popular technology, particularly in the stationary sector as explained earlier. The most high profile announcements during the past year have centred on Bloom Energy which has received over $1.2 billion (£778 million) in funding in the twelve years since it began operation. To date Bloom has concentrated on its domestic market, finding customers from States that have favourable incentive programs in place for fuel cells, but a number of announcements during the past year indicate the company is looking to expand its operations overseas. Bloom entered into a 50/50 joint venture with Japan's third largest telecom provider, SoftBank. The joint venture plans to install its first 200 kW fuel cell system in the Fukuoka hydrogen town.

Bloom also received a €91.5 million ($120 million, £77.8 million) investment from German utility E.ON, the world's largest investor-owned electricity utility, and such a large sum of money could suggest E.ON is positioning itself to introduce fuel cell power plants to the European market.

Bloom entered into a 50/50 joint venture with Japan's third largest telecom provider

In Japan, Mitsubishi Heavy Industries is developing a hybrid SOFC system that it claims will result in improvements in power generation efficiency on the order of 10-20%. The company is integrating a large SOFC with a combined cycle gas turbine and is expecting to enable hundreds of megawatts of power generation at efficiencies greater than 70% (LHV).



UTC announced the sale of UTC Power to ClearEdge Power

Phosphoric Acid Fuel Cells

For many years the leading company in the field of phosphoric acid fuel cells (PAFC) was UTC Power, formerly owned by United Technologies Corp. (UTC), which we reported in our 2012 Review was trying to sell its fuel cell business. After more than six months on the market, UTC announced the sale of UTC Power to ClearEdge Power (CEP). The terms of the sale were not disclosed at first, but UTC has since published its first quarter 2013 results detailing a payment of $49 million (£31.8 million) to ClearEdge, which covered 'capitalization of the business prior to the sale and interim funding of operations as the buyer took control of a loss generating business.'

Alkaline fuel cell electrode lifetimes have increased to twelve months

Since starting business in 2003, CEP has focused on the commercialisation of 5 kW stationary fuel cells based upon high-temperature PEMFC, so it was interesting to see it take control of a loss making PAFC business. HT-PEMFC has generally struggled to deliver on performance and durability due to certain technical issues and since the two technologies are not too dissimilar this acquisition should enable CEP to improve its technology based upon the intellectual property it has obtained. CEP has also restructured its manufacturing base, reducing its workforce in Connecticut by 39% shortly after the acquisition. It continues to sell 400 kW PAFC systems under the PureCell® brand and, with a reduced cost base for manufacturing, its financial circumstances could be better than those which encouraged UTC to sell the business.

Fuji Electric has also continued with its development of PAFC technology with its smaller, 100 kW system which it is aiming to install at a number of its facilities across Japan. It has also maintained its collaboration with N2telligence targeting markets which can take advantage of the inherent fire suppression capabilities of fuel cells. In operation, the exhaust from air-breathing fuel cells produces air with reduced oxygen content. This air can be directed into workplaces where fire prevention for critical infrastructure is imperative, such as in data centres. The environment is safe for people to work in, with a high enough oxygen content to breathe but not sufficient to support combustion. Equinix recently installed a 100 kW PAFC from Fuji Electric at its data centre in Frankfurt, Germany for just this purpose. The electricity generated by the fuel cell can be used to power the data centre and the associated heat can be used in adsorption chillers for cooling purposes.

Alkaline Fuel Cells

The development of alkaline fuel cells continues to be dominated by UK-based AFC Energy, which is continuing research to improve its fuel cell systems while targeting the market for stationary power generation. The company also received a high-profile investment of £8.7 million ($13.4 million) from Ervington Investments Ltd, an investment company owned by Russian business tycoon Roman Abramovich.

At the time of our 2012 Review, AFC Energy was reporting a lifetime for its electrodes of three months, which it claimed was the minimum required for its technology to be economical in certain applications. Since then AFC Energy's research has progressed well, and lifetimes have increased such that, under laboratory conditions, its electrodes now have a lifetime of twelve months. This fourfold increase in durability has been achieved in conjunction with a 60% increase in power output for its fuel cell systems and the company is now aiming to reproduce these results under real-world conditions at customer sites. AFC Energy's first commercial system will be known as Kore and will be sized at 250 kW. This is likely to be the building block used for the 1 MW alkaline fuel cell system to be installed at the UK-based chlor-alkali facility of Industrial Chemicals Limited (ICL), which was announced last year and funded by a grant of up to €6 million ($7.9 million, £5.1 million) from the FCH JU; AFC Energy's Beta fuel cell system was delivered to ICL in early 2013 and is already in operation at the plant.

AFC Energy continues to view Korea as a potentially lucrative market for expansion, due to its favourable incentives for stationary fuel cell systems, and is actively seeking new partners there. The company opened its first office in the country in February 2013.

AFC Energy is the project lead for an FCH JU funded project, Alkamonia, which looks to develop ammonia as a fuel soure for alkaline fuel cells. As part of the project, AFC Energy aquired select assets from Diverse Energy, who had been developing ammonia-fuelled PEMFC telecommunications backup power systems for African markets before a failed funding round. Other project partners include Acta, who is supplying ammonia cracking catalysts, and integrator Fuel Cell Systems, who will design and develop power-conditioning equipment and integrate the final product.

Outlook

In our 2012 Industry Review we said that we expected the industry as a whole to 'go from strength to strength' and this is a view we have maintained throughout 2013. Despite setbacks during the year, 2012 outshone 2011 in terms of shipments and megawatts and 2013 is on track to eclipse all previous years and set new records for the industry. Looking to the future, the imminent launch of fuel cell electric vehicles and the global adoption of stationary fuel cells is expected to provide manifold benefits to the industry.

Despite setbacks during the year, 2012 outshone 2011 in terms of shipments and megawatts.

Portable

The market for portable fuel cells encompasses a wide range of sub-applications, from auxiliary power units to consumer electronics. It is the latter which has the biggest scope in term of market size with mobile devices permeating every aspect of our lives. Last year we expected the launch of a number of charging products aimed at the consumer electronics market, and the sale of tens of thousands of units. While actual shipments ended the year considerably lower than that forecast, a number of key partnerships were formed that should pave the way for increased growth in the future. Outdoor retailers REI and Brunton in the USA specialise in selling products to power electronic devices in off-grid environments, and with fuel cells now in their product portfolio the technology will benefit from the brand recognition and marketing opportunities these companies can offer.

Military portable devices, for both vehicular and soldier-borne power are also gaining recognition and adoption is increasing. While the benefits in terms of weight reduction and reduced fuel consumption are known, it can be difficult to introduce new technologies using new fuels into such a regimented environment. Nevertheless, adoption is increasing and we expect this application for portable fuel cells to grow from the strong position it has established. Orders in this area are irregular, but a significant order from a major armed force could be a turning point for the portable sector.

Stationary

Stationary fuel cells dominate in terms of both unit shipments and MW

The prospect for strong growth in stationary fuel cells at all scales has true potential in the coming years. At the large scale, fuel cells for prime power have been successfully deployed in Korea and North America and this looks set to continue with Korea leading the way and deploying multi-megawatt fuel cell power plants. Europe also holds promise, and companies such as FuelCell Energy have formed joint ventures there to exploit the opportunity. In Japan, large stationary deployments to date have been limited to domestic provider Fuji Electric, but a recent agreement between Bloom Energy and Softbank, Japan's third largest telecommunications company, is set to change this. The two companies see a wealth of opportunities for distributed fuel cell prime power in Japan and will be targeting this sector.

Residential micro-CHP fuel cells outsold conventional micro-CHP boilers for the first time in 2012, and with the growth expected in Japan alone we would expect fuel cells to remain the dominant technology in this sector. Larger-scale European field trials are underway, and if they follow the same trajectory as those in Japan significant shipments of fuel cells could be expected once the demonstration phase moves towards commercialisation.

Fuel cell technology has also proven itself as a viable backup power option in telecommunications markets worldwide, and as the cost of the technology decreases this value proposition will only improve. There is a lot of interest in the Chinese telecommunications sector, one of the fastest growing telecoms markets in the world and home to two of the largest mobile providers in the world; there is potential for fuel cells to make a significant impact here. Continued deployment elsewhere in Asia, Europe and North America will also support shipments in the near term.

Fully automated fuel cell manufacturing will improve quality and lower costs

Transport

The transport sector will fundamentally drive improvements across the PEMFC industry over the coming years. All of the major global automakers have fuel cell development programmes underway and all have plans to launch vehicles between 2015 and 2020; Hyundai is preceding its launch with a run of 1,000 vehicles for lease between 2013 and 2015. The scale of these FCEV launches will be small by automotive standards, but relatively large by the standards of the fuel cell industry. One key difference from current fuel cell manufacturing is that the manufacture of vehicles will be setup at much larger scales, with fully automated processes and high levels of quality control and reproducibility. This will bring benefits not only in terms of reduced costs, and raised standards, but is likely to encourage standardisation across the wider PEMFC market as the benefits can be exploited in other applications.

It will be interesting to see the impact of these improvements in other applications, such as buses, which have been expensive to date and have relied heavily on subsidies. When fuel cells can compete on capital cost with incumbent technologies this will open the floodgates to wider deployment of the technology. Currently fuel cells compete on cost on a total cost of ownership basis, but if capital costs can be reduced the added benefits fuel cells offer will make them the preferred choice.

Conclusion

It is quite conceivable that by 2015 the size of the fuel cell industry could be measured in gigawatts

In 2013 we expect the fuel cell industry to ship in excess of 200 megawatts of systems, its highest total to date and 30% higher than the previous year. This growth shows no signs of slowing, and with continued growth in all existing sectors and a successful launch of fuel cell electric vehicles expected by 2015 it is quite conceivable that the size of the industry could be measured in gigawatts within the next five years.

Data Tables

Annual Unit Shipments 2009–2013

Shipments by application					
'000 Units	2009	2010	2011	2012	*2013*
Portable	5.7	6.8	6.9	18.9	*13.0*
Stationary	6.7	8.3	16.1	24.1	*51.8*
Transport	2.0	2.6	1.6	2.7	*2.0*
Total	**14.4**	**17.7**	**24.6**	**45.7**	***66.8***

Shipments by region					
'000 Units	2009	2010	2011	2012	*2013*
Europe	4.4	4.8	3.9	9.7	*6.0*
N America	3.2	3.3	3.3	6.8	*8.7*
Asia	6.7	9.5	17.0	28.0	*51.1*
RoW	0.1	0.1	0.4	1.2	*1.0*
Total	**14.4**	**17.7**	**24.6**	**45.7**	***66.8***

Shipments by fuel cell type					
'000 Units	2009	2010	2011	2012	*2013*
PEMFC	8.5	10.9	20.4	40.4	*58.7*
DMFC	5.8	6.7	3.6	3.0	*2.6*
PAFC	0.0	0.0	0.0	0.0	*0.0*
SOFC	0.1	0.1	0.6	2.3	*5.5*
MCFC	0.0	0.0	0.0	0.0	*0.0*
AFC	0.0	0.0	0.0	0.0	*0.0*
Total	**14.4**	**17.7**	**24.6**	**45.7**	***66.8***

Throughout the five-year period, portable shipments have been underpinned by sales of fuel cell APU into the leisure segment. Portable unit shipments increased in 2012 with the launch of fuel cell consumer electronics charging devices, but 2013 sales are expected to be lower as the technology establishes itself in this market. Shipments of stationary fuel cells have ramped up steadily since 2009 with deployments of micro-CHP, particularly in Asia, as well as UPS in North America. In the transport sector, hundreds of fuel cell materials handling vehicles have been shipped, particularly since the start of large-scale demonstration programmes from 2008/2009.

Asia has been the dominant region of fuel cell adoption for the past five years with growth from 2009 onwards due to the commercial deployment of Japanese fuel cell micro-CHP products. North America has experienced consistent unit shipments of fuel cell systems since 2009 with the roll-out of FCEV and materials handling demonstration fleets under the Recovery Act, sales of portable fuel cells, stationary prime power and UPS shipments but remained flat for the following three years.

For the past five years applications using PEMFC have grown rapidly. PEMFC technology dominates fuel cell shipments due to its widespread use in small stationary, transport and portable applications. Due to the relatively small number of PAFC, AFC and MCFC units shipped and the impact of rounding, no values appear in the table above. In 2013 SOFC is expected to overtake DMFC in terms of the number of units shipped – this is due to shipments of stationary systems in the Japanese Ene-Farm scheme.

Annual Megawatts Shipped 2009–2013

Megawatts by application						
	MW	2009	2010	2011	2012	*2013*
	Portable	1.5	0.4	0.4	0.5	*0.3*
	Stationary	35.4	35.0	81.4	124.9	*186.9*
	Transport	49.6	55.8	27.6	41.3	*28.1*
	Total	**86.5**	**91.2**	**109.4**	**166.7**	***215.3***

Megawatts by region						
	MW	2009	2010	2011	2012	*2013*
	Europe	2.9	5.8	9.4	17.3	*17.3*
	N America	37.6	42.5	59.6	61.5	*74.7*
	Asia	45.3	42.5	39.6	86.1	*122.9*
	RoW	0.7	0.4	0.8	1.8	*0.4*
	Total	**86.5**	**91.2**	**109.4**	**166.7**	***215.3***

Megawatts by fuel cell type						
	MW	2009	2010	2011	2012	*2013*
	PEMFC	60.0	67.7	49.2	68.3	*68.0*
	DMFC	1.1	1.1	0.4	0.3	*0.2*
	PAFC	6.3	7.9	4.6	9.2	*7.9*
	SOFC	1.1	6.7	10.6	26.9	*47.0*
	MCFC	18.0	7.7	44.5	62.0	*91.9*
	AFC	0.0	0.1	0.1	0.0	*0.3*
	Total	**86.5**	**91.2**	**109.4**	**166.7**	***215.3***

In terms of megawatts shipped, 2012 broke the 150 MW barrier for the first time. The stationary sector remains the largest, indicating the importance of large stationary installations as well as the high number of micro-CHP units adopted in Asia. The impact of materials handling vehicles and FCEV demonstration programmes can be seen in 2009 and 2010 when there were significant increases in megawatts shipped in the transport sector versus recent years. Although portable fuel cells are important in terms of unit shipments, due to their small size they are a minimal contributor in terms of shipments by megawatt.

Over the last five years, North America and Asia have competed for position as the leading region of adoption by megawatt. This is largely explained by the role of large stationary prime power and CHP/UPS in those regions. In 2012 and 2013, Asia has emerged as the dominant region of fuel cell adoption due to its adoption of large, multi-megawatt stationary units in recent years.

PEMFC technology is used in a range of application segments, for instance in transport and stationary applications, and has a power range up to hundreds of kilowatts. Therefore PEMFC has contributed around 50% of the shipments by megawatt since 2009. Due to the large size of many stationary MCFC and SOFC units, the dominance of PEMFC by MW is waning and we expect MCFC become the leading fuel cell type in terms of megawatt in 2013.

Table Notes

- Our 2013 figures are a forecast for the full year.
- The regional numbers represent system shipments by region of adoption.
- Unit numbers are rounded to the nearest 100 units. An entry of zero indicates fewer than 50 systems were shipped in that year.
- Megawatt numbers are rounded to the nearest 0.1 MW. An entry of zero indicates less than 100 kW was shipped in that year.
- Portable fuel cells refer to fuel cell units designed to be moved. They include fuel cell APU, and consumer electronics. Toys and educational kits are no longer reported in the portable total to allow for greater visibility of industrial systems.
- Stationary fuel cells refer to fuel cell units designed to provide power at a fixed location. They include small and large stationary prime power, backup/uninterruptible power supplies, combined heat and power, and combined cooling and power.
- Transport fuel cells refer to fuel cell units that provide propulsive power or range extender function to vehicles, including UAV, cars, buses, and materials handling vehicles.
- Our geographical regions are broken down as follows: Asia includes all Asian countries including Japan; Europe comprises all eastern and western European countries, including Iceland; North America comprises Canada and the United States; the Rest of the World region includes all other countries.
- Shipments by fuel cell type refer to the electrolyte. The six main electrolyte types are included here; high temperature PEMFC and conventional PEMFC are shown together as PEMFC. Other types of fuel cell such as microbial fuel cells are not included in our numbers as these are generally still at the R&D stage.
- The data presented here are based on interviews between Fuel Cell Today and key industry players, publicly available sources such as company statements or stock market filings, and planned demonstration programmes by companies and governments.
- The data presented here may differ from those previously published by Fuel Cell Today: shipment figures are based on region of system adoption and the dataset has been updated in the light of new information.

About the Authors

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Dan joined Fuel Cell Today in January 2011, having worked as an industry analyst for more than five years at Johnson Matthey researching and forecasting the automotive, electronics, chemicals and fuel cell industries. Dan has presented at international industry events around the world and has extensive experience of the Asian fuel cell markets. He is a chemist by training and graduated with an MChem (Hons) from the University of Wales, Swansea and a PhD in Inorganic Chemistry from the University of Nottingham.

Jonathan Wing

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Jonny joined Fuel Cell Today in April 2011 having graduated from the University of Reading with a BSc in Environmental Science. Jonny took a particular interest in energy resources during his studies and his thesis focused on micro-generation. A digital enthusiast, Jonny has travelled globally and is particularly interested in the commercialisation of fuel cells electric vehicles, European initiatives and the opportunities for hydrogen to link the three energy silos of electricity, heat and transportation.

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Note on currencies:

Unless stated otherwise, all currencies are quoted in US Dollars ($). The following exchange rates, based on average exchange rates from 1st January 2012 to 1st July 2013, have been used:

$1 = €0.7623	*$1 = CNY 6.1907*
$1 = ¥95.5679	*$1 = $1.0161 (Canadian)*
$1 = £0.6481	*$1 = $0.9872 (Australian)*

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