New \(\mu\)-CHP network technologies for energy efficient and sustainable districts

Executive Summary:
The overall objective of the FC-DISTRICT project is to optimize and implement an innovative energy production and distribution concept for sustainable and energy efficient refurbished and/or new “energy autonomous” districts exploiting decentralized co-generation coupled with optimized building and district heat storage and distribution network. The concept is based on dynamic heat exchange between the building(s) (fitted with m-CHP systems based on Solid Oxide Fuel Cells – SOFCs, for energy production collaborating with improved thermal storage and insulation building systems), the distribution system (optimized piping and district heating with or without a heat buffer) and the consumer (new business and service models), aiming to achieve energy balance at district level. Advanced insulation materials have been developed and implemented for the improvement of building and pipe thermal response. The energy reduction originates from improved efficiency and cost effective high temperature SOFCs, to act as micro heat and power cogeneration (\(\mu\)-CHP) systems providing demand-flexible electricity and heat to the building and district, coupled with optimised energy and power distribution networks that will optimally control heat storage at building and/or district level. Integration of biomass energy generation will be implemented through a flexible and distributed system of collection and densification of food wastes, demonstrated at small scale in order to assess the full scale upgrading into the gas distribution grid.
The effective management of the produced heat reduced heating/cooling consumption at district level up to 55% (when the district includes buildings of different typology and variable energy profiles) with expected return of investment in 4-5 years. Demonstration has been undertaken at different sites (Spain, Greece and Poland) and in three phases: unit, building, district. The distinct demonstrations act as a best-case model for a heat-optimised district. In this way it will be possible to demonstrate the link between energy consumption at building level and district. Current and optimized situation will be recorded.
The FC-DISTRICT project aimed to prove and demonstrate that:
- The proposed micro-grid/heat network arrangement of dispersed \(\mu\)-CHPs, can lead not only to significant reduction in power transmission loss and heat dissipation loss but also will ensure direct energy savings at both building and district levels.
- SOFC \(\mu\)-CHP systems can lead to significant (up to 55%) reduction in primary energy use at district level when combined with appropriate building thermal storage, materials and district heating technologies (“Intelligent Heat Network”) and that are fully compatible with the integration of renewable energy from wastes.
- Distributed energy production based on SOFC \(\mu\)-CHP systems coupled with improved district heating technologies can offer significant savings in CO2 emissions.
The FC-DISTRICT concept aimed to achieve building energy and power autonomy via demand-flexible balance at district level and will be appropriate for a wide typology of ‘districts’ (determined on a case basis), ranging from a typical housing estate, isolated rural
Project Context and Objectives:
The overall FC-DISTRICT objectives are:

- Develop a high temperature SOFC with versatile fuel processor and optimised peripheries making successful integration with district networks possible. CHP production and efficient fuel use results in reductions in carbon emissions and costs, savings in losses over long transmission and distribution lines. It offsets the use of centrally-generated electricity from the grid and allows local voltage regulation.
- Develop and implement advanced, durable and cost effective insulation materials for improved thermal responses in building and district piping.
- Integrate food waste disposers with anaerobic digesters to produce biogas.
- Implement an "Intelligent Heat Network" equipped with smart control and hybrid wireless network systems.
- Optimise and tailor the characteristics of the energy and power distribution systems to meet the energy and power demand of various building and district typologies.

The FC-DISTRICT project lasts 48 months and is structured in 11 WPs that cover a broad range of activities. The project is organized in a matrix of horizontal and vertical actions comprising three horizontal and eight vertical Work Packages, with strategic and distinct deliverables covering R&D, integration of knowledge and technology; demonstration; innovation and sustainability activities, dissemination - training activities and project management.

Project Results:
The main technical achievements during the entire duration of the project are:

- **Micro-CHP System**: Micro-cogeneration systems (micro-CHP) produce heat and electricity and combine efficient fuel use with potential reductions in carbon emissions and costs. The major benefits of distributed cogeneration systems are that they can reduce energy and power losses associated with long transmission and distribution lines, installation costs, support local voltage regulation, and have the ability to add a small unit instead of a larger one during peak load conditions. FC-District focused on the development of a number of SOFC (Solid Oxide Fuel Cell) based micro-CHP units able to deliver up to 2 kW electric power and 6 – 8 kW thermal power, with an overall efficiency up to 90%. They are demonstrated at two sites – one in Spain (domolab, Ikerlan) and one in Poland (IEI).

  **Major peripheral components of the SOFC including CPOX (Catalytic Partial Oxidation) reformer, Anode off-gas burner, Heat exchangers, DC/AC inverter, and Heat recovering unit have been developed and tested. The new SOFC based micro-CHP system has passed the certification procedure of KIVA-gastec. It nominally provides 1.5 kWe and 2.75 kWe with a 5–7 year return on investment.**

  Technical developments closely follow the current EU SoTA in the field. Patented off-gas burner.

- **New External Thermal Insulation Compound (ETIC) Systems based on Vacuum Insulation Panels (VIP) coupled with dry wall construction and Phase Change Material (PCM)-boards. They have been developed and demonstrated at two demonstration sites in Greece. System developer – Knauf Gips KG leads the development of the new ETICS that has been installed, tested, monitored and modeled by Knauf Gypsopilia ABEE and National Technical University of Athens, at the demo site in Greece. Installation of the developed ETICS in the mock-up in Athens. Monitoring of their performance. Monitoring results are available online: [http://demohouse.hmcs.mech.ntua.gr/demohouse_site/?lang=en](http://demohouse.hmcs.mech.ntua.gr/demohouse_site/?lang=en_).

- **New VIP based hybrid insulated pipe prototypes and production scheme.** FC-District developed a new heat distribution pipeline concept based on recent progress in nano-structured thermal insulation. The development focuses on combining Vacuum Insulation Panels (VIP) and polyurethane (PUR) in a hybrid insulated pipe. For a single pipe configuration this combined insulation has been evaluated. When a constant temperature is applied on the service pipe, the improvement is about 15-20% less supplied power. The production process development is focused on a twin pipe configuration (two service pipes in one casing pipe) with VIP. The flow of polyurethane has been studied to ensure that the complete volume is filled with insulation.

- **Innovative biogas tanks.** It is possible to integrate the production of biogas, through the introduction of upgraded wastes into centralized anaerobic digesters. The gas could be injected into the grid after purification, removal of inerts and sulphur and deodorization of the biogas derived from this renewable resource. The first prototype, developed within the FC-District project, allowed simulation of tank working conditions, of discharge and the thickening control system. The tank is a crucial element of the district waste collection system, and represents the first step for further biogas generation in anaerobic digestion facilities. It is demonstrated in an apartment in Milan, Italy.

- **Wireless Communication System.** A prototype hybrid network has been developed and implemented within FC-District. Data communication requirements have been identified and a ranked communication strategy necessary to achieve the desired performance is deployed. The demonstration site in Poland has been investigated and the most appropriate communication standard has been chosen and successfully installed. The system allows securing control of fuel cell units, heat demand, fuel supply and other devices at the district level.
New models for district heating including supply of heat, networks, buildings and consumer behaviour.

One year demonstration in Poland to validate the energy-autonomous district concept. Installation of the Intelligent heat network and of three m-CHP (sterling) units at the Polish district demo site completed.

Active Dissemination and Training activities.

The overall achievements during M1-M18, in relation to the objectives of the project in the individual WPs are as follows:

WP1: Management
- Continuation and reinforcement of the well-established and effective communication between the partners at the technological/scientific level as well as at a dissemination level.
- Management and review of project tasks for successful achievement of the project goals in terms of concept definition, design, performances, timely delivery and validation.
- Quality assurance (peer review procedure for all deliverables, further use of the EMDESK for files and messages exchange)
- Preparation and submission of D1.3.1 Periodic Activity with Cost Report
- Follow up of finances and second transfer of pre-financing.
- Scheduling and organisation of project meetings.
- Introduction in the consortium of a new partner (SOFC stack manufacturer): SunFire GmbH, Germany
- Revision of DoW to include new partner and update content and timing of some tasks to match the up to date progress.
- Deliverables: 34 deliverables up to M18 (Feb 2012). Modifications: 6 of them have been shifted (within M18). Only 3 pending deliverables: D3.7.1 D3.7.2 D7.2.2 delayed due to Staxera – SunFire issue and the HAZOP meeting (M19 – still within 60 days). 93% submitted on time! No delays encountered. Peer-review process has been established and implemented

The deliverables of WP1 submitted during the current period are: D1.1: Project Management and Quality Guidelines (MOSTOSTAL, M2), D1.2.1: Periodic Progress Report (NTUA.HMCS M6), D1.2.2: Periodic Progress Report (NTUA.HMCS M12) and the current report which is D1.3.1: Periodic Activity Report with Cost Report (MOSTOSTAL, M18).

WP2: System Requirements
- District type definition has been completed. The identification of appropriate “reference buildings” has been finalised. Four reference buildings were selected for the target district:
  1. Office building: a detached three-level building with 1200 m2 total surface.
  2. Single-family houses (SFH): a two storey detached house with 144 m2 total surface.
  3. Small Hotel, integrated in a building block: a five storey building with 30 rooms and 700 m2 total surface.
  4. Multi-storey residential buildings (Multi-family, MFH) integrated in a building block: five storey building with 10 apartment (two apt./floor) and 800 m2 total surface.
Each fictitious district would be a combination of the above four “district components”. Each type of building has different heat and electricity demand profiles. Profiles of single family houses have significant deviation from each other, even with the same building geometry and thermal characteristics.
- Definition of three district type cases:
  - Real case: Compliant with the demonstration site in Poland.
  - Simulation case I: District area with existing district heating network and a mixture of non-refurbished and refurbished houses.
  - Simulation case II: New district area with fuel cells as primary heat source complemented with a backup source. The overall energy reduction should be 60%. Building performance should follow recommendation concerning passive house technique (e.g. space heating should not exceed 15kWh/m2/year).
- Climate chosen: Polish weather conditions (Warsaw)
- Ratio of residential floor area to the commercial floor area: equal to unity.
- System design: Fuel cells, backup heating system and heat storage facility. The storage facility could be arranged in each building or on district level.
- SOFCs will be used for the production of energy for space heating; thus there is no need to calculate the energy demand related to cooling and hot water.
- Rough estimation of total heat energy demand and average heat energy demand presented in D2.1.2.
- In collaboration with WP6, WP7 and WP8, potential scenarios for the integration of the SOFC unit into the district were identified:
  1. BIG (MAIN) DISTRICT: FC UNITS ASSOCIATED TO REFERENCE BUILDINGS: Hotels (single user), Offices (single user), Multi-family houses (multi owners), Group of single family houses (multi owners)
  2. SMALL (SECONDARY) DISTRICT: FC UNITS ASSOCIATED TO SINGLE FAMILY HOUSES (Apartment or Detached)
3. STAND ALONE HOUSES WITH ONE FC UNIT (demo sites Spain and Greece)

- Economic analysis for the above scenarios was also made.

Eight deliverables have been completed during M1-M18: D2.1.1: District typology document (MOSTOSTAL, M6), D2.1.2: Definition of at least three type cases, out of which one is compliant with the Polish demonstration site and technical requirements for heat distribution systems (CUT, M6), D2.2: Unit specification (TU-BAF, M6), D2.3.1: Coupling of μ-CHP systems with energy and power storage requirements for energy efficient buildings and districts (NTUA-HMCS M9), D2.4: Control and monitoring techniques and telecommunication requirements (RINICOM, M9), D2.5.: Description and working model of district demonstration site (IEn, M12), D2.6: State-of-the-art inventory for energy storage at district level (ACCIONA, M14) and D2.7: Scenarios for energy autonomous districts (in terms of thermal and electrical needs), version 1 (VITO, M18). A second version of this deliverable will be submitted in M24.

The duration of WP2 has been extended up to M24 to finalize the energy autonomous district scenarios to include the work of all partners.

WP3: Building and district tailoring of SOFC

- In collaboration with WP2 the system architecture and the specifications for the overall unit as well as for major component sub-groups were defined.
- Major components such as the CPOX reformer and the off-gas burner have been successfully developed, manufactured and experimentally characterized. Design and manufacturing of final prototype components is completed.
- The German company Staxera was evaluated as the most appealing option for SOFC stack provider. Staxera has been renamed to sunfire GmbH and has accepted to become a member of the Consortium instead of just a stack provider.
- The activities concerning the HAZOP and certification of the micro-CHP units are on-going.
- The evaluation of use of alternative fuels and especially biogas, as feedstock for SOFC systems is continuing.

WP3 has contributed with seven deliverables completed in the period of M1 to M18: D3.1.3 (Equipment list and Equipment summary sheets; Reformer catalyst selection; Technical layout and evaluation report of CPOX reformer, ECN, M12), D3.1.4.1: Report on development of the basic components (TU-BAF, M16), D3.1.5: Report on fabrication technologies for mass production of single components and complete system (FAGOR, M16), D3.2: Report on material evaluation and FEM analysis of complete components (EBZ, M18), D3.6.1: Specifications on sensors and actuators for unit/district integration (FAGOR, M18), D3.7.1: 3D Layout P&ID review and Process flow diagram (EBZ, M18), D3.7.2: HAZOP evaluation (ECN, M19).

Small delays – of the order of one month – may occur in the submission of the final version of the T3.7 deliverables due to the finalization of the entrance of SunFire in the consortium (EC official approval pending to allow the company's participation in the work of the project).

WP4: Biogas production in district waste disposers

- Business scheme development has been finished (D4.1.1). Tank Network Management: At district level the tanks are managed by a superimposed intelligence which optimizes the waste collection and the maintenance operations.
- Definition of specifications and technical targets has been completed. Tank functional requirements, design and control system have been completed (D4.2 D4.3 D4.4).
- A tank prototype with filtering elements, discharge system and actuators has been constructed. Filtering and settling solutions for tank have been defined (D4.3). A monitoring system for the tank, based on LED emitting at specific wavelength and software for data elaboration are nearly completed (D4.4)
- Two technical guides for “Filtering and Settling Tank” and “Control and Monitoring System” are provided in D4.3 and D4.4.
- In the frame of the collaboration between WP4 and WP9, WP4 prepares a document on the requirements and plan for demonstration in a real district (in WP9) of a system constituted by food waste disposers, filtering and settling tanks and A.D. for biogas production (to be completed in March 2012).

Deliverables completed in the period of M1 to M18: D4.1.1 (Business model – 1, DAPP, M8), D4.1.2: Business Model – 2 (DAPP, M16), D4.2 (Tank functional requirements, DAPP, M9), D4.3: Tank Design, Characterization, and technical guide (ECOFAST, M16) and D4.4: Control and monitoring system Design, Characterization, and technical guide (ECOFAST, M18).

WP5: Thermal storage systems for building and district

- Development of new ETICS focuses on: new mortar without mesh (in 6-in-1 concept), new VIP and aerogel containing panels for external building insulation. VIP and six-in-1 development nearly (80%) completed.
- The new ETICS will be installed and monitored at the mock-up house in Athens which has been repaired and equipped with sensors for the monitoring procedure (collaboration with WP8)
- Assessment of internal versus external thermal insulation for South European conditions (in Greece) has been completed.
• Detailed simulation of thermal performance of the Greek demo house including storage (PCMs) and a variety of thermal energy production systems (e.g. heat pump, SOFC) continues. Simulation of Demo house (TRNSYS, MATLAB model for PCM simulation) and the mock up (TRNSYS, CFD-CFX code) will be completed in M30. The PCM effect in buildings is additionally simulated using the Heat and Mass Transfer Tools (CUT).
• Extension of storage strategies for district – Development of approach for modelling thermal storage for district and of heat demand coverage. Calculation of primary energy savings of installing a “swarm” of μ-CHP SOFC units in a district.
• Development of control scenarios for the operation of the SOFC at the Greek demo house has started. Also, the study of insulation materials for the Polish demo site is progressing.
No deliverables were planned for the period of M1 to M18.

WP6: Efficient heat distribution network and micro-grid
• Inventory of insulation materials and requirements for resource efficient installation methods have been established. Technical requirements for heat distribution network have been set.
• Literature and patent review analysis on currently applied solutions for insulation has been completed. Aerogels in a blanket (as a matrix), vacuum insulated solutions, phase change materials (PCM), mixture of aerogels and polyurethane, and mixtures of other nanoparticles and polyurethane have been investigated.
• A hybrid insulation of vacuum insulated panels (VIP) and polyurethane has been chosen for the development of the new pipes. Prototypes of pipes hybrid insulation were tested in laboratory and the results showed that the performance of the pipe could be 20 to 40 % (depending on the thickness of the VIP) better than the polyurethane insulated pipes.
• Two pipes were manufactured manually and installed in a distribution system (Varberg). The configuration is a twin pipe assembly with two service pipes in one casing.
• The development of the optimization code continues for the simulation of district type cases. The code will incorporate central storage for both for electricity and heat. The connection to external energy sources is included in the model. Modeling of heat losses will be included (collaboration with WP5).
Submitted deliverables for the period of M1 to M18: D6.1.1: Technical requirements of pipeline components (SP, M18) and D6.1.2: Choice of material for further pipe development (CUT, M18)

WP7: Dynamic control and wireless communication
• Technical requirements for integrated communication system and local micro-grid control have been accomplished on the basis of a successfully completed questioner (D2.4).
• New communication instrumentation/equipment (routers) has been developed by RINICOM. The new district's management strategies have been defined.
• The monitoring and communication scheme have been prepared. Monitoring and communications hardware have been selected.
• A presentation of the “Polish District” has been prepared.
Submitted deliverables for the period of M1 to M18: D7.1.1: Technical specification on the dedicated state of the art communication system for monitoring and control (RINICOM, M9), D7.1.2: Dynamic mesh network management system (RINICOM, M18), D7.2.1: Technical requirements for local micro-generator control and fault protection functionalities (IKERLAN, M9), D7.2.2: Report on local micro-generator control and fault protection functionalities (IKERLAN, M18)

WP8: System integration – Proof of concept (started earlier in M13)
• At the mock up house in Athens, preparatory works are completed (high performance door and windows installed). The monitoring software is completed (temperatures, heat fluxes, humidity of external /internal walls recorded). The installation of heat pump, sensors, heat and electricity meters at the Greek demo house has been completed; first data acquisition-measurements without heating /cooling achieved. The development of a web site for viewing monitoring results from demonstration house in Amphilochia and the mock up is nearly completed. Discussions on technical details for production and installation of VIP at the mock up have started. Installation is planned for summer 2012.
• At the Polish demo site, a new building will be fitted with ETICs to be developed by Knauf. The building will be used to demonstrate jointly the ETICs and the SOFC unit and will be linked to the FC-DISTRICT Polish site district heating network. Mostostal, IEn and Knauf Poland work together with an architect to implement necessary changes in the construction project. Acciona simulates the building in order to get the best U-value for the walls.
• Testing of μ-CHP components and control systems/Small scale demonstration in Spain: Components for the calibration and sensors for the laboratory test have been bought.
• Certification requirements/licenses for demo units (μ-SOFC, piping systems, building systems etc): The standards and guidelines for the CE certification of the system have been identified. Kiwa-Gastec has been chosen as the notified body. HAZOP analysis is in
• The simulation of the feasibility of the integration of the SOFC components in the framework of heat transfer of the system enclosure is progressing. Three components (Off-gas burner, Heat-exchanger and CPOx reformer) are already being simulated with insulation.

WP10: Decision support – Certification Procedures - Business models – Exploitation road map. Started in M12 instead of M7. Work within WP10 started six months later than originally planned, in order to utilize important information from other WPs, regarding the layout and components of the SOFC unit (WP3 - D3.1.3) the determination of the district types and loads (WP2) and the alternative integration scenarios (T7.3).

• Work in progress towards fulfillment of requirements regarding the initial methodological steps of the LCA within the FC-District framework.
• Payback calculation for heating and hot water in individual houses with the use of the SOFC performed.

WP11: Awareness and Dissemination

• The public and internal websites have been regularly updated – ways for increasing public site's visibility have been explored. The public web site has been updated with partner news and progress relevant to the project.
• EMDESK has been established as the main communication tool between the project partners.
• Liaison to other EU projects (e-hub, COST, Einstein), national and EU Technology Platforms has been realized.
• Project leaflets published in English and Portuguese. Project poster prepared and circulated.
• 18 project presentations in public events.
• 4 publications in international journals and 16 International Conference presentations.
• Project presentation in the EeB leaflet, June 2011 - “EeB PPP Project Review 2011”.
• Exhibition of FC-DISTRICT prototype at Hannover-Messe. Seminar for Greek engineers on “Energy saving potentials”.

The overall achievements during M19-M36, in relation to the objectives of the project in the individual WPs are as follows:

WP1: Management

• Continuation of effective communication between the partners at the technological/scientific level as well as at a dissemination level.
• Management and review of project tasks for successful achievement of the project goals in terms of concept definition, design, performances, timely delivery and validation.
• Scheduling and organisation of project meetings.
• 2nd Review Meeting (RV2)
• GA postal Vote on adoption of the contingency plan
• Implementation of contingency plan
• 3rd Review Meeting (RV3)
• Special Partnership Agreement
• Bankruptcy of OVM ICCPET
• Resignation of FAGOR
• Preparation and submission of D1.2.3: Progress Report-3 (M24)
• Preparation and submission of D1.3.2: Periodic Activity with Cost Report (M30)
• Preparation and submission of D1.2.4 Periodic Progress Report - 4 (M36)
• WP1 is 75% completed. Continues until end of project
• Achievements: Robust management – active involvement of all partners – early identification of risks – effective preparation of contingency plan – collaborative solution of problems

IMPLEMENTATION OF CONTINGENCY PLAN UNDERTAKEN BY PROJECT COORDINATOR

Steps undertaken:
• March 2013: Vote of consortium to accept contingency plan (MOSTOSTAL)
• April 2013: Revised time plan for WP3 activities (TU-BAF)
• April 2013: Market review for technology substitutes (IC/Sterling engines for m-CHP) (IKERLAN, TU-BAF, NTUA)
• May-June 2013: Assessment of compatibility of options with FC-DISTRICT plan/required modifications (IKERLAN, TU-BAF, NTUA)
• June 2013: Communication with PO – approval for charging costs as consumables – no possibility for leasing (MOSTOSTAL)
• May-July 2013: Negotiation with technology providers (Vaillant and ehe)/1st option failed (MOSTOSTAL)
May – August 2013: Intensification of work at Polish demo site (MOSTOSTAL, IEn and partners)

July 2013: Special Partnership Agreement for budget shift and additional tasks – modified after RV3 to include suggestions of PTA (inclusion of IPR, vote of consortium to accept contingency plan) (MOSTOSTAL, NTUA)

July – Aug. 2013: Ordering of 3 ehe units and accessories /delivered August 2013 (MOSTOSTAL)

During M19-M36, substantial technical achievements have been realized in very short time, considering that in the contingency plan the Project has to deal with new technological units not yet fully present in the European market. Communication with “special project teams” of the technology developers has been necessary.

The success of the implementation of the contingency plan is the result of active, substantial and continuous project coordination: The Project coordinator (MOSTOSTAL) with the support of the scientific coordinator (NTUA) have continuously organized and motivated the work of the involved partners in relation to the contingency plan (telephone calls, e-mails, technical meetings, communication with technology providers, provision and assessment of solutions, balancing interests among competitive partners etc).

Flexibility in the participation and collaboration of all partners involved in the implementation of the contingency plan: partners agreed to perform additional work – not initially planned – without erasing administrative or financial hurdles.

Continuous support from PO and PTA substantially facilitated decision making and helped in achieving flexible and on-time solutions. Positive attitude of PO and PTA motivated partners to continue and ensured that the necessary financial shift and partner role changes will be accepted by the EC.

NEED FOR CONTRACT AMENDMENT DUE TO REMOVAL OF TWO PARTNERS

The following two partners have requested to leave the Consortium.

1. Institute Oskar von Miller SC OVM ICCPET S.A. due to liquidation. The partner has performed most his tasks. The preparation of one remaining deliverable (D4.7) will be undertaken by D’ Appolonia (with corresponding budget shift). The partner did not submit Form C for M19-M36 because the liquidation took place on 23.05.2013.

2. Fagor ElectrodomesticosS.Coop.Ltda. due to the adverse financial situation in Spain. The partner has performed most his tasks. The remaining tasks will be undertaken by Ikerlan S. Coop and MOSTOSTAL (with corresponding budget shift).

The requests have been submitted by the two partners in M36 and the request for a Contact Amendment to the EC, will be implemented after the submission of the current report covering M19-M36.

WP2: System Requirements

- Energy autonomous district scenarios have been completed.
- Updated description of Polish demo site.
- Implementation of the results and findings of WP2 into other project’s WPs.
- WP2 has been completed (M24).
- Achievements: New knowledge on district energy management – How to combine buildings to create “energy autonomous districts”/restrictions/technical challenges.
- Achievements: Practical implementation of new knowledge in Polish demo site

WP3: Building and district tailoring of SOFC

- 3D-layout and the P&ID were updated – Completion of the design, manufacturing and testing of m-CHP (SOFC) system components according to the new design.
- Completion of mechanical and electrical integration testing.
- The tests with the 1st version of SOFC based micro-CHP unit were completed in April 2013
- During the fore-coming period any remaining open technical issue related to performance, to the inverter and to some of the minor components e.g. valves, are about to be solved.
- The operating parameters for the start-up of the unit were identified and the unit was put into operation at the beginning of September
- Inverter development has been completed.
- Manufacturing of 30 cell sub-stacks of Mk200 type (ESC2 cells) for integration in the prototype units
- Adaptation of the Integrated Stack Module (ISM)
- The evaluation of use of alternative fuels and especially biogas, as feedstock for SOFC systems has been completed.
- HAZOP evaluation completed
- Certification of the micro-CHP units expected to be completed in December 2013 (M40).
- TUBAF has delivered 4 off-gas burners and 4 CPOX reformers which are required for the construction of the next 4 micro-CHP units.
- Manufacturing of the second unit for Greece is planned for M40
- Delay of around 12 months is expected concerning the delivery of the first system.
- SOFC trigeneration system operation possible, having payback times of around 10-12 years.
WP3 duration finished, an extension will be required in order to complete the building of the first prototype fuel cell unit.

WP3 is ca. 85% (actually) competed.

Achievements: Patented off-gas burner – New m-CHP configuration – Unit currently under certification - Project technical developments follow closely the current EU SoTA in the field.

Achievements: Very active WP that yielded several publications/event presentations

WP4: Biogas production in district waste disposers

Further development of tank prototype with filtering elements, discharge system and actuators.

Completion of monitoring system for the tank, based on LED emitting at specific wavelength and software for data elaboration.

Analysis of biogas/landfill gas completed.

Performance evaluation will continue until M36.

WP4 is ca. 95% competed – small delay on the preparation of D4.7

Achievements: Significant step forward towards commercialization of tank prototype with new control system. Market potentials established.

Achievements: link to the demonstrator – residential building in Milan – one year monitoring until the end of the project.

WP5: Thermal storage systems for building and district

Completion of the development of new ETICS: new mortar without mesh (in 6-in-1 concept), new VIP containing panels for external building insulation. VIP and six-in-1 development completed.

The new ETICS have been installed at the mock-up house in Athens.

Study of insulation materials and their installation at the Polish demo site completed.

Detailed simulation of thermal performance of the Greek demo house including storage (PCMs) (TRNSYS, MATLAB model for PCM simulation) and a variety of thermal energy production systems (e.g. heat pump) completed.

Storage strategies - modeling of thermal storage for district and of heat demand coverage for district completed. Calculation of primary energy savings of installing a “swarm” of m-CHP SOFC units in a district completed. Software development.

Development of control scenarios for the operation of the SOFC at the Greek demo house completed. The model predicts approximately 52% contribution from the solar system and 40% from the SOFC. The heat pump, which is kept as a backup heat source, contributes the remaining 8% of the total heat demand, and is also used for cooling during summer.

Set of recommendations for the design of heating and air conditioning of buildings connected to a district heating and cooling system.

WP5 completed (M30).

Achievements: New VIP based ETICS for lightweight construction. New software (DEPOSIT) for m-CHP driven energy efficient districts.

WP6: Efficient heat distribution network and micro-grid

Testing of hybrid insulated pipe prototypes with hybrid insulation (vacuum insulated panels (VIP) and polyurethane) completed.

Propositions for production process: Production of the hydride pipe in an existing line or building a new line for a larger production volume.

Concept validation of hybrid pipes insulated with aerogel blankets and polyurethane. A new blanket has been evaluated thermally by use of “Guarded hot plate”. The cell gases of the polyurethane close to the blankets have been evaluated.

Thermo-hydraulic modelling of intelligent heat network configuration with optimization algorithms. The development of the optimization code continues for the simulation of district type cases. The code will incorporate central storage for both for electricity and heat. The connection to external energy sources is included in the model. Modeling of heat losses will be included (collaboration with WP5).

Simulations of districts with SOFC and electrical storage completed. Parameters investigated include normalized heat and electrical storage capacity, price of energy bought, amount energy bought for the electrical grid and energy consumed.

Development of a self-learning and locally simple control strategy for district heating systems.

Delays in the development of the interface between the µ-CHP units and the heat distribution network: Heat transfer characteristics of internal heat exchanger will be validated during operation of the 1st µ-CHP system

Extension of WP6 until M42 (originally planned to finish in M34).

WP6 ca. 95% overall actual completion - continuation of parts of WP6 up to M42.


WP7: Dynamic control and wireless communication

Development of management strategies for the new district.

Monitoring and communications hardware have been selected.
• Mesh hybrid network configured for dynamic control and wireless communication.
• Conceptual control management for demonstration sites (x3) completed. Integration and testing of the control system completed.
• WP7 completed (M30)
• Achievements: New wireless communication solutions. New control strategies (reactive power injection) for SOFCs at district level. New control system.

WP8: System integration – Proof of concept (started earlier in M13)
• Installation of VIP sandwich panels at the mock-up house in Athens, Greece.
• At the Polish demo site, the new building fitted with ETICs has been completed by Knauf Poland, Mostostal and IeN.
• Site with monitoring results: http://demohouse.hmcs.mech.ntua.gr/demohouse_site
• Testing of μ-CHP components and control systems/small scale demonstration in Spain is on-going.
• HAZOP analysis is completed.
• The simulation of the feasibility of the integration of the SOFC components in the framework of heat transfer of the system enclosure is completed.
• A new task added as consequence of contingency plan implementation, and new deliverable D8.7.
• WP8 ca. 90% completed
• Achievements: Preparations of sites for m-CHP system installation completed.
• Achievements: Software developed by ACCIONA and NTUA.HMCS for district simulation can be added to exploitable results

WP9: Demonstration in industrial settings
• Monitoring of the mock up: Good performance of VIP ETICs
• Monitoring of energy systems and PCM-storage at the demo house in Amhilochia, Greece.
• Construction works performed at real scale demo site in Poland. The demo installation will be fully operating before space heating of buildings is needed.
• Establishment of dedicated sites for monitoring results:
  District demo site in Poland: www.ieninnovacje.pl
  Demo house and mock-up in Greece: http://demohouse.hmcs.mech.ntua.gr
• WP9 ca. 55% completed (M36)
• Achievements: First positive validation results for VIP-ETICS performance.

• Exploitation Strategy Seminar completed.
• Market study for m-CHP system completed.
• Initial methodological steps of the LCA within the FC-District framework completed.
• Payback calculation for heating and hot water in individual houses with the use of the SOFC performed.
• WP10 ca. 70% completed (M36)
• Achievements: Exploitable results identified. Business models developed.

WP11: Awareness and Dissemination
• Continuation and enhancement of use of EMDESK as main communication tool between the project partners.
• Overall: 23 project presentations in public events
• FC-District leaflet in two European languages (English and Portuguese)
• Media dissemination: Video presenting waste collection concept with use of the tanks
• 30 contributions to national and international conferences
• 9 publications in international journals
• Preparation of an added value section for each dissemination activity achieved within the project
• WP10 ca. 75% completed (M36).

The main technical actions undertaken during the reporting period (M37-M48) of the project were:
• WP3: District system operation / SOFC unit / Delays: The FC-DISTRICT system operation with three EHE sterling m-CHP units has been demonstrated.
• The components of the SOFC based m-CHP units have been demonstrated during the RV4 meeting in Warsaw (M43, March 2014) and the 1st assembled SOFC unit has been displayed with open casing.
• EBZ finished the assembly of the 2nd unit, after performing all necessary tests. The unit has been delivered to IKERLAN without undergoing a commissioning phase at EBZ. In parallel, the issues related to the high EMC emissions were tried to be resolved. During the test phase at Domolab, the CPOX reformer was damaged rather fast during the start-up of the unit by excessive build-up of solid carbon within the component. As it was not possible to continue the tests without replacing the CPOX catalyst and checking the
condition of the SOFC stack, the tests at IKERLAN were stopped and the unit was shipped back to EBZ at the end of August (M47). New catalysts were purchased by TUBAF and were sent to EBZ. The unit has already been repaired and has been commissioned before its shipment to the Polish demo site.

The 3rd SOFC unit was completed and successfully operated at EBZ, for approximately 100 h (July-August 2014). The thermal load could be varied from 2.5 kW to 4 kW (based on methane LHV) without any problems in the stability of the process, while a maximum electrical output of 800 Watt was achieved for full load operation and the corresponding electrical efficiency was 21%. Stack efficiency was 25%, while the thermal efficiency was found to be 22%. After the end of the tests in M48, the unit will be delivered at the Polish demo site.

TUBAF and EBZ have delivered a CPOX and an off-gas burner to NTUA.HMCS according to the contingency plan. These components were originally planned to be used for the manufacturing of the second SOF unit for Greece. The components will be used for laboratory testing.

The agreed extended monitoring period will consider IEn’s district in Warsaw, Poland, with SOFC operation.

- WP8 and WP9: Finalization of works at the demonstration sites / final requirements / preliminary operational results. Three SOFC based units have been manufactured and will be installed at the industrial demo site in Poland after M48.
- WP10: ESS: Refinement of exploitable results and further awareness to the public. Development of a solid Plan for Use and Exploitation of Knowledge generated within the project. Finalization of LCA and MCA activities.
- WP11: Active dissemination – More intense training activities. Preparation of the project booklet.

Potential Impact:
Overall Impact:
- Number of demonstrators and countries where they are hosted: Four demonstrators in Spain (building), Italy (apartment), Greece (two buildings) and Poland (small district) are currently operable.
Reference to a virtual residential large district for realistic energy assessment: 1km2 of district/approx. 2800 single family houses with one micro-CHP each (simulated).
- Reduction in Energy use (%) and CO2 savings (Mt per year): 1. Approx. 55% reduction in primary energy consumption for residential districts. 2. Approx. 3.8 kt of CO2-eq savings per year (referring to 1 km2 of residential district).
- Estimate of return on investment (%): micro-CHP: 5-7 years, Hybrid insulation pipes: 10 years, VIP ETICS: 10 years, Biogas tanks: 10 years
- Key actions on training: 20 project presentations in public events; 8 journal publications and 23 presentations in international conferences; Training of Greek energy auditors on project construction concepts. Training events in Spain and Poland. Overall, more than 1000 people have been trained via the Project's training activities. More than 5000 people reached by dissemination activities.

List of Websites:
http://www.fc-district.eu/

Project coordinator:
Mr Juliusz Zach
Mostostal Warszawa S.A.
Konstruktorska 11A, 02-673 Warsaw, Poland
www.mostostal.waw.pl
e-mail: j.zach@mostostal.waw.pl

Scientific coordinator:
Prof. Maria Founti
National Technical University of Athens, Greece
www.hmcs.mech.ntua.gr
e-mail: mfou@central.ntua.gr

Related documents

 final1-fc-district-booklet-net.pdf