FUEL CELL TODAY

Opening doors to fuel cell commercialisation

Fuel Cell Market Survey:
Small Stationary Applications

Stefan Geiger, Mark Cropper – Fuel Cell Today, 30 July 2003

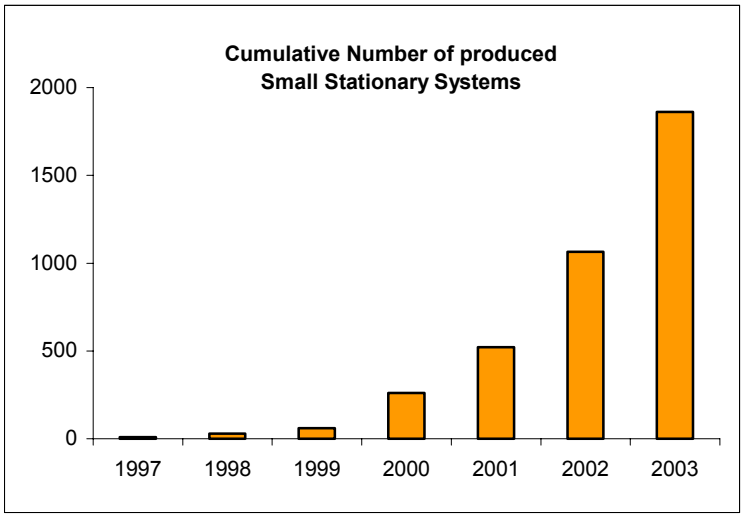
Since we last looked at the small stationary (residential) fuel cell market in February 2002, there have been many changes. Hundreds more systems have been installed all over the world, and many more companies have shown an interest in this application. There are now around eighty companies active in the development of complete small stationary fuel cell systems worldwide. Furthermore, some of these have begun selling units openly, while others have announced plans to introduce their first commercial products within the next two to three years.

Natural gas powered small stationary fuel cell unit; developed by Vaillant for the European domestic market in conjunction with Plug Power (Source: Vaillant)

So far, we estimate that a total of 1,900 small stationary fuel cell systems have been built and operated worldwide. This number includes systems installed in homes and units in the 0.5-10kW range that have been operated in other related small stationary applications, including uninterruptible and back-up power supply in commercial and remote locations. It is almost four times the number of units that had been built when we last measured this market at Fuel Cell Today.

The growth curve, which is shown in the chart below, is not as steep as might be expected, especially in comparison with the portable fuel cell sector. This is

disappointing although not surprising given that delays are inevitable when introducing a new technology and that most of the systems developed to date are still demonstration units rather than commercial systems. Several companies are taking much longer to introduce products than promised, while a number have disappeared from the scene altogether, including **DCH Technology** (bankrupt), **H Power** (absorbed by **Plug Power**), and **Reliant Energy** (ceased development owing to financial difficulties at its parent company).



Another feature of recent development has been the continued shift away from the residential market, which we recognised in our February 2002 survey. Although this remains the largest potential market, companies recognise that it cannot support the fuel cell systems they can produce today, not only as prices will be too high but also because the lifetime of systems is still too short. It is generally agreed that fuel cell systems in households will need to operate for around 40,000 hours (or five years) without a major rebuild, which might include changing the stack. However, few companies have demonstrated individual systems for more than 10,000 hours.

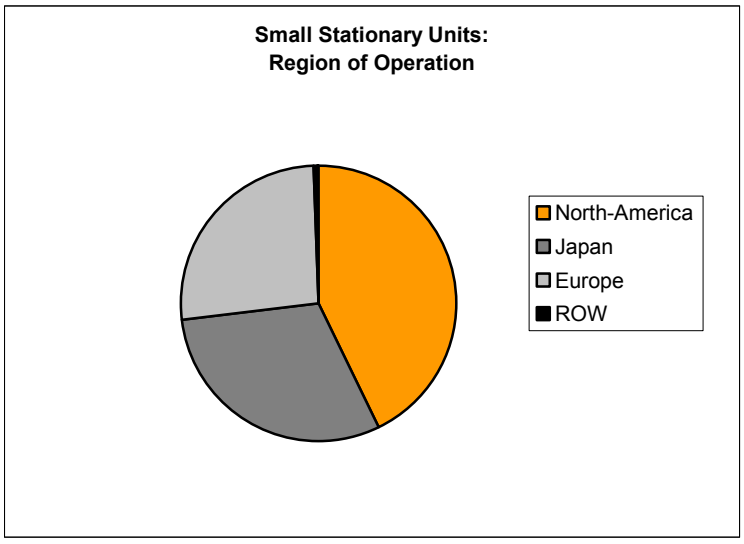
As a result growing numbers of developers are repositioning themselves away from residential towards back-up, uninterruptible and remote power, including **Avista Labs, IdaTech** and **Plug Power.** The back-up power market in particular seems attractive, since there is a demand for reliable power from a number of potential customers, such as banks and telecom companies, where power breakdowns can cost US$ 6 million/hour or more. In addition, back-up power units will only be required to operate intermittently, meaning that short system lifetimes are less of a

problem. For these reasons, we have recently changed our categorisation of units in this survey from 'residential' to 'small stationary', which we think is now more appropriate. To avoid confusion we have also renamed our 'stationary' category to 'large stationary'. This covers fuel cells with an electrical output ranging from 10kW to the megawatt level and above. Large stationary fuel cells were reviewed in a May 2002 survey, which will be updated later this year.

Region of Operation

A year and a half ago nearly 80 per cent of systems built had been installed in North-America, mainly in the USA. Since then Japan and Europe have caught up dramatically. The increasing percentage of systems installed in Europe is mainly down to the efforts of Swiss heat equipment manufacturer **Sulzer Hexis** and the German company **Vaillant**, which has established a partnership with **Plug Power**.

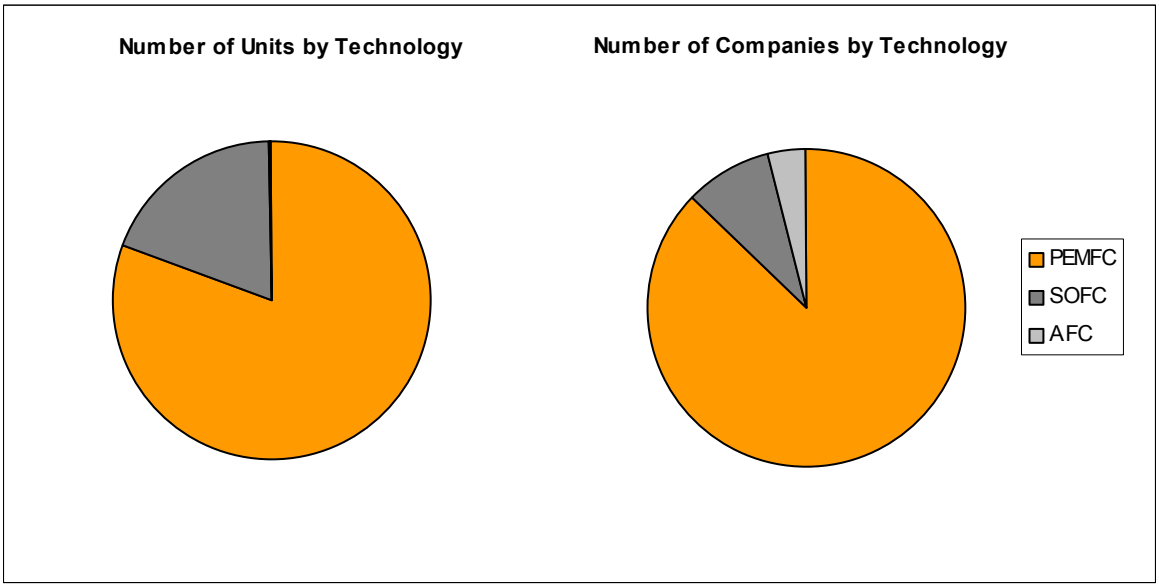
In Japan, companies such as **Ishikawajima-Harima Heavy Industries (IHI), Nippon Oil, Osaka Gas** and **Sanyo** are the biggest names looking at mass production of small stationary fuel cells and aim to bring 1kW units to the market by 2005 for around US$4,200. It is notable, that the majority of small stationary manufacturers in Europe and Japan are household companies with a good knowledge of conventional heating/energy products as opposed to the USA where these organisations have been founded as pure fuel cell development companies.



Development effort in other parts of the world (ROW) is still at very a low level, which is reflected in the low number of systems installed.

Technology

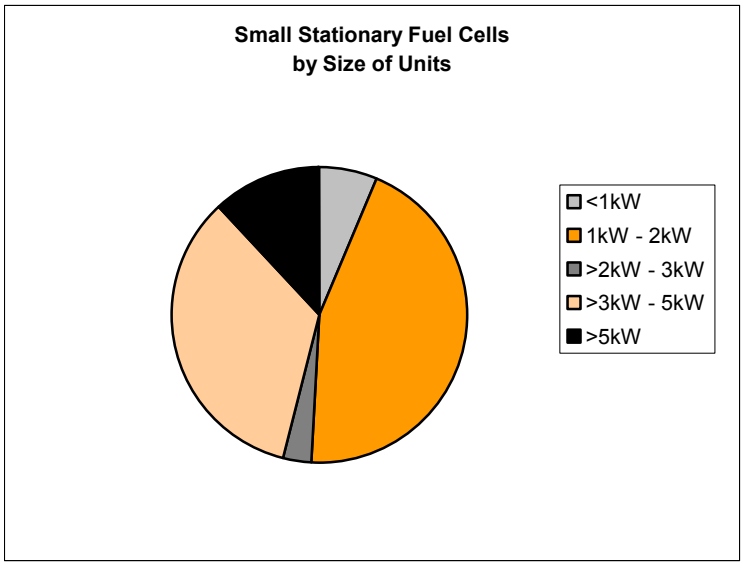
So far, as technology type is concerned, most systems in this sector use proton exchange membrane (PEM) fuel cells. However, the proportion of units equipped with solid oxide fuel cells (SOFC) has risen from five percent to more than twenty percent in the last 18 months. However, from the eighty or so developers and manufacturers, only seven are involved in this latter technology.



The power output of these units varies. Some small stationary fuel cells supply just above 0.5kW while other manufacturers favour larger units with 3kW-5kW or even up to 10kW.

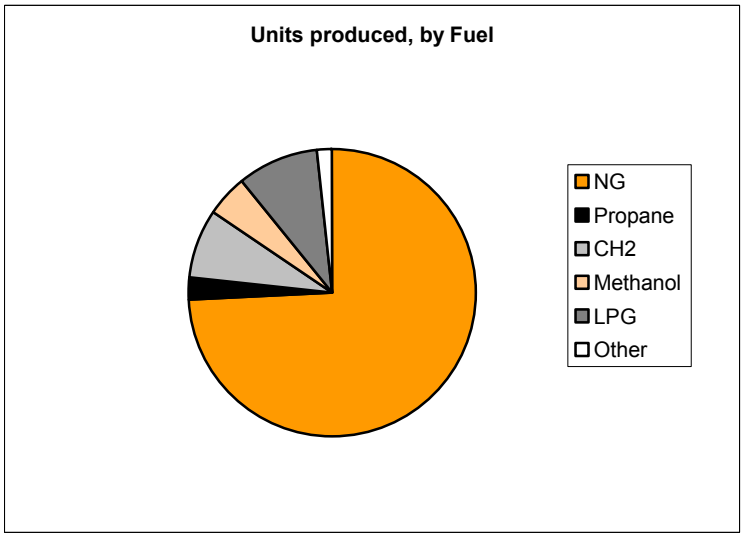
This is mainly due to the different consumption needs of households across the world. While Japanese and European homes normally require around 1-2kW of electrical power, larger households in the USA use more power. Additionally, larger units are often used as stand-alone, grid-independent power sources to provide electricity and heat for remote households. North-American manufacturers currently focus mainly on the production of small stationary fuel cells for back-up power systems, while their Japanese and European counterparts direct their efforts more on units for the residential market. It is also notable, that all Japanese developers concentrate solely on PEM technology.

The following graph gives an indication about the different unit sizes produced so far.



Fuel Choice[1]

When it comes to fuelling these units, there is a strong trend towards natural gas (NG). As shown in the following graph, about three quarters of all installed units are operated using this fuel. There are two main reasons for this. Firstly, NG is widely available and a supply infrastructure is in place in many countries around the world.



[1] NG=natural gas, CH2= compressed hydrogen, LPG=liquefied petroleum gas

The second reason is that gas utility companies are playing an important part in the development and introduction of units, particularly in Germany and Japan. German utilities backing small stationary fuel cells include **EnBW, E.ON** and **RWE**, while in Japan they have been backed by major gas suppliers such as **Osaka Gas** and **Tokyo Gas**, which have both carried out significant R&D on natural gas processors.

Utilities have an additional interest in this technology, due to the fact that small stationary systems offer far more than just a power supply for homes and offices: they can also act as a decentralised power supply, grid support, peak shaving, power back-up or uninterruptible power supply (UPS).

However, in other small stationary markets, different fuels are likely to be more commonplace. For early markets, such as back-up power where systems are only expected to operate occasionally, hydrogen could be used. Where fuel cells are used in remote locations, propane could be an option. Finally, methanol also has potential, particularly as a fuel for PEMFC, as it is easier to reform than other hydrocarbons, and is easier to transport and store than many alternatives. Additionally, most manufacturers have also conducted research in powering these units with heavier fuels such as diesel.

Funding

To reach a commercial status, start-up investment and funding of demonstration projects is essential. While government bodies in the USA, mainly the **Department of Energy** (DoE) and the **Department of Defense** (DoD) and Japanese bodies such as the **Ministry of Economy, Trade and Industry** (METI) provide sufficient funding in this sector, the situation in Europe is different. Funding from the **European Union**, mainly through the Framework 4, 5 and 6 programmes, has concentrated on transport, infrastructure and larger stationary applications. Additionally, most of the European demonstration projects, apart from those where Sulzer Hexis is involved, depend on US technology.

The commercialisation of small stationary fuel cell development could also be accelerated by financial incentives, such as premium prices for electricity sold back to the grid. So far Germany is the only country to offer such incentives: its federal government has introduced a programme which subsidises the electricity produced

by combined heat and power (CHP) systems up to 2MW in size. The programme includes subsidies for electricity produced by stationary fuel cells with an output up to 50kW worth € 0.0511/kWh for 10 years after instalment (compared to an average electricity price of about € 0.13/kW). Units must be installed before the end of 2005 to qualify.

Major Demonstration Projects

There are two major demonstration projects in Japan, where development is focused upon the residential market. The **Japan Gas Association** (JGA) is coordinating the **Millennium Project** to develop fuel cells for residential use. Partners in this project include **Ebara Ballard, Fuji Electric, Japan Gas Appliances Inspection Association, Matsushita Electric Industrial, Matsushita Electric Works, Mitsubishi Electric, Mitsubishi Heavy Industries, Mitsui, Sanyo Electric, Toshiba International Fuel Cell** and **Toyota Motor**. So far units have been tested inside the laboratory, as pictured below. Demonstration tests are expected to start in 2004.

Range of residential systems being tested
by the Japan Gas Association (Source: Japan Gas Association)

The **New Energy Foundation (NEF)** is part of the Japanese Ministry of Economy, Trade and Industry (METI) and has carried out surveys on the Japanese fuel cell industry and established demonstration projects throughout Japan. NEF aims to install 1kW and 5kW fuel cell demonstration units at 31 residential and commercial

premises in Japan in 2003. These units will be fuelled by city gas, liquefied petroleum gas (LPG), kerosene and naphtha. Partners include: **Ebara Ballard, Hitachi Home&Life Solutions, Ishikawajima-Harima Heavy Industries**, **Kurita Water Industries**, **Marubeni**, **Matsushita Electric Industrial**, **Mitsubishi Heavy Industries**, **Nippon Oil**, **Sanyo Electric**, **Toshiba** and **Toyota Motor**.

In conjunction with development partner **Plug Power**, **Vaillant** (Germany) is leading the EU-backed **Virtual Fuel Cell Power Plant** project. Around forty units are being installed in multi-family houses, small enterprises, public facilities etc., for individual heating, cooling and electricity production. Centrally controlled and grid-connected, these elements of the virtual power plant contribute to meet peak energy demand in the public electricity grid. The systems have been tested in German, Dutch and Austrian households since December 2002 and will demonstrate reliability and sturdiness in domestic and small business CHP installations.

Another large demonstration project in Europe involves **Sulzer Hexis**. The Swiss company planned to test up to 400 units of its 1kW solid oxide fuel cell (SOFC) HXS Premiere pre-commercial system, in conjunction with several European utility companies including **EnBW**, **EWE**, **EWR**, **E.ON**, **GVM**, **RWE**, **Thyssengas** and **VNG**. It has now, however, decided to deploy a total of 150-200 units, as this will provide sufficient data and allow the company to focus on research into its next generation SOFC system. Prototypes of this are currently being tested and are expected to hit the market by 2005-06.

McDonald's restaurant in North Babylon (NY) partially powered by a fuel cell (Source: LIPA)

Plug Power has installed many small stationary fuel cells across the USA. One of the largest programmes is being conducted with the **Long Island Power Authority** (LIPA), which has operated as many as 75 units at an electricity substation. LIPA is now installing a further 45 units across its territory, one of which was installed at a McDonalds restaurant in February 2003, pictured above. Others will be installed in homes.

A similar, albeit smaller, field trial is being conducted by **IdaTech** with the **Bonneville Power Administration** (BPA). Contracted to deliver 100 1kW units, IdaTech has started delivery of a number of systems, which will still provide sufficient data to move to the next stage.

Outlook

Most of the manufacturers of small stationary fuel cells with higher electrical power output, and many market research bodies have forecast the market size in 5-15 years. Most of the surveys conclude that small stationary fuel cells will succeed in the mid- to long-term. Since there are a lot of manufacturers with eager plans to bring their first models to a commercial market in 2004-06, we expect production numbers to continue growing strongly. However, conclusions from various companies, which predict production of CHP fuel cell units to exceed 500,000 units per year by 2010 are probably too optimistic.

So far, there are only five to six manufacturers that could increase their annual production to around 10,000 units a year by 2005-6. Additionally, one should not forget that increasing the production of units will put pressure on suppliers of sub-systems, materials and components, which may not be able to cope with significantly higher demand at short notice. Finally, where consumer domestic markets are concerned, it is worth noting that households normally only replace their heating/boiler units every 20-30 years.

Key Players

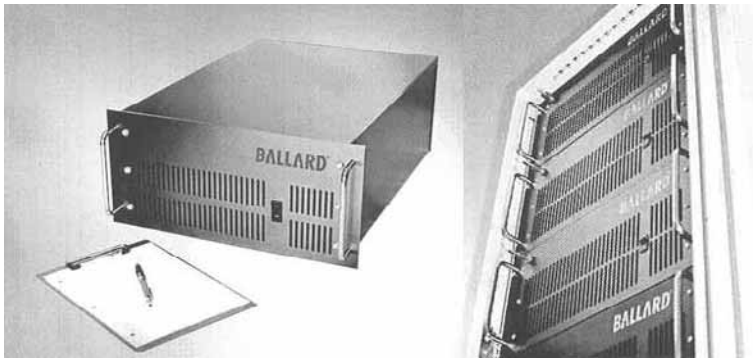
Today, there are about eighty companies world-wide which have produced small stationary fuel cell units. However, about two thirds of the installed systems have been built (or will be built by the end of 2003) by only six manufacturers, including

Avista Labs, H Power, Nippon Oil, Plug Power, Sanyo Electric and Sulzer Hexis. Details on leading players within this field follow below.

Acumentrics (USA) is a manufacturer of direct natural gas and propane fuelled solid oxide fuel cells that generate electricity and heat for small to medium scale distributed generation and power quality applications. The company's pre-commercial power units in the 2, 5 and 10kW size are used for commercial and industrial back-up and micro-scale distributed power applications.

Avista Labs (USA) is developing PEMFC systems in the 50W-5kW power range. Its systems are based on a unique modular design, where groups of MEAs are housed in a cartridge, which can be readily swapped without having to take the stack apart if there is a problem. Since 2002 Avista has sold three different products, all fuelled by industrial grade hydrogen, two of which (0.5kW and 1kW) might be considered small stationary systems. Units can also be connected in series for higher power outputs. For example, a 3kW fuel cell system (made up of six 500W units) was recently supplied to the US Federal Aviation Administration, to provide critical back-up power for a radio transmission site. Avista distributors include **havePOWER** (USA) and **Aperion Energy Systems** (USA). In July 2003 it announced that it had secured US$7.5M in its first round of independent financing.

Ballard (Canada/Germany) is commercialising fuel cell engines for transportation applications and fuel cell systems for portable and stationary products. The company’s 1.2kW Nexa PEM power module was designed for integration into stationary power generation through original equipment manufacturers (e.g. **IdaTech**). A new prototype of a multi-use 1kW scalable power product was unveiled in 2002 (see figure below).



Ballard 1kW scalable power product, alpha prototype. (Source: Ballard)

Ballard's Japanese subsidiary **Ebara Ballard** is developing a 1kW, natural gas powered cogeneration stationary system using **Osaka Gas'** fuel processing technology. Ballard has also developed the 1kW AirGen fuel cell generator, although the company considers this unit as a portable fuel cell.

Eneco was founded in February 2002, when it acquired technology developed by **Fuel Cell Systems**, which went into administration following the collapse of parent company **Zetek Power**. It is developing alkaline fuel cells for stationary applications.

European Fuel Cell (EFC) (Germany), formerly linked to Hamburg Gas Consult, now owned by the British Baxi Group, develops and produces residential PEM fuel cell heaters. The company's natural gas powered, 1.5kW beta unit is to be field tested with plans for 100 installations at a later point.

European Fuel Cell (efc) 1.5kW PEMFC beta unit prototype. (Source: efc)

The company has signed a co-operation agreement with **IRD Fuel Cell** (Denmark) for development and production of fuel cells and system components. EFC has just recently opened a new 23 million Euro research facility in Hamburg, Germany.

Fuel Cell Technologies (FCT) (Canada) is an advanced fuel cell power system integrator. The company is developing modular 5kW solid oxide fuel cell electrical power systems for distributed generation, using **Siemens Westinghouse** (USA) stacks. These systems will provide electricity in residential, small commercial, and

remote facility applications. FCT has also an agreement with **NKK** in Japan to commercialise its systems in the Asia Pacific region.

Fuji Electric (Japan) is involved in developing residential fuel cells in a range of 1-5kW and is taking part in the Japan Gas Association (JGA) demonstration project. Previously, Fuji has been focusing on PAFC but has now changed its efforts towards PEM units and increased 1kW stack run-time to more than 15,000 hours.

Global Thermoelectric (Canada) is aiming to develop 2kW low temperature (650-700ºC) commercial solid oxide fuel cells. The company has a strategic alliance with **Enbridge**, the largest Canadian gas utility, **Suburban Propane**, a US Propane distributor, and **Citizens Gas & Coke** Utility of Indianapolis. The company has demonstrated and tested various units. Its recent prototype RP-2 has achieved operating times of more than 4,100 hours. A new natural gas powered prototype ("Aurora"), which will include significant reductions in system size and cost, is due to be tested in 2003.

Global Thermoelectric 2002-3 prototypes under test in its Calgary facility (Source: Global Thermoelectric)

Since the beginning of 2003, Global has cut 47 jobs in a bid to reduce expenditure. In April 2003, **Quantum Fuel Systems Technologies** announced the signing of an agreement in which Quantum will acquire all of the outstanding shares of Global Thermoelectric.

IdaTech, formerly known as NorthWest Power Systems (USA), is developing fuel cell systems up to 2kW in output. The company is concentrating on systems integration and fuel processing development, using stacks bought from other companies, particularly **Ballard**, from which it buys Nexa 1.2kW PEMFC modules. In recent

months it has been extending the range of fuels its systems can use, including diesel, kerosene and gas-to-liquids.

The company has shipped 19 units and is anticipated to enter the market by the end of 2003. Furthermore, IdaTech has signed an agreement with **Tokyo Boeki** to bring its technology to Asia. The company is not focusing on residential units as a first market, but rather looking at back-up power.

Ishikawajima-Harima Heavy Industries (IHI) (Japan) participates in the development of fuel cells, cogeneration and coal gasification combined power generation. The company will start tests on propane gas reformers for home use 1 kW PEMFC systems. Furthermore, IHI has developed a 5kW PEM unit powered with city gas which aims to be sold as a commercial power back-up unit. The company is trying to achieve a cost target of about US$1,650/kW in 2010.

Independent Power Technologies (IPT) is a new privately owned Russian fuel cell company which emerged from Research Production Enterprise **Kvant** – the vanguard of Russian fuel cell technology. IPT specialises in design and manufacture of industrial fuel cell generators based on advanced AFC technology. The company has presented its first product, a 6kW small stationary back-up power system at the Hannover fair in April 2003.

Intelligent Energy (UK) is a developer of PEM fuel cell systems. The company plans to supply complete systems rather than stacks. With regard to higher power systems, a 4kW portable genset unit (complete with battery for 8kW peak output) has been developed for the military. The same platform will be used in a CHP system. Larger units are under development, including a 50kW system (incorporating two 25kW stacks). Looking forwards, Intelligent Energy intends to supply systems with integrated fuel processors developed in-house.

Jemmytex International is the leading Taiwanese volume producer of conventional power generation modules with R&D and business development programmes involved in providing fuel cell power system solutions for the telecom industry as well as standard commercial applications and the more specific military uses. The company developed a 1kW PEM system in 2003.

Matsushita Electric Works (MEW) (Japan) is developing compact fuel cell power generators for both portable and residential applications. A power conditioner for a residential cogeneration system (1kW) has been developed. The company is taking part in the Japan Gas Association (JGA) demonstration project and is aiming to put 1kW PEMFC systems on sale in 2005.

MER Corporation (USA) is developing fuel cell based residential generators with power outputs from 1 to 3kW. The systems include all auxiliary components and are currently in their third generation. The company completed the first prototype residential generator in July 2002. The generator is a fuel cell powered unit that produces 120 V, 60 Hz AC power. The stand-alone device generates electricity entirely independent from the grid. A simple switch starts the generator. It is part of a modular power generator system of units from 1 to 10 kW and will be tested by a major utility company.

The Hiroshima Research & Development Centre of **Mitsubishi Heavy Industries (MHI)** (Japan) is responsible for the development of MHI's environment-friendly PEMFC power generation system as the next-generation energy source. In June 2003 it was reported that MHI had developed an extremely compact 1kW unit.

Nippon Oil (Japan) is preparing to commercialise stationary fuel cell products for business and residential use. In July 2001, the Company began pilot operations at one of its service stations of a compact stationary fuel cell system. This system is used together with a regular electrical power source to supply electricity for fuel pumps and lighting in the case of power outages or emergencies. Furthermore, the company is interested in the development of more compact 1kW fuel cell units for home use. In April, they started a nationwide test with 100 1kW PEM units, powered by LPG. Nippon Oil aims to sell these units by 2005 for about US$ 4,200 each.

Nuvera Fuel Cells (Italy/USA) was formed in April 2000 from a merger between De Nora Fuel Cells and Epyx. Working on PEMFC, it aims to manufacture stacks and fuel processors for residential and automotive applications. The company is designing and manufacturing 5 kW units which are being developed and tested for manufacturers of home power generators and backup power equipment. Nuvera has distribution and joint-venture agreements with **Mitsui** (Japan), **RWE** (Germany)**, Best Water Technology** (Austria) and **Verizon Communications** (Canada).

Additionally, the company is developing a 4kW natural gas system (branded the Avanti) that responds to heat rather than electricity demand. These first units are expected to be in the field by the end of this year. In May 2003 Nuvera was selected by the US Department of Defence to demonstrate an Avanti unit at a US Coast Guard facility in Rhode Island. Nuvera also revealed that it is planning to integrate a PEMFC with a small turbine, producing an innovative cogen product, branded the DuAlto. Field tests of prototypes are expected from 2005.

Osaka Gas is the major natural gas supplier in the Osaka and Kyoto area of Japan. In June 2003, the company announced plans to launch 500 – 5,000 domestic PEMFC cogeneration systems in 2005 after developing cogeneration systems with each of **Ebara Ballard, Matsushita, Sanyo** and **Toshiba International Fuel Cells**.

Plug Power (USA) is a developer of fuel cells for homes using natural gas and propane. The company develops on-site power generation systems for commercial and residential dwellings, as well as for automotive applications, using PEM fuel cells. In November 2002, Plug Power acquired competitor **H Power** for approximately US$50 million. So far, the company has installed 75 systems at a LIPA substation on Long Island amongst others and is overall the company with the most installed systems in this sector.

In February 2003 Plug Power signed a joint marketing agreement with **Toshiba International Corp (TIC)** to explore the application of fuel cells for industrial premium power markets, and develop a product that combines Plug technology with TIC's uninterruptible power systems. The companies expect the joint marketing agreement to lead to subsequent product development and commercialisation cooperation. In June 2003 Plug Power introduced the GenCore system, a 5kW direct hydrogen fuel cell unit, priced at US$ 15,000 and especially designed to provide extended back up power specifically for the telecommunications industry.

Proton Motor (Germany) is developing fuel cells for residential heat and power supply. It is involved in a prototype project for a 1.7kW cogeneration system funded by the German government, fuelled by natural gas. Due to run until mid-2003, the project also involves **Bosch, Fraunhofer ISE, Kaco Gerätetechnik** and **Süd-Chemie** (all Germany).

Roen Est (Italy) is active in the development of PEMFC systems based on its own patented MEGA MEA technology. This was developed with ENEA (the Italian National Agency for New Technology, Energy and the Environment), and makes it easier to repair stacks and offers the possibility of testing each single MEA during production. Following its recent merger with Italian firm **Arcotronics Nissei**, Roen Est plans to market a 5-kW natural gas fulled CHP system for domestic applications. Its first prototype related to this system was the 5kW hydrogen fuelled PENTA unit unveiled at the Hannover Fair in April 2003, which is pictured below.

Roen Est Penta h2 5kW PEMFC system, unveiled in 2003.
The measurements are given in millemetres. (Source: Roen Est)

Sanyo Electric (Japan) intends to develop 1kW PEMFC domestic application systems and aims to put them on the market in 2005. The company has signed a development contract with **Hoku-Scientific** to develop MEAs for PEM fuel cells. Additionally, Sanyo has an agreement with **Samsung** to jointly develop PEM technology. The companies aim to develop compact 1kW to 10 kW units for household and back-up power applications. Sanyo is taking part in the New Energy Foundation project and the Japan Gas Association demonstration project.

Sulzer Hexis (Switzerland) develops, produces and distributes SOFC systems for single-family homes. The company has started a large demonstration project with its 1kW "HXS 1000 PREMIERE" systems which are being tested and further developed within the framework of a pre-series phase in co-operation with utilities and installers on end users' premises. The company plans to bring a commercial product onto the market in 2005/06 which will be manufactured in quantities of 1,000-10,000 year.

Teledyne Energy Systems (TES) (USA), a division of Teledyne Technologies, is developing stationary PEM fuel cell stacks and systems in the 1-7kW range. It has said little about its development work in recent months, and appears less interested in this particular market than **Energy Partners**, the PEMFC business it bought in 2001. However, a small number of prototype systems have been developed, including a 7kW natural gas system developed under a contract from the US Department of Energy that was awarded in the first place to Energy Partners. This was due to be delivered in late 2002.

Toshiba International Fuel Cells (TIFC) (Japan), a joint venture between Toshiba and **UTC Fuel Cells** announced in 2001, is developing two small stationary PEMFC units: a 5kW system for commercial use, and a 1kW system for home use. It plans to start selling the 5kW unit in 2004. The unit will be aimed at the commercial market in Japan and the residential market in Europe and the USA. Powered by city gas or LPG, the fuel cell system will use a partial oxidation reformer which was developed by **Hydrogen Sources**, a joint-venture of UTC and **Shell Hydrogen** (Netherlands). Earlier this year it was reported that Toshiba plans to sell the unit for 3 million yen (US$ 25,000). Toshiba is also working on the development of a 1kW system with **Cosmo Petroleum**. Cosmo has developed a 1kW-class butane reformer, and is now working on the development of a kerosene reformer.

UTC Fuel Cells (USA), previously International Fuel Cells, is developing small stationary PEMFC systems in conjunction with both **Toshiba IFC** (as detailed above)

UTC Fuel Cells 5kW Alpha prototype, clothed and unclothed. (Source: UTC Fuel Cells)

and **Tokyo Gas**. The German heat appliance manufacturer **Buderus** will market UTC PEMFC systems in Europe: initial tests are scheduled for 2003, larger field tests will follow in 2004. UTC plans to introduce the system to the market by 2005.

Another German heating appliance manufacturer **Vaillant**, is demonstrating a virtual power plant, consisting of 54 decentralised residential PEM fuel cell systems. The company is partnering with **Plug-Power** and approaching the heat driven commercial market first such as shops, offices and swimming pools.

Viessmann (Germany) – is one of the leading European manufacturers of heating technology products. The company is currently developing a 2kW domestic cogeneration unit on a PEM fuel cell base. Development partners are the German companies **SGL-Carbon** for the development of the bipolar plates, **Siemens HVAC** division for the steering and control, **OMG** and **Südchemie** for catalyst development and the **Zentrum für Sonnenenergie und Wasserstoffforschung (ZSW)** for the design of the cells.

Viessmann 2kW PEM prototype. (Source: Viessmann).

Other companies which have built or are developing small stationary fuel cells include **Anuvu** (PEM, USA), **Aperion Energy Systems** (using Avista PEM units, USA), **Apollo Energy Systems** (alkaline fuel cells (AFC), USA), **Astris Energi** (AFC, USA) **Axane** (PEM, France), **BCS Fuel Cells** (PEM, USA), **Bosch** (PEM, Germany), **Ceramic Fuel Cells** (SOFC, Australia), **Clamper Engineering** (PEM, Brazil), **Fraunhofer Institute for Solar Energy Systems** (Fuel Processor, PEM R&D,

Germany), **Helion Fuel Cells** (PEM, France), **Hiroshima Gas, Hitachi Research Lab, Hokkaido Gas** (all PEM, all Japan), **Hydrogenics** (PEM, Canada), **Industrial Research Limited** (PEM, New Zealand), **Kawasaki Heavy Industries** (PEM, Japan), **Kyocera** (PEM, Japan), **Loughborough University** (PEM, UK), **Matsushita Electric Industrial** ('Panasonic', PEM, Japan), **Mitsubishi Electric** (PEM, Japan), **Mosaic Energy** (PEM, USA), **Naps** (PEM, Finland), **Nisseki Mitsubishi** (PEM, Japan), **Phocos** (PEM, Germany), **Proton Energy Systems** (PEM, USA), **Protonetics International** (PEM, USA), **Sanko Jidokiki** (PEM, Japan), **Schatz Energy Research Centre** (PEM, USA), and **Sorapec** (PEM, France).

Further references

- The last survey on this subject and other fuel cell surveys can be downloaded from our website at www.fuelcelltoday.com/surveys
- To contact the authors, please send an email to marketsurvey@fuelcelltoday.com Alternatively, you can also phone us on +44 (0)20 7269 8326 or send a fax to +44 (0)20 7269 8169.
- During August 2003, we will also have an online discussion on this topic in our Industry Forum. If you have any questions or comments on small stationary fuel cells, please feel free to add your thoughts to the board.