Report number: GT-140195
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Higher Efficiencies for micro CHP using fuel cells

Laboratory and field tests with micro combined heat and power based on fuel cell technology

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Colophon

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Summary

Commissioned by the Rijksdienst voor Ondernemend Nederland and GasTerra B.V., Kiwa Technology has performed the Unieke Kansen Programma UKPT09000000U (Project number UKP01023). The project title of the program is 'Higher Efficiencies for Micro CHP'. The aim of this project was to investigate whether gas fired micro combined heat and power (mCHP) based on fuel cells would be suitable for the Dutch market (domestic houses) to achieve much higher efficiencies and energy and energy cost savings compared with a reference situation (electricity from the grid/power plants and generated with a net efficiency of 43 %, condensing boilers for room heating and hot tapping water).

The project has started in 2008 and has been performed in four phases: in phase one a search/investigation has been carried out to find mCHP units based on fuel cells for Dutch domestic houses. In phase two available and potentially suitable fuel cell mCHP units have been purchased and tested in the laboratory of Kiwa Technology. Some of the fuel cell mCHP units have been tested in a field test/demonstration test in phase three. Phase four has been designated for sharing/spreading the knowledge gained from this project with/to interested stakeholders.

The investigation of potentially suitable fuel cell mCHP units in Europe , Japan, USA, Canada and Australia in the years 2008, 2009 and 2010 resulted in five potentially suitable and available units, based on solid oxide fuel cells (SOFC) and polymer membrane exchange fuel cell (PEM FC): Hexis Galileo 1000N (SOFC), Baxi Innotech beta 1.5 Plus (PEM FC), Baxi Innotech Gamma 1.0 (PEM FC), Hyteon CHP 850 (PEM FC) and CFCL BlueGen (SOFC).

These five Fuel cell mCHP units have been tested in the laboratory of Kiwa Technology. Static tests have been performed to measure the heat input, electric power output and thermal power output of the fuel cell and (if available) the auxiliary boiler for determining the electric, thermal and total efficiencies. Dynamic tests have been performed to investigate whether and how the fuel cell mCHP units are able to perform under real circumstances in Dutch houses. The fuel cell mCHP's have been connected to a hot water storage vessel according to the specifications/instructions of the manufacturers, so that a maximum of running hours could be performed and that heat could be used for space heating and/or domestic hot water under different outside temperature conditions. Based on these tests and measurements the Hexis Galileo 1000N, the Baxi Innotech Gamma 1.0 and the CFCL BlueGen where considered suitable for field testing. The Baxi Innotech beta 1.5 plus was a previous version with a lower developmental level compared with the Baxi Innotech Gamma 1.0. Therefore it has been decided not to use the Baxi Innotech beta 1.5 plus for a field test. The Hyteon CHP 850 was not designed to handle heat loads of a Dutch house and it was not possible within an acceptable period of time to change the software and carry out tests for a better heat management. Therefore it has been decided not to use the Hyteon CHP 850 for a field test.

Field tests have been performed with the Hexis Galileo 1000N (start in 2008) and with a CFCL BlueGen (start in 2010). The Hexis Galileo 1000N functioned well during the field test period in a bigger Dutch house using sufficient heat for space heating and domestic hot water , achieved in 2010 an average electric efficiency of 26.5 % (in 2014 30 – 35 % has been achieved) and an average total efficiency of 95.3%The annual saving has been estimated with about € 660,-- per year (with 30 – 35 % efficiency the savings will be higher), compared with the reference situation. The CFCL BlueGen performed also well during the field test and had an average electric efficiency of 54.8 % and an average total efficiency of 70.5 %, which resulted in a saving of almost € 1000 per year compared with the reference situation.

The heat produced by the CFCL BlueGen was used only for domestic hot water, which limited the heat output and therefore thermal and total efficiency. Both fuel cell mCHP's were floor standing, needed a storage vessel for hot water, and needed more space for installation compared with a condensing boiler. For this reason the fuel cell mCHP units can be installed in Dutch houses which have possibilities to contain the whole system (e.g. enough space somewhere in the house, extra room, …). Up to now the fuel cell mCHP units are limited available on the market.

Realistic prices of the fuel cell mCHP units are not yet available and pay back periods have not been calculated.

Energy Matters and Kiwa Technology established the Fuel Cell Expertise Network (FCEN) in 2011 (http://www.fuelcellnetwork.eu/). The primary function of the FCEN is to develop and share knowledge about fuel cell market deployment.
Activities of the Fuel Cell Expertise Network include:

- Build-up international network front-runners in fuel cell technology
- Develop state-of-the-art inventory of available fuel cells
- Identify market opportunities & threats
- Create market vision for fuel cell development
- Develop basic communication on fuel cells

This project has shown that natural gas using fuel cell mCHP is a suitable technology to achieve a lot of energy and energy cost savings.

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Content

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1 Introduction

At 12 of March 2009 the Rijksdienst voor Ondernemend Nederland has granted subsidy in the frame Unieke Kansen Programma for the project ‘Higher Efficiencies for MicroCHP’; UKPT09000000U. The subsidy had been granted to GasTerra B.V and Kiwa has carried out the project commissioned by GasTerra B.V.

Micro combined heat and power (mCHP) is a promising technology to increase the energy efficiency regarding the use of natural gas compared with the state of the art technology ‘condensing boiler’. With mCHP Dutch houses can be provided with electricity, heat for space heating and for domestic hot water.

The Dutch government has the aim to reduce the total emission of CO_2 by 30 % in 2020, compared to 1990. This is a reduction of the CO_2 emissions by 96 million ton per year. Natural gas is very important regarding the energy supply in The Netherlands. Almost 50 % of the total energy consumption (1.510 PJ) is covered by natural gas, divided in the generation of heat (70 %) and electricity (23 %) and in the use of the chemical industry (7 %).

Dwellings

Because of the growth of the population and the decreasing of the family size, the number of Dutch houses in The Netherlands will grow from about 6 million in 1990 to about 8,9 million in 2030. It is expected that between 2020 and 2030 newly build houses have to use sustainable energy. The electricity consumption will increase by 67 % in 2030, compared to 1990 (from 165 PJ to 276 PJ)and the heat demand will decrease by about 21 %, due to insulation of existing houses, better insulation of new houses and climate change (increasing temperature). The use of hot tapping water is slightly increasing due to the increasing number of dwellings.

Utility buildings

About 14 % of the primary energy consumption in the Netherlands is caused by the utility buildings. The electricity consumption will increase by 345 % in 2030, compared with 1990 (from 69 PJ to 307 PJ)and the heat demand will decrease by about 15 %.

The main reason of the huge increase in electricity consumption in 2030 compared with 1990 is

- More ICT-equipment and infrastructure;
- Increase of building surface;
- Increasing cooling demand (because of higher requirements regarding comfort and increasing environment temperature.

The Dutch Government has the goal to reduce the energy consumption each year by 2 %. This would be:

- 22% energy saving in 2020 compared with 2007;
- 36% energy saving in 2030 compared with 2007.

The goal will not be achieved with an unchanged policy. For the reduction of the primairy energy consumption it is very important to reduce the heat and electricity consumption and to generate heat and electricity sustainable.

The following question can be formulated:

In which manner can electricity be produced with high efficiency and with the use of the heat generated during the electricity production for the domestic houses?

There are different technologies able to fulfill the requirements to answer the question above. The development of the mCHP appliances based on stirling engines is quite far. First manufacturers are entering the market with stirling mCHP appliances (e.g. Remeha Evita). The electric efficiencies are between 5 and 15 % and therefore quite low and improvements regarding life time, vibrations, noise and costs have to be performed. Other technologies under development are small gas turbines, ORC's, small gas engines and fuel cells.
Fuel cells are very promising at the application of mCHP because of the high electric efficiencies, there are no moving parts causing vibrations and noise because of the electrochemical conversion of gas into electricity and heat (with the exception of e.g. solenoid valves, fans, pumps, …).

Fuel cells have the highest potential to convert the energy content of natural gas in electricity and heat and therefore the main objective of this project is the testing of fuel cell mCHP units for the Dutch domestic houses and dwellings.

2 Investigation of suitable fuel cell mCHP appliances

Worldwide search in 2008 and 2009:
At the beginning of the project potential suitable fuel cell mCHP appliances have been investigated. Some mCHP appliances have an integrated auxiliary boiler while other do not. The search has been carried out in Europe, USA, Canada, Australia and Japan. In Europe, USA, Canada and Australia the following fuel cell mCHP with and without auxiliary boiler have been found:

Name	*country of origin*	*Type of fuel cell*
Hexis Galileo 1000N (with auxiliary boiler)	Swiss	SOFC
Baxi Innotech (with auxiliary boiler)	Germany	PEM FC
Acumentrics (FC) / MTS (auxiliary boiler)	USA / Italy	SOFC
Ceres Power (with auxiliary boiler)	UK	SOFC
DanTherm	Denmark	HighTemp. PEM FC
CFCL (BlueGen)	Australia/Germany	SOFC
Hyteon	Canada	PEM FC

Tabel 2-1: Fuel cell mCHP appliances found in Europa, USA, Australia en Canada.

Based on the availability and the expected suitability the fuel cell mCHP Hexis Galileo 1000N and the Baxi Innotech beta 1.5 plus have been purchased for testing in the laboratory of Kiwa Technology.

Acumentrics was developing a compact SOFC fuel cell. MTS (now Ariston) was developing a compact wall hung fuel cell mCHP unit using the Acumentrics SOFC. Acumentrics unfortunately decided to stop the SOFC development in 2010.

Ceres Power was also developing a small compact wall hung fuel cell mCHP unit, but has stopped the activity in 2011.

DanTherm was not able to deliver fuel cell mCHP's because of other obligations during this project.

The CFCL (BlueGen) and the Hyteon fuel cell mCHP's have been purchased and tested.

There are a lot of manufacturers of condensing boilers who are also developing fuel cell mCHP units. During the project no boiler manufacturer had a for the Dutch marked suitable fuel cell mCHP developed for testing in the frame of this project.

Search in Japan in 2010:
In Japan there are a lot of manufacturers developing fuel cell mCHP technology for electricity and domestic hot water production. The application was mainly focused on the Japanese marked up to now, and these appliances cannot be used in The Netherlands without significant adaption to the Dutch market. Table 2-2 shows manufacturers developing fuel cell mCHP units:

Name	*Type fuel cell*	*Remarks*
Aisin Toyota	PEM FC	1 kW_e/1,4 kW_{th}
Aisin Toyota	SOFC	0,7 kW_e/0,62 kW_{th}
Eneos	PEM FC	0,75 kW_e/1 kW_{th}
Eneos	SOFC	0,7 kW_e/0,62 kW_{th}
NGK	SOFC	0,7 kW_e/0,55 kW_{th}
Panasonic	PEM FC	1 kW_e/1,4 kW_{th}
Toshiba	PEM FC	0,7 kW_e/1 kW_{th}
Toto	SOFC	0,85 kW_e
Rinnai	SOFC	0,7 kW_e/0,58 kW_{th}

Table 2-2: Fuel cell mCHP in Japan

There was no fuel cell mCHP from Japan applicable for the Dutch market up to now. The Japanese fuel cell mCHP technology is very interesting for the Dutch/European market because of a high developmental level and high potential for mass production in the future. There are Japanese fuel cell manufacturers cooperating with European boiler manufacturers to develop fuel cell mCHP units for the European market. The market introductions are expected to start in 2015.

The following fuel cell mCHP units have been purchased and tested in the laboratory of Kiwa Technology and some of them also in a field test.

Ful cell mCHP purchased and tested
Hexis Galileo
Baxi Innotech Beta
Baxi Innotech Gamma
Hyteon
CFCL

Table 2-3: Fuel cell mCHP units tested in the laboratory of Kiwa Technology.

Please find more information of the testing in the next chapters.

3 Results laboratory testing

3.1 Hexis Galileo 1000N

The Hexis Galileo 1000N SOFC is shown in figure 3-1 below.

Figure 3-1: Hexis Galileo 1000N

In the table 3-1 below the specifications of the Hexis Galileo 1000N are given:

Parameter	Value
Type fuel cell	SOFC
Maximum thermal power	20 kW
Maximum thermal power fuel cell	1,8 kW
Maximum electric power	1 kW
Electric efficiency	30 - 35 % (2014)
Total efficiency	> 90%
Operation temperature stack	850-950 ^{o}C
Startup time SOFC	about 24 uur
Size (l x w x h)	0.62 x 0.56 x 1.6 m
Mass	170 kg

Table 3-1: Summary specifications Hexis Galileo 1000N (based on the lower heating value)

In 2—8 the Hexis Galileo 1000N has been tested in the laboratory of Kiwa Technology on a dynamic efficiency test rig to measure static specifications like electric power, electric efficiency and thermal efficiency and to simulate a dynamic and real operation under different climatic conditions to find out the possibility to use the Hexis Galileo 1000N in a field test and the best configuration for a field test (size of hot water storage, size of house, et cetera).

The result of the testing was that the specifications were so good that a field test has been started in 2009.

3.2 Baxi Innotech Gamma 1.0

The Baxi Innotech Gamma 1.0 (see figure 3-2 below) is the successor of Baxi Innotech beta 1.5 plus (PEMFC). The electric output is 1,0 kW.

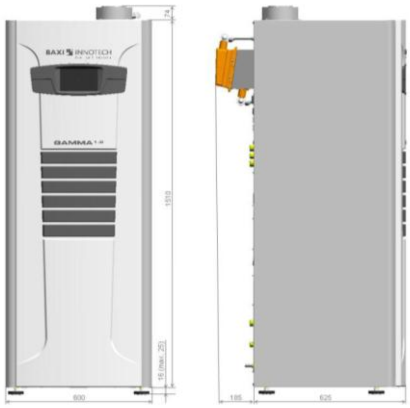

Figure 3-2: Baxi Innotech Gamma 1.0

In the table 3-2 below the specifications of the Baxi Innotech Gamma 1.0 are given:

Parameter	Value
Type fuel cell	PEM FC
Maximum thermal power	15 or 20 kW
Maximum thermal power fuel cell	1,7 kW
Maximum electric power	1 kW
Electric efficiency	32%
Total efficiency	85% (FC), 96% (incl. boiler)
Startup time fuel cell	about 4 hours
Size (l x w x h)	0.6 x 0.6 x 1.5 m

Table 3-2: Summary specifications Baxi Innotech Gamma 1.0 (based on the lower heating value)

In 2010 the Baxi Innotech Gamma 1.0 has been tested in the laboratory of Kiwa Technology on a dynamic efficiency test rig to measure static specifications like electric power, electric efficiency and thermal efficiency and to simulate a dynamic and real operation under different climatic conditions to find out the possibility to use the Baxi Innotech Gamma 1.0 in a field test and the best configuration for a field test (size of hot water storage, size of house, et cetera).

The Baxi Innotech Gamma 1.0 performed well in the laboratory of Kiwa Technology. To carry out a field test has been recommended by Kiwa Technology.

3.3 CFCL BlueGen SOFC

Ceramic Fuel Cell Limited (CFCL) has developed a solid oxide fuel cell (SOFC) with an electric power output of 1,5 kW and an electric efficiency of about 60 %, the CFCL BlueGen.

The CFCL BlueGen does not have an integrated auxiliary boiler and has been developed as an electricity generation unit with an option for heat recovery. The heat can be transferred to a hot water storage vessel for space heating and domestic hot water.

The figure 3-3 below shows the CFCL BlueGen.

Figure 3-3: CFCL BlueGen SOFC

In the table below the specifications of the CFCL BlueGen are given:

Parameter	Value
Maximum thermal power	0.6 kW
Maximum electric power	1.5 kW
Electric efficiency	about 60 % on Groningen gas
Total efficiency	about 85 %
Dimensions (l x b x h)	0.6 x 0.66 x 1.01 m
Mass	195 kg

Tabel 3-3: Summary specifications CFCL BlueGen (based on the lower heating value)

The CFCL BlueGen can be added to the already existing heating system.

In the laboratory of Kiwa Technology the CFCL BlueGen has been tested on a dynamic efficiency test rig to measure static specifications like electric power, electric efficiency and thermal efficiency and to simulate a dynamic and real operation under different climatic conditions to find out the possibility to use the CFCL in a field test and the best configuration for a field test (size of hot water storage, size of house, …). The CFCL BlueGen functioned well during the laboratory tests and we could confirm the manufacture specifications. Therefor it has been decided to use the CFCL BlueGen in a field test.

3.4 Baxi Innotech beta 1.5 plus and Hyteon CHP 850

The Baxi Innotech beta 1.5 plus has been tested in the laboratory of Kiwa Technology in 2009. In 2010 the Baxi Innotech Gamma 1.0 came available for testing, therefore it has been decided to proceed with the newer model of the Baxi Innotech fuel cell technology.

The Hyteon CHP 850 has also been tested in the laboratory of Kiwa Technology. The fuel cell performed well. However, because it was not designed to handle heat loads based on a Dutch house and because the timeline involved in making the required software changes was not practical, it has been decided not to use the Hyteon CHP 850 for a field test.

4 Results field tests

A field test has been carried out with the Hexis Galileo 1000N and with the CFCL Bluegen.

4.1 Results field test Hexis Galileo 1000N

The field test was running in the period from November 2008 until the end of 2010. The field test location was a free standing house with a garage in Oss (a city in the Dutch province Brabant). In the figure 4-1 the house is shown and also the garage, where the Hexis Galileo 1000N has been installed including a storage vessel for hot water and the measurement equipment for the measurement and monitoring of the system.

Figure 4-1: Field test location and installation room Hexis Galileo 1000N

In the figure 4-2 below one measurement day is shown (0 – 24 h). The outside temperature during the night time decreases from 7 to 4 ^{o}C. During daytime the outside temperature increases to about 12 ^{o}C and sinks in the evening to between about 8 to 10 ^{o}C. The electric power output was between 0.7 and 0.8 kW (switching between because of switching on and off electric components like circulation pumps). The indoor temperature is set to and measured 21 ^{o}C. The green line represents the delivered thermal power and the blue line represents the use of domestic hot water.

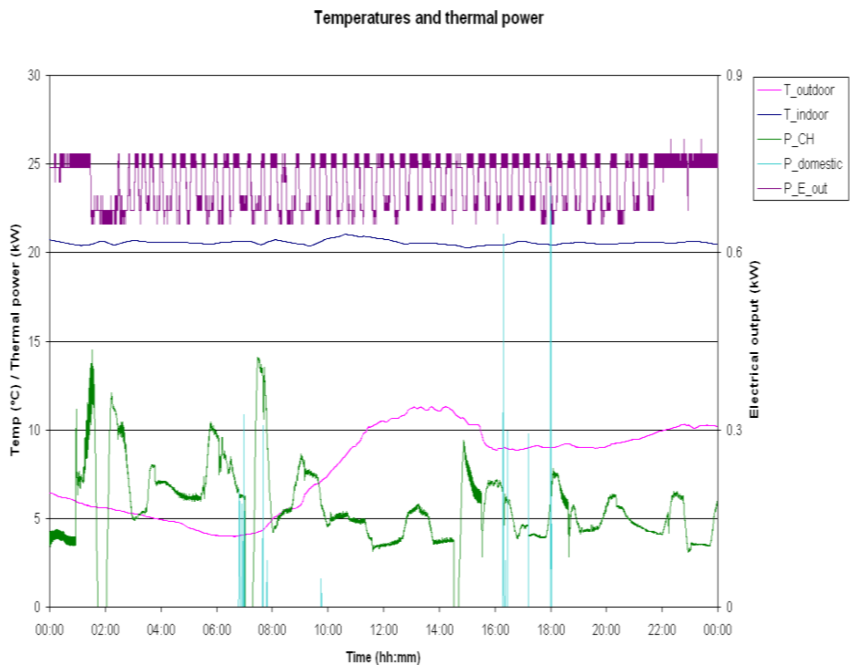

Figure 4-2: Temperatures, thermal and electric output Hexis Galileo 1000N during one day in the field test in 2008 and 2009

The electric power output was between about 0.7 and 0.,8 kW. Due to successive improvements the electric power output and efficiency are increasing. In the measurement period between 1 February 2010 till 27 April 2010 the maximum power output was 0.9 kW and the average electric efficiency 26.5 % .

In table 4-1 the results are represented:

Gas consumption Hexis Galileo 1000N	(η_{th} = 0.85, η_e = 0.265)	1560m^3
Gas costs Hexis Galileo 1000N	(€ 0.65/m^3)	€ 1014
Gas consumption condensing boiler	(reference situation, η_{th} = 0,95)	1419 m^3
Gas costs condensing boiler	((€ 0.65/m^3)	€ 922
Produced electricity		1398 kWh
Saved gas consumption power plant	(1398kWh/(0.43 * 8.86kWh/m^3)	367 m^3
Value produced electricity	(€ 0.226/kWh)	€ 316
Net savings	(€ 922 – € 1014 + € 316)	€ 224
Net savings primary energy	1419 – 1560 + 367	226 m^3

Table 4-1: Hexis Galileo 1000N: energy cost savings in the period 1 February till 27 April 2010 compared with a condensing boiler (reference situation)

Extrapolated to a whole heating season the total annual savings would be about € 660 and about 670 m3 gas (5940 kWh primary energy) per year.

In 2014 the electric efficiency has been increased to about 30 to 35 %. Because of the higher electric efficiency the annual savings will be higher because of a higher annual electricity production. This makes the business case more interesting.

4.2 Results field test CFCL BlueGen

The CFCL BlueGen has been tested in the field in the period of October 2010 until August 2013. The field test location is a free standing house with floor heating and radiators in Haren (province Groningen).

The figure 4-3 below shows the installation room of the field test.

Figure 4-3: The CFCL BlueGen installed in an installation room. De CFCL BlueGen stands on the floor and there is a 100 liter warm water storage on the wall.

In the figure 4-4 the hydraulic connection of the CFCL BlueGen system is shown. The heat of the CFCL BlueGen is supplied to the 100 liter storage vessel and is used only to preheat domestic hot water for the already existing condensing boiler of the house.

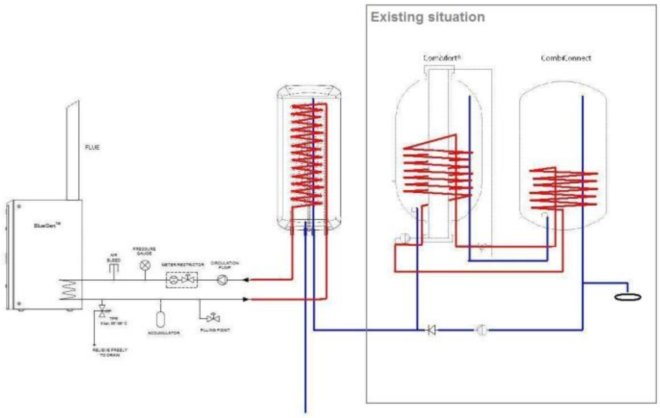

Figure 4-4: Hydraulic installation and connection to the existing central heating system

Table 4-*Table 4*-2 represents a summary of measurement results with the BlueGen SOFC from the start (October 2010) till 31 December 2011. This period contained 430 days of measured operation. 20 days have been missed during the replacement of the stack in the end of July.
During the measured operation days the FC produced 15371 kWh of electricity, 4024 kWh of heat and used 3140 m^3 gas. The net profit realized in this period was € 1778.60. The avoided CO_2 was 4413 kg.

Days of operation	430	
Total thermal power	4024	*kWh*
Total gas input power	27843	*kWh*
Cumulative total imported power	7	*kWh*
Produced electricity	15371	*kWh*
Average exported power	35.7	*kWh*
Average daily imported power	0	*kWh*
Total used gas with fuel cell	3140	m^3
Total used gas with normal generation	3835	m^3
Total avoided gas	1036	m^3
Total avoided CO_2	4413	*kg*
Average thermal efficiency	15.4	*%*
Average Electrical efficiency	54.8	*%*
Average total efficiency	70.5	*%*
Gas costs	€ 1,678.97	
Electricity production profit	€ 3,190.77	
Heat production profit	€ 264.23	
Net profit, excl. parasitic	**€ 1,778.60**	

Table 4-2: Summary measurement results CFCL BlueGen field test in 2011.

The parasitic energy used by the circulation pump is constant 11 watts, which is an annual electricity consumption of 95.4 kWh. Subtracting this from the produced electricity, the total system profit is € 1,758.60.
During this test period,with and electricity generation of 36 kWh, the average daily savings resulted in € 4.00, which leads to an estimated annual profit of ca. € 1500, -.

Recent stack improvements have resulted in a stack design which, according to the manufacturer, is in 2014 capable of running at least one your with an average electrical efficiency of over 60%, which increases the potential annual profit.

5 Transfer of knowledge

Kiwa Technology organizes in cooperation with Energy Matters 'Webinars' (seminar by internet) for interested parties to create a forum for exchanging the newest information and the newest developments with respect to fuel cells.

Kiwa Technology regularly gives presentations for different occasions. Please see or example

- http://www.ameland.nl/document.php?m=11&fileid=14243&f=0d50f622f1f81aac62d4f00649ec4163&attachment=0
- http://www.marcogaz.org/egatec2011/PS5/PS5B_Fennema_egatec2011.pdf
- http://www.fuelcellnetwork.eu/wp-content/uploads/1-FCEN-intro-webinar-26-June-2014.pdf
- http://www.fuelcellnetwork.eu/wp-content/uploads/1.-Fuel-Cell-Expertise-Network-Introduction.pdf
- http://www.fuelcellnetwork.eu/wp-content/uploads/FCEN-Technical-issues.pdf

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Activities of the Fuel Cell Expertise Network include:

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- Develop state-of-the-art inventory of available fuel cells
- Identify market opportunities & threats
- Create market vision for fuel cell development
- Develop basic communication on fuel cells

Each year a fuel cell conference has been held to transfer and exchange knowledge to and with the interested stake holders.

6 Final conclusions

6.1 Results

At this moment (in the year 2014) fuel cell based mCHP appliances have reached a level that a broader applications becomes possible. Improvements with respect to the electric efficiency, the sensitivity and the life time of the stacks, and the total efficiency would help to achieve a maximum of energy savings and via the energy cost savings to an interesting business case for the end user.

The consumer price at this moment is according to the expectations too high for a broader application. The price for a CFCL BlueGen fuel cell inclusive the installation costs and the costs for needed equipment like a hot water storage seems to be between about EUR 20,000.-- and 40,000.--. Several incentives have recently been established by EU and local governments to stimulate market introduction of fuel cell CHP. Including these incentives and with an achievable maximum of energy cost savings of about EUR 1000.,-- per year during lifetime, the payback period would still be over 10 years. The reduction of the consumer price is needed to achieve a broader application of fuel cell based mCHP.

To keep the dimensions of the total fuel cell mCHP system as small as possible is important for the application in smaller houses and dwellings. For newly build houses it is easier to plan sufficient space for the fuel cell mCHP before building the house. In existing houses the compactness is very important to be able to install fuel cell mCHP including the hot water storage system. The fuel cell mCHP's Hexis Galileo 1000N and Baxi Innotech Gamma 1.0 have been designed in the first place for the German market, because German houses are bigger that Dutch houses and German houses have a special room voor de heating installation (Heizungskeller).Manufacturers of the fuel cell mCHP have to consider the space constraints with respect to Dutch houses and to design the systems as compact as possible.

6.2 Perspective

On the isle of Ameland 45 CFCL BlueGen's will be placed for full time electricity generation. Annually about 6 GWh of electricity will be produced (8760 h x 45 CFCL BlueGen's x 1500 W = 5.913 GWh). For more information please see http://www.onlinepersberichtplaatsen.nl/cfcl-levert-45-bluegen-brandstofcel-systemen-grootste-europese-virtual-power-plant-voor-duurzaam-ameland/.

As soon as the consumer price has been reached a level for achieving an acceptable payback period, the CFCL BlueGen will be very interesting for the Dutch market due to the possibility to integrate the unit into an already existing heating system. Additionally the noise level and the dimensions have to be reduced.

The other tested fuel cell mCHP like the Hexis Galileo and the Baxi Innotech Gamma 1.0 are also very interesting for the Dutch marked, whereas the Hyteon system has been designed to be more suitable for larger houses for example in Germany.

Japanese manufacturers of duel cells cooperate with European boiler manufacturers to develop mCHP units for the European market. The first market introductions seem to take place in 2015.

In Germany there is another promising wall-hung fuel cell mCHP with 300 W electric power output available (Elcore). In 2014 the consumer price of this alliance seems to be about EUR 9000.--. An auxiliary boiler is not part of the Elcore.

6.3 Contribution to the target of the UKP program

The aim of this project was to test the suitability of fuel cell mCHP units for Dutch houses and dwellings.

Fuel cell based mCHP units are of interest with respect to the technological and economical level for generating heat and electricity for Dutch houses and dwellings.

Carrying out this project has shown that using natural gas fuel cell mCHP is a way to reduce the overall energy consumption of domestic houses.

If for example in the year 2020 two million houses in the Netherlands would be equipped with fuel cell mCHP units using natural gas, having an average electric efficiency of 40 % and save in average 7000 kWh of primary energy per year, the total annual energy saving would be 14 million MWh or 50.4 PJ. This is about 10 % of the prognosis of the annual energy consumption of domestic houses regarding the consumption of electricity and heating of the year 2020 (493 PJ).