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ORAL Presentation / F
What are the opportunities for natural gas in homes and businesses of the future?

MCHP & FUEL CELLS

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1. ABSTRACT

The energy market is undergoing profound change. Inter-fuel competition has never been more intense. As it is the market with the highest energy demand, the residential and commercial heating market has come under significant pressure in most European countries. The situation can be described as follows:

- **Downward trend in heat demand due to more stringent building insulation requirements**
- **Emergence of highly efficient electrical appliances**
- **Rising trend in demand for renewable energies**
- **Weakening perception of natural gas as a clean fuel**
- **Relative absence of new gas technologies on the market**

The gas industry is facing new challenges: it has to cope with effects from changes in legislation and meet its customers' expectations and new requirements on the market.

Teaming up with its market partners, the gas industry needs to initiate further developments, offer technical options which include mCHP and renewable energies to ensure that the heat requirements of buildings are met in an optimum manner, restore the image of natural gas as a clean and innovative fuel and demonstrate that gas technology is indispensable for achieving the targets set for global climate protection.

The paper discusses the aspects of future technologies for the residential and commercial heating market. It also stresses the gas industry's task of promoting and marketing new technologies and evaluating their potential for generating additional revenue along the value chain. It focuses on mCHP and fuel cells from the perspective of German energy suppliers in general and, more specifically, of E.ON Ruhrgas and provides some information about the company's motivation and activities.

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2. NEW TECHNOLOGIES & INNOVATIVE APPLICATIONS – THE GAS INDUSTRY's ANSWER TO NEW CHALLENGES

Situation

The energy market is undergoing profound change. Inter-fuel competition has never been more intense. As it is the market with the highest energy demand, the residential and commercial heating market has come under significant pressure in most European countries.

European governments are in the process of organising the change-over to sustainable energy supplies for the future. Governments and authorities have identified a multitude of country-specific measures relevant to natural gas, all strongly affecting the residential and commercial market.

A number of influencing factors, such as legislation, initiatives or other measures (more or less strongly pronounced in the different countries), increase the risk of the gas industry losing market shares:

- **Downward trend in heat demand due to more stringent building insulation requirements**
- **Emergence of highly efficient electrical appliances**
- **Rising trend in demand for renewable energies**
- **Weakening perception of natural gas as a clean fuel**
- **Relative absence of new gas technologies on the market**

The gas industry should map out a strategy to be pursued in this changed environment. New technologies are required to compensate for declining market shares which many countries have already experienced. Synergy effects should be exploited in the development and marketing of new technologies, while effective and efficient cooperation of the key players is essential in ensuring successful implementation. Otherwise natural gas might gradually disappear from some markets, for example from the heating market.

Together with appliance manufacturers and other market partners, the gas industry is now facing the challenge of offering consumers alternative technical options in a difficult competitive environment. Energy suppliers and appliance manufacturers should adopt a common approach vis-à-vis the government and step up efforts to gain financial support for creating an mCHP market.

Gas-based mCHP in residential and commercial market

Combined generation of heat and power (CHP) is considered one of the most efficient measures for enhancing energy efficiency and curbing CO_2 emissions. The share of CHP in total electricity generation should therefore be expanded over the coming decade. CHP is becoming increasingly interesting against the background of the targets set for climate protection and the trend in energy prices. Natural gas has been widely used in the medium to large CHP range for a long time. CHP achieves very high efficiencies thanks to the simultaneous generation of heat and power. Up to 90% of the energy used as input can be converted into useful energy. Primary energy savings as high as 30

to 40% are possible compared to the conventional approach of generating heat and power in separate processes (for example, electricity from a central power station and heat from a boiler). Moreover, CHP involves considerably lower CO_2 emissions, and heat and electricity are generated locally where they are needed, minimising transportation losses.

Natural gas is a particularly suitable option for efficient CHP. Natural gas-based CHP and gas turbines have been used successfully as energy-saving techniques for years, above all in the range from 50 kW. Thanks to substantial progress in developments the spectrum of natural gas-based CHP will be expanded to include more solutions in the low-output range.

Technologies discussed in connection with mCHP include the Stirling engine, the steam engine or fuel cells. The technologies are all still in the process of development. Two low-power units suitable for single-family or semi-detached homes entered the European/ German markets in 2010. Up to four units from other manufacturers are expected to follow in 2011.

In light of rising energy costs and ambitious climate protection targets CHP is an important option in future energy supplies. The technology involves huge potential for saving primary energy and reducing CO_2 emissions in single-family or semi-detached homes or small commercial operations. Natural gas can be a valuable tool in tapping this potential. The heat generated in mCHP units can be used for space heating and hot water production and excess electricity not needed on site can be fed into the electricity network.

mCHP technologies

Several conversion technologies have been examined for use in mCHP systems.

Stirling engines are external combustion engines which alternately heat and cool a working gas in a closed chamber; the pressure rise and drop from the changing volume of the working gas causes a piston to move, thereby driving the electricity generation system.

Steam engines are also external combustion engines which use, for example, natural gas burners. Water is heated to form steam, greatly expanding in volume and driving a piston. The steam cools and condenses and the heat released in the process is returned to the heating system.

Fuel cells convert chemical energy into electrical and thermal energy in an electrochemical process. The design includes a catalyst which causes hydrogen to split into positive hydrogen ions (protons) and negatively charged electrons. The protons and electrons then travel to the cathode, being forced to use different ways. Natural gas serves as a hydrogen source. It is produced in a separate fuel reformer which is fitted in the stationary fuel cell enclosure.

Reciprocating engines are conventional internal combustion engines coupled with generators and heat exchangers to recover heat from the exhaust gas and cooling cycle.

Market

Potential for the application of mCHP systems is mainly seen in buildings with central heating systems. Basically this means that conventional heating systems will be replaced by electricity generators with heat exchangers. The heat generated is used for space heating and hot water production. The electricity generated is consumed on site or fed into the electricity network.

Renowned manufacturers have been examining the technical side of mCHP for quite some time. But the technical solutions available so far, based on the technologies mentioned in this paper, are just about to enter the market. Fuel cell-driven mCHP, for example, will probably take several years until the first appliances will be launched. In Germany, the Callux demonstration project was initiated in 2008. The systems being tested under the project are not expected to be launched until 2015. In Japan, PEM fuel cells have successfully passed the demonstration phase. More than 10,000 PEM systems have now been installed. The trend in Europe seems to be clearly towards Stirling engines. The units already available on the market have so far mostly been operated under field tests which are to provide reliable results as to functional capability and use in practical operations. In Japan, the ECOwill gas engine has proved successful on the market; more than 100,000 appliances have been sold so far. It will soon also be available on the European market.

The success of CHP will also depend on capital expenditure and technical developments (need for compact, quiet and reliable appliances). CHP technology is considered an interesting option at political level and therefore included in funding programmes. Some manufacturers consider CHP as the technology replacing condensing technology in residential applications. For natural gas suppliers, mCHP is a new outlet on the market.

mCHP is very suitable as a new natural gas technology in residential appliances:

- **New buildings**
  Engine-driven mCHP is not considered a reasonable option (low electrical efficiency); a low-rated fuel cell should be used instead (high electrical efficiency).
- **Existing buildings**
  In this case, engine-driven mCHP is a reasonable option because of high thermal output which can be used to meet higher space heating requirements.

Under quite a number of projects and studies attempts were made to predict the potential for mCHP in Europe. Predictions ranged from about 5 million to an optimistic number of 12 million mCHP appliances in Europe by 2020, identifying the United Kingdom, Germany and the Netherlands as initial markets. The mCHP mass market will mainly cover the replacement of gas and oil-fired boilers.

Triple win situation

An mCHP market can be considered a triple win situation reflecting the interests of governments, energy suppliers and manufacturers.

- **Governments – compliance with CO_2 reduction targets**

In keeping with the goals of saving energy, reducing CO_2 emissions and enlarging the share of renewable energies in the energy mix, many EU countries are setting up their own energy efficiency action plans. Organising their fuel and energy supply for the future, research and development on mCHP is gaining increased favour at national (government) level. Government policy support mechanisms which are designed to promote mCHP market introduction vary considerably between countries. These measures include sales subsidies paid by governments to home owners or mCHP manufacturers, bonus payments for exported/generated electricity and other country-specific bonuses like energy tax exemptions or similar.

- **Energy suppliers – own business advantages, more value from supply chain, higher gas sales**

Energy suppliers wish to position themselves for a potentially new market opportunity while mitigating any possible threats from new-entrant CHP players taking market share. For energy suppliers, CHP offers the means to increase the value of their portfolios, enhance efficiency and portfolio diversification as well as secure new customers.

There are a number of ways for energy suppliers to secure value from the mCHP value chain. They can

- Become involved in creating intellectual property through research and development by investing in a start-up hoping to gain return of investment when the developer introduces the product on the market;
- invest in product manufacture, working closely with a technology developer to bring the product to the market;
- sell products to customers, eventually including financing packages;
- sell fuel or energy;
- provide warranty and service packages;
- include all technology options, that means act without link to a technology or exclusive ties with a manufacturer, just facilitating mCHP markets by supporting field tests, helping to remove barriers or similar.

- **OEMs – mass market opportunity, with government and energy supplier backing**

For gas appliance OEMs demand for distributed generation solutions provides a new product line, enables them to stand out from competitors, and follows company philosophy committed to innovation, careful use of resources and efficient energy use. Because of an innovation gap in the heating appliance market OEMs realise the opportunity to enlarge the product portfolio based on energy saving and environmentally friendly technologies hoping/expecting to get support from the government and/or energy suppliers.

Technology availability; research, development and demonstration (RD&D)

Much of the RD&D conducted by utilities and OEMs will be motivated by opportunities in what is seen as a promising new market sector.

RD&D activities and involvement can take several forms. In Japan, the gas industry is deeply involved in component and sub-system R&D for fuel cell units, and the gas industry also supports field trials. In the United Kingdom, the Netherlands and Germany, gas suppliers are heavily involved in

- **lab testing** in order to better understand the actual status of a product development and suitability for the market and in
- **field testing** under real-life conditions as a vital prerequisite for taking a product from the lab to commercialisation. Field tests in close cooperation between gas suppliers and OEMs help identify unforeseen problems and help manufacturers to overcome such problems and get their product to the market.

Gas suppliers must be involved as main player when the market develops. It is necessary to gain in advance the knowledge and skills required to extend their coverage to the business (such as secure gas sales, energy service business, customer acquisition, customer retention). From an RD&D perspective gas suppliers focus therefore on the identification and evaluation of near market ready or recently introduced technologies to support diverse product portfolios. In order to be able to offer appropriate distributed generation installations and related high quality advice to a wider range of customers, gas suppliers will be well placed if they are fully familiar with the range of technologies and able to offer at least several different systems.

3. MCHP – E.ON RUHRGAS AS A DRIVING FORCE

Motivation and drivers

E.ON's interest focuses on stationary applications for the residential market, in particular on mCHP systems. The technology is still in the process of development and an mCHP market does not yet exist. But once it has reached a mature stage, the technology is expected to create additional market potential. The E.ON Group will not take an active part in technology development or appliance manufacture, but it considers it a key task as energy supplier to offer its customers attractive products. It has already gained extensive experience in field testing mCHP fuel cell systems at customer sites and is closely working together with important mCHP manufacturers. E.ON adopts a comprehensive approach not limited to certain developers/manufacturers or specific appliances. It is mainly interested in obtaining information about tests with advanced prototypes (coming close to pre-commercials); but the company also includes demonstration projects covering promising early prototypes in its considerations.

3.1 mCHP user group – E.ON Ruhrgas encouraging innovation

Innovative technologies based on natural gas will continue to be indispensable. As electricity-generating heating systems, mCHP appliances can be an attractive alternative to proven gas condensing appliances in combination with solar heat. Today, virtually all important appliance manufacturers are involved in the development of mCHP heating appliances.

The first units have been offered on the market in relatively low numbers this year. Manufacturers will continue to expand the range of products. Several technically mature appliances are expected to be launched in 2011. As a supporting measure E.ON Ruhrgas is currently making the largest mCHP

heating appliance field test throughout Germany in cooperation with many market partners. At the same time the appliances tested in the field are also subjected to comprehensive testing in the laboratory.

Strong arguments in favour of mCHP

Protection of the climate and the environment

Decentralised combined generation of heat and power based on natural gas can contribute to reducing CO_2 emissions by up to 40%. This helps protect the environment and promote the image of natural gas as a clean fuel. Energy suppliers can benefit from the situation and adopt a more offensive marketing approach to promoting the innovative technology in the single- and two-family home segment (in particular existing buildings).

Acquisition of new customers

Energy suppliers with a proactive approach and concrete activities also have convincing arguments. This is a good opportunity to expand product portfolios and win new customers.

Customer retention

Energy users have growing expectations for modern energy supplies. This is also confirmed by rising growth rates in the renewable energies segment. Companies supporting innovative energy saving technologies use the opportunity to present themselves as innovative and modern players.

Energy consumption and natural gas sendout

Active commitment means setting trends. The less-is-better concept also applies to energy consumption: with total efficiencies of more than 90%, mCHP heating appliances are very attractive energy saving options. Compared to conventional generation of heat in a boiler and electricity supplied from the network the primary energy consumption of a residential building can be reduced by up to 40%, higher gas consumption for the generation of electricity already taken into account.

In September 2009, E.ON Ruhrgas established the mCHP user group. With this step the E.ON Ruhrgas Marketing Services Department provided the basis for the most comprehensive mCHP heating appliance field test throughout Germany conducted together with the company's reselling customers. The members of the user group exchange information about appliance developments, results from field and laboratory tests, experience from practical operations and current trends on a confidential and regular basis following discussion with the appliance manufacturers. This approach ensures direct and prompt exchange of experience among the members of the user group, keeping individual input to a minimum.

The common goal is the efficient market introduction of technically reliable appliances. More than 200 mCHP heating appliances of different manufacturers and designs are being put to the acid test in a comprehensive field test as well as in the laboratory. For this purpose, the members select

appropriate residential buildings in their supply areas where the new appliances are installed. Experts monitor operations using comprehensive measurement equipment and submitting regular reports on the results obtained. The data are made available to the manufacturers providing them with a reliable knowledge base for technical optimisation.

The most important benefit energy suppliers derive from the mCHP user group is constantly up-to-date information about the status in mCHP heating appliance developments. The user group members can use the knowledge to gain a competitive edge, helping them to make decisions and enhance selective end user communication in the field of mCHP heating appliances.

A constantly rising number of energy suppliers make use of this interesting offer of E.ON Ruhrgas. The mCHP user group now (May 2011) has more than 52 participants, including municipal utilities, gas transmission companies and E.ON marketing companies.

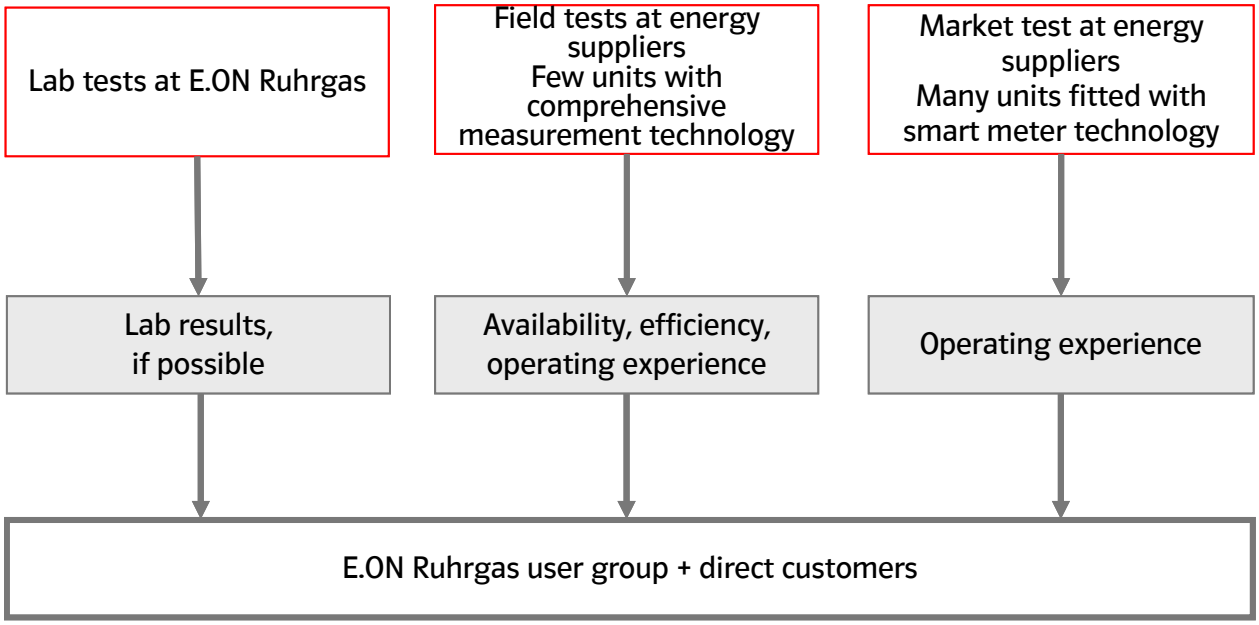


Figure 1:
Innovation support: mCHP user group

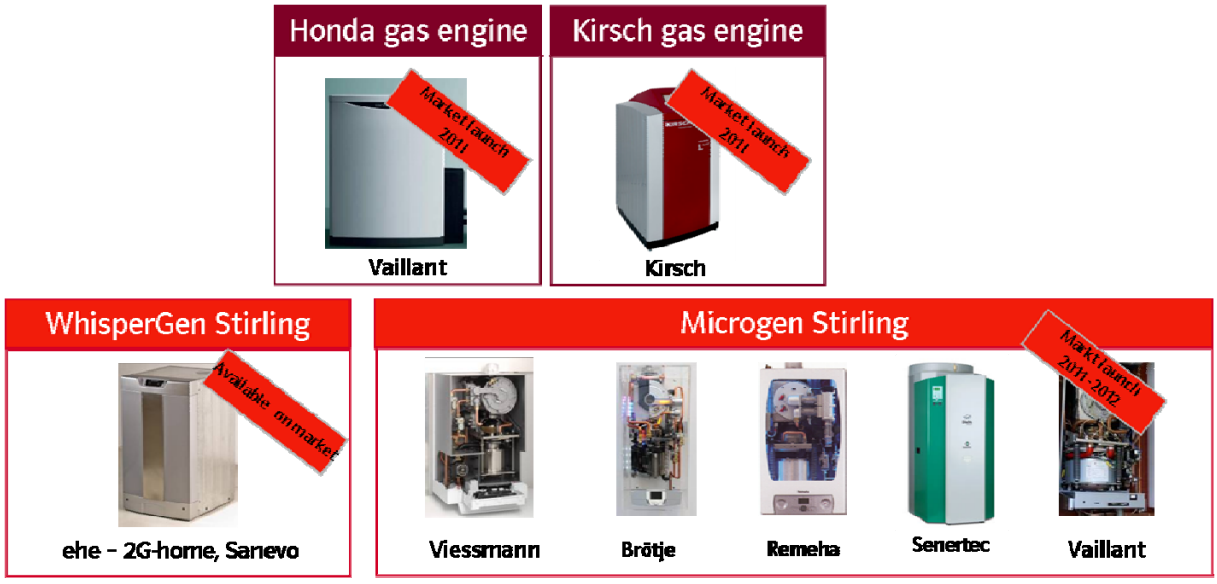


Figure 2:
Core technology and system integrators
Technology partners in E.ON Ruhrgas mCHP user group
Overview of current technical developments

3.2 Hydrogen & fuel cell technology – E.ON Ruhrgas supporting National Innovation Programme (NIP)

Fossil energy sources are becoming increasingly scarce and expensive. At the same time, excessive levels of CO_2 emissions are changing the climate. That is why alternatives to oil and gas are needed. Together with industry, the federal government, as part of the high-tech strategy for Germany, is promoting applied research into drive train systems and stationary energy systems using hydrogen and fuel cell technologies.

NOW spearheading the innovation programme

Germany is the leading European country in the field of hydrogen and fuel cell technology. It is imperative to continue to assert and develop this international competitiveness. For this reason, the National Organisation for Hydrogen and Fuel Cell Technology (NOW) was established in February 2008. It is designed to be the driving force in the development and commercialisation of internationally competitive hydrogen and fuel cell technology products and to assume control of the overall programme. The federal government and industry will provide a total of 1 billion euros for research, development and demonstration projects over the next 10 years.

NOW is a component of the National Hydrogen and Fuel Cell Technology Innovation Programme (NIP), launched jointly by the Federal Ministry of Transport, Building and Urban Affairs, the Federal Ministry of Economics and Technology, the Federal Ministry of Education and Research and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The programme is part of the high-tech strategy for Germany and ties in with the federal government's fuel strategy.

The National Innovation Programme provides a common framework for numerous hydrogen and fuel cell research projects conducted by academic institutions and industry. The public-private partnership (PPP) is scheduled to run for 10 years. Over this period, the federal government will provide 500 million euros, with industry contributing at least the same amount to the project.

The objective is to develop viable market products from hydrogen and fuel cell technology research and development projects. The process of development should involve as many industrial companies, small and medium-sized enterprises, users and research institutions as possible. Illustrative demonstration projects are to prove that hydrogen and fuel cell projects that are now ready for deployment are suitable for everyday use. The research funds are thus not only an investment in a clean environment but also help to create sustainable jobs in Germany.

Callux lighthouse project

On 23 September 2008, the German Federal Ministry for Traffic, Construction and City Planning (BMVBS) started Callux, the biggest nationwide field test of fuel cell heating systems for private homes. The test is being made together with nine partners from industry. This marks a new phase in decentralised energy supplies in Germany. Within the framework of NIP, the hydrogen and fuel cell technology innovation programme coordinated by NOW, industry is investing in the promotion of innovative technologies together with BMVBS.

Fuel cell heating appliances are to support the development of highly efficient decentralised energy supplies in the long term. Under the most comprehensive field test of fuel cell heating appliances for single-family homes so far in Germany, appliances and components are to be tested and operational experience is to be gathered in order to work out solutions to user problems. The project partners together have contributed around 86 million euros to make the innovative technology a success on the market. Over a period of eight years, a total of around 700 fuel cell heating appliances are to be installed primarily in single-family homes and tested for their suitability in practical operations.

Callux is of Latin origin and derived from *calor* (= heat) and *lux* (= light). This is a clear reference to the key benefit of fuel cell heating appliances: the combined generation of heat and power (CHP) achieving high efficiencies. Depending on the design, efficiencies may be as high as 50 to 60% (thermal) or 30 to 40% (electrical) with a total efficiency of approx. 90%. Fuel cell heating appliances save up to 30% primary energy compared to conventional systems. Fuel cells are therefore considered an important option for future energy supply, in particular with a view to achieving the goals set for climate protection and CO_2 emission reduction. Moreover, the appliances are versatile and have low noise levels. The outlook is particularly promising for residential CHP plants with natural gas-driven fuel cells in the lower output range around 1 kW_e. Three appliance manufacturers (Baxi Innotech, Hexis and Vaillant) as well as five energy suppliers (EnBW, E.ON Ruhrgas, EWE, MVV Energie and VNG Verbundnetz Gas) have teamed up under the Callux project.

Callux allows the systems to be tested in the field under real conditions and potential for improvement to be identified. This is a very important step on the way towards a marketable product as it provides statistical data on performance, reliability and service life of individual components and the system as a whole.

Further goals include:

- Prepare market for natural gas-based fuel cells
- Support development into marketable appliances and demonstration projects
- Secure orders for large numbers of plants to develop production chain
- Intensify advertising
- Develop new concepts for fuel cell integration in existing infrastructure
- Train HVAC trade
- Validate customer and market requirements
- Enhance value creation in Germany

callux
Praxistest Brennstoffzelle fürs Eigenheim

Energy suppliers:

EnBW e·on Ruhrgas EWE MVV Energie Verbundnetz Gas AG

Fuel cell manufacturers:

BAXI INNOTECH fuel cell heating

HEXIS

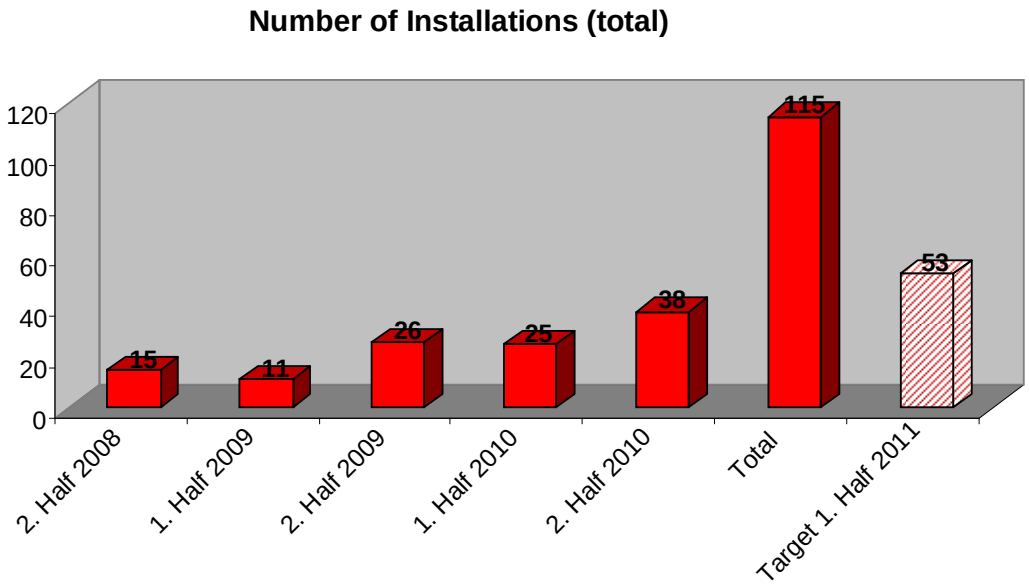
Vaillant

Figure 3:
Members of Callux consortium

Public Fleet Report

(Overview: 01.07.2008 – 31.12.2010)

Fleet Stock (total)



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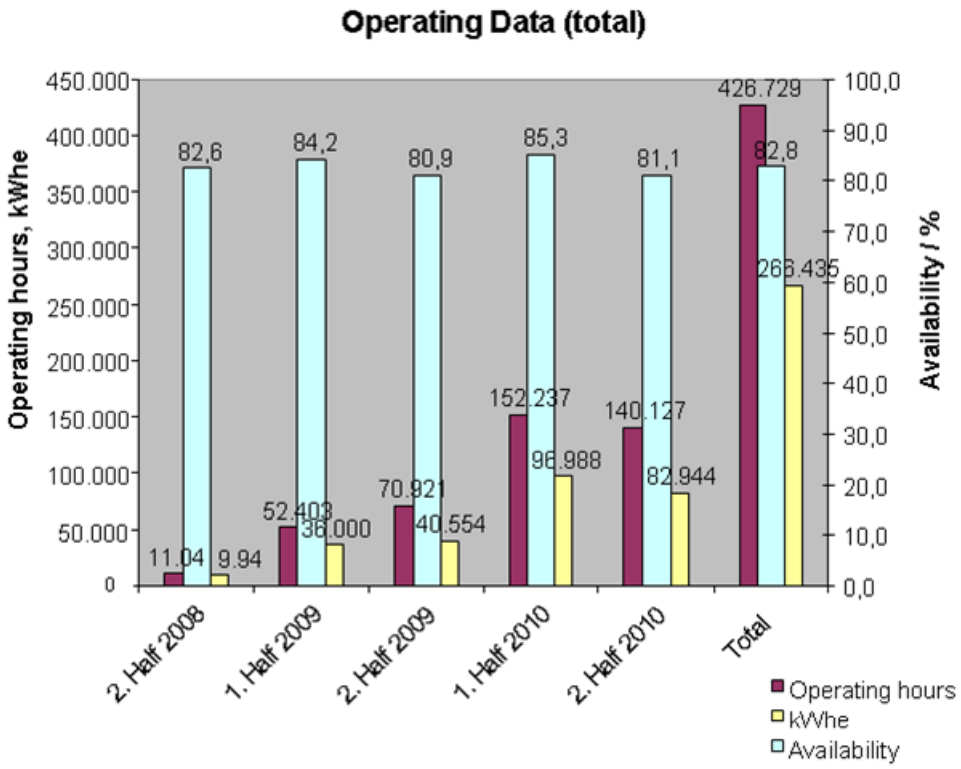

Figure 4:
Public fleet report

Late last year, around one hundred systems had been commissioned under the Callux project, the field test of fuel cells for use in residential buildings. The systems have been installed by the five energy suppliers involved in the project in their respective supply areas for the combined generation of heat and power in single-family homes.

Project participants report positive feedback. Home owners do not really perceive a difference compared to their old, conventional heating systems. Only more frequent visits of service technicians always required under field testing remind users of the innovative fuel cell heating systems they have installed in their basements for the combined generation of heat and power.

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