Projektinfo **05**/2012

Detailed information on energy research

New approaches to supplying domestic energy

Generating electricity and heat more efficiently using fuel cell heating units

BINE Information Service

Fuel cells have unique abilities: in contrast to other co-generation (CHP) plants, they directly convert the chemically bound energy of fuel sources such as hydrogen or natural gas without using a flame. If they are deployed in heating devices, they generate electricity and heat efficiently. Indeed, they are considerably more efficient than combining conventional electricity generation and condensing boilers.

DThe new fuel cell heating units supply the entire heating in residential buildings. They consist of a fuel cell that co-generates electricity and heat in combination with an integrated boiler. A heat storage tank stores hot water and heating energy. The units can be deployed both in new buildings as well as in the modernisation of central heating systems.

Compared with the separate generation of electricity in power plants and heat in condensing boilers, the new systems enable CO_2 savings of between 25 and 35 %. They have an overall efficiency of more than 96 %. Their particular advantage is that the electrical efficiency is more than 33 %.

For an average single-family home, a manufacturer calculates that the costs for electricity and heating are reduced by several hundred euros per year. However, the fuel cell heating units, which are currently only produced in small numbers, are still considerably more expensive than comparable conventional technology.

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New technology is ready for the market

The successful market introduction of fuel cell heating units now depends on optimising the service life, efficiency and costs. The progress made until now by the researchers and developers is nevertheless impressive: the lifetime of the fuel cell stacks has doubled to 20,000 hours and continues to increase, and thanks to initial small-scale production runs it is becoming cheaper to manufacture components and peripheral devices. Still existing challenges identified by the manufacturers include reducing the investment and operating costs, further increasing the stack service life, simplifying the systems and reducing servicing and maintenance requirements. The developers estimate that the fuel cell heating technology will be ready for the marketplace by 2014.
Field tests now need to establish the long-term suitability of the tested systems in practice. This energy-saving, future-oriented technology will then be ready to conquer the boiler rooms. However, they first of all need start-up funding from energy supply companies and the government to enable larger production runs to compete with other CHP plant systems in the medium term.
Various cell types are being tested for the fuel cell heating units. Low-temperature polymer electrolyte (PEM) fuel cells work in a temperature range from around 80 °C and can be started up and shut down in a short period of time without the material being damaged by heating or cooling. Because they cannot be operated directly with natural gas but only with hydrogen, a reformer is connected upstream of the fuel cell stack to treat the gas.
Solid-oxide fuel cells (SOFCs) work with temperatures above 600 °C. This technology has the advantage that the pre-treatment of the natural gas is substantially simplified. Using funding from the German government, the manufacturers developed optimised fuel cell heating units based on laboratory models and several prototype generations. Complete systems are now being field-tested that compactly combine all components in a functional as well as user- and service-friendly manner. A typical system consists of the following components: gas treatment (reformer, desulphurisation), fuel cell system as well as additionally required components for the system integration (pumps and blowers, valves, connection technology, sensors, condensate separator, water treatment, air filter). In addition there is also the electrical system with the control and management system as well as an auxiliary boiler, heating manager and the heat storage tank.
The researchers and developers have conducted a comprehensive package of development work and tests to complete the system: materials and core components had to be adapted to the special requirements and correspondingly more precise specifications drawn up, while processing and production procedures also had to be optimised and suppliers obligated to meet the high quality requirements.

Testing fuel cells for domestic use in practice

In the Callux project, natural gas-operated fuel cell heating units are being tested in practice with private customers. Appliance manufacturers and energy supply companies are involved in the project, which is being coordinated by the Centre for Solar Energy and Hydrogen Research (ZSW). This test programme has enabled the appliance manufacturers to develop initial small production runs in conjunction with the respective supply chains. The aim is to use the data from the field test to establish the maturity of the technology in order to then start serial production of a commercially ready product.
Further measures are currently being worked on including the development of specifications and standards and, in particular, the training of specialist installers. Supported by NOW (National Organisation for Hydrogen and Fuel Cell Technology), the new technology is being developed as part of the National Hydrogen and Fuel Cell Technology Innovation Programme (NIP).
The aim of the Callux project is to further develop the devices to form systems that are suitable for everyday use. Launched in 2008, the German government's flagship project is the largest practice test being conducted in Germany, with 232 fuel cell heating units already installed by the end of 2011. According to current plans, 500 devices are due to be installed by 2015 with both PEM and SOFC technology. By the end of 2011, more than 600,000 kWh of electricity were generated in more than one million operating hours.
The manufacturers and energy suppliers are testing the new devices as part of development and demonstration projects. The devices deployed in the

Fuel cell units used in the field test

Manufacturer	**Baxi Innotech**	**Ceramic Fuel Cells***	**Hexis**	**Vaillant**
Fuel cell type	*Low temperature PEM (70 °C)*	*Solid oxide (SOFC)*	*Solid oxide (SOFC)*	*Solid oxide (SOFC)*
Output ($_{el/th}$)	*Max. 1.0 kW_{el} / 1.8 kW_{th}*	*1.5 kW_{el} / 0.6 kW_{th} (continual operation)*	*1 kW_{el} / 2 kW_{th}*	*1 kW_{el} / 2 kW_{th}*
Electrical efficiency	*32 %*	*up to 60 %*	*30 – 35 %*	*30 – 34 %*
Output of the additional heat generator	*3.5 – 15 kW / 20 kW*	*–*	*4 – 20 kW*	*Variable, depending on the building requirements*
Overall efficiency	*97 %*	*Without condensing boiler up to 85 %*	*95 %*	*90 – 109 %*
Fuel	*Natural gas, bio natural gas*	*Natural gas, bio natural gas*	*Natural gas, bio natural gas*	*Natural gas, bio natural gas*
Size, (L x W x H)	*60x60x160 cm*	*66x60x101 cm*	*55x55x160 cm*	*60x62x98 cm*
Weight	*200 kg*	*~ 200 kg*	*170 kg*	*~ 150 kg*
Modulation	*Approx. 100 – 30 % P_{elN}*	*0 – 1.5 kW_{el} 0,3 – 1.0 kW_{th}*	*100 – 50 %*	*100 – 50 %*
Number of devices in the field test	*140 (in GER., NL, LUX)*	*400 (in GER., NL, F, UK)*	*Approx. 110*	*15*

** Not participating in the Callux project*

Fig. 1 *Technical data for fuel cell heating units*
Source: Manufacturer information

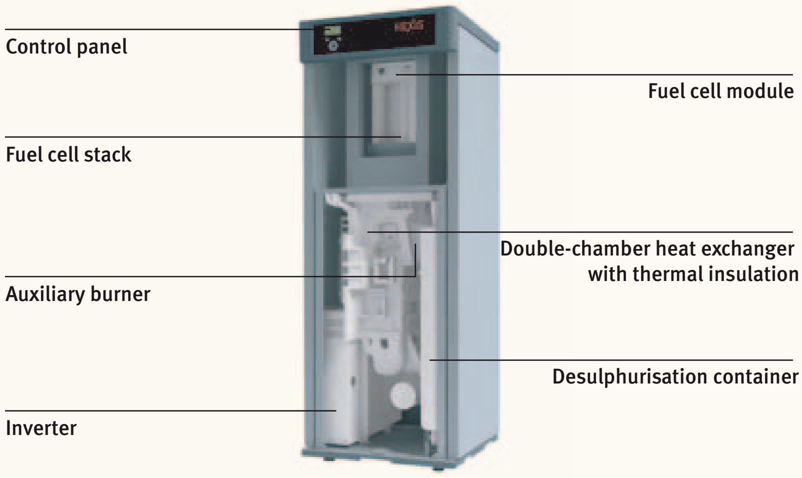

Fig. 2 *Structure of a fuel cell heating unit*
Source: HEXIS AG

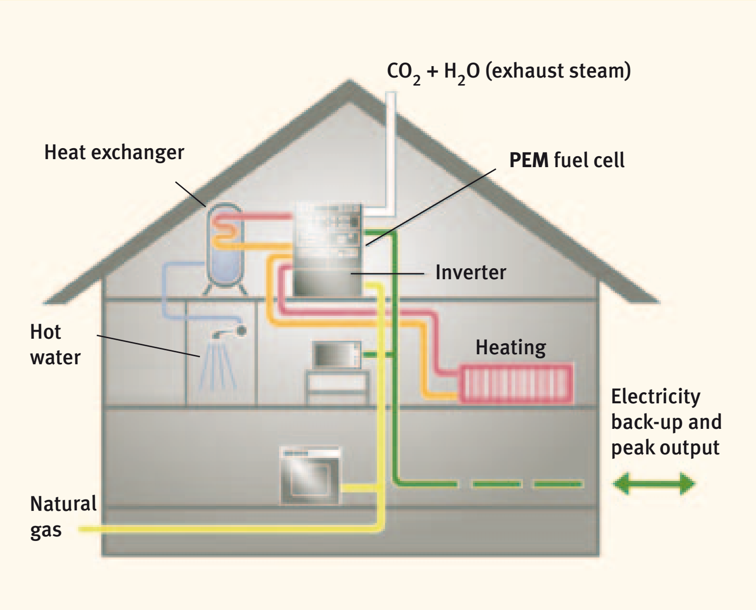

Fig. 3 *Schematic overview showing how a fuel cell heating system functions in a residential building Source: BAXI INNOTECH GmbH*

Fig. 4 *Fuel cell heating unit in a basement Source: Vaillant GmbH*

field test have so far been running for an average of between 4,000 and 6,000 hours, whereby individual units have already been running for more than 15,000 hours. As of May 2012, more than 230 units were being operated as part of the Callux project. More than 1,000,000 operating hours have now been achieved in total. The EnBW energy supply company has been able to gain experience with different fuel cell systems in more than 400,000 operating hours, whereby one fuel cell has been operating for more than eight years. The lifetime has been considerably improved from device generation to device generation, and the degradation has also been considerably reduced (to less than 2 % per 1,000 hours). The average electrical efficiency for all manufacturers is now more than 33 %, which means that the electrical efficiency for fuel cell CHP units is considerably higher than for engine-powered CHP systems, and even double as high as systems using Stirling engines. This high efficiency in generating the higher value electrical energy is a feature that sets the fuel cell heating technology clearly apart from other CHP plants.

The fuel cell units in the field test

The first prototype devices were still very susceptible to faults during the field-testing and their performance, output and operating times were considerably less than that striven for. The manufacturers have specified the following target values for the latest systems with an output of 1,0 kWel: the service life is intended to exceed 40,000 operating hours (more than 30,000 hours have already been reached) and the costs are supposed to be halved, whereby the overall efficiency has now reached 97 %. Fig. 1 provides an overview of the technical data for the various systems that have been tested in different projects.

Baxi Innotech Gamma 1.0: The low-temperature (LT) PEM fuel cell heating units from the latest test device generation have been undergoing testing in single-family homes since 2009. It is considerably smaller, more powerful and has a longer service life than the predecessor models that have been undergoing field-testing since 2005. It is deployed as a comprehensive fuel cell heating system with an integrated condensing boiler, energy manager and heat storage tank. The system can meet up to 100 % of the heating requirements and more than 75 % of the electricity requirements. It achieves a high efficiency with full and partial loading, and can be modulated throughout the year in accordance with requirements.

Ceramic Fuel Cells' BlueGen micro power plant: (not participating in Callux) After 500,000 hours of field tests at customers in nine countries, an initial small-scale production run comprising 1,000 units of the SOFC fuel cell system has been available on the market since the beginning of 2012. It is mainly intended for use in Germany, the Netherlands and the UK. It can be incorporated into existing heating systems as an add-on device and remotely maintained and controlled via the Internet. Together with energy suppliers and a boiler manufacturer, the company is developing a complete fuel cell heating unit based on the system.

Hexis Galileo 1000 N: The device consists of an SOFC fuel cell module and components for converting electricity, extracting heat and providing additional heating. The main component is a double-chamber heat exchanger in which the auxiliary burner is integrated along with a ventilator, gas/air ratio control system and heating circuit pump. It is designed to meet the basic electricity requirements (4,000 – 5,000 kWh/a) and the entire heating requirements (15,000 – 30,000 kWh/a) for a typical Central European single-family home.

Vaillant fuel cell heating unit: Following comprehensive evaluation of the technology and European-wide field tests with 60 systems and more than 400,000 operating hours, the company is now focussing on the further development of a fuel cell heating unit that is based on SOFC technology. The core of the system is a stack model from Staxera GmbH. Further components have been developed in cooperation with Fraunhofer IKTS. The device is mounted on a wall and the system can be started and stopped without any significant drop in the electrical performance. Maintenance intervals are specified at every 10,000 hours. The cold start-up time has now been reduced to 2-3 hours. Together with EnBW, the first wall-hung trial device began operation at the beginning of 2012. After testing 24 devices during the first stage of the Callux project, it is now planned to test a total of 120 fuel cell heating units by 2013.

Good things take time

Developers and manufacturers initially concentrated on low-temperature PEM technologies but are now increasingly working on high-temperature PEM and SOFC systems with a particular focus on improving the material properties, start-stop cycles and service life. The developers still need to improve the lifetime of the components, optimise both the production technologies and quality assurance, and develop reliable supply structures, in particular for the peripheral components. The fuel cell heating unit costs are still higher than expected. An improvement can be made here if manufacturers can agree on a joint basic stack and thus enable cheaper production in larger series.

Whereas in the EU the first large-scale field tests are being conducted with a few hundred devices, the dissemination of fuel cell heating units has already progressed further in Japan thanks to the availability of state funding: more than 18,000 units were already installed by 2011. Several major Japanese manufacturers market their devices, which were developed separately but in accordance with joint specifications, under a joint umbrella mark.

The semi-nationalised Japanese New Energy and Industrial Technology Development Organization is striving to improve the lifetime from 40,000 hours at the moment to 90,000 hours by 2030, whereby the unit costs are intended to drop during this period from almost 20,000 euros to around 3,000 euros. The aim is to install 300,000 units by 2015. Manufacturers assume that around one quarter of the energy costs can be saved.

Technical problems and the poor lifetime of the systems means that Europe is still lagging behind in terms of introducing the fuel cell technology. The optimistic expectations have not been realised and technology introduction programmes that were planned several years ago are yet to be implemented. Thanks to the development progress that has been made, however, the technology is now fully developed and subsidies should help the technology find its way into basement boiler rooms: Saxony is planning a “1,000 basement programme” and funding for micro CHP plants based on fuel cells is currently being discussed in five other federal states in Germany. The Callux flagship project is being followed by the expanded “BZHregio” demonstration project (with 1,350 units), which is intended to lead to a technology introduction programme. The National Development Plan envisages that more than 70,000 fuel cell heating units will be introduced per year by 2020.

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Links and literature (in German)

- www.callux.net | www.baxi-innotech.de | www.cfcl.com.au | www.hexis.com | www.vaillant.de www.zsw-bw.de | www.now-gmbh.de | www.ibz-info.de
- Gummert, G. u.a.: Entwicklung einer Hausenergiezentrale auf Basis einer PEM-Brennstoffzelle. Abschlussbericht; Baxi Innotech GmbH, Hamburg, (Hrsg.). 2011. FKZ 0327143D.
- Paulus, J. Entwicklung eines 1 kW SOFC-Brennstoffzellen-Heizgerätes (KWK) auf Basis einer SOFC-Kernkomponente, die in mikroKWK-Systemen und mobilen Bordstromversorgungen (APU) eingesetzt werden kann. Abschlussbericht. Vaillant GmbH, Remscheid (Hrsg.). 2010. FKZ BMWi 0327750 - 0327750A - 03ET6002.

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