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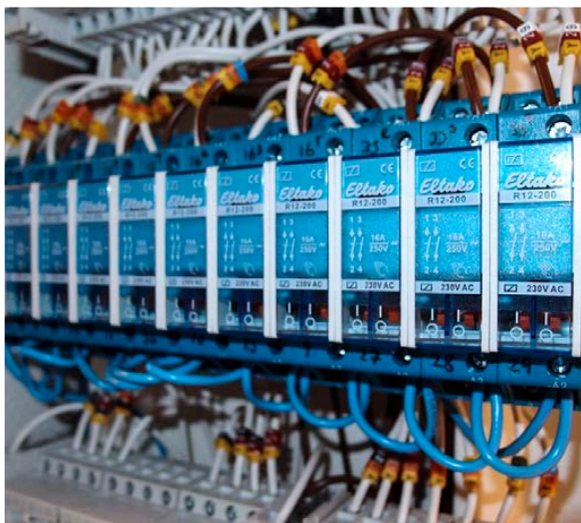
EcoGrid EU: From Implementation to Demonstration

A large scale demonstration of a real-time market for demand side participation



EcoGrid EU: From implementation to demonstration

PREFACE

The EcoGrid EU project has come to an end after four and a half exciting, productive and challenging years. The project was granted by the European Commission FP7 'ENERGY .2010.7.1.-1' call and has been running since March 2011. The Danish Transmission System Operator (TSO) Energinet.dk was the initiator of the project, and the Danish island of Bornholm was chosen as the demonstration site. The efforts of the local utility (DSO) Østkraft and the positive involvement of test customers have contributed to making this project a unique demonstration of a new market concept.

This project has truly demonstrated the complexity of translating a theoretic concept into a full-scale live demonstration with real customers using the existing market framework as a basis.

The project differs from most smart grid projects because it uses the market mechanisms to motivate the consumers to adapt their consumption to the marginal price of electricity. Thereby, the costumers contribute to balancing electricity generation and load in the power system.

The results of the project show that it is possible to use a price signal to control load up and down at short notice without compromising the customer's comfort requirements.

The challenges and successes and subsequent discussions during the project period have strengthened the EcoGrid EU Consortium's level of knowledge, innovative ability and practical problem-solving skills. The yearly consultations with the project's Reference Group have additionally yielded corrective questions and ideas and valuable input for the further action to be taken.

The evaluation of the results of the demonstration shows that almost all the key performance indicators (KPIs) have been met, and that the concept of the near real-time market is viable. The project recommends, however, an evolution of the EcoGrid EU concept in Europe where the starting point for power market development varies from country to country. The lessons learned concerning consumer recruitment, motivation and participation, deployment and use of metering with high sampling frequency (5 minute) and load control technology should be more generally applicable in the near future.

The Consortium is satisfied with the overall achievements of the EcoGrid EU demonstration project. We are now looking forward to sharing the results, insight and lessons learned from the project, and hope that our final documentation will inspire stakeholders to promote further development and utilisation of the demand response potential of Europe.

Ove S. Grande
SINTEF
Project Coordinator

Reader's Guide

This is the final EcoGrid EU report, highlighting the main results and lessons learned from the field test of the EcoGrid EU real-time market on Bornholm. The report is targeted not only towards the expert reader, but also towards people who in general want to gain more insight into smart grid and active participation in the power market from the demand side.

The report consists of two main parts:

– The first part presents highlights and main results, starting with the EcoGrid EU storyline (chapter 1), a description of how the EcoGrid EU concept was demonstrated (chapter 2), before presenting overall evaluation results (chapter 3), the replication of the EcoGrid EU project (chapter 4), conclusions, and recommendations (chapter 5).

– The second part includes interviews with EcoGrid EU experts, where the partners talk about their experiences and individual points of view: Per Lund and Preben Nyeng (Energinet.dk), Jacob Østergaard (DTU-CEE), Bernhard Jansen and Olle Sundström (IBM), Martin Sjøberg (Siemens), Maja Bendtsen (Østkraft), Jessanne Mastop (ECN), and Georgios Giannopoulus (ELIA).

New readers, less familiar with the project, are recommended also to read the mid-term status report 'EcoGrid EU: From Design to Implementation' which focuses on the preparation for demonstration: The recruitment of customers, development of the EcoGrid EU market concept and ICT design.

The reader who wants further details and background of the results is recommended to read the final technical EcoGrid EU reports:

- Overall evaluation and conclusion, Deliverable 6.7 (2015)
- Exploitation Plan, Deliverable 7.3 (2015)
- Replication Road map, Deliverable 7.4 (2015)

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

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Contents

Summary

Demand response is no longer a nice add-on to the power system. The continuing increase in fluctuating forms and difficult-to-forecast nature of renewable energy (eg wind power and solar energy) and simultaneous phase-out of thermal power plants across Europe has increased the need for new, fast ways of balancing the power system, especially during the critical peak hours.

The EU´s electricity and energy efficiency directives clearly state that the demand side should have access to the power system on an equal basis as that of generation. Also, the European Commission has mandated the TSOs (ENTSO-E) to develop clear rules (Network Codes) for system operation and market functions that foster demand-side participation in power market balancing.

OBJECTIVES AND CHARACTERISTICS OF ECOGRID EU
From the very beginning, the ambitious objective of EcoGrid EU was to develop and demonstrate - on a large-scale - a generally applicable real-time market concept for smart electricity distribution networks with high penetration of renewable energy sources and active user participation. It should thereby reduce the need for costly flexibility on the production side and/or compensate for traditional balancing power and services from conventional generation displaced by generation based on renewable energy sources.

The very fundamental concept of EcoGrid EU is to balance the power system by repeatedly issuing a real-time price signal for flexible resources to respond to. The price signal will be continuously updated in order to keep the power system balanced, by increasing the price when there is a power deficit in the system, and vice versa.

To test the EcoGrid EU concept, smart home equipment was installed at a large number of households. Customers were able to either manually respond to real-time prices, or they received equipment that controlled their heating system to respond automatically to price signals.

MAIN FINDINGS
The EcoGrid EU demonstration has proven that the customers reacted in a way that helped balancing the power system following a real-time price signal.

Also, there is a significant peak load reduction potential: The activation of flexible consumption with a five-minute real-time signal reduced the total peak load of the EcoGrid EU participants by approx. 670 kW. This is equivalent to 1.2% of the peak load on Bornholm. Households, having equipment that controlled their heating system to respond automatically to price signals, accounted for 87% of the peak load reduction.

In a replication perspective, customer involvement is the key to success. It took extensive communication efforts on the part of Østkraft to fulfil the ambitious target of attracting almost every tenth of all residential electricity customers on the island of Bornholm. Moreover, a big task was keeping the participants involved throughout the project. Lessons learned is that personalised customer advice works best, but should be kept to a minimum due to the sheer volume in a national roll-out.

Another precondition for wider smart grid roll-out in general and the EcoGrid EU real-time market in particular is the design of immediately available equipment that is specifically designed for automatically providing power system services to the TSO or DSO upon receiving an external control signal of any kind (market or technical).

The EcoGrid EU project hardware and software providers (Siemens, IBM, TNO and Landis+Gyr) all had to develop laboratory prototype equipment utilising existing home automation energy saving equipment with, eg external communication and power supply add-ons. Furthermore, much of the software in the form of the so-called price-agents (energy management systems) for each individual house had to be developed almost from scratch. Hence, to facilitate a much more seamless functioning of the equipment the development of dedicated 2nd generation equipment is necessary.

THE ECOGRID EU PARTNERS WILL MOVE FORWARD...
The EcoGrid EU project and the solutions developed are core to the smart grid strategies of the industrial project partners. In the interviews with the EcoGrid EU partners (Part II). Siemens and IBM are sharing their experiences in the project and how they think the solutions deployed in the EcoGrid EU project will lead to (or have led to) new product features in existing control products and software. ELIA (Belgium) and Energinet.dk (Denmark) are representing the TSOs in the EcoGrid EU project. Their advice is first to increase demand-side participation within the current market setups across Europe while driving a development that will prepare customers and market actors for the future challenges of the power system and how each of us can contribute to help balancing and operate the power system for the benefit of society and individuals.

EcoGrid EU has shown Østkraft – the DSO on Bornholm – that many of their customers are ready for the smart grid, and Østkraft is ready to take the lead in a smart grid deployment. The EcoGrid EU representatives from academia (DTU-CEE and ECN) point out their focus area from a research and development perspective. For example one of the critical factors in the development of smart technology is the development of standards to ensure interoperability between different home automation solutions. Although the interviews in this report represent the individual partners' point of view, it is hard to disagree with the following statement: 'We have to think out of the box...smartness from a consumer point of view is certainly not about kWh, but rather about convenience or comfort...". (Interview with Jacob Østergaard, DTU-CEE).

Terminology and Acronyms

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

Demand response (DR) – is the terminology used in EcoGrid EU to describe 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 wholesale 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 a fast response compared to conventional markets.

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

Smart grid – is an electricity framework that can intelligently integrate the actions 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.

AMR – Automatic meter reading
BRP – Balance responsible party
DER – Distributed energy resources
DR – Demand response
DSO – Distribution system operator
EDSO – European Distribution System Operators
ENTSO-E – European Network of Transmission System Operators for Electricity
HEMS – Home energy management systems
ICT – Information and communication technologies
ISP – Imbalance settlement period
KPI – Key performance indicators
RES – Renewable energy sources
TSO – Transmission system operator

1. The EcoGrid EU Storyline

The large-scale EcoGrid EU demonstration on the Danish island Bornholm was launched in March 2011 and finalised in August 2015. The project efforts in the first two years focused on the design of the real-time market concept, demand response modelling and the implementation of the backbone hardware and software solutions. The last two years focused on test, tuning and demonstration (see figure 1).

In parallel with the concept development and design of the ICT architecture, the local network operator – DSO – Østkraft (host of the EcoGrid EU field test) was completing the recruitment of participants. At the end of 2013, the objective of about 2,000 test households was met. Smart meters had been installed at all participants and, in addition more than half of the customers were provided with home automation equipment. Furthermore, the installation of 18 automation systems at industrial/commercial customers took place throughout 2014.

In November 2013, the first houses were activated for automated price response (demonstration phase I). The initial plan was to start the full-scale demonstration (demonstration phase II) as of January 2014, but the demonstration was put on hold due to the unexpected technical problems influencing both expected demand response and customer satisfaction.

A full end-to-end tests of the entire demonstration set-up (hardware, software etc.) were performed in December 2013 and the first quarter of 2014 in order to remove technical errors and bugs and to fine-tune for optimal price elasticity.

The full-scale demonstration included two heating seasons and was successfully completed April 2015. Project delays, however, limited the testing of resolving local congestions by locational pricing (demonstration phase III) which only can be regarded as a prototype test for further development.

A summary of the three demonstration phases is given in the text box below. The demonstration phases are described in more detail in the technical EcoGrid EU report: Overall evaluation and conclusions [1].

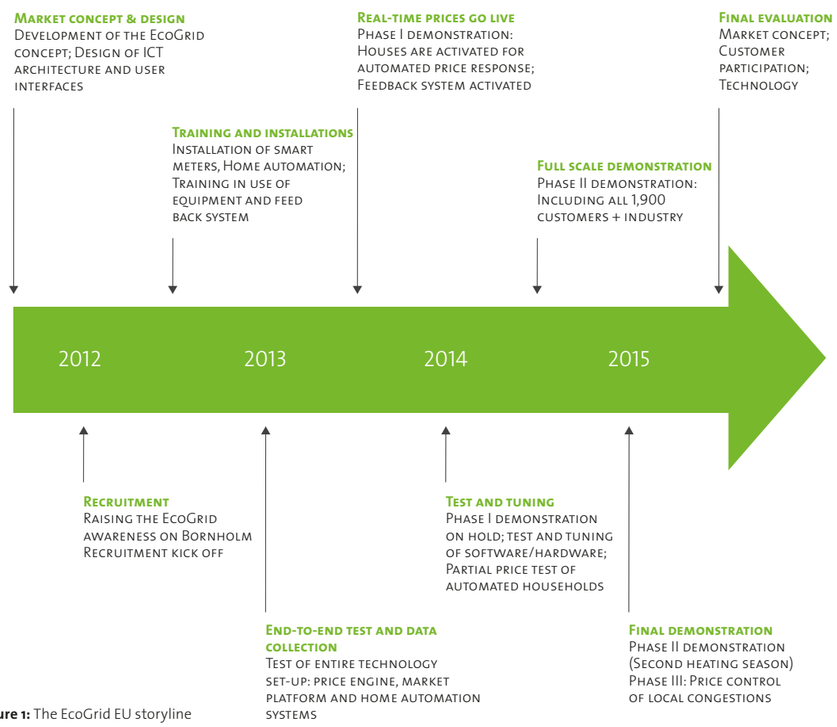


Figure 1: The EcoGrid EU storyline

THE THREE ECOGRID EU DEMONSTRATION PHASES IN BRIEF

Demonstration phase I: Basic real-time pricing
The overall purpose of this demonstration phase was to get experience with the response of the participating devices and customers to real-time price signals. The project team could use this phase to gain experience with customer installations, expectations, and price responsiveness. The focus of the tests was to investigate the response of automated and manual customers to external prices as well as test price profiles. The tests and analyses focus on the inputs (prices) and outputs (meter readings) of the 'test object' comprised of installations and automatic/manual control.

Demonstration phase II: Advanced real-time pricing
The market concept is expanded with closed-loop real-time price calculation and the use of price response forecasts. It means that the price calculation engine needs to get feedback about the response obtained for each update of the five-minute price signal. This feedback is used as input to the price calculation engine to constantly provide updated knowledge about the systems state and aggregate demand response. The price calculation engine uses live feedback about the response on the present price, for the calculation of the next price.

Demonstration phase III: Locational real-time pricing
Adding to phase II, this demonstration phase was planned to demonstrate the use of locational pricing to provide incentive-based congestion management. The setup was designed with the concept of a 'virtual feeder' where a selected sub-set of the demonstration participants is arithmetically considered to be on the same feeder. The aggregate load (or production) of the sub-set must be within the virtual feeder capacity, imposed as a constraint on the maximum load (or production) level for the sub-set.

2. The EcoGrid EU Concept and Demonstration

The primary purpose of EcoGrid EU is to develop and demonstrate in large-scale a generally applicable real-time market concept for smart electricity distribution networks with high penetration of renewable energy sources and active user participation.

The ambition was to develop and demonstrate a new market tool to enrich the existing power market systems across Europe. The EcoGrid EU market operates on a five-minute basis, which is a higher resolution than the one balancing markets operate with today, where the typical market time resolution is between 15 and 60 minutes.

THE BASIC CONCEPT

In contrast to direct control, where devices are turned on and off remotely, the EcoGrid EU concept uses indirect control by means of a real-time price signal which influences the electricity load to change the consumption. While direct control is typically targeted at medium and large commercial and industrial loads, indirect control is aimed at a large number of various customers. The core principles of the real-time concept are:

- The EcoGrid EU market is *bid-less.* One of the major advantages is that the market participants do not need to submit bids and schedules as known from conventional auction-based power and regulating markets. This minimises the efforts (transaction costs) put in by small-scale electricity customers or small power generation units, because they can simply respond directly to the actual market prices.
- The EcoGrid EU real-time market lets *small-scale electricity consumers and distributed energy resources (DER)* receive and respond to variable electricity prices. Every five minutes, the TSO will issue a price signal to keep the power system balanced, using the overall system balance as feedback.
- *An imbalance price* is added to the existing day-ahead power market. Soon after clearing, the electricity price from the day-ahead market is sent to the customers. This price acts as a forecast of the EcoGrid EU real-time price. In the course of the day, the price signal is updated in real time, every five minutes, to reflect the need for upwards or downwards regulation due to an imbalance in the power system. If no imbalance exists, the real-time price will be equal to the day-ahead price.

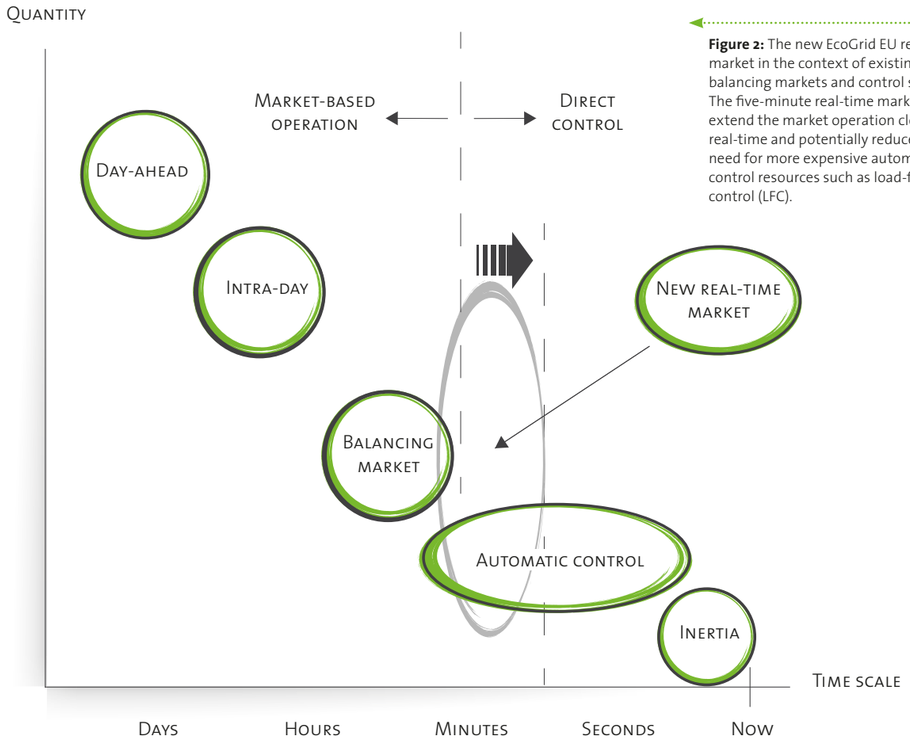
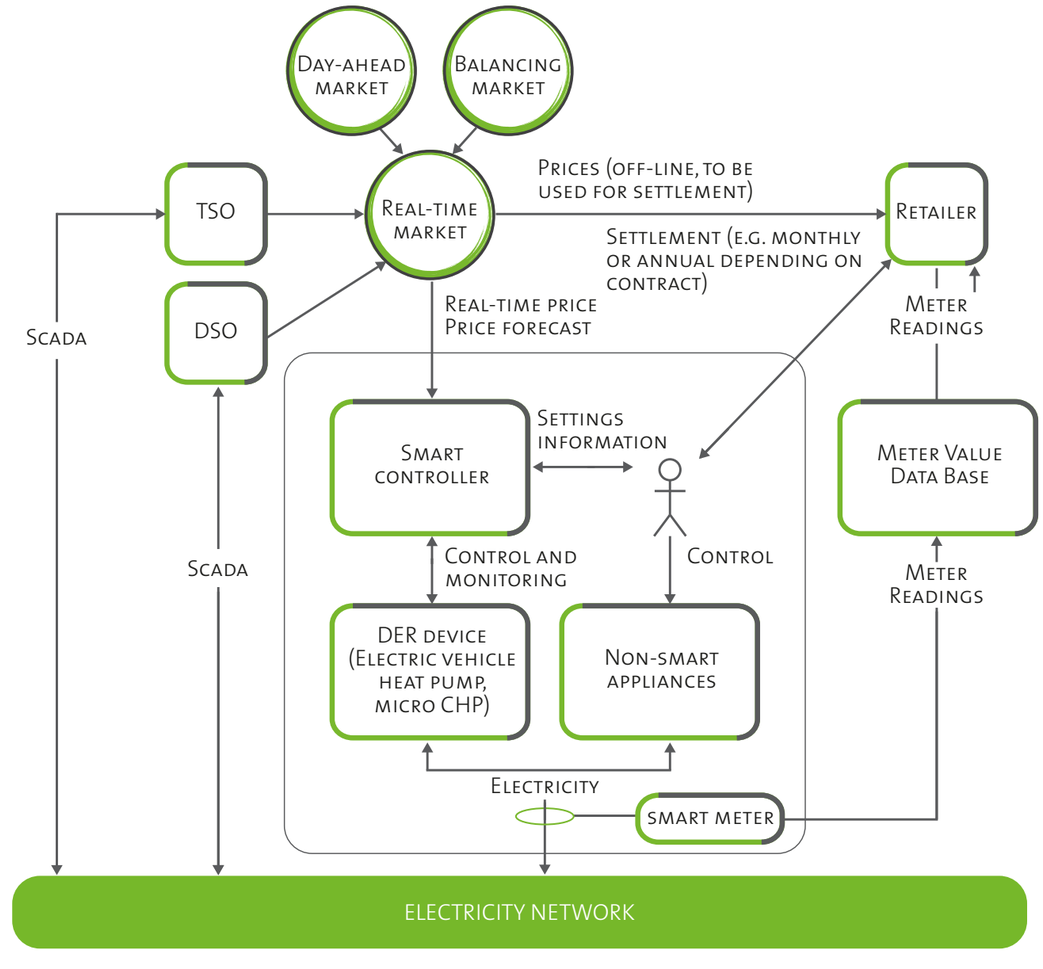


Figure 2: The new EcoGrid EU real-time market in the context of existing power balancing markets and control systems. The five-minute real-time market will extend the market operation closer to real-time and potentially reduce the need for more expensive automatic control resources such as load-frequency control (LFC).

The EcoGrid EU concept provides a market-based platform – with enabling ICT software and hardware solutions – that extends the current electricity market closer to operation (see figure 2) and integrates smaller assets such as electric heating and heat pumps.

Operating the power system closer to real time offers a unique opportunity for efficient exploitation of resources on the demand side that are currently inactive. Furthermore, it will facilitate and ensure a more efficient integration of intermittent and less predictable renewable energy sources.

Figure 3: The EcoGrid EU concept architecture [1] Note; In the Nordic market the day-ahead market is named Elspot. Elspot refers to the spot market for physical power turnover on the Nordic power exchange Nord Pool. It is important to be aware that this is wholesale turnover of electricity. In the Nordic system the balancing market is called the Nordic regulating power market.



ADAPTION OF THE ECOGRID EU CONCEPT TO THE DEMONSTRATION

The EcoGrid EU concept was demonstrated in the context of the present Nordic power market, while adapting the field-test conditions as close as it was possible, to the 'virtual reality' of tomorrow's EcoGrid EU real-time market.

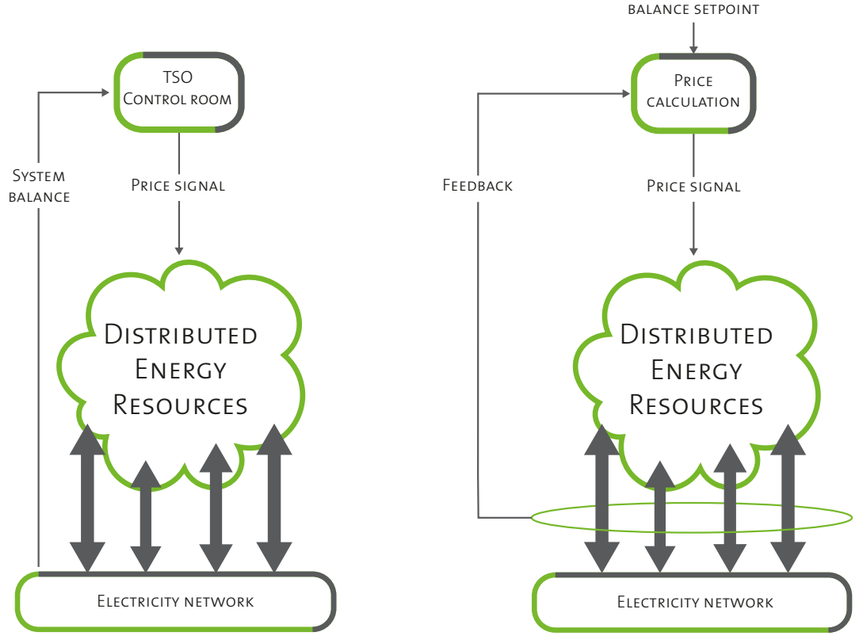
The very fundamental idea of the EcoGrid EU market concept is to balance the power system by repeatedly issuing a price signal for flexible resources to respond to. The price signal will be continuously updated in order to keep the power system balanced, by increasing the price when there is a power deficit in the system, and vice versa (see figure 4.a).

In the demonstration, the TSO was not issuing the actual price, because this is not accepted in the framework of the current Nordic regulation power market (publishing of the current balancing price is not accepted by NOIS). The price is calculated by the project´s 'price engine' that computes an artificial price which is sent directly to the customer equipment and aggregators (see figure 4.b).

The price calculation engine needs to get feedback on the response obtained for each update of the price signal. This feedback is used as input for the price calculation engine to constantly provide up-to-date knowledge about the system's state and aggregated demand response. Note that in a real world/replication scenario the information about the total imbalance would be obtained at the system level (via frequency deviation and/or the Area Control Error) and not through individual metering.

Figure 4.a: The fundamental real-time market concept: The TSO issues a price signal to keep the power system balanced, using the overall system balance as feedback

Figure 4.b: The practical demonstration (phase II): A price engine modifies the price to reach a certain balance position. Thus, the prices depend on the DR response to prices (feedback), equivalent to the characteristics obtained in a competitive market



The real-time price engine model emulates the existing Nordic power market as much as possible. The real-time market price calculation takes into account the (simulated) set points of conventional generation in day-ahead and (simulated) real-time regulating power market bids in real time[3].

The price engine generates real-time prices every five minutes and a real-time forecast once per hour[4]. The real-time price and forecast include:

- Estimates of model parameters for the load forecasting
- Day-ahead unit commitment (generation production level and states, load shedding and wind power curtailment)
- Real-time market dispatch of generation
- Day-ahead wind power forecast
- Real-time wind power forecast
- Spot prices (wholesale power prices)
- Balance signal (estimate of the real-time wind power imbalance on Bornholm)

The last step adjusts the five-minute price for demand to remedy any residual imbalance. As the market is not cleared in a conventionally way this step is only performed to use the latest observations from the power system to ensure system balance [1][2].

A CONCEPT FOR CONGESTION MANAGEMENT

The activation of the demand side, through the real-time market also enables locational pricing for congestion management. In the basic concept of the EcoGrid EU project, control of active power is generally done by leveraging the global real-time market price and its corresponding forecast. Based on this, price deviations for each of the local areas can be computed in order to relief active power issues within that area. The influence on local active power is for instance needed in order to prevent imminent overloads, for example on connection lines. If no local price adaptation is required, the local price is equal to the global real-time market price.

PROJECT RESOURCES FOR THE DEMONSTRATION

Different approaches were used to implement and realise the real-time price response of the EcoGrid EU customers:

- Manual control – participants only have access to real-time price information, (none of their electric household devices are automatically controlled)
- Automatic control of individual electric devices/resources
- Aggregated control of a portfolio of electric devices/resources

Table 1 gives an overview of the final number of residential customers (1,948) divided into the groups to which they belong, and into what type of equipment they have installed.

The semi-automated group consists 'IBM houses' with installation of a home energy management system (HEMS)[5]. These houses are equipped with a solution that includes simple and cheap instrumentation, ie using a single indoor temperature sensor per household, and providing only indirect and potentially delayed throttling of the heating system.

The fully automated group consists of 'Siemens houses' with Synco Living HEMS (supplied by Siemens). These houses are equipped with a solution that includes sensors and actuators reaching out to multiple heating zones and thermal valves.

All EcoGrid EU households were equipped with new automatic meter reading (AMR) and infrastructure with a five minute sampling resolution and no load control (metering and automatic control options for DR devices are separated). The meters are supplied by Landis+Gyr.

Besides being responsible for the fully automated residential houses, Siemens was responsible for the installation of 18 industry/commercial industry solutions developed for 13 industry forklift chargers, three farm manure mixers, one commercial building automation solution (the Bornholm ferry terminal) and one commercial battery storage charger.

The industrial processes are remotely controlled via Siemens equipment used in daily business to control substations in power grids. It is engineered such that it bypasses existing automation if the system is connected to the overall distributed energy management system (DEMS). If not, the existing automation is enabled. Information sent to DEMS is typically only the state of the activation relays. There is typically no direct measurement confirming the actual consumption of the process; only the state of the relay.

For the Building Management System at the Bornholm ferry terminal, a more specialised system is used. All demand response functions reside in the building management system itself and are activated by a smart grid controller upon request from DEMS.

A full description of hardware and software solutions brought into and developed for the EcoGrid EU project by the industrial partners IBM, Siemens and TNO Landis + Gyr is provided in the EcoGrid EU report: Exploitation plan [3]. This report also includes a full description of the overall ICT system implemented and operated by IBM, and the price agents from IBM, Siemens, and TNO.

[3] Simulated generator behaviour is based upon historical Nord Pool bid curves. The real-time price is centred on the real spot price.
[4] The original concept intended to clear the market every five minutes. However, this was deemed impractical by the ICT implementation teams.
[5] The HEMS is supplied by GreenWave Reality (GWR).

	HOUSEHOLD DEVICES	EQUIPMENT	NOTES
654 semi-automated households	Electric heating (384) Heat pumps (270)	Landis+Gyr AMR meter GWR HEMS	A GreenWave Reality website gives access to tailoring and pre-programming the preferred balance between comfort, consumer flexibility and cost savings. GWR also offers an app which allows temperature and consumption monitoring via a smart phone. The web portal My EcoGrid gives access to price information, consumption data and bonus calculations.
444 fully automated households	Electric heating	Landis+Gyr AMR meter Synco Living HEMS	The Synco living website gives access to tailoring and pre-programming the preferred balance between comfort, consumer flexibility and cost savings. The Synco living houses can also use a central in-house unit or a room unit to regulate the temperature or override the control. The web portal My EcoGrid gives access to price information, consumption data and bonus calculations.
500 manually controlled households	A mix of household devices. Only a part of the participants have electric heating systems	Landis+Gyr AMR meter	They only have access to the web portal My EcoGrid with price information, consumption data and bonus calculation.
350 Reference group	n/a	Landis+Gyr AMR meter	Consumers have no specific access to price information and consumption data etc.

Table 1: Groups of residential participants divided into what type of equipment they have installed

3. Overall Evaluation Results

The hard work of testing and tuning the EcoGrid EU equipment proved to be worth the effort. By the end of the demonstration period (winter 2014/2015), the automated parts of the demand response system implemented within the EcoGrid EU project worked reliably, with (thermal) comfort criteria being satisfied using the thermal inertia of buildings. The manual contribution on the other hand was significantly lower than expected.

Figure 5 shows the extracted demand response from all EcoGrid EU measured groups on a winter day in November 2014. This is the actual balancing power activated in the real-time market, which provides the TSOs with an additional source of balancing power. The upper curve shows the real-time price. The lower curve shows the demand response activated.

SIGNIFICANT PEAK LOAD REDUCTION

Load shifting by activating demand response with a five-minute real-time signal reduced the peak load of EcoGrid EU customers by approx. 670 kW. This is equivalent to 1.2% of the overall peak load on Bornholm (55 MW)[6]. This result is very satisfying, even higher than the projekt target (see table 2).

More than half of the peak-load reduction comes from customers with fully automated control of their heating system (52%), while one-third of the reduction are achieved by those with semi-automated control of heat pumps/electric heating (35%). The industrial and commercial customers account for 9% and the manual control group for 4%.

DEMAND RESPONSE CHARACTERISTICS FOR THE AUTOMATED HOUSEHOLDS

Figure 6 is showing the single biggest observed decrease in consumption in a situation with a high real-time price (the balancing power activated is negative). The figure shows that the IBM heat pump group takes about 30 minutes to deliver its peak demand response while the Siemens heating group takes about 10 minutes to deliver its peak demand response. The tests revealed that there is a delay in the response from the heat pump group, as many heat pumps, to protect themselves, have a minimum running cycle of typically 20 minutes, which means that the heat pump will continue to run for up to 20 minutes after receiving the down regulation signal.

In the example, the largest amount of activated balancing power (peak DR) is -167 kW for the IBM heat pumps and -286 kW for the Siemens electric heating.

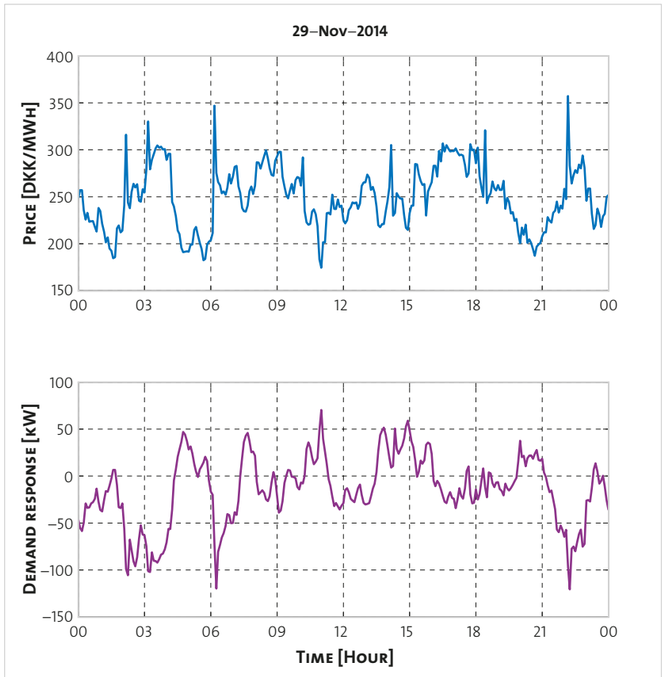


Figure 5: Time-series of demand response extracted for all measured groups. The first plot (upper curve) is the real-time price. The second plot (lower curve) is the resulting demand response

[6] The result is based on the evaluation of 1,499 households and 18 industry/commercial participants

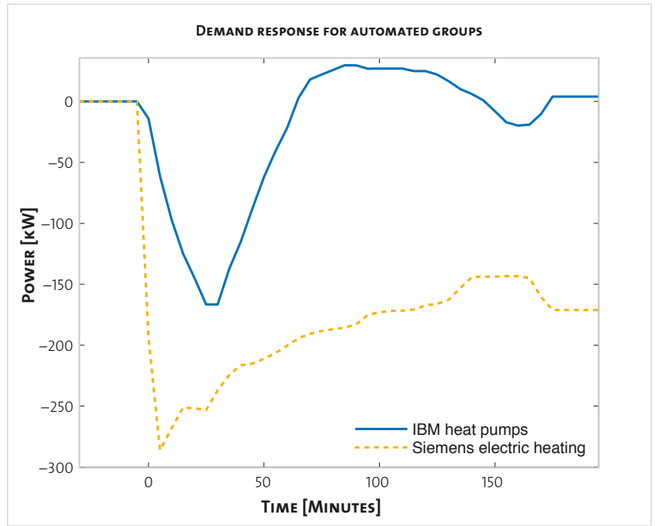


Figure 6: The demand response characteristics for the automated groups, showing the biggest observed consumption decrease, given a high price, according to a model based upon observations from 22 September 2014 to 7 February 2015 [1]

EFFICIENCY GAINS OF THE ECOGRID EU REAL-TIME MARKET CONCEPT

The model-based evaluation results shows that the real-time market has performed better than the baseline market. The social cost of regulating power has decreased by 5.4%, especially due to less curtailment of wind power and lower cost for activation of spinning reserves.

The estimated wind power curtailment has (virtually) been reduced by almost 80% (see figure 7). The estimated wind power virtually curtailed is the amount of wind power which has been lost because the wind turbines could not be operated to their optimal level according to the predicted wind power production. Compared to the baseline consumption, the RES share has increased by 8.6%.

Moreover, the use of spinning reserves has (virtually) been reduced by 5.5%. This means that energy payments for spinning reserves (extra generation capacity) would be cheaper and spinning reserve capacity could also potentially be reduced.

Overall, the results from the real-time market are positive as indicated by the economical evaluations[7].

[7] The estimates of spinning reserves and wind power curtailment are model-based; no action has been implemented in the physical system.

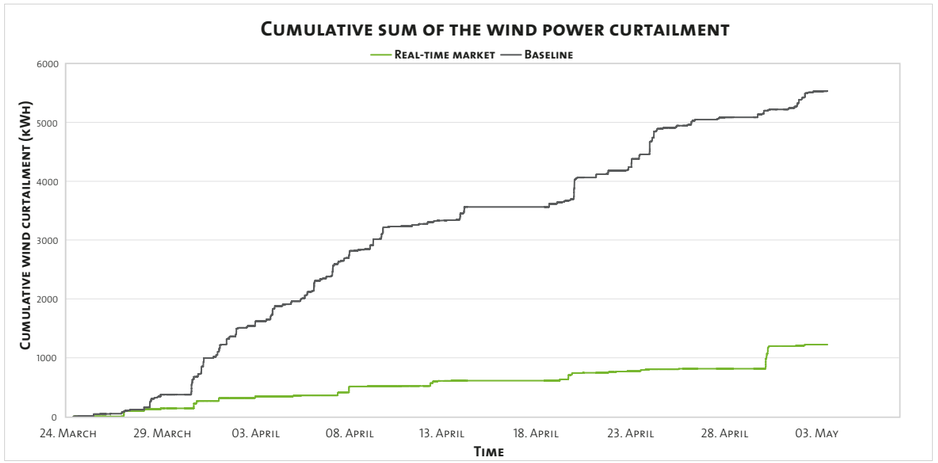


Figure 7: Cumulative sum of the wind power curtailment with the baseline market and the real-time market [1]

CUSTOMER PARTICIPATION AND INVOLVEMENT

Early in the project – in the recruitment phase – it was decided to put the main customers' focus on the environmental benefits of EcoGrid EU participation rather than the ability for the participants to save money. However, it was stressed that the participants would not suffer financial loses and they would incur no expenses as a result of their participation. Highlighted was also the possibility of getting equipment that automatically would control the electrical heating/heat pump according to a variable price. Finally, it was mentioned in the recruitment material the possibility of gaining a better overview of the energy consumption through personal access to the web-based user portal 'My EcoGrid' [6].

SELF REPORTED MOTIVATIONS

Although the importance of financial incentives for the EcoGrid EU participants is evident (41% rated money savings as their first priority), a considerable percentage of respondents rated environmental aspects very highly (24% rated the environment as their first priority). The 'top 4' motivating factors of the participants also included the innovative aspect of the project (19%) and the prospect of having smart equipment installed (6%). These results are based on what 1,609 of the participants applicants reported when they signed up for EcoGrid EU [7].

RECRUITMENT

It took a considerable communication effort on the part of Østkraft to fulfil the ambitious recruitment target. The last recruitment effort was made towards people who are generally not particularly interested in energy issues. It made the recruitment of the last 500-600 test participants more complex in that they could not be randomly selected because the project wanted more households equipped with either heat pumps or electric heating

At the end of the project, 1,948 households had signed up for EcoGrid EU and 18 industry/commercial customers. The recruitment targets for the automated customers were not completely fulfilled, but are considered satisfactory by the evaluation team.

KEEPING THE CUSTOMERS INVOLVED

Applying active regulation in winter times resulted in a strong increase in the number of requests for technical support. In the course of the project, much of the advice to customers was delivered through personalised consultancy, eg through home visits by electricians, training sessions at Villa Smart and an EcoGrid EU phone help service from Østkraft´s EcoGrid EU team[8]. Other supportive communication/training tools included the EcoGrid EU website (www.ecogridbornholm.dk) with access to news, FAQ, user guides and the feedback systems My EcoGrid and My EcoHome.

The number of phone and mail requests from the customer requests from the EcoGrid EU customers to Østkraft was particularly high in the initial phase of the demonstration and so were the amount of dropouts. During the first six months of 2014, Østkraft received 1,700 phone calls (approx. 70 per week).

A total of about 200 participants decided to drop out of the project. A majority of them (>90 %) belong to the participants in the automatic control group. Their primary motivation for participating was the prospect of saving money (all).

CONFIDENT CUSTOMERS

In the final customer survey about 70% of the respondents answered positively on the overall EcoGrid EU project and 78% would like to participate in a project such as EcoGrid EU again.

The survey also show that the customers felt most enabled by the project to obtain social goals, and less to obtain personal benefits such as saving money or increasing insight in own consumption. In the final survey the four reasons that were enabled most by the project were: 1) being part of a new exciting project, 2) doing something good for the environment, 3) doing something good for the community of Bornholm, and 4) contributing to the image of the island.

Almost half of the respondents (47%) indicate they would prefer variable prices over traditional prices in the future, 19% tends to prefer traditional prices, and 34% is neutral on the matter. At the end of the project, more than half of the respondents indicated that they have changed something in the way they use appliances. Similar to previous surveys, the participants prefer to change the time they turn on their appliances in response to price changes (43%) over changing the frequency of use (7%).

A special test performed for the manual control group showed that changes infrequency only increased when prices were low[9]. This might indicate that it is easier for customers to increase the frequency with which they use appliances than it is to reduce it. Customers who did not change anything in the way they used their appliances said the most important reasons were that it was impossible to change anything and that the incentive was too small.

Satisfied with automatic control. Automatic control was perceived as moderately convenient, not noticeable and led to a slight increase in comfort. In the fully automated group, a larger increase in comfort was observed. This might have been caused by the additional means of this group to adjust temperature settings. Overall, 63.5% of the 664 respondents think automatic control is convenient.

More than 50 % was positive to 'My EcoGrid' online feedback system. The feedback system gives information on electricity prices and insight into consumption. For the manual response group, the feedback system is of great importance, as it is necessary to adequately respond to price signals.

Halfway through the project, the majority of the customers were satisfied with the frequency and amount of information. They were also positive about the Østkraft's communication and service. However, they indicated that the period between the time of subscription and the actual start was too long.

With regard to the equipment and the installation process respondents were moderately positive. By the end of the project, the frequency and amount of information was perceived as 'just right' or slightly too low. Customers were even more pleased with Østkraft's service and communication than they were halfway through the project, and were also happier with the installation process.

TARGETS NOT COMPLETED

Demand response from the 500 participants in the manual customer group account only for 29 kW demand response, which is less than 50% of the project target (60 kW). The most import reasons for the lack of (or small) demand response is mentioned as the most detrimental by the evaluation team [1]:

- The high frequency of price changes
- The overall conditions of the demonstration, with the premise that the customer will not pay more than their usual costs anyway
- Initial faults in the feedback systems
- The times of the day with inexpensive or expensive energy

It was expected that the increased customer awareness would lead to an overall reduction in energy consumption. In the customer survey, 46% of the respondents said that they used less energy than they would have used had they not participated in the EcoGrid EU project. Statistically, no energy savings could be documented. It is worth mentioning that these results reflect energy savings activities (or absence hereof) that are related to the latest period of the demonstration. Thus, it cannot be concluded whether or not a reduction in overall energy consumption has been realised by the participants in the earlier demonstration phase.

The project did not show significant statistical results from demonstrating distribution feeder congestion, but as this was conducted as the last experiment, there was not much time left for improving and fine-tuning the concept. Thus, the EcoGrid EU concept for distribution feeder congestion management should be regarded as a prototype test for further development.

[8] The key EcoGrid EU team: Østkraft´s EcoGrid EU project manager, the installation coordinator, two electricians and one person from the communication appartment

[9] This test took place during four weeks at the end of the demonstration phase, and it was specifically designed for the manual customers with very high and very low prices during times where the participants had reported to be often at home. In addition to the feedback system the participants were informed via e-mail about these prices and received special information about load shifting and manual possibilities for load shifting.

Table 2: Overview of the project evaluation targets. The targets represent the key performance indicators (KPI) defined in the project. More detailed information is given in the EcoGrid EU report: Overall evaluation and conclusion [1].

Completed Almost completed Targets not completed

Topic	Results	Comments
Recruitment 200 reference houses	350	150 of the participants who did not want HEMS to be installed wanted to be moved to the reference group.
500 manual control houses	500	
700 semi-automated houses	654	654 semi-automated houses 444 fully automated houses
500 fully automated houses	444	
20 automated industrial/commercial	18	
Customer participation and acceptance		The results reflect the opinions of half of all EcoGrid EU customers who participate in the final customer survey
70% are positive about the project	70%	
50% are positive about the real-time pricing	47%	
50% are positive about how their appliances are controlled	64%	
50% of the customers are positive about their feedback system	54%	
Peak-load reduction		
60 kW total peak-load reduction in 500 manual houses	29 kW	
425 kW total peak-load reduction in 1,200 automated houses	583 kW	
50 kW total peak-load reduction in 18 automated industrial/commercial entities	61 kW	13 industry forklift chargers Three farm manure mixers One commercial battery storage charger One commercial building (Bornholm ferry terminal)
The peak load of a suitable sub-set of participants must not exceed the peak of the baseline load for the same sub-set	True 51% of the time	28 customers participated in the test
The share of renewable energy sources should be 5% higher	8.6%	When comparing the metered consumption of the project participants with the calculated baseline
The electricity consumption must be reduced by 5%	3%	All participants except for the Reference group

4. Replication of the EcoGrid EU Real-time Market

The overall evaluation results from the EcoGrid EU demonstration on Bornholm show very promising perspectives for the scalability of the flexibility potential to Denmark – and the replication to the rest of Europe. Especially with the big advantage of the automatic demand response as it can be realised nearly effortless for the consumers and with increased comfort.

MORE FLEXIBILITY POTENTIAL 'OUT THERE'
The main goal, proving that an energy market using small customers and a very small time step has a significant impact in terms of load distribution in time was achieved for all automated installations. In total, the automated heating units delivered enough demand response to satisfy project targets (KPIs) set, although the comfort settings were chosen quite conservatively (or safely) with respect to room temperature and activation times. At higher fluctuating prices, and therefore the chance of real savings, actual flexibility can be expected to be much higher than demonstrated due to more flexible building energy systems [1].

Also, the flexibility potential could certainly be even higher with '100% interoperability' between especially the heat pumps and the EcoGrid EU control system and further developed algorithms. Table 3 shows the observed demand response potential for the semi-automated households with heat pump and the fully automated household with electric heating. The average demand response to the real-time prices was ±1.5% for the semi-automated heat pumps group and ±1.9% for the fully automated electric heating group.

Moreover, 99 of the automated houses were not responding and excluded from the evaluation for the following reasons:

- Lack of consumption data – in some cases, the smart meter did not respond due to poor Internet connection
- Loss of control – the control system failed, and it was not possible to re-establish working condition
- Quitting the experiment – control hardware was installed, but the household left the experiment before enough data for a meaningful evaluation was accumulated

THE SCALABILITY OF THE ICT ARCHITECTURE
According to the replication study the EcoGrid EU ICT architecture is well scalable. The only real-time communication necessary is the one-way broadcasted price. Generally, one-way signalling of low-bandwidth information can be done very efficiently and scales well with the number of listeners to the broadcast.

The largest change from the state-of-the art triggered by a roll-out of the EcoGrid concept, is the higher resolution of the automatic metering. The common practice in automatic meter reading implementations, is a metering interval between 15 minutes and an hour. The EcoGrid EU concept takes this down to 5 minutes, which increases the amount of data that needs to be collected, communicated, stored and processed into billing information. For an EcoGrid EU roll-out, however, this is not time-critical information, as the metering data is solely used for billing purposes.

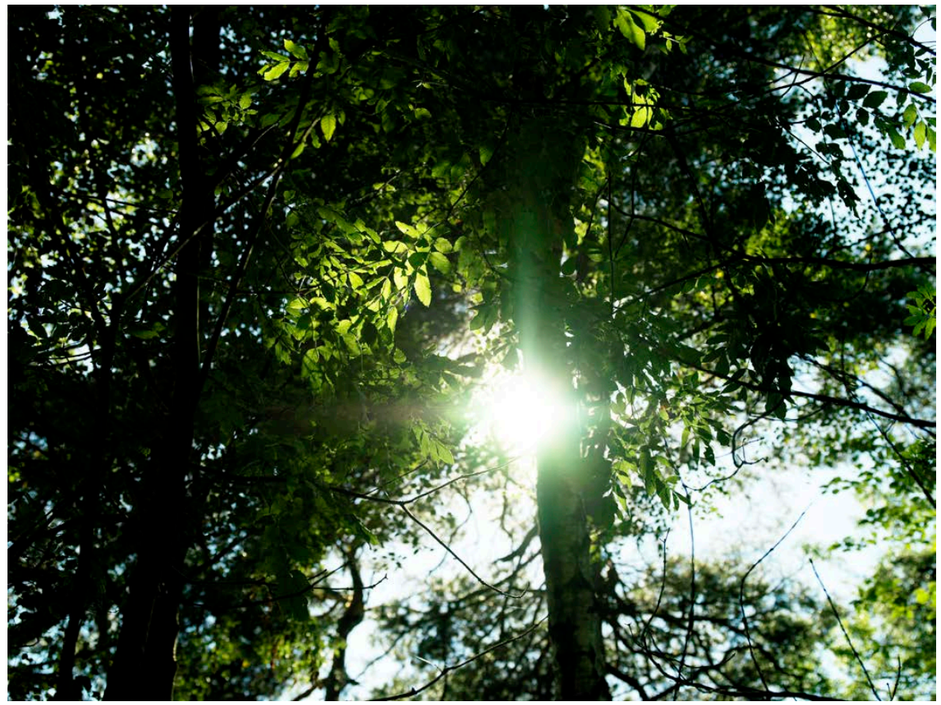
CUSTOMER MOTIVATIONS
A wider implementation of the EcoGrid EU concept depends on the degree of smart grid readiness among the customers. Today, electricity is taken for granted by most people. The strong support for the EcoGrid EU project from the public on Bornholm is probably due to the fact that a large part of the population was already well aware of the challenges associated with wind power and of the goal of converting to CO_2-neutral electricity generation.

One of the largest tasks, preceding the EcoGrid EU, has therefore above all been to establish a broader understanding of the Smart Grid vision behind EcoGrid EU and the concept of 'flexible consumption'. Hence, in the initial phase of a roll-out it is recommended to focus on customer information, i.e. to increase the awareness of 'a smarter grid', the system requirements, and its costs. People must also be informed about the potential benefit for the individual. In the short term, the advice is that the message to be communicated will include not only financial benefits (unless the potential savings are very obvious), but also societal and environmental benefits.

Table 3: Demand response potential for automated households, % [4]

	INCREASING REAL-TIME PRICE		DECREASING REAL-TIME PRICE	
	Best	Average	Best	Average
Semi-automated heat pumps (IBM)	-20,5%	-1,5%	20,5%	1,5%
Fully automated electric heating (Siemens)	-41,7%	-1,9%	27,6%	1,9%

Note: To draw conclusions for longer periods than for the 5 minute periods only these periods were considered where prices showed in the same direction for at least 12 five-minute periods.



TECHNOLOGICAL REQUIREMENTS
Another prerequisite for a large-scale deployment of smart grid and an EcoGrid EU real-market is the readiness of the enabling technology. Automatic control using the best technology available is needed to reap the full benefits of real-time flexibility. Today the market consists of many different types of home energy management systems and ad hoc solutions developed for other needs and in an era where energy saving was (and still is) the predominant goal.

THE DIVERSITY OF MARKET DESIGNS
Balancing markets across Europe are quite diverse in design. Some features will make it easier or more difficult to implement EcoGrid EU. Within the current market framework situation it will certainly not be possible to implement just one standard EcoGrid EU concept.

Replication is not only about the possibilities of adapting the EcoGrid EU solution to different types of balancing market designs. The perspectives of EcoGrid EU need to be studied case-by-case, depending on the flexibility potential and market profitability of different types of customers.

Currently, some countries are allowing large industries to participate in the balancing market. Before moving towards a (further) roll-out of demand response, the advice of the EcoGrid EU Replication Roadmap is to identify the sector with the highest flexible potential at the lowest costs:

'Taken as given, that large industry already is participating in the balancing power markets, possible candidates for the next step could be the tertiary sector, commercial buildings, small and medium sized industries, as well as the residential customers', the experts write in the EcoGrid Replication Roadmap [4].

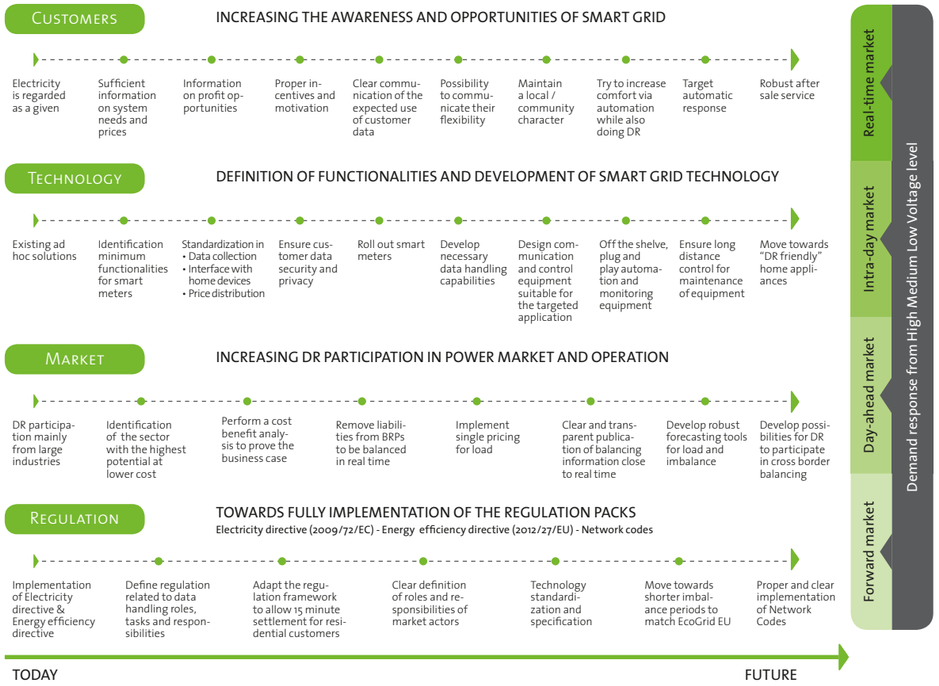
REGULATION AND STANDARDISATION
Regulation and standardisation play a very critical role in accelerating the evolution towards full roll-out of smart grids. Deployment of the EcoGrid concept must be discussed in the context of the regulatory framework. Implementation of the European electricity directives (2009/72/EC) and the energy efficiency directive (2012/27/EU) is the key. It clearly states that load demand should have access to the power system on an equal basis as generation.

In addition, the European Commission has mandated the European TSOs (ENTSO-E) to develop clear rules (ie Network Codes) for system operation and market functions that foster demand-side participation in power market balancing. In the latest version of the Network Code on Energy Balancing there is a tendency to suggest a so-called imbalance settlement period of 15 minutes, meaning that more market players are allowed to trade closer to real-time. This development fits very well with the EcoGrid EU approach.

It is important that consumers are able to switch energy suppliers without having to change their equipment. For this reason, regulators should make sure that well-designed standards are implemented to facilitate interoperability. Minimum functionality requirements should be identified regarding the smart meters, and a potential roll-out should not be delayed in case of a positive-cost benefit analysis.

To sum up: The evolution towards smart grid, including EcoGrid EU, and similar DR programmes, depends on the harmonisation process of the electricity markets in Europe – a process of drafting framework guidelines and network codes aiming at providing harmonised rules for cross-border exchange of electricity. It is in this perspective the EcoGrid EU replication roadmap (see roadmap illustration in figure 7) and the EcoGrid EU Consortiums´ recommendations in chapter 5 should be read.

Figure 8: The EcoGrid EU Replication Roadmap [4]



5. Main Conclusions and Recommendations

Despite the project delays, hard work, the challenge of keeping the customers involved and hours of internal discussions, the intensive testing and tuning of the system later turned out to really pay off in the final phase of the demonstration.

In their final report the EcoGrid EU evaluation team concludes [1]:
"The EcoGrid EU project has fulfilled its overall objectives and has created value for the European society as a whole as well as for the involved partners. The experience gained from the project may prove very valuable to system/network operators and industrial parties in the future conversion of the energy system to a power system based on renewable energy sources".

Even better: According to the final customer survey, the majority of EcoGrid EU customers were very happy with their participation in the project; they perceived it as a positive experience, would like to participate in a project such as EcoGrid EU again and also said it is likely that they would recommend others to participate as well. Moreover, the customers were happier at the end than halfway into the project, which was very well expressed in a comment by a participant in the final customer survey:
"The start was difficult because the equipment was not fully developed. Therefore, it took time before we were fully integrated into the project. After that everything has been positive".

These overall conclusions are based on the key findings:

- *A real-time price signal can be used to activate the demand response potential:* The customers reacted in a way that helped the balancing of the power system following a real-time price signal.
- *There is a significant peak load reduction potential*: The activation of flexible consumption with a five-minute real-time signal reduced the total peak load of the EcoGrid EU participants by approx. 670 kW. This is equivalent to 1.2% of the peak load on Bornholm.
- *The flexible demand response can be forecasted* – with some certainty – resulting in overall improved system efficiency.
- *Automatic load control is the key to achieve significantly demand response;* households, having equipment that controlled their heating system to respond automatically to price signals, accounted for 87% of the peak load reduction.
- *Involving the customers is the key to success.* Personalised advice works best, but should be kept to a minimum due to the sheer volume in a national roll-out.
- *Standardised 2nd generation smart grid equipment is necessary.* The solutions should specifically be designed for automatically providing power system services to the TSO or DSO upon receiving an external control signal of any kind (market or technical).

THE SUCCESS OF DEMAND SIDE PARTICIPATION IN THE FUTURE POWER SYSTEM

The EcoGrid EU demonstration taught us that society and the DSO/TSO in particular would benefit from additional balancing resources created by demand-side participation in a real-time power market. Therefore, the EcoGrid EU Consortium favours initiatives bringing us one step closer to demand-side market participation at all time scales.

The EcoGrid EU Consortium supports approaches that allow for more efficient market integration of renewable energy sources and support the European 20-20-20 targets and the 2030 energy and climate targets by initiating market activities that are close to the real-time operation of the power system.

Other models should also be considered. Inspiration can be taken from, for example, Belgium and the Netherlands where indicative price signals are published in real time. Though deviating slightly from the EcoGrid EU concept, the basic advantages are the same, and such concepts may be easy to incorporate into the present market set-ups.

It is important to discuss the EcoGrid EU concept – and other concepts that adress demand-side participation – in the context of the ENTSO-E framework. This implies the development of a Network Code for Energy Balancing as well as the key recommendations included in ENTSO-E's recent policy paper for demand-side participation (2014) [5]:

- Efficient demand-side participation requires a clear definition of roles and the responsibility of TSOs/DSOs and commercial market actors
- Efficient data handling procedures, including metered data and communications.

THE ECOGRID EU CONSORTIUM'S OVERALL RECOMMENDATIONS:

- The TSOs/ENTSO-E and the DSOs/EDSO should develop a long-term balancing strategy in order to increase market participation from demand response and renewables. The EcoGrid EU concept should be considered as one of several options.
- The evolvement of market concepts and frameworks to allow for better DER flexibility markets should be addressed in the context of the on-going harmonisation of the European power markets.
- An evolutionary approach rather than a revolutionary approach should be adopted in the rollout of demand response.
  - The first step should be a further integration of demand-side participation in the existing power market, eg by successive revision of size requirements for DR participation.
  - The second step should be the development and introduction of a new real-time market for power balancing.

SHORT-TERM RECOMMENDATIONS: FIRST STEPS

The short-term recommendations highlight some of the most important initiatives that are included and elaborated on in more detail in the EcoGrid EU Roadmap [4]. The recommendations in the Replication roadmap are addressed specifically to policy makers who can use them as a guideline for further integration of the demand side in the power system balancing and operation.

The recommendations are divided in customer, technology and market-related initiatives, respectively.

Technology:

1. *Technology standardisation and plug-and-play functionalities should be a prerequisite.* Standardisation minimises interoperability problems that lead to incompatible technologies and unhappy customers.
2. *Separation of metering and automatic control options for DR devices* ensures easy and cost-effective replacement of either the meter or the smart-box independent of each other.
3. *Automatic Meter Reading (AMR) should be used for billing purposes and information.* Many countries have infrastructure metering based on hourly sampling frequency. However, meters with a 15-minute time resolution is recommended to be prepared for wider demand-side participation closer to real-time.
4. *Automated control of DR devices* will improve controllability, increase flexibility potential and could increase comfort. More robust and convenient smart home equipment and user interfaces could be developed, eg based on experience from EcoGrid EU and customer feedback.

Customers:

1. *Demand response solutions should move forward as customers are willing to be part of smart systems.* Residential customers are motivated by electricity cost savings, environmental issues and interest in innovation.
2. *Raising the smart grid awareness of the customers and develop proper incentives.* People must be prepared for higher energy prices/costs and how they can help balancing the power system. Innovative ways of motivating factors should be explored. This could be related to environmental benefits, good citizenship, etc.
3. *EcoGrid EU should serve as a best-practice approach for recruitment and involvement of the customer.* Crucial for the success of customer recruitment and involvement is, among other things, training of the technical and social skills of the installers and support staff.
4. *Business models should be developed in order to increase customer convenience and benefits.* Utilising synergies between products and services could be one way.

Market:

1. *The present markets should reduce the threshold for demand-side participation in the power balancing markets,* provided that the appropriate metering infrastructure is established (minimum of hourly billing of end customers).
2. *Development of trustworthy forecast models for demand response.* The Balance Responsible Parties could benefit from bidding the expected flexibility from consumption into the day-ahead. To that end, further research, development and utilisation of the EcoGrid EU short-term forecasting model for demand response will be needed.
3. *Interim market trials/pilots* are recommended as a way to test market requirements before considering wider deployment. In this way, both market participants and TSOs/DSOs can gain operating experience in a low-risk set-up.
4. *Identification of the sector with the highest flexibility potential at lower cost* and development of business models to extract this flexibility.

LONG-TERM RECOMMENDATIONS: SECOND STEP

Several of the above-mentioned activities are seen as necessary preconditions for the deployment of a full real-time market concept. This must be taken into account in the final long-term recommendations:

- Introduction of the bid-less EcoGrid EU real-time market concept. Appropriate meter infrastructure should be adapted to the EcoGrid EU real-time market concept or similar concepts (5-15-minute resolution), taking into account the different future AMR specification and data management rules across Europe.
- Automatic control using the best technology available is needed to reap the full benefits of real-time flexibility.
- The uncertainty in the response must be minimised. A price signal can be used to activate demand response close to real time, but the demonstration also revealed uncertainty in the response. The expected 'system costs' caused by this uncertainty should not outweigh the expected efficiency benefits of a real-time market.
- Raising the customer awareness of the benefits of demand side participation in the power market is not only relevant in the short term. Information about actual profit potential due to high price volatility close to real-time operation is important for motivation.

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[5] Demand side response policy paper (2014), The European Network of Transmission System Operators for Electricity (ENTSO-E)

[6] EcoGrid EU: From Design to Implementation (2013)

[7] The Danish Smart Grid information and communication project, ForskEL no 10640 (2011-2015)

The EcoGrid EU reports and the scientific papers can be downloaded on the project website www.eu-ecogrid.net

Interviews

In front (from the left): Martin Sjøberg, Maj Dang Trong, Florian Judex, Guillaume le Ray, Maja Bendtsen, Per Lund, Jacob Østergaard, Ove Grande, Guilherme Jacinto, Stig Holm Sørensen

Behind (from the left): Dieter Gantenbein, Andrei Morch, Ivo Palu, Jessanne Mastop, Koen Kok, Bernhard Jansen, Jeannette Møller Jørgensen, Georgios Giannopoulos, Rune Duban Grandal, Preben Nyeng

Per Lund

Interview with Preben Nyeng and Per Lund, Energinet.dk

Over the past few years, smart grids have grown to be one of Energinet.dk's key focus areas, and EcoGrid EU is just one example of an international smart grid field test in which Energinet.dk has been actively involved. Energinet.dk's major task was to show us what we have all been waiting for: the overall evaluation and conclusions of the EcoGrid EU demonstration. In this interview, Per Lund, Energinet.dk (head of the evaluation team), and Preben Nyeng will share with us what they think are the main findings of EcoGrid EU.

– From a TSO perspective, one of the most interesting results of the demonstration is that it is possible to use a real-time price signal at the wholesale level to activate flexibility in residential homes.

The project demonstrated different automatic solutions for controlling the household's heat pumps and electric heating devices: one method is using automatic control of individual/single household devices (without an aggregator), another is the control of a portfolio of resources (so-called aggregated control). – Customers are free to choose between different options and whether they want to remain 100% in control or let an aggregator control their devices for them, says Preben Nyeng.

THE CUSTOMERS ARE CONFIDENT

According to the final customer survey, 78% of the participants said that they would like to participate in a project such as EcoGrid EU again and 76% would recommend others to participate as well.

– In the half-way survey, the participants were less happy than in the final survey. This can be explained by the higher amount of technical problems that occurred in the beginning of the project. Fortunately, we were able to resolve most of these during the last part of the demonstration, says Per Lund.

– It is very positive that the customers were happy with their participation in the end of the demonstration. This shows that the EcoGrid EU solutions did not compromise with the comfort requirements of the customer, Preben Nyeng points out.

Did any of the evaluation results surprise you?

– It was surprising to see so little response from the manual group. This contradicts many previous experiments with demand response. I think it can be attributed to the design of the demonstration where no one risks losing money. The main driver for manual response is to avoid high prices, but if you know in advance that the market is risk-free this may limit your willingness to adapt your consumption, says Preben Nyeng.

Also, the test of peak-load constraint on a virtual feeder did not work as expected:

– This experiment was conducted with very little time left in the demonstration phase. I think these findings are somewhat tentative and it might have been possible to improve the concept to achieve better results, says Per Lund.

Nevertheless, the performance of the market algorithm relies on good forecasts of the demand response which can be difficult to make for a small population. So the conclusions may be right, and it may turn out that price signals are not a good way to handle distribution grid congestion – but we don't really know, adds Preben Nyeng.

Preben Nyeng

IS CONGESTION MANAGEMENT IN THE LOCAL GRID A MATTER FOR A TSO?

– From the TSO perspective, distribution grid congestion may hinder the participation of the demand side in the wholesale markets, so to us it is important that this issue is handled somehow, says Preben Nyeng.

Other interesting approaches could be more 'technical control' or simply upgrading the distribution lines. – In a Danish context, the distribution lines have already been upgraded due to aging in many places, and this tendency will likely continue. In the end, it is a question if 'smart' control/markets in the distribution grids is made superfluous due to the natural evolution and development of the physical grids, says Preben Nyeng.

Energinet.dk concludes in their evaluation report that many of the enabling technologies for the EcoGrid EU real-time market are first-generation solutions. – There is no off-the-shelf equipment today that is specifically designed for automatically providing power system services. Such equipment could effectively be developed based on the existing home automation systems designed for home energy savings and comfort control as a new added functionality inclusive of external communication capability, says Per Lund.

– International open standards are needed to handle easy and seamless communication horizontally and vertically between these new generations of smart home appliances and home automation systems from different vendors and the aggregators. – Furthermore, an increasingly large number of data will potentially have to be moved between different actors for, for example, energy measurement and billing purposes. The emerging IEC 61850 standards could be a good candidate for technical communication and CIM for actor-actor communication. – To ensure a viable European activation of demand response, I believe that the end result should be full plug-and-play capability for the full technical chain as well as for the full value chain, says Per Lund.

How will Energinet.dk use the lessons learned from EcoGrid EU?

– We are considering that right now and will take the lessons learned and apply them in our work. Markets are being developed in an international context, so we will bring the EcoGrid EU experience with us in the collaboration with other TSOs.

– The future perspectives of EcoGrid EU depend on how the overall system will develop. Every measure that is applied must be proportional to the problem it is designed to solve, says Preben Nyeng.

NO BURNING PLATFORM IN DENMARK

According to Per Lund and Preben Nyeng there is no 'burning platform' in terms of system balancing in Denmark. The current regulating power market performs well and provides ample and cost-effective balancing resources.

Energinet.dk is presently taking steps to prepare a framework for demand response in the day-ahead market (the so-called market model 2.0). This step is considerably less advanced than a real-time market and provides significant benefits for the system in terms of system adequacy, focusing on the system's ability to handle generation scarcity.

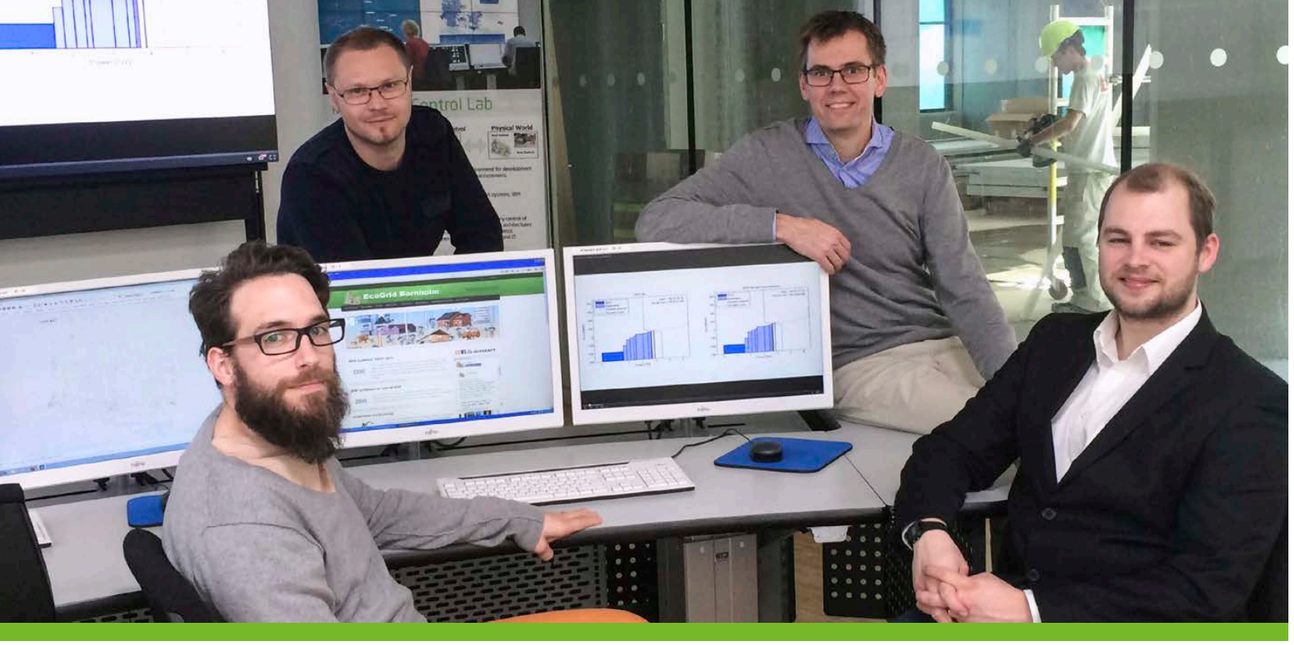
In a future with considerably more wind power and more electricity-intensive loads, it can be necessary to trade energy, including flexible consumption, closer to the time of operation. The price for balancing services will decide the direction of the power market development. Flexible generation plants and a strong connection to the Norwegian hydropower system give us access to efficient balancing services. Therefore, the situation for Denmark is not alarming.

– Energinet.dk is involved in smart grid projects like EcoGrid EU to stay abreast of the market and technology development. This way, we hope to be prepared and plant seeds in the business, bearing in mind that we always aim for the most effective tools for balancing the power system, says Per Lund.

Energinet.dk's EcoGrid EU team and its responsibilities

Energinet.dk was responsible for the final evaluation of the EcoGrid EU demonstration. They performed the evaluation together with DTU-CEE, AIT, ECN and Østkraft. The evaluation included evaluation of the real-time market as well as optimal distribution grid operation, DER response and end user involvement from small and large consumers as well as power producers and prosumers.

Energinet.dk participants in EcoGrid EU:
Per Lund (WP leader), Stig Holm Sørensen, Rune Duban Grandal, Jeannette Møller Jørgensen and Preben Nyeng.



Interview with Jacob Østergaard, DTU-CEE

Professor Jacob Østergaard and his colleagues at the Technical University of Denmark have established the foundation for the EcoGrid EU real-time market and are responsible for the design of the concept. They also played a significant role in the implementation and evaluation of the demonstration.

What do you consider to be the most innovative parts of the project in terms of market concept design and development?
– First of all, EcoGrid EU is a unique market concept which allows a large number of residential electricity customers to actively and seamlessly participate in balancing the power system with benefits for both the system and the consumers. The real-time power market prices are updated every five minutes, thus giving the customers incentives in real time and vital resources for short-term balancing to the TSO and grid services to the DSO, says Jacob Østergaard.

One limitation of today's framework is that market operation is based on an hourly time resolution that does not reflect the full dynamics of the power system. This leads to lower efficiency, which means that the cost of operating the system may become excessively high.

LOWERING THE THRESHOLD FOR CONSUMER PARTICIPATION
In contrast to the current market principles, the participants can respond directly to the market prices in form of real-time prices and forecasted future prices.

–They don't need to submit bids and schedules to provide flexibility. Therefore, active participation requires a minimum of effort, thereby reducing transaction costs. The EcoGrid EU concept removes the barrier currently preventing residential customers from participating, says Jacob Østergaard.

PRICE SETTLEMENT ON THE BIDLESS ECOGRID EU MARKET
A bidless market means that the real-time price is not a result of traditional market clearance between supply and demand bids. – The real-time price is an external price signal reflecting the system state, which is published in advance of each five-minute interval. In case of imbalances, the market operator sends a price signal to the consumers and producers (the premises behind the meter) every five minutes until a certain objective is achieved (ie the TSOs need for balancing power).

DESIGN OF SHORT-TERM FORECASTING MODELS
The forecast of the aggregated demand response is critical information for the real-time market operation in order to be able to issue the real-time price that triggers the necessary amount of flexibility.

– One of the main tasks and challenges of the EcoGrid EU concept were to develop reliable methods for forecasting the demand response to the short-term price signals. There is little experience with flexibility forecasting, and several approaches were discussed.

– The EcoGrid EU demonstration provided observations on the aggregated total load for the participating household. The total load includes price responsive as well as non-price responsive loads. We have developed a novel flexibility forecasting model which separates these two parts of the load, providing us with some degree of certainty about the price responsiveness and enabling us to make short-term demand forecasts and operate the market as a bidless real-time market. To our knowledge, the developed models are very innovative.

ROBUSTNESS OF THE MARKET CONCEPT
According to Jacob Østergaard, the EcoGrid EU idea and concept were carefully prepared. – The concept has been verified through simulations and was subsequently demonstrated on Bornholm where we proved that it actually works in real life. Still, some components are missing:
– We have proven that the system works for the consumers, the aggregator, the market operators as well as for the TSOs. We have also prepared tests of how the concept can assist the distribution system operator (DSO) in managing their grid in form of congestion management. Yet, we have not proven the real-time market´s capability to manage local congestions due to the need for a more advanced market design, which was not possible to implement within the project timeframe. We need to make further investigation on how the market concept can deal with these challenges, says Jacob Østergaard.

Will the EcoGrid EU real-time market replace the existing power markets?
The EcoGrid EU real-time market will be an additional source for the TSOs in parallel with the existing regulating power market. Consequently, the transmitted price must be set in close coordination with the price development on the existing regulating power market.

– The present Nordic regulating power market should be maintained and developed in parallel with the EcoGrid EU market concept. The existing Nordic market is well suited for balancing services from large-scale units which are able to schedule their operation. So the existing regulating power market and the EcoGrid EU market are well suited for different types of players.

– The way TSOs are performing balancing management and imbalance price settlement today does not affect whether or not EcoGrid EU can be implemented. However, we believe that the EcoGrid EU market or some of the developed mechanisms may have to be implemented in different ways in the different countries in order to operate well and be compatible with the existing market designs and solutions in Europe, Jacob Østergaard points out.

STANDARDISED AND USER FRIENDLY SMART GRID TECHNOLOGY
– One of the critical factors in the development of smart technology is the development of standards to ensure interoperability between different home automation solutions. The IT architecture which supports the EcoGrid EU real-time market must be able to communicate with several brands of smart home equipment that respects the customers' individual choices. In the telecom sector, customers need not throw away their phone when they switch to a new telecom network operator. All they need to do is to replace their SIM card.

– We learned from EcoGrid EU that the IT solutions must be customised. In the project, we did not take into account that some of our participants turn off their modem at night to save electricity, with the result that they could not be flexible anymore. The most important thing, however, is to get customers involved. Jacob Østergaard thinks the financial benefits for each individual customer are a challenge. We have to think outside the box. – The EcoGrid EU product could be an attractive element bundled with new business models and contracts, eg together with other products. It could be services which include monitoring and maintenance of, for example, a heat pump utilising the IT-infrastructure investment and improving the overall business case and end user benefits. Smartness from a consumer point of view is certainly not about kWh, but rather about convenience or comfort. This requires a better understanding of the customers' needs; after all, it's all about people.


Jacob Østergaard

TIME PERSPECTIVE
When do you think it is possible to prove a business case for the roll-out of EcoGrid EU? Is this likely to happen without major political push and/or public funding?
– In principle, much of the market system can be rolled out today without any major challenges. Of course, the market rules have to be adjusted to take into account the EcoGrid EU market, but this is basically not any different from other changes made now and then. Whether the market will be successful will depend on the consumers' acceptance. If they can be presented with clear benefits and a convincing business model, the market may be successful, says Jacob Østergaard.

The DTU-CEE EcoGrid EU team and its responsibilities

The Centre for Electric Power and Energy (CEE), Technical University of Denmark, was in charge of the research part of EcoGrid EU. They performed the main scientific work together with other research institutes (SINTEF, AIT and TUT) and energy consultancy firms (ECN, TNO and TECNALIA). The TSO partners Energinet.dk and ELIA also played an active role in the EcoGrid EU design.

CEE participants in EcoGrid EU:
Jacob Østergaard (WP leader), Emil Mahler Larsen, Guillaume Le Ray, Pierre Pinson, Christian Brandt Rasmussen, Nils Nielsen, Anders Bro Pedersen, Alessandro Pensini, Qiuwei Wu, Niamh O'Connell and Rasmus Reeh Pedersen. Other contributors were Yi Ding and Salvador Pineda Morente who are former employees of CEE.

Bernhard Jansen and Olle Sundström

Interview with Bernhard Jansen and Olle Sundström, IBM

The team at IBM Research in Zurich was responsible for the implementation and operation of the overall ICT system that lays the foundation for the EcoGrid EU real-time market and, the price agents from IBM, Siemens and TNO. The team also handled the data warehousing, part of the analysis as well as the user feedback components and integration aspects of a home automation system.

In your opinion – what is IBM´s most significant contribution to the EcoGrid EU project?

– Architecturally, the most innovative feature is the concept of the very scalable one-way real-time price distribution. According to the overall predicted flexibility, this subgroup of individual devices, household units, and aggregated consumers, responds according to the needs of the power system, which only measures the aggregated information and does not require individual information, says Bernhard Jansen.

With the lessons learned from this project, we are convinced to now be able to build a commercially efficient ICT system that can scale to millions of users, Bernhard Jansen continues.

It means that the overall ICT system implementation achieved high system availability and scalability, a core requirement for system acceptance and a wide replication and dissemination of the solution beyond the pilot test on Bornholm.

SIMPLE APPROACH WITH HIGH FLEXIBILITY POTENTIAL

Domestic buildings and their heating systems represent significant energy buffers. Exploiting the energetic flexibility of these systems can help balance the power grid. The idea of making this flexibility available and controlling it by means of a single real-time price signal is both simple and compelling.

– One key feature of EcoGrid EU is the usage of a broadcasted real-time price for market coordination. The chosen mechanism does not require any real-time action by the customers. From an ICT perspective, this makes the EcoGrid EU approach much more efficient, scalable, user-friendly and privacy protecting than comparable approaches, says Olle Sundström.

USING LOW-COST EQUIPMENT FOR HOME AUTOMATION

A key responsibility of the IBM team in the EcoGrid EU project was the evaluation of the economic potential – and the consequences – of using low-cost home automation equipment. For these 'semi-automated households', the architectural pilot decision was to deploy a simple actuator that applies a throttling signal to the heating system, and an indoor temperature sensor to get input about the current comfort conditions.

– This part of the EcoGrid EU project successfully proved that already low-cost automation is able to influence individual household heating systems based on the EcoGrid EU real-time price while preserving comfort for the consumers, thus showing that energy-efficiency improvements do not have to carry high up-front investment costs, says Bernhard Jansen.

–The benefit of using low-cost equipment is that the cost can be recovered earlier than more expensive alternatives which facilitates a faster penetration of 'smart energy' technologies. This is an important aspect because the value to the power system of shifting an individual residential load is still relatively small, Olle Sundström explains.

In the EcoGrid EU project the challenge for IBM was to integrate and control the heating systems using this low-cost equipment without modifications. The most important objective was to always keep customers comfortable, even when components or communication channels were temporarily unavailable. This led to the investigation of sophisticated control mechanisms and mathematical models, parameterised for the individual houses and heating systems.

What are the prospects for standardisation of smart grid solutions, including the systems used in the EcoGrid EU project?

– The standardisation of home automation solutions is still not where it needs to be to facilitate grid-centric energy optimisation projects. Many de-facto standards compete for acceptance. It is a matter of finding the right open interfaces inside the physical households as well as allowing secured networked access to implement global scenarios, such as predicting human presence and opening doors when people come home, says Bernhard Jansen.

Presently, little has been agreed with regard to the secure support of millions of participants. Moreover, schedules following the IEC 61850 standards do not allow the inclusion of price forecasts in the way required by the EcoGrid EU five-minutes real-time market.

EcoGrid EU used the available standards wherever possible. The IBM EcoGrid EU team believes that the main standards around IEC 61850 used by the power industry alongside IETF data communication standards, are strong candidates for the future – particularly, if they continue to morph and introduce more features such as security and distributed co-generation support, including flexible price information exchange.

– EcoGrid EU's unique mechanism of near-real-time one-way bid-less price streams can be implemented highly efficiently, and the IBM team is certain that the work done in EcoGrid EU will contribute to documenting and highlighting these points, while providing valuable insights and requirements for future standards, Bernhard Jansen points out.

DATA PRIVACY AND DATA SECURITY

A significant effort was put into the pilot implementation to ensure proper protection of all participant data. Codified references to individual households were used basically everywhere from collecting the data all the way to analysing it. All data was protected on secured servers via elaborate firewall setup and proper data access schemata among other security mechanisms.

– In the pilot, the IBM team made the 5-minutes household consumption data available in almost real-time via the web interface 'EcoGrid EU Feedback'. This data was useful for the consumers to monitor and to understand their consumption and energy costs, and, of course, for the Consortium-side pilot development, monitoring and demonstration tasks, says Olle Sundström.

EXPLOITATION OF ECOGRID EU RESULTS

Olle Sundström and Bernhard Jansen are convinced: Overall, EcoGrid EU demonstrated that the use of dynamic energy prices is a successful approach that could be used in reality already today, to create demand-response from distributed commercial and household loads. This is a very important global TSO message. The next step must be to fully integrate DSO locational requirements as well. Bornholm will be an ideal pilot site to demonstrate such integration.

In a next phase, the IBM team suggests to pursue a radical simplification of the semi-automated households to facilitate both a low-cost and reliable infrastructure. For example, all components and features that can be misunderstood or operated erroneously by the consumer should be removed. This starts by simplifying the user interface and making it more intuitive by deploying promising technologies such as Low-Power Wide Area Networking (LPWAN) to avoid communication failures and frequent battery exchanges to developing sophisticated and robust models capable of fully utilising all existing sources of housing information to optimally control the devices to the comfort of the consumer.

– While one should immediately start working on a wider dissemination and adoption of the concepts developed in EcoGrid EU, R&D needs to learn how to fully exploit the energetic flexibility of individual components, like domestic buildings, without jeopardising the users' comfort and how to incorporate this on an energy network level, says Bernhard Jansen.

– Only this way, one will be able to create a highly efficient and reliable smart grid with distributed energy resources. This challenge calls for sophisticated and yet robust approaches that are highly cross-discipline, including engineering, computer science, mathematics and psychology – just to mention a few, Bernhard Jansen concludes.

IBM's EcoGrid EU team and responsibilities

The IBM EcoGrid EU team was responsible for the implementation and operation of the overall ICT system that lays the foundation for the EcoGrid EU real-time market and, the price agents from IBM, Siemens, and TNO. Moreover, IBM was responsible for the data warehousing, part of the analysis as well as the user feedback components and integration aspects of a home automation system.

IBM participants in EcoGrid EU:
Bernhard Jansen (WP leader since 2015), Dieter Gantenbein (WP leader until 2015), Michael Baentsch, Carl Binding, Alexandru Caracas, Ulrich Dangel, Doug Dykeman, Ines Elloumi, Metin Feridun, Marvin Kornhaas, Thorsten Kramp, Michael Kuyper, Julienne La Chance, Aditya Mishra, Fabian Müller, Mike Nidd, Tim Nonner, Anders Pedersen, Vit Prajzler, Anders Quitzau, Ulrich Schimpel, Florian Schmidt, Hansruedi Steinauer, Olle Sundström, Axel Tanner, Fabian Theuretzbacher.

Interview with Martin Bo Sjøberg, Siemens

In this interview, Martin Bo Sjøberg tells about Siemens' role in the EcoGrid EU project and the solutions that he thinks have added value to the project. Although most of Siemens' products are available on the market, the solutions have been further developed and 'smart grid adapted' during the EcoGrid EU demonstration. For Siemens, this has opened up new commercial opportunities.

– Siemens' main task in EcoGrid EU has been to contribute know-how of innovative grid management and building automation. Moreover, new control options for small-scale electricity users and producers have been integrated into the central energy management system, says Martin Bo Sjøberg. Experience with Siemens installations in the homes of the EcoGrid EU households gives us a better understanding of the customers' needs which, among other things, can be used for further improvement of smart home automation solutions.

DEVELOPMENT OF THE SIEMENS ENERGY MANAGEMENT SYSTEM

Until recently, Siemens' decentralised energy management system (DEMS) was focused on the production side, the wholesale market and the large industrial electricity users or loads (eg large 250 kW compressors). – The EcoGrid EU field test proved that the system has the intelligence to also manage small devices such as electric heating, heat pumps and hot water boilers in the household. This means that DEMS can financially optimise everything from small to large consumption units, small-scale RES generation (eg CHP and wind turbines) to large conventional power plants. The DEMS system determines the optimal exchange of power with the neighbouring electricity markets, taking into account the price of the import/export of power, explains Martin Bo Sjøberg.

INTEGRATED BUILDING AUTOMATION SOLUTION

At the ferry terminal in Rønne on Bornholm, Siemens has installed a building automation system that is fully integrated with the power system via a connection to the Siemens energy management system. As the project wanted to use the latest available technology, Siemens decided to fund a state-of-the-art building automation system for the ferry terminal, such that the EcoGrid EU concept could be conceptually proven with building automation systems.

According to Martin Sjøberg, the development of an end-to-end solution from the DEMS to the building automation system is one of Siemens' most innovative contributions to the project. – In a modern, intelligent building, there are already many energy-saving, intelligent solutions measuring ambient light in all rooms, dimming the lights accordingly or turning off ventilation in empty rooms. This is not new technology, but it does mean that many sensors are installed in modern buildings. In our concept for EcoGrid EU, we use the building automation system to schedule the consumption of ventilation and cooling to low-price periods, while using the sensors to closely monitor the indoor comfort. The goal is to balance energy savings, time of energy consumption and optimal user comfort. This is exactly what we do in the ferry terminal.

IMPROVEMENT OF THE HOME AUTOMATION SYSTEM

The automation system that regulates electricity consumption in private households (Synco living) has been developed using open standards and fits the project perfectly. – If you have Synco living equipment and have access to the Internet, you can log in to the web interface from anywhere. This makes it possible to change your settings, eg adjust the temperature settings when you are not at home and reduce your electricity bill in case of high real-time prices.

How do you deal with data privacy and security issues?

– In the Ecogrid EU project, Siemens must ensure the data privacy and security of the process data. First, processes cannot be remote controlled if they pose a security risk – this is by design. Second, no control signals are actually sent to the system; only modifiers (incentive signal) to change existing control algorithms slightly. Nothing from the outside can tell a heater to turn on; it can only change the thermostat setting slightly. Third, all communication with the aggregator is encrypted.

Of course, if you implement a system where your data are placed in the cloud, you may also be exposed to a security risk, because the data may potentially be accessed by third parties – it is not within the owners' control anymore. In our concept, no automation data is sent from the home. Actually, all data owned by the user stay in his home, on the equipment, and the user has full control of the privacy of those data and who can access them, says Martin Bo Sjøberg.

In EcoGrid EU, all participants have been given permission to use their metered power data for the evaluation. Most participants have also given Østkraft access to their automation system for support and service needs. But for the Siemens systems, the participants can actually decide to close all access to their home automation system from Østkraft, Siemens or others and still respond to prices.

EMPOWERMENT AND INVOLVEMENT OF CUSTOMERS

There has been a strong focus on informing and training the EcoGrid EU participants, especially customers using automated equipment. *From a deployment perspective: To what extent do you think these customers will request or need consultancy to understand the functionality of their equipment and how it interacts with the power system and real-time prices?*

– In an experiment such as EcoGrid EU, unforeseen situations may happen. In some periods, Østkraft was under additional strain which increased the customers' need for information and advice. Østkraft has done a fantastic job of supporting the participants during the EcoGrid EU demonstration. We assisted Østkraft with telephone support.

In retrospect, Martin Bo Sjøberg thinks that many of the technical issues experienced by customers could have been avoided if the installation work had been postponed. – We were under time pressure due to the delay of the project start. Prior to the project initiation, we should have spent more time on the definition of minimum technical requirements to be met by the households.

– I don't think that there is a need for more information about the use of home automation equipment than is required for the installation and use of an alarm system. There is always someone who needs support and someone who prefers to do it himself. When the Internet was introduced, there was a great need for information about how to use it. Today manuals, web and telephone support are sufficient.

Martin Bo Sjøberg points out that Siemens' key business area is industry. For industry, it is finances and facts that count, not convenience, which makes it much simpler: the information can be communicated by means of a table. – There are and always will be companies that specialise in intelligent control systems for households. For these companies, information and customer support will be an integral part of their business. They know what information needs their customers have.

WHAT IS IN IT FOR THE CUSTOMERS?

What is really in it for the customer in the current phase of the smart grid development?

– I am convinced that the benefits are related to automation; at least for the private customers. Automation is about convenience for them. Customers do not associate the benefits with the power system, but they think that remote control is a convenient way to control their heat pumps or electrical appliances. In the current phase of the smart grid, I think it is the 'gadget effect' that is the driver. We all have a smart phone and are using apps because it makes life easier and more fun.


Martin Bo Sjøberg

Martin Sjøberg has a Synco living installation in his home. – I am an engineer and really think it's fun to play around with. I can do that with the web interface. But this is not the case for my girlfriend. She wants it to be easy to use. She only wants to touch one button to achieve a comfortable temperature. She can do this on the room units, so for us, the Siemens solution satisfies both my tech geekiness and her focus on convenience.

– EcoGrid EU adds an extra element that relates to how flexible you want your electricity use to be, eg how much will you allow the temperature to go up and down when you are at home. This is one of the new 'EcoGrid EU' elements which make our system more complicated to use, and for some participants make it a bit too complicated. In the project, we underestimated how important it is that the new features are intuitive for the consumer. Our focus was on the content of information (the correctness), and not so much on how the information was communicated, says Martin Bo Sjøbjerg.

Siemens' EcoGrid EU team and its responsibilities

Siemens is overall responsible for the work package "Implementation of DER response", including deployment of the distributed demand response solution based on it's DEMS (Distributed Energy Management System), that ties into the market system, building level integration and the device level for demand.

Siemens participants in EcoGrid EU:
Andreas Arendt (WP Leader), Martin Bo Sjøberg, Werner Ziel, Andreas Schirm, Can Uz, Claudia Haertlein, Cyrill Jung, Detlef Schuette, Erich Fuchs, Heinz Cech, Henning Ochsenfeld, Jan Christensen, Joerg Hammer, Joerg Helffenstein, Karl Heinz Jakobs, Keld Mogensen, Kenneth Soede, Kenneth Soede, Michael Jørgensen, Morten R. Sandholm, Roland Ullmann, Rolf Apel, Sandra Potzahr, Susanne Juhler, Thomas Mittermeier, Thomas Werner, Vladimir Klasovity, Wolfgang Hass, Zhenying Ma.

Interview with Maja Bendtsen, Østkraft

Maja Bendtsen from Østkraft elaborates on her perspectives on her involvement as DSO and field-site host for the EcoGrid EU project. Being one of the persons closest to the participants, she has gained new and important insight into the customer needs and expectations for a future smart grid.

The many technical hurdles along the way came as a surprise to Maja Bendtsen. Early in the installation stage, the issues mainly concerned the technical compatibility of various components of the demonstration. Later, the issues were to a greater extent related to the participants' understanding and use of their home automation system and bugs in the installations.

Applying active control of heating in the first winter test of the EcoGrid EU experiment resulted in a number of customer requests. They were typically minor issues that could easily be handled by a technician, but were too complicated for the customer to solve without assistance.

Her advice is not to underestimate the internal resources required for technical support in a project that involves introduction of new technology in the form of home automation equipment.

– We experienced that employees must be highly skilled at dealing with many different kinds of customers. Installers and electricians must have both technical and people skills. Additional training should be given if one of these skills is underdeveloped, says Maja Bendtsen.

CUSTOMERS WANT PERSONALISED CUSTOMER SERVICE

– Our experience from EcoGrid EU is that from the customers' point of view, the best advice is provided through personal contact. However, to keep costs at an acceptable level, I think 80-90% of the consultancy can be provided through mass communication and successful installation. The rest of the support must be provided through personalised customer service.

– Many customers will need further training after a while and training works best when it is personal. People do not read what is written, but what they think is written, and people quickly get impatient if things are not working properly or if they do not understand how things work.

Small and seemingly trivial errors/vulnerabilities in the installations had a major impact, not only because they were costly for Østkraft in terms of man-hours, but also because many of the customers were uncertain, with some even opting out.

– Some of the situations could easily have been avoided if we had been told from the beginning not only how things worked, but also how to deal with things when they were not working, says Maja Bendtsen.

MINOR TECHNICAL ISSUES CAUSED PROBLEMS

– It turned out that the batteries in about 500 of the installed temperature sensors quickly went flat and we had to ask participants to change them periodically. Unfortunately, it was so complicated to swap the batteries that in the worst cases our electricians were called out to help the customers.

– Had we known about the battery issue from the very beginning, the electricians could have brought with them a pack of batteries when they did the installation in the first place, along with a brief guide for the customer on how to swap batteries. It could have saved us many hours of work – and frustrated customers.

– Of course, in the future the technology provider must develop or chose better temperature sensors, ideally where neither Østkraft nor the customer should be bothered with swapping batteries, says Maja Bendtsen.

What were the most typical requests from the participants?

– Especially during the first test in the heating season, customers with automatic control of their heating system were not satisfied with the room temperature in the house. We spent a lot of time training the customers in how they could change the temperature settings and EcoGrid EU control of the heating to avoid the temperature going beyond their comfort limits.

Other frequently asked questions were about passwords and instructions for the web price portal My EcoGrid EU.

From time to time, customers also contacted Østkraft because they felt uncomfortable with noisy and/or blinking equipment when the automatic control was activated.

– Fortunately, we received few requests from customers with an urgent need for assistance, Maja points out.

LITTLE ROOM FOR BIG TEMPERATURE VARIATIONS

The customers did typically not want temperature fluctuations higher than 1-2 degrees. In the beginning, extensive daily temperature variations caused many discontent participants. Later in the demonstration, they were recommended to change towards more conservative temperature settings, resulting in less demand response/flexibility for the system.

– My advice is to give the participants the (technical) opportunity to compromise own thermal comfort for a short period with extreme prices (allow for large temperature variations). At the same time, it is important to communicate clearly with the customer how much economic benefit they could obtain from this, says Maja Bendtsen.

DSOs WILL BENEFIT FROM REMOTE CONTROL ACCESS

EcoGrid EU is an experimental project which legitimises a heavy workload related to personalised customer support, but this may not be a sustainable approach in a wider perspective. *Do you see ways to reduce the number of visits by electricians? Cost-cutting initiatives?*

– It is very important that the home automation systems become more robust in every respect. We need equipment with a long battery lifetime in sensors, high communication stability between sensors and controllers as well as a high degree of connectivity to the Internet. The good news is that it is technically possible with the technology available today,

Maja Bendtsen

but it requires players to work closely together to map all links in the chain from aggregator to the flexible load of the customers.

A major improvement will be the possibility to make remote update of the home automation systems, not requiring an electrician to visit every time there is a need for update or change in software configuration. Also, it must be very easy for the customer to disconnect the automatic control, ie you do not need to be an expert to find the override button, says Maja Bendtsen.

Will the EcoGrid EU concept survive on Bornholm, – will Østkraft do an EcoGrid EU version 2.0?

Definitely. – This is an exciting project, and we want to improve the functionality, so it can work even better for the customer than it does today. And most importantly: many of our participants want to continue in the project, Maja Bendtsen concludes.

Østkraft's EcoGrid EU team and its responsibilities

Østkraft is the local DSO/utility hosting the EcoGrid EU demonstration on Bornholm. The company was overall responsible for the EcoGrid EU recruitment and installation activities. IBM, Siemens and Landis+Gyr contributed technical support and ECN social science expertise.

The Danish-funded (ForskEL) project: 'Smart Grid customer information and communication' was supporting Østkraft with communication material.

Østkraft participants in EcoGrid EU
Maja F. Bendtsen (WP leader), Mark Moseholt, Iene Seifert Bech, Pauli Hjort Hansen, Claus Vesløv, and the electricians Lars Rasmussen and Torben Kure, in addition to the other nine electricians who have been actively involved in the installation of EcoGrid EU equipment.

Interview with Jessanne Mastop, ECN

Together with a team at ECN, Jessanne Mastop is responsible for the overall evaluation of EcoGrid EU customer participation and satisfaction. EcoGrid EU is a special project for Jessanne, since it involves a large group of customers: with every tenth of the electricity customers on Bornholm participating in the project, we gained insight into what people on Bornholm thought about changing their energy use and how they perceived their participation in a large project such as EcoGrid EU.

According to Jessanne Mastop, the conditions for field tests are particularly well suited for island communities. – People want a positive image of their island. This creates greater personal involvement in, for example, environmental issues. In large cities, the motivating factors are typically much more complex, and significant variations in the factors that motivate urban people are to be expected.

DIFFICULT TO MAKE A GENERAL ASSESSMENT OF THE RESULT

– As is the case with many energy pilots with a technical focus, more men than women participated actively in the EcoGrid EU project. Furthermore, participants were also older than what could be expected when looking at the population on Bornholm. We do not know for sure why, but it may be that families with small children simply have less time to participate in projects such as EcoGrid EU, or have other priorities. The challenge for projects such as EcoGrid EU is therefore to design a project in such a way that it will attract a diverse group of participants, says Jessanne Mastop.

On average 70% of the respondents in the final customer survey were male, and the average age was 60 years, while the average age of the island is 46.

'BEST RECRUITMENT PRACTICE'

According to Jessanne Mastop, in many ways the EcoGrid EU project can be used as best practice for other smart grid projects with respect to customer recruitment and involvement.

What do you think was the key to its success?

– Østkraft made a great effort in the recruitment of their customers. They involved their customers in the process from the start. The technical and social skills of the installers were also important, including Østkraft's own electricians and the industrial partners of EcoGrid EU. From the very beginning, the installers helped making the participants feel comfortable about the project. It is a challenge, however, to have a similar intense communication strategy for large-scale projects.

Is there anything that could/should have been done differently?

– Looking back it is easy to say that we should have done things differently. First of all, the recruitment suffered from equipment issues. Ideally, you should test all the equipment before it is installed in all the households. Unfortunately, this was not possible within the given time frame. Prior to the installation, we could have made a greater effort to recruit a wider mix of participants. Instead we recruited a large number of relatively well-established consumers who already behaved energy-efficiently, thereby reducing the flexibility potential of the project.

– The financial incentive in the project could have been clearer. About one-third of the respondents in the online customer survey indicated that the incentive to change their appliance use was too small.

WILLINGNESS/ABILITY TO RESPOND TO REAL-TIME PRICES

More than half of the 689 respondents in the final survey said that they had made some changes to the way they used their appliances since they joined the EcoGrid EU project. 42% of those who did not change anything said that it was not possible for them to make changes, thought the incentive was too small, or said it was too much of an effort to change anything.

– In the group in which the participants had no automatic control of their heating (the manual response group), the highest score was found among those who said that they had changed their consumption. Similar to other surveys, the respondents were more willing to change the way they used their dishwasher, washing machine and dryer, and less willing to change the way they used their TV and computer.

Please note that these findings are based on what the respondents said they did, ie self-reports by customers.

– The overall statistical analysis of actual behaviour showed only significant changes in consumption patterns (demand response) within the group of customers who had installed equipment for automatic control of their heating. However, results from a partial test performed for the manual response group indicate that people do respond, but only to very low/negative real-time prices. They increase their electricity consumption, but as soon as the low price period ends, their consumption returns to normal, says Jessanne Mastop.

Do you think the EcoGrid EU project has managed to keep the participants involved?

– With regard to communication, it seems that the hard work put in by Østkraft paid off: In general, project participants are positive about the communication and service they receive and say that the amount and frequency of information is just right.

– At the start of the project, the respondents' most important reasons for participating were to do something good for the environment, to be part of a new and exciting project and to lower their energy consumption. Additionally, they also think that the project allows them to contribute to a positive image of Bornholm. Fortunately, most respondents also feel that the project enables them to fulfil these goals. Over time, it seemed that customers became less positive about the potential to save money or reduce consumption, but instead focused more on the environmental and social benefits of the project.

– Of course, not everything went smoothly. The equipment for the automatic control of the heating systems did not always work as intended and it took a long time to install everything properly. Furthermore, not all customers were satisfied with the online feedback system.

Did any of the results surprise you?

– An interesting finding was that there were many participants who did not know that their heating is controlled automatically. We are not sure what the cause of this finding is. It could indicate that automatic control runs smoothly and is not very noticeable for the customers, but it could also be that customers are overruling the automatic control or are unfamiliar with the terminology used.

Also, it was surprising to see how many customers said they would prefer variable prices over the traditional prices by the end of the project (47%). People usually prefer what they already know, so apparently the three year project was sufficient to make customers feel positive about this flexibility

– When the respondents were asked whether they knew that their heating was controlled automatically, indeed many customers said that they hardly noticed this automation. They mostly perceive it as a convenience and also say that it has a small positive effect on the comfort level in their homes.

Overall deployment perspective/considerations and lessons learned: how do you think we can use the customer experiences on Bornholm in a wider EcoGrid EU replication scenario?

Jessanne Mastop

– EcoGrid EU has provided valuable insight into the difficulties that arise when targeting a large group of participants. For example, the problems that were encountered with equipment and installation at the beginning of the project were tough to tackle, as it required so many house visits. Roll-out on a larger scale would be impossible. A smaller scale test set-up of equipment would be advisable, although such a test group should be sufficiently diverse to ensure that all possible difficulties are addressed.

– Furthermore, EcoGrid EU demonstrated the necessity of making a project appeal to a diverse group of customers. While most customers are interested in increasing insight into their own consumption, they may be so for different reasons. Some customers are interested in the technology behind it; others are aiming to save money. This insight is not only valuable for finding customers to (start and continue to) participate in a project, but also for designing the project and realising demand response or energy savings, Jessanne Mastop concludes.

The ECN team and its responsibilities

ECN has together the main responsibility for the social science studies in the EcoGrid EU project and was an important contributor to the overall evaluation work (led by Energinet.dk). The acceptance of the EcoGrid EU products and services by the different customer groups was analysed and evaluated by qualitative and quantitative methods. ECN also was main responsible for the task related to framework conditions across Europe together with ELIA (WP leader), AIT, TECNALIA, EANDIS, TUT and EDPD.

The ECN EcoGrid team:
Jessanne Mastop, Suzanne Brunsting , Mariette Pol, Matthijs Uyterlinde, Frans Nieuwenhout, Marielle Rietkerk , Koen Straver, Jeroen de Joode.

Interview with Georgios Giannopoulos, ELIA

Georgios Giannopoulos represents the Belgian TSO. He was leading the EcoGrid EU work package deployment and replication – perhaps the most challenging job in EcoGrid EU. All the time, he had to closely monitor the concept on Bornholm as well as contribute with advice on how to demonstrate it. And, at the same time he knew it would be difficult to realise the exact concept outside Bornholm, due to the very different approaches to power balancing markets across Europe.

Despite these challenges, Georgios Giannopoulos remains optimistic. – The market framework conditions are constantly changing. The ongoing implementation of the electricity and energy efficiency directives, including the obligations related to roll-out of smart meters, are positive from an EcoGrid EU perspective.

– Similarly the new Network Codes currently drafted by ENTSO-E support the development towards a more active involvement of DR in the balancing markets. EcoGrid EU is one way to stimulate this development.

THE PERSPECTIVES OF ECOGRID EU IN THE BELGIAN SYSTEM
How replicable the concept will be to other markets across Europe depends on what Georgios Giannopoulos refers to as its replicability and scalability properties. In other words: *How easily can the concept be duplicated to another demographic location and modified to other balancing power markets, for example in Belgium?*

– In many respects the Belgian system parallels the EcoGrid EU concept. Compared to other markets, the Belgian system motivates the balance responsible parties (BRP) to participate in market operations close to real-time in order to restore the system balance.

– BRPs are incentivised to use their resources connected to all voltage levels to balance the system even if this means creating an imbalance in their own portfolio. In addition to this voluntary response, ELIA is currently sourcing a significant part of its contracted reserves from load. At the moment, however, only industrial loads connected to the high and medium voltage level are able to access this market, says Georgios Giannopoulos.

In order to trigger a voluntary, real time response, the TSO is publishing real-time information, such as imbalance prices, volumes, and forecasts for every imbalance period (15 min in Belgium) that helps the market actors understand the needs of the system.

– The aforementioned voluntary response is not restricted to production means, but could come from all kinds of loads. Consequently, demand response could be activated, hereby reducing the residual imbalance to be resolved by the TSO, says Georgios Giannopoulos.

Thus, the objective is to keep the residual imbalance to be resolved by the Frequency Restoration Reserves of the TSO as small as possible.

The share of wind power capacity in Belgium is much lower than for example in Denmark. Do you have an urgent need for short-term balancing power in Belgium?

– At the moment, approximately 5 GW wind and solar capacity is connected to the grid. This represents almost 40% of the peak demand in Belgium. Furthermore, in Belgium the energy mix is relatively inflexible, resulting in a more urgent need for new flexibility sources. Some years ago, it was decided to allow larger industrial loads to participate in the balancing market.

– This has turned out to be a competitive alternative to conventional balancing reserves. Today, the demand response potential from large industrial loads has been utilised to a great extent. Therefore, we look for cost-efficient models (such as EcoGrid EU), which could allow smaller industrial units and residential loads to participate in power balancing, Georgios Giannopoulos says.

CUSTOMERS ARE WILLING TO BE PART OF SMART SYSTEMS
Georgios Giannopoulos and his team have learned that residential customers are eager to participate in a smart grid project. – The prospect to save money is not the only driver, but also environmental issues and interest in innovation are important motivating factors for the costumers, he says.

AUTOMATION IS PROMISING AND CAN INCREASE CUSTOMER COMFORT
The automatic response was found to be very promising compared to the manual one. A majority of the customer survey respondents indicated that the automation system was convenient and for some customers, the automation system could even increase the comfort.

– I think one of the future motivating factors for customers could be higher comfort levels. As a result, it is advised to focus a possible roll out of demand response on automatic response in order to have more promising results, Georgios Giannopoulos points out.

NEXT STEP...
The replication perspective – when do you expect an EcoGrid EU market or wide participation of smaller demand response units in power market balancing?

– I believe that in order to be pertinent with the way the current markets are designed we should further develop the participation of demand flexibility in the day-ahead and intraday markets to enable balancing production and consumption as soon as possible.

– Furthermore, new real-time approaches similar to the EcoGrid EU concept could be considered as they offer a relatively simple way of demand response integration of different types of loads in the flexibility markets.

Georgios Giannopoulos believes that automation is the key to activate demand response at the residential level on a large-scale:

– The technological aspect is very important for the success of a demand response project. Regulators should develop communication standards and technology suppliers should respect them in order to avoid interoperability problems that lead to incompatible technologies and finally lead to dissatisfaction of the end users.

Given that a home automation system is smart grid-ready, how can we make 'the man in the street' ready for smart grid, and how can we make the EcoGrid EU market attractive to him?

Georgios Giannopoulos

– We should never forget that at the end of the day, the customer is the one who is bearing the additional costs that the power system challenges are generating. As a result, we need to communicate to the customers that they will get a piece of the pie if they actively participate in the system balancing.

How will ELIA use the experience gained from EcoGrid EU?

– The EcoGrid EU project triggered an interesting reflection at ELIA regarding the potential of residential demand response and deployment of simple ways to use it for balancing.

– Until now, ELIA was familiar with few large industrial loads, and EcoGrid EU gave a taste of the particularities of many smaller loads from residential houses. As a next step, ELIA is planning to also look more closely into the flexibility of commercial buildings and to study suitable models on how to bring this load to the market, Georgios Giannopoulos says.

ELIA's EcoGrid EU team and its responsibilities

ELIA was leading the work on the EcoGrid EU Deployment and Replication issues with contributing partners such as Energinet.dk, AIT, TECNALIA, TNO, ECN, Eandis, and EDPD. In addition, at the beginning of the project it was heavily involved in the design of the concept and its architecture.

ELIA participants in EcoGrid EU:
Georgios Giannopoulos (WP leader), Bob Hebb, Johnathan Sprooten, Sophie Gorlé, Alexandre Torreele, and Stephane Otjacques (former employee of ELIA).

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-CEE	Denmark	Centre for Electrical and Energy 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