EcoGrid eu
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EcoGrid EU: From Design to Implementation

A large scale demonstration of a real-time marketplace for Distributed Energy Resources

EcoGrid EU: From Design to Implementation

PREFACE

The EcoGrid EU project is sponsored by the European Union from the FP7 programme giving a valuable contribution to the European SET plan as well as to the European Electricity Grid Initiative (EEGI). The EcoGrid EU project is a large-scale demonstration of consumer participation in the balancing of renewable electricity generation by active demand response to real-time price signals, created from the current prices in the conventional balancing market. This is by far the most complete attempt to ensure consumer participation in the effort of allowing for more than 50% fluctuating sustainable power generation in a complete and market-integrated electricity system. The results from Bornholm will be scalable for both the rest of Denmark and for European benefit.

The design phase of the EcoGrid EU project is completed and the first phase of the field test on the Danish island Bornholm has been ramping up since May 2013.

EcoGrid EU is much more than one single solution – it is development of a new novel market concept and it is implementation and further refining in a large scale demonstration in a real power system. The demonstration is a challenging period for the whole project, when expected and unexpected issues pop-up and need to be resolved on time, and focus on good teamwork and efficient solutions are needed.

We are now looking forward to seeing how the theoretical concept developed in the initial part of the project will be materialised in real life on Bornholm. The customers' feedback regarding the ICT technology introduced in the project and their ability and motivation to change consumption based on five-minute prices will be most valuable as source for concept adjustment in the final part of the project.

Our hope is that the experiences from EcoGrid EU will contribute to the ongoing development of the current electricity market functions in Europe, making a smooth and efficient integration of more variable renewable energy sources, and thus, also contributing to the development of the European Smart Grids and the European 20-20-20 energy and climate goals.

Ove S. Grande

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SINTEF
Project Coordinator

Reader's Guide

The EcoGrid EU status report is targeted at an audience interested in participating in discussing how to develop a sustainable future power system.

The target group of the status report is not only Smart Grid experts, but also other people and stakeholder groups with interest in this field, including transmission system operators (TSO), local grid companies/distribution system operators (DSO), scientists, industry and governmental authorities.

The report starts with a summary that provides the readers with an introduction to the most significant parts of the project in relation to the development and implementation of the EcoGrid EU real-time market concept. The following chapters describe the key tasks in and experiences from the project acquired so far, before initiating the next two years' large-scale demonstration on Bornholm:

Chapter 1: Why an EcoGrid EU Real-time Market?
Chapter 2: The Fundamentals of the Real-time Market Concept
Chapter 3: The ICT Platform and EcoHome Solutions
Chapter 4: Recruitment and Customer Involvement
Chapter 5: Next Steps and Open Questions

The report can along with other information about EcoGrid EU be downloaded from www.eu-ecogrid.net.

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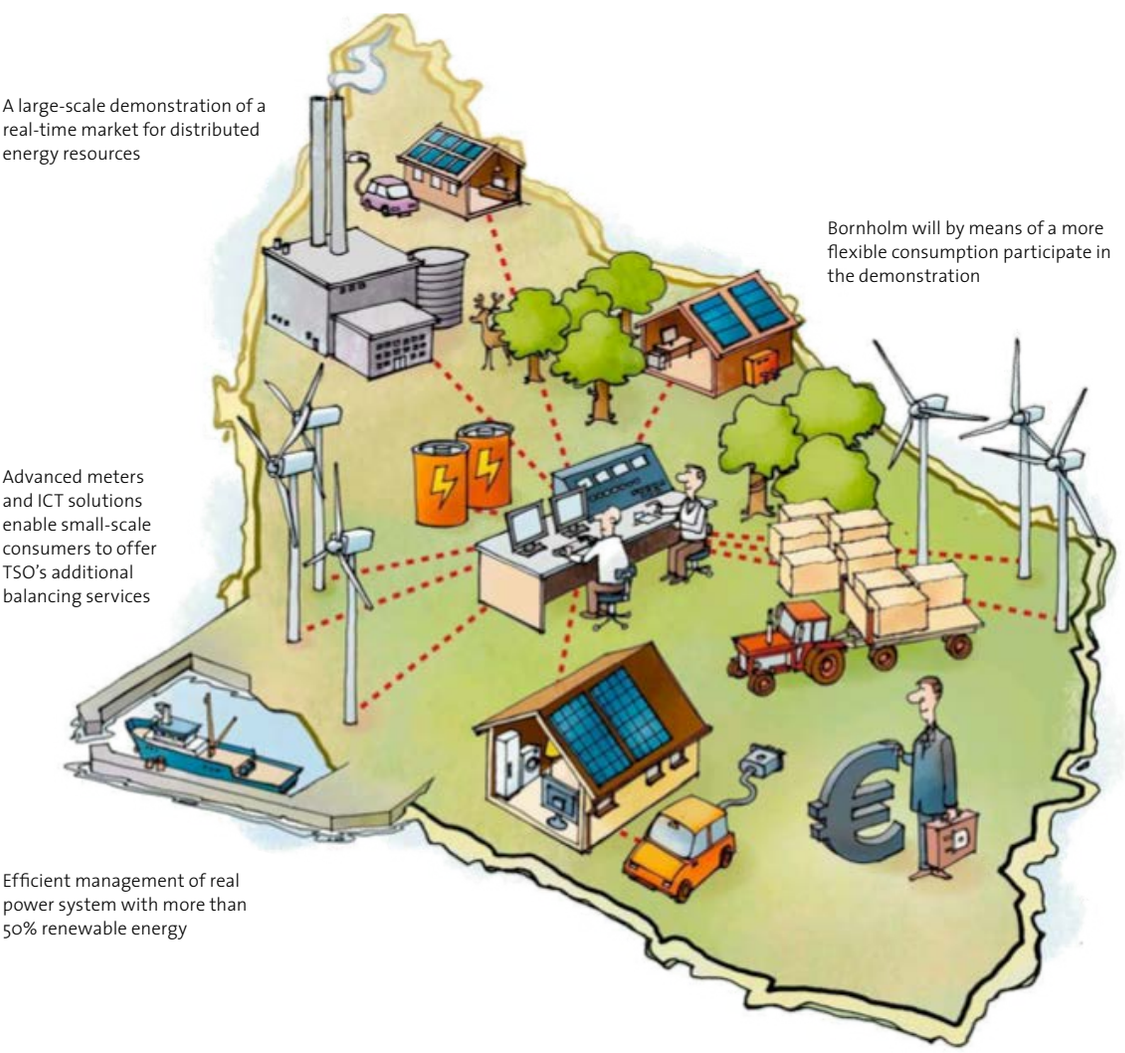


An interactive EcoGrid EU modell of the island of Bornholm. See YouTube for a video:
http://www.youtube.com/watch?v=ZLNxkJTA5boQ

Contents

Summary

The objective of the EcoGrid EU project is to illustrate that modern information and communication technology (ICT) and innovative market solutions can enable the operation of a power system with more than 50% renewable energy sources (RES) such as wind, biomass and photovoltaic (PV).

Activating electricity demand and bringing electricity customers into the power market provides additional capacities to balance the power system in a secure and economical way. EcoGrid EU proposes to extend the current wholesale electricity market to allow increased participation of so-called distributed energy resources (DER). The modernisation of the existing power market design will increase the market value of wind power and other RES, which in the long run is expected to provide the economic incentives for a higher penetration of renewable energy.

The project demonstrates a real-time market concept in a large-scale field test on the Danish island Bornholm. Bornholm is an ideal field test site: including 1,900 electricity customers and up to 100 industry/commercial buildings on Bornholm, the EcoGrid EU demonstration intends to show the potential of power system balancing from different kinds of electricity customers.

The fundamental principle of the EcoGrid EU real-time market concept is to exploit flexibility in electricity consumption. Flexibility (later also named flexible consumption) in this case is typically associated with heat pumps and electric heating, either for hot water or to keep the house warm. The consumption is flexible since the heat can be stored and there is normally a range of acceptable temperatures. There may be other significant sources of flexibility consumption in homes, eg if an electric vehicle is used.

In order to exploit this flexible consumption, the house must be 'smart'. It must have the capability of acting on external input to either consume more or less electricity than planned in a particular time period. The house must also have meters that are able to register the consumption of the electricity customers very close – from minute to minute, to be used in advanced demand forecast models of electricity and settlement.

Furthermore, the house must have direct and online customer feedback systems, ie communicating current consumption data and electricity prices in real-time. In the EcoGrid EU project, changes to participants' consumer behaviour can be tracked directly via the web portal 'My EcoGrid'. The feedback system will inform, motivate and sensitise customers to the adjustments of their consumption, eg according to the variations in the electricity prices. In the EcoGrid EU case, this means a real-time electricity price varying every five minutes.

In short: The EcoGrid EU concept brings all elements of the electricity system – generation, transmission, distribution and consumption – closer together to improve the overall power system operation for the benefit of the consumer and the environment.

THE ROLE OF THE ECOGRID EU PARTICIPANTS

The EcoGrid EU households are divided into three groups: Statistical control group, manual control group and automatic control group. The automatic control group is divided into so-called IBM houses and Siemens houses that use different technologies to implement and test the real-time prices responsiveness of the EcoGrid EU customers.

In order for the customers (except for the statistical control group) to be able to respond to the realtime prices, they receive manual response assistance, eg through online customer feedback system providing overview of consumption patterns, prices and price forecasts. The automatic control group will in addition to manual assistance have equipment installed in their homes to optimise the operation of their electric heating or heat pump. All EcoGrid EU customers get smart meters, collecting data about their consumption within five-minute intervals.

The test of the industry/commercial buildings focuses on new control and scheduling systems that enable industrial and commercial customers to take part in the real-time market. This involves automatic control of different types of large electricity consuming units and energy storage capabilities.

2,000 participating customers in the demonstration

Statistic control group

200 households with smart meters

No acces to specific information or 'smart' equipment

Manual control group

400-500 households with smart meters

Receiving simple market price information

Must move their energy consumption by themselves

Automatic control group

700 automated housegolds with IBM Green Wave Reality equipment and smart meters

All houses have heat pumps or electric heating all responding autonomously to price signals

Automatic control group

500 automated households with Siemens equipment and smart meters

All houses have heat pumps, or electric heating all responding to aggregator control

Industry/commercial buildings group

Up to 100 commercial with smart meters

Include also small public customers

Connected smart appliances responsive to control signals

REALISTIC MARKET CONCEPT AND ICT APPROACH

To make the EcoGrid EU solutions widely applicable, the real-time market concept is designed for existing power exchange(s) and balancing market(s).

However, in order not to interfere with the present wholesale market operations on the Nordic power exchange (NordPool), the EcoGrid EU demonstration is market-wisely operated as an isolated entity. For this to work, a number of adaptations have been made. The challenge is to create a market mock-up that will demonstrate the principles of the envisioned market concept without disturbing the Nordic wholesale markets, which Bornholm is a part of.

The EcoGrid EU pilot test includes different demand response solutions for real-time activation of the flexibility consumption. The central part of the ICT real-time market place and systems are based on three robust and well-proven software developments and solutions developed by the industry partners IBM, TNO and Siemens. In other words, EcoGrid EU investigates the technical and commercial feasibility of 'state of the art' ICT solutions rather than constituting novel standards for the utilised hard- and software components.

REAL-TIME PRICES GO LIVE

The initial part of the demonstration focused on the conceptual market design, recruitment and installation, including testing and activation of individual equipment in residential homes. That part of the demonstration took place without activation of the market concept, ie implementation of real-time price signals.

On 15 May 2013, the project made a significant breakthrough: the first live test of the real-time pricing concept. The basic real-time market concept is operational, and the project team will gain the first experience with live customer installations, real customer experience and real-time price responsiveness.

HOW WILL THE CUSTOMERS RESPOND TO REAL-TIME PRICES?

So far, the grid company on Bornholm, Oestkraft, has been busy fulfilling the goal of involving 2,000 of their electricity customers. In the course of the next two years, the interesting question is whether and how five-minute varying real-time price signals and related forecasts can influence the demand of electricity customers. Furthermore, it is a challenge for the demand response techniques to accomplish the intended goals without violating comfort constraints and processes of customers or commercial/industrial sites, respectively.

Terminology and Abbreviations

Distributed energy resources – comprise generation, storage and demand response connected to the distribution system.

Demand response – is the end-users' change of normal electricity consumption patterns in response to changes in the price of electricity over time, or changes to incentive payments designed to induce lower electricity prices over time, or changes to incentive payments designed to induce reduced electricity use at times of high whole sale market prices or when system reliability is jeopardised.

Real-time price signals - are used as a market instrument to control the balance between supply and demand in a power system. In the EcoGrid EU market concept, a new price is published every five minutes to allow for fast response compared to conventional markets.

Smart Grid – is an electricity framework that intelligently can integrate the action of all users connected to it – electricity consumers and producers and those that do both – in order to efficiently deliver and balance sustainable, economic and secure electricity supplies.

Smart meter – is an electricity meter capable of communicating the meter readings to other devices (in this case only to a central database). The Landis+Gyr smart meters in EcoGrid EU are able to meter electricity consumption or generation with a five-minute resolution.

Smart controller – is a local device that controls the electricity consumption/generation from appliances and assets based on a price signal and user settings.

BRP – Balance responsible party
DER – Distributed energy resources
DR – Demand response
DSO – Distribution system operator
ICT – Information and communication technologies
PV – Photovoltaic
RES – Renewable energy sources
TSO – Transmission system operator

1. Why an EcoGrid EU Real-time Market?

Today, the electricity grid is primarily a road for moving electricity in a one-way flow from large power generation plants. Significant changes to the power system must be foreseen, as traditional energy resources are replaced by local renewable generation connected to the distribution system.

Tomorrow's power system will include a variety of distributed and local energy resources as well as accommodating electric vehicles. This will require two-way flow of both electricity and information as new technologies enable new forms of generation, supply and uses.

New solutions, including wider use of information and communication technologies (ICT) and automation will be necessary, as well as reinforced electricity grid and improved power trading opportunities. Without this, there is a risk of insufficient power system security and reliability, as well as inefficient utilisation of eg new wind power capacity.

Generation of electricity from fluctuating renewable sources such as wind, biomass and photovoltaics poses a challenge to the power grid. Although generation from these sources can be forecasted, the availability of power fluctuates and always depends on weather circumstances that cannot be controlled (wind, rain and sun). Even if the energy generated follows the forecast perfectly, it may still not match the consumers' need for electricity.

THE WIND POWER CHALLENGE

Renewable energy in general and wind power in particular already plays an important role in many areas in Europe.

In Germany, the share of wind power is 7.8% of electricity consumption (2012). A high concentration of wind power in the Northern part of Germany creates together with the import from north a surplus of electricity which must be moved to the west and to the south of Europe.

In Denmark, the share of wind power is 30% of the total electricity consumption (2012). In 2020, the energy strategy of the Danish government is to increase the share of renewable energy to 35% of total energy consumption, implying that 50% of the electricity consumption in Denmark is supplied by wind power in 2020.

Wind power already covers and exceeds the entire Danish demand for electricity in many hours the course of a year. This situation will appear more frequently in the future – significantly increasing the need for power balancing resources. Currently, international connections provide most of the balancing of wind power in the power system. In future, there will be more competition for power balancing resources and the costs of these resources are expected to increase significantly.

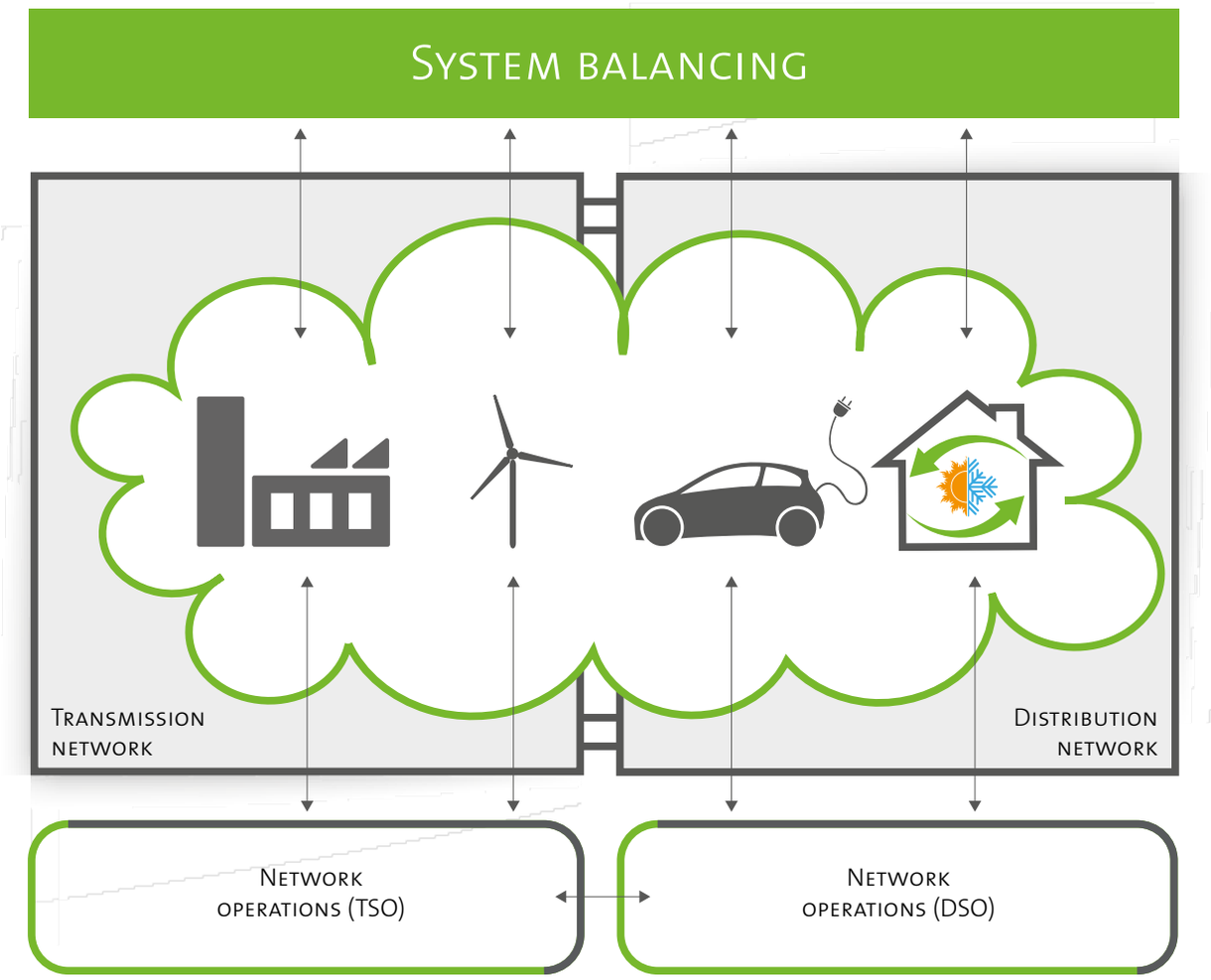


Figure 1: Demand-participation in the system-wide market for energy and balancing in the transmission network

THE REAL-TIME MARKET MAKES ACTIVE USE OF PASSIVE RESOURCES

The development of a real-time electricity market is considered one of the most efficient ways to meet the challenges in operating a power system with increasing shares of renewable sources:

- The EcoGrid EU real-time market has a very high time resolution (five minutes), which improves the capability to manage high amounts of rapidly fluctuating renewable energy sources.

- The market price is set in the very last minute, meaning that very accurate forecasts of wind power and demand can be utilised when determining the market price. It means that problems with forecast errors inherently present in conventional markets are minimised.

- Compensate for traditional balancing resources: The real-time market will increase the demand-side market participation and thereby reduce the need for costly flexibility on the production side and/or compensates for traditional balancing power and services from conventional generation displaced by generation based on renewable energy sources.

- The EcoGrid EU real-time market will improve the utilisation of the inherent (free) flexibility in eg thermal loads (load-shifting potential).

- Activation of a large number of customers will improve the function and competition in the power market through increased market participation and by connecting the wholesale market with the retail market (increase retail competition).

Furthermore, the activation of the demand side, through the real-time market, enables locational pricing for congesting management. This will result in better use of grid capacity, reducing and deferring costs for reinforcements of the distribution network.

2. The Fundamentals of the Real-time Market Concept

The EcoGrid EU market concept is based on the publication of real-time price signals. Adapting the behaviour of flexible resources like electric heating and heat pumps will contribute to maintaining the balance of supply and demand in the power system.

From the wholesale market perspective, this implies that a five-minute price signal is created by for example the TSO, by continuously monitoring the power system and adjusting the price signal to correct the balance of the system. To do so, it is necessary to create reliable forecasts of the expected response to price changes. These will be utilised when computing the marginal price change required to trigger a response of the right size, leading to a proper rebalancing of the system.

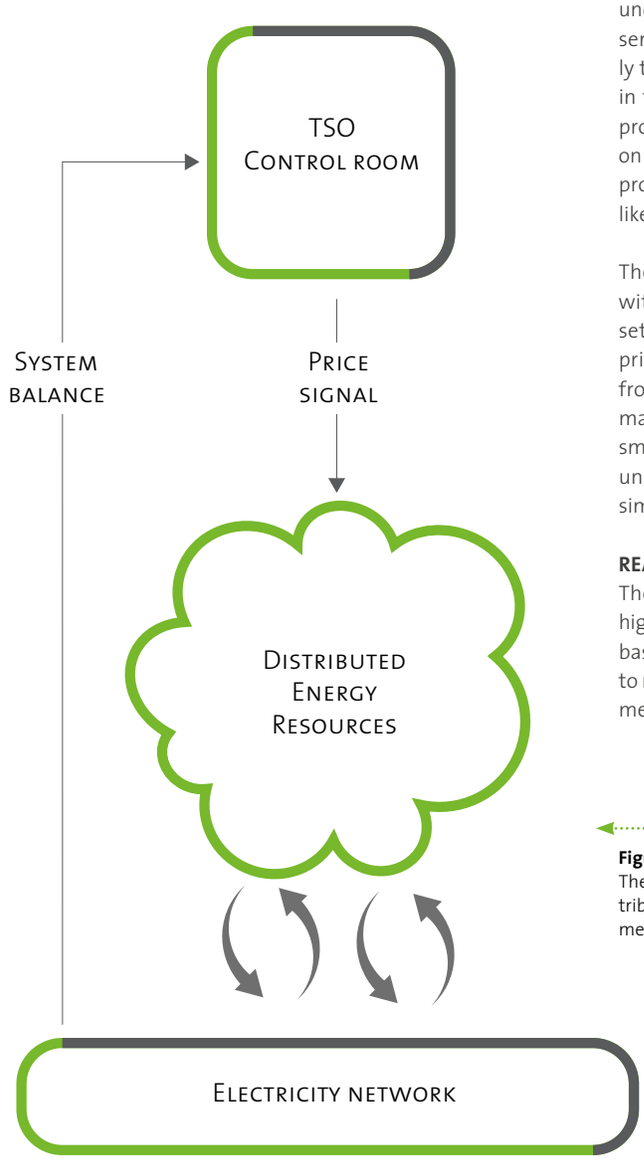


Figure 2: The fundamental idea of the EcoGrid EU market concept. The EcoGrid EU real-time market concept allows regulation of distributed energy resources (DER) through price signal without direct measurement of the individual DER response

MODERNISATION OF THE POWER MARKET(S)

As the wind power and photovoltaics production increases, so will the need for more dynamics in the power system. The real-time market makes it possible to manage many resources, ie activate a great potential of flexible resources on the demand side that is currently inactive.

Therefore, the introduction of real-time market will be an obvious step in the further development of the existing electricity wholesale markets and balancing markets that creates more favourable conditions for the future composition of renewable generation and energy resources. This will not necessarily require a replacement of, but an extension of the current market set-up.

Today and in the future, most of distributed energy resources under the current framework face barriers to supply balancing services. The market operation is currently based on an hourly time resolution that does not reflect the actual dynamics in the power system. The EcoGrid EU real-time market approach means that the trades in the power market are based on what the market players actually do, rather than what they promise to do, which is the practise in the current markets like the day-ahead spot market.

The real-time market concept is based on a 'bidless' market with price announcement ex-ante. This implies that the final settlement price is determined by prediction of the real-time price responsiveness rather than on explicit bids as known from conventional auction based power markets. A bidless market minimises the efforts (transaction costs) put in by small-scale electricity customers or small power generation units, because they must not create bids and schedules, but simply respond to the actual market prices.

REAL-TIME IN FIVE MINUTES

The proposed real-time market concept operates with very high time resolutions (five minutes). It will increase the market-based balancing options and will be an efficient supplement to more costly direct control options (eg congestion management).

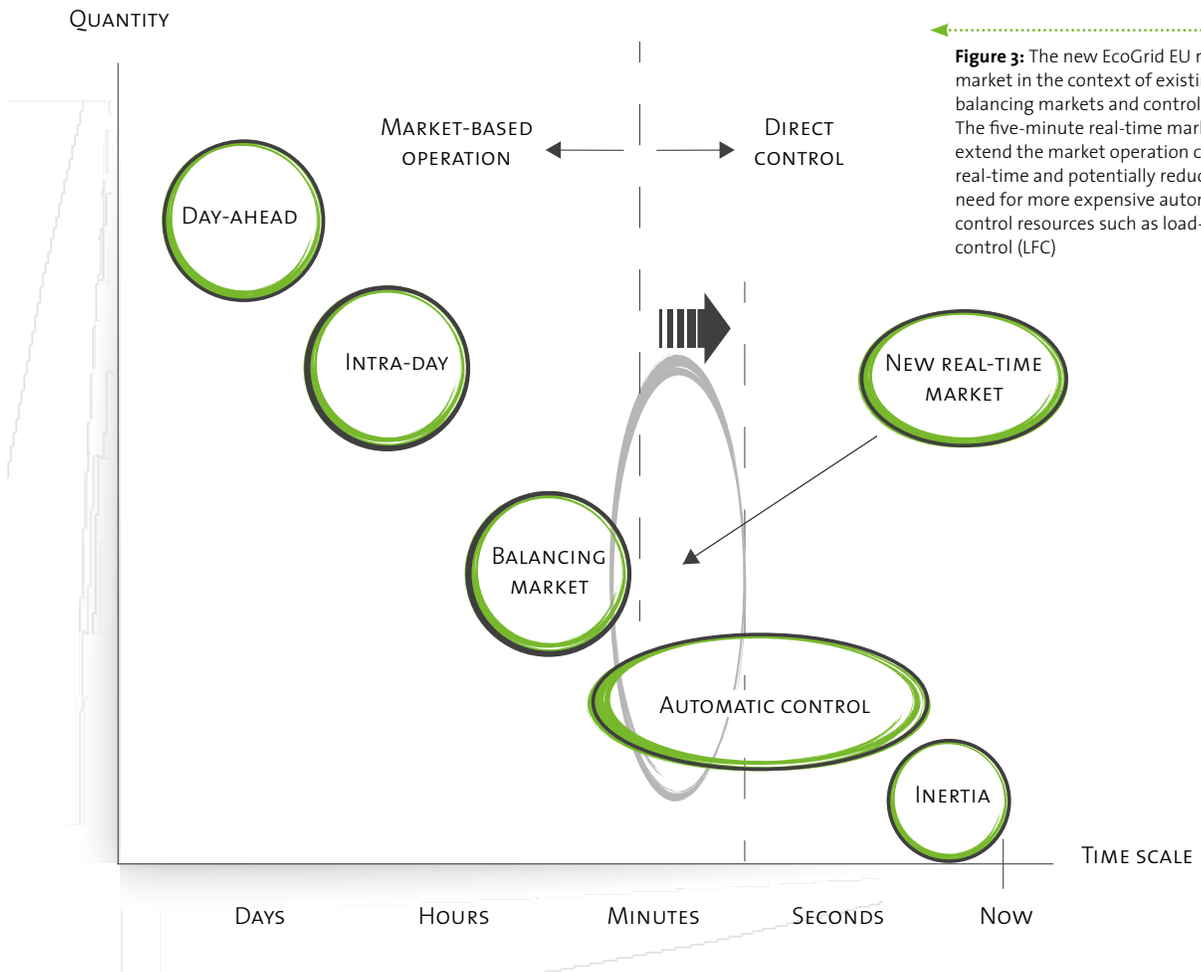


Figure 3: The new EcoGrid EU real-time market in the context of existing power balancing markets and control systems. The five-minute real-time market will extend the market operation closer to real-time and potentially reduce the need for more expensive automatic control resources such as load-frequency control (LFC)

THE CUSTOMER – AN ADDITION TO THE EXISTING POWER MARKET AND SYSTEM

The customer as we know him or her today wants to consume electricity, so they start the 'money flow' by purchasing such electricity from retailers. In addition, the customers pay the electricity grid company/distribution system operators (DSO) for the use of the electricity grid and for the meter and for billing. The market operator trades electricity by 'buying' electricity from producers and 'selling' it to retailers.

In the EcoGrid EU market, the situation is identical with the situation today, but the EcoGrid EU customers also provide balancing power - a flexibility service to the transmission system operator (TSO). It is the retailer or the balance responsible partners that manages this transaction with the TSO on behalf of their customers.

In the EcoGrid EU model, the relation between the retailer and the customer stays entirely in the liberalised market and the customer is free to choose a retailer and a contract model as offered by the retailer of his choice.

BASIC REAL-TIME PRICING VERSUS ADVANCED REAL-TIME PRICING

The first phase of the EcoGrid EU demonstration was initiated in May 2013. During this phase, the basic real-time pricing is tested through a so-called 'open-loop' approach. This implies that the real-time price only will be based on external price information from the Nordic power market (Nord Pool) and balancing markets, as well as system information about availability of wind power. Market rules of the Nordic power system prohibit publishing information reflecting the present power system balance. Therefore, the development of five minute real-time prices are based on the experience gained through the actual demand response of the test participants on Bornholm and realistic public information available about power prices.

Experience gained from the test participants' reaction to basic real-time price signals provides valuable knowledge and input to forecast of demand response. This facilitates testing more advanced real-time pricing through a so-called 'closed-loop' approach that expands the market concept with forecasts of demand response in the second phase of the EcoGrid EU project. Based on the forecast of demand response, real-time prices are calculated and broadcasted to the market in order to obtain a certain objective, ie the amount of balancing resources required by the system operator(s). The balancing services can include a certain net consumption/generation from the distributed energy resources, or a certain reduction of import of electricity with the neighbouring countries or the mainland.

This will facilitate testing the system's ability to follow an objective, eg a certain area or portfolio balance position, thus bringing the demonstration scenario one step closer to a full-

scale implementation, where the objective is overall system balance. The price calculation will utilise advanced demand response forecast models to calculate the price corrections necessary to follow the objective.

The impact on the overall power system balance (ie the Nordic power system) will be negligible, and it is therefore not feasible to generate the price signal at the Nordic power system level, using the system-wide balance as feedback. Therefore, (live) feedback signal will be obtained at local area level (ie for the Bornholm power system area) and/or from live signals from the interval meters.

DIFFERENT WAYS TO TEST PRICE RESPONSIVENESS

The real-time price response can be realised in several different ways – with and without help from automatic control systems and home automation solutions. Four test groups will test different solutions to realise the demand response to real-time prices:

- The manual control group (500 residential consumers)
- The automatic control group with IBM/GreenWave home automation system (700 residential consumers)
- The automatic control group with Siemens/SyncoLiving home automation system (500 residential consumers)
- The group of industry/commercial buildings with Siemens automation systems (up to 100 companies)

The manual control group only has access to real-time price information, ie none of their electric household devices are automatically controlled. The manual control group will only receive manual response assistance, eg through training/energy advice and a feedback system with consumption and price information (see type A in the figure 4).

The automatic control groups and the group of industry/commercial buildings will beside manual assistance also receive technical assistance. All of the automated households will have home automation equipment installed in order to optimise the operation of their electric heating, heat pumps or similar large appliances.

Two main approaches are used to realise the demand response of the automated test participants:

1. Automatic control of individual electric devices/resources (see type B in figure 4)
2. Aggregated control of a portfolio of electric devices/resources (see type C and D in figure 4)

The next chapter 3: 'The ICT platform and solutions' will explain in more detail the use of different ICT software solutions to release the automatic real-time price responsiveness. The chapter also present the two home automation systems GreenWave Reality and SyncoLiving.

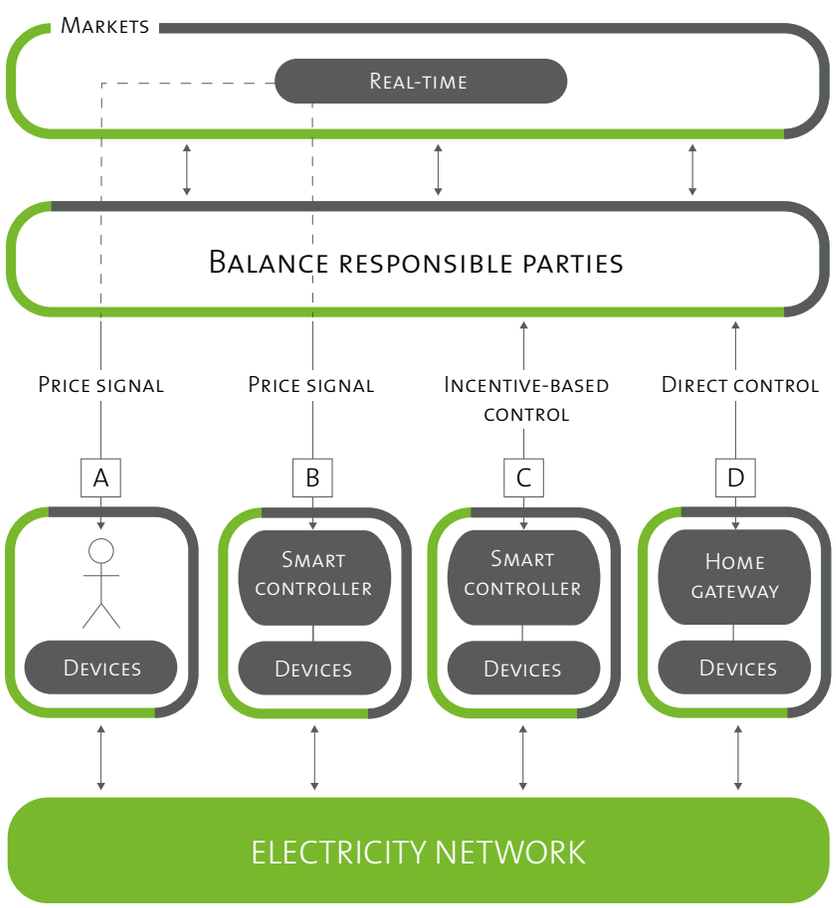


Figure 4. Four different ways to implement real-time price response. Type A responds to one-way real-time price signals by manual control of individual devices/resources. Type B responds to one way real-time prices by automatic control of individual devices/resources. Type C and D use automatic aggregated control of a portfolio of devices/resources

3. The ICT Platform and Software Solutions

The ICT system and software solutions supporting the EcoGrid EU real-time market concept do not start from scratch. The ICT architecture is based on existing software solutions available on the market today, which have been tested in other field situations. The project demonstrates software, all developed to address the development of Smart Grid functions and in this case, the function of the real-time market.

KEY COMPONENTS OF THE ICT APPROACH

Real-time electricity prices are generated at the price generation module every five minutes. The ICT implementation consists of a price generation module and price distribution components. The price generation module takes input from i) TSO, ii) electricity spot market, iii) historical metering data, and iv) weather forecasts. The generation module sends prices and price forecasts to the price distribution system, which uses publish-subscribe technology to broadcast the real-time price information to the customers. The EcoGrid EU ICT concept describes a solution to combine publish-subscribe and so-called internet provider multicast technologies (a method for sending Internet Protocol datagrams to a group of interested receivers in a single transmission). This functionality is required for scaling the ICT system up for nationwide use.

Different internet service providers (ISPs) of an area subscribe to the relevant price signals and within the ISP domains, relevant price streams are multi-casted. This means that the solution can be scaled-up, and in case of a massive deployment of the real-time market concept system across the EU member states, it could accommodate millions of residential electricity customers.

Smart devices or end-nodes adjust their planned consumption according to the price information. All households are connected to a smart electricity meter, which measures the power consumption of the device(s) every five minutes. The measured power consumption data is uploaded to the historical metering data repository once every 10 minutes.

Figure 5 shows the implementation and the key components of the ICT architecture for real-time price distribution in EcoGrid EU.

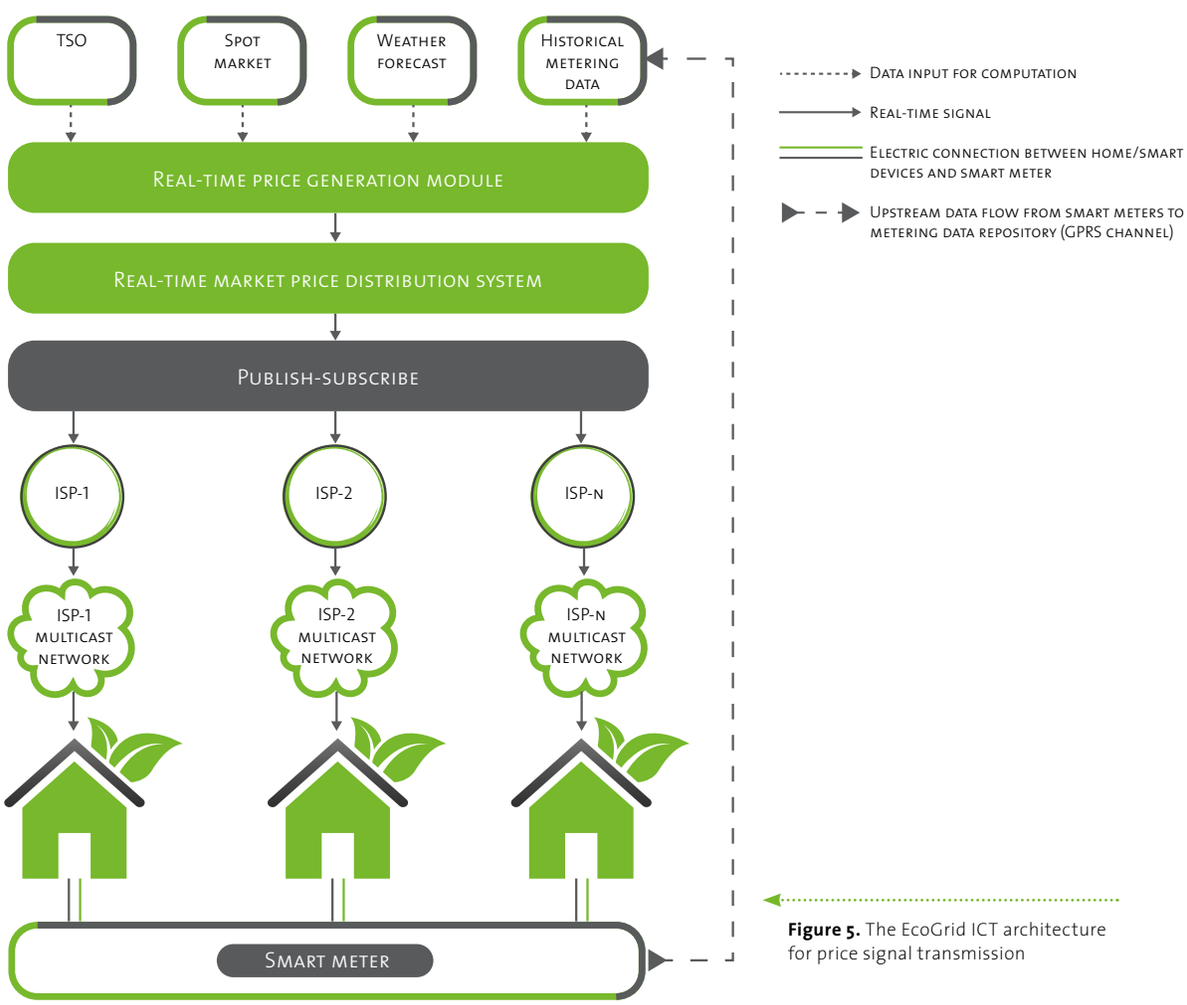


Figure 5. The EcoGrid ICT architecture for price signal transmission

FURTHER SECURITY REQUIREMENTS
A bid-less, real-time electricity market based on five-minute price forecasts, and five-minute price signal resolutions pose new and complex requirements to data, data security and scalability that must be addressed in the development of ICT solutions.

To ensure confidentiality, the security requirements considered in EcoGrid EU are related to:

- The origin price information must be trusted (authenticity)
- The price information is not altered while being transported (integrity)
- The source cannot deny published price information (non-repudiation)
- The price information distributed cannot get injected at a later point in time for another time period (non-re-playability)

THE ICT MARKET SERVER FUNCTION IN ECOGRID EU
The central component for implementing the EcoGrid EU real-time market and interface between the existing power markets and the households is an IBM BladeCenter server, which is installed at an Oestkraft facility on Bornholm. In addition to hosting the EcoGrid EU real-time market, this server hosts the billing application, which is adapted to the real-time market price interval, database and asset management subsystems, user administration, as well as central components of the IBM and the Siemens solution solutions. The server is network connected with appropriate security mechanisms, including user authentication and firewalls.

The ICT platform supports a number of user interfaces to allow the various actors to interact with the systems, eg

- Customers of Siemens and IBM houses are granted access to a portal to view the current status of the houses, including control parameters and temperature readings
- Customers are given access to billing information, including a view of their economic benefits
- Customers are allowed to see all aspects of price information, including historical, current, and forecasted values

HOUSEHOLDS UNDER AUTOMATIC CONTROL
The test households under automatic price control will be tested in houses with IBM-GreenWave equipment and Siemens equipment respectively. The solutions are based either on individual-household control or so-called aggregator control.

Aggregator control is a solution which aggregates the participants' consumption/generation and influences the behaviour (eg new temperature set points) of the connected appliances – depending on the flexibility of the individual participants on the one hand and the requirement of the power system on the other hand. In this way, the available flexibility in the aggregated set can be strategically operated to maximise the financial yield. At the same time, this maximises the impact on power system balancing as the available flexibility is used at the times when the imbalance situation is the most severe.

One part of the IBM-Greenwave houses can be configured into single-household price agent, and another part into aggregated control. All Siemens houses will be under aggregator control.

Two types of aggregated price response methods will be tested. A distributed energi management system (DEMS) application (DEMS) from Siemens and a PowerMatcher application (PM) from TNO/IBM. The DEMS and the PM control the price response in an optimal way for both the power system and the flexible consumer or supplier.

IBM HOUSES WITH AUTOMATIC CONTROL OF INDIVIDUAL DEVICES
These houses are controlled by individual price agents implemented by IBM. This means that there is a smart controller connected to each household, containing a model of the individual heating system, household and inhabitants' requirements.

The models receive input from archived historic power needs for seasonal ambient temperatures in the context of desired user settings.

The one-way price agent embraces the model and predicts the optimal heating panel or heat pump control to stay over time within the desired comfort settings, while exploiting the five-minute real-time price signals.

The control decision to optimise consumption/generation according to the price and the forecasts is then taken locally and under the responsibility of the customer/owner, who is then settled using this price.

Key components in the IBM-GreenWave houses with automatic control of individual devices

The individual devices are controlled by one-way price signals from the real-time market place – through a home agent that communicates with a home gateway (developed by GreenWave reality).
This home gateway is connected to the internet and functions as a hub that wirelessly communicates with individual electrical devices – creating a home area network (HAN) that can be monitored and controlled.

The energy resources controlled include electric heating/heat pumps.

A web-based EcoGrid EU user interface (UI) named 'My EcoGrid' provides the test participants with online access to historical and real-time information about electricity consumption and electricity prices and forecasts.

IBM HOUSES WITH AGGREGATOR CONTROL
These houses use a so-called PowerMatcher software solution. It follows the same EcoGrid EU real-time price signal, but

optimises the consumer flexibility for an entire group of households with a single controller. More simply: Individual 'agents' compete with each other in order to sell their resources in an electronic market place. This increases the probability that demand response is immediately balanced according to the actual amount requested from transmission system operators (TSO) or the balance responsible parties.

Key components of the IBM houses using aggregated control

The IBM households use aggregator control based on the PowerMatcher multi-agent solution for which TNO is responsible. PowerMatcher uses a 'Cluster optimiser' to optimise the response for an entire group of households.

Similar to the other IBM houses, GreenWay reality home automation solutions are used and the participant has access to identical online information from the web portal 'My EcoGrid'.

SIEMENS HOUSES WITH AGGREGATOR CONTROL

These houses are controlled by an aggregator thats influence the behaviour of automatically controlled devices. The user pre-sets the comfort limits and the local controller ensures that these are always satisfied, guaranteeing the comfort of the user locally. The centralised energy management system, DEMS, decides, based on the current price, expected future prices and other connected energy resources, the best way to optimise the consumption/generation of its total portfolio and direct influence each energy resources. This system gives the balance responsible parties certainty about the expected response and a tool to optimise across the entire portfolio.

The Siemens houses can be aggregated together to optimise their energy costs. The system can also easily be extended by additional controllers for additional equipment.

Key components of the Siemens Houses using aggregated control

A central part of the Siemens solution is the energy management system (DEMS) for central control and optimisation of complex decentralised power systems. The 'clever part' is the system's ability to have direct access to and control of the participants' devices to the extent that the balance responsible parties' objective is followed.

In the EcoGrid EU case, the system is used in direct control of relatively simple equipped residential customers by Siemens home automation system (Synco Living).

Participants in Siemens houses have access to online information identical to the IBM houses.

DIRECT CONTROL WITH REACTION FROM AUTOMATED COMMERCIAL BUILDINGS

The EcoGrid EU project will test direct control options with reaction from automated end-users in advanced commercial buildings. Depending on the building complexity, the systems at customer level are configured in a way that a Siemens-deployed building management system (BMS) is capable of integrating with an energy management system through the Siemens DEMS technology. Each local controller ensures comfort levels are maintained, while the DEMS affects the overall parameters in the building's automation system. The process optimisation at building level is managed via BMS or building automation system (BAS), including building equipment control. The cost optimisation, realised by managing real-time pricing, is covered by the central energy management system DEMS.

In many industries (eg chemical, manufacturing, office building) process automation is applied to control and supervises not only the manufacturing process, but also the energy consumption or generation.

It is conceivable that large customers with building automation systems can provide load planning/forecasting capabilities or flexibility information to the aggregator system beforehand. This additional information enables the aggregator to prepare better estimations of the expected response and to optimise across the entire portfolio.

The next sections introduce the two home automation systems used for the EcoGrid EU project based on the GreenWay Reality solution and the SyncoLiving solution respectively – in the project context also called EcoHome(s).

THE ECOHOME SOLUTIONS

Smart Home automation systems (hereafter: EcoHome solutions) will be installed in 60% of the test households. The equipment facilitates automatic control of the heating in the house. Heating can be remote-controlled according to agreement with the user to which extent each household is willing to let the heating be controlled.

Experience shows that a house can easily maintain a stable temperature for a period, even though the heat pump or electric heating is switched off periodically during the day. In the EcoHomes, the electricity consumption can automatically be reduced or moved to other times of the day, from the minutes or hours of the day where all households typically use a lot of power at the same time, or when there is not that much electricity from the wind turbines. In this way, the participants can contribute to relieving the power system, ie avoiding overloading the power grid and at the same time make room for more renewable energy.

THE GREENWAVE REALITY SOLUTION

The equipment from GreenWave reality includes systems for controlling of heat pump and electric heating.

The GreenWave Reality 'package' delivered to the EcoGrid EU customers with heat pumps is illustrated in figure 6. A gateway, which is connected to the household Internet connection,

communicates to a relay connected to the ripple switch of the heat pump. A thermostat regulates the operation of the heat pump together with the heat pumps own control logic and is also communicating with the gateway. A clamp reader can register the actual consumption from the heat pump, and a pulse reader will register the real-time consumption on the smart meter. The participants get power nodes that can be used to retrieve consumption data on the attached appliance as well as timer functionality for these appliances. All settings are made on a GreenWave web user interface.

SIEMENS SYNCO LIVING SOLUTION

The Synco Living home automation solution – an already existing product portfolio from Siemens – is used to control the electric heating and/or domestic hot water boiler via contactors installed in the fuse box of the participants and thermometer probe in the boiler. Depending on the accessibility and wiring of the house, several heating zones, as well as control of the boiler control are created. The automation can be bypassed via manual switches on the contractors.

The equipment package to the EcoGrid EU customers consists of a central unit/control panel that is connected to the internet. Settings can be made both on this unit as well on a web user interface. Micro circuit breakers (MCBs) provided by Siemens perform control of the electric heating. These MCBs are controlled from the central unit based on wireless temperature measurements from the inside and outside of the houses. By attaching an additional thermostat on the hot water boiler and by overriding the normal temperature setting, the electrically heated hot water can be controlled. Enabling control of the domestic hot water boilers is essential, as they can provide flexibility all-year round in contrast to space heating appliances.

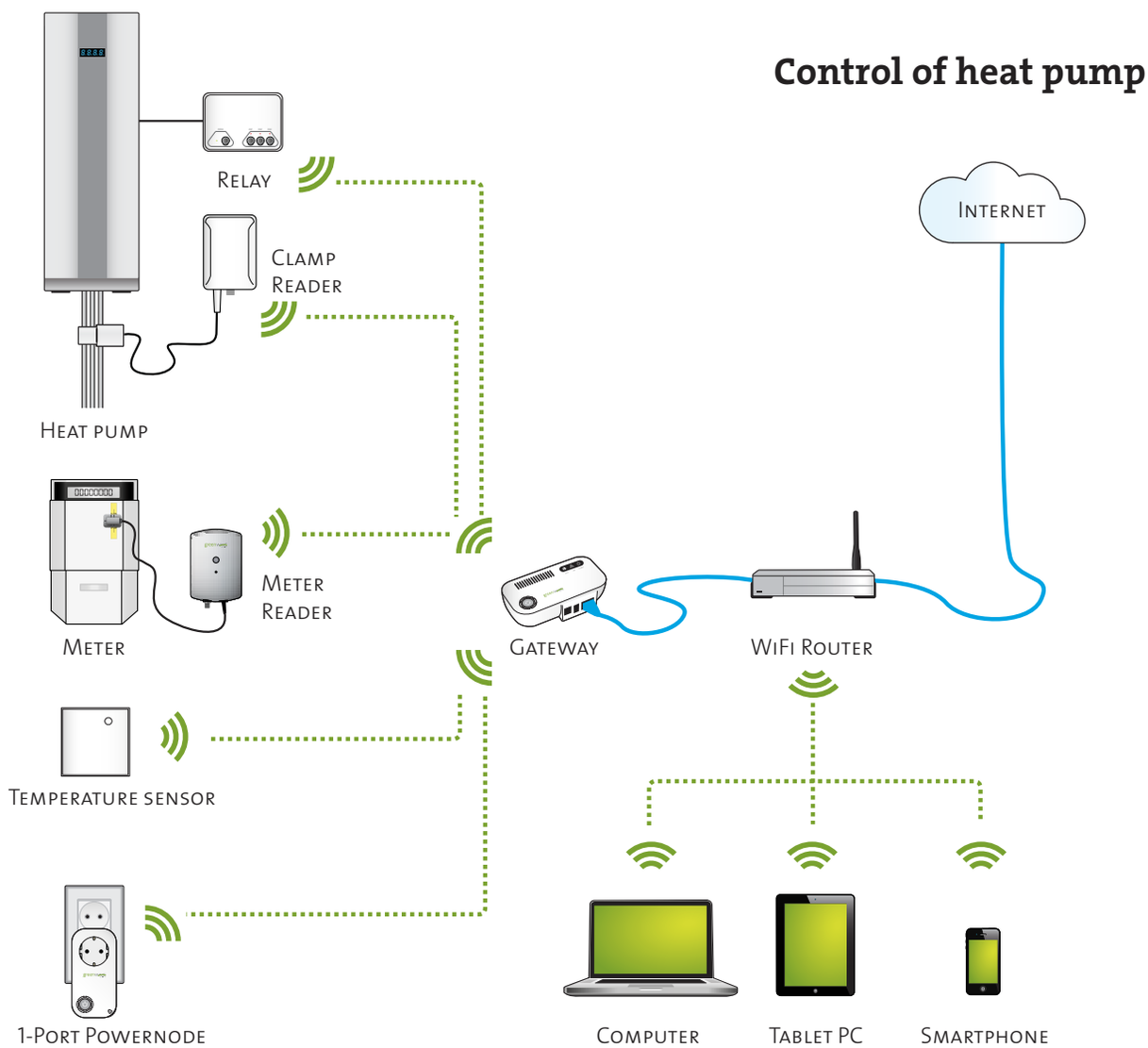


Figure 6. Example of the GreenWave Reality Smart Home solution

Maja Felicia Bendtsen from Oestkraft explains the EcoGrid EU concept to the participants during a training session at Villa Smart

At a public EcoGrid event in February 2013, Martin Sjøberg from Siemens explained the customers how the Synco Living equipment works

NEW SMART METERS

All test participants are equipped with new remotely read electricity meters provided by Landis+Gyr. Settlement of account and registration of the actual power consumption make it easy to get minute-to-minute overview of the power consumption in the course of the day and the month (in Eco-Grid EU, the price is settled every five minutes).

The meter will send consumption data to a database from Oestkraft. Most of the meters will be read based in the mobile network which means that the meter data is sent to the database every 10 minutes. Some meters will also be read based on PLC or fibre optic. Real-time data can be provided from these meters.

THE SMARTNESS FROM THE PERSPECTIVE OF THE INDIVIDUAL CUSTOMER

The Smart Grid innovations in the EcoGrid EU project will be 'invisible' for most people. However, what is visible for the test-participants are the EcoHome equipment, eg how does the equipment work and what does it look like?

A considerable share of the test participants have expressed that the motivation for participating in EcoGrid EU was the

The customers can set up different programs on the Siemens SyncoLiving in-house control panel eg "night", "away" and "home". The information is simply entered on the control panel by pressing the button

installation of new smart equipment. Once the customers have signed up for EcoGrid EU, one of the most frequently asked questions to Oestkraft has been: "When will my smart equipment be installed"?

The living room in Villa Smart

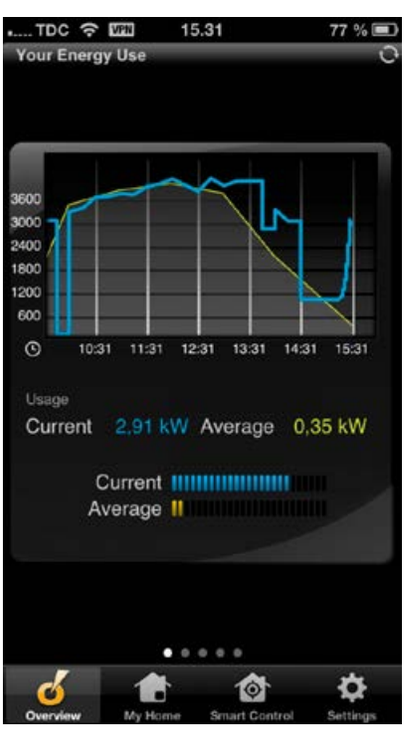
SMART FEEDBACK SYSTEMS

An important part of the IBM/GreenWave smart solution is the user interfaces/feedback systems connected to the home automation system.

The participants will have online access to information about the household's electricity consumption and more detailed information about their EcoHome controlled equipment, eg heat pump or electric heating.

The participants with solutions from Siemens have access to a central control panel installed with the equipment in the house. Some customers prefer this kind of user interface, so they do not necessarily need access to a computer to control their heating. The settings can also, if preferred, be made on the web-based user interface.

All EcoGrid EU participants (except for the statistical control group) will also be introduced to the common user interface 'My EcoGrid', which is the real-time price feedback system developed specifically for the project. The feedback system 'My EcoGrid' is described in more detail in chapter 4.



Some participants with GreenWave reality equipment can use a GWR app and receive feedback on their smartphone/ iPhone: "This is smart...", said one of the test participants on a training session in Villa Smart while she was demonstrating to the other participants how to download and use the app

4. Recruitment and Customer Participation

The recruitment process is considered a success. By August 2013, the objective of 1,900 test households on Bornholm was almost realised.

Before starting the EcoGrid EU recruitment, the communication activities on Bornholm were targeted at raising general awareness of Smart Grid and the EcoGrid EU project among the entire public on the island. The media was informed through press releases and a press conference. EcoGrid EU folders were distributed at local events such as the annual Energy Days on Bornholm. Oestkraft was represented with posters and information material.

Ostkraft's investment in the demonstration house, Villa Smart, represents an important part of the communication about EcoGrid EU and Smart Grid. The demonstration house is one of the first of its kind that puts the ordinary electricity consumer in the centre. The house represents a 'normal' house, showing the visitor the equipment used in EcoGrid EU – called EcoHome.

PROMISING START-UP...

One month after the recruitment kick-off at the demonstration house Villa Smart (February 2012), approximately 366 households corresponding to 15% of the required households were signed up for EcoGrid EU. During the next six to eight months, almost 50% of the participants were enrolled in the project without very strong information activities, although more focused acquisition and recruitment efforts. For many, the enormous interest in participating in the pilot test was unexpectedly high.

In a field test that will have to involve every tenth residential household on Bornholm, it is not realistic that you will find only enthusiasts, first movers or early adopters of new technology/Smart Grid solutions. The recruitment efforts must pay a lot of attention to the so-called mainstream group – people generally not especially interested in energy issues. This was also Oestkraft experienced during the recruitment process.

MEET YOUR CUSTOMER WHERE THEY ARE

The first EcoGrid EU survey and interviews of electricity customers on Bornholm – in advance of the recruitment – showed that a very large group of the respondents were positive towards real-time tariffs and wanted to be flexible and use electric equipment when electricity prices were low. A very high percentage of the respondents (72%) would accept remote/automatic control of their household equipment. Although the importance of financial incentives for end cus-

The electrician team from Oestkraft in front of the demonstration house Villa Smart

tomers in the survey is clearly evident, a considerable percentage of participants in the survey rated environment very high. However, the 300 customers included in the survey are not representative for Bornholm. They have higher income than that of the average household and belong to a privileged group, which is supposed to be 'first movers', and were also the first customers who signed up to EcoGrid EU. It is estimated that approximately 90% of the customers in the first survey have signed up for EcoGrid EU.

It was decided early in the project that the communication with the public should focus on the social values and environmental aspects rather than individual financial benefits of participating in the EcoGrid EU field test. In addition, the participants are guaranteed that they will not 'lose money' by participating in EcoGrid EU. In total, the participants will never pay more for the electricity compared to what they pay according to their normal contract.

ECOGRID EU RECRUITMENT CAMPAIGN(S) AND ECOGRID EU EVENT

Along with direct mails to electrically heated households, an ambitious information and recruitment campaign was initiated. On 3 February 2013, Oestkraft invited to public EcoGrid EU event on Bornholm.

Aside from the goal of involving the existing participants, the objective was also to attract new participants. In order to create 'word-of-mouth', EcoGrid EU postcards and advertisements were distributed to 70% of all households on Bornholm through the local newspaper 'Bornholms Tidende'. The message of the campaign was: "We are still looking for more participants, particularly those with electric heating/heat pumps".

The first part of the event was dedicated to the existing participants. The second part was an open EcoGrid EU café for all customers on Bornholm, where the visitors could ask questions and sign up for the demonstration. The visitors could enjoy free cake and coffee, exhibitions, short talks by the mayor of Bornholm, Energinet.dk and the Danish Consumer Council as well as entertainment by a local band. About 1,000 persons showed up and spent a great part of their Sunday at the event.

To attract the last participants, Oestkraft sent a second direct mail to 2,500 customers with electric heating. The message was: "If you want to participate – this is your last chance...". It proved to be very efficient. In one week, 100 more electrically heated households were recruited.

EcoGrid Event, February 2013

EXAMPLE OF COSTUMER INFORMATION AND RECRUITMENT ACTIVITIES					
	Information and recruitment phase O (before official recruitment kick-off)	**Information and recruitment phase I**	**Information and recruitment phase II**	**Information and recruitment phase III**	**Information and recruitment phase IV**
Target group	The general public/The press/ Politicians	All customers on Bornholm with focus on the 'first movers'	More focus on customers using electric heating/ heat pumps	Only customers using electric heating/heat pumps	Only customers using electric heating/heat pumps with focus on 'the main stream'
Main message	Introduction of the Smart Grid vision/The EcoGrid EU project	"Join EcoGrid EU– help make a difference and put Bornholm on the world map"	Greater focus on formulating gains participating in EcoGrid EU	"If your neighbour is participating, then maybe you could be interest-ed"	"Your last chance for signing up to EcoGrid EU." Personal support/ help during the demonstration period
Instruments	Press release A brochure for distribution at local events such as the energy days on Bornholm	The mayor inaugurates Villa Smart by starting an interactive EcoGrid EU Lego® model Press conference in Villa Smart and official start-up of recruitment EcoGrid EU magazine	Direct mail to electric heating customers Information material on the 'EcoHome'-solutions Online sign up assistance	Information campaigns in the media (word of mouth post cards etc.) Direct mails / personal phone calls	Second direct mail to 2,500 custom-ers with electric heating
Results	Great media attention/positive reception of the EcoGrid EU project 50 households wish to sign up beforehand	Great media attention and approximately 100-200 locals visited Villa Smart on the open house event 366 new sign ups (status June 2012)	All in all 877 participants (status October 2012)	Approx. 1,500 participants (March 2013)	Approx. 1,700 (June 2013).

CHANGE IN RECRUITMENT CONDITIONS

At first, it was envisioned to control a whole suite of household machines. It turns out though that although such appliances have been on the market for years, there is still no standard protocol for automating them. Therefore, it was decided only to install EcoHome equipment in households with either electric heating or heat pump. This was also preferable in order to maximise the total volume of load-shifting capacity achieved during the EcoGrid EU demonstration. To put it in another way: the electric consumption of the heat pumps and electric heating devices are typically higher than that of other electric household appliances (eg washing machine, dishwasher etc.) – thus increasing the potential of flexible consumption. Furthermore, the customers are not expected to experience serious losses in heat comfort, if they are flexible in their consumption by shifting the use of heat pumps/electric heating in short periods in the course of a day.

Focus in the recruitment process changed, as the participants could not be randomly selected. It was also necessary to recruit participants who were not particularly interested in the EcoGrid EU project. In the direct-mail campaign targeted these customers, Oestkraft emphasized that they would offer individual service and support during the entire demonstration. The importance of allowing for personal contact with the 'mainstream' group of customers should not be underestimated.

MANY HOUSEHOLDS ARE ON A WAITING LIST

By the end of August 2013 1,900 residential EcoGrid EU households had enrolled for demonstration, which was the amount required for the demonstration.

Later on, it turned out that many of the customers who had signed up were not qualified for participation, eg participants who already had heat pumps installed that were not compatible with the EcoHome equipment. Also, many of the customers with electric heating who had signed up to EcoGrid EU did not use electric heating as their primary heating source. Therefore, many of the participants with heat pumps and electric heating have been signed out of the project.

All in all, the Bornholm citizens have shown an enormous interest in participating in the EcoGrid EU project. About 180 customers are on waiting list – and Oestkraft is continuously receiving requests from customers with heat pumps/electric heating who want to take part of the demonstration.

Today most people on Bornholm have heard about EcoGrid EU. Information about the project appears regularly in local newspapers and TV. The local electricity company Oestkraft and EcoGrid EU families contribute with interviews and stories from every-day use in the media.

THE 'CHICKEN OR EGG' DILEMMA

Experience from similar demonstration projects shows, how important it is that the participants have their equipment installed relatively short time after signing up for the project. From the outset this was also the aim of Oestkraft and the project in general. The reality is that the recruitment for the demonstration project has taken place at a faster pace than the instalment of the equipment. In retrospect, it could have been wiser to start the recruitment at a later time and have taken the fact that not all components of the EcoGrid EU equipment are standardised products and that development takes time into account. On the other hand, it was impossible to know in advance whether enough participants would sign up for the project within the determined period of demonstration. The wait can feel long for the participants, which is why it is important that they are continuously being updated and informed about the project.

ECOGRID EU TRAINING

The primary information channel is e-mail and the website www.EcoGridBornholm.dk. Oestkraft also invites all participants (except for the statistical control group) to training sessions.

The education of participants takes place in the demonstration house Villa Smart and communication and technical advisors from Oestkraft will give individual advice to the participants regarding their particular role in the project and the new equipment.

An interactive educational wall in Villa Smart showing the EcoGrid EU setup will give the participants an overview of the communication and power flows in the EcoGrid EU system. Especially important is how the installed EcoHome solutions communicate with customers' household equipment (eg heat pump and electric heating) and interact with the rest of the power system through real-time price signals

The training will be organised so participants in the different participant/equipment groups have training together. The training is planned to take 1-2 hours per session.

The training session will be split in different topics depending on what is relevant for the type of group receiving the training. However, all participants will have a general introduction to EcoGrid EU. They will also be informed about the general energy transition happening in Denmark and the challenge this presents to our energy systems and how they, as consumers, can play an active role in overcoming some of these challenges.

MY ECOGRID

After the general introduction to EcoGrid EU, the participants are introduced to the customer feedback system 'My EcoGrid'. At 'My EcoGrid', the participants can find information about current prices and prognosis for the coming hours. They can also find data from the meter installed in their homes and compare price, consumption and cost over time. Once every month, the participant can find a report informing them about their performance for the past month, where the EcoGrid EU cost is compared to the cost of a non-Smart Grid product.

TRAINING FOR WHAT?

The purpose of the training session is to give the participants an understanding of Smart Grid in general and EcoGrid EU in particular. The concept of the real-time market is a complex topic to communicate, especially for the average power consumer. Until now, the normal consumer has not paid special interest to the timing of their electricity consumption, as time-of-use had no influence on the size of their bill. In EcoGrid EU, the participants will have a radically different setup, as they not only get a lot of information about their consumption, but they must make up their minds about whether they are willing to compromise their normal comfort level in the prospects of saving money.

Another challenge is to explain to the participants that they certainly cannot expect reductions in their electricity bill, if any at all. Therefore, it is important to tell the participants about the future benefits of EcoGrid EU and Smart Grid not only from an individual point of view, but also from the perspective of the society.

INSTALLATION AND CONSULTATION

Some of the persons closest to the EcoGrid EU customers/participants are the seven electricians from Oestkraft installing the EcoHome equipment in households on Bornholm. It typically takes from one to three hours to install the EcoHome solutions and make it fit the consumers' wishes; the time spent depends on how many questions the consumer has. It is the electricians that together with the consumers define the comfort preferences and priorities, eg minimum temperatures in the house and flexibility in usage of electricity. The industry partners provide continuous support via telephone and email to ensure that the electricians become experts in the EcoHome equipment.

A price speedometer from 'My EcoGrid' showing the real-time price. The participants can also find information about minimum and maximum price during the last 24 hours and the price trend within the current hour, next five hours and next 10 hours

Lars Rasmussen, electrician at Oestkraft, installing EcoHome equipment. He and his colleagues spend much of their time in the homes explaining the customers how the equipment works

5. Next steps and open questions

In the first part of the EcoGrid EU project, the task was to prove the sustainability of the market concept in theory. Much effort has been put into the establisment of a common understanding and consensus of the fundamental principle of the EU real-time market concept. The concept has continuously been challenged by ongoing discussions among the project partners and through interesting dialogues with external stakeholders, including discussion and workshops with the EcoGrid EU reference group.

THE ROBUSTNESS OF THE ECOGRID EU REAL-TIME MARKET
Will the EcoGrid EU market concept work 'outside' Bornholm? It will certainly not be possible to implement a single-standard EcoGrid EU real-time market concept all over Europe without changes to the current regulation framework situation(s). An example of the current differences in market design is the choice of gate closure time, ie the moment from which the TSO does not allow action by market parties anymore and is resolving all remaining imbalances by himself. Another example is the imbalance settlement, ie imbalances are settled between the balance responsible parties and the TSOs using different pricing methods.

Nevertheless, in a deployment and replication scenario of the EcoGrid EU real-time market, it is important not only to focus on the barriers due to the current differences in market designs. The implementation of the real-time market mechanisms must also consider the harmonisation process of the electricity markets in Europe, eg a process of drafting framework guidelines and network codes aiming at providing harmonised rules for cross-border exchanges of electricity.

Furthermore, some of the real-time market core elements are likely to be more easily integrated into some systems than in other.

THE FLEXIBILITY OF THE ECOGRID EU MARKET CONCEPT
Currently one of the open questions is whether or not the EcoGrid EU market concept can be replicated without replacing the existing markets or changing the fundamental principles of the current power balancing mechanism?

Several parts of the EcoGrid EU concept are flexible, ie does not conflict with the current practises, eg:

- The EcoGrid EU project implements one specific retailer contract model in the Bornholm demonstration, but the concept does not endorse or rely on a specific contract model.

- Likewise, the EcoGrid EU project uses different smart home solutions and different ICT control technologies. This means that the systems are vendor independent, allowing for competition and freedom of choice on the hardware and software components.

- The fundamental concept and the infrastructure allow a 'real time' market with lower time resolutions than five minutes. It is relevant in markets where, eg the smart meters with 15 minute or even hourly data readings have already been rolled out, although the dynamic response for balancing and congestion management will be reduced.

THE STANDARDISATION ISSUE
In the view of rolling out a smart grid solution that encompasses different vendors, standardisation on the communication and interfaces of the smart home devices need to be taken into account. Another important aspect is the security throughout the system and the use of existing standards for security as well as measures to put privacy in place. Based on the demonstration experiences, the industry partners in EcoGrid EU will provide a framework for standards in communication and device descriptions, so an interoperable system can be assembled.

RECRUITMENT OF COMMERCIAL CUSTOMERS
The recruitment of industry/commercial buildings is still ongoing. The commercial customers that Oestkraft has visited have been positive towards EcoGrid EU, but technical challenges prevent many from participating. At present, automating solutions are considered for the operation of manure mixers, electric fork-lift chargers and cold storage. The ferry terminal in Rønne is a good candidate for upgrading the existing building automation system. The project is also considering the energy storage potential related to eg electric vehicles and mobile cell mast batteries.

THE ROLE OF THE TSO AND THE BALANCE RESPONSIBLE PARTIES
An important task in the project is to define the role of the TSO versus the role of the balance responsible parties. So far two alternatives are discussed.

In alternative 1, the TSO is responsible for organising the EcoGrid EU market, in parallel with (or potentially replacing) existing balancing markets. In this case, the flexibility of EcoGrid EU costumers is directly offered to the TSO via the retailer and the balance responsible parties, allowing for system-level optimal dispatch.

The TSO issues a fixed price for imbalances prior to each market time unit, which means that the TSO carries the whole risk of setting the price at a value that will balance the system. In contrast, the commercial stakeholders, eg BRPs and retailers, can choose their own risk level by responding to the prices or not.

In alternative 2, the real-time pricing concept is used by balance responsible parties, retailers, or VPP operators to control a portfolio of customers, whilst still bidding into the present balancing market. This allows for implementation without altering or adding to the system-level markets. The caveat is that one real-time price signal would be generated per BRP/retailer/VPP, potentially leading to sub-optimal dispatch from a system-level perspective.

The risk of price setting is shifted from the TSO to the commercial stakeholders. In this scenario, the TSO operates the normal balancing market with firm bids, whereas the commercial stakeholders need to create the real-time price signal and thus carry the risk. The TSO may provide information about eg activated volumes and prices in the balancing market to reduce the risk, but at the end of the day, the risk stays with the commercial stakeholders.

The risk of chosing alternative 2 is that the EcoGrid EU flexibility is used to reduce the imbalances of the individual BRP, rather than reduce the system imbalance, because the system imbalance can be in the opposite direction than the BRP imbalance. This may lead to sub-optimal dispatch from a socio-economic perspective. On the other hand, this solution can be implemented without altering the present markets at all, thus providing a possible fast-track for utilising small-sale demand-side flexibility.

ARE PEOPLE READY FOR SMART GRID?

The experience from the EcoGrid EU recruitment process shows that communication and involvement of the participants are key elements to project success. It has proven successful so far to keep the participants interested and signed into the project. Now comes the even greater task of keeping them involved. Based on relevant theory on consumer behaviour and experiences, an ongoing task is to plan and initiate activities for the involvement of the participants during the demonstration phase.

The project experience is that the great support of the EcoGrid EU project from the public on Bornholm has been an important precondition for the recruitment to the EcoGrid EU demonstration and willingness to test the real-time market concept.

Therefore, perspectives for a wider implementation of EcoGrid EU depend on the degree of 'Smart Grid readiness' among the electricity consumers. The support of the project from the public on Bornholm is probably due to the fact that the population already was aware of many of the challenges associated with wind power and that the goal of converting to a CO_2-neutral electricity generation is deeply entrenched among the people on Bornholm and the Danes in general. In other words, it will be easier to realise the EcoGrid EU project in areas where the environmental awareness is already high, and the challenges of handling more renewable energy and wind power are largest – and thereby also the wish for effective solutions for how to meet the challenges.

One of the largest tasks, preceding the EcoGrid EU demonstration (and later: in a deployment perspective), has therefore, primarily been to establish a broad understanding of the Smart Grid vision behind EcoGrid EU and of how activating small-scale electricity consumption /electricity production via a real-time market can make a difference. The communication with the electricity consumers has furthermore appealed more to good citizenship rather than narrow financial gains.

NO SILVER BULLET

It is important to clarify that the EcoGrid EU market concept only represents one possible suggestion for a cost-effective activation of flexible consumption at household customers and/or smaller production units.

The project's most important contribution is to demonstrate (or make plausible) that the EcoGrid EU concept – under the right conditions and with a reasonable effort – could be made to work in a long-term time perspective and to identify the necessary and sufficient preconditions, eg:

- The real-time market concept must be accepted/understood by regulators and existing market players.
- The real-time market concept must prove its economic value for the society and for stakeholders, eg the 'retailer-balance responsible parties' must be convinced about the added value for him and his customer (good business case).
- The real-time market concept must prove its ability to provide reliable and efficient balancing services to the TSO without jeopardizing the grid security (at system level and at distribution operator level)

THE TWO ALTERNATIVE RESPONSIBILITIES OF THE MAIN STAKEHOLDERS IN THE REAL-TIME MARKET		
	1) Real-time market implemented at system level	2) Commercial stakeholders create their own real-time prices (system-level markets potentially unchanged)
TSO	Responsible for EcoGrid EU market, providing real time price signals to balance the system	Provide information on balancing status for commercial stakeholders
BRP	May or may not respond to the EcoGrid EU system price. Potentially risk free.	Bid into balancing market, and generate real-time prices to control portfolio according to accepted bids.
DSO	Contracts with commercial stakeholders to contribute to congestion management (optional)	
Retailer	Settle with customers based on real-time price contracts, fixed bonus contract or other contract of customer's choice	As in 1) + may potentially take the role of real-time price provider (depends on the relation BRP-retailer)
Customer	Choose retailer with suitable product, reflecting customer needs and wanted risk level. Allow for automatic control of selected appliances and/or provide manual demand response.	

The issue of replication and deployment of the EcoGrid EU real-time market is an ongoing project task that runs in parallel with the field test.

This is a key dilemma in relation to the replication of the EcoGrid EU concept: It is hard to believe that radical changes can happen overnight in order to achieve a 'perfect EcoGrid EU real-time market'. On the other hand, a gradual introduction of the EcoGrid EU concept parallel to existing market – without dealing with this challenge – could be undermining the true effect of the real-time market.

Roles and Responsibilities of the EcoGrid EU Partners

COMPANY	COUNTRY	ROLE IN THE PROJECT
SINTEF (Coordinator)	Norway	WP 9 leader: Project management. Have a significant role regarding eg demand response, including forecast models of aggregated demand response
Energinet.dk (TSO)	Denmark	Project initiator WP 6 leader: Demonstration and evaluation WP 8 leader: Disseminaton. Contributes significantly to energy RTD and manage the national Danish programme for energy research
Østkraft	Denmark	DSO – hosting the field-test on Bornholm. WP 5 leader: Installation and Training. Contribute with comprehensive experience with local energy field-test on Bornholm
DTU-CET	Denmark	Centre for Electrical Technology is a part of the Technical university of Denmark. WP 1 leader of the RTD part: Market concept and architecture
Siemens	Denmark/ Germany/ Switzerland	WP 4 leader: Implementation of DER response. Contributes with knowledge and products around eg innovative buildings automation and the energy management system DEMS
IBM	Denmark/ Switzerland	WP 3 leader: Implementation of market place and ICT. The key task is development of the prototype market and other server software components. These are required to execute the real-time price-stimulated demand-response capabilities
ECN	The Netherlands	Energy research centre. Assists with knowledge with e.g. end-user interfaces, demand response system and active customer participation. Has a central role in the evaluation of the demonstration
ELIA (TSO/DNO)	Belgium	WP 7 leader: Framework, condition, deployment, replication and international collaboration
Tecnalia	Spain	Private, non-profit technology research and innovation centre. The main project contribution is eg development of models of the relevant loads of residential and commercial customers to be used for active demand
AIT	Austria	The Austrian institute of Technology. Main project task is related to small-scale production units, and AIT has a central role in the evaluation of the demonstration.
TNO	The Netherlands	Energy and innovation consultancy company. Brings knowledge from the PowerMatcher aggregator technology
Eandis (DSO)	Belgium	The biggest DSO in Belgium. Assists EcoGrid with knowledge of eg large-scale meter roll-out. Main task in the project is related to deployment perspectives
EDPD	Portugal	DSO in Portugal. Support the project with Portuguese Smart grid experiences. Main task in the project is to perform barrier analysis in relation to deployment perspectives
Tallinn University Technology, TUT	Estonia	Assist the project with modelling and measurements, and experiences/ modelling in particular related to electric vehicles and storage devices
Landis+Gyr	Denmark	Provider of advanced meter and responsible for meter infrastructure installations on Bornholm, including meters, AMR software and communication between central servers and meters

* EnCT GmbH was previously a part of the EcoGrid EU consortium. The consultancy company was responsibility for eg customer surveys on Bornholm and development of the EcoGrid EU feed back systems

EcoGrid EU Partners