MIRACLE

Micro-Request-Based Aggregation, Forecasting and Scheduling of Energy Demand, Supply and Distribution

Specific Targeted Research Project: 248195

D6.1 Report on the current systems

Work package 6: Trial Test Integration and Validation

Leading partner: INEA

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1 Summary

Integration, testing and validation of the developed Miracle methodologies and algorithms will be performed in two testing environments. In one, an important part will be simulation based data analyses of the MeRegio project; and in the other, the running of the test scenarios on in the CRES test bed.

The MeRegio project plans to set up the pilot region with 1,000 consumers, with the goal to minimize the CO_2 emissions at energy supply. A side result of the project will be also substantial amount of the measured energy consumption data, which shall be used as an input for the testing and validation of the Miracle project.

The CRES test bed provides the necessary facilities and resources like RES, measurement equipment and corresponding infrastructure to implement and test the Miracle features in a controlled environment.

Both in the development as well as in the testing phase of the project, the approaches, solutions and experiences of other similar projects can be of benefit. In its second part, the report briefly describes the projects in the same general field as the Miracle project, and which are now in the developing or concluding phases and which – to the extent that the concepts and solutions are already formulated and available for interested parties outside the project partners – could be used as references for state-of-the-art in the neighboring and cross-section fields with Miracle. The projects identified, shortly presented and their intersection with Miracle discussed, are: FENIX, EU DEEP, AEOLUS, MORE MICROGRIDS, ADDRESS, EDISON, DLC-VIT4IP and Smart House/Smart Grid.

2 Description of current systems in existence

2.1 MeRegio project

Description of the project MeRegio [MEREGIO] consists of comprehensive description of the project background, purpose, goals, subject matter and project specifics.

2.1.1 "E-Energy: ICT-based energy system of the future"

E-Energy is a priority support and funding program of the Federal Ministry of Economics and Technology (BMWi) as part of the strategic technology policy of the German Federal Government. The primary goal of E-Energy is to create E-Energy model regions that demonstrate how the potential for optimization presented by information and communication technologies (ICT) can best be tapped to achieve greater efficiency, supply security, and environmental compatibility (vertices of energy and climate policy) in power supply, and how, in turn, new jobs and markets can be developed. The particularly innovative approach of this program is that integrative ICT system concepts optimizing the efficiency, supply security, and environmental compatibility of the entire electricity system along the supply chain, are developed and tested in real-time in regional E-Energy model projects. More information is available on www.e-energy.de.

2.1.2 MeRegio - Minimum emission regions

Minimum emission regions are areas possessing energy supply systems that are optimized with respect to their greenhouse gas emission. In particular, electric and thermal energy should be produced, transported, and consumed efficiently using low-emission power plants as well as Smart Grid innovative functions and components.

2.1.3 MeRegio project overview

In 2007 the European Union set up their "20/20/20" energy target: Until the year 2020 a 20% reduction of CO_2 emissions based on 1990 levels, a 20% higher efficiency in energy consumption, and 20% of primary energies should be achieved with respect to renewable energies. In this context, the project "MeRegio – Minimum Emission Region" was set up in the course of the "E-Energy Program" with the objective to develop regions with power supply systems that are optimized with respect to their greenhouse gas emissions. The project's approach is mainly based on three components, namely:

- E-Energy marketplaces, which bring together all energy market roles (e.g. utilities, owners of distributed generation, end customers, and intermediaries) for an efficient allocation of energy and system services;
- an innovative technical energy infrastructure (smart grid), which provides the foundation for future proliferation of distributed generation and the development of pervasive demand side management;
- and a powerful information and communication infrastructure that links the physical infrastructure to the marketplaces, which allows to operate the infrastructure according to the specific market situation at hand.

The project focuses on developing technical and economic concepts, which implement the three components and puts them to work in a "real" pilot region with 1.000 participants in the areas of Göppingen and Freiamt (Baden Württemberg, Germany). Furthermore, the project plans to develop a minimum emission certificate for the regions using new specifications and standards based on the experiences gathered in the field test. At the end of the project this certificate is planned to be available for all regions which actively reduce their greenhouse gas emissions.

The interdisciplinary project team combines the expertise of five chairs of the Karlsruhe Institute of Technology (KIT) and several considerable industrial partners: EnBW (having the project lead), ABB, IBM, SAP, and the system plan. The industrial partners focus on the business context applicable to the field trials and the implementation of new Smart Grid and IT technologies as well as standards and standardization (like dynamic tariffs, the trading marketplace or new applications in the network control system). The KIT, however, is mainly involved in the analysis, simulation, and development of concepts for each area. The concept phase (resp. the official E-Energy start date) started in October 2008. The project announced the official "real" pilot start (Phase 1) by the beginning of November 2009; corresponding private customers are at present equipped with displays showing a fully dynamic tariff. A schematic drawing of the MeRegio project is shown in Figure 1.

2.1.4 Project criteria - 6 critical elements

MeRegio's Smart Grid Project – as one of the six E-Energy model projects – aligns with the six critical elements that EPRI has identified as key criteria to achieve the goals of its five-year Smart Grid initiative [PNM]. They are: Integration of multiple distributed resource types, application of critical integration technologies and standards, incorporation of dynamic rates or other approached to link wholesale conditions to customers, integration into system planning and operations, compatibility with initiative goals and approach, and leverage of additional funding sources: Some of them, deemed relevant to MeRegio, are fuether discussed in the following Section 2.1.5.

2.1.5 Integration of multiple distributed resource types

The project integrates conventional power plants, distributed combined heat and power plants (CHP), distributed energy storage systems, as well as renewable energy sources like wind turbines and photovoltaic systems mostly at customer level. In order to integrate these devices and to provide various system services, such as idle load or balancing power, innovative control strategies will be developed and implemented. These strategies will be based on the concepts of liberalized energy markets but will include direct interaction with the network control center to maintain or even increase the grid reliability. At the customer level, demand response will be achieved via various regional energy marketplaces for the allocation of energy and ancillary services resulting in dynamic rates, control signals for home appliances, and an overall power management. An awareness of the need for energy-efficient acting will be created in both the population and the (local) politics and economy. Industrial and public (B2B) customers will be consulted specialized on energy efficiency topics and measures in order to boost their efficiency and awareness for saving valuable energy and reducing CO_2 emissions.

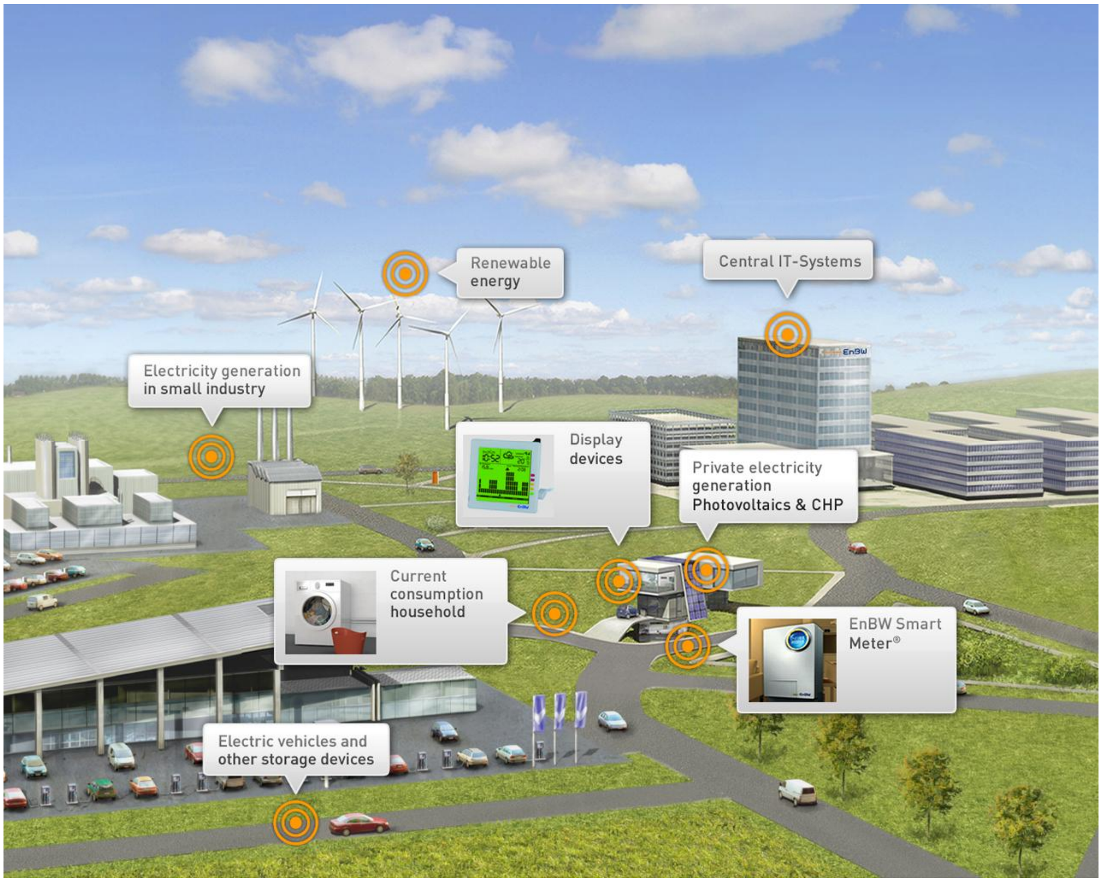

Figure 1: Schematic drawing of the MeRegio project (Chapter 2.1)

2.1.6 Incorporation of dynamic rates or other approaches to link wholesale conditions to customers

In the project MeRegio the efficient coordination of energy supply and demand will be developed and tested using 1.000 existing EnBW B2C and B2B customers. Therefore, various marketplaces will be implemented in order to trade energy products and system services. These marketplaces employ different mechanisms to match supply and demand, for example dynamic tariffs that provide an incentive to shift loads, or auctioning mechanisms that can help establish new business models, such as aggregators who bundle the Distributed Energy Resources (DERs) and resell capacities. At the customer level, demand response will be achieved by dynamic tariffs and control signals for home appliances. On the one hand, the dynamic tariffs will be tested according to their benefits along the complete energy value chain (cost-based view). On the other hand, the tariffs will be adjusted to the end-customer's needs (market-based view). In order to understand customer needs, both B2C (household) and B2B (industry and public sector) customers are in focus. For understanding the needs of industrial and public customers, there are consulting and measuring processes, which help the customers to optimize their approach, boost energy efficiency and also save money with their participation on the market. Parallel to the development of the tariffs, control signals ("efficiency and priority signals") are tested, which enable utilities to automatically shift loads adjusting the energy consumption and generation in private households.

Integration into system planning and operations
Within the project, simulation components will be developed and applied to analyze the different design features of the MeRegio concepts. There will be simulations that are directly coupled to the pilot region (online simulations) and simulations that do not influence the field test participants (offline simulations). These simulations comprise different market mechanisms, network management concepts and business models as well as tests that cannot be implemented in a real environment, such as power outages or extreme weather events. Long-term effects of a decentralization on the development of the power plant mix will be investigated within an energy system model. Additionally, short-time aspects and their influence on the generation mix will be considered. Power grid simulation tools will be used to analyze the influence of new network control strategies and to identify how additional decentralized capacities can be linked at a grid node.

Application of critical integration technologies and standards
Existing and emerging technologies for DER integration will be applied including a broad range of DER types, communication platforms for smart metering (at B2B and B2C level), and distribution automation. The MeRegio consortium is heavily engaged in a number of standardization boards in the area of smart metering, smart grids, and the adaptation of the legal framework.

Compatibility with initiative goals and approach
An integral part of this project is to create a certificate for minimum emission regions. Additionally, a catalog of options is designed to improve the energy efficiency of regions and to increase the number of DERs. This certificate will create awareness of the need for energy-efficient acting. In addition, the certification will enable the comparability of regions.

Leverage of additional funding sources
This project will leverage the extensive existing energy-infrastructure and experience of the industrial partners EnBW, ABB, IBM, SAP, and the system plan and the competence of the Karlsruhe Institute of Technology, which is an internationally leading research center on energy systems and ICT. The project is co-funded to a significant extent by the Federal Ministry of Economics and Technology (BMWi), whereas all partners contribute additional resources to the project. Furthermore, most project partners are simultaneously involved in complementary projects (especially projects with focus on e-mobility) funded by public sources.

2.2 Description of the CRES test bed and its capabilities

This document provides a brief description of the two tests sites, located at CRES [MICROGRIDS], which are going to be used as test fields in the frame of WP6. The first one is the experimental micro grid which due to its flexibility and automation provides the possibility for investigation of a large number of applications. During the experiments of MIRACLE, the system will be used as a residential consumers' simulator. In addition to this, a part of the experiments are planned to be performed in the building of PVs and DER systems department, which is the second test site. Main scope of this selection is the implementation of the proposed technology in a real field. In the following paragraphs, the main characteristics of the two sites are given.

2.2.1 Test sites description and capabilities

This part of the document provides information about the configuration, characteristics and the capabilities of the two test sites. Special attention is paid to the experimental micro grid because this is the site where the main part of the experiments will be performed.

2.2.2 Test Site 1: Experimental microgrid

The Experimental Microgrid of the CRES laboratory has been developed in the framework of EU projects and its purpose is two-fold, since it can be used in order to study the performance of stand-alone or interconnected hybrid systems and micro grids, but also as a simulator of autonomous mini-grids, like the power systems of islands. For this scope, the system is equipped with a number of devices which offer lots of capabilities for various cases of study. The most important advantages of the system are the following:

- It integrates a number of devices which cover a wide range of study cases (stand-alone or interconnected, single or three phase operation).
- It utilizes many innovative systems with plenty of abilities towards the smart grids context.
- The power level of the micro grid is high enough to give realistic experimental results (especially when micro grids or residential consumers are considered).
- It provides easy access to the operation of all of its components through a user-friendly graphical environment locally and through remote computers.
- It provides a wide range of data measurements which cover a large number of applications.

Regarding its configuration, we distinguish three layers, which are in interaction: a) the power components layer which includes all generators, consumers and the electrical installation parts of the micro grid (cables, relays etc.), b) communication and control layer consisting of data acquisition and control units, and c) the interface console used for the supervision and control of the system.

2.2.2.1 Power components layer

Starting from the power components layer, each of its parts is briefly described in the following paragraphs.

Photovoltaic generators: The system comprises two independent PV arrays (PV1 at 1.1 and PV2 at 4.4 kWp capacities). Both arrays utilize multi-crystalline silicon modules. The basic difference between these two generators is that PV1 is fixed at a tilt angle of 45°

and oriented to South while PV2 has an automated single-axis tracking system which gives the ability to change the azimuth of the panel so as to obtain higher production.

Photovoltaic inverters: Each of the above PV generators is interconnected with a three phase power line through PV inverters. More analytically, PV1 is interconnected through a single phase inverter of 1,1kW nominal power, while PV2 is currently interconnected through a 2.5 kW single-phase inverter. These inverters have capabilities of commercial inverters like Maximum Power Point Tracking, Anti-Islanding Protection and Power Factor Correction.

Battery storage: The system is equipped with two separate battery banks for the storage of the produced electricity. These systems have the following features:

- One bank consists of two parallel strings. Each string consists of 48 lead-acid (FLA) battery cells of 2 V and 200 Ah each. Totally, the bank contains 96 cells while the total voltage is 96 V and the cell capacity is 400 Ah (approximate energy capacity 40 kWh).
- The second battery system consists of 30 lead-acid cells of 2 V, 690 Ah, connected in series. The total capacity is 690 Ah while the nominal voltage is 60 V (approximate energy capacity 40 kWh).

Battery inverters: The interconnection of the batteries with the AC grid is obtained through two independent systems:

- One three-phase battery inverter at 9 kW, 96 VDC, 230/400 VAC. This device has the capability of operation as voltage source (grid-forming) or current source (grid-tied operation). In each of these modes the controllable quantities are the voltage and frequency or the real and imaginary current components. The energy flow can be also controllable so that the charger operation with specific current/voltage profiles is obtained.
- Three single phase battery inverters of 4,5 kW, 60 VDC, 230 VAC. These devices have multiple possibilities of operation with the most interesting being the three-phase operation during which one of the three inverters (Master) controls the other two (Slaves) through an RS485 communication port, the single-phase operation with only one of the three inverters, grid-forming operation where voltage and frequency are controlled, grid-tied operation where current is controlled, and finally, the droop mode. Additional features of these inverters are the calculation of the state of charge (SOC) of the batteries through which charge procedure can be started and multiple other capabilities. It is worth mentioning that these inverters are equipped with their own data acquisition and control system which cover many demands and renders the devices suitable for experimental applications without additional sensors.

Diesel genset: The system is equipped with a diesel generator of 400 VAC, 50 Hz, 12.5 kVA.

Loads: The system includes a load bank of resistors totaling 20 kW. These loads are equally distributed into the three phases. Apart from the resistive loads, the system includes a three-phase capacitive load, a three-phase induction motor of 2.2 kW and two small single phase water pumps.

Load controllers: One of the possibilities of the system is the use of load controllers which are electronic devices responsible for shedding loads when necessary. These controllers operate based on the grid voltage and frequency and shed loads when these quantities undergo crucial values. The controllers also determine whether the load should be reconnected or not.

Reverse osmosis desalination unit: Its maximum consumption is 3.5 kW and is one of the most important loads when island power system is simulated.

2.2.2.2 Extension of the power system

The existing system has been recently interconnected with the installations of the RES & Hydrogen Technologies Integration Section of CRES, offering additional capabilities for plenty of experiments and studies which cover a wide range in the RES field. The units that can be interconnected are:

- One Proton Exchange Membrane (PEM) fuel cell. The PEM fuel cell has a nominal capacity of 5 kW (DC). A DC/AC three-phase system will also be integrated in the PEM fuel cell system in order to supply AC electricity to the micro grid. The fuel cell requires a hydrogen purity of 99.95% dry, therefore hydrogen produced by both the PEM and the alkaline electrolyzer is suitable for use in this fuel cell. On the other hand, hydrogen produced from bio ethanol reformer will need extra purification in order to be used in the specific PEM fuel cell. Hydrogen consumption is 40 NL/min when producing 3 kW, and 75 NL/min when the fuel cell produces 5 kW. Hydrogen fuel should be delivered in the fuel cell inlet at a pressure of 4.5–6.5 bars. The PEM fuel cell stack is composed of 63 cells and single cell monitoring will be available. Start up time of the PEM fuel cell ranges between 8 and 12 s. Moreover, the specific PEM fuel cell has a very good transient response.
- One PEM electrolyzer. The electrolyzer has a nominal hydrogen production capacity of 0.5 Nm^3/h, at a pressure of up to 13.8 bar and can be connected directly to an RE source, namely PV panels. The electrolysis unit is fully automated and delivers ultra pure hydrogen with purity better than 99.999 % vol. containing less than 5 ppm of H_2O and less than 1 ppm of other gases. It must be noted that the purification section of the Hogan PEM electrolyzer comprises only a drier and not a deoxidizer unit, since the production of hydrogen and oxygen take place in different compartments which do not communicate to each other under any circumstance. This electrolyzer requires high quality de-ionized water (ASTM Type II, < 1 micro Siemens/cm), which will be supplied through a Reverse Osmosis (RO) deionizer that will be integrated to the RES & Hydrogen Technologies Laboratory. RO deionizer will provide ultra high quality water (ASTM Type I, < 0.1 micro Siemens/cm). Power consumption of the PEM electrolyzer ranges between 6.08 and 7.6 kWh/Nm^3 of hydrogen produced. The AC feed of the PEM electrolyzer is 1 phase, 200–240 V, 50–60 Hz, isolated.
- The storage of the RES & Hydrogen Technologies Laboratory is a compressed hydrogen storage tank at the maximum pressure of 16 bar. The compressed hydrogen storage tank, which has already been installed, has a physical volume of 3000l, and has a nominal hydrogen storage capacity of ca. 47 Nm^3.

In Figure 2, a detailed block diagram of the power components combined with the communication and control layer is given. It is worth mentioning that the power units are connected with a three-phase line which can be also connected with the mains through remotely controlled switch.

2.2.2.3 Communication and control layer

The communication and control layer is the system Interbus based on the serial RS-485 protocol. More analytically, each of the power units is accompanied by analog and digital I/O devices that communicate through the Interbus protocol, transferring data to the interface console and control signals to all controllable devices. One of the basic advantages of the system is that it can be easily extended. Apart from Interbus, the micro grid includes a power quality meter for monitoring quantities like active and reactive power at the mains. The communication of this system with the control console is achieved through the Modbus protocol. Finally, it is worth mentioning that the three single phase battery inverters utilize their own interface with the central console based on the RS485 communication protocol.

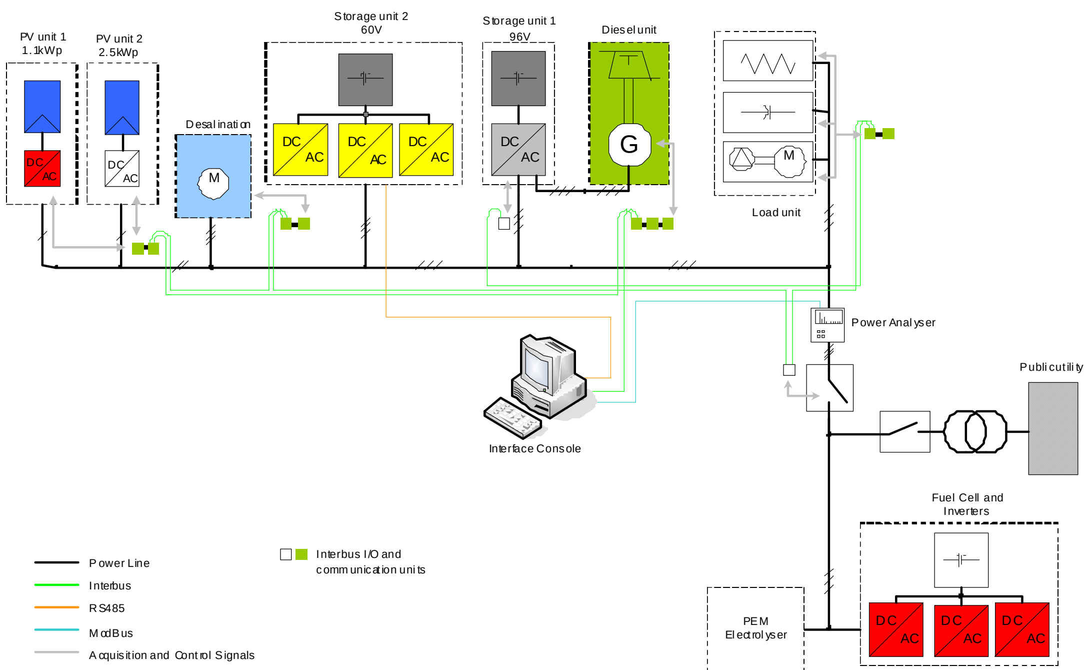

Figure 2: Block diagram of the experimental micro grid

2.2.2.4 Graphical interface and supervision console

One of the most critical parts of the system is the control console (fig. 3). This is a graphical interface and has been developed in Lab VIEW. This console provides the user with some capabilities like:

- Easy access to all the devices. This includes the control of operation of each device. All the controls are fully automated which means that through the interface the operator can perform any desired experiment.
- Data acquisition monitoring and storage to files for further processing.
- Ability of operation remotely through web publishing tool.
- The modular construction of the interface as well as the multiple features provided by the platform makes the modifications very easy.

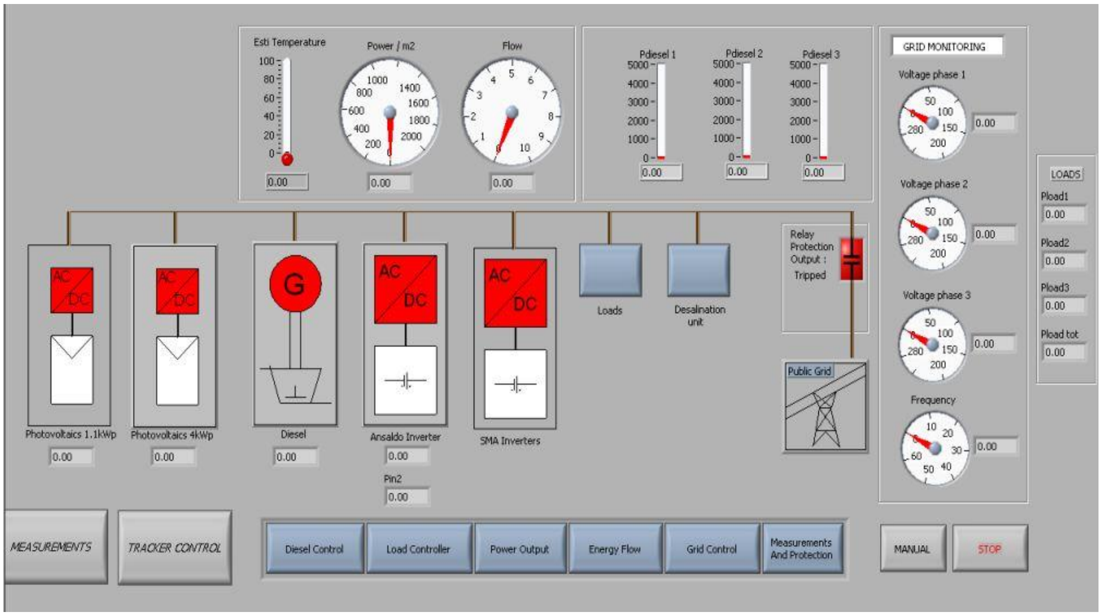

Figure 3: Graphical Interface

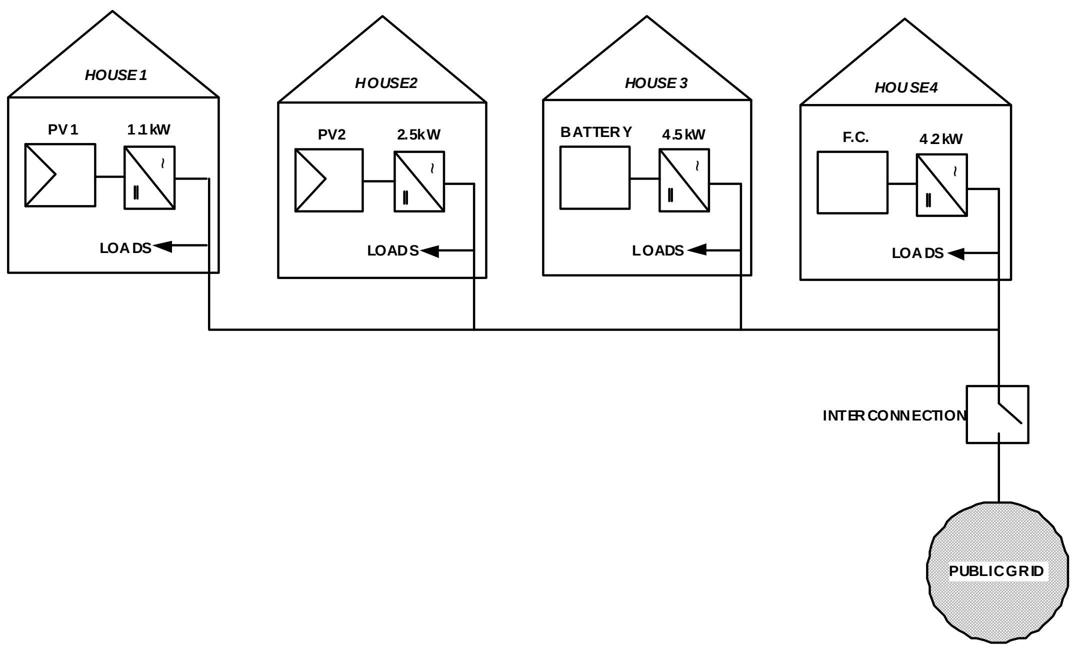

Figure 4: Proposed simulation configuration for the needs of the project

For the needs of the project the experimental micro grid is going to be used as a simulator of residential producers/consumers in which the proposed control technology will be tested. More analytically, the proposed configuration as shown in Figure 4 simulates four (4) houses, each equipped with RES or storage units. This configuration is beneficial due to the following reasons:

- Repeatability of experiments without causing any kind of inconvenience as would happen in real houses
- Reproduction of a large number of scenarios by changing input data in the console
- Minimal preparation since there is a readily available infrastructure. The proposed configuration requires minor hardware and software changes into the existing system.

2.2.3 Test Site 2: The building of PVs and DER systems department

For the project needs a number of tests under real consumption/production conditions will be performed. For this purpose, the use of the building of PVs at CRES is proposed as a test field. The site is depicted in Figure 5.

Figure 5: CRES, building of PVs and DER systems

The site has the following characteristics:

- It consists of a single floor building of 440 m^2 and houses, the department of PVs and DER systems.
- It comprises offices and laboratories.
- On the roof a PV array of 22 kWp total capacity is installed. As it is shown in Figure 4, there are three different installed subsystems.

• The main electricity consumption of the site is due to the central heat pump used in order to cover heating/cooling needs during the year. The pump is accompanied by a water circulation pump and fan coils across the building.
• Apart from the heating/cooling system the rest of electricity consumption is due to lights, computers, laboratory and office equipment, etc.

It should be noticed here that the site has participated as a test field in the projects related to Demand Management like EUDEEP. Concretely, in Work Packages 4 and 5 of this project, two experiments were executed:

- Flexibility tests during which the loads were divided into critical and flexible. Specifically, the heat pump was selected as a flexible load. Different flexibility scenarios where tested under various weather conditions. The experiments focused not only on the technical aspect but also the sociological part was inspected.

- MultiAgent System tests: During this campaign, the MAS technology was examined into various loads such as the heat pump and also the PV production. Basic aim of these tests was the examination of how possible the consumption is to follow the generation and vice versa.

Another important project was "PV Enlargement" which was related to the Photovoltaic's installation and tests. Within the frame of this project the PV system of the building was installed.

2.2.3.1 Consumption profile of Test site 2

The site presents a consumption profile which is strongly related to occupation and weather conditions. More analytically, the building is occupied by permanent personnel (6 persons) and occasionally by students working on Diploma theses. It is occupied mainly weekly from Monday to Friday and around 10 hours/day (8:00–18:00). The activities of occupants affect the electricity consumption since there is a large number of laboratory and office equipment. The main laboratory devices include battery life cycle testers, one solar simulator, one PV array simulator, one grid simulator, one climatic chamber and one PV module laminator. All these equipment is used for the research needs of the department which include PV cell and module testing, inverter testing, battery testing and PV module construction. In addition to these, there are several office devices like computer, printers and, of course, lighting of the building. However, the main consumer in the building is the heating/cooling system. The main parts of this system are: the central heat pump with 61 kW cooling/67.5 kW heating capacity, 22.6 kW/20.6 kW consumption when heating/cooling, 50 A maximum current, operation from –5 to 15 °C, and produced power 44–90 kWth when heating, operation from 28 to 42 °C, and produced power 67–46 kWc when cooling. A number of fan coils deliver the thermal energy to the building areas. Their electricity consumption is included in the office equipment electricity consumption.

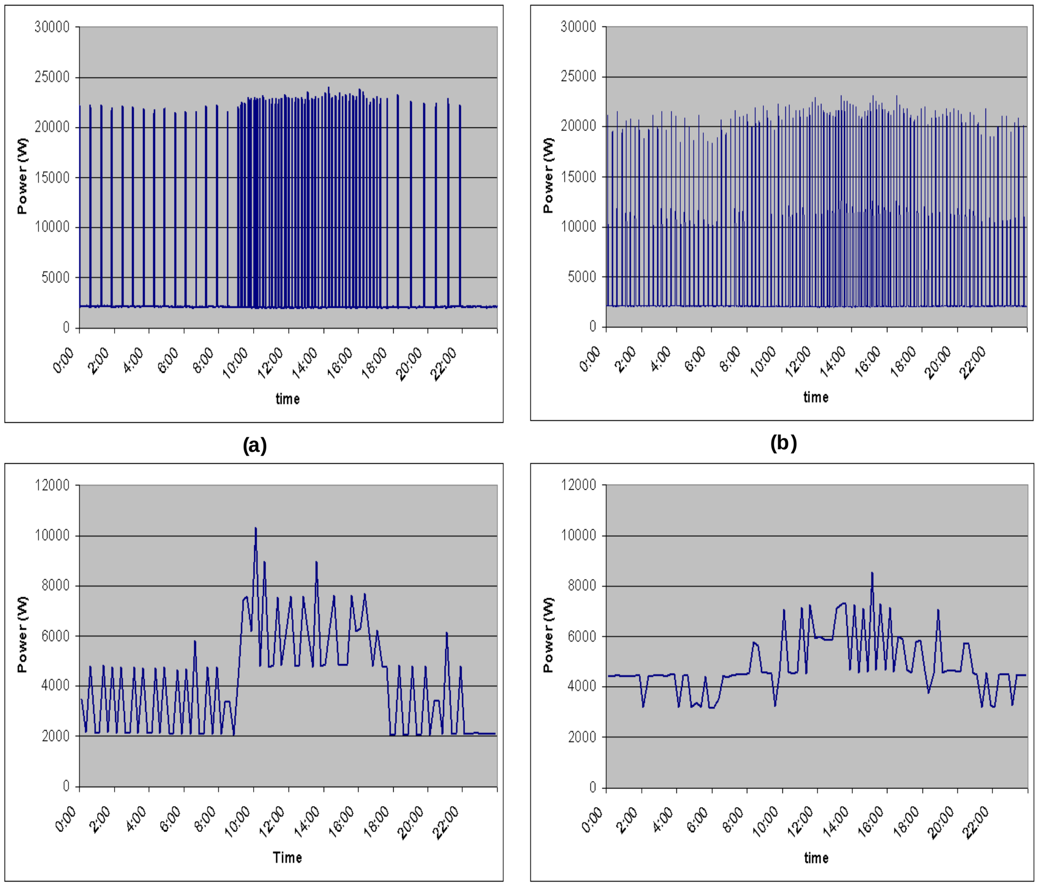

Figure 6: Heat pump consumption: a) Momentary consumption during a typical winter day, b) Momentary consumption during a typical summer day, c) 15-min average consumption during a typical winter day and d) 15-min average consumption during a typical winter day

In Figure 6, the characteristic curves of the heat pump as well as the other loads consumption are illustrated. Specifically, fig. 5 depicts the heat pump consumption during a winter and a summer day. The diagrams show the momentary and the 15-min average values. It is evident that the momentary power is switching due to the operation of the system between two values. However the duration of each state defines the total consumption. Due to this, in Figure 6a there is an enhancement of the power pulses which affects the average consumption (Figure 6c). In Figure 6d, the consumption of the other loads during two successive days is shown. The presence of up to 16 kW peaks in power consumption is due to the climatic chamber operation. The duration of such peaks is short and generally this consumption is low compared with the heat pump. Finally, Figure 7 illustrates the PV production during a cloudless and a partially cloudy day. The power level of the array reveals that generation and consumption of the building are generally balanced.

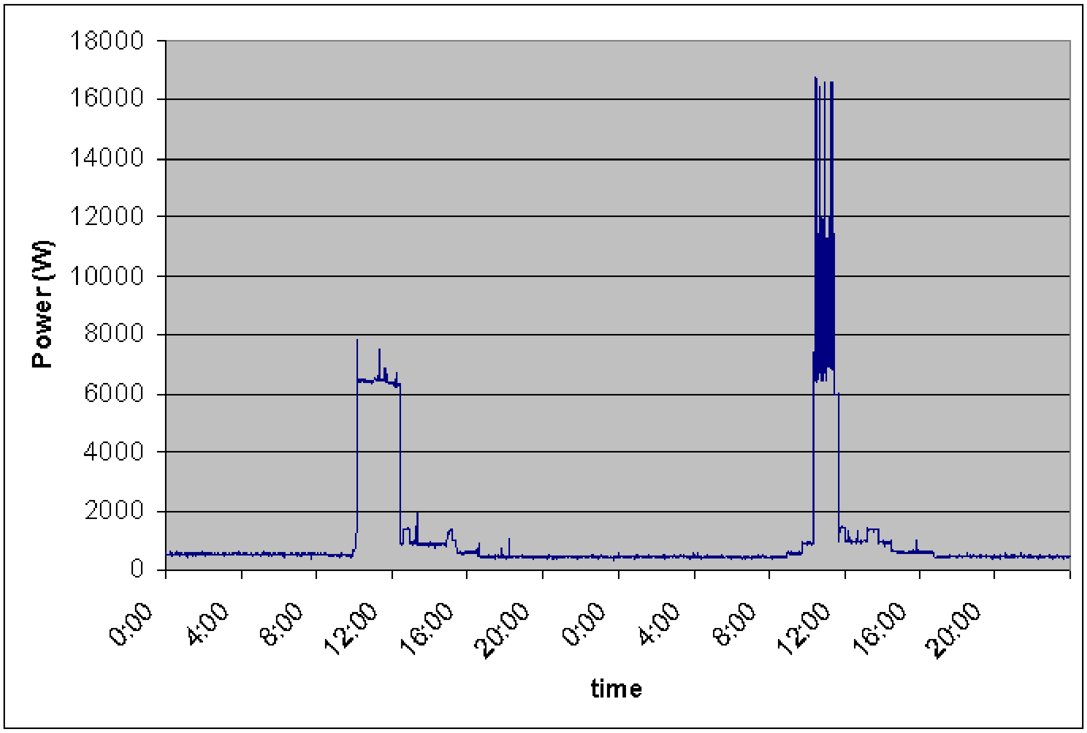

Figure 7: Consumption of laboratory and office equipment during two days

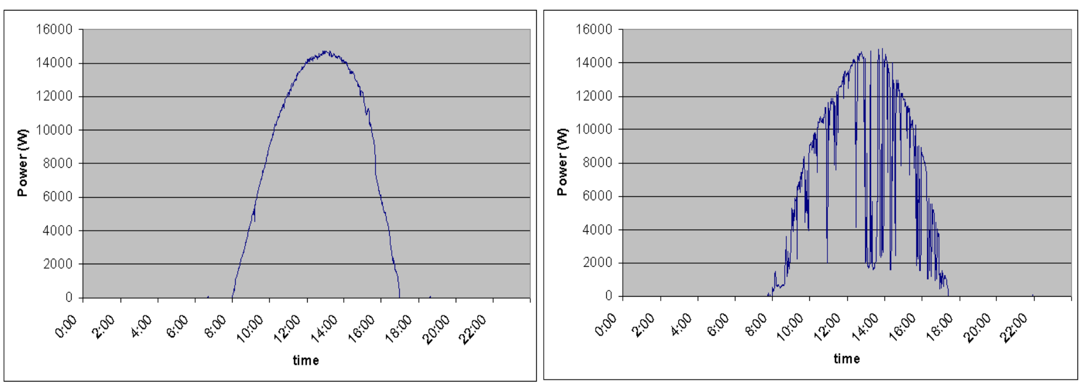

Figure 8: PV production during a cloudless and a partially clouded day

3 Related projects

3.1 MEREGIO

This project MEREGIO [MEREGIO] is described in substantial detail in Section 2.1 of this report and will not be additionally summarized here.

3.2 FENIX

3.2.1 Basic information

FENIX [FENIX] was a European collaborative project, partly funded by the European Commission within the 6th Framework Program for Research. Launched in October 2005 and its duration is 4 years (ended September 2009).

20 partners were involved: Iberdrola, Electricité de France, EDF Energy Networks, Red Eléctrica de España, National Grid Transco, Siemens PSE, Areva T&D, ZIV, Korona, Scalagent, Ecro, Poyry Energy Consulting, Labein-Tecnalia, IDEA, Fraunhofer IWES, and Energy Research Centre of the Netherlands, The University of Manchester, Vrije Universities Amsterdam, Imperial College London, and Gamesa Innovation & Technology. The total budget was 14.7 MEUR.

3.2.2 Description

The objective of the FENIX project as stated by the authors was to enable the Distributed Energy Resources (DER) making the EU electricity supply system cost efficient, secure and sustainable through aggregation of DERs into Large Scale Virtual Power Plant (LSVPP).

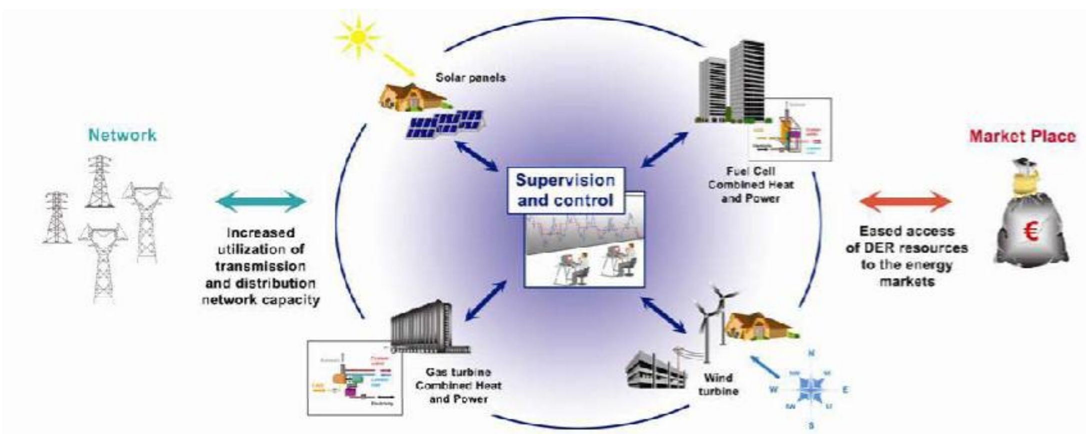

Figure 9: Graphical representation of the FENIX concept [FENIX]

FENIX dealt with the problem of non-point sources operating in the electricity network in the framework of virtual power plants.

A Virtual Power Plant (VPP) aggregates the capacity of many diverse Distributed Energy Resources; it creates a single operating profile from a composite of the parameters characterizing each DER and can incorporate the impact of the network on aggregate DER output (see Figure 10).

A VPP is a flexible representation of a portfolio of DER that can be used to make contracts in the wholesale market and to offer services to the system operator. There are two types of VPP, the Commercial VPP (CVPP) and the Technical VPP (TVPP).

DER can simultaneously be part of both a CVPP and a TVPP.

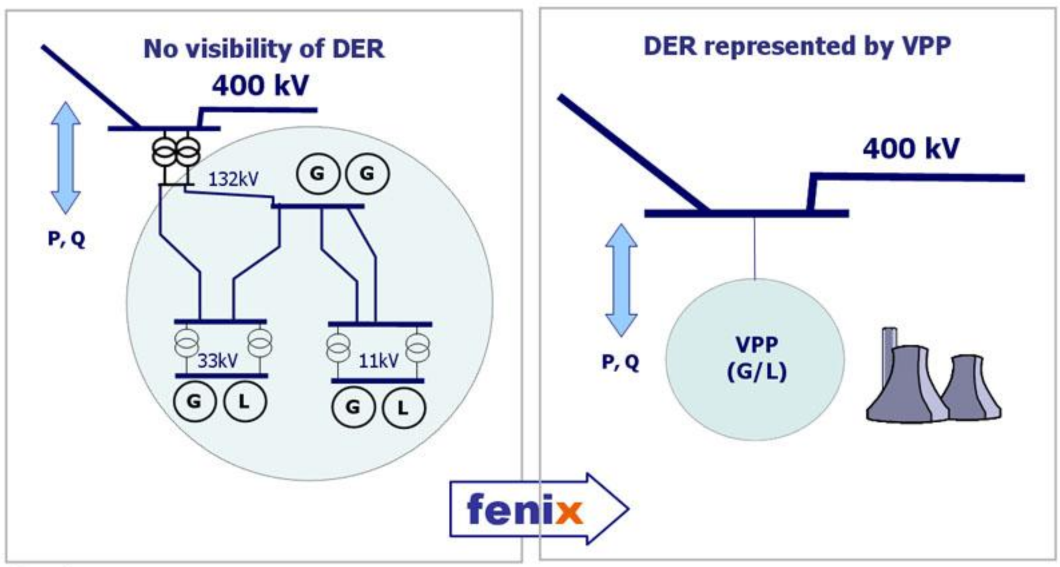

Figure 10: Characterization of distributed energy resources as a virtual power plant [FENIX]

3.2.2.1 Technical VPP

A Technical VPP is a type of VPP. The TVPP consists of DER from the same geographic location. The TVPP includes the real-time influence of the local network on DER aggregated profile as well as represents the cost and operating characteristics of the portfolio.

Services and functions from a TVPP include local system management for Distribution System Operator (DSO), as well as providing Transmission System Operator (TSO) system balancing and ancillary services. The operator of a TVPP requires detailed information on the local network; typically this will be the DSO.

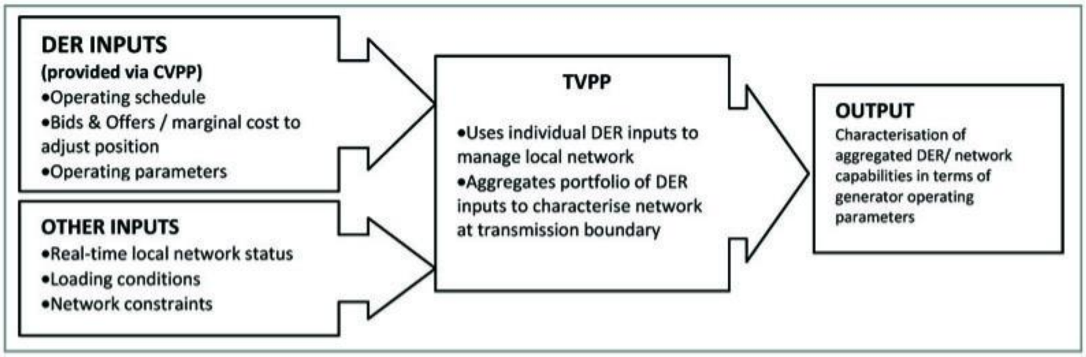

Figure 11: Inputs and outputs of technical VPP activity [FENIX]0

3.2.2.2 Commercial VPP

A Commercial VPP is a type of VPP. A CVPP has an aggregated profile and output which represents the cost and operating characteristics for the DER portfolio. The impact of the distribution network is not considered in the aggregated CVPP profile.

Services/functions from a CVPP include trading in the wholesale energy market, balancing of trading portfolios and provision of services (through submission of bids and offers) to the system operator. The operator of a CVPP can be any third party aggregator or a Balancing Responsible Party (BRP) with market access; e.g. an energy supplier.

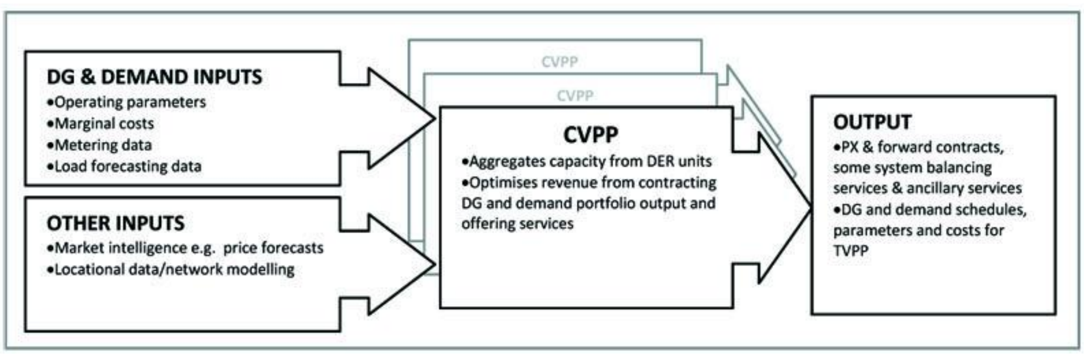

Figure 12: Inputs and outputs of commercial VPP activity [FENIX]0

3.2.3 Intersection with Miracle

FENIX investigated the possibility of operation and management of distributed energy sources on the level of electricity distribution network would be carried out in the same manner as it is presently done on the level of the transmission network. The DER were treated as a virtual power plant, emphasizing their new importance in assuring the stability of the grid. Distributed energy sources are also central to MIRACLE project, since the micro-request based trading of energy implies a number of prosumers. However, the main foci of the project are different. FENIX focused on stability problems and technical implications of DERs as units in the distribution system, whereas MIRACLE is concerned with energy trading processes in the DERs environment. Also the marketing implications are different: FENIX stressed the sales of the ancillary services generated by inclusion of DERs as VPPs into the portfolio of electricity production units on the grid, whereas MIRACLE targets the energy trading market on all levels of the electricity market system.

3.2.4 Source of information

- Link to the project web page http://www.fenix-project.org/ [FENIX]

3.3 EU DEEP

3.3.1 Basic information

Duration: The project EU DEEP [EU DEEP] started in June 2004 and was successfully completed in June 2009 (total duration 5 years).

Total Budget: The total budget of the project was 30 M€.

Partners: GDF SUEZ, SEAES, SAFT, Technofi, Transénergie (France), Iberdrola, CENTER, IIE-UPV, Labein (Spain), Tractebel, Laborelec, KULeuven (Belgium), RWE Energy, GASAG, MTU, Siemens PTD, ENPROM, Axiom (Germany), EPA Attiki, AUTh, ICCS/NTUA, CRES, Heletel, ANCO, RAE (Greece), EAC, FIT (Cyprus), Latvenergo, RTU (Latvia), IEA/LTH, Enersearch, STRI (Sweden), FEEM (Italy), VEIKI (Hungary), VTT (Finland), TUBITAK (Turkey), Imperial College, Bowman (England), Siemens PSE (Austria), TEDOM (Czech Republic), EnergoProjekt, KAPE (Poland)

3.3.2 Description

During the 5 years, 42 partners from 16 countries were involved, in order to detail the conditions under which all players will be able to cope with the growing demand for DER units. Firstly, the project has identified the current “hosting capacity” of the electrical power system and the conditions that will enable this to be increased at an acceptable cost. Following this, an in-depth economic analysis of DER reveals that they can provide significant added value for the electrical system when they comply with network design constraints and contribute, in a reliable way, to better management of peak consumption. Using three aggregation business models extensively tested in the field, the project highlights the most promising directions to take from now on, to ensure efficient and sustainable integration of DER in the current electrical power system. The overarching goal of EU-DEEP was to: design, develop and validate an innovative methodology, based on future energy market requirements, and able to produce innovative business solutions for enhanced DER deployment in Europe by 2010.

The project objectives were to address the removal of specific barriers by providing solutions based on a demand-pull approach:

- Innovative business options to favor DER integration

• Equipment and electric system specifications to connect safely more DER units to existing grids
• An in-depth understanding of the effect of large penetration of DER on the performances of the electrical system and on the electricity market
• Market rules recommendations to regulators and policy makers that will support the three studied aggregation routes
• A comprehensive set of dissemination actions targeting all stakeholders of DER in Europe

The activities were structured along two axes:
• A set of 8 technical work packages (WP), each focusing on a specific technical issue or type of activity,
• Three transverse task forces (TF), exploiting the results of all work packages to provide some integrated outputs (evaluated in the last work package – WP8).

3.3.3 Intersection with Miracle

During the project part of the activities and studies were focused on Demand Side Management and Load Aggregation, similarly to MIRACLE. Especially two of the five conducted experiments included testing of aggregation of micro-CHPs in the German residential sector, while in Greece the feasibility of decentralized control architecture for load and generation aggregation. These experiments were carried out for two Business Models investigated in EUDEEP. More specifically, Micro-CHPs aggregation tests included 10 residential customers with specific energy needs. The sites were equipped with μ-CHP units (1 kWe). The main scope was the Business Model validation through tests under real conditions and data feedback. In the second case, the main objective was the validation of Business Model focusing on CHP and demand response aggregation at small and medium size customers. In these tests, the MultiAgent System technology was deployed in a cluster of four sites (including residential and commercial customers).

3.3.4 Source of information

Link to the project web page: http://www.eu-deep.com/ [EU DEEP]
Project fact sheet:
http://cordis.europa.eu/fetch?CALLER=FP6_PROJ&ACTION=D&RCN=73969&DOC=20&CAT=PROJ&QUERY=1

3.4 AEOLUS

3.4.1 Basic Information

Full Name: AEOLUS - Distributed Control of Large-Scale Offshore Wind Farms

Duration: May 2008-April 2011

Budget : 3.36 MEUR

Partners. The project consortium consists of these 6 partners:

1. Aalborg University, Denmark (coordinator)

2. Industrial Systems and Control Ltd., United Kingdom
3. Lund University, Sweden
4. University of Zagreb, Croatia
5. Energy Research Centre of the Netherlands, The Netherlands
6. Vestas Wind Systems A/S, Denmark

3.4.2 Description

The AEOLUS (Distributed control of large-scale offshore wind farms) project [AEOLUS] is supported by ICT-2007.3.7 “Network embedded and control systems.” Its focus lies on how to deal with climate change while meeting the rapidly increasing demand for energy in Europe at the same time. The consortium sees the use of wind energy, particularly large-scale offshore wind farms, as a major clue when tackling this challenge. To reach the full potential of wind-energy-based solutions, though, research has to address existing weaknesses regarding the efficiency, stability, safety and predictability of the wind power cycle.

Research within AEOLUS is based on models that allow real-time prediction of wind flows with the help of incorporated data from spatially distributed sensor devices. This leads to new control paradigms that acknowledge the uncertainty in the modeling and optimize specific control objectives. AEOLUS allows shifting from a level of the single turbine control to the level of farm control and it provides optimal solutions to maximize power production while minimizing structural loads.

AEOLUS develops wind farm control paradigms that use dynamic wind flow models. Based on meteorological and wind turbine related measures, the models describe the flow of wind within the farm and the associated expected electrical power output and the mechanical loads. The control principles incorporate knowledge of the wind flow variations to provide automatic reconfiguration of the farm to meet a set point given by the network operator and at the same time minimize the (extreme and fatigue) loads experienced by turbines.

AEOLUS investigates a decentralized principle of the control, where the global objective for the wind farm is split into separate utility functions for each turbine. The turbines cooperate by buying and selling support from each other in an on-line virtual market system. In AEOLUS, simulation software is built to support their models.

AEOLUS is structured into six work packages. WP1 concerns project management. WP2 develops generic quasi-static flows models that relate the production of a single wind turbine and the fatigue load to the wind speed map. WP3 develops a dynamic flow model that describes the deviation from a static flow model due to rapidly changing flow effects. WP4 develops principles for supervisory wind farm power and load optimization. WP5 develops principles for decentralized control of wind power and the fatigue load relations. Finally, WP6 demonstrates the approach on a case study, and performs dissemination and exploitation.

3.4.3 Intersection with Miracle

AEOLUS is relevant to Miracle primarily through its decentralized controlling techniques. Both in Miracle and AEOLUS, systems at low levels are controlled based on plans that are established at high levels. AEOLUS's wind farm controlling methods might be used to support the scheduling of Miracle to make subsystems collectively react to instabilities based on real-time measurements in the electricity network, related to MIRACLE WP5. There might be interesting ideas from AEOLUS for MIRACLE in the areas of prediction-based tracking of sensor values (MIRACLE WP3) and/or prediction-based control (MIRACLE WP4+WP5). The "market-driven" control paradigm has some resemblance to the MIRACLE paradigm, and is thus also relevant for MIRACLE WP5.

The AEOLUS project focuses exclusively on wind power and their developed prediction and controlling techniques targets wind farms. The project does not consider the energy grid beyond a wind farm. The AEOLUS project does not consider the demand side at all, unlike MIRACLE. For example, the prediction components of AEOLUS are focused on wind farm parameters like wind speed, and do not include, e.g., electricity demand Additionally, AEOLUS has no focus on large scale distributed data collection and management.

3.4.4 Source of information

Link to the project web site: http://ict-aeolus.eu/ [AEOLUS]

Conference paper: Distributed Control of Large-Scale Offshore Wind Farms
http://ict-aeolus.eu/pub/246_EWEC2009presentation.pdf

3.5 MORE MICROGRIDS

3.5.1 Basic information

Name: The full title of the project MORE-MICROGRIDS (contract no.: 019864) is "Advanced Architectures and Control Concepts for More Micro grids" [MICROGRIDS].

Duration: The project started in January 2006 and was successfully completed in December 2009 (total duration 4 years).

Total Budget: The total budget of the project was 8 M€.

Partners: 1) ICCS/NTUA (Greece), 2) ABB (Switzerland), 3) SIEMENS (Germany), 4) SMA (Germany), 5) GERMANOS (Greece), 6) ANCO (Greece), 7) EMforce (The Netherlands), 8) EDP (Portugal), 9) CONTINUON (The Netherlands), 10) MVV (Germany), 11) ELTRA (Denmark), 12) CESI (Italy), 13) LRPD (Poland), 14) CRES (Greece), 15) LABEIN (Spain), 16) Manchester (UMIST-UK), 17) INESC, Porto (Portugal), 18) ISET (Germany), 19) ARMINES (France), 20) ZIV (Spain), 21 I-Power (UK)

3.5.2 Project description

This project aimed at the increase of penetration of micro generation in electrical networks through the exploitation and extension of the Micro grids concept, involving the investigation of alternative micro generator control strategies and alternative network designs, development of new tools for multi-micro grids management operation (involving Distribution Management System architectures and new software adaptation) and standardisation of technical and commercial protocols. In all this development the Micro grids concept plays a key role. Concretely, the objectives of the project were:

- Investigation of new micro source, storage and load controllers to provide efficient operation of Micro grids
- Development of alternative control strategies (centralized versus decentralized)
- Alternative network designs
- Technical and commercial integration of Multi-Micro grids
- Field trials of alternative control and management strategies
- Standardization of technical and commercial protocols and hardware
- Impact on power system operation
- Impact on the development of electricity network infrastructures

Methods and technologies used for the project purposes are listed below:

- Experimental validation of Microgrid architectures and interconnected and island mode, as well as during transition (HW+SW)
- Development and experimental validation of alternative control concepts and algorithms in actual Micro grids (SW)
- Development and testing of Distributed Generation and Load Intelligent Controllers (power electronic interfaces) (HW)
- Development and testing of storage technology systems, able to support Micro grid operation during transition to islanded mode (HW)
- Development of advanced protection hardware and algorithms, as well as solid state network components of Micro grids (SW+HW)
- Development of control and management algorithms for their effective operation and for interfacing them with the upstream Distribution Management system (SW)
- Quantified evaluation of the Micro grids effects on Power System operation at regional, national and projected EU level.
- Quantified evaluation of the Micro grids effects on Power System expansion planning at regional, national and projected EU level.

3.5.3 Intersection with Miracle

From a general perspective, MoreMicrogrids and Miracle have similarities because both projects focus on the distribution grid. The general objective of these projects is the development of strategies and algorithms for obtaining balance between demand and supply which is one of the most critical challenges in the development of future grids. The focus of MoreMicrogrids however is limited within the boundary of a micro grid. In other words, the developed strategy and control focuses on a concrete part of the distribution grid, located at the same region (as a micro grid is) while the Miracle project focuses on a wider approach of the distribution grid, emphasizing the micro-requests.

3.5.4 Source of project data

http://www.microgrids.eu/ [MICROGRIDS]

3.6 ADDRESS

The ADDRESS project (Active Distribution Networks with Full Integration of Demand and Distributed Energy Resources) 0, funded within the ENERGY-2007-07.1-01 objective, aims to provide a commercial and technical framework for the development of 'Active Demand' in smart grids. This project started in June 2008 and will end in June 2012. Furthermore, 25 partners from 11 European countries are involved in this project.

The main focus of the ADDRESS project lies on the development and deployment of technologies that increase the use of distributed generation in order to exploit more renewable energy resources by fostering active participation of domestic and small commercial customers in the power system markets.

3.6.1 Project Description

ADDRESS develops scalable, open, real-time communication architecture in order to enable active demand and to allow real-time responses to requests from markets and/or other power system participants. Aside from technical aspects, ADDRESS also tries to identify and to overcome regulatory, economic, social and cultural barriers of active demand.

The main concepts are (1) interaction through real-time price and volume signals, (2) the 'demand approach' to foster the flexibility and active participation of consumers (in contrast to the 'generation approach'), where supplies/services of consumers are requested through the developed price and/or volume signal mechanism and will be provided on a voluntary and contractual basis, and (3) distributed intelligence and local optimization (various levels of aggregation and optimization).

Putting it all together, ADDRESS tries to balance the power generation and demand in real-time and hence, it allows the involved operators, consumers, retailers, and stakeholders to benefit from the increased flexibility of the entire system.

3.6.2 Intersection with MIRACLE (Relation to MIRACLE)

There are several aspects that are commonly shared by MIRACLE and ADDRESS. Most importantly, both projects follow the same objective of balancing and shaping/sharing energy load in order to achieve flexible and reliable energy provisioning. Furthermore, both projects use the price as a regulatory metric.

Apart from their common general goal, both projects focus on distributed, scalable communication architecture (in the sense of a SW system) with different levels of aggregation and optimization.

In conclusion, the MIRACLE project should be aware of (1) changed process models affected by the 'demand approach', (2) the results of the ADDRESS projects, which could be a good starting point for parts of the supply side, and (3) maybe architectural considerations, which could be reused as well.

3.6.3 Differences to MIRACLE

Despite the same objective, both projects follow a fundamentally different approach. ADDRESS uses the 'demand approach' to request energy supply from domestic and small commercial customers. In contrast, the MIRACLE project differs in two major aspects.

First, the MIRACLE project has a larger scope because it includes energy demand and supply and thus, all producers and consumers rather than only small commercial customers are taken into account.

Second, and most importantly, MIRACLE's 'request-based' approach is the direct opposite of the 'demand-approach'. Using the request-based approach, the individual consumers and producers actively send energy demand or supply requests that include the power profile flexibilities (time shifts or amount of energy). This allows for scheduling at higher aggregation levels. In contrast, within the 'demand approach' of ADDRESS, scheduling is realized by actively requesting resources from individual small producers as they are needed.

3.6.4 References

There are several publicly available sources of information on the ADDRESS project:

- Project website: http://www.addressfp7.org/ [ADDRESS]
- Overview Paper 2008: [BDV+08]
- Overview Paper 2009: [PBB+09]
- Deliverable Conceptual Architecture: http://www.addressfp7.org/config/files/ADD-WP1_Technical_and-Commercial_Architectures.pdf
- Presentation of Conceptual Architecture: http://www.addressfp7.org/config/files/ADDRESS_23062009.pdf

3.7 EDISON

3.7.1 Basic Information

Name: Electric vehicles in a Distributed and Integrated market using Sustainable energy and Open Networks (EDISON) [EDISON1], [EDISON2]

Cost: 49 million DKK, financed by the Danish ForskEL program https://www.forskel.dk/Pages/default.aspx and the partners.

Duration: Mid 2009 to end 2011

Partners: The EDISON consortium consists of the following 7 partners:

1. Dansk Energy, Denmark
2. Technical University of Denmark

3. DONG Energy, Denmark
4. IBM, Switzerland
5. Siemens, Germany
6. Østkraft Production, Denmark
7. Eurisco, Denmark

3.7.2 Description

The dominantly Danish EDISON project focuses on electric vehicles in a distributed and integrated market using sustainable energy and open networks, and aims to develop possibilities for using a large fleet of electric vehicles (EVs) to consume surplus energy (e.g. wind-based power generated at night) and deliver energy back to the grid from their batteries in case of demand peaks.

In EDISON they analyze power system balancing situations in Denmark concerning technical details and costs for various ancillary services in relation to wind power balancing. Then they develop an optimal control scheme for power balancing based on pooling of EVs resources and study its impact on the power system. They balance the peak loads and overproduction of electrical energy by buffering energy for short and midterm for the Danish electrical grid. Thus they utilize charging stations as significant MW (Megawatt) resources for the use as energy reserve, reactive power compensation, active power, and power quality or frequency stabilization. They develop and test in the real-world a secure server solution that supports the functioning of a wide-area intelligent system and various classes of intelligent devices generating huge amounts of real-time data flows. Their test and benchmark their solution in both laboratory and real-life setting and address balancing issues of the power grid by testing bidirectional energy flows, i.e. grid to vehicle and vehicle to grid, in a micro scale system.

The work in EDISON is organized into seven work packages. WP1 – EV Technology studies state-of-the-art in EV technology and scenarios for future EV development, interact with the auto industry, investigate EV driving and parking patterns, participates in international working groups, develops battery models, and perform economic analyses. W2 – System Architecture Design for EV Systems investigates EV system architecture scenarios, analyses power system balancing and services, develops an optimal control scheme for power balancing based on EV resource pooling, develops an optimal portfolio management scheme for the EV pool related to wind power, study network impact on distribution and transmission levels, and make standards recommendations for EV integration. WP3 – Distributed Integration Technology Development develops a technical solution for intelligent system integration of distributed EVs, plugged into the grid at private homes or (semi)public charging stations, including developing a suitable aggregation technology for integration of small-scale distributed energy resources (in this case EVs) into the grid. The focus is on developing a secure IT system for this, entailing huge real-time data flows. WP4 – Central Fact-Charge and Battery-Swapping Devices evaluate central charging station design options, develops the technical concepts of central fast-charging and battery-swapping stations, performs network analysis of the grid connection for stations, investigates communication and control within central stations, and investigates charging/de-charging optimization algorithms. WP5 – EV Communication and Physical Charging Posts develops charging posts for private homes and the communication system between the EV and the power system, and provides input to grid codes and standardization. WP6a – Functional Testing (Syslab) makes a lab-based small-scale integrated test of the developed approach, while WP6b – Field Testing (Bornholm) performs large-scale real-life testing at the Danish Baltic island of Bornholm. Finally, WP7 - Project Management manages the project and ensures dissemination. The EDISON approach is a mix of large-scale HW (EVs, charging and battery-swap stations/posts, grids) and SW (for overall control and balancing, and local simulations and analyses), with a significant SW component in several WPs. The most relevant is WP3, see below.

3.7.3 Intersection with Miracle

While the EDISON idea related to balancing is similar to MIRACLE's idea of shifting demand to a different time, EDISON only does this for new and additional demand (as recharging electric cars is not part of the current demand) but not for the general demand that always exists. MIRACLE will tackle this disadvantage by also allowing the shifting of regular demand.

In EDISON they exploit the possibility to be able to "buffer" energy when balancing the grid. In Miracle such buffering is not possible and the grid is balanced only through mid and long term scheduling of demand/supply. EDISON does not have any concept of stated, expected demand, like the micro-requests of MIRACLE, and seem to only consider demand at a rather aggregated level.

There might be interesting relations to EDISON with respect to the prediction of energy demand (MIRACLE WP4), the (re)scheduling of charging (MIRACLE WP5), the management of real-time data flows (MIRACLE WP3) and the employed control and portfolio management schemes (MIRACLE WP5). The relevant EDISON work packages are EDISON WP2 (control and portfolio management schemes) and EDISON WP3 (prediction, scheduling, data flows).

3.7.4 Source of information

Link to the project web site: http://www.edison-net.dk/ [EDISON1]0, http://www.edison-net.dk/ [EDISON2]

EDISON flyer 1: http://www.edison-net.dk/~/media/EDISON/Edison_Flyer.pdf.ashx

EDISON flyer 2: http://www.edison-net.dk/~/media/EDISON/Flyer_final.pdf.ashx

Article about EDISON from Nordic Energy Solutions
http://www.nordicenergysolutions.org/innovation/agencies-and-programmes/danish/the-edison-project

3.8 DLC-VIT4IP (TUD)

The DLC+VIT4IP project [DLCVIT] focuses on power line communication on distribution networks (Distribution Line Carrier). This project started in January 2010 and will end in December 2012. Furthermore, 12 partners from 7 European countries are involved in this project.

This project will design, implement, evaluate, and test a communication infrastructure using the existing power distribution network. As a result, this open platform will allow the interconnection of sensors and actuators to implement services for energy consumption observation and energy management and efficiency and thus, for advanced network monitoring and control

3.8.1 Project Description

Existing broadband and narrow-band power line communication systems (PLC or DLC) do not fulfil the requirements for advanced monitoring and usage control of electricity distribution networks in particular for modern and new smart grid applications, where huge amounts of data have to be transferred. Hence, within the DLC+VIT4IP project, a system will be developed that assures the efficient integration of the Internet Protocol (IP) with (multiple) existing power line communication technologies by extending and improving existing high-speed narrow-band power line communication solutions, provisioning of an IP convergence layer that guarantees transparent data flow and quality of service (QoS). Furthermore, the contributions include the verification and development of channel models, physical layers, and topology and network models as well as the integration of PLC technology and energy applications using IP (v6) efficiently.

3.8.2 Intersection with MIRACLE

In a sense, the developed system of DLC+VIT4IP can be a precondition for the MIRACLE micro-request-based approach without the need for DSL (domain specific language). For this reason the aimed architecture might be an alternative for the physical implementation (HW) of data transfer within the distributed MIRACLE system architecture.

Despite this technical issue, there is an explicit request of co-operation from DLC+VIT4IP. In other words, MIRACLE is a use case for DLC+VIT4IP. For example, the results of MIRACLE WP1 and WP2 can be direct input to DLC+VIT4IP because the amount of transmitted data in our system represents quantified requirements for them. Thus, it is beyond all questions that we should actively participate in this co-operation.

3.8.3 Differences to MIRACLE

The difference between MIARACLE and DLC+VIT4IP is fundamental. While MIRACLE aims to develop a concrete architecture for micro-request-based balancing of energy demand and supply, DLC+VIT4IP aims to develop an architecture for communication on distribution networks and thus, its focus is broader with regard to the application area but limited to a physical communication infrastructure.

3.8.4 References

There are publicly available sources of information on the DLC+VIT4IP project:

- Project website: http://www.dlc-vit4ip.org/wb/ [DLCVIT]

- Partner website (CRAT): http://infocom.uniroma1.it/crat/index.php?option=com_content&task=view&id=33&Itemid=50

3.9 Smart House/Smart Grid

3.9.1 Basic information

The Smart House/Smart Grid project is an EU-funded collaborative project. It started in September 2008 and runs until February 2011 (30 months). The full name is “Smart houses interacting with smart grids to achieve next-generation energy efficiency and sustainability”. It is funded in the objective ICT-2007.6.3 ICT for environmental management and energy efficiency. The project budget is 3.81 million €. The funding is 2.56 million €.

The following institutions and companies are involved in this project:

- SAP AG, Research Center Karlsruhe, Karlsruhe, Germany (Coordinator),
- Fraunhofer Institute for Wind Energy and Energy System Technology Kassel, Germany,
- MVV Energie AG Mannheim, Germany,
- Energy Research Centre of the Netherlands, The Netherlands,
- Institute of Communication and Computer Systems, University of Athens, Athens, Greece, and
- Public Power Corporation S.A. Athens, Greece.

3.9.2 Description

The goal of the Smart House/Smart Grid project is to validate and test how ICT-enabled collaborative technical-commercial aggregations of smart houses in smart grids can achieve high energy efficiency.

Customers are actively involved. They use the in-house energy management system Energiebutler [EnBtl] to monitor and also control demand and supply and to receive real-time information about prizes in a system with dynamic tariffs. The interaction with the smart grid uses the BEMI interface [KWNSWKDD][NRS][NBR]. The smart grid is controlled in a distributed fashion by agents and web services. The multi-agent system architecture is called Power Matcher [PwrMatch][KWK][KWNSWKDD].

3.9.3 Intersection with Miracle

The Energiebutler and the BEMI interface are technologies for energy management that allow controlling appliances and are therefore related to MIRACLE. The Power Matcher is a hierarchically organized market-based control concept for matching of supply and demand. It is related to MIRACLE negotiation. The three concepts and their relation to the MIRACLE project are described in this section.

3.9.3.1 BEMI interface and Energiebutler

The bidirectional energy management interface has been developed by Fraunhofer IWES. BEMI communicates bi-directionally between the central control station (Pool BEMI) and the energy management systems at private households and small SMEs (local BEMI) based on the standard IEC 61850. The price profile or the tariffs for the following day are sent from the central control station to the local BEMI which then calculates schedules for the so-called controllable loads and controllable generators. Controllable loads and controllable generators are devices. Devices are classified into three types:

- Devices with a thermal or battery storage, which state of charge must be maintained
- Devices which carry out a fixed program with a shift able starting time (e.g. washing machine)
- Devices which can reduce their power at high electricity prices (e.g. dimmable lighting)

The local BEMI schedules the demand. It uses a specific algorithm for each device type. To avoid avalanching effects that is that all appliances are turned on at the same time, the algorithms introduce small, random shifts. Furthermore, tariffs for customers are varied. The BEMI interface has been realized. The technical realization includes the control of the devices.

The Energiebutler [EnBtl] is an energy management system developed and tested by Energies AG. Among other functionalities, such as monitoring of electricity demand and costs of appliances, the Energiebutler automatically schedules appliances based on the tariff information provided by the utility company for the next day. It switches appliances on and off. The system has been tested with 20 customers. The test used the following appliances: washing machine, dryer, dish washer, freezer and fridge. The effect on a customer profile is shown in Figure 13.

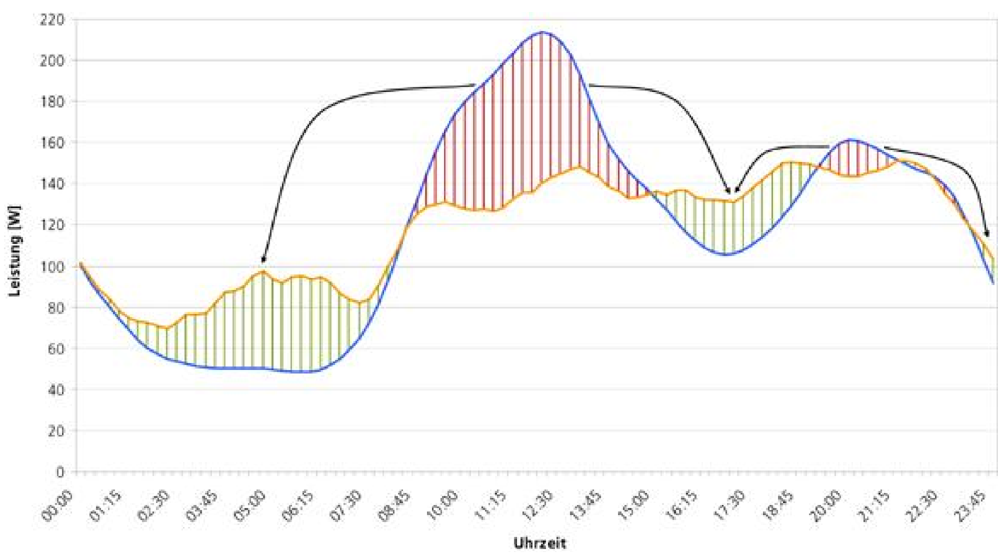

Figure 13: Average customer profile for a Sunday/holiday before Energiebutler usage (blue line) and afterwards (yellow line)

The technical realization of BEMI and the Energiebutler complement the work in the MIRACLE project because they show that appliances can be controlled technically by energy management systems. They use an alternative approach to schedule “controllable” load and generation. In both approaches, the scheduling is done locally at the customers based on tariff information sent by the utility company. In MIRACLE, requests are scheduled and also dynamically re-scheduled centrally in near-real time, e.g. at the utility company.

3.9.3.2 Power Matcher

The Power Matcher is a multi-agent, market-based control concept for supply and demand matching. Each electricity producing and consuming device is represented by a control agent who operates the device in an economically optimal way. Devices are classified into 6 types:

- Stochastic operation devices are devices for which demand and supply cannot be controlled like solar and wind energy systems.
- Shift able operation devices are devices with operations that are shift able within certain limits, like washing machines, dryers, swimming pool pumps, assimilation lights in greenhouses and ventilation systems.
- External resource buffering devices are devices that produce a resource other than electricity which can be buffered such as heating or cooling devices (electrical heating, heat pump devices, combined generation of heat and power).
- Electricity storage devices are devices which can store electricity like conventional batteries.
- Freely-controllable devices are devices that are controllable within certain limits like a diesel generator.
- User-action devices are devices whose operation is a direct result of a user action such as audio, video, lighting, and computers.

Each device agent is tailored to its specific device type.

The electricity consumed or produced by the device is traded by the device agent on a market. The market is a tree of so-called SD-matchers (see figure 14). An SD-matcher matches demand and supply of its sub-tree. It performs aggregation of the bids. The root SD-Matcher performs the price-forming process.

The structure of the bids is not specified. Therefore it is not clear if the concept can handle shift able demand or supply. If it could handle it, the mechanism could be used in MIRACLE as one mean to set prices for MIRACLE requests.

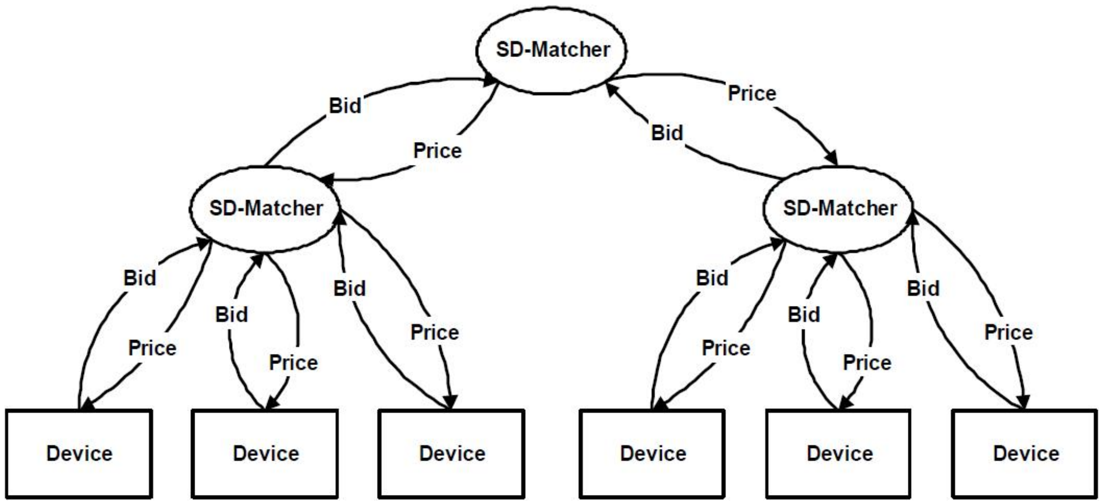

Figure 14: Tree of demand & supply matchers in the Power Matcher concept

4 Source of information

***Note**: links to individual project websites are included in respective sections with project description.*

[MEREGIO]; http://www.meregio.de/en/

[FENIX]; http://www.fenix-project.org/

[EU DEEP]; http://www.eu-deep.com

[AEOLUS]; http://ict-aeolus.eu/

[MICROGRIDS]; http://www.microgrids.eu/

[ADDRESS]; http://www.addressfp7.org/

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