Review of the Workshop on DSM Potentials, Implementations and Experiences

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During the Austrian Smart Grids Week in May 2014, the IEA DSM Task 17 and the European project EcoGrid EU jointly organised a workshop to foster the exchange between experts and stakeholders.

The workshop was intended to present latest activities in the field of active demand response (DR) and demand side management (DSM). The IEA DSM Task 17: “Integration of Demand Side Management, Distributed Generation, Renewable Energy Sources and Energy Storages” and the European project “EcoGrid EU” jointly organized this workshop. The contributions are structured into four blocks which will cover “DMS potentials of buildings”, “DSM for distribution networks”, “DSM and market operation”, “DSM and electric vehicles” and a panel discussion with the presenters.

Over 70 participants from 15 different countries have been attending the workshop and a very positive feedback was received afterwards. Presentations have been put online and are available at: http://www.ieadsm.org/ViewTask.aspx?ID=16&Task=17&Sort=0#anc1254

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1 Introduction

IEA DSM Task 17 Phase 3

The aim of this task is the exchange of experiences and knowledge transfer on integration of demand side management (DSM) and demand response (DR) in residential and commercial buildings in order to achieve optimal embedding of renewable energy resources in electricity networks and markets. In the framework of this project, the role of available technologies like PV systems, electric vehicles, electric and heat storage systems, heat pumps, micro-CHP in combination with energy management systems and smart meters for implementing dynamic tariffs will be assessed.

Besides, the existing experiences of conducted and ongoing pilot projects which combine these aspects will be analyzed and discussed. The application and realization of executed projects in participating countries with respect to the specific regional differences and requirements are in focus.

Phase 3 of IEA-DSM Task 17 will address the current role and potential of flexibility in electricity demand and supply of systems of energy consuming/producing processes in buildings (residential, commercial and industrial) equipped with DER (Electric Vehicles, PV, storage, heat pumps, ...) and their impacts on the grid and markets. The interdependence between the physical infrastructure of grid and the market side will also be looked upon. The scalability and applicability of conducted and ongoing projects with respect to specific regional differences and requirements will be explored.

Project EcoGrid EU

The objective of the EcoGrid EU project is to develop a prototype of a European Smart Grid market platform able to incorporate small-scale distributed energy resources as well as flexible demand into a new market platform using real time pricing. The key idea of the project is to introduce a real time market (close to operation) distributing a real time price on which distributed energy resources and flexible demand can react.

Welcome and opening words

Boris Papousek, Austrian ExCo member of the DSM Implementing Agreement, opened the workshop and gave a short introduction about the Demand Side Management Program of IEA. His main point was about the possibility to achieve 2/3 of required reduction in energy demand can be by energy efficiency.

Benoît Bletterie from AIT (Austrian Institute of Technology) gave a brief introduction of EcoGrid EU, which is a large demo project (2000 customers) at island of Bornholm. EcoGridEU objective is to establish a real time market in order to mobilize balancing resources to integrate more RES.

Matthias Stifter from AIT (Austrian Institute of Technology) introduced IEA DSM Task 17. Experts from different nations are discussing demand response, possibilities to enable flexibility in households and other buildings (esp. office) and provide them to the electricity grid. About 10 participating countries, industry have or are joining the task.

The workshop has been organized in four blocks: 1. DSM potentials of buildings, 2. DSM for distribution networks, DSM for market participation, 4. DSM and electric vehicles.

2 DSM potential of buildings

The first session which dealt about the potential of DSM - how big & how can it be accessed? – had four speakers from academia, consultant and industry.

In the first presentation *‘Buildings as interactive participants in Smart Grids: a demonstration project for DSM’* Georg Siegel (AIT, Austria) presented an interactive apartment building which is capable of reacting to certain grid signals for the network operator (“grid friendly”). This is achieved by a combination of automated control of HVAC system (room heating, domestic water) and interaction of the residents, provided by information, devices supporting demand response and incentives. A forecast clock displays green, yellow and red as incentives using electricity. This is operated under the constraint of not harming the comfort of the users. A big heat storage system is used for shifting the load according to the requirements, together with a combined heat and power plant, a PV systems and district heating for optimizing the electricity consumption from the grid.
Figure 1 shows the heat storage tank and Figure 2 the FORE-watch. Extensible long-term monitoring is ongoing for the period of this year.

Figure 1: Smart building with 5 level high heat storage tank (source: Salzburg AG)

Figure 2: FORE-Watch to indicate times of high and low energy prices (source: Salzburg AG)

‘Load flexibility in small and medium enterprises and criteria for successfully enabling them’ was elaborately answered by Michael Wedler (B.A.U.M consult, Germany). A survey was conducted of existing studies for load shifting potentials of enterprises and 30 enterprises investigated in detail.
The main finding was that business enterprises have high potentials and are able to shift one third of daily peak load for 15 minutes once a day. The success factors depend on using existing energy management systems and communication technologies, which are used by third party to aggregate and provide the service. Preconditions for enabling the flexibility are still appropriate framework conditions provided for market participation. Still subject to research are cost-benefits for such grid services in combination with the integration of renewables.

The project *‘LoadShift - Load shifting in homes, industry and communities’*, presented from Michael Schmidthaler (JKU Linz, Austria) analyzed potentials in details. By identifying the energy consumption of different household devices an estimation for load shift potential has been proposed for the case of Austria (Figure 3). Different barriers like the possibility to deactivate participation or the adaption of the behavior as well as the role of flexible tariffs are discussed.

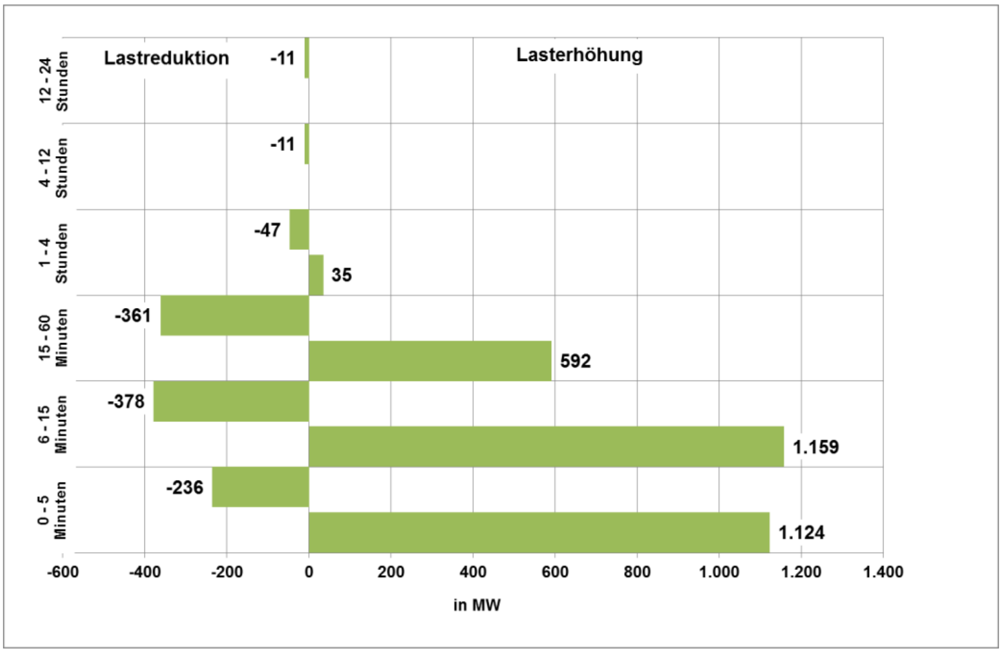


Figure 3: Potentials of load reduction and increase for different activation periods (source: JKU Linz)

The question, *'What can the industry provide to enable DSM in buildings'*, has been answered by Werner Ziel (Siemens). The reason for demonstrating a real time market in the EcoGrid EU project on Bornholm (DEN) is because small end-users can participate and the transmission operator (TSO) gets access to alternative balancing potentials. The real-time market is an additional market operating in minutes, means price signals are sent in 5 minute intervals.

A number of buildings has been aggregated and communicate with the Energy Management System. Automatic controlled devices used are domestic hot water boiler and electric heating. The system is able to vary temperature set-points during day (different during day and night) via the heating controller. It provides a smart user interface for the customer to make adjustments. Figure 4 shows the interaction of the various components of the smart home automation system 'Synco'. The solution for commercial buildings used BACnet to communicate with the building management system and the aggregator system (DEMS). Implemented functionalities include for instance a peak demand limiter. More details could be found under eu-ecogrid.net.

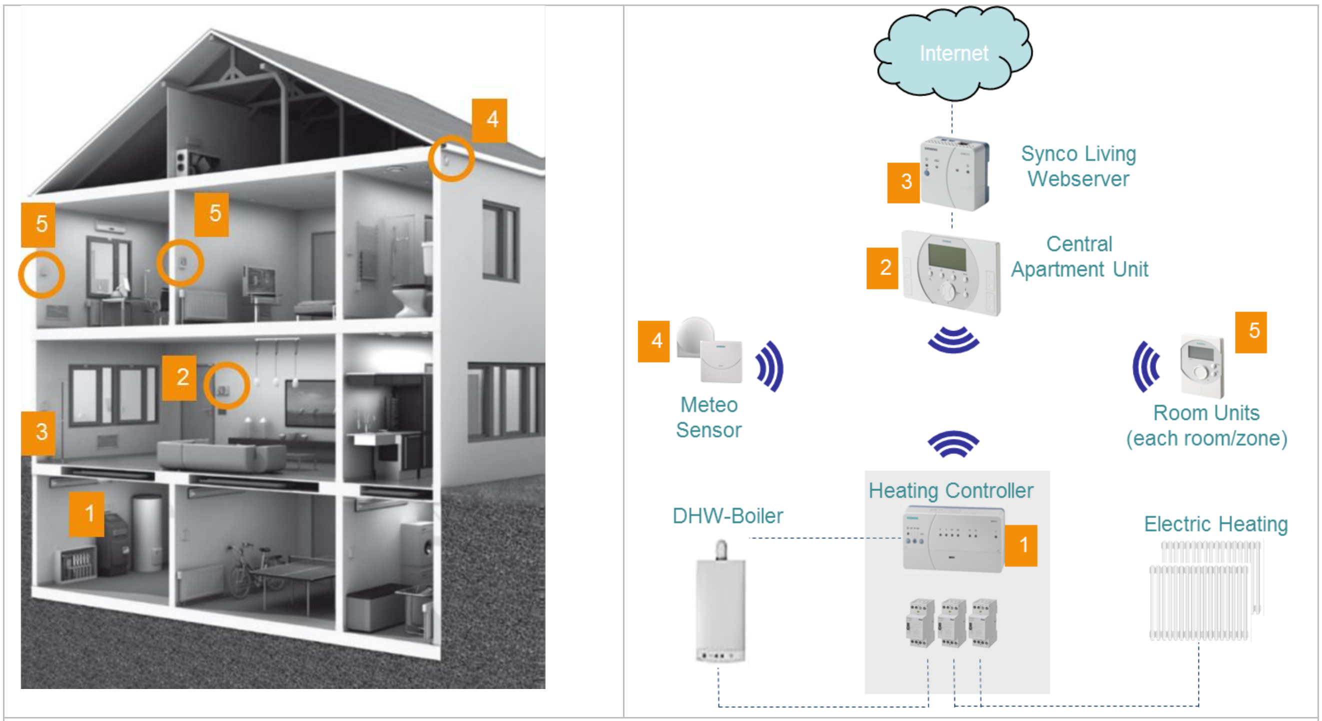


Figure 4: EcoGrid EU residential solution Synco living Home Automation (source: Siemens)

3 DSM for distribution networks

The next block focused on the impact and interactions of flexible loads with the distribution grid. Three speakers from academia and government gave a comprehensive overview about ongoing efforts and projects.

An invaluable insight into ‘C*urrent status, issues and potentials in India’* was given by Prof. Suryanarayana Doolla (IIT India). The regulatory process of initiating DSM projects – including planning, proposal, vendor and customers selection, implementation and measurement and verification – was explained. An example of the huge potentials and savings with the retrofitting of street lights with LED demonstrated an impressive 55% increase of savings. The concentration of DSM projects in regions where private utility was mentioned as a problem with respect to the outreach of the programs. The technology options for DSM projects are dominated from the classical energy efficiency perspective with manual demand response among them. The BEE 5 star rating program (comparable to energy efficiency labels) is quite successful in saving energy by providing additional a power saving guide for the devices. The issues and barriers – divided into structural, availability, behavioral and regulatory – are dominated by the financial issues of capital costs and return of investment, the non-reflected savings through energy efficiency and the uniform policy on state level.

The successful an agent-based market bid driven automated demand response implementation was presented by René Kamphuis (TNO, The Netherlands) with the title ‘*Power Matching City II (PMC-II) - Demonstration of multi-objective optimization in a living lab’.* 25 households, equipped with Stirling micro combined heat plant (µCHP), hybrid air to air heat-pumps, solar cells, wind turbines and two EVs, communicate through a concentrator agent with an auctioneer agent to form a virtual power plant (VPP). Different use cases utilize the demand response potential given by the thermal heating buffers. Among others one of use case is the support of the electricity system with intelligent use of the gas infrastructure for congestion and capacity management, home energy optimization, reducing wind imbalance and photovoltaic generation in real-time. Figure 5 shows the output of the VPP and the reaction due to price changes of the project PowerMatchingCity II by intelligent buffering. If the price is forecasted to rise, the heat pump buffers are filled; if the price is expected to drop the micro-CHPs pre-emptively fill the heat buffer.

In the second phase of PMC a ‘distribution agent’ was implemented taking care of grid constraints, like congestions. Together with the trade dispatch and the community proposition, these objectives form a multi-objective optimization which has to be solved. The strong involvement of community led to two priorities, one the utilization of renewable energy and the interest in smart cost saving. Figure 6 shows the energy dashboard of PowerMatchingCity with feedback on cost-effective operation of devices, cost savings and the home and community energy balance. The agent system additionally takes forecast into consideration (generation, price changes) in order to adjust the behavior.

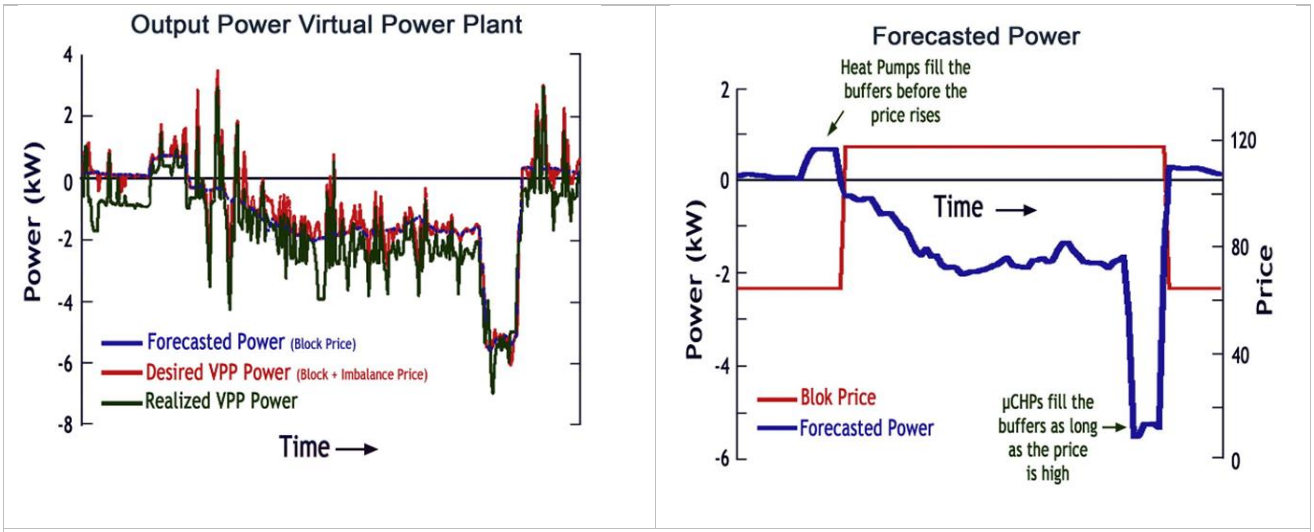
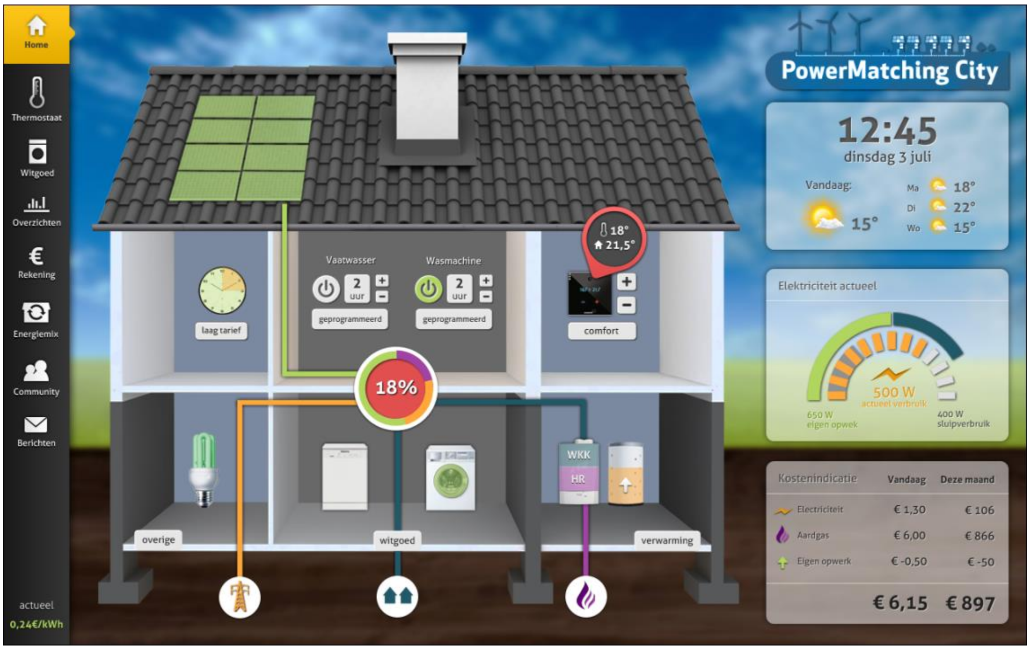


Figure 5: Output of the Virtual Power Plant (VPP) and the reaction on price changes (source: TNO)



Kostenindicatie	Vandaag	Deze maand
Electriciteit	€ 1,30	€ 106
Aardgas	€ 6,00	€ 866
Eigen opwerk	€ -0,50	€ -50
	€ 6,15	€ 897

Figure 6: Energy Dashboard of PowerMatchingCity (source: TNO)

‘*A Swiss perspective of DSM for electricity networks – Overview of ongoing projects’* including research and demonstration projects, was given by Matthias Gallus (BFE, Switzerland). The widely used ripple control which is used for shifting a large number of thermal loads (electric water heaters) to evening hours is in place for several decades now. It is mostly used to relieve network load and shift load peaks in order to reduce the demand for additional infrastructure capacity and network tariffs.. Renewable and distributed energy resources are the driver for more control on shorter time scales. The high potential of DSM through the aggregation and control of thermal storages (mostly heat pumps but also electric water heaters) introduces helpful flexibility. Ongoing projects investigate strategies for control and communication of large aggregated household appliances (‘Distributed Load Management’), electric vehicles (‘THELMA’ - www.thelma-emobility.net) and small scale energy storages in big buildings (SmartGrid-Polysun); The projects analyze effects on the distribution grid and evaluate business models for DSO and retailers. The new challenges to planning tools for distribution grids are also addressed in research. Demonstration projects tap the flexibility of thermal heat storages and power-to-heat devices through a centralized management in the project ‘WarmUp’ (Figure 7). A recently founded company named ‘BeSmart’ functions as an aggregator. It uses ICT to connect large numbers of small scale devices (mostly heat pumps) in the distribution network to perform dynamic load management on a second by second basis. With the offered control it supports the integration of the fluctuating generation of renewable energy sources.(secondary and tertiary control). The customer gets no financial remuneration but other benefits e. g. from monitoring, from increased comfort and efficiency and from an automated alarm in case of technical failures.

Another project, pursued by a large utility, aims for the aggregation of large infrastructure system such as water supply or sewage plants. The pooling and active control shall allow offering of positive and negative balancing energy on control reserve markets. The imposed load control will not affect the normal operation of the plants. Currently, a pilot is implemented in the field.

Although various approaches for load control exist, the interaction between grid and markets – at the time technically feasible – is so far unresolved. The question of how loads can serve the network in phases of congestion while at the other times being utilized for market actions is open. It is by far not only a technical question but also a regulatory question as unbundling issues and have to be considered. Finally, a non-discriminatory solution needs to be implemented in order to leave the market as much freedom as possible without jeopardizing network security. Customers will benefit directly through new services. If in the end costs will drop is a subject for further investigation, as the implementation of coordination schemes between market and grid incur cost in the network, e.g. costs for supervision of the network, while generating the benefits mostly on the market.

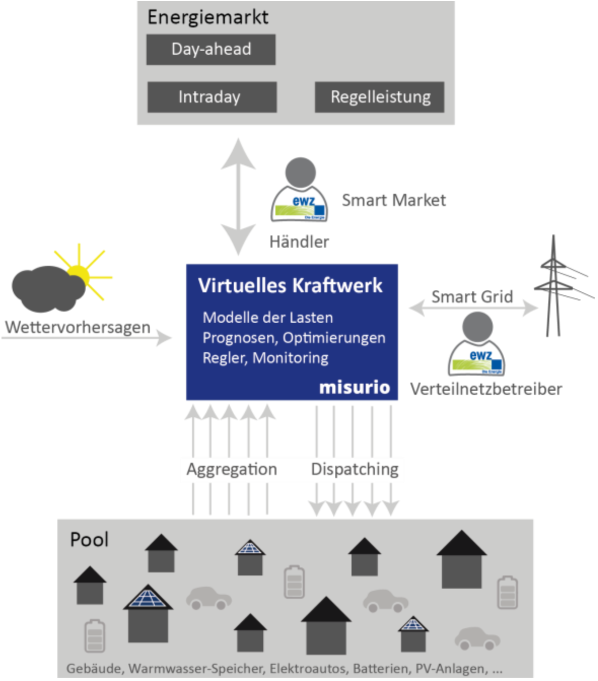


Figure 7: Swiss project 'warmUp' develops a Virtual Power Plant which interacts with all relevant actors (source:ewz & misurio AG)

4 DSM for market participation

In the block of market participation five presentations have been given from academia, industry and transmission operator perspective. Discussions started from validation of the new real time market implementations of EcoGrid EU at small scale up to country wide and European level market integration.

The challenge of *quantifying the demand shift on the basis of statistical methods – first evaluation from the project EcoGrid EU* was pinpointed by Florian Judex (AIT, Austria). Validating if the implemented automated demand response mechanism really worked with respect to the influence of the price on the consumption. After going through a couple of statistical analysis processes it could be proved that there is a reaction to price signals and the automated control works as intended. Figure 8 shows the correlation of the consumption with realistic price signals from the market.

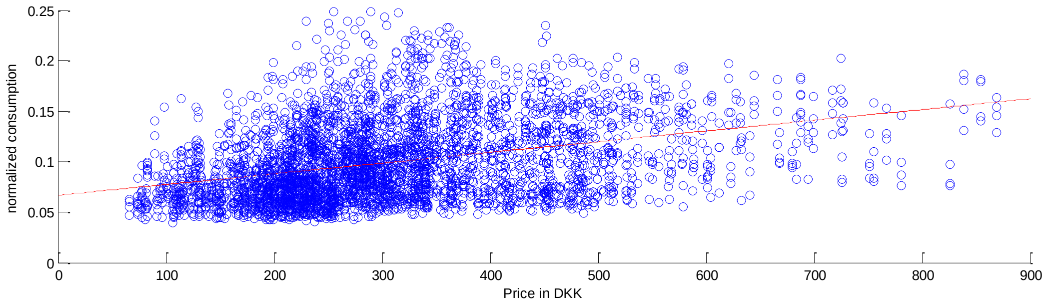


Figure 8 EcoGrid EU: Correlation of the consumption with realistic price signals (source: AIT)

The presentation about *Analysis of the European Framework for Balancing Power – opportunities and new trends identified within the EcoGrid Eu project* was given by Georgios Giannopoulos (ELIA, Belgium). The classical balance responsible party (BRP) is responsible for the supply demand match of producers and retailers within its zone. If this could not be achieved – either by using day-ahead, intra-day market or own assets, the transmission system operator (TSO) has to take over, acting very close to real time. In some cases, like Denmark, the TSO acts more proactively and takes control of the balancing one hour before real time. The BRP can balance its portfolio via their demand. So demand response, under the aspects of duration, reliability, energy neutrality / rebound effects, can be used for balancing in a closed-loop pricing process.

Figure 9 shows the type of services of DR: balancing and ancillary services for power and energy market for the benefits of BRP and TSO; grid constraints (congestion) for benefit of distribution system operators (DSO). From the different balancing mechanism implemented in Europe the need of the reaction time of BRP can be determined as a requirement for the implemented DR response times (Figure 10). Transparency guidelines approved from the European Commission oblige TSO to publish, close to real time, information about balancing, thus moving closer to the concept of real time markets.

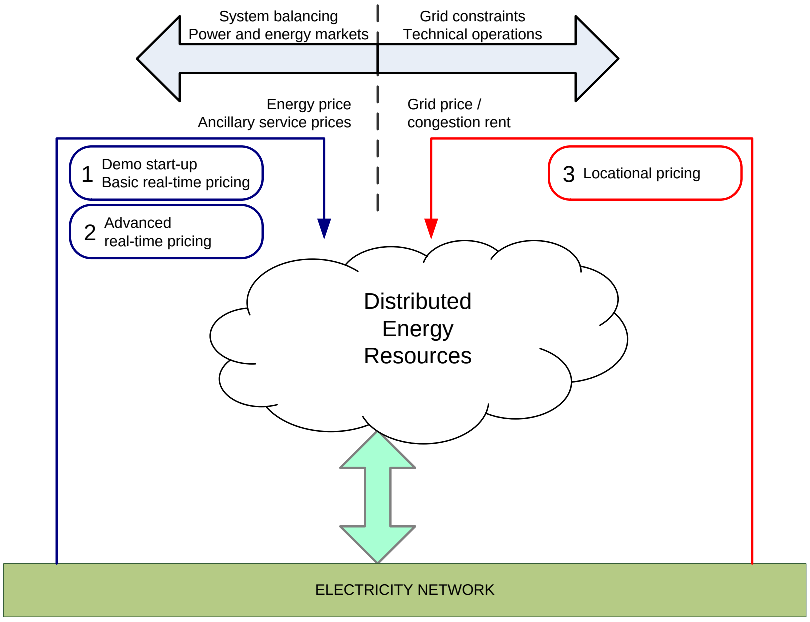


Figure 9: Demonstration phases of EcoGrid EU (source: EcoGrid EU)

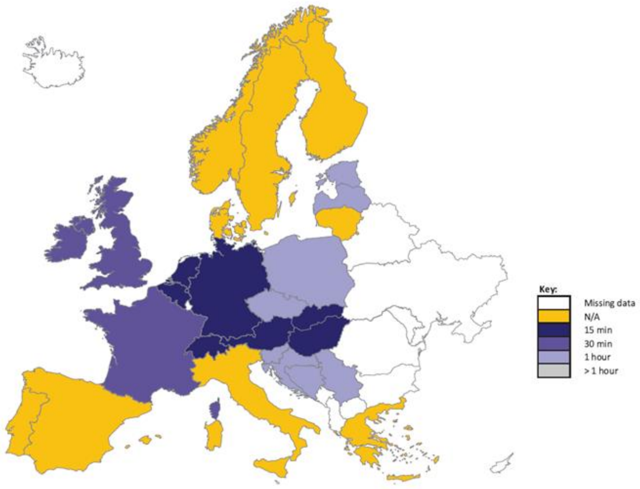


Figure 10: Imbalance settlement period in European countries (source: ENTSO-E)

In the next presentation of the project *'Smart Grids and Energy Markets'*, Jan Segerstam (Empower IM Oy, Finland) showed how the Finnish vision of DR integration becomes reality. From a long history of market based integration of resources the rollout of smart meter (>90%) paves the way for direct market participation, as the data is already used heavily for balancing. As a fact, 600.000 already time of use tariff controlled heat loads are now adapted to be controlled via smart meter system. A control platform, developed by Empower IM, allows to channel the DR load / generation control service requests to the DSO, for checking technical constraints, and then to the customer. Figure 11 shows the schema of 'Fortum', one of the smart grids products. Future research efforts include: the market wide ICT and process architecture which enable "smart customer functions", enabling distributed generation impact on market price and management of imbalance, optimization of resources through demand response, involvement of customers into DR and home energy management systems and achievement of European level electricity market structures including interoperability.

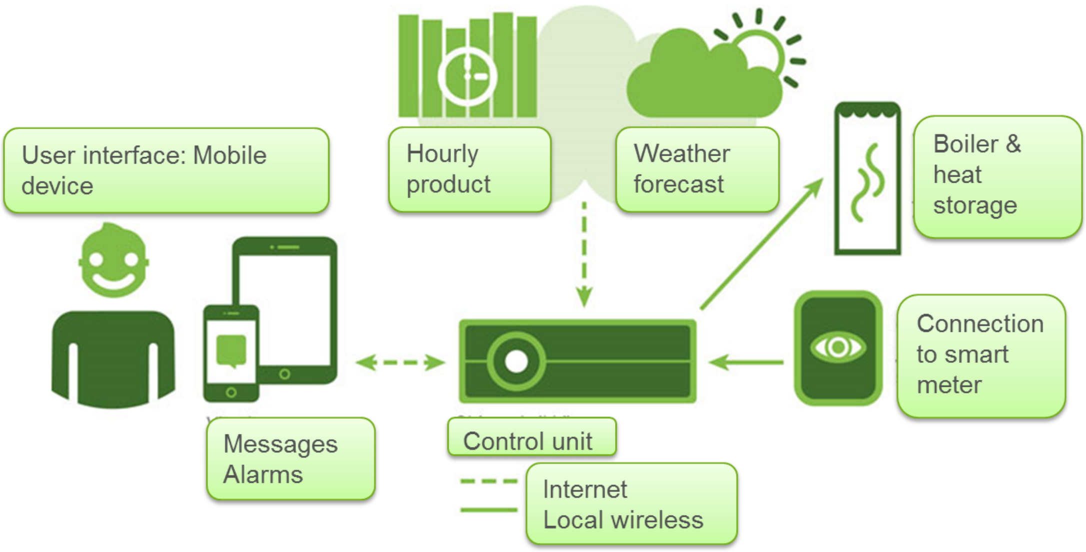


Figure 11: Project SGEM: Smart Grid product 'Fortum' (source: Empower IM)

The project *'eBADGE – Integrating the European electricity market'* presented by Alexander Lurf (cyberGRID, Austria) shows the way to integrate virtual power plants (VPP) in a pan European balancing market (Figure 12). The objectives in this project are to implement simulation and modeling tool, protocols and control strategies, a home energy cloud and business models and demonstrate it in the lab and field trials. Simulation results, where the usage of transmission capacity was analyzed as well, show a total saving of 40% in the common balancing market scenario between Slovenia, Italy and Austria. In order to realize the integration of European balancing markets, a big step toward harmonization of the markets are necessary.

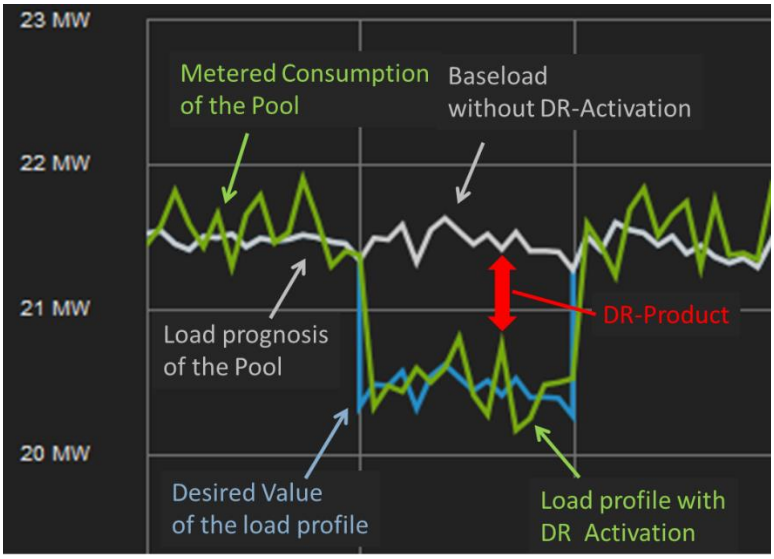


Figure 12: Example of a Virtual Power Plant in action (source: CyberGRID)

The 'Residential real-time pricing experience' was presented by Steve Widergren (Pacific Northwest National laboratory, Washington USA). The 'transactive grid control' mechanism includes: the automated aggregation of the flexibility of the customer's devices, the aggregation of all curves by the utility, the settlement of the price were the objectives for the grid are achieved and finally the broadcast back to the customer (Figure 13). Implemented demonstrations of a real time market in the project 'gridSMART RTPda' show benefits for the energy purchase, capacity and ancillary services. With about 200 homes on four feeders, a market bidding mechanism performs distributed optimization, with a separate market on each feeder and a 5 minute clearing time. Smart thermostat (HVAC) and home energy manager enable automated bidding, were the customer still can set comfort or economy preferences. Figure 14 shows the reaction of the HVAC units following price signals. In summary, the transactional framework is designed to coordinate millions of distributed energy resources. A good solution has the characteristics of security and privacy, simple interaction, viable transition path co-existing with traditional approaches, stable and predictable.

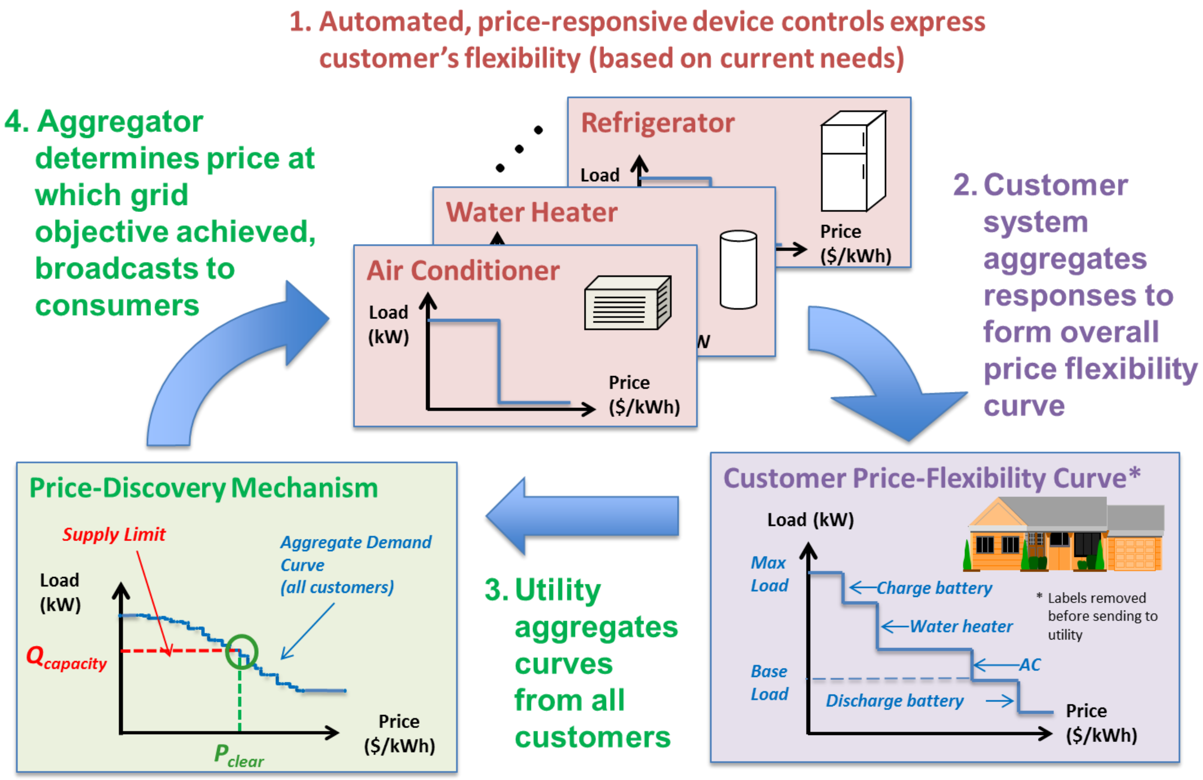
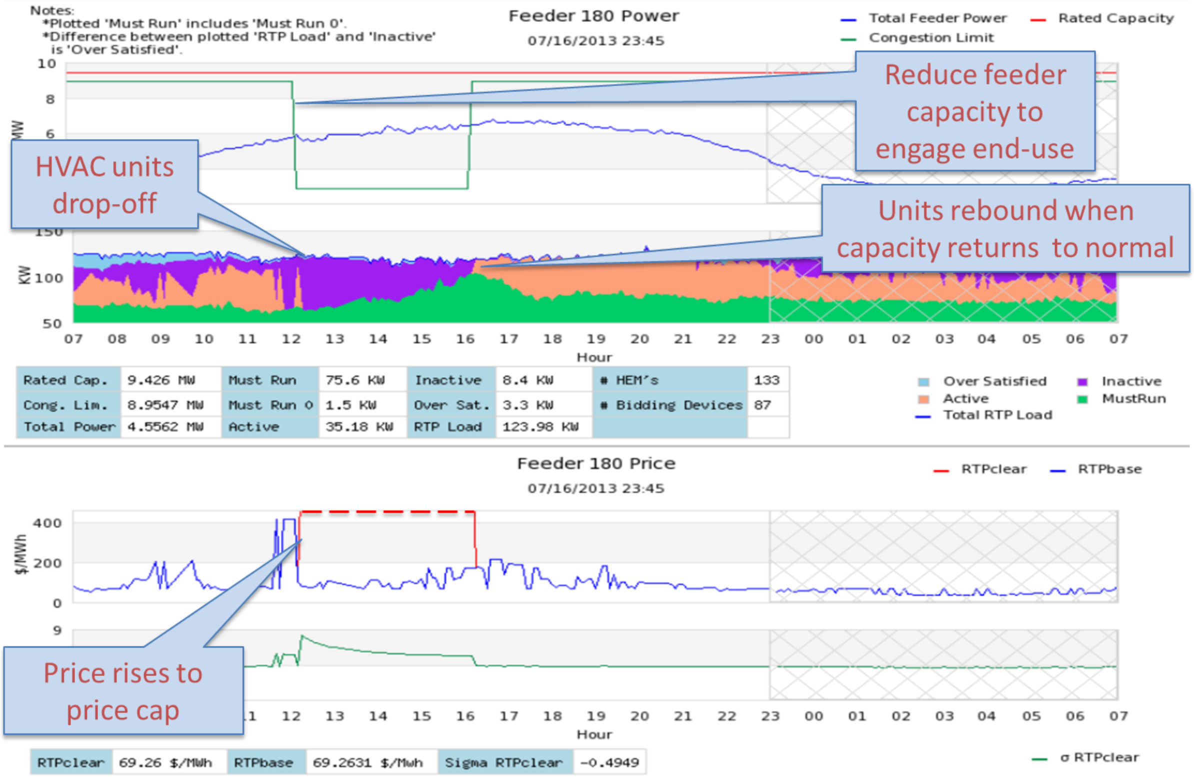


Figure 13: The 'transactive grid control' concept (source: PNNL)



Rated Cap.	9.426 MW	Must Run	75.6 KW	Inactive	8.4 KW	# HEM's	133
Cong. Lim.	8.9547 MW	Must Run 0	1.5 KW	Over Sat.	3.3 KW	# Bidding Devices	87
Total Power	4.5562 MW	Active	35.18 KW	RTP Load	123.98 KW		

RTPclear	69.26 $/MWh	RTPbase	69.2631 $/Mwh	Sigma RTPclear	-0.4949

Figure 14: Demand response of HVAC systems due to price signal (source: PNNL)

5 DSM and EV

The last block was focusing on controlled charging of electric vehicles as a resource of demand response. Two Projects have been presented from distribution system operator and academia.

Implementation and experiences of controlled e-car charging in the Smart Grids Model Region Salzburg have been presented by Markus Radauer (Salzburg Netz, Austria). The demonstration site in Köstendorf is supplied by 250 kVA transformer and half of the 90 houses have a PV system installed (total 193 kWp), 36 households have an electric vehicle (EV) with an intelligent charging station. The goal to integrate this into the grid without grid reinforcement combines transformer control and control of the distributed generator so that voltage limits are not exceeded.

A building energy agent is responsible for communication and a central voltage controller uses measurement data gathered by smart meters (Figure 15). For controlling the EV the user sends a time when the EV needs to be fully charged via a charging 'app'. The technical optimization tries to use EV to mitigate impact of PV on the grid. The main issue with this objective is, that there is no EV at home very often in times of high generation. EV charging in the evening is not problematic, because voltage limits are kept. Key finding are: smart technologies can ease integration of RES, single phase charging and PV systems are a problem (put more stress then necessary on the grid), DSM using EV is possible and necessary, and standardization of components is an issue. Figure 16 shows a controlled charging process of one of the building energy agents (BEA).

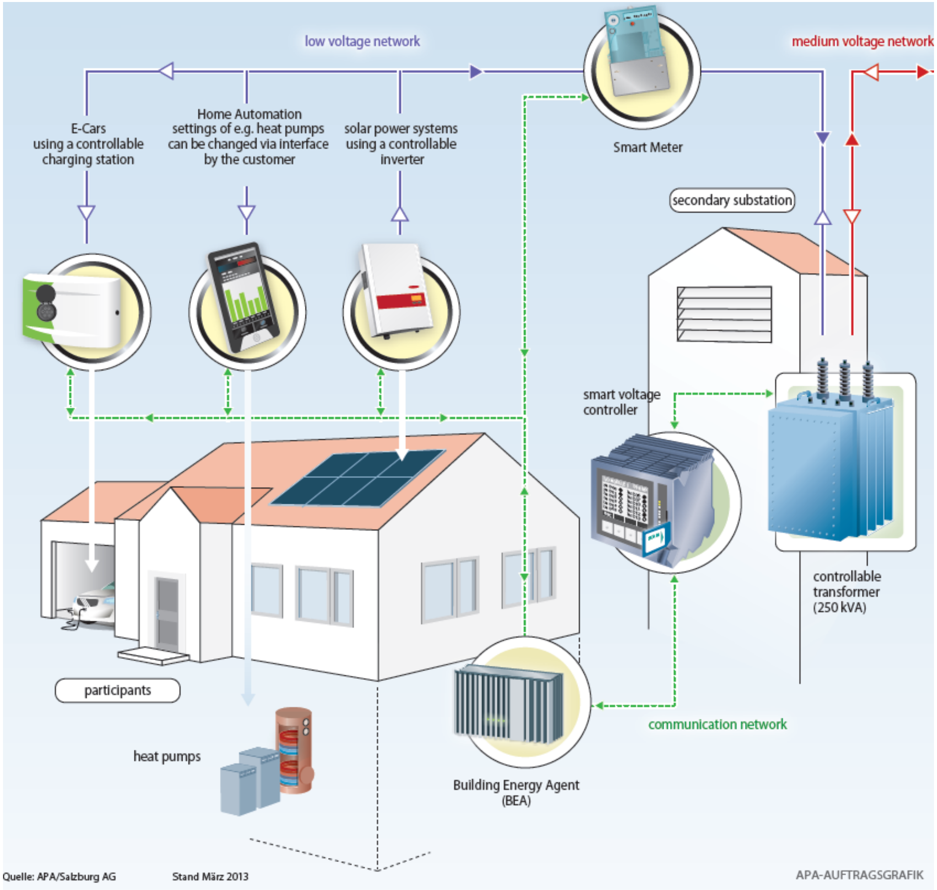


Figure 15: Smart Grids Model Community Köstendorf (source: Salzburg AG)

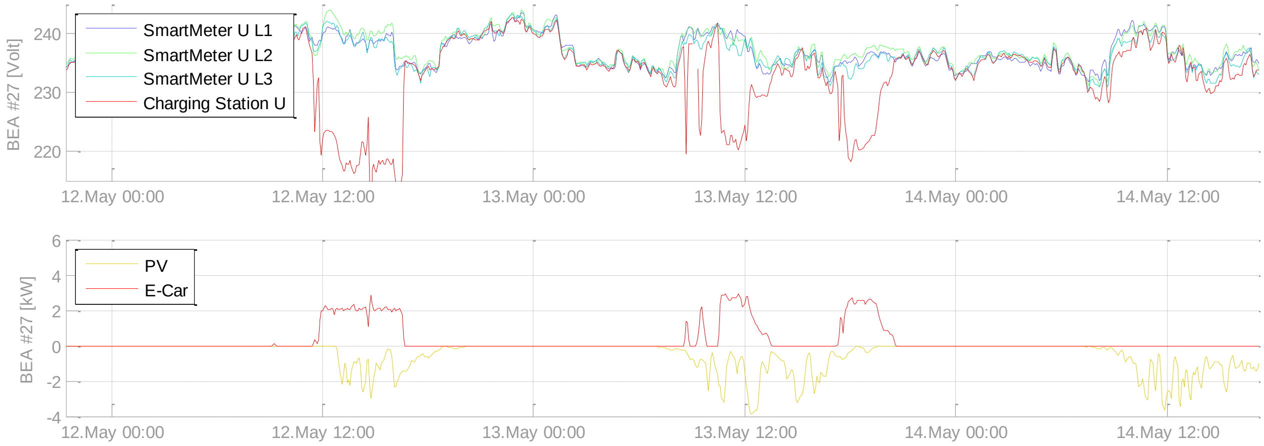


Figure 16: Controlled charging of electric vehicle in Köstendorf – Building Energy Agent 27 (source: AIT)

The concept of '*Active DSM by forecasting'* is presented by Christoph Maier (TU Vienna, Austria) A generic model settlement (various types of residential buildings / households, which are equipped with up to 50 different devices, simulation with resolution of 1 minute) has been created for further studies. EVs have been included, supporting only charging (no vehicle to grid discharging). A set of DSM rules have been developed. The objectives for the operating behavior include: efficient usage of available DSM potential; design of a local DSM model and operation under uncertainty; weighted multi-objective optimization (maximize self-consumption and minimize load peaks). A baseline scenario is compared to variations in terms of EV penetration, controlled load groups. Simulation results show that self-sufficiency and self-consumption are significantly influenced (Figure 17).

Findings of this project are: DSM increases the self-consumption of PV systems and the degree of self-sufficiency of households significantly (Figure 18). Cooling and heating devices (HVAC) and electric vehicles (EV) have the highest potential. In the project, DSM could not achieve significant effect on capacity of LV transformers and lines. Maximum voltage levels couldn't be reduced, but minimum voltage level could be increased. A demonstration is currently ongoing in Austria.

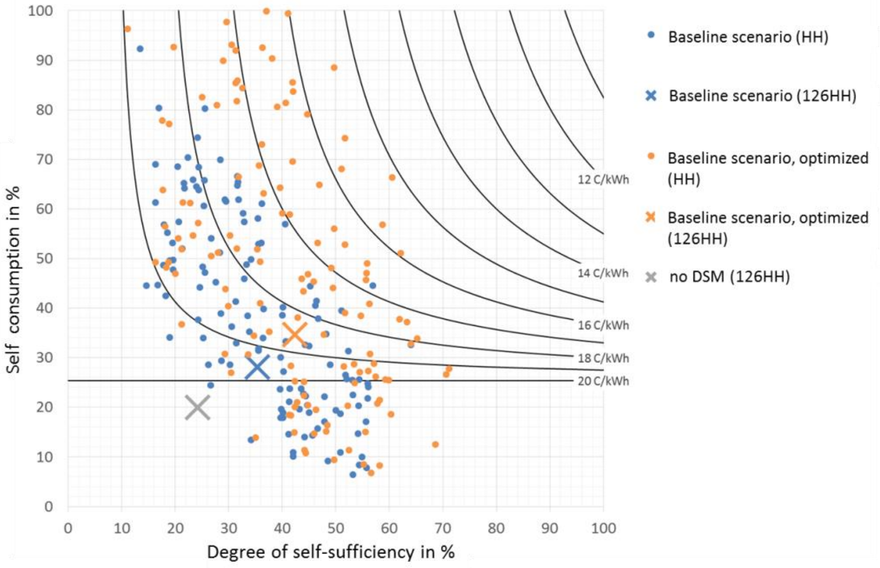
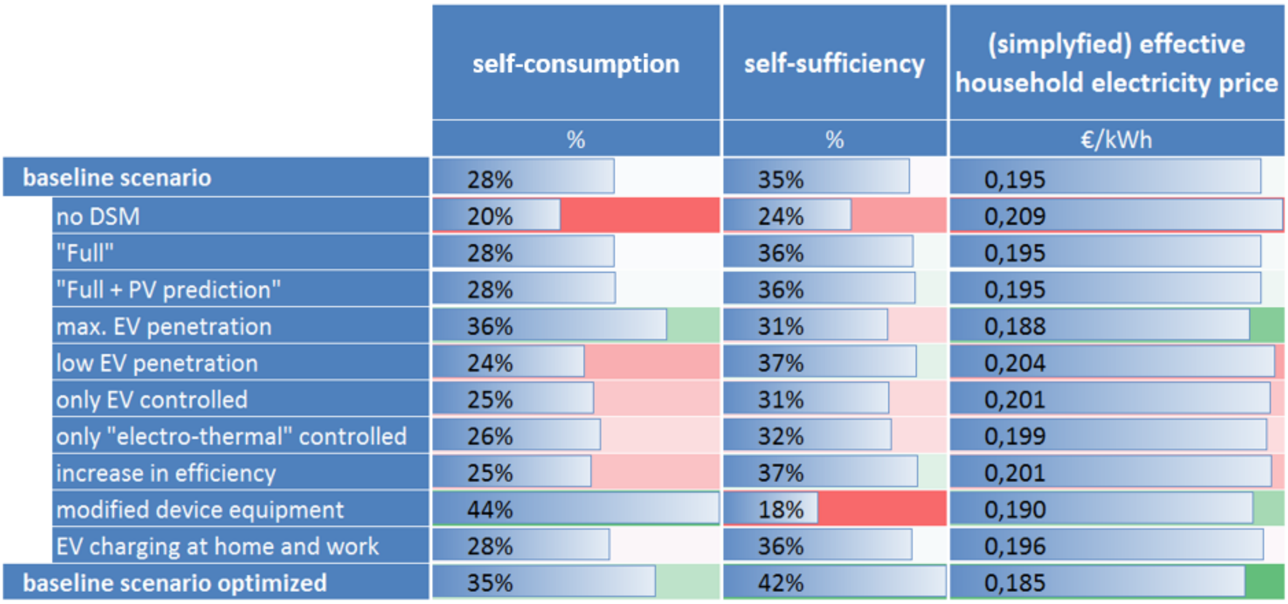


Figure 17: Simulation results of project aDSM: degree of self-consumption vs. self-sufficiency (source: TU-Vienna)



	self-consumption	self-sufficiency	(simplyfied) effective household electricity price
	%	%	€/kWh
baseline scenario	28%	35%	0,195
no DSM	20%	24%	0,209
"Full"	28%	36%	0,195
"Full + PV prediction"	28%	36%	0,195
max. EV penetration	36%	31%	0,188
low EV penetration	24%	37%	0,204
only EV controlled	25%	31%	0,201
only "electro-thermal" controlled	26%	32%	0,199
increase in efficiency	25%	37%	0,201
modified device equipment	44%	18%	0,190
EV charging at home and work	28%	36%	0,196
baseline scenario optimized	35%	42%	0,185

Figure 18: Overview of results for variations of controlled devices and scenarios (source: TU-Vienna)

6 Round Table Discussion

In a round table discussion all presenters were invited to answer questions from the session chairs and the audience. Within this insightful discussion, following questions were discussed and answered:

Impact on the electrical network:

- Finnish Project SGMS tries to reduce the needed voltage band as much as possible, which avoid costly grid reinforcements.
- Costs for grid reinforcement due to PV can be reduced by 30-50% if you consider generation reduction
- Is there a critical mass of active loads which can de-stabilize the system due to oscillation effects? Large amounts of dynamic reacting loads can cause large problems (re-bound effects).

Main motivation to move to closed loop demand response in the USA:

- Closed loop has been chosen because they anticipated a smoother and determinable response from the system.

Drivers for demand response

- Mostly system conditions and not primarily the customer benefits in Europe and the States. Where in India the energy and cost effectiveness of the energy system is improved through DSM.

Is it possible to store the energy and thus increasing the load with demand response?

- From a technical point of view it is possible, but there are huge investments due to physical constraints (storage capacities, etc.). Pre-cooling has been researched in the US, but it does not seem like an efficient way to use energy.

Market based demand response and experiences from DSO to solve regional and local problems:

- Aggregators must not be discriminated or detained. The system responsibility should stay at DSO level, while maintaining an overall optimization concept. The physical capability of the network is always the limiting factor, and grid operator needs to be the last instance.
- Should DSO send limits? DSO may put price on capacity limits.

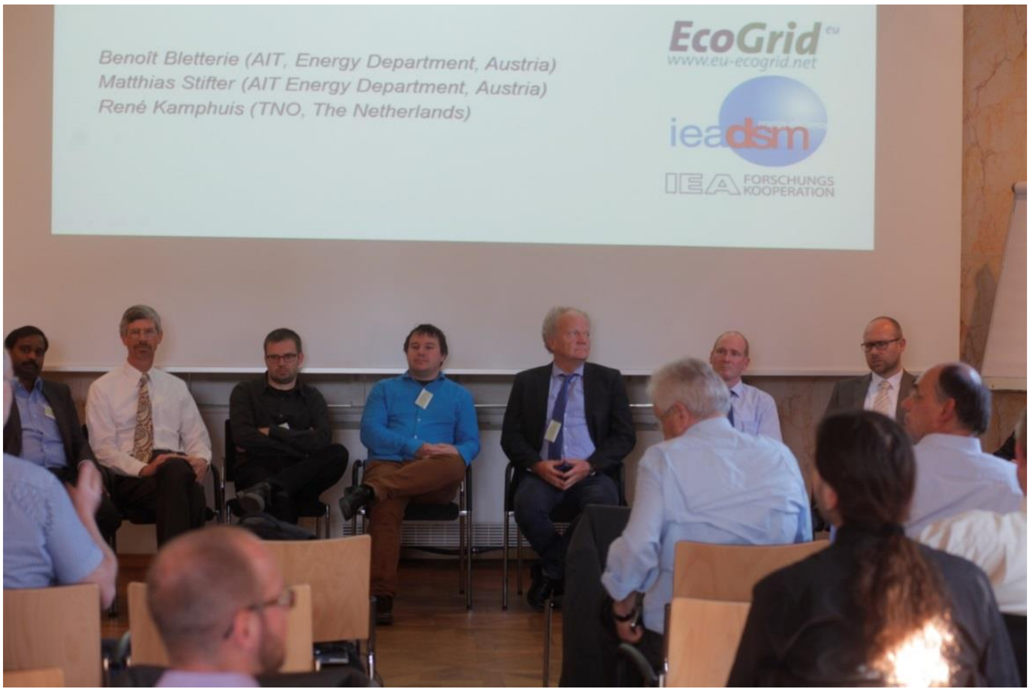


Figure 19: Open discussion between the presenters and the audience (source: SG Week).

7 Summary of the workshop

Comprehensive analysis studies and simulations have been done to estimate various response potentials for different devices and control levels as well as energy efficiency potentials for DSM. It appears that the energy system performance is the overall driver, but while load levels are primarily the concern where the energy system struggles to bear the total demand in peak times (lower reliability), the dynamic load flexibility is needed where massive intermittent renewable and distributed generation is taking over to dominate the generation portfolio. It seems to be obvious that the low energy price and missing market mechanism are still the main barriers for automated demand response and return of investment the barrier for energy efficiency.

Successful technical implementations of demand response projects show the enabling of these identified potentials, in case the missing market structures are provided. Especially real time markets for closed loop demand response, based on bidding and auctioning have been proofed to fulfil expectations.

Experiences so far strengthen the decision to wide-area adaption and implementation. This applies for the presented contributions of DR in the USA and Europe and energy efficiency measures in India. The first systems are going into daily operation on basic time of use tariffs (e.g. Finland). Still the way to a nationwide rollout and implementation need to overcome harmonization for regulation and market participation in most of the participating countries. New methods and simulation tools, which are able to investigate impact of DR and system interaction on a large scale, will be needed to support rollout.