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Cogeneration in Single Family Homes with Fuel Cell Heating Appliances

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1 Fuel Cell Manufacturer Hexis

Since beginning of the year 2006 Hexis Ltd. is working as an independent company on the further development of SOFC heating appliances for the environmentally sound and cost-effective energy supply of single family and small multi family homes. Hexis restarted its business with the background of more than 20 years experiences in solid oxide fuel cells (SOFC) ranging from materials to systems development as well as field trials. In 2007 Hexis started its new business in Konstanz, Germany. A Swiss foundation in Winterthur funds this effort as a 100 percent owner of the company.

Figure 1: Galileo 1000 with domestic hot water tank in a single-family home.

Hexis has an extensive laboratory and test infrastructure. The company experienced the operation of more than 100 fuel cell systems from the first system generation. As a result of this effort the new fuel cell system called Galileo 1000 N has been developed. In the mean-time it showed already good results. All that and an extensive knowledge for the integration of the stack in a fuel cell module and a system makes Hexis confident to progress with its 18 member team, mainly scientists and researchers on the development of the SOFC based

micro-CHP (Combined Heat and Power) unit Galileo 1000 N. As such this device will substitute the gas boiler and, in addition, produce electrical power. Generation of electricity will be shifted from the central power plant to the fuel cell system in a household.

2 Fuel Cell System for Single Family Homes

This fuel cell heating appliance is developed to cover both the entire heat requirements and the basic requirements for electrical power of a single-family home. Galileo 1000 N works efficiently, with lowest emissions and virtually silently.

Fuel cell heating appliance Galileo 1000 N	
Fuel cell	
Electrical Output	1 kW_{el}
Thermal Output	2 kW_{th}
Type	Solid oxide fuel cell (SOFC)
Fuel processing	Catalytic partial oxidation (CPO)
Electrical efficiency$_{ACnet}$	30 % (Target 35 %)
Overall efficiency	> 90 % LHV
Operation mode	Modulating, steady operation, switch-off in summer
Emissions	NOx < 22 mg/kWh, CO < 20 mg/kWh
Integrated back-up burner	
Output	4-20 kW_{th}
Operation mode	Condensing boiler, modulating 1:5, DHW in summer
Entire system	
Overall efficiency	90-105 % LHV
Fuel	Natural gas
Dimensions	550 x 550 x 1600 mm
Mass	170 kg

Figure 2: Specifications of the fuel cell heating appliance Galileo 1000 N [1].

Galileo 1000 N basically consists of two parts. In the upper part is the fuel cell module with insulation which is easily accessible in the case of maintenance. In the lower part are the components for power transformation, the heat transfer and the supply of the additional heat. This fuel cell system is compact and light because functions and components have been combined and simplified, and it is easy to service and suitable for series production and so, Galileo 1000 N combines high-tech with user friendliness.

The fuel cell supplies an electrical power of 1 kW and a thermal capacity of about 2 kW. If heat requirements of the building exceed this value, an integrated back-up gas burner will provide another 20 kW of heating energy. Overall efficiencies of more than 90 % and electrical efficiencies of more than 30 % have been demonstrated in the field. About 47 systems are currently in service, approximately 43 Galileo 1000 N and some less of its predecessor. Galileo 1000 N is significantly smaller and lighter than this predecessor. Its manufacturing costs have been significantly reduced and the system is easy to operate and fully integrated. It operates directly on natural gas which is converted by an integrated partial oxidation cata-

lyst. The integrated SOFC stack consists of circular electrolyte-supported planar cells and metallic interconnectors. The post-combustion zone is located around the open stack, minimizing sealing demands and simplifying the thermal management of the system.

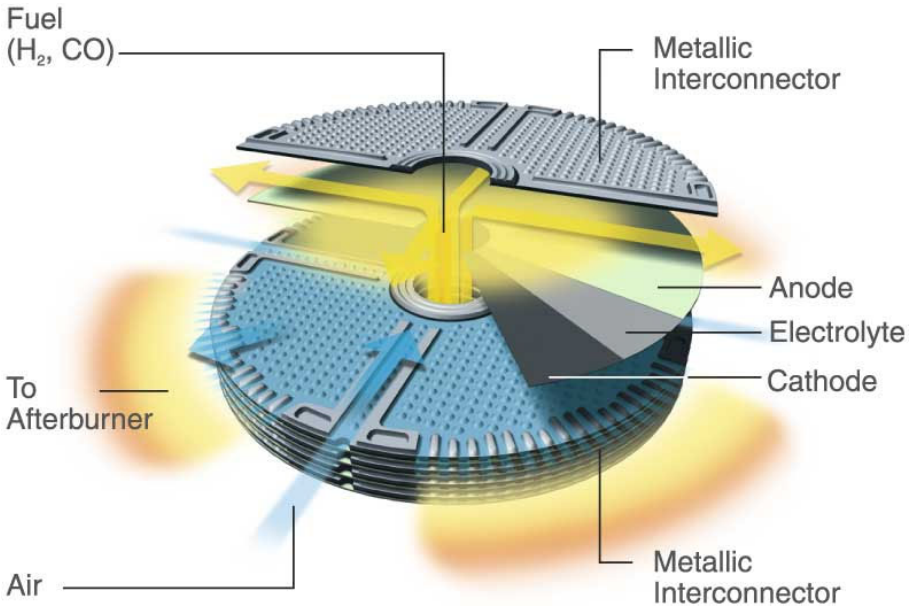

Figure 3: Hexis fuel cell stack and its basic principle.

A double chamber heat exchanger serves as the central supporting component. The additional burner with blower and gas-air ratio control as well as the heating circulation pump are integrated in there. By means of a hot water circuit the waste heat of both the fuel cell and the additional burner can be used for the supply of space heat and domestic hot water. The exhaust gas flows are combined in a condensate collecting pan. The induced draft fan of the fuel cell integrated here provides the air for the electrochemical reaction in the fuel cell.

The system operates in low air pressure which means that it is inherent safe against leakage. The transformation from direct in alternating current of 230 V is carried out by an inverter. Energy management software makes the system to run during the entire year. When the heat demand of the building becomes too small in summer the system switches off. Domestic hot water will be provided by the back-up burner during that time. In autumn when average outside temperature becomes lower, the fuel cell itself will be started again automatically.

Within the fuel cell itself the pre-reformed gaseous mixture of hydrogen and carbon monoxide oxidizes at the anode. On this occasion electrons are released that are then conducted on the cathode by an electrical conductor outside the fuel cell. At the cathode a part of the air oxygen is reduced with the released electrons which produce oxygen ions. At an operating temperature of between 800 and 1000° centigrade these are carried through the now ion conductible electrolyte. At the anode end these ions recombine with the oxidized fuel to water vapour and carbon dioxide. The electrons that are conducted from the anode to the cathode are used as electrical power on that occasion.

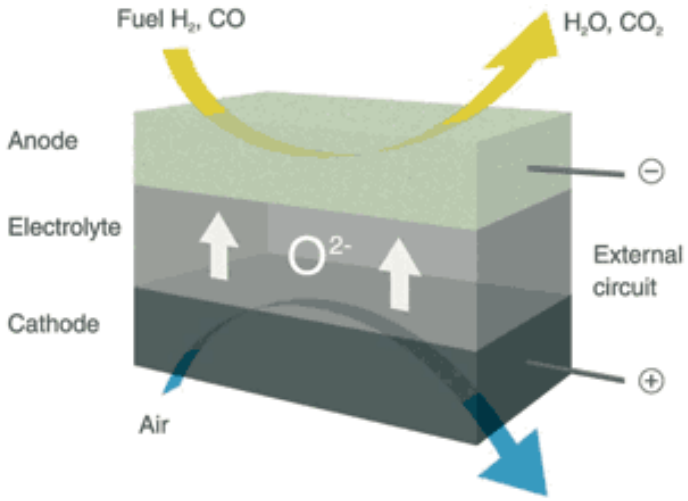

Figure 4: Electrochemical process.

3 Experience from the Laboratory and the Field

In the laboratory overall efficiencies of approximately 95 % and electrical efficiencies of more than 35 % have been demonstrated [2]. A significant reduction in primary energy consumption and therefore in carbon dioxide emissions is possible. Both emissions of pollutants and noise are extremely low. Very low noise emissions of 30 dB (A) have been measured in front of the system [3]. Stack lifetime of more than 24'000 operating hours in the laboratory and more than 9'000 hours in the field have been showed. Those systems are still in operation.

Figure 5: Single-family home in Mülheim/Ruhr, Germany, with Galileo 1000 N [Source: T.B.E. GmbH, Duisburg].

Systems tests are being conducted especially in the field to gather experience under real operation conditions and feedback for further improvements. So, field systems will be operated together with field test partners in the energy industry. The picture on the left shows a single family home in Mülheim/Ruhr, Germany next to the WHEC's venue where Galileo 1000 N will be operated until end of April 2010.

4 Micro CHP Market

Target market of Hexis' fuel cell heating appliance is the building refurbishment market in Europe. All houses which provide a sufficient heat demand, a connection to the grid and natural gas supply as well have a central heating system can be equipped with such a CHP device.

Hexis plans to introduce the fuel cell system Galileo 1000 N from 2012/2013 into the European market. After comprehensive field test the company expects to achieve reach the technical and economical qualification for a successful market launch. Until than the good technical status regarding stack lifetime and system reliability will be improved so that customer requirements can be fulfilled.

In future end customer will either buy a fuel cell system – analogue to a conventional gas boiler today - and operate it self dependently, or provide in the context of a energy service contract an operation site for that fuel cell system and just pay for the supplied heat and electricity. Everything else, from financing, planning, installation, commissioning, operation and service until billing will be done by the energy service company.

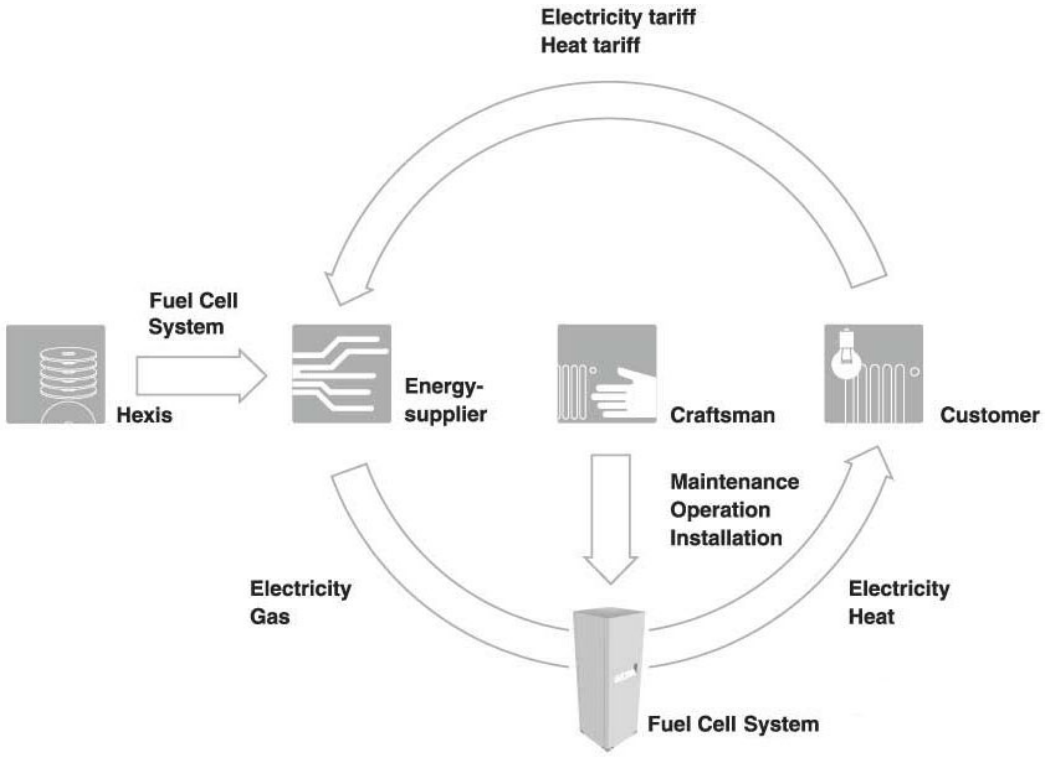

Figure 6: Business Model Energy Service with fuel cell systems.

The other option is: The end customer will buy a fuel cell system via the installer. The latter will deliver, install, commission and maintain if needed the system. The customer will operate it on his own responsibility. To access this sales channel Hexis started a sales and service cooperation with two well established companies in the heating market. These are Stiebel Eltron, Holzminden in Germany, and Hovalwerke, Vaduz in Liechtenstein [1].

5 Summary

The presentation will not be an announcement of a tomorrow market launch, but it will show clear perspectives of a micro CHP solution based on fuel cells made by Hexis. Although, most steps to improve the fuel cell system and its core component, the fuel cell stack, are well known and understood, its further development is time consuming. By-and-by, those steps will be transformed into system technology in order to make Galileo 1000 N being a product, not a prototype.

Long term successful and broad execution of laboratory and more than ever the field tests represents the next challenge on the road to marketing these systems. Statistically firm data of field test operation will be one crucial basis to make Hexis sure to be ready for the market with Galileo 1000 N from 2012 approximately. Additionally, the callux project of the German "National Innovation Programme for Hydrogen and Fuel Cell Technology" pushes the technology forward to improve and enables the manufacturers to head for the market.

The manifold advantages provided by the fuel cell system Galileo 1000 N make Hexis to work hard and to create a marketable and an outstanding product. The experience and knowledge the team gained already makes us confident to continue the Hexis track record.

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