SOFT-PACT Project

SOFT-PACT

PROJECT FINAL REPORT

"**Publishable**"

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SOFT-PACT

Solid Oxide Fuel Cell micro-CHP Field Trials

Project Beneficiaries

e·on ideal CERAMIC FUEL CELLS HOMA

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Ideal Boilers Ltd	UK	Elaine Lancaster
Ceramic Fuel Cells GmbH	Germany	Guido Kroll
HOMA Software BV	Netherlands	Walter Elskampt

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Project Objective

SOFT-PACT has been established to undertake large scale field demonstration of SOFC generators that can be utilised in residential applications.

The project goals and objectives are as follows:

- European demonstration of fuel cell microCHP systems
- Trialling of modular and integrated Fuel Cell microCHP systems
- Utilisation of Gennex: world's most electrically efficient fuel cell module (60%)
- Determine EU Market Opportunity for domestic Fuel Cells
- Deployment of up to 100 Fuel Cell microCHP systems – 3 System Configurations
- Analysis of real world data from field units
- Commercial configuration and component optimisation

In order to achieve these objectives the project has been split into two distinct phases:-

a) Phase 1: Deployment of forty BlueGen™ 2kW SOFC generators with domestic hot water thermal stores (Pathfinder systems)

b) Phase 2: To design, build and deploy up to sixty 1-2 kW_e SOFC micro-CHP units based on current prototype test systems (integrated systems with condensing boilers)

Pathfinder System units will act as long-term (40 month), baseline test systems to learn and understand the issues and problems that the fuel cell units will face in the field. All data to date has been obtained in the laboratory or simulated residential conditions. A key issue will be in establishing installation procedures for the systems and associated monitoring and control equipment. BlueGen™ has been released to the market in small numbers and has the following specifications:

Dimensions	(H x L x W) (970 x 660 x 600mm)
Weight	~200 kg
Fuel	Mains natural gas (0.9 to 5 kPa)
Power Output	0 – 2000 W (230V @ 50Hz)
Start-up time	~20 hours
Efficiency	60% net electrical at 1500W output (LHV)
Operating conditions	+1 to +45 C (ambient temperatures)
Inlet air temperature	-20 to +45 C
Maintenance intervals	3 months (minor), 12 months (major)
Approvals	CE, PAS 67
Emissions	340g/kWh (negligible NOx or SOx)
Communications	Standard Ethernet port

Tests carried out to date show a stack degradation rate <2% per 1000 hours.

Deployment of units will be in occupied residential locations with a small number also being installed in test homes to provide reference data with the existing tests of prototype units and as a baseline for the field trial systems. Products will be deployed in multi-regional areas and in a range of homes with varying annual energy consumption (i.e. low heat-high electrical, med heat-medium electrical, high heat-high electrical demands etc.). The project consists of twelve work packages, led by various members of the consortium which consists of E.ON Technologies, Ideal Heating, Ceramic Fuel Cells and HOMA Software. In the sections that follow each work package is described together with its high level findings.

The project planned to progress beyond the state-of-the-art

Current state-of-the-art

Fuel cell microCHP systems have been under development for over 10 years. Historically most of the early prototype systems tested were based upon low temperature Proton Exchange Membrane (PEM) technology. PEM systems operate at 60-80C and have electrical efficiencies of 30-40%. Lifetime data to date suggests that stacks can last from 10 000 to 20 000 hours in residential use (Japanese ENEFARM data)

Over the last 4/5 years there has been a transition from PEM to higher temperature (700C+) solid oxide fuel cells (SOFC) for microCHP as this technology has: -

a) High electrical efficiency
b) Production of high grade heat
c) Excellent long term performance at constant load
d) Ability to internally reform natural gas into hydrogen

E.ON have been active in microCHP developments for over 10 years, with E.ON Ruhrgas specialising with in-house testing and evaluation of fuel cell based systems. Over this time E.ON has tested and deployed fuel cell CHP systems from Sulzer-Hexis, Vaillant, Ceramic Fuel Cells Ltd and others.

HOMA-Software BV has developed an advanced, highly scalable Information and Communication Technology (ICT) system for the control and monitoring of residential CHP systems. This also allows the creation of Virtual Power Plants (VPP) via the bundling of a large number of micro-generators. The system is currently being used for the field trials and early market deployment of Stirling Engine and internal combustion engine CHP systems in the UK, Germany and The Netherlands.

Ideal Boilers Ltd (ISG), part of the Ideal Stelrad Group, has been awarded “World Class Manufacturing Status” reflecting the investment made in advanced manufacturing technologies and systems. Based in Kingston-upon-Hull they have a brand that has been established for over 100 years. They are developing their traditional heating products to take advantage of renewable energy (solar, heat pumps), advanced control systems to maximise system efficiency and reliability, and high efficiency micro CHP systems.

Ceramic Fuel Cells (CFC) has been developing solid oxide fuel cell technology since 1992 and has established a manufacturing plant in Germany to service the new market being developed for its fuel cells. It currently has a number of systems installed around Europe that are supported by its European based engineering team.

Beyond state-of-the-art

This project plans to go beyond the state-of-the-art by:-

- Targeting 50% net electrical efficiency and 80+% total system efficiency in occupied residential locations, (all previous data has been derived from laboratory and prototype units)
- Extend the available run-time during the summer season, ultimate aim is to be able to demonstrate 24/7 capability throughout the year
- Using Domestic Hot Water (DHW) only SOFC based mCHP units to compare and contrast with the fully integrated system, particularly in highly insulated homes with little or no space heating requirements or in homes using alternative heating systems (biomass, heat pumps, solar thermal)
- Mid-term project review will include the final design and system specifications of the integrated fuel cell (IFC) unit from the market survey and first stage pathfinder results
- Pathfinder results will also provide indicators on stack/system performance with regards to efficiency and durability targets
- Demonstrate 40,000 hr life capability on key components (i.e. degradation rates of <1% per 1000 hours of stack run time)
- Gather data on user control methodology and suitability for domestic usage patterns.
- Equip systems with local intelligence so that :
    - Remote monitoring and control systems can be optimised without homeowner input.
    - Identification of energy behaviour changes in the home that will enhance the benefits of the system
- Identification of design changes/improvements to overcome user or gender perceived installation and operation challenges
- System design improvements to enhance reliability and serviceability
- Miniaturising the current prototype to meet acceptable size constraints for domestic installation while maintaining the thermal extraction levels and allowing for servicing and maintenance
- Cost and performance analysis of sub-components and redesign necessary to meet JTI commercial system cost target of €4-5k per kW in mass production post 2015
- Promotion of the technology to consumers highlighting the economic and environmental benefits that the systems deliver
- Training and re-skilling of installation and maintenance engineers to remove a key barrier to mass market exploitation

Force Majeure

It should be noted that at the project midpoint and project end, three key events occurred that altered the projects final exploitation plan and planned legacy. These events were;

i) Fuel Cell component failure, causing the consortium to perform a “technical reset” (replacement) of all BlueGen units deployed, resulting in a requirement to update them to the latest commercial specifications and manufactured components to overcome the failures, whilst removing some units that had been used as fact finders for the Beta-1 system design and some systems that had been experiencing extreme water hardness issues. This reduced the deployed fleet numbers.

ii) An extension request for an additional 12 months was made to the FCH-JU allow for the field trial of the Integrated Fuel Cell, which had taken considerable longer to design, manufacture and test, than originally envisaged due to knowledge transfer and numerous redesigns of the SOFT-PACT Integrated Fuel Cell (SIFC) to meet the required design goals.

iii) Finally in the last 6 months of the extended project, two of the consortium members went into administration causing support issues, which resulted in the unfortunate removal of most of the planned BlueGen systems, and therefore no post project systems legacy.

There were however lots of successes, exceed expectations and ground breaking design work performed during the project and this report details these as publically as possible without infringing on IP and future product design.

It should be noted that both of the companies that went into administration have now been bought so there is a future for this technology and the SIFC design could it be resurrected. The improvements in the BlueGen system realised by the project have been incorporated into the BlueGen now manufactured by SolidPower and it is a considerably better product for being part of this project.

Project Successes

The Fuel Cell & Hydrogen Joint Undertaking have, by providing the grant funding for this project enabled the first successful SOFC field trial in Europe, moving the technology closer to commercial readiness. The work packages were all completed and all of the 2010 Project Call Annual Implementation Plan (AIP) and Multi-Annual Implementation Plan (MAIP) targets were met and in most cases exceeded, the project achieved;

- Up to 65 systems deployed of a target of up to 100
- System life time with a target of 10k hours, shown to be 12k hours at time of removal with an expected 27k hours lifetime given the degrade rate calculated
- Electrical Efficiency of between 61.5–46% (LHV) over lifetime against a target >40%
- System target of 25% cost reduction was met.

These are show in the table below against their formal targets.

Programme objective/target	Project objective/target	Project Final Achievement
MAIP 2008-13		
FC system life time (h) >5,000	FC system life time (h) >10,000	At end of project: **12,792 hours** Given this degrade rate, stack would be expected to reach **27,118 hours**
AIP 2010: SPI-JTI-FCH-2010.3.5		
Deployment of fuel cells with Trial 10	Deployment of fuel cells with Trial Up to 100	39 BlueGen Pathfinder Systems 26 Integrated Fuel Cell Appliances (SIFC) **Total: 65 Fuel Cell Systems deployed**
FC System Electrical efficiency Target >40 (%) (HHV)	FC system Electrical efficiency >40 (%) (HHV)	**From 56% to 42% (HHV)** **From 61.5% to 46.0% (LHV)** **Over lifetime**
Cost Reduction (€/kWe) €5000/kWe	25% Reduction on BlueGen Costs	**Achieved: 25% BlueGen Cost Reduction** via Reengineering components & supply chain enhancements

Exploitation Plan

Although no exploitation plan was conceived due to the issues at the end of the project, there were exploitable outcomes from the project for all parties, that may be explored at a later time, namely;

- Vast amounts of monitoring data from the two field trials, some of which is unique; (BlueGen Pathfinder) due to separation of central heating and hot water circuits requirements during the field trial. We believe this has never been achieved before and provides unique usage data for the homes showing the true cost of heat vs hot water

- Ideal Heating's licensable IP from the development of the Integrated Fuel Cell around a unique low grade heat recovery system.

- Lessons learnt for all parties regarding not only field trials installation and support, but product development and knowledge transfer, and customer feedback, providing guidance should a final production system ever be considered for manufacture.

- A Market Survey of Fuel Cell opportunity by EU region, which has and continues to be used in discussions with E.ON regional units and should now be refreshed by the FCH-JU as it is over four years old.

System & Component Design & Manufacturing

In addition, there are benefits arising out of project not originally envisaged for the BlueGen and should prove invaluable SolidPower, the new owners of the company;

- Improved exhaust heat recovery heat exchanger developed utilising trials provided data;
    - Realising an Average 20% improvement in effectiveness across the range
- Improved thermal integration;
    - Real world customer experience helped optimise Beta 2 design
    - BlueGEN plus heat pump design and installation using pre-heat tank was produced
    - Pre-heat tank concept included within IFC design
- New stack designs for increased stack lifetime through lower degradation, and improved thermal cycling for robustness
- New cell supplier for cost reduction, quality and consistency, previous supplier had supplied a faulty batch which adversely affected the BlueGEN Pathfinder project, Faulty cells displayed accelerated degradation and hence shorter operational stack life
- New supplier for other stack components for cost reduction through increased volumes
- First 4x4 furnace (16 stacks at a time) now operational for providing increased manufacturing capacity and cost reduction on production overheads
- New water meter providing reduced cost and Improved reliability

- Elimination of one flow meter, providing reduce component count and manufacturing cost
- Introduction of additional filters to reduce service intervals, reducing service costs

Customer Interface

- Improved customer interface completion of the BlueGen.NET platform providing additional customer control ability which provides;
  - Programmed modulation of power output
  - Similar logic to a 7 day heating controller
  - Scope for real time response to pricing signals
  - Fast modulation observed
  - Capability of 0%-100% modulation within 15 min. intervals capable of supporting a wholesale market pricing

Global Warming Benefits

- The BlueGen Life Cycle Analysis (LCA) Report created as part of the project illustrated the benefits of Fuel Cells to assist in the reduction of Global warming.
  - The global warming per kWh of electricity generated by the BlueGen is 10% lower than that for electricity supplied by a conventional large combined cycle gas turbine, even if the highest possible efficiency of approximately 60% is applied.
  - Compared to the average gross efficiency of 53% for natural gas power plants in the United Kingdom, the BlueGen reduces the global warming emissions by 18%.
  - Compared to a gas turbine with 40% efficiency the reduction is 37%.

Recommendations

The consortium has some recommendations that fall outside the scope of the project but felt would benefit future field trials and deployment projects and may wish to be addressed by the FCH-JU in future programme calls;

Increase Fuel Cell Public Awareness

There is a long way to go with public awareness of the fuel cell technology, the automobile industry has achieved considerably more through the engagement with the public than the stationary fuel cell market, and the consortium therefore recommends that the FCH-JU considers funding more direct public knowledge exchange programmes such as the following:

- Satellite Channel Infomercials e.g. via EuroNews
- Fuel Cell placement within Property Make Over Programmes
- FCH JU Stands at Heating / Technology Shows showing the technology to the public
- In flight adverts / magazines placements
- European technology / property / lifestyle magazines information articles.

Hybrid Fuel Cell Installers Qualifications (Gas, Elec, ITC)

One of the highest costs seen during the project was due to the deployment of various installation engineers that are required to install a fuel cell; namely the electrician, plumber, ICT technician. The consortium recommends that the FCH-JU consider developing with the relevant training bodies across the EU, hybrid technicians that can be used to perform such installations and minimise these costs, suitable bodies identified by the consortium would be;

- UK Skills Council Promotion
- Sector Skills Councils
- Euroskills Promotion

These bodies would under FCH-JU guide develop recognised Fuel Cell Installer Vocational Qualifications.

Work Package Specific information

The following section provides details on each work package that made up the schedule of work shown below:

		2011						2012												2013												2014												2015						Mop-Up		
		Month																																																		
WP #	Work Package	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
1	Market review to identify prototype specifications																																																			
2	Micro CHP and thermal store lab test unit																																																			
3	Pathfinder trials with BlueGen																																																			
4	Integrated mCHP System specifications																																																			
5	Component/subsystems optimisation																																																			
6	System Design and Build																																																			
7	Codes, standards and safety regulations																																																			
8	Training, Installer accreditation & Field Support																																																			
9	New Unit Field Unit (Installation and monitoring)																																																			
10	Consortium Management and Reports																																																			
11	Knowledge Dissemination and cross cutting																																																			
12	Project Review																																																			

Consortium Activity | Field trials | PM & Coordination Activities

WP1: Market Review to identify prototype IFC Specifications

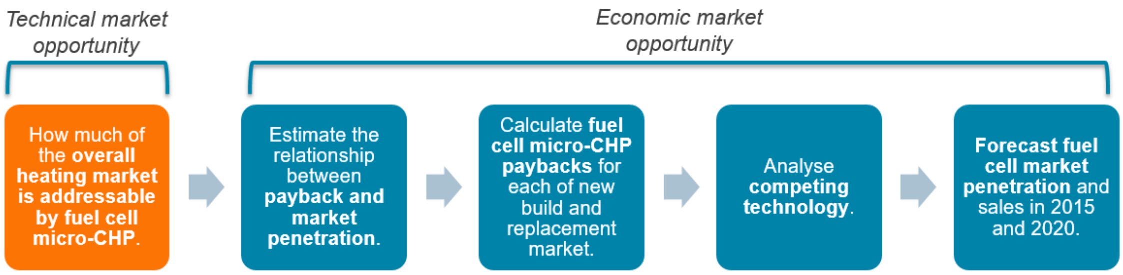
Objective:
To determine the optimal outputs for the field trial mCHP systems so that performance monitoring can determine energy, environmental and economic benefits of the system

Deliverables:

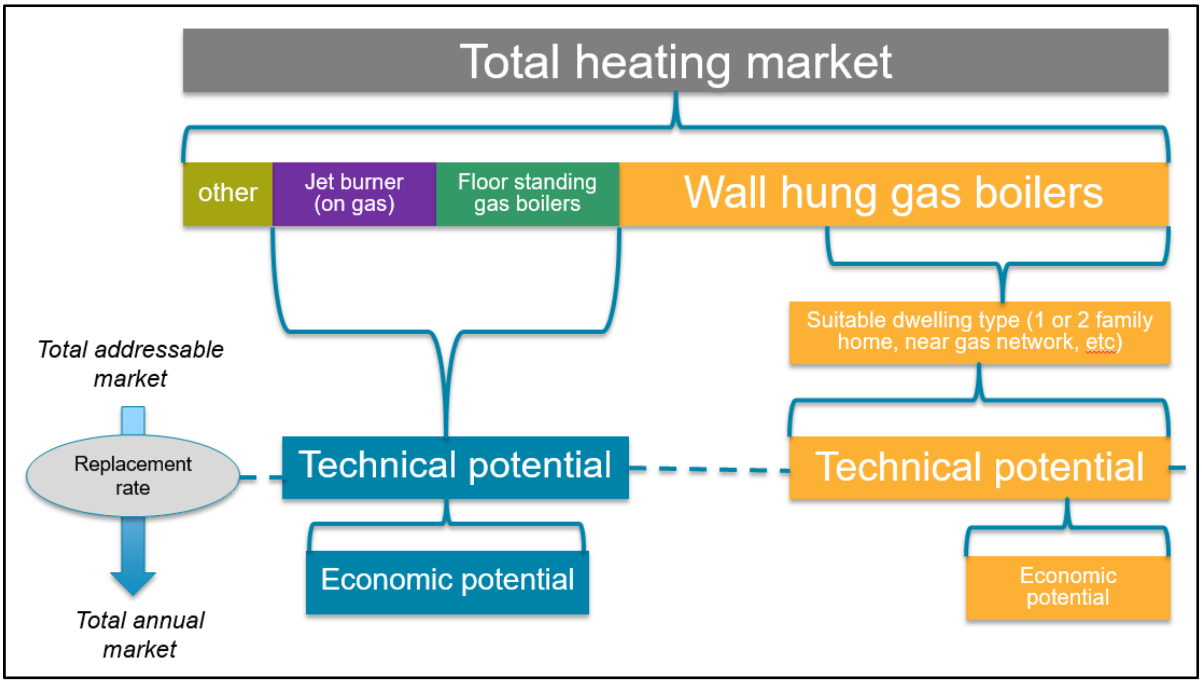
- Optimised design specification for this system
- Target market segments and application to be evaluated in the field trail
- System efficiency targets, thermal and electrical outputs, thermal store capacity
- Assessment of gas and electricity metering in target home country by country

The EU Market Survey

To determine the optimal outputs for the field trial mCHP systems so that performance monitoring can determine energy, environmental and economic benefits of the system, an EU market study was required. It became apparent that our in-house data was insufficient to create a detailed market study, we therefore commissioned Delta-EE and BRG Group through a tending process to provide a report which was then reviewed in January 2011 when the first consortium meeting was held after receiving JTI funds.



Steps used to determine the fuel cell opportunity for each region.



Overview of the market reduction methods used to determine the opportunity for each region

The EU market study provided the best the target locations (EU Regions) for our integrated Fuel Cell (IFC) system now and in the near future based on the space and economic potential. The study also highlighted a number of design challenges that our system would need to overcome which if achieved would allow us to access a significantly sized market segment.

The study provided the following results, ranking each EU region for opportunity for 2011 and the future;

Ranking	2011	Future
1	UK	Germany
2	Germany	UK
3	Netherlands	Belgium
4	France	Netherlands
5	Italy	France
6	Belgium	Italy
7	Spain	Spain
8	Czech Rep.	Poland
9	Poland	Hungary
10	Hungary	Czech Rep.

Best market opportunity for an integrated fuel cell micro-CHP appliance was at the time of the project (2011) in the UK, Germany, Netherlands, France and Italy.

Netherlands and Italy looked to be a good opportunity but their potential annual sales where downgraded substantially due to the popularity of combi wall hung boilers and their typical installation in lofts/living areas, which would not be suitable for our fuel cell.

The workshop reviewing these study highlighted a number of challenges that the IFC design would need to overcome, but also the significant market available.
It became apparent that the design was going to take a lot more time than planned to determine system targets, outputs and storage capacity.

Metering varied considerably from target country to country; three phase metering in Germany, single phase metering in the UK, standards will have to be address on a per region basis.

WP2: mCHP & Thermal Store Test Rig setup

Objective:

To provide a long term bench test for the field trials, a comparator for the previous tests carried out on the proof of concept and prototype systems and a test stand for improved designs on the thermal components prior to the field trial system build.

Deliverables:

CHP thermal test facility for long term testing:

- A system that can be swapped with varying thermal store/integration systems
- Hot swapping capability no need to turn off the BlueGen™
- Provide data outputs for comparing to the field trial units
- Long term ageing test for the stack and balance of plant components
- Identification of installer skill requirements

The Laboratory Test System Details

A micro Combined Heat and Power (mCHP) appliance and thermal store test rig was designed and constructed to meet the requirements of Work Package Two of the SOFT PACT delivery programme.

As part of the proof of concept of the Beta1 (the partially integrated fuel cell system) product the design, development and implementation of a Test Rig (TR) was seen as crucial for the evaluation and development work of the product. The TR was designed by Ideal Heating Ltd working in conjunction with CFCL and was installed at Ideal's research and development facility based in Hull, UK. The TR is housed in a controlled environment with limited access to site personal.

The test rig has been manufactured to support the following activities;

- For Ideal's R&D department to gain "real product experience" of the early product designed, developed and inherited by the SOFT PACT project from Gledhill Cylinders Ltd.
- To evaluate the long term performance of the Beta 1 unit the findings of which resulted in the development of an improved Beta 2 appliance.
- To provide a performance test bed for Beta-2 / Integrated Fuel Cell (IFC) SOFT PACT variants providing data on product performance including DHW delivery, thermal store delivery and recovery.
- To act as a test appliance for interim CE approval needed to facilitate installation of field test appliances. As part of the CE approvals process the appointed external certification test body, Kwia Gastec, will witness performance test work undertaken on the rig.
- To provide continual reliability testing of integrated system to ensure robust operation before manufacture of field test appliances to be tested in Work Package Nine.
- To provide a test bed for software development and application of HOMA embedded communications system. The test rig appliance is connected to all relevant internet communications to allow proving of remote monitoring systems.

- To provide a development test bed and proving reference for field test monitoring instrumentation and systems that is intended for field test monitoring as demanded in Work Package Nine.
- To act as a training rig for teaching appointed installation contractors SOFT PACT field test appliance installation and commissioning procedures needed for correct and safe field test requirements.

These goals were achieved during the first period of the project and will continued to provide value in the second period of the project.

The test rig developed to meet the deliverables of Work Package Two worked well in providing an essential test bed for appliance development / optimisation. Concurrently the rig ran continually to prove the ongoing reliability of the Beta 2 Integrated Fuel Cell product and associated monitoring systems giving confidence for the reliable operation of the field trial installation and testing planned in Work Package Nine.

Learning's from the Beta 1 appliance have been captured and the consortium have recognised that optimising the way waste energy is captured and subsequently deployed is key in optimising the benefits of SOFT-PACT integrated Fuel Cell mCHP.

Accordingly the consortium has developed an innovative Beta 2 Integrated Fuel Cell system using the test rig. It is recognised this innovative work is of significant value and a patent to protect the innovative features of the design has been applied for.

Product development progressed to Beta 2 Integrated Fuel Cell schedule testing against essential requirements of the Gas Appliance and Boiler Efficiency Directives in readiness for witness testing by an approved external test body (Kiwa Gastec) to obtain interim CE approval to facilitate field trial installation.

The test rig continued to be utilised until the end of the project as a long term reliability testing platform.

WP3: BlueGen Pathfinder Field Trials

Objective:

BlueGen™ has already gained CE approval for use in residential locations and has a heat exchanger incorporated into the waste gas flue to provide a heat source for domestic hot water. The systems will be deployed in friendly locations (trial volunteers) to gain information about operational issues that will need to be overcome for the larger scale field trials of the integrated CHP systems. The systems will be equipped with a data acquisition, monitoring and control system, allowing the utility to monitor the operational state of the systems and surrounding environment; and record and aggregate performance data.

Deliverables:

- Installation of 40 BlueGen™ pathfinder systems:
- Inputs for the design and operation of the integrated mCHP systems
- Installation and operation of 40 systems
- Solutions for large scale data collection, processing and interpretation
- Ability to monitor and control large numbers of systems in the field in real time
- Long term ageing test for the stack and balance of plant components

Summary:

- 40 BlueGen units ordered once grant arrived, training of our internal installation division was completed
- Decision to deploying some BlueGens with our Beta-1 (Boiler and tank) configuration to see the how close this modular system behaved to our IFC design.
- Design of the monitoring solution for two systems, Third party M&E consultancy reviewed design safety, compliance and functionality. Identification and selection of the trialists
- A Dummy install was performed and then a series of installations in a row of houses at Harper Adams University to determine the cost reductions of 'batch' installations.
- Installations then continued throughout 2012 to friendly customers and staff.
- Despite steep learning curves, under estimates for installation times and costs, monitoring equipment issues we have gathered a vast amount (10GB) of data.
- Similar trialists selections and installations began in Hamburg but were over engineered, stopped for a review.
- Towards the end of 2012 we became aware of stack issues, a CFCL internal investigation highlighted a supply chain issue resulting in short <8000hr lifetime stacks needing replacement in the fleet. Further deployment of the remaining 10 units was halted until a remedy could be found. We then performed a 'technical reset and beta-1 removal' of the fleet to stablise the fleet.
- We hoped to provide the remaining BlueGen units as a legacy, post project, however once CFC went into administration in early 2015, it was deemed that these units would become standed assets that may become unmaintainable so the decision was made to remove them all.

BlueGen Pathfinder Field Trial Details

The BlueGen Pathfinder units acted as long-term (48 month), baseline test systems to learn and understand the issues and problems that the fuel cell units will face in the field.

All publically available data previous to this field trial had been obtained in the laboratory or simulated residential conditions, this was they reason to deliver this field trial.

A BlueGen

A Booster Unit for a BlueGen (Beta1)

A key issue to this work package was in establishing installation procedures for the systems and associated monitoring and control equipment.

The Pathfinder field trial of the BlueGen Fuel Cell has provided extensive insights into the capabilities, efficiency, technology issues and deployment challenges of installing and operating a fuel cell in domestic properties.

To maximise insights during the trial period of just over four years, two variants of the BlueGen Pathfinder systems were installed in two very different EU regions (UK and Germany), with a further trial of an upgraded BlueGen (Technical Resets) unit showing progression of the fuel cell stack technology and the BlueGen components was installed in the UK, replacing existing units.

Comprehensive monitoring devised for the systems resulted in a total of 655 million raw data points being collected with 5 different data logging systems, and was analysed with bespoke routines to provide insights.
One of the configurations of the system separated the Central Heating requirements from the Domestic Hot water requirements which for the first time allowed the consumption of gas required for heating a property over a year to be determined separately from the domestic hot water requirements.

Training installation engineers in both deployment regions allowed the building regulations and health and safety requirements to be determined but also highlighted the training and skills required for scaling to commercial deployments levels.

The performance of the monitored systems provided invaluable data for the design of the integrated Fuel Cell system not only in system performance but trialist usage statistics; therefore it has been a successful pathfinder field trial, achieving its objectives and deliverables namely:

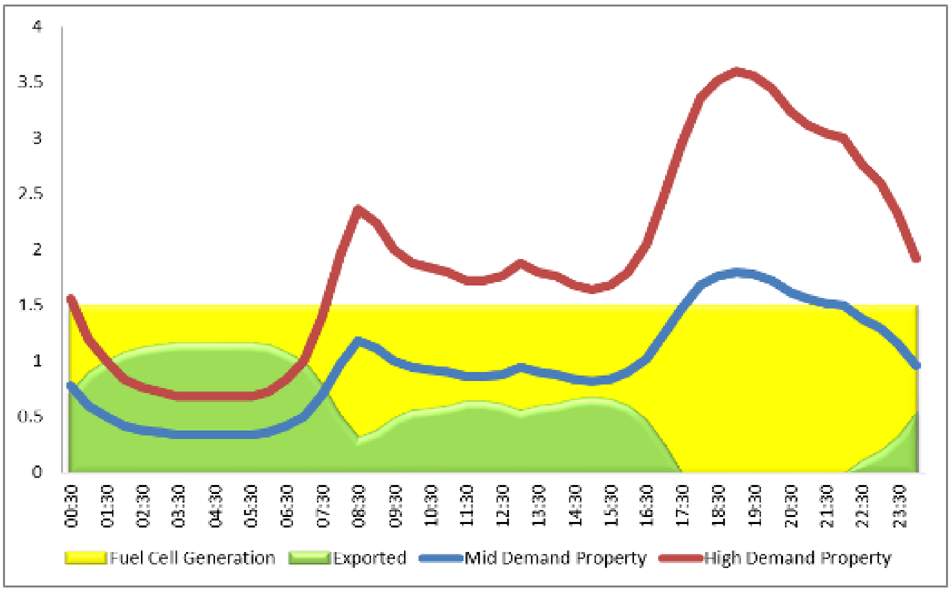
- Delivering a Pathfinder field trial of fuel cell microCHP appliances.
- Determining the inputs for the design and operation of the integrated mCHP systems.
- Installation and operation of 40 systems.
- Solutions for large scale data collection, processing and interpretation.
- Ability to monitor and control large numbers of systems in the field in real time.
- Long term ageing test for the stack and balance of plant components.

Deploying the BlueGen Pathfinders was a challenge, initially utilising the E.ON internal services and E.ON Hanse's preferred installers, then having to go through a tending process to source new installers for the integrated unit both in the UK and Germany, requiring re-training costs and requiring onsite mentoring and monitoring by the deployment manger in each region during a "technical reset" programme due to stack performance issues.

Having extensively monitored the BlueGen systems, E.ON could determine the operational variables that mattered and incorporate these into the monitoring on the SOFT-PACT Integrated FC (SIFC) unit during the design process which was a successful collaboration between E.ON's monitoring team, CFC and Ideal Heating's design teams.

Deployment of the 30 units in the UK between standard BlueGen systems and BlueGen plus Beta-1 prototypes provided great insights into the amount of supplementary heat required to meet hot water demand which also impacted the design of the SIFC unit.

Utilising the BlueGen.Net and the HOMA HMMS EC communications units allowed the monitoring and support teams to obtain real time and daily system information resulting in gigabytes of data that was analysed, to determine the overall efficiency of the systems and long term stack aging data, together with insights into component life times.



A diagram showing how the typically met the requirements of a mid-demand property but only provide base load of a high demand property.


A typical installation in a UK garage

In Q1 2015 all monitoring and operation of the pathfinder BlueGen units had completed, and the units were removed and replaced with conventional boilers due to the issues with CFC.

It was also noted that the BlueGen water heat recovery alone was unlikely to allow the tank to reach a temperature suitable for hot water delivery for most sites with average hot water demand. It is therefore necessary for there to be an alternative heat source to boost the temperature. This effectively reduces the efficiency of the system, but in theory is only required to add a small amount of temperature to the hot water supply.

For trials of the SIFC units, the monitoring evolved based on the BlueGen monitoring and took advantage of diagnostic and control sensors that are already integrated into the unit. A small number of additional meters were fitted to provide additional essential external monitoring to the system, but the on-board PLC and HOMA box were used as a logging system, removing the need for a separate data logger. The parameters being monitored were reduced to the minimum necessary to provide an assessment of the innovative features of the SIFC.

RECOMMENDATIONS

Issues discovered and resolved during the BlueGen Pathfinder field trial have led to a more robust and more efficient BlueGen appliance with less service intervals moving forward through to the design of better filters and water treatment modules.

Replacement of the inverter should be considered, moving way for the lack of support provided by the current manufacturer who only solved the G83/2 compliance issue after complex discussions.

One of the most important findings from the system A (BlueGen + Tank) phase of the trial - that there is a conflicting requirement from the BlueGens system tank: its main purpose is to store heat so that it is readily available, which implies that it remains as hot as possible, however for the BlueGen to recover heat efficiently, the tank needs to be as cold as possible.

Sites which had low water usage were able to switch their immersion heater off with these systems. However at these sites the BlueGen was providing all of the hot water, and the thermal efficiency of the BlueGen was much higher, but demand was not always met. This demonstrates the need to carefully consider the system that the BlueGen operates in to maximise the heat recovered from the BlueGen.

This implies that the sharing of water between the boiler, BlueGen and central heating is not an efficient way of extracting maximum heat from the BlueGen. For the SOFT-PACT Integrated FC trial the BlueGen waste heat recovery water is kept completely separate so that heat transfers can be controlled via a heat exchanger, this provided a much better system efficiency.

Grid connectivity, despite supplying a constant output fuel cell, we were forces to pay for some grid infrastructure improvements by a local gird operator. If fuel cells are to be rolled out in significant numbers the aging underlying grid system may add unforeseen costs to deployment.

If the water quality is known, then this limits the potential customer base to locations which have a suitable water source, without extensive and costly water filtration systems.

To facilitate faster deployment the FCH-JU should promote the development of Hybrid installation engineers for this new industry.

WP4: Integrated mCHP System Specifications

Objective:

- Ensure that the system can run and deliver the energy requirements needed for the applications
- Identification of the data outputs, communications and monitoring needed
- Thermal storage capacity, auxiliary burner size, de-sulphurization filters, water treatment requirements
- Control strategy for generator and system
- Interfacing with the grid, smart metering and remote monitoring and control systems
- Identification of installation and maintenance requirements and be fit for purpose

Tasks:

- Review of work package WP1 and identify the range of home sizes/occupancy and system configurations that will be included in the trial
- Ensure that the system does not limit the provision of energy to the home if the fuel cell stack fails
- Thermal storage and heating systems linked
- Specify requirements to enable internet-based monitoring and controls for heating and generator system
- Identification of serviceable components for simple exchange
- Footprint, height and weight parameters
- Identify the norms, and safety regulations system has to comply with

Deliverables:

Integrated FC mCHP specifications:

- Final specification of the integrated mCHP field trial system(s) suitable for installation in the residential and other relevant market(s)
- Specifications so that field trial customer locations can be identified

Summary:

Meeting the challenge of the designing this specification to meet the requirements was greatly underestimated in this work package. The time required for the exchange of knowledge between Ideal and CFCL was quite considerable. Numerous meetings and redesigns were held to overcome the issues that resulted from requirements in thermal storage, control strategies, flue integration, waste heat recovery connections, control architectures, user interfaces, size, weight and ease of maintenance.

Reviewing the monitoring data from the BlueGen Pathfinder field data to see usage patterns and the function of the Beta-1 units highlighted demand requirements and the conflicting requirements of maintaining a high cooling coefficient for waste heat recovery vs high temperature for meeting demand.

The specification was agreed upon by the consortium in Jan 2013, delaying the start of WP 6 by 7 months.

SOFT-PACT Integrated Fuel Cell System Design Details

The BlueGen Pathfinder field trial has provided extensive insights and data, despite the deployment challenges, technology issues and delays.

The detailed analysis of the relationship between tank temperatures, heat recovery and secondary heat input in system A systems (BlueGen + Storage Tank) has provided understanding of the limits of the system and influenced the design of the SIFC unit.

The insights on the draw off patterns and tank thermal recovery and behaviour of the system B systems (BlueGen + Booster Unit) has helped refine the design of the integrated fuel cells innovative and unique thermal store design which has be patented.

The monitored losses from the BlueGen tank separation in field has defined the maximum distance between the two halves of the integrated field cell unit, and has shown that any significant distance between them causes large heat losses without expensive thermal lagging.

The comprehensive monitoring through wireless and wired data loggers in the UK and Germany highlighted the ease of deployment verses battery usage and we are modifying the monitoring design of the integrated fuel cell to take this into account.

Issues regarding installation of monitoring equipment in the UK has shown the necessity to comprehensively train installers, and to provide close support throughout the installation and commissioning process to ensure reliable installations and minimal return visits. A normally qualified electrician required for boiler installations is unqualified for the Information Technology and Communications (ITC) wiring requirements of fuel cell mCHP with control and condition monitoring.

The separation of the central heating usage from domestic hot water usage has never been done in field trials to date and provided invaluable lobbying statistics to show the proposition of gas usage within homes for heating verses hot water for washing.

The BlueGen Pathfinder trialists appear to be happy with the performance of their systems installed except for where there was very high hot water usage – our design addressed this issue in all but an extreme high demand case (a cafeteria area within a school with both high space heating and hot water requirements).

Deployment has provided insight into the health and safety requirements for fuel cell deployment from the commissioning equipment (Gas sniffers to check for leaks post desulphurisation) to the creation of a stack crane for lifting and lowering the GENNEX stack into position on the balance of plant in the field.

The unexpected rapid decline on the faulty stacks has allowed us to understand the warning signs that would signal an end of life which was not expected to be seen with the field trial.

After reviewing the outsourced EU Market Opportunity report by consultancy Delta Energy & Environment , it became clear that our target countries, that are interest to the Consortium are the UK, Germany, Netherlands, Belgium, and Italy as these are the most favourable for policy and regulations support and property suitability (on gas, installation space) now and expected in 2015.

After numerous meetings exchanging information between Ideal Boilers design team and Ceramic Fuel Cells Ltd technical team and consortium reviews it became clear that a target requirements specification should be devised to focus the design considerations.

The consortium also reviewed the data from the BlueGen Pathfinder Field Trial which utilised two systems: System A (BlueGens and standalone CH boilers) and System B (BlueGens and a Booster Unit (Beta-1)). It became obvious that the tank was too small on the Booster Unit and that the boiler and fuel cell should be housed in the same box, leaving the full height of the second box for a larger tank configuration.

The resulting design moved through four options as each was evaluated for integration, controllability, logistics and meeting Domestic Hot Water (DHW) and Central Heating Demand (CH), whilst incorporating essential monitoring and remote diagnostics requirements.

Through the design meetings that then followed a unique tank design was devised to maximise the waste heat recovery from the fuel cell, combined with smart blending and a booster boiler to meet the DHW and CH requirements, a patenting application has been applied for. Problems of combining the two flues, gas types of the required counties, control strategy requirements and maintenance access were also resolved.

To meet the various heating requirements of the target countries properties two variants of the system are planned (15kWt and 26kWt). A prototype of this system was built by Ideals design team as a test rig to perform DHW draw off tests and after reviewing with the consortium it was however agreed that a single 26kWt design would form the system build for the field trials as this could be modulated down to the lower 15kWt output.

Calling on the services of a design company (Cambridge Design) we then reviewed the most suitable outward skin that would appeal to customers and be practical in the field, although too costly from for the field trial units which were destined to be installed in garages and basements this ‘skin’ would be used on the commercial unit.


The proposed skin of the commercial product

WP5: Fuel Cell Component/subsystems Optimisation

Objective:

Reduce the component count, system size and cost. Simplify functionality and improve durability/reliability of the integrated system. Tasks:

- Separation of Fuel Cell system(s) into a number of discrete modules
- Analysis of components most suitable for optimisation
- Targeted redesign of highest cost components
- Design input into integration stage (WP4)
- Component supply into build stage (WP6)

Taking into consideration:-

- System modules to be designed for semi-automated scale-up
- That relevant modules have the flexibility to be customised for specific market use
- Minimise energy losses for electrical and thermal parts of the system

Deliverables:

- Reduced component count and cost, life cycle analysis:
- Prioritised list of components for optimisation
- Cost down on the grid parallel inverter units/power management systems
- Reducing the cost of the thermal insulation, fuel cell stack and other components
- Optimised component designs
- Life-cycle analysis of components

Summary:

- Improvement to FC heat recovery unit performance achieved since Beta 1 appliance.
- Improvement incorporated to heat recovery heat exchanger / Gennex module sealing.
- Ongoing development of Gennex module reliability performance.
- 25% Reduction in cost to build achieved.
- FCH LCA Project assigned to PE International. LCA analysis expected complete by end Yr.2013

Fuel Cell Component / subsystems Optimisation Detail

Priorities Modules identified for reengineering were:

- Invertor – cost down;
- Fuel cell stack – lifetime, thermal robustness, cost down;
- Manufacturing Improvements – 4x4 furnace now operational,
- Robot Stack assembly; Insulation – cost down; Improved efficiency of waste heat exchanger; Water Treatment System – new water meter, elimination of one flow meter, reduced service internals via additional filter.

Benefits arising out of project not originally envisaged;

- Improved (average 20% effectiveness) exhaust heat recovery heat exchanger;
- Improved thermal integration using pre-tank produced outstanding results in SIFC / Beta-2;

- Circulating fan redesign - too noisy for internal installations in Europe, an upgrade to control electronics eliminated noise issue and made BlueGEN virtually silent in operation
- Customer Control panel - Capability for customer power control developed in response to customer demand, No current commercial incentive to operate in this mode, despite system Benefits
- Water quality much more variable in the UK than elsewhere. Improvements to extend water treatment system lifetime advisable.

Impact Assessment:

- SOFT-PACT has helped to accelerate the development and cost-down of components and sub-assemblies
- SOFT-PACT helped take production levels from a run rate of 10s per year to 100s per year
- Gave confidence to CFC's supply chain and customers
- Allowed us to negotiate cost downs
- Helped justify investment in 4 x 4 furnace, allowing higher volume, lower cost manufacture of stacks
- Retail price fell from £30k per unit to £20k per unit in 2 years

Conclusions:

25% cost reduction achieved through reengineering components and supply chain improvements.

Improved heat exchanger increased the efficacy of the SIFC units waste heat recovery system improving the performance of the integrated unit and resulting in the integrated unit being 4% more efficient.

Unforeseen project benefits and impacts have been considerable more valuable than expected.

LCA report concluded that compared to a Gas Turbine (with 40% efficiency) a BlueGen would reduce Global warming emissions by 37%.

Improved customer control interface developed allowing programme control (similar to 7 day timer) of modulation output over a 15minute timescale allowing for real time responses to price market signals or user scheduled generation

Recommendations:

- Policy development custom led power control
- Recommend harmonisation of EU grid connection regulations
- FCH-JU to consider a project/process for reducing insulation costs on an industry-wide basis by aggregation of demand from manufacturers
- Call for a study on time of use consumption, generation and export tariffs as part of a smart grid using fuel cells [an E.ON PhD sponsorship EPSRC project has been setup to achieve this]

WP6: Design & Build of mCHP System

Objective:

To build integrated (condensing boiler and SOFC generator) micro CHP systems that can be used in the market segments identified in WP1, to the specifications in WP4 and utilising the optimised components from WP5 and learning's from WP2. Life cycle assessment will also be used using the International Life Cycle Data Systems Handbook requirements.

Tasks include Production and validation of test units taking into consideration:-

- "Quick change" for serviceable items, Integrated heating, domestic hot water and thermal store modules
- Common gas train and safety systems, Integrated control for heating system and generator
- Implementation of data acquisition, monitoring and controls solution; transfer of data to central server, visualisation of information via utility portal, Validation of the above under laboratory conditions, End of life issues

Deliverables:

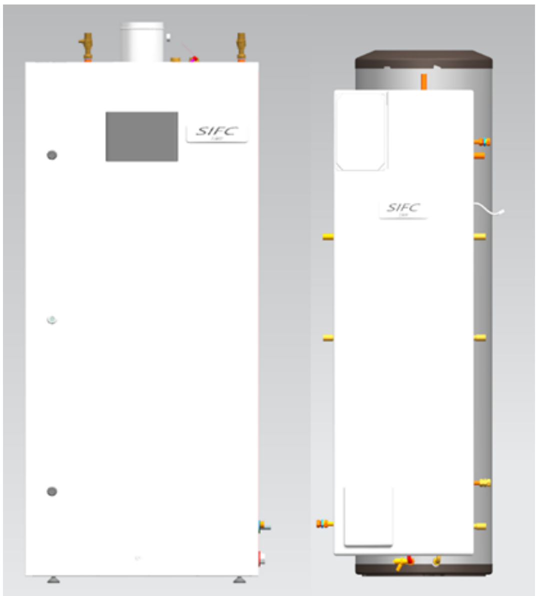
- Design and build of up to 60 integrated mCHP systems with provision of spares
- Validation of integrated microCHP system for each identified application, Systems must meet compliance & norm testing
- Production of up to 60 systems for field trials incorporating data acquisition and monitoring and controls,

Summary:

- Integrated unit is now optimal following analysis of customer needs, installation requirements, ability to manufacture and operation.
- Modular build allows optimal manufacture and subsequent servicing. Use of technoplastic manifold components combining water system components.
- Integrated three pass DHW plate heat exchanger reduces part count and size envelope.
- Common appliance design can be configured for 15 or 26kW heating output. Axillary heat engine burner technology accepts varying natural gas supply composition as seen in all regions installed.
- Appliance employs common gas supply and flue connection to provide ease of installation. Common flue achieved by developing non-return valve system.
- Innovative custom cylinder design employs two integrated volumes in a single cylinder reducing assembly and installation time in the smallest possible size.
- Survey of HW tank manufactures undertaken. DeJong Chosen for best design and manufacturing capability.
- Development of PLC based controller incorporating touch screen HMI interface with real text and system modulating. For volume manufacture this control architecture can be easily transferred to dedicated custom PCB control cards. Linkage to HOMA embedded computer and internet connection achieved by the addition of an internal router.
- Supporting Failure Mode & Effect Analysis (FMEA) undertaken on all product systems.
- Build of Beta 2 / SIFC field trial product is in progress.

The Design & Build of FC mCHP System Details

Ideal Heating undertook to design and build forty integrated Fuel Cell mCHP systems for the project during work package 6. The design phase was the culmination of the market study, prototype performance testing, agreed specification targets and technology transfer between the consortium partners.



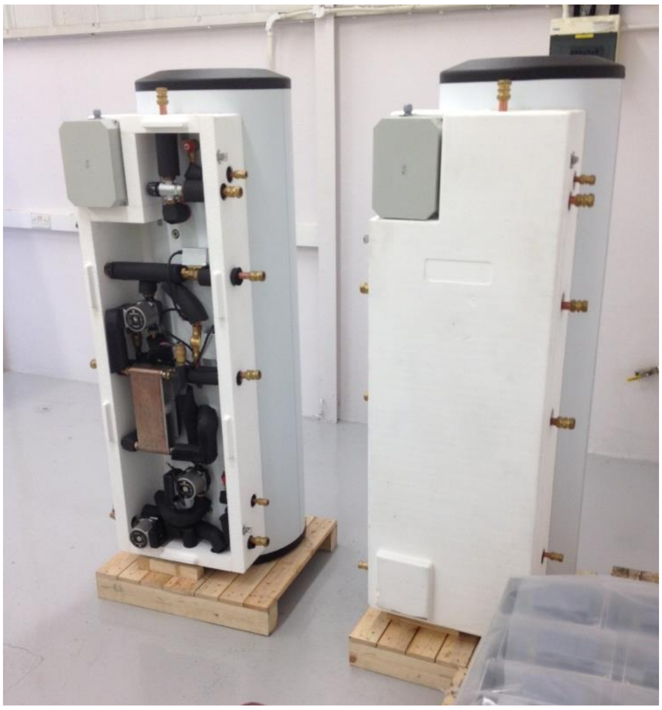
SIFC Unit as deployed

Overcoming the design challenges and considerations in relation to the technology platforms within the integrated unit; of a fuel cell, auxiliary heat engine, hot water storage tanks and integrated control system; the areas of technology integration driven by the specification; the approval requirements and the costs and timescales of the overall project. In addition to the product design the packaging and handling for outbound logistics and installation and service were also considered.

The project had to take into account the supply chain and build considerations for a low volume of forty demonstrator units of mixed production and pre-production parts and details the integrated control system, while designing production build steps, quality and product test procedures and develop an audit checklist. An end of life decommissioning process was also developed.

Overall there was good knowledge transfer between parties and the project as a whole went well once established. The units were built and despatched within the work package deliverables, albeit with a short delay. The technical challenges were understood and solutions implemented. Not all countries were ultimately catered for in the project but the product was built to specification for the two key countries of UK and Germany.

Power units in production



Storage units in production

Mockup of SIFC within a utility room

Recommendations

Another development cycle is required to remove the issues found during the field trial and to improve the electronics and communications integration and to extend the deployment into other EU regions through the adoption of a boiler burner that can accept a wider range of EU regional standards and gas types and through the development of installation and owner manuals supporting other regional languages. Further research should be undertaken to develop a database of EU regulations to aid this testing process.

Increasing the build volumes would improve the supply chain development discussions, small quantities are plagued with quality and delivery timescale issues, developing test systems is costly and inefficient for low volumes.

WP7: Codes Standards and Safety Regulations

Objective:
Integrated microCHP systems that are safe to install and operate in residential and other locations that comply with all relevant safety and operating standards. Systems tested and verified by an independent third party test house.

Tasks:

- Final system design to be validated against specific norms prior to build
- Supply of systems (2 or 3 units) for compliance approval
- Compliance testing to be undertaken by an external test house
- Systems to be tested for unit verification CE, PAS67 (or equivalent) and G83/1 grid connection

Deliverables:

- Codes of certification:
- Integrated microCHP system that is safe to operate in residential and other locations
- Reports and certifications

Summary:

- Ideal originally worked with the BSI to cover the safety testing of the integrated fuel cell but switched to Kiwa Gastec's testing facility.
- The BlueGen became fully compliant as the project started and has verified with CE, and G83/1 grid connection certificates
- The Vogue Boiler being integrated into the system is also CE approved
- Ideal have developed a conformance test rig to check the system before packaging for shipment.
- Test units were installed at installers (Ideal) HQ prior to full scale field trial deployment.
- It was decided that obtaining a PAS67 test & results would delay the field trial further (4-6 weeks) and this was eventually found to be too costly and would be sort commercial version of the unit should one be developed.
- MCS approval for a limited run field trial units in a small production facility would not be cost effective.

Codes Standards and Safety Regulations Details

The integrated fuel cell system was tested and approved to validate the product was safe to install and operate. Systems were tested and verified by an independent third party test house as part of the approval process.

The integrated unit was able to utilise the CFCL BlueGen CE Verification and G83/1 grid connection certificates that came online during the project. The decision was made to use the existing approved heat exchanger from Ideal's Vogue domestic gas condensing boiler range and work with Ideal's existing third party house BSI to aid certification. All selected components for the SIFC units were independently approved by component suppliers to the applicable EC directives alongside the product type testing approval. Ideal developed a final conformance test rig as part of the manufacturing area for the 40 unit build to test and check the full working operation of the system to the specification, before packaging for shipment in accordance with the relevant norms and standards.

SIFC Power units being tested

A complete engineering appliance manufacturing test specification and procedure was in place for manufacture and testing and was conducted to defined procedures for every appliance to ensure quality control of manufacture. This traceable quality control, alongside Notified Body certification was required to fit the CE mark to the appliances.

Despite these controls there were issues in the field from component failures (from shipping, unforeseen design and manufacturing complications) which resulted in field visits, work arounds and component replacement. Unfortunately due to limited the limited manufacturing quality some production units were cannibalised to provide components for units in the field.

Because of the small quantity of units being produced on a small production facility it was impractical to perform and certify the unit for PAS67

WP8: Training, Installer Accreditations & Field Support

Objective:

Training and standard operating procedures for installers and maintenance engineers to be qualified to install, connect and service field trial systems. The scope is limited to the appliance only and assumes candidates are already approved and comply with local regulations and standards.

Deliverables:

- Training and re-skilling installers:
- Training manual and installation procedures
- Training courses for installer and service engineers
- Qualified installation and maintenance engineers

Summary:

- We trained the our own internal installation division MicroGeneration Support Services (MSS) as the first MCS approved fuel cell installers in the UK which required a training trip to CFCL's Heinsberg Factory.
- We also trained the two 'family installation businesses' in Hamburg to enable the other BlueGen pathfinder installs.
- Each developed procedures for safely installing BlueGens within the building regulations of each region – in Hamburg this included liaising with the 'Chimney sweep' to sign off the safety of the installation.
- We have also trained up the replacement for MSS which has now been shutdown, Forrest are now trained and are handling support and further installations.
- CFCL have developed these courses as their installation partners has expanded in different regions.
- Work has just begun on the IFC manual and installation procedures in the required languages

Training, Installer Accreditations & Field Support Details

This work package looked at challenges of the introducing fuel cells to installers across Europe and determined if the skillsets of the installers could be extended to enable them to successfully and safely carry out the installation, commissioning and maintenance of new fuel cell based technology and monitoring equipment for the duration of the 4 years of field trial.

With an initial training programme provide by Ceramic Fuel Cells for E.ON's Microgen Support Services division and E.ON Hanse's preferred installation companies GTH Gebäude Technik Hamburg GmbH and KAS Anlagen GmbH for the BlueGen Pathfinder field trials, installations progressed but were problematic due to the large amount of auillary monitoring equipment that was installed around the units.

Ideal Heating training developed with Cermanic Fuel Cells for the SOFT-PACT Integrated Fuel Cell (SIFC), providing training manuals (in English) and performed a test installation with the installers at their training facility to eliminate and trouble shot any issues prior to the fleet being deployed.

Attempts at multiple, repeat BlueGen Pathfinder installations showed some benefits, however the underlying costs of multiple visits from heating technicians, electricians, monitoring staff and ITC trouble shooting personnel.

It was also recognised early in the project that the up skilling of trade's people in all regions would be a requirement for a successful deployment of the trial. Each phase also presented different training requirements as the product changed and developed.

A Stack being installed on site

E.ON provided an experienced consultant installer as a trouble shooter during 2014-15 who had experience with micro CHP and the issues of quality installations. He attended BlueGen technical reset installations, which stabilised the fleet and attended most of the SIFC installations in the UK and Germany, highlighting processes and improvements that could be made to the system to ease installation.

Conclusions

Despite the challenges of training installation companies in different regions the fields trials deployed and maintained a fleet of three configurations of fuel cell systems for the time of the project.

There was an additional regional challenge around engaging with installation companies in different countries (UK, German, and Netherlands) with different cultures, property designs, regulations, gas types and skills requirements.

Despite some products coming into the market, it is very early in the fuel cell products market place and their development lifecycle, many of the components are hard to service or should last longer between servicing to reduce overall servicing costs by reduced visits. This is expected as the supply chains are still evolving together with the products.

Both German and UK installs excelled in their areas of expertise, German installers expect to install high quality, long life, systems and the UK installers know the standard UK market product and its configurations and therefore both had issues with prototype pre-commercial equipment which resulted in larger than expected call outs and work arounds.

Recommendations

Hybrid Installation Technicians must be encouraged to reduce the cost of installations and number of personnel on site during installations. FCH-JU should maintain a database of regulatory installation requirements and accredited installers per member state so that its members can determine which regions are easiest for deployment of their fuel cell technologies.

WP9: New Unit Field Trial

Objective:

The objectives of this work package which is led by E.ON Technologies Ltd is to install, maintain, monitor, control and operate up to sixty Integrated fuel cell systems in a variety of residential and various other locations.

Description of Work

- Validate set up of data acquisition and monitoring in sample field installation
- Create (central) server with the necessary capabilities for data handling, mining, analysis and presentation. Server should have an open-standard interface for communication with external IT systems, as determined during the course of the trial.
- Install field trial systems and monitoring equipment
- Real-time monitoring and control of all the field trial systems via appropriate distributed software applications and the surrounding environment
- Determine conditioned based maintenance service intervals from aggregated field data
- Gather customer experience information via web interfacing and face to face surveys

Deliverables

The deliverables from this work package are as follows;

- Field trial units and monitoring deployed
- ICT solution for secure data collection and transmission
- Develop a software platform for integration of monitoring, fleet management and control applications
- Collate performance data, energy consumption patterns for different run conditions and optimum profiles for efficient operation
- Field trial data collection and analysis
- Customer experiences case studies

Conclusions

Meeting the challenges of performing a field trial on the prototype Integrated Fuel Cell has provided extensive insights and data, despite the deployment challenges, technology issues and delays, this information will be utilised in future field trials and modelling projects.

Initially planning to deploy in 4 countries highlighted in the original market opportunity report, the consortium soon learned that connection regulations (Italy) and Gas Type Variations (Netherlands) can stop deployments very quickly. The resulting system deployments in two very different EU regions (UK and German) provided sufficient insights during the trial period to determine the effectiveness of the integrated system over a modular system.

Training installation engineers in both deployment regions allowed the building regulations and health and safety requirements to be determined but also highlighted the training and skills required for scaling to commercial deployments levels.

Reduced, but effective monitoring devised for the system generated resulted in 24 Gigabytes of data to be analysed consisting of 588 million data points.

The mean overall system efficiency was 79.0% for UK sites and 78.3% for German sites (due to higher temperatures in heating system), this was 4% higher than for the BlueGen Pathfinder systems monitored during the Phase 1 field trial.

An integrated Fuel Cell system has been proven to be more efficient (by 4%) than a modular solution, through comparison of the system efficiencies between the two field trials. The mean overall efficiency is 79.0% for UK sites and 78.3% for German sites – due to higher temperatures in their heating systems, decreasing efficiency in thermal transfer.

Recommendations

Further efficiency improvements can be realised by a better control system as some bug workarounds in the controller logic caused some unnecessary extended boiler usage to meet customer heat requirements.

Separation of heating system circuit from hot water demand and maximising waste heat recovery through thermal differences will maximise the efficiency of the system, however the unique tank adds the overall size of the unit and therefore phase change technology should be considered to reduce the physical volume of the appliance long term.

Developing a more generic boiler burner that is suitable for more EU gas types would extend the deplorability of the unit, together with a rework of the communications and electronics (PLCs, routers, HOMA EC units) for commercial manufacturing could eliminate further issues seen in the field trial.

Another round of development and testing would produce a commercial product ready for the market.

The SOFT-PACT Integrated Fuel Cell (SIFC) Field Trial Details

The SOFT-PACT Integrated Fuel Cell appliance was deployed in residential and commercial locations in the UK and German regions between 2014 and 2015.

Initially planning to deploy in 4 countries highlighted in the original market opportunity report, the consortium soon learned that connection regulations (Italy) and Gas Type Variations (Netherlands) can stop deployments very quickly. The resulting system deployments in two very different EU regions (UK and German) provided sufficient insights during the trial period to determine the effectiveness of the integrated system over a modular system.

The SOFT-PACT Integrated Fuel Cell (SIFC) field trial incorporates a system design, which uses the insights from the BlueGen Pathfinder (System A) trials, most noticeably the unique tank design, to maximise heat that can be recovered from the BlueGen.

The monitoring for this trial took advantage of direct data access from the HOMA system, which connects to the on-board PLC that already has vast majority of the required monitoring parameters already being monitored for the purposes of operating the SIFC unit. This avoided the need of a separate data logger installed on site.

Furthermore, additional heat and water meters were connected to the PLC, so that extra critical parameters are also measured to assess the thermal efficiency of the system. This reduced, but effective monitoring devised for the integrated system generated, resulted in 24 Gigabytes of data to be analysed consisting of 588 million data points.

There were 27 SIFC units installed in this trial; 27 in the UK and 10 in Germany. The monitoring period is between 1 May 2014 and 31 March 2015.

The overall thermal efficiency for this trial is 16% while it is nominally 12% for the BlueGen + Tand (System A) trials. With about 4 percentage point's greater thermal efficiency than the System A trials, the SIFC design is clearly making better use of the waste heat from the BlueGen, and thus increasing its overall efficiency.

Across all sites, thermal store energy is used more for hot water than for space heating. For the hot water demand, between 40% and 60% of the total hot water demand comes from the thermal store for almost all the sites. Only one site is less than 40% because of its high hot water usage, which is driven by high occupancy traffic of being a guest house. For space heating demand, the contribution of the thermal store energy is more diverse across the sites. This is due to the same control system of the SIFC unit resulting in a very different energy extraction characteristics from the thermal store for space heating depending on the demand profile.

Issues found during the field trial

A thermal store charging issue was identified during the monitoring period. It was a control issue from the PLC and is related to heat from the boiler that is used to charge up the thermal store. This should not happen because there is less capacity for heat recovery from the BlueGen, and thus impacted on the thermal efficiency. The overall thermal efficiency without the boiler charging up the thermal store is 16.4% while it is about 1.8 percentage points less efficient, or 14.6%, when this issue occurs.

A SIFC unit was installed in a primary school to provide space heating for the entire school, and hot water for its kitchen. The unit was only installed for 1 month around December 2014 because the customer soon complained the unit did not meet their heat demand. Analysis has shown this can be a control issue from the PLC and is related to how many timed hot water periods can be set in the system. Having a more frequent switch between the hot water and space heating modes can reduce the likelihood of temperature drop from the Domestic Hot Water (DHW) store when there is a high hot water demand. This is because the boiler should have enough capacity to heat up the water to maintain around 70°C.

Germany Trial Locations

The German SIFC trial locations were located around the installations company Lindorfer's[i] head office in Hosbach / Rottenberg, near Frankfurt, Germany, and are shown on the maps below, further detail is not possible due to data protection restrictions.

Image 1 Lindofer GmbH location near Frankfurt, Germany

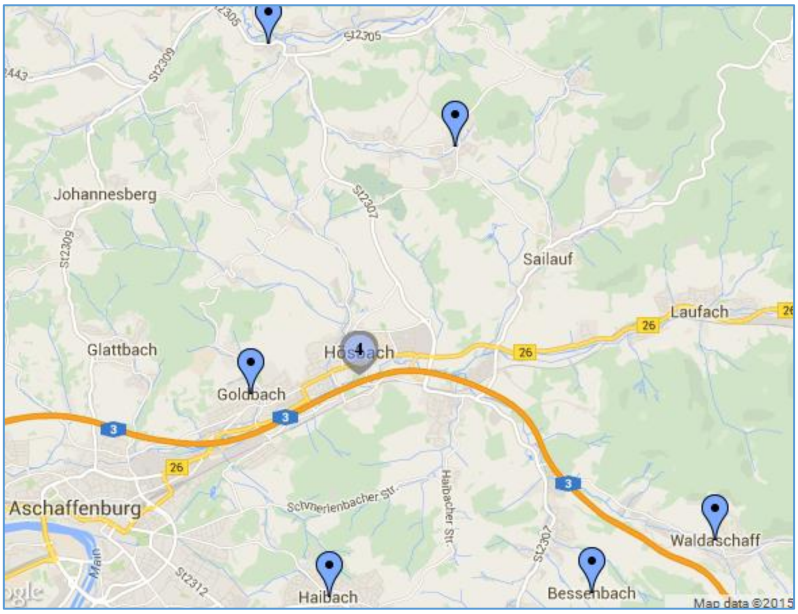


Image 2 Deployments around Hosbach / Rottenberg, near Frankfurt, Germany

UK Trial Locations

The UK SIFC trial locations were located around the installations company Herbert T Forrest's [ii] head office in Bolton near Manchester and are shown on the map below, with the exception of the unit that remained with Ideal Heading's training facility in Hull.

Image 3 Forrest's location in the UK

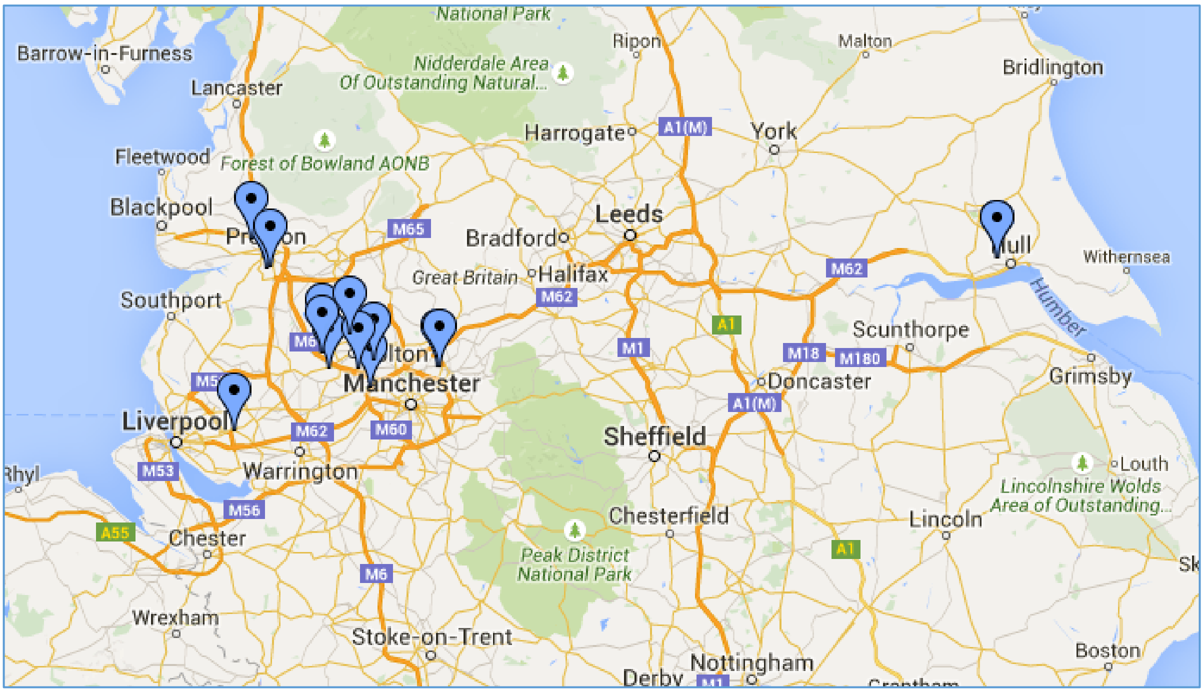


Image 4 Deployments in the UK

Data Analysis Results

For electrical efficiency, once a BlueGen inside the SIFC has started generating electricity, it would normally provide a steady 1.5 kW throughout its operation. It is expected the electrical efficiency is fairly consistent across all the SIFC units, as well as when comparing them across different trials, e.g. Pathfinder Systems A & B.

Figure 1 shows the electrical efficiency of the BlueGen inside the SIFC units across the trial. The mean electrical efficiency across the trial is 53.3%.

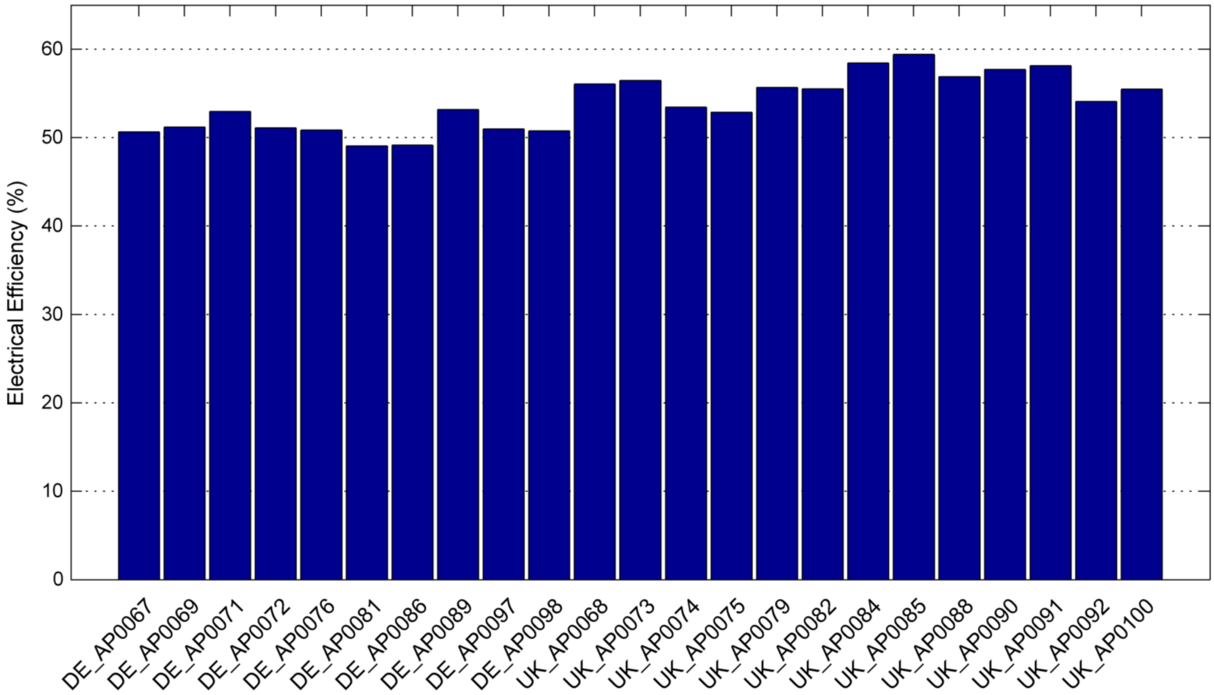


Figure 1: Electrical efficiency of the BlueGen across the SIFC trial.

The overall fleet efficiency for the SIFC units between 1 May 2014 and 31 March 2015.

The mean overall efficiency is 79.0% for UK sites and 78.3% for German sites.

UK_AP0075 has the lowest gas used by both the boiler and the BlueGen because the unit was taken out early in the trial due to the unit being unable to meet the customer demand.

UK_AP0091 has no ‘BlueGen Heat’ shown in this figure because total pulse count for waste heat was not incremented by the PLC when hot water flows through the pipe.

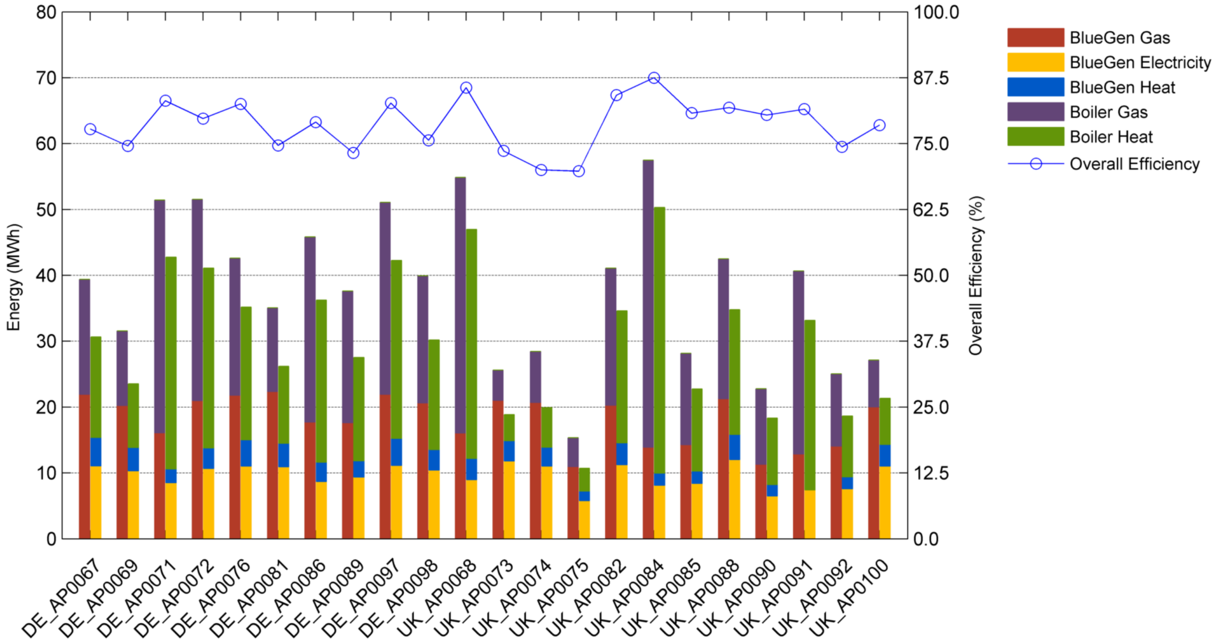


Figure 2: Overall efficiency for units across the SIFC trial.

WP10: Consortium Management

Objective:

Provide overall project management to ensure partners deliver milestones and work packages on time and on budget, project reports and validation of project spend. Tasks:

- Development of standard reporting pro-forma's
- Monthly updates from partners on progress against deliverables and milestones
- Quarterly and annual reports
- Validation of milestones
- Resolution of partner differences
- Stage gate prefect for distribution of project funds
- Creation and maintenance of project website

Deliverables:

- Work package, interim and milestone reports:
- Interim Reports
- Audit Reports and Certificates
- Work Package Reports
- Progress Reports
- Milestone Reports and validation of deliverables

Summary:

- Managing the project has been considerably challenging as the consortium members all have their own methods, processes and procedures.
- Attempting to have a web based project portal (Daptiv) proved to be too much of an overhead on all parties and was dropped in favour of email and meetings with actions, allowing each party to use their own internal PM systems to progress their own work
- Managing the field trials presented problems of design sign off, selection of staff and customers and deployment of two systems in the UK and Germany – all off which were overcome.
- Progressing the design and the production of the IFC has taken considerable longer that planned due to the complexities of realising a design that would meet the requirements.

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Managing the field trials presented problems of design sign off, selection of staff and customers and deployment of two systems in the UK and Germany – all of which were overcome. Technology failure and unforeseen environmental issues (extremely hard water, Grid Network issues, and damage from third party contractors) has caused higher than expected maintenance / support visits and therefore higher support costs.

The unplanned loss of the E.ON's internal installation division (MicroGeneration support Services) in the UK at the end of 2012 has presented challenges of maintaining field trial support; tendering for a competent replacement third party and their training and documentation hand-over, this has been overcome and the Pathfinder trials are now undergoing a technical reset to being the units up to the current supportable technical specification.

Progressing the design and the production of the IFC has taken considerable longer than planned due to the complexities of realising an uncompromising design that would meet the requirements of the project. Commissioning a third party design consultancy to develop the final commercial look and feel shows the detailed approach that we have taken to provide as commercially ready specification. Unique IP has been created within the design work which can be utilised by the consortium for this and other technologies.

Although the costs for installations, field support and clean-up of the field trials increased beyond the planned budgets considerably we intend to stay with the budget of the project and have reduced the number of Integrated Fuel Cells accordingly to 40 from the originally planned 60 units. Given the 10 Gigabytes of data already collected from the half way stage of the pathfinder field trial we believe that having the same amount of monitored Integrated Fuel Cell systems will provide a comparable dataset providing significant insights for development progress beyond this project towards a final commercial system.

After attended the very helpful FCH-JU Financial Communications 1 day training, the coordinator organised a briefing for the rest of consortium parties outlining the Financial Reporting requirements and then assisted the consortium members on the form filling.

Mitigation of Project Delays & Budgets

At the mid-term point of the project the consortium considered the issues that led to the delays within the project and planned to mitigate them as follows:

a) Perform a technical reset on the BlueGen Pathfinder fleet, which resulted in;

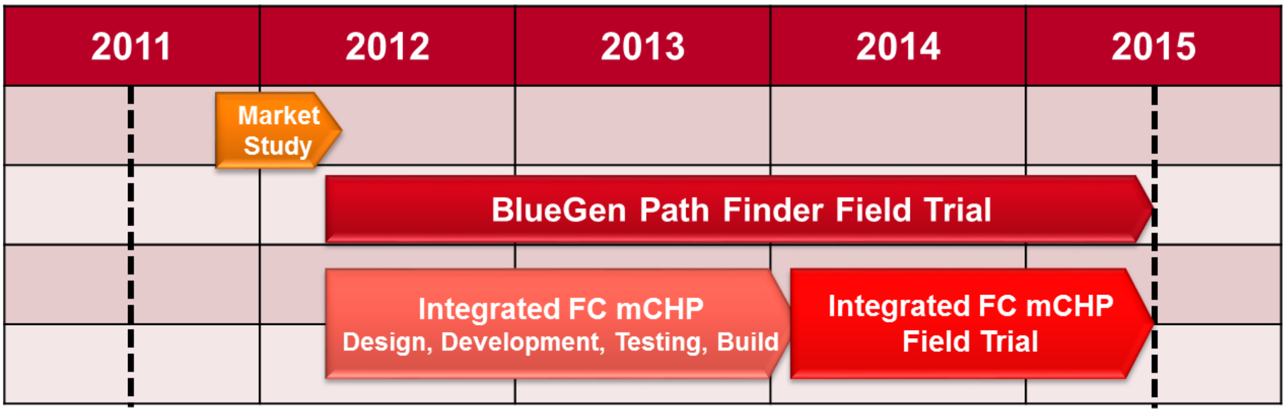
> i) The removal of Beta-1 based systems which have provided substantial data and insights to the design team to aid the design of the IFC, reducing support costs.
>
> ii) The swapping out of the BlueGen Systems are experiencing stack manufacturing issues with new systems updated to the latest software and hardware specifications
>
> iii) The removal of the 5 units at Harper Adams University as the extremely hard bore hole water supply has proved too much for the BlueGen water treatment module and cannot be continued to be supported moving forward.

b) Work on construction of the four Integrated Fuel Cell (IFC) prototype systems and then with a minimum delay start work (at risk) on the field trial systems on the assumption that only minor changes will be need on these units before shipment to installers. This will allow the bulk ordering of components as testing of the primary features of the prototype.

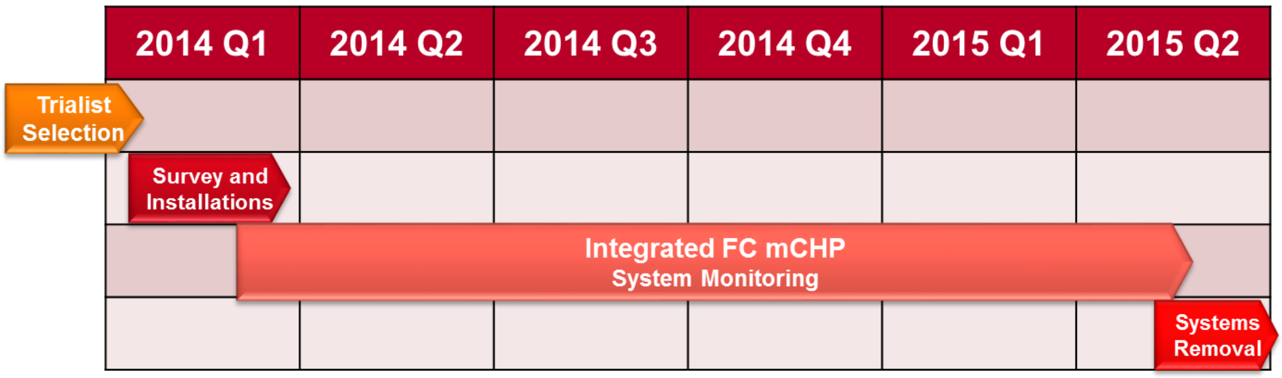
c) Reduce the number of field trial systems to be provided by Ideal and CFC which in turn will reduce the production timescales and provide funds to extend another year in resource and support costs.

d) Tender for best value third party installation companies to replace E.ON's internal installation division 'Microgeneration Support Services' which have been closed down. These new companies will be used support the existing BlueGen Pathfinders and deploy and maintain the Integrated Fuel Cell systems once manufactured.

e) extend another year to allow a meaningful field trial of the SIFC as shown in the schedule diagrams below:



Overall Project Schedule after extending for twelve months



Detail behind the IFC Field Trial Work Package

These mitigations where working well until February 2015 when Ceramic Fuel Cells went into administration. HOMA Software was also bought out in a mini administration. This presented the remaining consortium with a dilemma, there were plans for removal of the SIFC prototype units but now with no support the planned hand over of the BlueGen units to the trialists to create a legacy could not happen. E.ON could not leave stranded unmaintainable assets with the trialists so instead of visiting each site to remove the monitoring equipment the UK installers (Forrest) were tasked with removing the complete systems and providing a replacement boiler system.

The UK administrators created panic and administrative nightmare when they without consultation decided to sending out letters to each trialist telling them that they were due compensation, resulting a calls to E.ON's call centres, press office and the Project

Manager. Each trialist was contacted by the Project Manager by phone and post within 24hrs explaining that this was the administrator acting in error and that EON owned the units and would be replacing them with boilers.

Working with the remains of the CFC Germany personnel, the E.ON team and the installers devised a plan for collecting the BlueGen units and returning them to CFC Germany for recycling. The SIFC units were dismantled after their planned removal and also returned to CFC Germany.

With all of the CFC UK staff associated with the trial released from their roles following the administration detailed system call out and support information has not been available for writing the final reports.

Completing the final phase 2 SIFC related work package reports has unfortunately fell on the E.ON Team without input from CFC or HOMA as none of the staff remain who were directly working on the project (specifically in the UK).

WP11 Knowledge Dissemination and Cross Cutting

Objective:

Promotion of the technology and exchange of information with other project groupings within and outside the JTI such as; “callux” via E.ON Ruhrgas, “Genius” via CFCL, provide data to Stationary Fuel Cell Coalition

Updating of standards/norms/regulations in the markets identified to allow/promote the adoption of SOFC based mCHP. Tasks:

- Development of web site and portal for registered users
- Development of economic payback models for each region, produce promotional material
- Identification of exhibitions, seminars and promotional events for consortium representation
- Attendance at relevant standards and norms committees
- Information exchanges with other JTI groups and project/scientific committees

Deliverables:

Dissemination, promotion, exhibitions and benefit analysis:

- Project Web site
- Promotional literature, presentations and case studies
- Calendar for events, seminars and exhibitions to promote the project and the results
- List of norms and standards committees with “SOFT- PACT” representation
- Promotion of the economic, social and environmental benefits of the technology

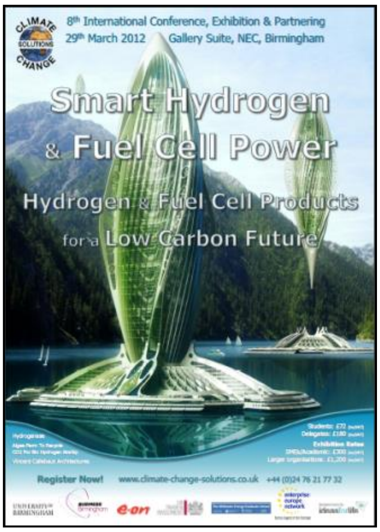
Summary:

- We have sponsored a conference (the 8th International FC Conference, NEC), placed a BlueGen in a TV show ‘Future Family’ on UK’s Channel 4 resulting in 300+ enquires. Case studies have been created by CFCL and placed on the bluegen.info website.
- Having trained the only installation team in the UK, we installed a BlueGen into the AIMC4 – DECC demonstration of a low carbon house with Crest Nicholson promoting the technology to house builders.
- Members of the consortium have shown the BlueGen at EOCBuild, Greenbuild, All Energy and CIH Conference.
- In Europe we have had the BlueGen at ISH, Hanover fairs and others and promoted the technology in local press in Hamburg and Heinsberg and with all the E.ON regional units and shareholders.
- Lobbying continues in all regions but already UK FIT increase and a 250M Euro capital subsidy in NWR of Germany

The consortium started the project with plans for extensive and wide ranging knowledge dissemination and promotions across various media channels and conferences focusing on the commercially available BlueGen Appliance, and engaged with standards committees and whilst builting a project website.

Highlights of the Knowledge dissemination and promotion are as follows:

- E.ON part sponsored the 8th International Fuel Cell Conference, NEC conference, displaying a BlueGen to the research, academic and industrial communities attending. E.ON & CFCL also presented at the conference.



- A BlueGen was featured in a TV show ‘Future Family’ on UK’s Channel 4 resulting in 300+ enquires for Ceramic Fuel Cells UK

Future Family’s Garage showing the BlueGen

- Having trained the only Fuel Cell installation team in the UK, we installed a BlueGen for the AIMC4[iii] project – a UK Government Department of Energy & Climate Change (DECC) demonstration of a low carbon house with Crest Nicholson promoting the technology to house builders.
- Members of the consortium exhibited the BlueGen at ECOBuild[iv], Greenbuild[v], All Energy and CIH Conferences

SOFT-PACT Stand at E.ON New Business Conference

- In Europe the BlueGen was exhibited at ISH[vi], Hanover fairs and others and together with promotions of the technology in local press in Hamburg and Heinsberg and with all the E.ON regional units and shareholders at the E.ON Shareholder conference.
- CFC received numerous awards for innovation for the BlueGen units as visibility of the technology increased.
- Lobbying managed to obtain UK FIT support for fuel cell micro CHP and an increase and a 250M Euro capital subsidy in North Rhine-Westphalia region of Germany
- Various members of the consortium attended standards committees relating to fuel cell appliances during the project lifetime
- Case studies have been created by CFCL and placed on the bluegen.info website covering various installation types, promotion of the economic, social and environmental benefits of the technology

Information exchanges with other JTI groups and project/scientific committees was somewhat strained as all data directly related to only one product with the SOFT-PACT project – the BlueGen appliance and was unshareable as it was commercial sensitive.

The Life Cycle Analysis (LCA) was carried out by a member of the FCH-JU community (FC-Hyguide) under a Non-disclosure Agreement (NDA) and a member of E.ON Technologies (Germany) attended FCH-JU working groups.

Development of economic payback models for each region proved highly complex task depending on the regulations, installation costs and government support funding within each region. Ceramic Fuel Cells developed payback models but these were commercially sensitive and could not be provided within this public document.

Fuel Cell technology has been promoted at conferences, shows, online and on TV shows, to the public and the Government creating awareness and increases in the Feed-in-Tariff (UK) and the provision of a 250M Euro capital subsidy in German (NWR).

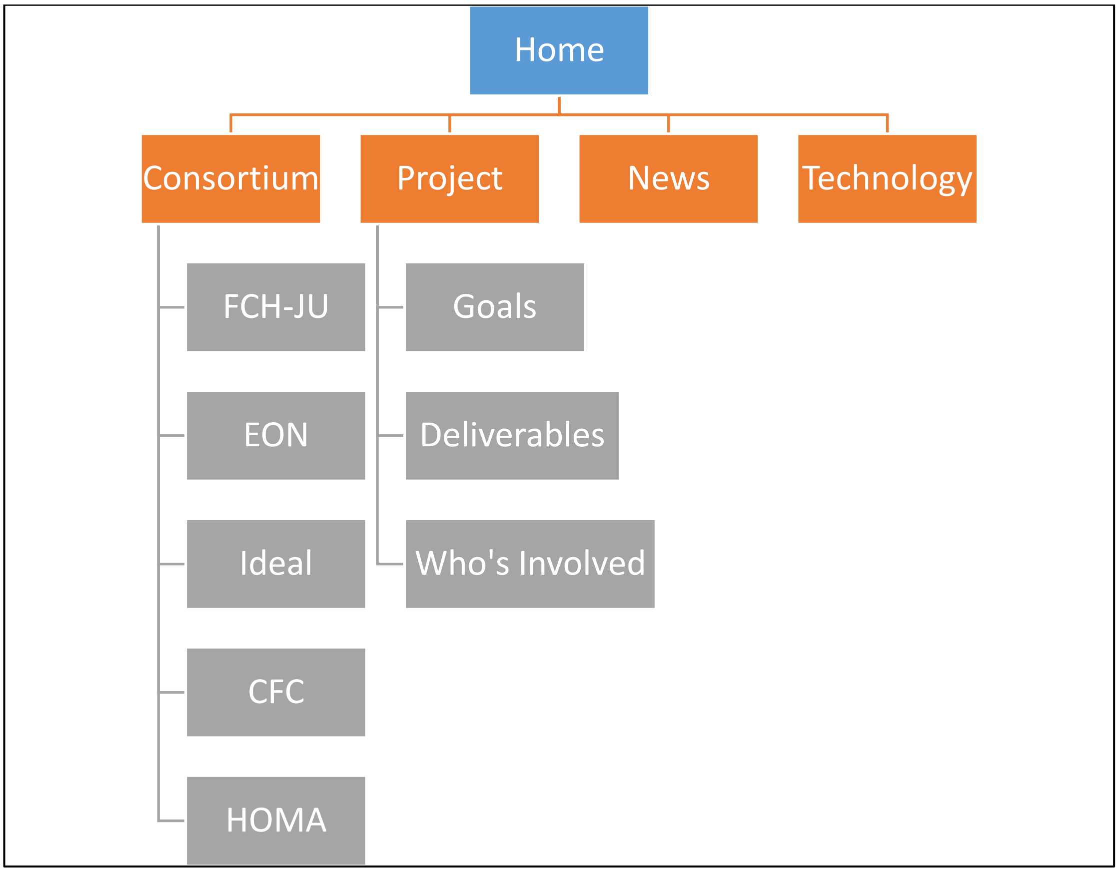
Unfortunately from 2013 as technical issues arouse around the CFC stack requiring a technical reset installation (update) programme and the technical issues that also plagued the field trial of the SOFT-PACT Integrated Fuel Cell, further consortium promotions were limited to just website updates and public presentations limited to FCH-JU programme days.

In 2015 Ceramic Fuel Cells went into administration and were acquired by SOLIDPower. HOMA Software also entered administration and is now owned by Service House B.V.

However, the SOLIDPower have been asked to participate in the Ene.Field Field Trial with their BlueGen appliance and be part of future FCH-JU deployment plans and BMWi - Bundesministerium für Wirtschaft und Energie (The Federal Ministry for Economic Affairs and Energy) has asked for €450 million for an 8 year support programme (Potentially January 2016 – December 2024), able to potentially support tens of thousands of residential fuel cell installations. It looks likely that the fuel cell market support programme will be included as part of the Ministry's National Action Plan on Energy Efficiency (NAPE).

Project Website

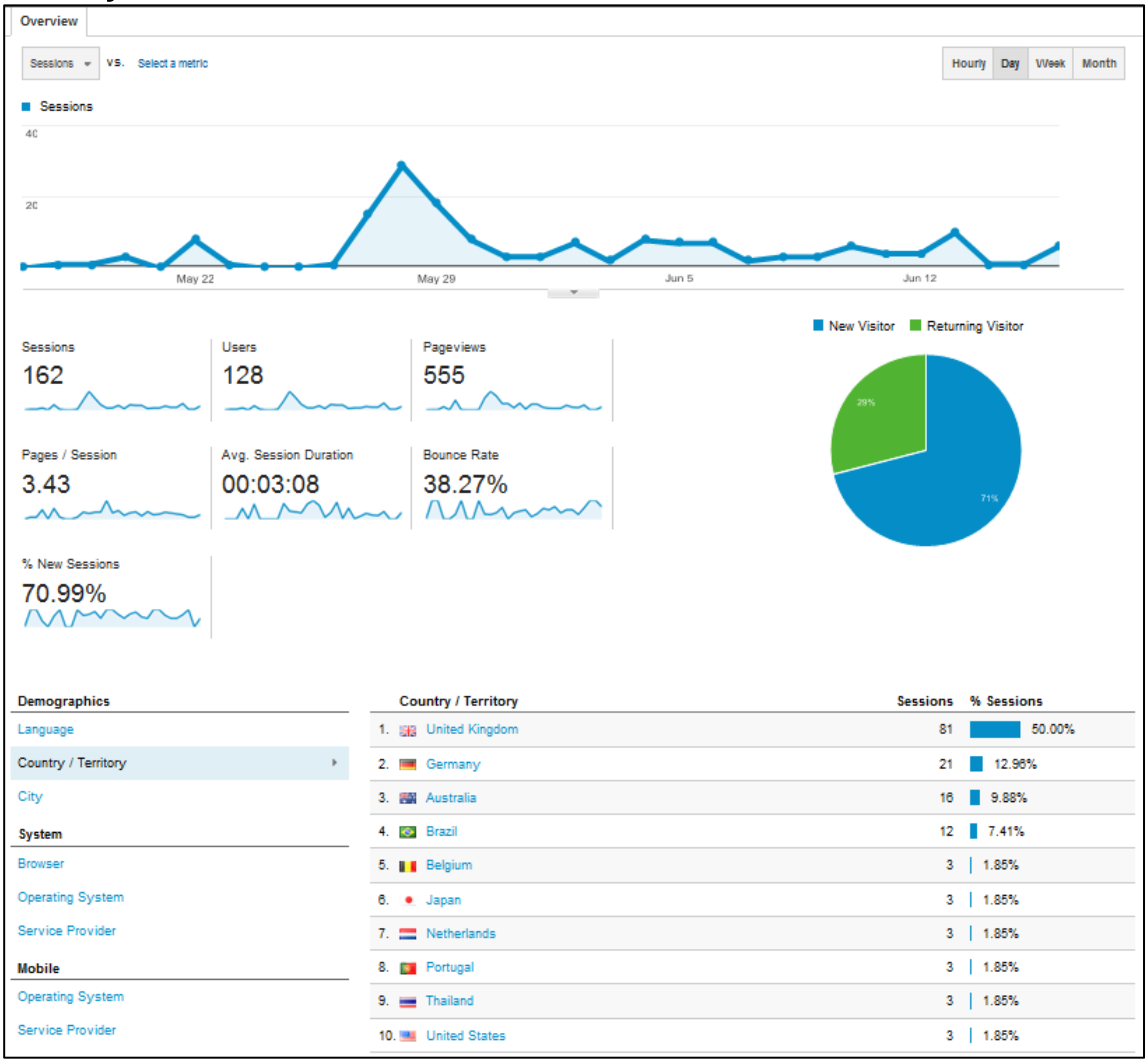
The project provided a website detailing the participants of the project, the technologies and the progress against the work packages. The website's domain was www.soft-pact.eu



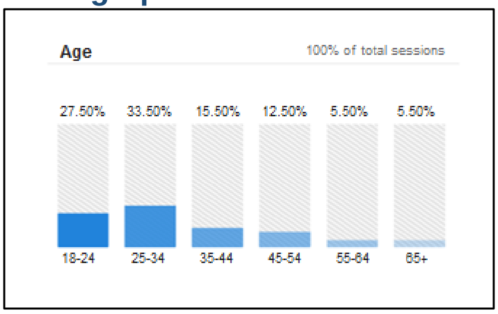
Website structure diagram

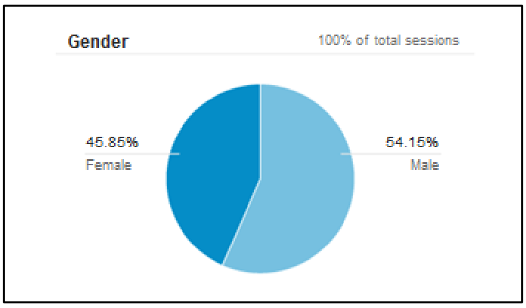
Website Statistics

Country Breakdown



Demographics





Most Visited Pages

	Page	Pageviews	Unique Pageviews	Avg. Time on Page	Entrances	Bounce Rate	% Exit	Page Value
		555 % of Total: 100.00% (555)	457 % of Total: 100.00% (457)	00:01:18 Site Avg: 00:01:18 (0.00%)	162 % of Total: 100.00% (162)	38.27% Site Avg: 38.27% (0.00%)	29.19% Site Avg: 29.19% (0.00%)	$0.00 % of Total: 0.00% ($0.00)
1.	/	178 (32.07%)	145 (31.73%)	00:01:32	137 (84.57%)	36.50%	37.08%	$0.00 (0.00%)
2.	/index.php/news	90 (16.22%)	70 (15.32%)	00:01:18	9 (5.56%)	22.22%	32.22%	$0.00 (0.00%)
3.	/index.php/soft-pact-project/milestones	63 (11.35%)	55 (12.04%)	00:01:33	2 (1.23%)	100.00%	38.10%	$0.00 (0.00%)
4.	/index.php/soft-pact-project/projectgoals	54 (9.73%)	45 (9.85%)	00:00:39	3 (1.85%)	66.67%	14.81%	$0.00 (0.00%)
5.	/index.php/technology	46 (8.29%)	35 (7.66%)	00:01:00	5 (3.09%)	60.00%	26.09%	$0.00 (0.00%)
6.	/index.php/soft-pact-project/whos-involved	29 (5.23%)	24 (5.25%)	00:01:02	0 (0.00%)	0.00%	3.45%	$0.00 (0.00%)
7.	/index.php/consortium/ideal-heating	21 (3.78%)	19 (4.16%)	00:01:57	0 (0.00%)	0.00%	28.57%	$0.00 (0.00%)
8.	/index.php/consortium/cfcl	20 (3.60%)	17 (3.72%)	00:02:14	1 (0.62%)	0.00%	10.00%	$0.00 (0.00%)
9.	/index.php/consortium/e-on	17 (3.06%)	16 (3.50%)	00:00:39	1 (0.62%)	100.00%	17.65%	$0.00 (0.00%)
10.	/index.php/consortium/fch-ju	14 (2.52%)	11 (2.41%)	00:00:36	0 (0.00%)	0.00%	21.43%	$0.00 (0.00%)

2.2 Use and dissemination of foreground

Section A (public)

This section shall include a list of planned dissemination activities (publications, conferences, workshops, web, press releases, flyers, etc) in free text format. Where articles have been published in the popular press, please provide a list as well.

In addition, please provide a list of all scientific (peer reviewed) publications relating to the foreground of the project, starting with the most important ones, in the table below.

TEMPLATE A: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
1	*Micro CHP Set for Houshold Trials*	*Adrian Waddington*	*Professional Engineering Magazine*	*Nov 2013*	*Professional Engineering Magazine*	*UK*	*2013*	*11*		
2										
3										

[1] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[2] Open Access is defined as free of charge access for anyone via the internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

Section B (confidential)

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable, contributions to standards should be specified.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.			
Type of IP Rights: Patents, Trademarks, Registered designs, Utility models, etc.	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Patent	Not known	Low Grade Heat Recovery System	Ideal Heating Ltd

B2: OVERVIEW TABLE WITH EXPLOITABLE FOREGROUND					
Exploitable Foreground (description)	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable, commercial use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved**
BlueGen Improved exhaust heat recovery heat exchanger	*Development of new waste heat recovery heat exchanger undertaken Average 20% improvement in effectiveness across the range*	*Residential & Commercial*	*2014*	*Patents pending*	*Beneficiary - Ceramic Fuel Cells (owner)* *licensing to Ideal Heating for Integrated Fuel Cell*
BlueGen Circulating fan redesign	*Upgrade to control electronics eliminated noise issue and made BlueGEN virtually silent in operation*	*internal installations in Europe*	2015	*Patents Pending*	*Beneficiary - Ceramic Fuel Cells (owner)* *licensing to Ideal Heating for Integrated Fuel Cell*
BlueGen Customer power control	*Not originally envisaged within SOFT-PACT* *– Capability for customer power control developed in response to customer demand* *–*	*Residential & Commercial*	*No current commercial incentive to operate in this mode, despite system benefits* *– Policy development recommendati on*	*Patents Pending*	*Beneficiary - Ceramic Fuel Cells (owner)*
BlueGen Improved thermal integration	*Real world customer experience helped optimise Integrated Fuel Cell design giving rise to pre-heat tank concept*	*BlueGEN plus heat pump installation using pre-heat tank produced outstanding results*	2015	*Patents Pending*	*Beneficiary – Ideal Heating (owner)* *licensing available to SOFT-PACT consortium*
New stack designs for *– Increased stack lifetime through lower degradation*					

B2: OVERVIEW TABLE WITH EXPLOITABLE FOREGROUND					
Exploitable Foreground (description)	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable, commercial use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved**
– Improved thermal cycling for robustness *– Cost down* *– Not available for BlueGEN Pathfinder; scheduled for IFC deployment* *New cell supplier for* *– Cost down* *– Quality and consistency* *– Previous supplier had supplied a faulty batch which adversely affected the BlueGEN Pathfinder project* *– Faulty cells displayed accelerated degradation and hence shorter operational stack life*					

2.3 Report on societal implications

Replies to the following questions will assist the FCH JU and European Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
FCH JU Grant Agreement Number:	278804
Title of Project:	Solid Oxide Fuel Cell micro-CHP Field Trials
Name and Title of Coordinator:	Mr Andrew Thomas

B Ethics		
1. Did you have ethicists or others with specific experience of ethical issues involved in the project?	**X**	**No**
2. Please indicate whether your project involved any of the following issues (tick box) :	***No***	
INFORMED CONSENT		
• Did the project involve children?	No	
• Did the project involve patients or persons not able to give consent?	No	
• Did the project involve adult healthy volunteers?	No	
• Did the project involve Human Genetic Material?	No	
• Did the project involve Human biological samples?	No	
• Did the project involve Human data collection?	No	
RESEARCH ON HUMAN EMBRYO/FOETUS		
• Did the project involve Human Embryos?	No	
• Did the project involve Human Foetal Tissue / Cells?	No	
• Did the project involve Human Embryonic Stem Cells?	No	
PRIVACY		
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)	No	
• Did the project involve tracking the location or observation of people?	No	
RESEARCH ON ANIMALS		
• Did the project involve research on animals?	No	
• Were those animals transgenic small laboratory animals?	No	
• Were those animals transgenic farm animals?	No	
• Were those animals cloning farm animals?	No	
• Were those animals non-human primates?	No	
RESEARCH INVOLVING DEVELOPING COUNTRIES		
• Use of local resources (genetic, animal, plant etc)	No	
• Benefit to local community (capacity building ie access to healthcare, education etc)	No	
DUAL USE		
• Research having potential military / terrorist application	No	

C Workforce Statistics		
3 Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).		
Type of Position	**Number of Women**	**Number of Men**
Scientific Coordinator		1
Work package leader	1	3
Experienced researcher (i.e. PhD holders)	1	1
PhD Students	1	1
Other	5	46

4 How many additional researchers (in companies and universities) were recruited specifically for this project?	
Of which, indicate the number of men:	None
Of which, indicate the number of women:	None

D Gender Aspects

5 **Did you carry out specific Gender Equality Actions under the project** ?

○ Yes
● No

6 **Which of the following actions did you carry out and how effective were they?**

	Not at all effective				Very effective
❑ Design and implement an equal opportunity policy	○	○	○	○	○
❑ Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑ Organise conferences and workshops on gender	○	○	○	○	○
❑ Actions to improve work-life balance	○	○	○	○	○

○ Other:

7 **Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?**

○ Yes- please specify

● No

E Synergies with Science Education

8 **Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?**

○ Yes- please specify

● No

9 **Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?**

○ Yes- please specify

● No

F Interdisciplinarity

10 **Which disciplines (see list below) are involved in your project?**

○ Main discipline[3]:

○ Associated discipline[3]: ○ Associated discipline[3]:

G Engaging with Civil society and policy makers

11a **Did your project engage with societal actors beyond the research community?** *(if 'No', go to Question 14)*

● Yes
○ No

11b **If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?**

● No
○ Yes- in determining what research should be performed
○ Yes - in implementing the research

[3] Insert number from list below (Frascati Manual)

○ Yes, in communicating /disseminating / using the results of the project

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ ●	Yes No

12 Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ● Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ● Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture		Energy	X	Human rights	
Audiovisual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		Environment		Internal Market	
Consumers	X	External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	
Customs		Fisheries and Maritime Affairs		Regional Policy	
Development Economic and		Food Safety		Research and Innovation	X
Monetary Affairs		Foreign and Security Policy		Space	
Education, Training, Youth		Fraud		Taxation	
Employment and Social Affairs		Humanitarian aid		Transport	

13c If Yes, at which level?

- ○ Local / regional levels
- ● National level
- ● European level
- ○ International level

H	Use and dissemination	
14	**How many Articles were published/accepted for publication in peer-reviewed journals?**	**None, just an information article**
	To how many of these is open access[4] provided?	**N/A**
	How many of these are published in open access journals?	**N/A**
	How many of these are published in open repositories?	**N/A**
	To how many of these is open access not provided?	**N/A**
	Please check all applicable reasons for not providing open access:	
	❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ■ other: Industry Specific Magazine (Practical Engineer Magazine)	
15	**How many new patent applications ('priority filings') have been made?** *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**1**

16	Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	
	Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	None
		Registered design	None
		Other	None

17		
17	**How many spin-off companies were created / are planned as a direct result of the project?**	**None**
	Indicate the approximate number of additional jobs in these companies:	

18 Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

■	Increase in employment, or	■	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify	❑	

19		
19	**For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:**	*Indicate figure:*
	Difficult to estimate / not possible to quantify	■

I	Media and Communication to the general public

20 As part of the project, were any of the beneficiaries professionals in communication or media relations?

● Yes ○ No

21 As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

● Yes ○ No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

❑	Press Release	■	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
■	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
❑	Brochures /posters / flyers	■	Website for the general public / internet
❑	DVD /Film /Multimedia	■	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	■	English
■	Other language(s)		German

Question F-10: Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)
3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)
3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES
4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)
4.2 Veterinary medicine

5. SOCIAL SCIENCES
5.1 Psychology
5.2 Economics
5.3 Educational sciences (education and training and other allied subjects)
5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES
6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)
6.2 Languages and literature (ancient and modern)
6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group] .

End Notes

[i] http://www.lindorfer.de/
[ii] http://forrest.co.uk/
[iii] http://www.aimc4.com/
[iv] http://www.ecobuild.co.uk/
[v] http://greenbuildexpo.co.uk/
[vi] http://ish.messefrankfurt.com/