MSc Program
Renewable Energy in Central and Eastern Europe

Lessons learned from European pilot projects: Recommendations on market access requirements for electricity consumers

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Affidavit

I, Julia Schmidmayer, hereby declare

1. that I am the sole author of the present Master Thesis, "Lessons learned from European pilot projects: Recommendations on market access requirements for electricity consumers", 112 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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Executive Summary

As more and more European citizens will move to cities over the next decades, the dynamics of urbanisation will result in an increase of energy demand and CO_2 emissions. The utilisation of renewable energy technologies will support to reduce the impacts of climate change and lead to a paradigm shift of the energy system. But only additional efforts will ensure security of energy supply. The concepts of Demand Side Management (DSM) and Demand Response (DR) offer new opportunities to face these challenges. DSM can be understood as a portfolio of measures aiming at the direct influence of electricity consumption, e.g. energy demand shifting from peak to off-peak times, energy efficiency measures etc. On the other hand, the consumer's reaction can be summarised as DR. This means that incentivising the consumer monetarily – by changing the electricity price - leads to a change in energy demand.

Major infrastructure investments in the European electricity grid are needed to keep up stability of energy supply. DSM has the potential to ease this pressure that the electricity market is technically and economically experiencing. But to fully tap the potential of DSM, European member states need to overcome current regulatory barriers and appropriate DR programs need to be implemented. Following up on these the following research questions will be answered in this thesis:

- Which kind of market access requirements need to be provided to electricity consumers in order to attract them accessing the energy market?
- What 'good practice' examples of DSM operator models can be identified in the pilot projects (e.g. pooling, aggregators, virtual power plant etc.)?

In many European countries large industry consumers participate in DR programs as a potential for DSM is given. The applicability in the residential sector is still controversial as only small electrical loads are available (e.g. dishwasher, washing machine, freezer etc.). In recent years many co-funded pilot projects has been carried out to further research the potential of DSM in this area and to prove its applicability in real-life conditions. In particular the concept of load aggregation seems promising as small electrical loads are aggregated which enables the trading of electricity at the energy market. Thus, this thesis aims at identifying the most promising pilot projects focusing on residential consumers that are granted access

to the energy market. In particular projects with concepts of load aggregation are selected to learn more about their applicability in Austria.

A profound literature review and state-of-the-art research builds the cornerstone of the methodological approach of this thesis. This endeavour is followed by a thorough work of structuring, comparing and interpreting meta-studies and other assessments of Smart Grid and DR pilot projects. Several indicators are carefully selected focussing on the analysis of requirements that are decisive for electricity consumers accessing the energy market. Finally, an analytical framework is developed with the aim to offer guiding principles for the assessment of pilot projects. In addition, technical experts with specific knowledge about the projects are contacted for telephone interviews. By consulting these experts an additional, external project assessment is gathered which is an important input for formulating the recommendations.

Based on the analytical framework developed in this thesis four different European pilot projects are analysed; one project in the Netherlands, one European project with pilot sites in France and Spain and two German pilot projects. These projects were selected as they integrate energy and ICT concepts focusing on load aggregation of demand side resources in the residential area and renewable energy generation systems (e.g. wind turbines, PV systems) via utilisation of an ICT platform. The findings of the pilot projects' analysis are condensed and summarised in recommendations concerning which kind of market access requirements need to be provided to electricity consumers. In total seven recommendations are presented which are listed in the following:

1. Community creation supports user activation
2. Variable tariff models need to offer an added value for an acceptable price
3. Based on visualised electricity consumption data consumers can be incentivised to participate in DR programs
4. Data protection, privacy & security aspects need to be considered early in the beginning
5. The regulatory transformation of the energy market requires the introduction of new market players that develop services attractive for consumers
6. As financial advantages for consumers are quite low, aggregators need to concentrate on key messages on a broader level to attract consumers

7. Standardisation and interoperability of technologies proved to be a basic condition for the interaction of technical appliances and enabling technologies

Based on the findings of the pilot project it can be concluded that the market access barriers for residential consumers are high as a lot of preconditions need to be fulfilled. These requirements start with the long-term activation of residents by intensive planning, structuring and implementing of community building measures. Attractive tariff schemes are needed that convey a key message with which the consumer identifies him- or herself. Tariff options as an economic (cost-optimal) and a sustainable (self-sufficient) one are in particular interesting for regions that have a high amount of customers with distributed renewable energy technologies. The visualisation of energy consumption is inevitable as relevant information about consumption data, price signals and even data of a reference group gives the consumer the chance to adapt his/her behaviour. Data protection is a prerequisite for residential consumers accessing the energy market. In all pilot projects analysed privacy and security concerns were early addressed by considering the protection of personal data via participation agreements as well as security demand and risk mitigation in the ICT design.

In the pilot projects DSM operator models were developed supported by different software solutions connected to hardware devices following the concept of a virtual power plant (VPP). In Austria a few VPP operators are currently active but which only commercialise flexibilities of industrial and commercial companies. The sector of residential consumers is still untapped. Although Austria has advanced its regulatory conditions the economic analyses in the pilot projects have proved that load aggregation in the residential sector does not offer a viable business model. Economic advantages for residential consumers are limited as well. Thus, other aspects as saving money or financial rewards need to attract or convince users to participate in DR programs.

Nevertheless, it can be expected that the market for DR in the residential sector will develop in the upcoming years (under the condition that technical requirements as a smart meter roll-out has been carried out and the interoperability of home energy management systems improved).

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List of Abbreviations

%	Percent
AD	Active Demand
BEMI	Bi-directional Energy Management Interface
BG	Balancing Group
BRP	Balancing Responsible Party
BSP	Balancing Supporting Party
CBA	Cost-Benefit Analysis
CEER	Council of European Energy Regulators
CEMS	Customer Energy Management System
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CHP	Combined Heat and Power
CO_2	Carbon dioxide
CPP	Critical peak pricing
CPR	Critical peak rebates
DER	Distributed energy resources
DOE	United States Department of Energy
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operator
EC	European Commission
EED	Energy Efficiency Directive
EEG	German Renewable Energy Act
e.g.	for example
ETSI	European Telecommunications Standards Institute
EU	European Union
EU-28	28 member states of the European Union (since July, 13th 2013)
EV	Electric vehicle
FP6	Framework Programme 6
FP7	Framework Programme 7
FRR	Frequency restoration reserves
GWh	Gigawatt hour

HAN	Home Area Network
HECUI	Home Energy Control User Interface
HP	Heat pump
ICT	Information and Communication Technologies
IEA	International Energy Agency
IKT-GW	Information and Communication Technology Gateway
k	Thousand
kWh	Kilowatt hour
LED	Light-emitting diode
MW	Megawatt
NAN	Neighbourhood Area Network
PC	Personal Computer
PLC	Power Line Communication
PRP	Program Responsible Party
PV	Photovoltaic
R&D	Research and Development
RR	Replacement reserves
RTP	Real-time pricing
SEC	Energy Sustainable Community
SEDC	Smart Energy Demand Coalition
SGA	Smart Grid Australia
TOU	Time-of-use tariffs
TSO	Transmission System Operators
US	United States
USEF	Universal Smart Energy Framework
VAT	Value added tax
VDE	Association for Electrical, Electronic & Information Technologies
VPP	Virtual power plant
WAN	Wide Area Network

1 Introduction

The following Section 0 starts with the problem statement; the question ‘why do we need demand side management?’ is addressed to give an overview about the topic. In a next step the research question is described and the structure and methodology, on which the entire approach is based, are presented. This section forms the core piece and guides the reader through this master thesis.

1.1 Problem statement or ‘why do we need DSM?’

Over the next decades Europe is facing major challenges. As cities become more attractive by offering various amenities as job opportunities, affordable housing, recreational activities, more and more people are moving to cities. By 2013 74% of the European Union’s citizens live in urban areas and this trend is expected to resume (The World Bank, 2013). Beside other implications the dynamics of urbanisation result in an increase of energy demand and CO_2 emissions and thus, new paths need to be taken in order to tackle the impacts of climate change.

Currently, the utilisation of decentralized renewable energy technologies such as photovoltaic (PV) systems, charging and discharging of smart electric vehicles (EV), the optimization of electricity storage and operation of heat pumps (HP) and (micro)-combined heat and power (CHP) units lead to a paradigm shift of the energy system. The further implementation of these technologies will require additional efforts to ensure a balanced energy market in terms of technical as well as economic aspects. In case of a major load fluctuation (e.g. power station outage, unpredictable variations of electricity generation by renewable energy sources etc.) system stability needs to be maintained by load frequency control. This increases costs tremendously as control power and the provision of control reserves are expensive.

Whilst ensuring security of energy supply new paths need to be entered in order to increase energy efficiency and reduce greenhouse gas emissions. Thus, flexible approaches, the re-thinking of the electricity market’s design and the definition of new market players (e.g. pool coordinators, aggregators, energy service companies etc.) are needed. These market players will act as intermediaries of consumer groups that are currently not active at the energy market (e.g. residential users, small and medium sized companies etc.) and provide their flexibilities to support security of supply taking into consideration the network, generation and consumers constraints (Eid et al., 2015). Thus, demand side management (DSM) – understood as the shifting of energy demands from peak to off-peak times, reducing of energy demand by increasing the energy efficiency etc. - offers new opportunities to face these challenges.

The support of DSM has already been granted on political level as the European Commission published a corresponding guidance notice on the implementation of the Energy Efficiency Directive in 2013 (EC Guidance note, 2013). A set of recommendations and actions have been identified concerning the definition of new roles for the different actors at the internal energy market, how energy efficiency criteria can be implemented in network tariffs and regulation, and by which measures demand response should be enabled and developed. Now, it is the turn of the European member states to take the next steps and legally enable the implementation of DSM.

1.2 Research question

Facing the above mentioned challenges the (European) electricity grid is exposed to continuous changes and major infrastructure investments in order to keep up stability of energy supply. In several studies and state-of-the-art literature it was proven that DSM has the potential to ease the pressure that the electricity market is technically and economically experiencing (Klobasa, 2007; VDE, 2012; SEDC, 2014; de Bruyn et al., 2015). Processes in the commerce, trade and service as well as industry sector offer opportunities for DSM due to continuous and stable operation and storage capabilities. For applications as heat pumps, ventilation and air conditioning systems and charging of electrical vehicles an increasing potential until 2030 has been identified as an intensified market penetration is expected (VDE, 2012).

But to fully tap the potential of DSM European member states need to overcome current regulatory barriers and appropriate Demand Response (DR) programs need to be implemented while the electricity market is subject to change. It should be intended that DSM forms an integral part of a new market system. These efforts are supported by the European Commission's Energy Efficiency Directive which was established as a set of binding measures to help the EU reach its 20% energy efficiency target by 2020 (EC Guidance note, 2013). Specified in Article 15.8 clear and specific requirements for European member states, national regulators and Transmission System Operators (TSO) are defined to allow consumers access to markets through DR programs by enabling the participation of service providers (e.g. aggregators etc.). At the moment the majority of EU member states do not enable DSM (SEDC, 2014). Figure 1 shows an overview about DR activity in Europe and reflects regulatory advances in comparing changes implemented from the year 2013 to 2014.

Overcoming these regulative barriers DSM is highly attractive for the balancing energy market to increase system security and reduce capacity requirements for power generation (Klobasa, 2007). By enabling consumers to access the energy market and offering their electrical loads, costs for control reserve can be saved (Vögel & Kabinger, 2014).

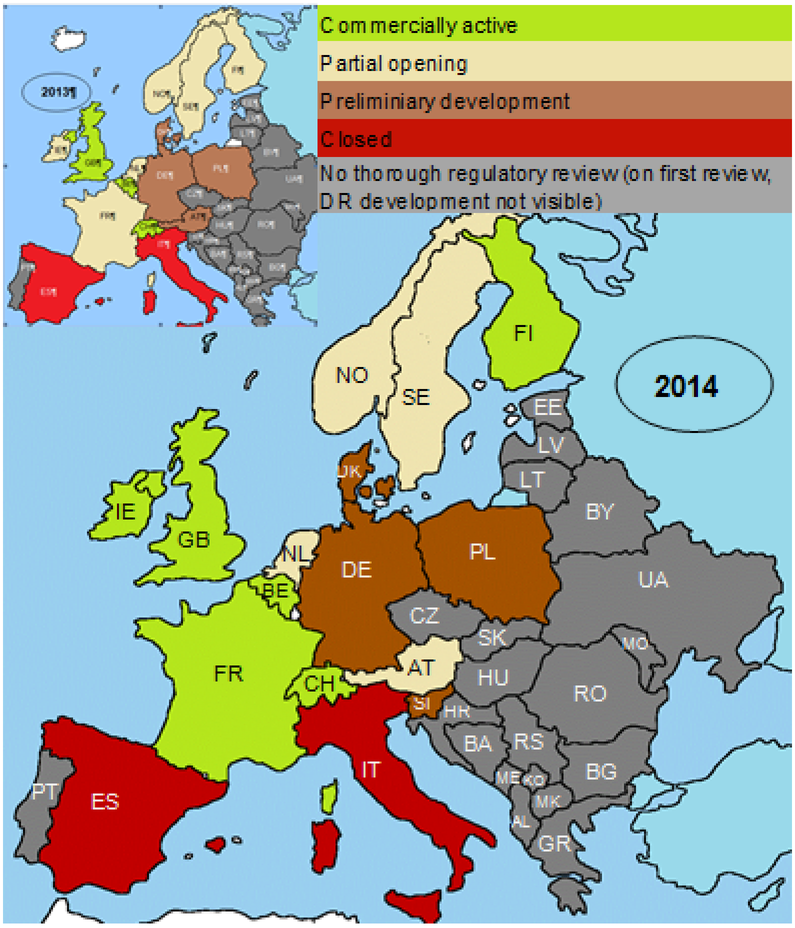

Figure 1 Demand Response Map of Europe 2013-2014

Source: Own graph based on SEDC (2014)

Following up on these developments the author of this thesis intends to answer the following research questions:

- Which kind of market access requirements need to be provided to electricity consumers in order to attract them accessing the energy market?
- What ‘good practice’ examples of DSM operator models can be identified in the pilot projects (e.g. pooling, aggregators, virtual power plant etc.)?

Electricity consumers can generally be distinguished in two groups: residential consumers (households) and non-residential consumers (large energy-intensive industries, small and medium commercial consumers, and service companies). Although it has been proven that all consumer groups offer a certain potential for DSM (e.g. Klobasa, 2007; Paulus and Borggrefe, 2011; Torriti et al., 2010 etc.), the applicability in the residential sector is still most controversial as only small electrical loads are available (e.g. dishwasher, washing machine, freezer etc.).

In recent years many co-funded pilot projects has been carried out to further research the potential of DSM in the residential area and to prove its applicability in real-life conditions. In particular the concept of load aggregation seems promising as small electrical loads are aggregated which enables the trading of electricity at the energy market. These projects mostly focus on approaches that integrate energy and ICT concepts and not only address the technical implementation of these solutions but also consider user engagement and the definition of use cases and their economic impacts reflecting national market regulations.

The project results build the cornerstone for further learning and recommendations how to adapt access requirements for entering the energy market which is still limited to large industrial consumers in many European countries. Industrial companies are used to measure their energy consumption and are equipped with a smart meter which enables them to be accurately informed about their energy data and easily discloses DSM potentials. Residential consumers are lacking this kind of information as electricity billing is done on a yearly basis and does not give any hints on consumption patterns and potentials for energy savings as well as shifting of demand. In addition to the measurement and visualisation of consumption data other factors do also influence consumers accessing the energy market.

Currently, practical approaches are on the way from piloting to commercialisation and further knowledge exchange based on actual experiences under real-life conditions facilitates this process. Thus, this thesis aims at identifying the most promising pilot projects focusing on residential consumers that are granted access to the energy market (under the condition that detailed information is publicly available). In particular projects with concepts of load aggregation are selected to learn more about their applicability in Austria.

1.3 Structure and methodological approach

A well-thought methodological approach is decisive when aiming at scientifically based findings to research questions raised and consequently formulating recommendations on how to provide electricity consumers access to the energy market.

With the intention to use existing know how in this field and have access to information of good practice pilot projects this thesis is written in the scope of the IEA DSM Task 17 which deals with the integration of demand side management, energy efficiency, distributed generation and renewable energy sources. This task focuses on the exchange of knowledge and the sharing of experiences on the integration of DSM and DR in residential and commercial buildings with an optimal embedding of renewable energy resources in electricity networks and markets (Stifter and Kamphuis, 2013).

Currently, the task's third phase is under operation and addresses *'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'.* (Stifter and Kamphuis, 2013)

The methodology of this thesis is outlined in Figure 2 and explained in the subsequent section in more detail.

Step 1 - Literature review: A profound literature review and state-of-the-art research builds the starting point of this master thesis. The most important findings are summarized in Chapter 2 in order to give an introduction about the basic DSM concepts.

Step 2 - Development of an analytical framework: This endeavour is followed by a thorough work of structuring, comparing and interpreting meta-studies and other assessments of Smart Grid and DR pilot projects (e.g. Covrig et al., 2014); Stromback et al., 2011). A set of indicators is grouped along the following categories:

- Participation and acceptance of consumers,
- Institutional and regulatory framework,
- Economic and financial aspects, and
- Technical aspects.

Each category is composed of several indicators which have been selected carefully focussing on the analysis of requirements that are decisive for electricity consumers accessing the energy market. The indicators are described in Section 3 of this thesis. The analytical framework shall finally offer guiding principles which can be followed in order to assess Smart Grid and DR pilot projects and finally derive recommendations.

Step 3 - Selection of pilot projects: In a next step four (European) pilot projects which are of interest for the IEA DSM Task 17 activities are selected. Projects with a focus on the implementation of aggregation mechanisms like virtual power plants and DR to aggregate the supply and demand flexibilities of decentralised resources are prioritised.

After giving a brief description of the pilot project and its concept the DR status of the country, in which the pilot project is implemented, is reviewed. Taking into consideration the mapping analysis in SEDC (2014)[1] barriers to DR and consumer participation are still significant although some European member states have already shown major progress in developing the market. In a next step the projects are analysed along the categories of the framework developed. The analysis is described in Chapter 4 and all project related reports, on which it is based, are listed in the Annex.

[1] In SEDC (2014) the gradual improvement of regulatory structures of 15 countries (13 EU member states, Norway, and Switzerland) between the year 2013 and 2014 has been mapped.

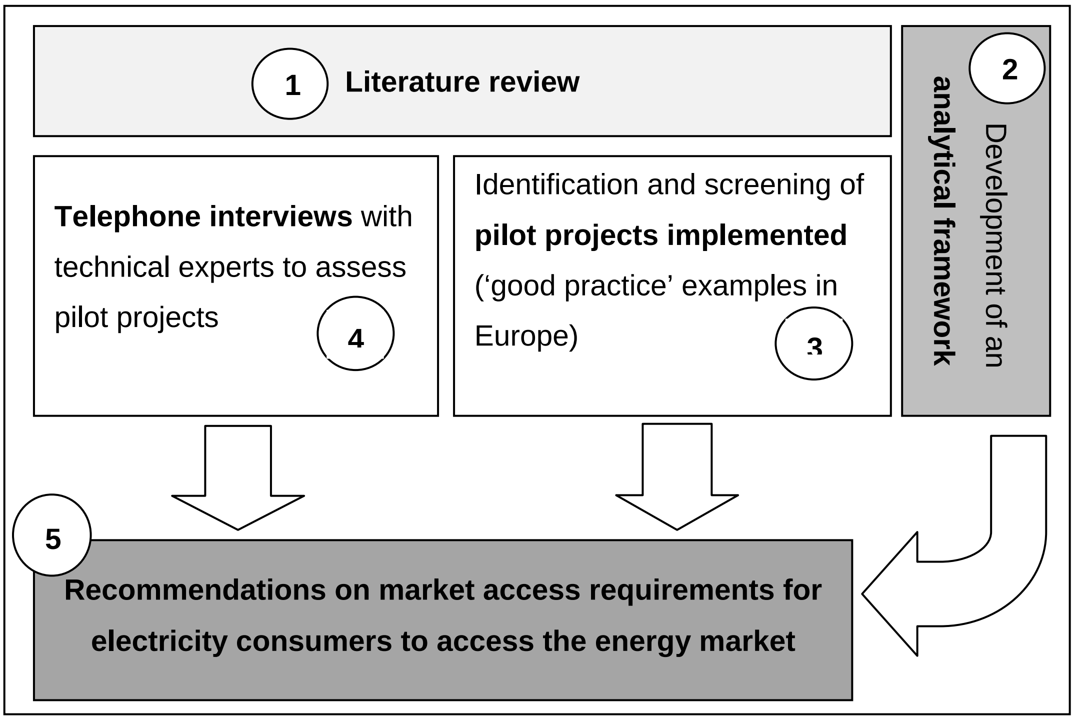

Figure 2 Methodological approach

Source: Own illustration

Step 4 - Telephone interviews with technical experts: Technical experts with specific knowledge about the pilot projects, that have been selected, are contacted for expert interviews via telephone. A list of the persons interviewed is provided in the Annex of this thesis.

The experts are asked to reflect on their experiences along a set of questions in relation to the pilot project, in which they have been involved or are still involved. The questionnaire (attached in the Annex) includes seven questions whereby five of them cover sections of the analytical framework and the other two questions ask for an assessment of the impact and replicability of the pilot project. The expert's consultation enables the author to gather an additional, external project assessment and is an important input for formulating specific recommendations.

Step 5 - Lessons learned and recommendations: Results from the state-of-the-art analysis, the analysis of pilot projects, and the experts' advice are condensed in Chapter 5 which finally allows deriving a list of recommendations on which kind of market access requirements need to be provided to electricity consumers in order to attract them accessing the energy market.

2 Demand Side Management

In this chapter an introduction explaining the basic concepts of Demand Side Management (DSM) is given. Basically, the balance between electricity supply and demand has to be given at any time in order to guarantee a reliable and stable power supply for all customer groups (Paulus & Borggrefe, 2011). As this interaction is set up via an electricity market different trading options exist: at the futures market electricity is bought and delivered at a given price over a predefined future period of time with the purpose to hedge against future spot price movements; whereas 24 hours forecasts on electricity generation and loads are scheduled in the day-ahead spot market segment. Any deviations have to be levelled out (e.g. power station outage, unpredictable variations of electricity generation by renewable energy sources etc.). Hence, DSM offers various opportunities to support a stable electricity market via intra-day or balancing energy trade market segments.

In the following a terminology for DSM and DR is presented in order to give the reader a basic understanding. Based on this, load shape concepts are explained and briefly compared to each other. Consequently, loads are influenced by DR programs to which customer groups respond. The two basic concepts of incentive-based and price-based DR programs are presented and assessed in relation to energy system management. Depending on the DR program's design different sectors are targeted at. The different sectors and the application areas for DSM are described. Wide DSM potentials are given in all sectors but the extent to which these potentials are exploited is not the same for each sector. Due to existing barriers in national regulatory and contractual framework conditions utilisation of DSM is hampered. In order to shed light on the development of DSM policies on European level is briefly explained.

2.1 Terminology

Although it seems that DSM is a new and innovative concept being associated with smart grid deployment, smart metering roll-out and extensive penetration of renewable energies its history dates back to the late 1970ies. In these times it became harder for US energy utility companies to predict energy demand and supply energy at low cost for the first time (Gellings, 1985). Traditionally, power system planning focused on increasing the supply by expanding the generation capacity and building a strong power transmission system (Lampropoulos et al., 2013).

Especially during the oil crisis in 1973 energy utilities were put under pressure as the dependency on foreign energy sources gained increasingly public attention (Eto, 1996). Thus, long-term policies and measures addressing energy efficiency and load management were introduced (Lampropoulos et al., 2013; Gellings, 1985). For the first time the customer – the demand side – was integrated as an additional factor to the utility's planning approaches with the objective to reduce costs and putting more emphasis on balancing energy demand.

Gellings (1985) defined the term DSM as follows: *'DSM is the planning, implementation, and monitoring of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape*[2]*, i.e., changes in the time pattern and magnitude of a utility's load.'* This means that the energy consumption on the demand side is directly influenced resulting in an increase or a decrease of consumption at a specific date (VDE, 2012).

Thus, DSM can be understood as a portfolio of measures aiming at the energy system's improvement. In addition to the increase of energy efficiency, flexible tariff schemes rewarding certain consumption patterns and real-time control of distributed energy resources can be summarised under this umbrella of measures. (Palensky and Dietrich, 2011)

These definitions of DSM show the utility's point of view. On the other hand, the consumer's reaction can be summarised as DR. The customer has an active role and participates in the electricity market by responding to changing prices (DOE, 2006). This means that incentivising the consumer monetarily leads to a change in energy demand. For example, a high energy price alters the short-term consumer's usage pattern by reducing consumption.

[2] The load shape is the daily and seasonal electricity demand by time-of-day, day-of-week, and season (Gellings, 1985).

2.2 Categorisation of load shaping concepts

In general, DSM activities aim at changing the energy utility's load. In state of the art literature six broad categories of load shape objectives are differentiated (e.g. Gellings, 1985). The following Figure 3 shows the basic categorisation how loads can be shaped. The first three load shape concepts – peak clipping, valley filling and load shifting - rank among the classic forms of load management.

1. *Peak clipping* is considered as the reduction of system peak load by direct load control which means that the energy utility has access to customer's appliances and the right to influence customer's electricity demand. This access is granted due to contractual agreements in which frequency and duration of peak clipping incidents are defined. This form of load management is mostly agreed on with industrial and commercial customers. (Gellings, 1985)

2. The second load management concept is *valley filling* which is considered as increase of system off-peak load. The customer's load is shifted to times when system loads and the variable electricity generation costs are low (Eto, 1996). With valley filling the energy utility aims at decreasing the average costs to customers (Gellings, 1985) and thus, offering a better electricity price to them.

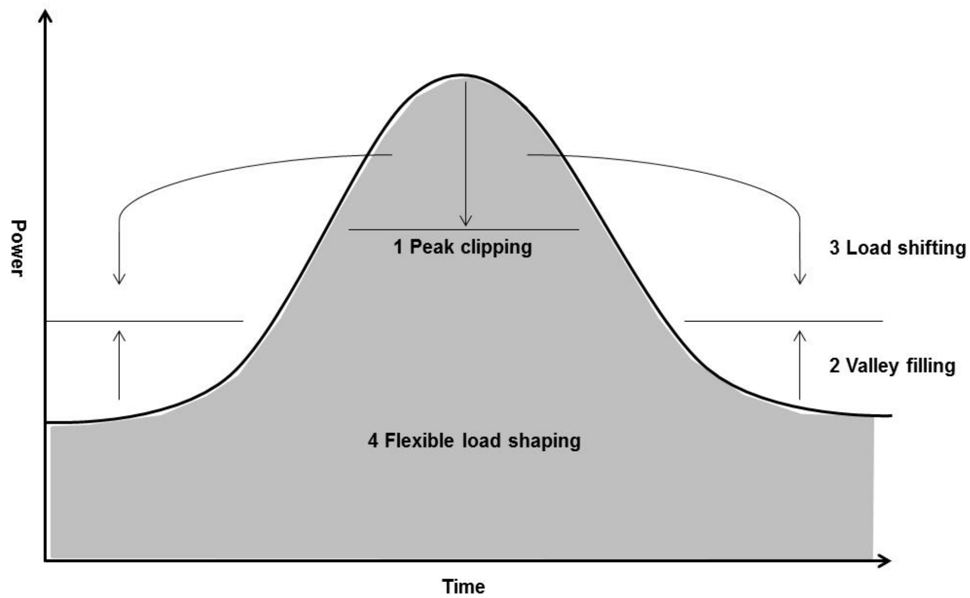

Figure 3 Classic forms of Demand Side Management
Source: Own graph, adapted from Lampropoulos et al. (2013)

3. Energy utilities have to offer critically high capacity in peak load periods. As this happens only a few times a year, which leads to high operating costs, *load shifting* to off-peak periods seems advantageous for both sides – energy utilities and consumers. Hence, the utility offers incentives in return for controlling customer's appliances such as electric water heaters and air conditioners (Eto, 1996).

4. The *flexible load shape* concept considers reliability as a first priority. Demand side activities of customers are taken into account when optimising energy supply options in order to anticipate the load shape. Customers are incentivised with flexible pricing tariffs, pooled integrated energy management systems or individual customer load control devices (e.g. smart meters). (Gellings, 1985)

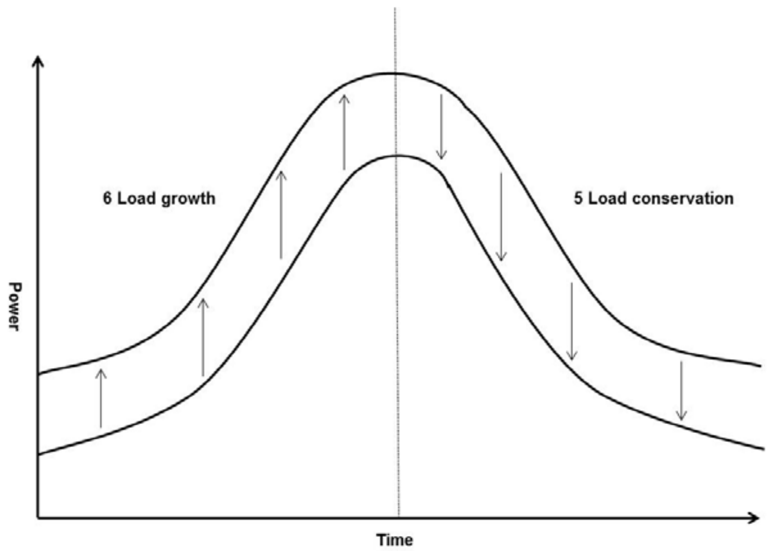

Figure 4 Other forms of Demand Side Management
Source: Own graph, adapted from Lampropoulos et al. (2013)

5. On the contrary to load management concepts *strategic conservation* aims at increasing energy efficiency with an interim to long-run view. Energy utilities incentivise customers with programs that direct at the reduction of energy consumption and saving CO_2 emissions. Examples for stimulation programs are the permanent change of inefficient equipment and appliances, incentives for insulating residential buildings, window replacements etc.

6. Currently, society is facing a paradigm change in terms of technologies. Processes are automatised and new technologies emerge with the consequence to lead to an electrification of services (e.g. heat pumps, electric

drive vehicles, industrial process heating etc.). *Strategic load growth* takes up this concept and refers to an increase of sales triggered by the energy utility (Gellings, 1985).

In the following Table 1 the six load shape concepts described above are briefly compared to each other. The load shaping concepts aim at different actions ranging from curtailing or shifting peak load, reducing or increasing consumption to providing system reliability and addressing different customer groups. Consequently, customer groups need to be attracted with DR programs tailored to their needs in order to provide their loads for DSM.

Table 1 Comparison of load shape concepts

	Name	Basic concept	Actions	Consequences
1	Peak clipping	Reduction of peak load	Direct load control of e.g. water heater, air conditioners	Reduction of operating costs and dependence on critical fuels
2	Valley filling	Building off-peak load	Adding new thermal energy storage (water heating and/or space heating)	Increase of long-run incremental costs to exceed the average electricity price Decrease of average cost to customers
3	Load shifting	Shifting load from on-peak to off-peak periods	Use of storage water heating and/or space heating, air conditioners	Reduction of operating costs
4	Strategic conservation	Reduction of consumption	Weatherisation Appliance efficiency improvement	Reduction in sales Change in the pattern of use
5	Strategic load growth	Increase consumption	Dual fuel heating Heat pumps, electric vehicles, automation Promotional rates	Increase in sales Economic development in service areas
6	Flexible load shape	Reliability	Variations of interruptible or curtailable load Pooled, integrated energy management systems Individual customer load control devices	Optimum of supply-side options by taking into account demand-side activities in forecasts of planning horizon

Source: Own summary according to Gellings (1985)

2.3 Demand response programs

The review of current state of the art literature shows many different types of DR programs. In Conchado & Linares (2010) a set of six classification criteria was developed which finally leads to two different types being either system-led or market-led (see Table 2).

Table 2 Basic classification of DR programs

Classification criteria	Dualities	
Purpose	Reliability	Economics
Trigger factor	Emergency-based	Price-based
Origin of signal	System-led	Market-led
Type of signal	Load response	Price response
Motivation method	Incentive-based	Time-based rates
Control	Direct load control	Passive load control

Source: Adapted from Conchado & Linares (2010)

Basically, literature sources distinguish between incentive-based and price-based DR programs. In DOE (2006) the following explanation is given for each motivation method:

- *Incentive-based DR programs* target at reducing demand in times of high electricity costs or network constraints (Conchado & Linares, 2010). In addition to commercial electricity rates customers are offered incentives to reduce their loads (DOE, 2006). Contractual agreements define time and duration of load reduction of customer's appliances.
- *Price-based DR programs* consist of time-varying rates setting electricity's value and cost at different time periods in relation. This means that customers voluntarily respond to price signals by reducing their demand in periods when prices are high and shifting their demand to lower-priced periods. (DOE, 2006)

The practical integration of DR programs needs to be considered in energy system planning and operation as these programs actively influence system management (see Figure 5). The process of planning and operation is split in five different phase spanning a timescale from years to less than 15 minutes.

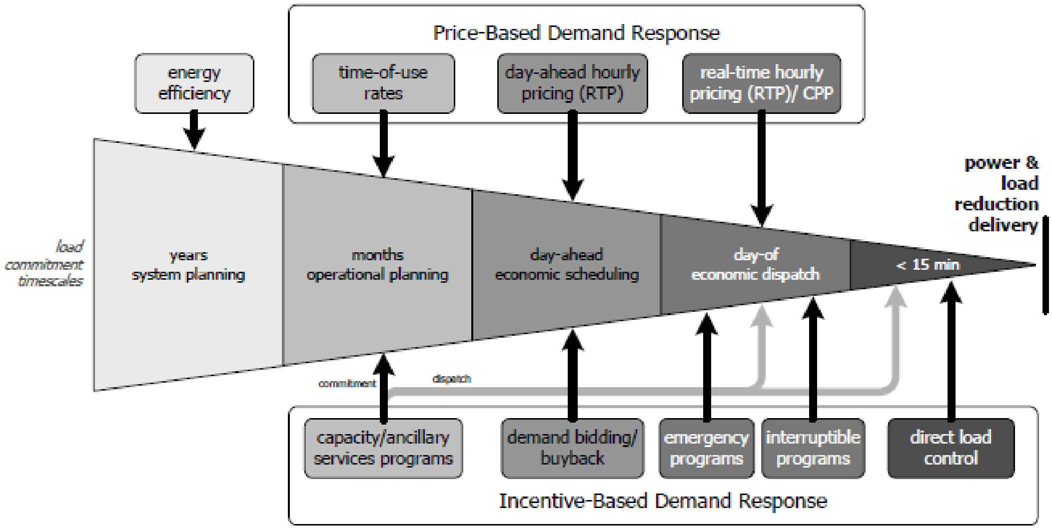

Figure 5 Role of DR programs in energy system management
Source: DOE (2006)

When planning how energy will be supplied measures aiming at energy efficiency need to be considered right from the beginning as they cause a reduction of energy consumption in the long run. The monthly operation planning of energy systems need to take into account which kind of DR programs are offered to customers and how do they respond to electricity price changes. Price-based programs are designed to encourage customers shifting demand from peak to off-peak periods by offering lower prices (Stromback et al., 2011). In current practice four different pricing mechanisms are distinguished:

- *Time-of-use tariffs (TOU)* are structured in two or even three levels of prices per day that are static (peak, off-peak and partial peak prices). Customers are informed about peak hours in advance. (Stromback et al., 2011; Palensky and Dietrich, 2011)
- *Real time pricing (RTP)* provides information about fluctuating hourly electricity prices to customers with day-ahead or hour-/minutes-ahead notice (DOE, 2006).
- *Critical peak pricing (CPP)* is a mixture of TOU and RTP design; the basic rate structure is taken from TOU but customers agree to have substantially higher tariffs during peak hours (DOE, 2006). Number and length of critical peak periods are agreed upon in advance and customers are usually notified a day before a critical peak period occurs (Stromback et al., 2011).

- *Critical peak rebates (CPR)* are inverse forms of CPP tariffs. Participants are paid for the amounts that they reduce consumption below their predicted consumption levels during critical peak hours. (Stromback et al., 2011)

Incentive-based DR programs often involve load reduction commitments of customers. For example, in capacity programs commitments are made ahead of time and allow the system operator to call a load reduction when needed. In ancillary services programs customers even agree to provide their load reduction often with less than one hour's notice. (DOE, 2006)

In demand bidding programs customers bid for curtailing at favourable prices (Palensky and Dietrich, 2011). System operators typically schedule load reductions day-ahead and value incentives with day-ahead energy markets (DOE, 2006).

DR programs with a very short timescale of less than two hours to notify load reductions are reliability-based; for example, in emergency programs program events are usually declared within 30 minutes to two hours of power supply and are often linked to real-time electricity market prices. Direct load control programs are deployed within minutes as the system operator has access to the customer's appliances and is allowed to initiate the reduction directly. (DOE, 2006)

2.4 Demand side measures in different sectors

Depending on the DR program's design different sectors are targeted. For example, incentive-based measures as demand bidding programs or direct load control are especially attractive for large industrial and commercial customers as they have large capacities to shift or curtail in peak periods. In comparison with other sectors the European industry sector accounts for 36% of the total electricity consumption (see Figure 6). The consumption of households and services is with 62% nearly as twice as high as the industry's one but the loads of households to be shifted can be better addressed with price-based programs. Thus, residential customers respond to price signals in order to shift their loads to off-peak periods. Capacity is built up by aggregating loads of single households. The services sector offers a high DSM potential although it is not based on production processes that can be influenced but on the operation of cross-sectional technologies. The electricity consumption of the transport sector is negligibly low. In addition, electrically operated public transport is scheduled and loads cannot be influenced (de Bruyn et al., 2015). In the following the different sectors addressed by DR programs described in Section 2.3 are briefly summarised.

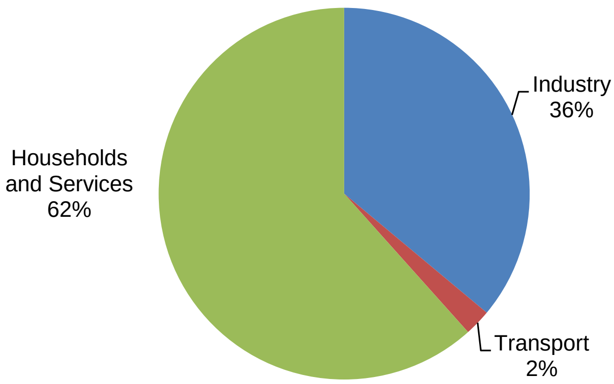

Figure 6 Electricity consumption in % (measured in GWh)
Source: Own graph, data taken from Eurostat (2013)

Industry sector

Industrial applications and processes offer a variety of advantages for DSM as connected loads are significantly larger and more energy-intensive compared to electrical applications in other sectors (Klobasa, 2007). In addition, Paulus & Borggrefe (2011) found out that many of (German) industry businesses investigated in a market analysis have already implemented data exchange equipment to allow real-time metering of electricity loads.

Due to capacity reasons of production processes and high capital costs the DSM potential is only given for a limited time period. Further restrictions for DSM are that quality of products must not be influenced and additional costs by ramping-up and ramping-down of the production process need to be kept low. In particular, industrial companies active in crude steel production, non-ferrous metal, chemical processing and paper industry offer a huge potential for DSM. (Klobasa, 2007)

Household level

Innovations in information and communication technologies (ICT) and further developments as well as the increasing energy awareness lead to a growing interest of residential consumers in DR (Torriti et al., 2010). Although pilot projects show that household appliances as washing machines, dishwashers, dryers, refrigerators and freezers offer a DSM potential to a certain extent, the applicability in a real-life environment is often controversial. Depending on the thermal inertia of residential buildings electrical space heating (e.g. night storage heater, heat pumps etc.), hot water storage facilities, and ventilation and cooling are very interesting application areas as electricity is utilised in a very efficient way (Prüggler, 2013; Klobasa, 2007). Nevertheless, the need to equip households with the necessary ICT infrastructure in order to utilise an existing DSM potential is a significant barrier for practical implementation. Prüggler (2013) shows in a calculation of break-even investment costs considering smart DR infrastructure costs that an application of spot market-oriented load shifting is not neither economically beneficial for the supplier nor for the aggregator.

Commercial and service sector

On the contrary to the industry sector in which energy-intensive processes cause electrical loads, DSM potential is offered by cross-sectional technologies in the commercial sector. This means that a technology with a specific service (e.g. cooling and ventilation) is utilised over a longer time period and therefore, the shifting or curtailing of loads is enabled.

Commercial sectors with a high DSM potential are retail and trade, businesses with a (large) portfolio of non-residential buildings (e.g. offices, production halls, retail spaces etc.), restaurants, hotels and any recreational facilities. In particular, these businesses are confronted with a high cooling and ventilation demand which can be utilised for DSM. (Klobasa, 2007)

In Table 3 the processes and services of the different sectors are summarised with the aim to give an overview on their corresponding application areas. Wide DSM potentials are given in all sectors but the extent to which these potentials are exploited is not the same for each sector. For example, DSM has a long history in the industry sector and corresponding DR programs have been designed and implemented for years (Lampropoulos et al., 2013). It has to be noticed that especially in sectors with small loads (e.g. households) a huge potential for DSM exists which has not been exploited until now due to high costs for ICT infrastructure, measurement and data transfer. DR programs have been complemented addressing needs of residential and commercial customer groups but due to existing barriers in national regulatory and contractual framework conditions the utilisation is hampered (Torriti et al., 2010; SEDC, 2014).

Table 3 Sectors and applications areas with DSM potential

Sectors, processes		Application areas considered
Applications on household level	Households	Refrigerator and freezer Hot water preparation Electrical direct heating Night storage heater Heat pump
Mobility	Electric vehicles	Charging and discharging of electric vehicles
Electrical refrigeration	Food industry Retail food trade	Food refrigeration
	Chemical industry	Air separation
	Services	Ventilation and air conditioning of buildings
Pump applications	Water supply	Groundwater and distribution pump
	Pumping station	Groundwater control, sewage treatment plant
Others	Chemical industry	Chlorine electrolysis
Electrical heating	Metal treatment – Heat treatment	Induction furnace, resistance furnace
	Foundry	Induction furnace, Arc furnace, resistance furnace
	Steel industry	Electro steel production
Grinding applications	Paper industry	Grinder, refiner, pulper
	Cement industry	Raw and cement mill
Municipal infrastructure	Waste water treatment	Sewage treatment plant
	Water supply	Pumps

Source: Adapted and translated from de Bruyn et al. (2015)

2.5 DSM policies in Europe

Across Europe DR developments and policies, programs and implementation schemes vary substantially reflecting different regulations and framework conditions in member states. This situation can be traced back to the fact that a single European energy market does not exist. (Torriti et al., 2010)

Despite facing the difficulty in finding agreements about the basic structure of an internal market the European Commission has demonstrated strong support for DR in recent years. With the decision of the European Court of Justice that electricity is a good and not a public service, the foundation of the liberalisation of the EU energy market was laid. The liberalisation process was established by Directive 96/92/EC concerning common rules for the internal market in electricity (the First Electricity Directive) and Directive 98/30/EG on common rules for the internal market in natural gas (the First Gas Directive). These directives specify the separate legal treatment of the commodity electricity and gas – as a good - and the supply of electricity and gas – as a service and therefore, enable the unbundling of activities. (Torriti et al., 2010; SEDC, 2013)

With the objective to improve legislation the Third Energy Package was finally adopted in year 2009 which requires network operators to take the potential of DR and energy efficiency into account when planning system upgrades (Kayikci, 2011; SEDC, 2013). Article 3.2 of Directive 2009/72/EC states that *'in relation to security of supply, energy efficiency/ demand side management and for the fulfilment of environmental goals and goals for energy from renewable sources, [...] Member States may introduce the implementation of long-term planning, taking into account the possibility of third parties seeking access to the system'* (EC Directive, 2009).

In a subsequent step the 2012 Energy Efficiency Directive (EED) mandates consumer access to the energy markets either singly or through aggregation required. According to EC Guidance note (2013) implementing EED Article 15 the main obligations for member states are inter alia to ensure that

- *'National regulatory authorities encourage demand side resources, such as demand response, to participate alongside supply in wholesale and retail markets'* and
- *'Access and participation of demand response in balancing, reserve and other system services markets is promoted, requiring that the technical or contractual modalities to promote participation of demand response in such markets – including the participation of aggregators- be defined'.*

Member States have the freedom to design their markets and regulatory frameworks to suit national conditions but need to ensure third party access to national markets and introduce competition. Thus, end users shall benefit from lower prices for energy and have a better quality of service by choosing a supplier that offers the best value for money. (Torriti et al., 2010)

The current situation in European member states shows a diverse picture as national market designs and policies have not promoted innovations or opportunities for DR in electricity markets to a full extent (Torriti et al., 2010). A few countries as

Belgium, Switzerland and the UK have already created the regulatory framework for commercial DR activities whilst others show significant progress in developing the market, e.g. Austria, Finland, France, and Ireland (SEDC, 2014). Countries as Spain and Italy have mainly focussed on large industrial consumers and no improvement in regulatory frameworks could be measured from year 2013 to 2014 (SEDC, 2014; Torriti et al., 2010).

Although some progress has been made in recent years to develop regulatory conditions in European member states, DSM addressing commercial and residential consumers is still limited (Torriti et al., 2010).

3 Guidance to analyse DR pilot projects

Following the previous chapter, in which an introduction and overview about the basic concepts of DSM have been given, an analysis of requirements that are decisive for enabling market access to electricity consumers follows in this section.

In a thorough work of structuring, comparing and interpreting meta-studies and other assessments of Smart Grid and Demand Response pilot projects a set of indicators is grouped along the following categories:

- Participation and acceptance of consumers,
- Institutional and regulatory framework,
- Economic and financial aspects, and
- Technical aspects.

The logical outline for guiding the reader through the individual categories in the subsequent sections is as follows:

1. Each category is composed of several indicators which have been selected carefully focussing on the analysis of requirements that are decisive for electricity consumers accessing the energy market.
2. In case the meaning of the chosen indicators is unclear to the reader or not self-explaining, a short description of those indicators is provided in each category.
3. Finally, at the end of this chapter an overview table is given which serves as an analytical framework offering guiding principles to be followed for assessing the pilot projects in Section 4.

3.1 Participation and acceptance of consumers

This category summarises indicators that mainly focus on consumer motivation to change their behaviour and engage participation in the electricity market via DR programmes. After analysing and interpreting meta-studies, papers and other publications in this field an overview of the indicators described in the following section is given in Table 4.

Table 4 Indicators of category 'Participation & acceptance of consumers'

Participation & acceptance of consumers	
User activation & customer engagement	User segmentation
	Motivation to participate
	Marketing, communication and education
Tariff structure	Incentives for participation (direct rewards, rebate checks, bonus system or free technology such as an in-house display)
	Cost-reflective pricing schemes
Access to information	Feedback system and visualisation of consumption: web portal, app for smartphones/ tablets, in-house or ambient displays, informative billing
	Feedback information types: actual and historical comparison, peer comparison, price of electricity, disaggregation of consumption, savings compared to previous periods, environment (CO_2 emissions)
Data protection, privacy & security	Access and utilisation of monitoring data of electricity consumption

Source: Own compilation

User activation and customer engagement

In order to appropriately address consumer groups and design DR programs tailored to their needs an energy service company needs to do a thorough analysis and segmentation of its client groups. Based on the descriptions in Section 2.4 the following consumers groups can generally be distinguished:

- residential consumers
- non-residential consumers
    - large energy-intensive industries
    - small and medium commercial consumers
    - service companies

Most commonly, the segmentation of residential energy customers follows demographic information as age, income, educational background, regional origin etc. Some energy service companies also consider information about consumers' propensity to use technology, product preference, and energy usage patterns (McNamara and Marshall, 2013). Taking these considerations as a starting point experts of the initiative Smart Grid Australia (SGA) analysed the research activities and results of Australian pilot projects and identified four main types of consumers (Burns et al., 2011):

- *The uncommitted consumer* who is unconcerned about level and pattern of own energy consumption and the associated energy cost both for themselves and the environment.
- *The informed consumer* who is aware of technological initiatives and dedicated to reducing energy consumption and its impacts on climate change.
- *The budget-conscious consumer* who focuses on a combination of price and service and tends to be more driven by price.
- *The hardship consumer* who suffers from health issues, disabilities and/or on low incomes. These customers may struggle to adjust consumption patterns and therefore benefit from smart grids.

Further on, SGA's research revealed that the 'uncommitted' group adds up to more than half of the electricity customers in Australia. Consumers that participated in pilot projects and trials mainly belonged to the group of 'informed' and 'budget-conscious'. (McNamara and Marshall, 2013)

In contrast to domestic energy customers non-residential ones have a better understanding of their consumption as well as the volatility of electricity prices (McNamara and Marshall, 2013). A high share of large energy-intensive industry companies has already invested in data exchange equipment to allow (nearly) real-time metering of electricity consumption (see Section 2.4).

Although commercial companies can offer a DSM potential through cross-sectional technologies, most of them are currently not metered. Information and understanding of how consumption levels and costs vary at different times is therefore limited.

Hence, public awareness and advertising campaigns as well as website communication and interaction on social media platforms are useful means to win consumer's trust and interest in participating in DR schemes. In addition to a high level of trust between the customer and energy service provider education and engagement with consumers before starting a DR program are crucial success factors. (McNamara and Marshall, 2013)

Often disregarded as soft measures education, public outreach and awareness campaigns help to minimise possible rebound effects and support long-term behavioural change. The impacts of these measures cannot be neglected as they address a range of informational and behavioural barriers particularly prevalent in the residential sector. (Haney et al., 2010)

McNamara & Marshall (2013) summarise that consumer's awareness about energy consumption and the wider impact of their behaviour needs to be addressed additionally when developing sophisticated approaches of DR schemes. Educational measures need to focus on specific actions that consumers have to take. Detailed and clear description of benefits further supports the realisation of customer's actions.

Tariff structure

According to Stromback et al. (2011) cost reflective DR pricing schemes are designed to encourage customers shifting their electricity consumption from peak periods to off-peak ones. The most commonly implemented pricing schemes are described in Chapter 2.3 of this thesis. Literature sources basically distinguish between incentive-based and price-based DR programs. Incentive-based DR programs target at reducing demand in times of high electricity costs or network constraints (Conchado and Linares, 2010). With price-based DR programs customers voluntarily respond to price signals by reducing their demand in periods when prices are high (DOE, 2006).

Access to information

Awareness and understanding of energy consumption and price volatility require that customers have access to consumption data via feedback systems. Different feedback program types are currently commercially available such as apps for smartphones and tablets, web portals, in-house or ambient displays, and informative billing. They are designed to support consumers with additional information in order to allow an energy consumption reduction and to lower distribution and supply costs (Stromback et al., 2011). In the following Table 5 the different feedback program types are briefly discussed.

Table 5 DR feedback program types

Program type	Description of device	Time interval	Information type
In-house display	Home screen which hangs on the wall or sits on a counter (additional feature: glows in a varying degree of colours to show if prices are high or low)	Close to real time information (5-15 minutes delay)	• Real time and historical data • Current price of electricity • Information how much money has been spent • Peer comparison* • Appliance specific consumption** • Indoor temperature • Weather forecasts
Ambient display	Attractive and intuitive handling		• No specific consumption information but rather signal to the customer • Messages about their general level of consumption and/or a change in electricity prices
Website	No additional device installed	Depends on how often smart meters are read or how often data is transferred to utility/retailer	• Actual and historical consumption data • Other functions
Informative billing	No additional device installed	End of billing period (1 year) or when resident changes electricity supplier	• Indirect feedback • Actual consumption data (in comparison to last year's data) • Peer comparison* (very rarely)

* showing the consumption rate of neighbours or consumers with similar conditions
** breaking down the energy usage of individual appliances in the home

Source: Own summary based on Stromback et al. (2011)

Data protection, privacy and security

All DR feedback program types (except informative billing) require an internet connection to access and show electricity consumption data. Thus, data privacy risks are caused by the transmission of consumer data via IP communication and availability of consumer data via internet portals (Burns et al., 2011). Awareness of energy utilities, network providers as well as hardware and software producers has recently been raised and approaches are discussed and developed to meet possible risks in order to safeguard customers' data privacy and security adequately. Drawing lessons from the banking and telecoms sectors might be useful in this regard (Hallberg et al., 2011).

3.2 Institutional and regulatory framework

This category summarises indicators that mainly focus on the set-up and structure of electricity markets to enable participation. In Table 6 an overview of the indicators described in the following section is given.

Table 6 Indicators of category 'Institutional & regulatory framework'

Institutional & regulatory framework	
Liberalisation of energy market/ unbundling	Consumers have access to markets
	Legality of (aggregated) DR
Definition of roles and responsibilities of market players	Market players as energy retailer, independent DR aggregator, grid operator, balancing responsible party (BRP)
Formalisation of interactions between different parties through connection agreements	Costs and risks of parties should be reflected
	Establishment of standard reimbursement for BRP and aggregators

Source: Own compilation

Liberalisation of energy market/ unbundling

In Section 2.5 of this thesis a short overview on the current situation of DSM policies in Europe is given. Across Europe DR developments and policies, programs and implementation schemes vary substantially reflecting different regulations and framework conditions in member states. Regulatory barriers stretching across almost the entire EU are effectively halting the establishment of these programs and the ability of third parties to enter these markets (SEDC, 2013). Nevertheless, the implementation of DSM plays an important role in the further establishment of an integrated internal energy market of the European Union (CEPA, 2014). To finally achieve that regulation and market structures enable the demand side to participate effectively in the electricity market, rules and responsibilities for all market players involved need to be defined.

Definition of roles and responsibilities of market players

In today's energy markets a variety of market players and stakeholders is involved (e.g. grid operator, BRP, energy service company, independent DR aggregator). But before the flexibility potential of any participating customer can be commercialised into the market contractual relationships with a lot of different stakeholders need to be established (SEDC, 2014).

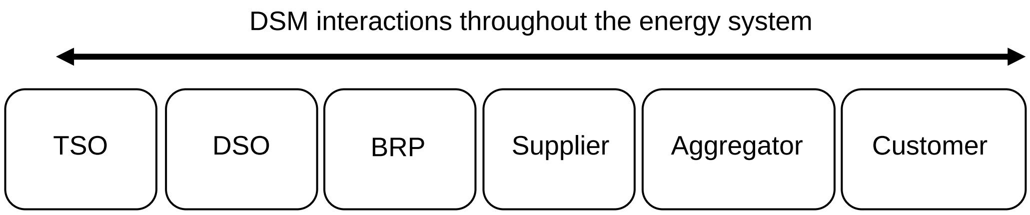

Figure 7 Market players involved in DSM interactions
Source: Own graph adapted from CEER (2013)

Due to the complexity of duties and responsibilities coordination among parties interested in accessing demand side services is needed. System operators must effectively provide information to other players in order to enable and validate DR events to ensure that the load modifications do not cause incidents to security and quality of supply. (SEDC, 2014)

Thus, the roles and responsibilities of stakeholders must be defined to enable a transparent and competitive DR development. In
Table 7 an overview according to SEDC (2014) is given.

There are many reasons why other market players than independent third-party aggregators are interested in DSM:

- DSO is interested to avoid investments in regional network capacity (SEDC, 2014).
- Although retailers often own generation assets and would have limited interest to incentivise the reduction of electricity consumption, they benefit from enhancing their balancing and hedging capabilities and portfolio optimisation (CEER, 2013).
- Retailers are interested to lower their purchasing risk as electricity is bought at market price (SEDC, 2014).

Table 7 Market players and their responsibilities

Market player	Main duties and responsibility	Additional information
Transmission system operator (TSO)	• Maintaining system security at the lowest possible cost • Maintaining system balance • Balancing group accounting and imbalance settlement	
Distribution system operator (DSO)	• Granting a proper quality of supply • Delivering reliable and sustainable electricity to consumers	DSOs are metering operators; provide metering data to other players involved in DSM
Balancing Responsible Party (BRP)	• Managing a balancing group (BG) • Achieving a balanced state for the BG by forecasting and planning energy flows from generation, consumption and trading	A BG is not a geographical concept.
Balance service provider (BSP) or aggregator or pool operator	• Recruiting and aggregating assets from third party balancing groups	Free access to market needed to offer DR aggregation services to any consumer or distributed generation resource
Retailer	• Ensuring consumers to have a reliable source of electricity • Buying electricity in forward, day-ahead and intra-day markets • Charging consumers for the cost of electricity, purchasing risk and profit margin	• Often acts as BRP • Also own generation assets • May provide aggregation services to their consumers

Source: Own summary based on SEDC (2014)

Thus, as many market players have an interest to participate in DSM the next logical step – after defining roles and responsibilities – results in the formalisation of interactions between different parties.

Formalisation of interactions between different parties

The current situation in European member states does not take DSM conditions into account adequately. A framework that formalises interactions between different parties is needed in order to improve regulations and practices across the entire value chain (Daniell, 2013). Simple and streamlined contractual and payment arrangements between retailers, BRPs and aggregators are needed reflecting respective costs and compensation as well as risks of all participants (SEDC, 2014).

The standardised formalisation of interactions defines what happens if one party calls for a DR action considering positive and negative consequences on other parties. For example, does a risk exist that the dispatch of DR to one party might reduce the capacity of DR to another one (Daniell, 2013)?

In Table 8 an example of a potential future agreement between different parties according to Hallberg et al. (2011) is shown. The agreement defines what is agreed on ('object') and why this agreement is taken ('purpose'). In addition the responsible actors as well as the service providers of the object to be agreed on are listed. Thus, it can be ensured that customers benefit from proper market functioning, smooth processes, and a secure and reliable electricity supply (Hallberg et al., 2011).

Table 8 Example of potential future agreement

Object of agreement	Purpose	Responsible actor	Service/product provider
Provide customers with information on energy consumption and related costs	Enhance customer awareness and their active role in electricity markets	Supplier	Supplier
Balance of demand/ supply in the transmission grid	Optimise demand and supply to balance the grid	TSO	BRP
Balance of demand/ supply portfolio at balance responsible level	Optimise demand and supply to ensure global system flexibility	BRP	Supplier, large customer
Security congestion management (short-term)	Operate the grid within the security standards	DSO	Supplier, large customer
Firm capacity management (long-term)	DSO planning purposes; optimise demand and supply with a view to using assets most efficiently	DSO	Supplier, large customer
Voltage control	High quality of service	DSO	Supplier, large customer

Source: Hallberg et al. (2011)

3.3 Economic and financial aspects

This category summarises indicators that focus on the financial profitability of DR services. In Table 9 an overview of the indicators described in the following section is given.

Table 9 Indicators of category 'Economic & financial aspects'

Economic & financial aspects	
Business models	Monetary assessment of future value to be created with DR
Profitability	Estimation of sales through DR services in contrast to operational and capital expenses needed to enable DR
Financial support in the development phase of DR	(Governmental) Incentives for Smart Grid enhancements or achievement of a certain percentage of energy savings

Source: Own compilation

Business models

Making flexibility technically available to the energy system is an important pre-condition but without a business case which creates an economic value such as revenues and profit the whole endeavour is not feasible. Thus, the economic implementation of DSM and DR must be based on solid business models that prove to be financially profitable with clear benefits for providers of flexibility services and service operators in the long run. Via suppliers and/or aggregators the DSO would procure this flexibility from residential and business consumers as well as distributed energy generators who need to be financially compensated for providing flexibility and contributing to the reduction of network constraints (Sánchez-Jiménez et al., 2015).

In particular, the pooling of a number of end users can be a viable business case for aggregators. By controlling flexibility a value is created. Thus, aggregators offer an interface with the energy market to end users and the ability to actively participate in the market. (Rammers et al., 2015)

Table 10 Examples of business cases for aggregators

Business case		Aggregator's service
System management	Tertiary control	Aggregator supports end users to meet the TSO requirements.
Imbalance market	Flexible prices via market access	Aggregator receives a transaction fee.
	Fixed price based on available flexibility	The customers get a fixed price for a set period of time (e.g. one year) and within an agreed usage bandwidth. The risk of price is shifted to the aggregator who charges a premium.
Congestion management	USEF market-based coordination mechanism	Flexibility can be offered to prevent a local congestion problem from arising. Local congestion is solved in cheapest way; e.g. less chance of unnecessarily expensive investments by DSO (e.g. local storage) when cheaper flexibility services might be available.

Source: Own summary based on Rammers et al. (2015)

In Table 10 examples of business cases for aggregators are listed. In Europe only a few aggregators are active due to regulatory barriers which impede market growth (see Section 2.5). Most of the existing aggregators are focused on a certain type of users (e.g. industry clients or even residential customer as in France) and specific types of flexibility sources (Eid et al., 2015).

On the other hand, providing flexibility must also be economically viable for the ones who provide it. The financial benefits for customers can originate from various sources, e.g. a direct financial compensation and/or savings on purchased energy (Sánchez-Jiménez et al., 2015).

Profitability

Based on these considerations the structure of energy prices has a significant impact on the exploitation of the flexibility potential; energy prices with a high share of taxes and other parts not directly related to the energy limit the growth of market models. (Bachiller et al., 2013)

For each business model the revenue streams need to be analysed in advance. According to Bachiller et al. (2013) the following economic aspects are considered:

- Electricity prices for each segment,

- Price structure (e.g. energy, grid, taxes),
- Level of subsidies,
- Current prices for flexibility on available markets and mechanisms,
- Range of tariffs and contracts available for consumers, and
- Cost of enabling ICT infrastructure

Financial support in the development phase of DR

With the aim to support the establishment of a flexibility market financial support in the development phase of DR can be given through incentives which motivate a decision or action by consumers, businesses or other commercial and regulated institutions (Sánchez-Jiménez et al., 2015). In Table 11 different types of incentives are summarised which should enable customers and other market actors to overcome potential financial, regulatory or psychological barriers in order to access energy markets.

Table 11 Types of incentives

Subsidies directly given to the end user or beneficiary or indirectly through a third party	**Tax benefits** possibility to deduce costs of smart appliances from income tax or a reduced value-added tax	**Low interest or specialized loans or project bonds** to attract additional private financing from institutional investors	**Co-financed funding** of research, innovation and demonstration activities of pilot projects

Regulatory incentives as 'quality of investment' indexes for remuneration schemes or decreased amortization periods	**Sustainable procurement** as Green Public Procurement (GPP) on the basis of life cycle costing	**Information and customer engagement programmes** can help create customer awareness about benefits and opportunities offered by the new solutions and tariffs

Source: Own summary based on Sánchez-Jiménez et al. (2015)

3.4 Technical aspects

This category summarises indicators that mainly focus on the technical conditions in relation to hardware, software and interoperability. In Table 12 an overview on the indicators described in the following section is given.

Table 12 Indicators of category 'Technical aspects'

Technical aspects	
Data communication standards, formats, and management	Appropriate measurement and verification protocols: performance measurement, baseline methodology, metering configuration and communication requirements
Enabling technologies	Smart meter, home automation systems, ICT infrastructure for network enhancement etc.
Interoperability	Definition of system specifications to enable/ allow interoperability of devices from different manufacturers

Source: Own compilation

Data communication standards, formats, and management

The successful implementation of DR and interaction of market players is based on an efficient communication infrastructure enabling a secure bidirectional data exchange between the actors involved (e.g. utility company, aggregator, end user etc.). Figure 8 illustrates the DR architecture in a schematic diagram. The data from individual customer's meter or an aggregator is collected through different communication means (e.g. wireless, PLC etc.) and sent to the utility control centre. (Mohagheghi, 2012)

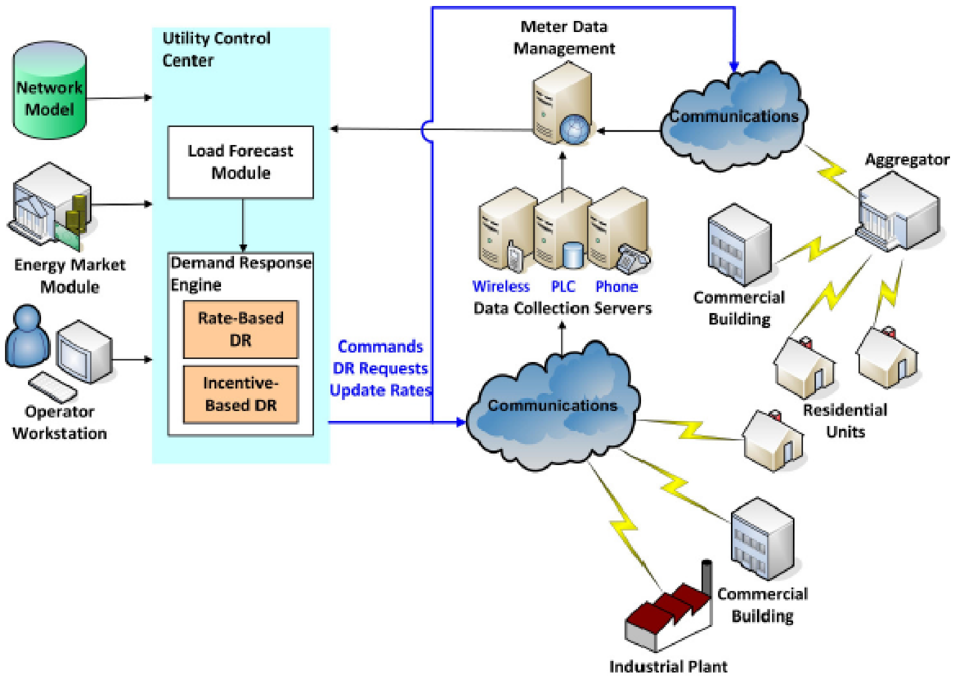

Figure 8 Schematic diagram of DR architecture

Source: Mohagheghi (2012)

A detailed explanation is given in Schwarzer & Engel (2015) which common data communication requirements are valid for DR models. In any case, a bidirectional communication link between CEMS (Customer Energy Management System) and user and CEMS and appliance is mandatory. In addition, communication links between user and utility or user and aggregator as intermediary needs to be considered. The data exchange must be based on standard measurement and verification protocols. As these requirements are currently not defined in all European member states the interaction between market players and a further market growth of flexibility services is hampered.

Enabling technologies

Based on smart technologies implemented at the consumer's facilities the data exchange between actors involved is enabled. The following technologies are examples how DR services need to be successfully implemented from a technical point of view:

- *Customer Energy Management System (CEMS):* The Smart Grid Coordination Group (2012) defines the general function of a CEMS as the optimisation of energy utilisation based on supply contracts or other economic targets at the demand side. The integration of smart meter functions is also common (Schwarzer & Engel, 2015).
- *Smart Meter:* A smart meter is a device communicating bi-directional and measuring energy consumption of appliances like electricity, gas, water or heat (Fan et al., 2013).
- *Information and communication networks:* As part of the communication system different types of networks need to be set-up. Fan et al. (2013) identifies three networks: a) the Home Area Network (HAN) formed by in-home appliances and devices; b) the Neighbourhood Area Network (NAN) collecting data from multiple HANs and delivering the data to a data concentrator; c) the Wide Area Network (WAN) as data transport network carrying metering data to central control centres.
- *Gateway:* The gateway collects or measures energy consumption data from the HAN members (and of the home as a whole) and transmits this data to interested parties (Fan et al., 2013).

Interoperability

A key feature of realising DR is the interconnection of electricity generating energy sources (e.g. PV systems, micro-CHP units etc.), energy networks and consumers. The devices of each entity need to exchange data via communication infrastructure independent of the physical medium used, manufacturer and type of device. Thus, many communication technologies and standards coexist in different parts of the system. In order to smooth the process of exchanging data communication standardization need to be developed with the aim to ensure interoperability between different system components, e.g. the standardisation bodies of CEN/CENELEC and ETSI are active in this area. Consequently, the successful commercial deployment of DR solutions will be closely linked to the availability of open and standard mechanisms enabling different stakeholders and manufacturers to interoperate and interface in a standard manner. (Fan et al., 2013)

3.5 Summary of the analytical framework

Table 13 Analytical framework summarising DR categories

Category	Indicator	Definition
1 - Participation & acceptance of consumers		
Consumer motivation to change their behaviour & accept to participate in the market	User activation & customer engagement	User segmentation
		Motivation to participate
		Marketing, communication and education
	Tariff structure	Incentives for participation (direct rewards, rebate checks, bonus system or free technology such as an in-house display)
		Cost-reflective pricing schemes
	Access to information	Feedback system and visualisation of consumption: web portal, app for smartphones/ tablets, in-house or ambient displays, informative billing
		Feedback information types: actual and historical comparison, peer comparison, price of electricity, disaggregation of consumption, savings compared to previous periods, environment (CO_2 emissions)
	Data protection, privacy & security	Access and utilisation of monitoring data of electricity consumption
2 - Institutional & regulatory framework		
Set-up and structure of electricity markets to enable participation	Liberalisation of energy market/ unbundling	Consumers have access to markets
		Legality of (aggregated) DR
	Definition of roles and responsibilities of market players	Market players as energy retailer, independent DR aggregator, grid operator, balancing responsible party (BRP)
	Formalisation of interactions between different parties through connection agreements	Costs and risks of parties should be reflected
		Establishment of standard reimbursement for BRP and aggregators

3 - Economic & financial aspects		
Financial profitability of DR services	Business models	Monetary assessment of future value to be created with DR
	Profitability	Estimation of sales through DR services in contrast to operational and capital expenses needed to enable DR
	Financial support in the development phase of DR	(Governmental) Incentives for Smart Grid enhancements or achievement of a certain percentage of energy savings
4 - Technical aspects		
Technical conditions in relation to hardware, software and interoperability	Data communication standards, formats, and management	Appropriate measurement and verification protocols: performance measurement, baseline methodology, metering configuration and communication requirements
	Enabling technologies	Smart meter, home automation systems, ICT infrastructure for network enhancement
	Interoperability	Definition of system specifications to enable/ allow interoperability of devices from different manufacturers

Source: Own compilation

4 Experiences gained from pilot projects

In the previous chapters the concepts of DSM as well as the conditions that have to be considered when implementing DR measures have been described. A list of indicators was gathered by the author serving as a guideline for the further analysis. In order to prove these assumptions the analysis of pilot projects follows in this section. In pilot projects the planning and implementation phases of project development are merged (Haithcoat, n.a.). The findings and experiences of pilot projects allow an evaluation of technical, economic and social concepts.

In the following section a brief explanation is given how and which pilot projects have been selected; in a next step the pilot projects selected are analysed in detail. Starting with a short general project introduction about the pilot project, information about specific regulatory conditions of DR and load aggregation in the country, in which the pilot project was implemented, follows. The projects are analysed along the categories and indicators of Section 3; the information presented is based on project reports, deliverables and papers. A detailed list of the sources utilised can be found in the Annex. Finally, each description of the pilot project is concluded with a technical expert's assessment about project impacts and transferability of project results to gather an additional, external assessment. The findings of this pilot projects' analysis will serve as an input for the recommendations in Section 5.

4.1 Selection of pilot projects

The selection of pilot projects is based on the general methodological approach described in Section 1.3; projects considering the aggregation of demand side resources are specifically addressed as projects implementing this approach are interesting in many ways: flexible electricity loads support the control of the distribution network and security of supply in times of highly fluctuating renewable energy sources; the aggregation of small loads enables the trading of these loads at the energy market. Thus, not only the technical implementation of these solutions has to be ensured in pilot projects but also aspects as user engagement, the definition of use cases and their economic impacts reflecting the national regulations in this sector need to be considered.

In order to learn from the experiences made in pilot projects the IEA DSM Task 17 experts collected a number of pilot projects covering various aspects of DSM but only a few of them focussed on aggregation of demand side resources. Therefore, the author of this thesis had to broaden the viewing angle and additionally screened the project catalogue in the 'Smart Grid Projects Outlook 2014' which lists 459 Smart Grid projects launched from 2002 up until today (Covrig et al., 2014). This catalogue structures the projects along a set of seven smart grid applications; one of them is 'Aggregation (virtual power plant, demand response)'. The list of suitable projects ranges from national projects from EU-28 member states as well as includes projects funded by the EC under FP6 and FP7.

Thus, the pool of projects, from which the author could select, seemed extensive but a closer look at the projects revealed the following barriers for project selection:

- Many national projects of EU-28 countries promised to be interesting after a first brief internet search. The collection of reports and other detailed information proved to be difficult as only information in the national language was available. Information in English was limited to an abstract or a short summary which provided too less information for an in-depth project analysis.
- In other cases general information in English or German (the author's mother tongue) were publicly available but they were not detailed enough to allow an intensive analysis along the categories described in Section 3. In particular, the assessment of economic and financial aspects was hampered as reports on the development of business models are kept confidential due to the involvement of industrial companies and energy utility companies who are setting-up use cases to be tested in a pilot project.
- In many projects research activities focussed on specific questions in the area of DSM and a demonstration and implementation of a pilot case was not intended.

As a consequence, the list of projects to be chosen was even further condensed. Finally, the author decided to analyse the following four pilot projects which offer an interesting concept and approach (see Figure 9).

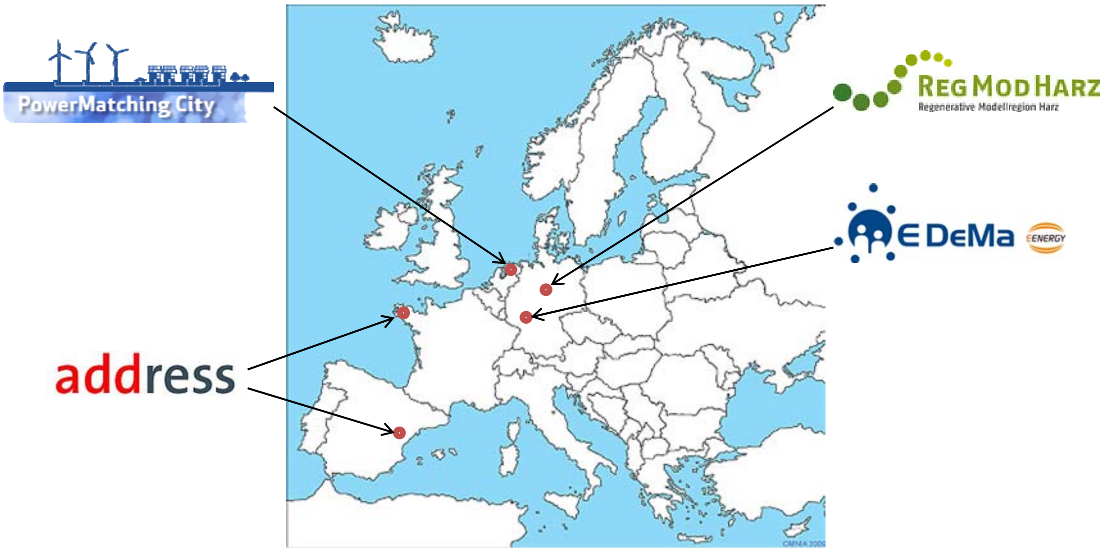

Figure 9 Map with pilot projects

Source: Own graph

1. The Dutch demonstration project **PowerMatching City** was started in the year 2007 as one pilot case of the European FP6 project INTEGRAL. Phase II started in September 2011 as a follow-up project funded by the Netherlands Enterprise Agency. The activities are based on the software solution 'Power Matcher Suite' which acts as a virtual power plant (VPP) with the aim to stabilise and optimise the electricity network through energy trading based on a real-time market approach.
2. The FP7 project **ADDRESS** was launched in June 2008 as a R&D project funded by the European Commission. Via the Energy Box and the Aggregation Box loads were controlled and optimised in residential buildings at two pilot sites in Spain and France. As mediator between consumers and other market players the aggregator offered services to its customers enabling them to exploit their flexibilities.
3. The German E-Energy project **E-DeMa** addressed the development and demonstration of decentralised energy systems as well as of the market place of the future. Activities started in November 2008 and set a focus on prosumers actively participating in an energy market place via an ICT gateway by shifting loads of household appliances.
4. The E-Energy project **RegModHarz** developed technologies and business models tailored to the challenges of future energy systems driven by decentralised and renewable energies. The pilot demonstration took place at the German county Harz starting with November 2008. A VPP coordinated various producers, consumers and storages (mainly electric vehicles).

The four pilot projects were selected as all of them address the aggregation of loads via utilisation of an ICT platform to implement a market-driven approach. Load aggregation is focussed on demand side resources in the residential area and renewable energy generation systems (e.g. wind turbines, PV systems). The pilot projects selected were implemented in four European countries (Netherlands, France, Spain, and Germany) with different regulatory market conditions for DR and aggregation of electrical loads.

The following analysis in Sections 4.2 to 4.5 turned out to be very time consuming as all reports needed to be collected, read and their concept understood. Deliverables and reports were written by authors coming from different disciplines who described the activities carried out from a specific viewing angle. For these cases the technical language and terminology was often not easy to understand and made the analysis difficult. Projects that integrate technical, economic, social aspects as well as national regulatory conditions add many layers of complexity which interact with each other and cannot be regarded as independent.

4.2 Pilot project 'PowerMatching City'

In the Netherlands the regulatory market conditions are very favourably compared to other EU member states. Currently, a number of independent third parties are active at the energy market aggregating loads of small industrial companies, hospitals or greenhouses. Load aggregation in the residential sector is still at the very beginning.

The Dutch pilot project 'PowerMatching City' addresses the residential area and offers a market-driven approach involving dynamic pricing on an end user level. The role of consumers is changed to prosumers that are part of a local energy market. This concept assumes a total market change which could mitigate high investment costs in additional energy infrastructure in a future energy system with a high penetration of renewable energy sources. (Kesting & Bliek, 2013)

4.2.1 General project information

The history of 'PowerMatching City' dates back to the year 2007 when one of the first Dutch pilot projects have been planned, developed and demonstrated in the city of Hoogkerk, near Groningen in the northern part of the Netherlands. The first technical concept (Phase I) was tested in the framework of the European

FP6 project INTEGRAL[3] as one field demonstration out of three others. The project started in November 2007 and was finalised in February 2011. Nine partners from the Netherlands, France, Greece, Spain and Sweden jointly

- developed a reference ICT-platform for distributed control at aggregated levels in the electricity grid based on commonly available ICT components, standards, and platforms;
- demonstrated the technology in three different field tests under normal (Netherlands), critical (France) and emergency conditions (Spain); and
- evaluated lessons learned and provided practical industrial guidelines for integrated distributed control.

In Phase I 25 Dutch households were equipped with a mixture of distributed energy sources (PV and micro CHP), hybrid heat pumps, smart appliances, smart meters and electric vehicles. Wind turbines supplied electricity to the network. The technical concept was proven and considered as a success.

Phase I ended in the first half of 2011. PowerMatching City II[4] started in September 2011 funded by the Netherlands Enterprise Agency and lasted three years. The Dutch project consortium consisted of partners from the entire energy value chain (e.g. distribution network operator, energy supplier, research partner, software company etc.). The pilot demonstration of Phase II was additionally equipped with 18 households, ten electric vehicles and two smart distribution transformers in June 2013. Activities focused on market mechanisms under a smart grid regime by demonstrating the energy system of the future with related smart energy services as well as validation of costs and benefits. Research questions addressed

- the testing of energy services and validations of demands and requirements of end users;
- capacity management with a smart grid and
- the smooth integration of innovative smart energy consumer products.

The pilot activities are based on the utilisation of the software solution 'Power Matcher Suite' which stabilises and optimises the electricity network through energy trading based on a real-time market approach. The loads of individual electrical devices are aggregated and their operation is optimised aiming at a balanced electricity production and consumption. The technology was developed in a joint

[3] http://www.integral-eu.com/ (visited at 23.07.2015)
[4] http://www.powermatchingcity.nl/site/pagina.php?id=41 (visited at 23.07.2015)

effort by research and industry partners and is tested and proven in various smart grid project implementations (e.g. EcoGrid EU, Couperus, Smart Grid Pilot Heerhugowaard etc.). (Power Matcher Suite, 2015)

4.2.2 Country-specific regulatory information

The regulatory conditions for demand side participation are much more progressed in the Netherlands than in many other European member states countries.

Table 14 Regulatory conditions for DR in the Netherlands

Country		The Netherlands
Consumer have access to …	Replacement reserves (RR)	Open
	Frequency restoration reserves (FRR)	Open
	Day-ahead market	Open
	Intraday market	Open
	Relationship prior to load curtailment	Agreement with the consumer's BRP and with its supplier needed
	Imbalance settlement	Price is established every 15 minutes
Program requirements	Minimum bid	RR: 4 MW; FRR: 20 MW
Measurement and verification	Baseline definition	Depends on the contractual relationship between end consumer, BRP and supplier
	Standardised data exchange	No standardised requirements available
Finance and risk	Availability payments	Energy only market with no availability payments (except contracted FRR)
	Penalty	Only for contracted products: 1/6th of the contractual fee
Availability of aggregators operating at the national market		Yes

Source: Own summary based on SEDC (2014)

BRPs and independent aggregators are active on the day ahead, intraday and balancing markets with a flexibility potential of around 1,500 MW and an estimated balancing volume of 500 GWh per year. Aggregation is especially interesting for BRPs in order to optimise their portfolio and management imbalances. Often independent aggregators are hired to take over this task. Currently, four Dutch aggregators are active which pool demand side resources from greenhouses, hospitals, small industries with CHP and load shedding capabilities. (SEDC, 2014)

4.2.3 Assessment based on the analytical framework

The analysis in the following section draws on information of reports downloaded from different websites and publicly available online sources as well as a telephone interview with Dr. Albert van den Noort, project manager of PowerMatching City at DNV GL, a consultancy company with expertise in maritime, oil and gas, and energy industries. Relevant findings are analysed and presented in a compact and brief manner. A list of all reports used can be found in the Annex.

In the following the information sources are listed for each category of the analytical framework:

- The section ‘participation and acceptance of consumers’ builds on the sources Mourik (2014) and Kesting & Bliek (2013).
- The analysis of the category ‘institutional and regulatory framework’ draws on information from Deliverable 4.4 (Kamphuis et al., 2009) and Deliverable 3.2 (Gustavsson & Stahl, 2008) of the FP6 INTEGRAL project. In addition, information from the expert interview with Dr. van den Noort was added (van den Noort, 2015).
- Information about ‘economic and financial aspects’ is taken from Deliverable 8.1 of the FP6 INTEGRAL project (Dimeas et al., 2009), the PowerMatching city website (PowerMatching City, 2015) as well as the expert interview (van den Noort, 2015).
- The section ‘technical aspects’ summarises information from the expert interview (van den Noort, 2015) and Kesting & Bliek (2013).

Participation and acceptance of consumers
Within IEA Task 24 Subtask 2 report the project PowerMatching City is described as a showcase on user engagement (Mourik, 2014). The following information is based on the project analysis in Mourik (2014). Information summarised from other sources is explicitly quoted.

As described in the general introduction in Section 4.2.1 additional participants were added to the pilot in Phase II, which involved residential buildings in the street ‘Thomsonstraat’ in Groningen. This particular street was chosen as residents had already started a participatory approach to become an energy neutral street. Based on the prior activities the feedback devices and tariff schemes (called propositions in this context) were developed in a **co-creational process with end users** from Phase I in Hoogkerk and Phase II in Thomsonstraat; the process lasted until June 2013. It was discussed in which products and services residents are interested and what were their drivers to participate. Then the implementation was prepared and the actual pilot activities started in October 2013.

The pilot activities showed that community creation is essential in the process of engaging residents on a mass scale as the sense of belonging to a community influences the engagement. This assumption was confirmed by many (green-minded) participants who joined the pilot in Phase II. Other recommendations for **building up engagement and support** are

- to carry out a pre-survey which takes stock of the strengths of the existing community aiming at a tailored communication system,
- to address communication needs (e.g. via a blog, website, chat program etc.) enabling a knowledge exchange and sharing of experiences, and
- to appoint an experienced testimonial answering questions from newcomers.

The project consortium recognised in an early project phase that financial rewards or incentives seem important but do not significantly **motivate residents to participate** in the field trial. More importantly, the comfort level of users needs to be ensured during the pilot activities. A close interaction with residents was necessary to inform them about the project's objectives and its progress. A series of **communication events** ensured that participants kept informed and were committed during the field trial.

Although this co-creational approach would be much too time and resource intense to be implemented in a commercial roll-out, useful findings were identified. The requirements of a commercial roll-out ask for tariff schemes with added value for an acceptable price. During the participatory process **two energy services with dynamic tariffs** were developed in Phase II together with the user groups focussing on the individual as well as community level:

- 'Smart cost reduction' – driven by cost reductions to use energy at cheapest times, and
- 'Together more sustainable' - driven by motivations of sustainability or even self-sufficiency to use energy when it was locally produced through the CHP unit or PV system.

The trial participants were randomly assigned to one of the two energy services by the project team and did not necessarily match the resident's actual motivation for changing their behaviour. This approach was chosen from a research perspective but the residents expressed that it created tensions. The testing of these services and the participant's acceptance were planned to be carried out until mid of 2014.

In the resident's homes in-house displays (referred to as 'Energy Monitor') were installed to give **feedback to end users** how much energy is used and locally produced at any time and what the costs are.

The Energy Monitor allowed to program the desired latest time when the smart appliance's process should be finished. Without the user interaction the devices were automatically controlled and the appliance was operated at the optimal period with the lowest costs. (Kesting & Bliek, 2013)

In addition to the in-house display users could access their aggregated electricity consumption and production data, detailed close to real-time data of individual devices (in five minutes interval measurement) as well as comparisons with the average data of the whole group drawn via their smart phones and computers. Thus, the end user questionnaire confirmed that consumers learned a lot about their energy behaviour by using the Energy Monitor and even adapted their behaviour based on their consumption patterns. (Kesting & Bliek, 2013)

Privacy issues and lack of trust were not addressed by the residents although the project consortium had a detailed knowledge about the resident's routines based on the daily diaries that were kept. As the pilot project was clearly positioned as a research project participants trusted in the project consortium's neutrality and objectivity and did not assume a commercial interest.

Institutional & regulatory framework

In Deliverable 4.4 of the FP6 INTEGRAL project the design framework for an integrated ICT-platform for distributed control is described (being considered as a pre-development phase of the software 'PowerMatcher Suite'). As part of that new stakeholder roles were taken into account which responds to the need of aggregating a certain type of device or regionally clustering a set of devices via a VPP. (Kamphuis et al., 2009)

Table 15 Stakeholder roles for operation of VPP

	Stakeholder	Responsibilities and activities
Traditional roles	Program Responsible Party (PRP)	• Supported by technologies to keep imbalance between the day-ahead prediction and realization low • Actively providing regulating or reserve power, depending on bids derived from the (expected) realizations • Accounting of transmission costs
	DSO	• Aims at an efficient operation of its network • Reimburses all households connected to its network to behave in a desired way • Aggregates and optimizes a high number of prosumers via a technical VPP
	TSO	• Transmission costs paid by PRP
Innovative roles	Commercial Aggregator	• Supplies and buys locally generated electricity aiming at a reduction of imbalance • Aims at a better position in the energy wholesale markets • Reimburses the households contracted to behave accordingly • Aggregates and optimizes a high number of prosumers via a commercial VPP
	Commercial Aggregating Agent	• Intermediate between prosumers, DSO and commercial aggregator • Receives bids from households
	Prosumer	• Can have contracts with different commercial aggregators • Aims at lowering energy costs by delivering active services to the DSO and commercial aggregator

Source: Own summary based on Kamphuis et al. (2009) and Gustavsson & Stahl (2008)

Thus, in Phase I of PowerMatching City the technical feasibility of load aggregation was proven and the stakeholder roles identified. In Phase II the technical implementation was supplemented with value adding services meaning that the commercial roll-out of dynamic tariff schemes was tested. Different roles in the energy system were addressed in the project (e.g. grid operator, energy supplier etc.). Dr. van den Noort reflected in the telephone interview that it became clear that the market role of an aggregator was missing during the project execution as the approach originally planned did not foresee this actor. A different implementation via an aggregator who distributes the flexibility was needed. (van den Noort, 2015)

Economic & financial aspects

In Deliverable 5.1 (confidential) a detailed use case description is presented. Evaluation procedures of these use cases are defined in Deliverable 8.1 and an evaluation per use case done. According to Dimeas and et al. (2009) the following use cases were identified:

- Cost-effective use of energy: prosumer operates electricity generation facilities (CHP, PV) as efficient as possible and consumes energy achieving a maximum of economic benefit
- Commercial imbalance reduction: portfolio planning of demand and supply according to forecasts via VPP, reduction of own imbalance, and dispatching of control and reserve power
- Valorisation of renewable electricity: lowering of peak consumption before high production period is forecasted (through PV and wind), revenue maximisation, and improvement of renewable energies embedding
- Monitor own household: cost reduction effects of real-time pricing and mapping of system costs
- Improving asset utilisation: congestion management, reduce investment in assets

The economic evaluation of use cases was planned to be based on future business models. Unfortunately, the results of the economic evaluation are not publicly available.

Van den Noort (2015) reflected on his experiences as he has been involved in the project since Phase I (see Annex for list of persons interviewed). He explained that DNVGL did a cost-benefit analysis (CBA) for smart grids in the past; the data of the flexibility measurements in PowerMatching City flexibility was added to the CBA model in order to calculate the benefits of flexibility in domestic markets to take advantage of different energy mixes and the penetration of various technologies. The benefits of the consumer market range from 1 to 3.5 billion Euros until the year 2050 and the results proved a profitable business considering an aggregator who distributes value of benefits. (van den Noort, 2015)

The results of Phase II showed that the benefits are partially based on money saved by the grid operator by avoiding costs for investments and maintenance of electricity networks. In addition, customers' energy consumption can be managed more effectively by energy providers and consequently, being able to purchase energy with more competitive wholesale prices. Locally produced energy can be used to match local supply and demand which also saves costs. (PowerMatching City, 2015)

Technical aspects

According to van den Noort (2015) the heat pumps which were newly implemented in Phase I were adapted to match the technical system requirements; in Phase II interfaces for existing heat pumps were developed. The involvement of manufacturers to build these interfaces was crucial. The current situation is that devices as washing machines and dish washers are not able to switch on and off when a price signal is received; thus, an additional plug-in is needed.

The households were equipped with smart appliances like dish washers or washing machines and smart hybrid heat pumps consisting of a high-efficiency air-to-water heat pumps with a condensing boiler and a 210 litre hot water buffer. Additional devices as smart freezers, an in-home battery system of 4 kW, and electrical vehicles with batteries of 40 kWh were tested. Bi-directional smart meters were implemented with the aim to measure power production of households and gas and electricity consumption of individual appliances. The data was exchanged with the home energy management system that provided detailed information on consumption and production profiles of the end users via the in-house display. For remote monitoring and maintenance purposes an operator portal was implemented to enable fault detection and corrective actions at a very early stage. In addition, automated reports as well as individually configurable reports for data mining were generated in a data analysis portal. (Kesting & Bliek, 2013)

Energy demand and supply of each household is matched by the in-home market concentrator whereas the local device agent exploits the flexibility potential. These processes are run on a low-power PC in each household which serves as the platform for the in-home energy service gateway. (Kesting & Bliek, 2013)

4.2.4 Impact and transferability

The activities of Phase II received a high attention of the national and international media. Finally, the project was listed in the UN ‘Sustainia 100’ in 2012 which is a collection of more than hundred projects and initiatives worldwide being known for their sustainable approach (Storm et al., 2012).

In the following the three most important project impacts are listed according to van den Noort (2015):

1. Development of technological standards: Standardisation is needed to operate devices and take advantage of flexibility. In an EU follow-up project questions related to this topic are addressed to further develop technologies in preparation for a large scale roll-out.
2. Extension of project to EnergyMatcher: In Phase I and II only electricity was considered. As a next step it is planned to involve other energy sources (e.g. gas, heat, coal) and extend the existing software.
3. Scale-up of the project: As a first step it is planned to roll-out the energy services developed to 100 households; in the long run a roll-out to 10.000 households will be prepared.

Van den Noort (2015) confirmed the transferability of the project results as different roles of the energy system were involved and it was tried to grasp the system complexity by considering different technologies to solve problems which concerns their efficient operation and interaction (e.g. smart meter, heat pump, micro-CHP unit, electric vehicles, smart devices).

4.3 Pilot project ‘FP7 ADDRESS’

The FP7 ADDRESS project implemented DR solutions in three test sites located in France, Spain and Italy. Taking into consideration the regulatory framework in this countries France is much more progressed in this area compared to the two other ones. In Spain and Italy stilly significantly regulatory barriers for DR and load aggregation exist.

It was planned to validate the proposed solutions with the focus on different network topologies, climate conditions and social acceptance. The validation in France and Spain focussed on DR implementation in residential areas; Italy addressed the grid operation on a large middle voltage grid. In the following section only the implementation of activities in France and Spain are assessed in detail.

4.3.1 General information

The FP7 project ADDRESS[5] (full title: Active Distribution network with full integration of Demand and distributed energy RESourceS) is a five year large-scale European R&D project launched in June 2008. The consortium consisted of 25 partners from eleven European countries spanning the entire electricity supply chain, qualified R&D bodies, small and medium enterprises and manufacturers. The project aimed at delivering a comprehensive technical and commercial framework for the development of active demand (AD) in the smart grids of the future and exploiting its benefits.

In this pilot project the active participation of small and commercial consumers in power system markets and provision of services to the different power system participants was enabled. Technical and business conditions were designed by aggregating flexible demand and generation of equipment installed at consumer's premises such as electrical appliances, distributed generation and energy storage. Via the Energy Box (E-Box) the loads were controlled and optimised. As mediator between consumers and other market players the aggregator offered services to its customers enabling them to exploit their flexibilities.

It was planned to validate the proposed solutions in three test sites in Spain, Italy and France providing different network topologies, climate conditions and social acceptance. The validation was done by simulations and laboratory tests as well as by the field trial in which the prototypes developed were implemented.

4.3.2 Country-specific regulatory information

Although the pilot test is carried out under specific framework conditions defined by the project, a brief overview on the national regulations for DR and aggregation is given in the following Table 16. The country which is much progressed in offering a favourable regulatory framework is France compared to the two other pilot sites. In Spain and Italy significant regulatory barriers for DR exist whilst in Spain DR is even an 'illegal' source of flexibility (Eid, 2015).

[5] http://www.addressfp7.org/ (visited at 09.07.2015)

Table 16 Regulatory conditions for DR in France, Spain and Italy

Country		France	Spain	Italy
Consumer have access to …	Replacement reserves (RR)	Open	To be implemented 2014/2015	Under development; only generation-oriented approach
	Frequency Restoration Reserves (FRR)	Open	To be implemented 2014/2015	Under development; only generation-oriented approach
	Capacity market	Access in 2016	-	Access in 2017 by generation side resources
	Day-ahead market	Open	-	Open, but low interest
Program requirements	Minimum bid	FRR: 10 MW RR: 10 MW	5 MW for interruptible load program	1 MW for interruptible load program
Measurement and verification	Baseline definition	-	No definition	No definition
Finance and risk	Availability payments	FRR (manual) and RR: from 10k to 40k Euro/ MW/ year	Based on consumption (limit of 20 Euro/ MWh); proposal for TSO led auction system under review	Based on number of interruptions called per year; auction system led by TSO
	Penalty	Reasonably proportionated; do not put business at risk	Min. size not fulfilled: 100% of yearly payments; failure to fulfil reduction order: proportional penalty; two failures:100% of total availability payments	-
Availability of aggregators operating at the national market		Yes	No	No

Source: Own summary based on SEDC (2014)

France has had a history of DR programs as residential pricing programs (e.g. TOU tariffs) and industrial load management programs for several years. Further mechanisms to open up the market to third parties and additional tender regulations which will enable the aggregated participation of demand side resources have been recently implemented (e.g. opening of the day ahead market to DR and aggregation in 2014) or are currently developed by the regulator (e.g. capacity market available in 2016). These changes put France as a frontrunner for enabling DR in Europe. At the moment multiple aggregators operate on the French market. (SEDC, 2014)

It is expected that further advancements related to opening balancing services to DR will happen in the next few years in **Spain** but currently only an interruptible load program directly managed by the TSO exists in Spain. This program is limited to large industrial consumers with an average reduction potential of 5 MW; currently about 150 providers are active in construction industries or other material factories. Currently, no aggregators are active in Spain, partly related to the fact that a standard is missing that defines their relationship with the BRP and TSO at the moment. (SEDC, 2014)

Italy has a long tradition in TOU programs for high and medium voltage consumers; since 2000 the programs are also available for low voltage consumers. In principle, Italian market operators can participate in the day-ahead market as aggregators but interest has been limited so far as the flexibility of demand is very low. Although Italy is one of a few European countries that have experienced a 100% smart meter roll-out, but rules for verification for demand side resources are not explicitly defined yet. Thus, high costs for measurement and verification present an entry barrier for independent DR aggregators. (SEDC, 2014)

4.3.3 Assessment based on the analytical framework

The analysis in the following section draws on information and findings of reports downloaded from the project's website as well as an expert interview with Dr. Regine Belhomme, technical manager of the ADDRESS European Project at EDF, a French electricity supplier and the worldwide second largest electricity producer. Relevant information is analysed and findings are presented in a compact and brief manner. In the following the information sources are listed for each category of the analytical framework:

- In section 'participation and acceptance of consumers' information from Deliverable 5.2 (Mander et al., 2013) is summarised and additional information from the expert interview with Dr. Belhomme added (Belhomme, 2015).

- The analysis of the category ‘institutional and regulatory framework’ draws on information from Deliverable 1.1 (Belhomme et al., 2009) and Deliverable 5.1 (Lago et al., 2012).
- Information about ‘economic and financial aspects’ is taken from Deliverable 5.3 (Linares, 2013), Deliverable 1.2 (Bouffard et al., 2010) as well as the expert interview (Belhomme, 2015).
- The section ‘technical aspects’ builds on information from Deliverable 6.1 (Eyrolles et al., 2011), Deliverable 6.2 (Delago et al., 2013) as well as the expert interview with Dr. Belhomme (Belhomme, 2015).

Participation and acceptance of consumers

The information in the following section was adopted from Deliverable 5.2 which reflects on key societal factors influencing the adoption of the ADDRESS Smart Grids architecture (Mander et al., 2013). Information summarised from other sources is explicitly quoted.

In this sociological study **user acceptance** of consumers was analysed aiming at the assessment of how consumers respond to the ADDRESS model of demand response as this is a crucial element of the technology solution’s success. A pre- and post-trial questionnaire as well as in-depth interviews and diaries gave insights about user’s perceptions. As technology solution the E-Box was installed in residential buildings and sites of small commercial consumers at the pilot sites in France (26 participants) and Spain (256 participants). The E-Box directly controlled the connected electrical appliances according to the consumer’s settings and in response to price-volume signals from an aggregator. The Italian pilot focussed on DSO and grid operation on a large middle voltage grid and the effect on AD on high voltage level. Thus, the direct interaction with the consumers was not addressed.

The sociological study took a thorough **user segmentation** based on indicators as age, gender, educational level, monthly salary of residents, the dwelling type, size and level of insulation as well as the occupancy level, and the ownership structure as a starting point. In addition, the availability of electrical appliances, frequency of utilization (how often is an appliance used?) and behavioural patterns (e.g. use of stand-by buttons, turning off the lights in unoccupied rooms etc.) were analysed in a survey.

The **motivation to participate** in the project's field tests was differently assessed by the residents of the two pilot sites. As the French participants live on an island in the Brittany region and regularly face power outages as well as have problems with the electricity distribution in peak demand times concerns about security of supply were more important (21%) than in the Spanish pilot (3%). In contrast to the French residents (21%) more Spanish households were interested to save money on their electricity bill (68%). The opportunity to try a new technology and concerns about the environment were more often mentioned by the French people than the Spanish ones (29% vs. 11%; 29% vs. 8%). For those households the opportunity to take part in the experiment was one way of learning more about their consumption and making changes.

The **communication and education activities** were differently addressed in both pilot cases. The recruitment phase was quite challenging in France due to the technical criteria that the participants had to fulfil (aggregation of electrical loads in relation to the clarification of grid aspects for the DSO). The French field test started in October 2012 and only lasted for eight months. (Belhomme, 2015)

A variety of events and actions were planned in France to promote the project (e.g. open house days in holiday cottages to demonstrate how the system works, meetings at the town hall etc.). However, limited training was offered how to use the E-Box and the interaction of participants with the E-Box was complicated as no user manual was available before the trial started.

In Spain the E-Box was accessed via a website and, in this case, a user manual was provided to the participants at the time of the installation. However, the interest to read the user manual was rated as very low as it was not made clear in the beginning that all information to operate the E-Box was explained in the manual. No other information about the technology was provided to the Spanish households.

The lack of information available to the trial participants in both pilot sites at the beginning of the project strongly influenced the user experiences, their understanding of the technology and equipment installed and the trial as such. During events that varied from normal day-to-day household activities the residents stopped the E-Box control of an appliance or unplugged the smart plug to take back control (e.g. washing machine, dishwasher). In contrast, the interaction with electric heaters and water heating systems (France) was very successful.

As optimal **tariff structure**[6] respondents from both field trials preferred a combination of fixed and variable remuneration in which the variable element was related to the extent of AD provided by the consumer. This preference was more important for the Spanish respondents (83% compared to 54% in the French field trial). As second preferred option a variable tariff was chosen in both trials (31% for the French field test and 13% for the Spanish trial). A fixed tariff only for allowing control of appliances unrelated to the level of AD was less interesting for the residents (3% in the Spanish field trial and 15% in the French).

In the case the E-Box preference settings should be overridden the consumers expressed the wish that it should be made clear in the contract which penalties may incur using this option (including penalty free-override in cases households could not meet the confines of the system or of technical problems).

The **access to information** was an important issue in the ADDRESS project. The E-Box user interface was differently accessed in the two pilot sites: in France a laptop was connected to the system through which the user controlled the settings. The Spanish residents gained access through a website using a secure login. As the user interface was only a prototype it was described as ‘not easy to use’ or ‘complicated’ technology. The Spanish participants did not visit the website very often and were reluctant to interact with the technology and change the setting due to the lack of usability. Although the French households had an additional device, experiences to navigate the user interface were not much different from the Spanish pilot. As most beneficial outcome of checking the website information on overall electricity consumption and consumption of various electrical appliances was mentioned.

In terms of **data protection, privacy and security** the perception of intrusion and lack of privacy was believed to be a barrier. However, in France this concern was stronger expressed than in Spain. The ‘visibility’ of how much electricity an electrical appliance consumes was positively perceived and supports the identification of appliances consuming too much electricity. Generally, consumers showed a high level of trust that their data is protected and not sold without consent.

[6] Remuneration of consumers was based on virtual tariffs. As an incentive to participate in the field test vouchers were given to them. (Belhomme, 2015)

In the French field test contracts were signed between EDF, the French power company, and the consumers which defined the protection of consumer data. In addition, the data collected was declared to the ‘Commission Nationale de l’Informatique et des Libertés’ (CNIL), an independent administrative body that operates in accordance with the data protection legislation and measures have been identified to ensure data confidentiality.

Institutional & regulatory framework

The project consortium has intensively discussed the roles, responsibilities and interactions of market players. In Deliverable 1.1 the conceptual technical and commercial architectures developed to enable AD and exploit its benefits are described (Belhomme et al., 2009). All market interactions in the project were only simulated using a market simulator and not tested on real players. Besides the aggregator and consumer two other types of participants were identified:

- Regulated participants: DSOs and TSOs, and
- Deregulated participants (competitors) which can be categorised in three groups:
    - Producers: central and decentralised electricity producers, producers with regulated tariff and obligations (reserve, volume, curtailment, etc.)
    - Intermediaries: retailers, production aggregators, electricity traders, electricity brokers, BRPs
    - Consumers: large industrial or commercial consumers

In Deliverable 5.1 market mechanisms, which enable active demand participation in the power system, are described in detail (Lago et al., 2012). In the report elements how to design contractual, market and regulatory instruments necessary to allow and to improve the interactions between consumers, aggregators, regulated players and other power system players are proposed. In the ADDRESS project the following roles were of specific importance:

- Aggregator: deregulated player (an aggregator-retailer or any other type of player)
- AD consumer: residential consumer who accepts to offer his flexibility to the aggregator via a contract
- AD product buyer: regulated or unregulated player buying AD products proposed by the aggregator

In a next step the contractual interactions are discussed proposing three different types of contracts:

- Aggregator and AD consumer
- Aggregator and unregulated player as an AD product buyer
- Aggregator and regulated player (DSO, TSO) as an AD product buyer

Economic & financial aspects

In addition to the technical aspects and the interaction of market players in Deliverable 5.3 economic factors influencing the replication of the ADDRESS architecture were analysed in relation to estimates of costs and benefits of AD programs (Linares, 2013). The economic analysis was not directly related to the field test activities (Belhomme, 2015).

The report also provides a brief summary of Deliverable 5.4 (confidential) which outlines **business cases** for customers, aggregators and DSOs and further calculates the **profitability** of these AD services. Relying on the scenario approach elaborated in Deliverable 1.2 (Bouffard et al., 2010) a possible implementation of these business cases in four European countries (Spain, Italy, Finland, Belgium) was evaluated. In Table 17 the cases are listed.

Table 17 Business cases for implementation of AD cases

Service	Actor	Challenge
Management of energy imbalances	BRP	Imbalances within own portfolio
Tertiary reserve	TSO	Imbalances at the system level
Short-term load shaping to optimise purchases and sales	Retailer	Price risk at the wholesale market
Load reduction	DSO	Local constraints in the distribution grid

Source: Linares (2013)

In a further economic analysis the impact of each business case on the different actors was described and the changes in annual cash-flows per active consumer calculated depending in which country the aggregator intends to make business. Four countries (Spain, Italy, Finland, and Belgium) were chosen for this further in-depth analysis. The aggregator compares the services in each hour and activates the most beneficial one. Thus, the results do not show the sum of the particular service but the optimization of the four services at the same time. Generally speaking, the potential for providing the selected AD services in the countries analysed will strongly depend on the future development of electricity markets and regulation.

At the system level, the total figures calculated range from 400 to 2,200 million Euros per year and per country which amounts to 1.5 – 6.5% of each country's system typical costs. Most of these savings correspond to a reduction in fuel and emission costs, and a much lower share belongs to network benefits and savings in balancing. Although these benefits seem promising, the costs of setting up the infrastructure required for AD programs to take place need also taken into account. As only in a few pilot projects this kind of infrastructure has been implemented (which is much going beyond the installation of smart meters) the current situation does not make an estimation of such costs very easy. In projects for which infrastructure costs have been indicated the degree of commercialisation is quite unclear and the low level of dissemination of these technologies suggests much higher costs. As the infrastructure costs cannot solely be allocated to AD programs the comparison with its benefits is even more complicated.

A second analysis takes into account the current regulatory and market context. The aggregator's or consumer's financial benefit depends on the situation in a country and on the scenario considered for the dissemination of AD programs. The analysis showed that aggregators could benefit from three to eleven Euros per years; for consumers the financial value is even lower ranging from three to seven Euros per year. Although some findings have been made Linares (2013) points out that the results lack an extensive quantification of potential benefits of AD programs. An example could be a better management of network congestions and emergencies.

Based on a discussion with the technical project manager Dr. Regine Belhomme an aggregator needs to identify beneficial applications and build up a detailed portfolio; even though DR is currently not profitable (in France) (Belhomme, 2015).

Technical aspects

In Deliverable 6.1 all system tests are described that were performed to validate the technical solutions developed and integrated in the project (Eyrolles et al., 2011). The subsequent Deliverable 6.2 gives a description of the results achieved in the three field sites validating the project's concepts and test cases (Delago et al., 2013). The assessment of the results of the field tests and the effectiveness of the

ADDRESS concepts are described in confidential reports which are not publicly available. In the following section a brief summary of technical issues experienced in the field tests is given which is based on the findings in Deliverable 6.2 (Delago et al., 2013).

According to Delago et al. (2013) communication between E-Box and Aggregator Toolbox did not go as smoothly as planned in the Spanish field test as it varied from day to day. Results received from December 2012 to mid of February 2013 could not been taken in account due to inappropriate data measurement; additional developments were needed to compensate for missing functionalities. In February to April 2013 around 50% of the AD signals per month were not sent from the Aggregator Toolbox to the E-Box. In-house communication between smart devices (e.g. smart plugs, washing machine etc.) and the E-Box performed better as around 70% of the devices received a signal from February to April 2013.

The interaction of the technical concept at the French pilot site had to be adapted as other conditions were prevailing than at the Spanish pilot (e.g. electrical heaters were declared as shiftable loads rather than interruptible ones). Similar communication issues between the E-Box and the smart appliances were noticed in the French field test as in the Spanish one. On average a communication error of 20% was measured between February and May 2013.

The experiences described above were confirmed by the technical project manager Dr. Regine Belhomme who stated that interoperability was a big issue during project execution although it could be managed in the end. Use cases were developed based on existing standards (e.g. Zigbee) in the beginning which was very helpful. Further on, the software to be implemented was tested in laboratories before the field test started. (Belhomme, 2015)

4.3.4 Impact and transferability

The technical manager of the FP7 ADDRESS project, Dr. Regine Belhomme, was consulted to reflect on her experiences gained during the project planning and execution during a telephone interview (see Annex for the list of persons interviewed).

According to Belhomme (2015) the impact of the project was not only limited to the pilot project itself; know-how gained in relation to market interaction and roles of market players resulted in a high impact. The ADDRESS concept was adopted by other projects early on from the beginning after first project's publications had started in the year 2008. The phrase "active demand" (AD) was introduced and used first by the ADRESS project. Subsequently, the research community built on the AD approach. Medium impact was achieved for prototypes developed as a lot of improvements were needed and the E-Box technology had to compete with many other technical solutions in this field in France.

In terms of transferability of project results Belhomme (2015) confirmed the technical approach that was implemented in the French pilot trial in Brittany could be transferred to any other region in France; however, the reliability of the economic studies need to be reviewed. DR and aggregation is already implemented in residential buildings in France but currently no complete roll-out of smart meters has taken place until now.

4.4 Pilot project 'E-Energy: E-DeMa'

In Germany the aggregation of loads is legally allowed but measurement and verification requirements are not clearly defined which hampers aggregators in doing business as data availability and exchange are of high importance.

The project E-DeMa contributes with further advancements in this field by offering a holistic concept which combines technical and economic solutions. The project consortium covered institutions from the entire value chain being active in DSM. Residential consumers actively participated in an energy market place via an ICT gateway by shifting loads of household appliances.

4.4.1 General information

The project E-DeMa[7] (German full title: Entwicklung und Demonstration dezentral vernetzter Energiesysteme hin zum E-Energy Marktplatz der Zukunft) started its activities in November 2008 with funding from the German R&D programme ‚E-Energy – ICT-based energy system of the future' which is financed by the Federal Ministry for Economic Affairs and Energy as well we Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. The project consortium involved institutions from the entire value chain being active in DSM; RWE as energy supplier and distributor, the public utility company Krefeld, industry

[7] http://www.e-dema.de visited at 13.07.2015 (only in German)

companies as Siemens, Miele, the software company ProSyst as well as research organisations as the universities Dortmund, Duisburg/ Essen, Bochum, and the University of Applied Sciences Dortmund.

The project aimed at developing a holistic concept which combined technical and economic solutions. The active customer (defined as ‘prosumer’) played a central part in the project; the ‘prosumer’ produces electricity, feeds it into the grid as well as consumes energy at the same time. Benefits for the user are created by being informed about energy consumption, receiving price signals, actively participating in an energy market place via an ICT gateway and shifting loads of household appliances. The TSO has the advantage that the network management is improved through these activities. At both pilot sites in Mülheim (531 participants) and Krefeld (125 participants) private electricity customers were connected to a virtual market place interacting with energy traders, DSO and other players.

4.4.2 Country-specific regulatory information

At German balancing markets DR and aggregation are legally allowed and retailers are slowly starting to exploit these market opportunities, however, the lack of clearly defined measurement and verification requirements are hampering this process (SEDC, 2014). In Table 18 summarises the regulatory conditions for DR in Germany.

Table 18 Regulatory conditions for DR in Germany

Country		**Germany**
Consumer have access to …	Replacement reserves (RR)	Open; generation-oriented approach
	Frequency Restoration Reserves (FRR)	Open; generation-oriented approach
	Capacity market	Not available; introduction is part of the current coalition government agreement
	Intraday market	Aggregation is allowed
	Relationship prior to load curtailment	Permission of multiple parties (incl. BRP) needed; aggregator has to sign 5 different contracts
	Imbalance settlement	Imbalances of BG must be kept at a minimum
Program requirements	Minimum bid	RR: 5 MW (in 2012)
	Availability period time	RR: 4 hours FRR: 12 hours
Measurement and verification	Baseline definition	Unofficial baseline definition agreed by TSOs (not publicly available)
	Standardised data exchange	No standardised data exchange between BRP, aggregator and TSO
Finance and risk	Availability payments	Yes, provided
	Penalty	Reasonably proportionated and do not put business at risk

Source: Own summary based on SEDC (2014)

4.4.3 Assessment based on the analytical framework

The final project report of E-DeMa (Laskowski et al., 2013) that was submitted to the funding agency on October, 16th 2013 serves as the main information source. Any other source than the final project report, on which the following information builds upon, will specifically be referenced.

In the following the information sources are listed for each category of the analytical framework:

- The section ‘participation and acceptance of consumers’ builds on information from the final project report (Laskowski et al., 2013) and the expert interview with Dr. Michael Laskowski, project manager of E-DeMa and working at RWE as Head of Innovative Network Strategies (Laskowski, 2015).

- The analysis of the category ‘institutional and regulatory framework’ draws on information from Laskowski et al. (2013).
- Information about ‘economic and financial aspects’ is taken from Laskowski et al. (2013) and Belitz et al. (2012).
- The section ‘technical aspects’ summarises information from Laskowski et al. (2013), Belitz et al. (2012) and the expert interview (Laskowski, 2015).

Participation and acceptance of consumers

The analysis of **user behaviour and acceptance** is very important for the success of a field test. The identification of determining factors will support a further adaption of user attitudes in case the approach will be extended to a real business environment after the field test. The consortium of the project E-DeMa chose two different approaches how to attract the target group tailored to the needs of the respective pilot site. A marketing agency was assigned to develop a concept in Mühlheim; in Krefeld the marketing department of the public utility company SWK (Stadtwerke Krefeld) took over this task. In both pilot sites the approach was well planned and detailed information material tailored to the prevailing conditions of each target group prepared. For example, elderly people were motivated to learn more about energy topics as such and how to achieve energy savings; in contrast young people were interested in technical games available as mobile applications (Laskowski, 2015).

The target group was attracted with specific key messages (e.g. it is only an experimental game with no monetary risk; it is only successful if everyone participates). In addition, trainings for technicians and employees of the customer support (hotline support) were organized during the field test.

In the second half of the field test and at least three months after the field test has started a very detailed analysis of user behaviour and acceptance was carried out. A telephone survey and in-depth interviews at both pilot sites gave insight in topics as how do customers evaluate the tariff products and visualisation, assess their success in load shifting (manually triggered), and do they accept the ‘Smart-Start’ function (automated load shifting). In addition to a standard descriptive analysis the effect and influence of sociodemographic factors (gender, household size, family status, age, education, income) on attitudes and motivation, product satisfaction and utilisation of tariffs was assessed.

For the E-DeMa field tests two groups of **TOU tariff schemes** with three variable products each were developed specifically addressing residential customers. Tariff group 1 (IKT-GW1) consists of two time frames (7 a.m. to 9 p.m. and 9 p.m. to 7 a.m.) with different prices which change every month. The second tariff group (IKT-GW2) has eight time frames with five different prices which change daily. These tariff schemes only reflect the energy price excluding taxes, network charges and other costs and were set in relation to EEX exchange price plus a fixed margin of 2 cent per kWh. Daily price profiles address a timeframe of 24 hours and are provided at least 18 hours in advance to customers. As the tariffs were only virtual products a historical dataset of EEX exchange price was used which reflects a significant difference between peak and base load exchange price.

The consortium tried to address the challenge to reduce complexity of the tariff structure but still had to meet the technical and economic requirements of the project concept; the tariffs needed to reflect that users of one pilot site only manually reacted on price signals (IKT-GW1) and the devices of the other group were enabled to react automatically (IKT-GW2).

Another important aspect of the project addressed the **visualisation of price signals and consumption data**. The consortium assumed that the user behaviour can be influenced if consumption is made visible and thus, transparent. The group IKT-GW1, which only manually influenced their consumption, was equipped with an in-house display which showed the actual consumption of a household (in 15 minutes time interval) and other information that leads to an action (e.g. tariff and price colourfully visualized, load curve of the last 24 hours, time of the day, meter reading for electricity (kWh), gas and water etc.). The Home Energy Control User Interface (HECUI) of the group IKT-GW2 provided additional information about the actual consumption data of the devices being able to automatically react on price signals to the customer.

As a high number of field test participants have an android tablet or smartphone the consortium developed the mobile application ‘EnergyDisplayApp’ which showed the same information as the in-house display with the advantage that information can be accessed everywhere.

Additional information about historical consumption data was monthly provided to the user at the marketplace website. Fictional expenses or savings were shown and compared to reference users according to the tariff zone. Although users did not experience any additional costs, this information should support the user's reflection on tariffs and consumption behaviour. One of the key messages communicated to the users were that only joint efforts lead to success. Thus, groups were formed and consumption of single users accumulated to incentivize additional savings which were rewarded with premiums.

Privacy and data security aspects were treated as of utmost importance by the project consortium. Customer information started in the beginning of the project; a participation agreement was developed by data protection officers and legal departments of the public utility company and DSO to inform users about their rights and obligations as well as give detailed explanations how will the data be used and why is this specific information collected. In addition, ICT systems and infrastructures were analysed in relation to their security demand and risk mitigation. Security and privacy aspects were considered from the beginning and respectively implemented in the ICT design.

Institutional framework

The E-Energy market place plays a central role acting as a communication platform at which customers interacted with different market players. Considering the core activities at the electronic market place and the 'traditional' energy market there is not much difference except information about supply, consumption and price signal is provided immediately at the electronic market place. Thus, transaction costs are reduced or even saved. Now, the major challenge is to define an institutional framework which enables an accurate operation of this electronic market place.

In a first step the **roles of all players interacting at the E-Energy market place** are defined in detail:

- Suppliers that supply energy and sell it to their customers
- Prosumers that produce electricity, consume energy and provide flexibilities
- Aggregators that create portfolios being composed of small loads (produced and provided by prosumers) and bring them to the market
- DSO that connects the customers to the grid and ensure system stability
- Meter-reading companies that provide and maintain smart meters

- Energy service providers that offer consultancy, planning and the implementation of energy efficiency and energy saving measures

The **interaction at the market place** aims at creating additional value that is currently not captured and intends to support the transformation of the energy market. The operator of this market place acts as an intermediary bringing together supplier and consumer and increasing efficiency of business operations along the entire value chain (information phase, negotiation phase, transaction phase, after-sales phase). A detailed data model defines the administration of master and transaction data of each market actor.

Economic & financial aspects

In the pilot tests of E-DeMa the product tariffs are only virtually provided to the customers with the aim to draw conclusions on the actual flexibility potential. The economic translation of these tariff models to the energy market is currently not possible but the project gives some indications if the market place will be feasible in the future.

The consortium developed a number of use cases on the level of business-to-customer (B2C) and business-to-business (B2B) which are briefly summarised in Table 19.

Belitz et al. (2012) evaluated the economic potential for a retailer with variable tariffs in detail by comparing the installation and energy procurement costs of a regular retailer and an E-DeMa retailer on a basis of current market prices for electricity and current prices for ICT components. According to Belitz et al. (2012) an E-DeMa retailer will only result in a cost reduction if the participating households are already equipped with the necessary ICT or if the ratio of participating households is very small and the ratio of households with standard tariffs dominates. Assuming that the range of market prices increases until the year 2020 and the acquisition costs for ICT components decrease retailers will be able to reduce their costs and thus, make valuable business. As the deployment of ICT components to enable DSM is currently quite low the business model of a retailer with variable tariffs is not profitable yet.

Table 19 Use cases B2C and B2B level

	Use case	Provider	Consumer	Focus
B2C	Supply	Supplier	Prosumer	Energy supply contract with variable/ fixed energy price and network charge
	Meter-reading	Meter-reading company	Prosumer	Assignment to install, operate and maintain a smart meter and other enabling ICT equipment
	Energy service	Energy service provider	Prosumer	Service contract to provide an energy service
	Aggregation	Aggregator	Prosumer	Service contract to buy energy, flexibilities and storage
B2B	Network operation	DSO	Supplier	Framework supply contract
	Energy service	Energy service provider	DSO, supplier, aggregator, meter-reading company	Service contract to provide an energy service
	Aggregation	Aggregator	DSO, supplier	Distribution of aggregated energy and services

Source: Translated and adapted from Laskowski et al. (2013)

Technical aspects

A great effort was made to develop an interoperable ICT architecture ensuring interconnectivity of all enabling technologies. Software solutions as well as hardware technologies were further developed and adapted to be successfully deployed at the pilot sites. In particular, the smart meter solution was further developed to enable the data exchange between the enabling technologies (Laskowski, 2015).

As the harmonisation of communication was very time consuming and cost intense **standardisation and interoperability** proved to be a basic condition for interaction of technical appliances and enabling technologies. In order to create acceptance of users (for this kind of technologies) standards need to take into account current technical solutions considering the current technology's service life.

The project consortium had to integrate different technologies that are used for the interconnectivity of the in-house devices; several of them even competing with each other (e.g. smart meters and the metering gateway). It became apparent that pragmatic approaches to interlink and connect devices are not feasible for a large-scale rollout in future scenarios. Thus, the need and utilisation of a dedicated smart home network seems a feasible solution. (Belitz et al., 2012)

4.4.4 Impact and transferability

According to Laskowski (2015) the project results led to several follow-up projects focussing on different topics (e.g. clarification of questions related to limiting a network extension through load shifting, further development of energy services as the ‘traffic lights’ concept). Laskowski (2015) confirmed that the successful definition of a project bundle is related to the following factors:

- The project consortium succeeded in building up a high reputation at the funding agency.
- The initial project E-DeMa covered a variety of topics which enabled the project partners to do further research addressing specific questions.
- The internal as well as external project communication helped to gain a common understanding and supported the regular exchange with stakeholders.
- During the project execution key issues of the future were discussed and awareness for new market roles at the energy market created (e.g. aggregators).

In general, the project concept is transferable to other countries although the learning curve would depend on the existing framework conditions (Laskowski, 2015).

4.5 Pilot project ‘E-Energy RegModHarz’

The project RegModHarz was chosen as second German pilot project for the following analysis as it took not only into account aggregation of demand side devices but also of energy production technologies. Various producers, consumers and storages were coordinated via a VPP aiming at a full exploitation of renewable energies.

4.5.1 General information

The project RegModHarz[8] (German full title: Regnerative Modellregion Harz) started its activities in November 2008 with funding from the German R&D programme ‚E-Energy – ICT-based energy system of the future‘ which is financed by the Federal

[8] http://www.regmodharz.de/ visited at 30.07.2015 (only in German)

Ministry for Economic Affairs and Energy as well we Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. The project consortium consisted of 18 regional partners involving stakeholders from a broad area as utility companies, distribution and transmission system operators, ICT and technology providers, research organisations, engineering companies and providers of renewable energies. Project activities were finished by January 2013.

The overall project objective focussed on enabling a stable, reliable and local supply with renewable energies (e.g. wind turbines, photovoltaic systems, hydro power plants). The project activities involved the development of technologies and business models tailored to the challenges of future energy systems driven by decentralised and renewable energies. The pilot demonstration took place at the German county Harz involving 46 participants. A virtual power plant coordinated various producers, consumers and storages (mainly electric vehicles) aiming at a full exploitation of renewable energies.

4.5.2 Country-specific regulatory information

As this is the second pilot project in Germany the summary of the country-specific information on DR and aggregation can be found in Section 4.4.2.

4.5.3 Assessment based on the analytical framework

The analysis in the following section draws on information and findings of reports downloaded from the project's website as well as an expert interview with Dipl.-Ing. Patrick Hochloff, project team member of RegModHarz and working at Fraunhofer Institute for Wind Energy and Energy System Technology. In the following the information sources are listed for each category of the analytical framework:

- The section 'participation and acceptance of consumers' builds on information from Funke et al. (2013), Speckmann et al. (2012) and the expert interview with Dipl.-Ing. Hochloff (Hochloff, 2015).
- The analysis of the category 'institutional and regulatory framework' draws on information from Speckmann et al. (2012).
- Information about 'economic and financial aspects' is taken from Filzek et al. (2012), Schlögl et al. (2012) and Speckmann et al. (2012). In addition, information from the expert interview was added (Hochloff, 2015).

- The section 'technical aspects' summarises information from Funke et al. (2013).

Participation and acceptance of consumers

The information in the following section is based on Funke et al. (2013) and Speckmann et al. (2012) in which all brochures are collected that were prepared during the project.

The general **user acceptance** of renewable energies was assessed during the project via a questionnaire which was sent to 2,500 households with a response rate of 17%. The results showed a high acceptance (4.39 on a scale of 5). 45% of respondents would be willing to use regional electricity provided by renewable energies through price variable tariffs. Load shifting of household appliances was good accepted; 72% of the survey participants agreed to shift the starting time of the washing machine, 67% dryer, 76% dish washer). More information about load shifting was asked. Acceptance of e-mobility was lower (59%) due to limited range of e-vehicles. In the county Harz high energy awareness is already available; 80% of respondents said that they completely switched off electrical appliances when not needed. 90% of respondents paid attention to energy efficient household appliances. (Speckmann et al., 2012)

The field test was prepared in detail and started with the **acquisition of participants** in April 2010 by publishing articles in regional newspapers, client magazines and information events. An additional funding project called 'Energy Sustainable Community' (SEC) was carried out by the 'Forschungsgruppe Umweltpsychologie' accompanying citizens in a participation process. Hochloff (2015) reported that the accompanying research experienced a lot of difficulties. Unfortunately, results of the SEC project were not available at the time the report was written by Funke et al. (2013). In the report of work package 4.3 this intensive process is described which finally led to 46 agreements to participate in the field test in August 2011 (Funke et al., 2013). Hochloff (2015) explained that it was planned to attract approximately 50 participants as a field test with a larger number of people participating would have been too expensive as the project consortium focussed on highly technology-driven solutions enabling the automated control of devices.

The 46 participants situated in the county Harz received a **questionnaire** with the aim to learn more about their electricity consumption, household size, type of building, and number and type of household appliances used. In addition, questions related to heating facilities and hot water preparation as well as renewable production facilities installed (e.g. PV) were asked to get an overview on possible loads to be shifted. (Funke et al., 2013)

During **regular information events and open house days** with the participants the project consortium learned that **participation motives** as environmental protection and sustainable thinking only trigger minor behavioural changes for load shifting; financial incentives to accept a reduction of comfort are of higher importance. (Funke et al., 2013)

According to Speckmann et al. (2012) the development of measures related to environmental communication and behaviour and awareness creation about renewable energies and regional added values, conscious consumption of products were additionally carried out as part of the communication campaign and participation process.

The field test took place in two phases; during the first phase from January to November 2011 electricity consumption patterns of households were measured by installing smart meters in all household participating and collecting data in 15 minutes time intervals. These consumption patterns formed the basis for the further development of **time variable tariff models** with nine virtual price classes. The second phase – the actual demonstration - started in June 2012 and lasted for six months. The households received a signal via a bi-directional energy management interface, the BEMI, to be able to adjust consumption accordingly. Two household appliances were automatically controlled via the BEMI (e.g. washing machines, dryers, dishwasher, refrigerator, freezer) and participants could fix time windows when consumption should be optimised automatically. (Speckmann et al., 2012)

The **BEMI** visualises the actual tariff and the next day's one via a display as well as the optimisation plans for the appliances automatically controlled within a household. In addition, a **LED tariff light** indicates the actual tariff class using three different colours. The settings for the optimisation plan and the minimum and maximum temperatures for a refrigerator and freezer could be changed at the **BEMI web portal**. It also gave detailed information about power and energy demand of appliances controlled as well as of the entire household on a yearly, monthly and weekly basis. The **market platform** acted as an add-on to the BEMI web portal and enabled the participants to analyse their consumption and virtual account balance. (Speckmann et al., 2012)

According to a user survey the BEMI display was intensively used to receive an overview about tariff schemes and optimization plans of appliances connected. Accessing the web portal via a computer was experienced as more time consuming, especially in cases when only minor settings should be changed. (Funke et al., 2013)

Data security and privacy were treated as highly important right from the beginning of the project. All households who agreed to participate in the field test had to sign a pilot test contract which gave detailed information what kind of data will be collected, who will use it and what will be finally done with it. (Funke et al., 2013)

Institutional framework

The development of business models was based on a market analysis and the access requirements to trade electricity on the wholesale market (spot market, balancing energy market). Thus, market access for new participants needs to be granted and refinancing of investments of fluctuating and flexible energy systems possible. (Speckmann et al., 2012)

In the project electricity from renewable energy systems was managed and commercialised via a VPP. To ensure the operation of the VPP two new roles were defined; the pool coordinator and the energy system manager. The energy system manager supervises and administers the operation of all energy systems and power plants connected to the VPP and supported by the control centre. His main duty is the troubleshooting of energy systems and power plants in coordination with the plant operator. The pool coordinator is responsible for the energy commercialisation and acts as a trader who aggregates electricity of decentralised energy producers. His tasks consist of the critical assessment of energy volumes and prices in relation to the operation plans of energy systems. In order to support the pool coordinator the VPP's control centre calculates the optimal bid at the spot market which can be approved or declined by the pool coordinator. (Speckmann et al., 2012)

Economic & financial aspects

According to Filzek et al. (2012) a business model is understood in this context how market participants can create values based on value adding processes and gain revenues. All stakeholders involved (e.g. plant operator, network operator, distributor, trader) were brought together in workshops to discuss requirements, chances and risks related to possible business models of the VPP. New market participants were identified, the energy system manager and the pool coordinator. The outcome of the development process was five specific business ideas (see Table 20).

During the project execution business idea 1 and 2 were followed up and further commercialisation strategies developed. Additional strategies that focus on the producer’s perspective were the development of a citizen’s participation model for electricity production and distribution and the electricity supply of end users from renewable energies locally produced. Each of these two commercialisation strategies were described in detail while addressing additional aspects as implementation concepts for each market player involved, economic barriers, and existing framework conditions. (Filzek et al., 2012)

In a next step the profitability of the developed business ideas was tested in technical simulations utilising three different scenarios (business-as-usual in year 2008, further implementation of renewables in 2020, 100% supply with renewables). In technical simulations an energy-efficient and economic optimal operation of energy systems, electricity commercialisation strategies and an optimal load management of the electricity grid were analysed. (Schlögl et al., 2012)

Speckmann et al. (2012) presented simulation results for the operation of a VPP (business idea 2) showing that business models are not economically profitable considering the current regulations defined in the German Renewable Energy Act (EEG 2012). Hochloff (2015) confirmed that portfolio management is economically not feasible. A detailed and complex simulation model proved the technical feasibility in optimising a portfolio of different renewable energy systems, e.g. wind, PV, biogas (Speckmann et al., 2012). But according to Hochloff (2015) the flexibility of the biogas power plant would be too expensive being able to offer an attractive end-user product.

Table 20 Business ideas for VPP

	Business idea	Central market role	Objective
1	Innovative electricity tariff from renewable energies regionally produced	Distributor (electricity supplier)	Supply of residential customers with electricity that is produced locally and from renewables (measured in 15 minutes time intervals)
2	Direct marketing of VPP's energy volumes	Pool coordinator	Market integration of renewable energy systems (wholesale market) Provision of balancing power through renewable energy systems Supply of distribution with renewable electricity
3	E-vehicles as flexible consumers of residential customers	Residential customer with e-vehicle	Business model as addition to Harz.EE-mobility and to business idea 1 aiming at the optimisation of electricity supply of residential customers
4	Storage services	Storage operator	Provision of flexibilities for the wholesale market and network operator
5	Network services in the distribution network	DSO	Utilisation of potentials of decentralised plants aiming at grid relief

Source: Translated and adapted from Filzek et al. (2012)

Originally, the project consortium aimed at implementing business idea 1 in the field test in and offer electricity from renewable energies regionally produced to residential customers. In the first phase of the project the feasibility of a commercialisation of this business idea was assessed in order to identify chances for the near future and prepare the exploitation of project results. Unfortunately, in-depth market analyses and detailed technical simulations revealed that the economic feasibility could not be proved as processes needed for the implementation were not set up at the stakeholders involved and additional costs could not be covered by the funding project's budget. (Schlögl et al., 2012)

According to Schlögl et al. (2012) some of the reasons why an economic and technical implementation of this business idea is not realistic with a short term perspective are presented in the following:

- The electricity price offered to end users may only slightly exceed the price of conventional electricity suppliers. Considering all fixed and operative costs and the current EEG remuneration paid to plant operators the price offered to the end user would not be competitive.

- In the long run production costs of renewable energy plants are low. Market and trade requirements for the first years of operation need to be adjusted in order to enable the profitability of the business idea.
- The range between highest and lowest electricity price offered by the time variable tariff does not incentivise the end customers adequately to exploit the load shifting potential available. Variable costs (as electricity production costs) only account for a quarter of the total electricity price; fixed costs (as EEG apportionment, grid utilisation fee, measurement costs etc.) are not flexible and thus, cannot be reduced.
- Accounting systems at the energy utility companies are not ready to implement time variable tariffs.
- Measurement equipment to enable readings in 15 minutes time intervals are not available in all households.
- Binding contracts between all stakeholders involved would have been to be concluded for the actual implementation of the time variable tariff in the field test. The assessment and implementation of contractual issues would have been very time intense and not all partners for the implementation needed were involved in the funding project. Thus, it was decided to carry out the field test with a virtual time-variable tariff which does not have any cost implications on the end customer.

Technical aspects

During the second phase of the field test several minor technical problems which were related to software and communication issues of components (e.g. firmware updates of components, WIFI connection of component to router etc.) were identified. Most of the technical problems were solved within a short time span and did not influence the project's operation significantly. One issue, which was experienced, was the control of the refrigerators and freezers. A software update of one of the components involved was needed and could not be provided within the duration of the field test. (Funke et al., 2013)

4.5.4 Impact and transferability

Dipl.-Ing. Patrick Hochloff explained that the project created awareness among project partners that the energy future will change. The first year of project execution was especially intense as the DSO was highly sceptical and cautious about the research approach. A trustworthy cooperation was set-up between the project partners, however, discussions and conflict situation with the implementation partners remained. (Hochloff, 2015)

Hochloff (2015) confirmed the transferability of the project, in particular the IT components and business models for energy economy that have been developed.

5 Recommendations and conclusions

This chapter summarizes the main findings of the previous sections, derives conclusions and addresses the research questions raised by the author of this thesis. Guided by the analytical framework, which was developed by structuring, comparing and interpreting meta-studies and other assessments (Section 3), four different DR pilot projects were assessed (Section 4). Based on these findings it is intended to give recommendations on which kind of market access requirements need to be provided to electricity consumers in order to enable them accessing the energy market (as described in Section 1.2). In total, seven recommendations are summarised in the following Section 5.1. Good practice examples of DSM operator models are presented in chapter 5.2. The DSM operator models are based on software solutions that were developed within the pilot projects and tested in a real life environment aggregating electrical producers and consumers via the approach of a VPP. Finally, the main findings and recommendations are concluded in Section 5.3.

5.1 Main findings and recommendations of the pilot projects' analysis

In the following the approach is shown how the conclusions and recommendations were drawn up:

- In an exercise with the aim to compare, analyse and conclude the results and activities of the four pilot projects are summarised.
- This endeavour is based on a comparative analysis of all four pilot projects.
- Main findings are structured along the categories of the analytical framework.
- In total, seven recommendations are formulated which address the requirements needed in order to enable electricity consumers accessing the energy market.

Recommendation 1: Community creation supports user activation as the sense of belonging to a community influences the engagement and participation.

The first step before enabling consumers to access the energy market is to activate their interest and engagement. Based on the findings and experiences of the pilot projects analysed the creation of a community supports user activation as the sense of belonging to a community influences the engagement. But this process needs to be well prepared; the following key components in setting-up and initiating this process were identified:

- An in-depth user segmentation and analysis of perceptions, attitudes and behavioural patterns is a cornerstone in developing a communication campaign. A participatory approach proved to be useful in PowerMatching City, but it is not feasible on a larger scale as the organisation of the process would be too time and resource-intense. Thus, a thorough analysis of user participation motives in DR programs is of high importance.
- Clustering of customer groups need to be based on their motivation to participate (e.g. trying a new technology, environmental consciousness, learning about energy consumption and making changes etc.) under consideration of sociodemographic factors.
- Although financial incentives seem to play a certain role in attracting users, the findings of the pilot projects showed that communication activities need to be tailored to the needs of the specific customer group (e.g. a blog, website, chat program etc.). For example, early technology adopters interested in the high level of ICT penetration and the interaction of devices, or energy conscious people interested in the effects of DR programs and how to save energy.
- With the support of an experienced testimonial, specific messages can be easily conveyed to the consumers (e.g. contributing to a sustainable future, joint efforts lead to a success etc.)
- Besides a series of communication events, regular information events and open house days, trainings how to use the technologies and the interaction of participants with the technology (user manual) support the engagement of consumers. Additional trainings for technicians and employees of the customer hotline support ensure a well prepared knowledge transfer to the consumers.

Recommendation 2: Variable tariff models need to offer an added value for an acceptable price to attract consumers.

The measurement of electricity consumption patterns of households provides a solid basis for time variable tariff models. Based on this baseline measurement it is easy to identify the change or shift of electricity consumption during a DR event.

Currently, dynamic pricing programs are only common in a few European member states as France or Italy. Numerous studies have shown that dynamic price signals show good effects to increase DR participation (Faruqui & Sergici, 2010) and they can lead to reductions in electricity consumption (Jessoe & Rapson, 2014). In general, tariff schemes should offer an added value for an acceptable price building upon a communication campaign keeping consumers informed and explaining to them how they can participate. Findings from the pilot projects are summarised in the following:

- The project PowerMatching City offers a good example of an energy service with a variable tariff. Two energy services were developed in a participatory approach; one tariff focussing on cost reductions using energy at cheapest times and the other one driven by motivations of sustainability or even self-sufficiency to use energy when it was locally produced.
- Pilot participants preferred a mixed tariff in the FP7 ADDRESS project combining a fixed and variable remuneration. The variable element was related to the extent of DR provided by the consumer.
- In the E-Energy E-DeMa project a performance-related tariff was tested, but it failed as the concept is for consumers too complicated to understand. The majority of consumers do not have any understanding how much power an electrical device consumes.

Drawing on the lessons learned from the pilot projects, the tariff structure must not be too complicated. For users an ‘easy to understand’ scheme is important and the tariff should match to their energy behaviour in order to promote user engagement in DR programs. Thus, not only the right services need to be offered to consumers but also a good understanding of the sales person and the customer support is needed to sell the right energy services.

Recommendation 3: Based on the visualised electricity consumption data consumers can be incentivised with premiums and other rewards to participate in DR programs.

In Faruqui & Sergici (2010) and in Stromback et al. (2011) it was confirmed that the utilisation of feedback devices visualising energy consumption data influences user behaviour. In the pilot projects different visualisation means were tested (e.g. in-house display, web portal, smart phone application). Users preferred in-house displays and mobile applications; thus, online web portals were used for more detailed assessments of historical consumption data aggregated on monthly or yearly basis. Additional functionalities, e.g. enabling the comparison with a reference group and offering competitive incentives, support customer engagement to participate in DR programs.

In the cases in which devices were automatically responding to DR signals users expressed the request to be easily able to change the settings via the in-house display, e.g. in the E-Energy RegModHarz project, it was only possible to adjust the schedules of automatically operated devices via the online portal which limited their interest and participation.

Recommendation 4: Data protection, privacy & security aspects need to be considered when ICT infrastructures and systems are designed and participation agreements with consumers concluded.

In the pilot projects no or only minor concerns were expressed about data protection, privacy or security aspects. This can be related to the early addressing of this kind of issues in the beginning of the project execution. Two levels were addressed in the pilot projects:

- ICT infrastructures and systems were analysed in relation to their security demand and risk mitigation. Security and privacy aspects were implemented in the ICT design.
- Participation agreements and contracts were concluded to summarise the rights and obligations of users and information about data utilisation and collection was given in detail.

Recommendation 5: The institutional and regulatory transformation of the energy market requires the introduction of new market players that develop services attractive for consumers.

All pilot projects selected focussed on load aggregation via different software solutions connected to hardware devices (following the concept of a VPP). Roles and responsibilities of market players were defined in order to ensure a smooth interaction. In this process the need for new roles of market players were identified. In addition to the aggregator, that creates portfolios being composed of small loads (produced and provided by prosumers) and brings them to the market, other market roles, e.g. energy system manager, are needed. These players do not directly interact with the consumers but provide services to enable an energy commercialisation. The energy system manager supervises and administers the operation of all energy systems and power plants connected to the VPP.

Good practice examples of operator models for load aggregation analysed in the pilot projects will be presented in Section 5.2.

Recommendation 6: Detailed cost-benefit-analyses are crucial for defining the added value of business models; financial advantages for consumers are quite low. Thus, aggregators respectively companies, who offer aggregation services, need to concentrate on key messages on a broader level in order to attract consumers.

Business models are understood in this context how market participants can create values based on value adding processes and gain revenues. In the pilot projects (in particular the E-Energy RegModHarz project) requirements for a sustainable development of business models were set-up:

- The development of business models needs to be based on a thorough market analysis and the existing access requirements to trade electricity on the energy market.
- The development of business models was bottom-up driven involving all stakeholders, e.g. plant operator, network operator, distributor, trader etc. They were brought together in workshops to discuss requirements, and chances and risks related to possible business models.

- The business models identified were described in detail, while additional aspects as implementation concepts for each market player, economic barriers, and existing framework conditions were addressed.

The economic translation of these business models to the energy market is still very difficult, but the pilot projects give some indications if these developments will be feasible in the future:

- In all pilot projects economic analyses were carried out; some of them were done on a broader system level (PowerMatching City, FP7 ADDRESS), others on the level of the specific business case (E-Energy E-DeMa, E-Energy RegModHarz).
- A cost-benefit analysis is due to various reasons difficult; costs for setting up the ICT infrastructure need to be taken into account which is difficult to assess as ICT solutions and devices needed for the enabling of load shifting are currently not commercialised or show a low level of technology penetration.
- In all cases the economic analysis showed that the commercial deployment of the business cases is not profitable yet.
- Considering national regulatory conditions and assuming increasing market prices for electricity until 2020 as well as decreasing acquisition costs for ICT components business could be viable.

As the economic analyses are done by project partners who have an economic interest (e.g. energy supplier, retailer, aggregator etc.), the detailed results are confidential and are not publicly shared. Therefore, an in-depth analysis of economic results has not been possible. In general, more insight on costs and benefits of DR programs would be favourable.

Recommendation 7: Standardisation and interoperability of technologies proved to be a basic condition for interaction of technical appliances and enabling technologies.

The findings of the pilot projects revealed that the harmonisation of communication of technical devices was very time consuming and cost intense; technical standardisation and interoperability proved to be a basic condition for interaction of technical appliances and enabling technologies in order to take advantage of

flexibility. User acceptance can only be achieved if standards take into account technical solutions that consider the current technology's service life.
Different technologies needed to be integrated that were used for the interconnectivity of the in-house devices; several of them even competed with each other (e.g. smart meters and the metering gateway). The involvement of manufacturers to build interfaces is crucial. The current situation is that devices as washing machines and dish washers are not able to switch on and off when a price signal is received; thus, an additional plug-in is needed.

Despite technical problems with hardware devices software and communication issues of components need to be considered (e.g. firmware updates of components, WIFI connection of component to router etc.).

It became apparent that pragmatic approaches to interlink and connect devices are not feasible for a large-scale rollout in future scenarios. Thus, the need and utilisation of a dedicated smart home network based on an interoperable ICT architecture ensuring interconnectivity seems a feasible solution.

5.2 Good practice examples of DSM operator models

In the pilot projects described in chapter 4 software solutions for load aggregation were utilised which are based on the approach of a VPP. VPPs have the advantage to balance fluctuations of distributed producers by pooling energy producers and consumers and enabling them to access the energy market (Krautzberger, 2014). Currently, this approach is gaining momentum in Europe as legislation and market regulation is changing. Thus, the transformation of the energy market is still ongoing and competition in retailer markets is needed to make this operator models attractive for consumers.

In the following section the findings of good practice examples of DSM operator models are presented. The DSM operator models are based on software solutions that were developed within the pilot projects and tested in a real life environment. A detailed analysis of each pilot project can be found in Section 4. Finally, conclusions for the further utilisation of these operator models are drawn.

PowerMatcher

In the project PowerMatching City (see Section 4.2) the software solution PowerMatcher Suite was utilised which development has started back in the year 2006. Devices producing or consuming electricity are intelligently clustered and aggregated with the PowerMatcher Suite. Their operation is automatically optimised with the aim to achieve an optimal match between electricity generation and consumption. (Power Matcher Suite, 2015)

According to Kesting and Bliek (2013) the Energy Monitor, an in-house display, was installed in the residents' homes which gives feedback to the end users about their energy consumption and local energy production of electrical devices as well as the costs at any time. It acts as the user interface which visualises consumption pattern and even enables the comparison with a peer group.

The PowerMatcher Suite has been commercialised as an open source technology and designed for various business areas that are based on utilising flexibility. For example, service providers can aggregate electrical loads of individual households and businesses and offer this flexibility to consumers. Energy service companies utilised the flexibility of businesses in order to reduce their connection capacity. Another business area is the intelligent energy management of consumption and production in the residential area. Based on these business areas electricity trading has proved to be a feasible business case by creating a VPP and clustering distributed generators, flexible loads and electricity storages in a single operational unit. (Power Matcher Suite, 2015)

E-DeMa market place

The operator of the E-DeMa market place acts as an intermediary bringing together supplier and consumer; prosumers are interacting with energy traders, DSOs and other market players (see chapter 4.4). During the pilot project the area was limited to the model region Rhein-Ruhr. (Laskowski et al., 2013)

Laskowski et al. (2013) describe in the final project report that two different in-home displays were implemented depending on electrical devices being automatically (IKT-GW2) or manually (IKT-GW1) controlled. The in-house display of group IKT-GW1 visualised the actual energy consumption in 15 minutes time interval and other information that led to an action (e.g. tariff and price colourfully visualized, 24-hours load curve, day time, meter reading for electricity (kWh), gas and water etc.). The

Home Energy Control User Interface (HECUI) of group IKT-GW2 provided additional information about actual consumption data of the devices automatically reacting on price signals. At the market place website fictional expenses or savings were compared to reference users and energy savings were rewarded with premiums. (Laskowski et al., 2013)

The creation of the E-DeMa market place enables electronic business and legal relations between market players and triggers positive effects as data consolidation, the shortening of clearing and business processes and the reduction of transaction costs through efficient communication. It offers business opportunities for various market players as energy suppliers, meter reading and energy service companies, aggregators as well as DSOs. (Laskowski, 2015)

E-Energy RegModHarz

In the pilot project E-Energy RegModHarz various producers, consumers and storages (mainly electric vehicles) were coordinated via a VPP aiming at a full exploitation of renewable energies.

The household’s devices were connected to a bi-directional energy management interface, the BEMI. Two appliances in each household were automatically controlled via the BEMI (e.g. washing machines, dryers, dishwasher, refrigerator, and freezer) and participants could fix time windows when consumption should be optimised. The BEMI visualised the actual tariff and the next day’s one via a display as well as the optimisation plans for the appliances automatically controlled. In addition, a LED tariff light indicated the actual tariff class using three different colours. The settings for the optimisation plan and the minimum and maximum temperatures for a refrigerator and freezer could be changed at the BEMI web portal. It also gave detailed information on power and energy demand of appliances controlled as well as of the entire household on a yearly, monthly and weekly basis. The market platform acted as an add-on to the BEMI web portal and enabled the participants to analyse their consumption and virtual account balance. (Speckmann et al., 2012)

Several business cases were developed and analysed in the project. One of them is the direct marketing of VPP’s energy volumes via a pool coordinator. The pool coordinator is responsible for the energy commercialisation and acts as a trader who aggregates electricity of decentralised energy producers (Speckmann et al., 2012).

It could be proved in the pilot projects selected by the author that the software solutions are technically ready to be utilised. But based on the recommendations presented in chapter 5.1 of this thesis there is much more to do than to provide technical solutions. Although they are the basis for further developments, there is still a long way ahead to change regulations, provide tariff models and enable consumers accessing the energy market. The country-specific analysis of regulatory conditions in Section 4.2 to 4.5 showed a different starting situation in the European member states – some of them already advanced, others still lacking behind.

5.3 Conclusions

In Section 5.1 the results of the pilot projects' analysis were summarised and in seven recommendations structured. In a next step good practice examples of DSM operator models were summarised in Section 5.2. Finally, these main findings are concluded.

User activation and participation

In all pilot projects analysed the participation of residential consumers was highly emphasised. The creation of a community – as summarised in Recommendation 1 – plays an essential role in long-term activation of residents supporting their market participation. The efforts in the pilot projects showed good results as long as the consumers had the feeling to be well informed and did not experience any technical problems. Thus, a continuous customer support is needed that immediately reacts on requests placed by consumers.

Although the projects had quite short piloting phases of less than twelve months, the user activation gave good insights how community building should be planned, structured and implemented to ensure an active participation and engagement of residential consumers.

Tariff schemes

Another aspect that adds on user activation is the provision of attractive tariff schemes offering an added value to customers (Recommendation 2). In the pilot projects different tariff models were tested ranging from performance-related tariffs, tariffs related to time zones or peak times and mixed ones combining a fixed and variable remuneration. Based on these findings it can be concluded that the emotional component has a high impact on the consumer. This means that the tariff scheme needs to convey a key message with which the consumer identifies him- or herself (as it was the case in the project PowerMatching City). The consumer could choose between an economic (cost-optimal) option and a sustainable (self-sufficient) one. This concept is in particular interesting for regions that have a high amount of customers with distributed renewable energy technologies (e.g. PV systems, heat pumps, CHP units etc.). In addition the tariff model needs to be 'easy-to-understand' and match the consumer's energy behaviour in order to promote user engagement in DR programs.

Visualisation of consumption data via an in-house display or smartphone app

The visualisation of energy consumption is inevitable when residential consumers access the energy market (Recommendation 3). Relevant information about consumption data, price signals and even data of a reference group gives the consumer the chance to adapt his/her behaviour. The freedom to decide and still being able to influence the automatic operation of devices is a strong request that was expressed by the residents in the pilot projects. Even if the automation of an electrical device as a washing machine or a dish washer is accepted, the possibility to interrupt is a 'must have' for users. The automated operation of heating facilities, e.g. heat pumps, electrical heaters or CHP units, was widely accepted under the condition that comfort criteria are not touched. In this case the settings (in form of time windows or operation schedules) should be easy to change via the in-house display or a smartphone app.

Protection of personal data and security

In all pilot projects analysed data protection, privacy and security concerns were early addressed in the beginning of the project execution considering the protection of personal data via participation agreements as well as security demand and risk mitigation in the ICT design (Recommendation 4). This is an important aspect which was rewarded by the residents with trust and openness to cooperate.

Data protection is a prerequisite for residential consumers accessing the energy market. Currently, it is a highly discussed topic in regards to the forthcoming roll-out of smart meters in the European member states. Through awareness and information campaigns existing concerns can be early addressed and met with explanation of procedures and risk mitigation measures.

Business models

The economic translation of business models to the energy market is still very difficult, but the pilot projects give some indications if these developments will be feasible in the future (Recommendation 6). Besides regulatory barriers the cost-benefit-ratio is still unclear as costs for setting up the ICT infrastructure needed for the enabling of load shifting are difficult to assess as technologies are currently not fully commercialised or show a low level of technology penetration. As acquisition costs of ICT components will decrease in upcoming years it can be expected that the cost-benefit-ratio of business models will become viable for DSM operators.

Nevertheless, DSM only constitutes limited economic advantages for residential consumers. Thus, other aspects as saving money or financial rewards need to attract or convince users to participate in DR programs (which refers to Recommendation 1 to 3 about community creation, awareness about energy behaviour and tariff schemes with added values for consumers).

Standardisation and interoperability of technologies

ICT technologies enabling DSM are widely commercialised but the harmonisation of communication of these technical devices is still very time consuming and cost intense (Recommendation 7). Technological progress has been made as findings and experiences of pilot projects are exchanged in networking activities about standardisation at the European level (e.g. CEN, CENELEC etc.). In addition the European Commission recognised the importance of open standards and highlights the need towards industry players to follow this recommendation in funded projects. Although developments are going in the right direction the lack of standards currently hampers the further commercialisation of DR.

Good practices of DSM operator models

In the pilot projects DSM operator models were developed supported by different software solutions connected to hardware devices (following the concept of a VPP). It became clear that the further utilisation of the VPP concept, which focuses on the aggregation of demand side resources optimally balanced with energy generation facilities, is promising and aims at the exploitation of DR solutions (Recommendation 5). In Austria aggregators are defined as market players according to the miscellaneous electricity market rules updated as of July 1st, 2015 of E-Control, the Austrian electricity regulator (E-Control, 2015).

In Austria a few VPP operators are currently active but which only commercialise flexibilities of industrial and commercial companies (e.g. Next Kraftwerke, VERBUND-Power Pool). The sector of residential consumers is still untapped due to several reasons: The basic technical equipment (e.g. a smart meter to measure energy consumption) is only implemented in a few households as the roll-out of smart meters is still in its beginning phase in Austria. Therefore, the energy consumption of residential consumers is only measured once per year and does not enable aggregators to take advantage of flexibilities unless they are willing to pay for the ICT enabling technologies.

The pilot projects show that the variety of software solutions, which technically enable load aggregation in the residential sector, is growing. But the interaction and interoperability with home energy management systems, which measure and control the energy consumption, still needs to be improved (as described in Recommendation 7).

As the economic analyses have proved in the pilot projects the current regulatory situation does not allow a viable business model for load aggregation. As the regulatory conditions have been improved in Austria, it can be expected that the market for DR in the residential sector will develop in the upcoming years (under the condition that technical requirements as a smart meter roll-out have been carried out). At the moment this kind of DSM operator models does not seem feasible to be implemented in Austria.

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Annex

Experts' questionnaire to assess pilot projects

A. Participation & acceptance of consumers

- If you reflect the implementation time of your DSM field trial how would you assess the active participation of consumers?
- Please identify the most important success factors for participation of consumers
- Can you think of any factors/ barriers that diminished success of participation in the field trial?

B. Institutional & regulatory framework

- If you consider the current regulatory situation in the country in which the pilot project has been implemented would you assess a commercial deployment of the pilot activities as feasible?
- Which market conditions do currently hamper a commercial deployment of load aggregation?

C. Roles, responsibilities, and interactions of market players

- How would you rate the set-up of market players in the project? Have the roles, responsibilities, and interactions of stakeholders been clearly defined?
- In which areas has the set-up of the market structure been modified to enable a smooth interaction of stakeholders?

D. Economic and financial aspects

- How do you evaluate the business models developed in the pilot project: Have the results of the pilot trial shown to be financially profitable for the stakeholders involved?
- What factors or barriers hindered the profitability of the business models developed in the pilot project?

E. Technical aspects

How do you assess the DSM enabling technologies (smart appliances and ICT infrastructure) in the project: could the project consortium succeed in enabling the interoperability of technologies and systems deployed?

F. Impact

If you reflect the results (output) and outcomes (effects) of the pilot project how would you rate the overall impact?

G. Replicability

- Assuming favourable regulatory policies and no or only limited market barriers how would you rate the replicability of the pilot project's results in the country in which the project has been implemented?
- What do you think which changes to the project set-up would have to be made to enable the replicability of the project?

List of reports for analysis of pilot projects

FP6 project INTEGRAL with focus on PowerMatching City

- PowerMatching City: power to the people? Showcasing the PowerMatching City project on user engagement, IEA DSM TASK 24 Subtask 2 report - The Netherlands (Mourik, 2014)
- From Consumer to Prosumer: Netherland's PowerMatching City Shows The Way. In: Energy Efficiency - Towards the End of Demand Growth (Kesting & Bliek, 2013)
- Deliverable 3.2 Service Models and Components (Gustavsson & Stahl, 2008)
- Deliverable 4.4 An Common Experiment Design Framework leading to an Integrated ICT-platform for Distributed Control (Kamphuis et al., 2009)
- Deliverable 8.1 Definition of test and evaluation procedures (Dimeas et al., 2009)
- Deliverable 8.2 Evaluation of the Results and Guidelines for EU Research (Dimeas et al., 2011)

FP7 ADDRESS

- Deliverable 1.1 Conceptual architecture including description of: participants, signals exchanged, markets and market interactions, overall expected system functional behaviour (Belhomme et al., 2009)
- Deliverable 1.2 Application of the ADDRESS conceptual architecture in four specific scenarios (Bouffard et al., 2010)
- Deliverable 5.1 Evaluation of Benefits of Active Demand (Lago et al., 2012)
- Deliverable 5.2 Key societal factors influencing the adoption of the ADDRESS Smart Grids architecture (Mander et al., 2013)
- Deliverable 5.3 Key economic factors influencing the adoption of the ADDRESS Smart Grids architecture (Linares, 2013)
- Deliverable 6.1 Description of the test location and detailed test program for (limited) prototype field test, simulation and hybrid tests (Eyrolles et al., 2011)
- Deliverable 6.2 Prototype Field Tests. Test Results (Delago et al., 2013)

E-Energy E-DeMa

- Konsortial- Abschlussbericht Verbundprojekt E-Energy: E-DeMa, Entwicklung und Demonstration dezentral vernetzter Energiesysteme hin zum E-Energy-Marktplatz der Zukunft (Laskowski et al., 2013)
- Technical and Economic Analysis of Future Smart Grid Applications in the E-DeMa Project, Conference Paper, 2012 3rd IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe), Berlin (Belitz et al., 2012)

E-Energy RegModHarz

- Landkreis als Vorreiter, Regenerative Modellregion Harz – Abschlussbericht (Schlögl et al., 2012)
- Landkreis als Vorreiter, Regenerative Modellregion Harz – Zusammenschau Infoblätter (Speckmann et al., 2012)
- Geschäftsmodelle für RegModHarz, Zusammenfassung Ergebnisbericht zu AP2.7.1 (Filzek et al., 2012)
- Arbeitspaket 4.3 Anbindung, Test und Betrieb von Haushaltslasten mit bidirektionalem IKT-Gateway (Funke et al., 2013)

List of persons interviewed

The following persons were interviewed for the external expert's analysis of the project (see Step 4 of the methodological approach in Section 1.3). In Table 21 the interviewees are listed followed by a short CV of each person interviewed.

Table 21 List of persons interviewed

Project	Interviewed person	Date and duration
PowerMatching City	Dr. Albert van den Noort, DNV GL, Project manager of PowerMatching City	24.08. 13:30 -
FP7 ADDRESS	Dr. Regine Belhomme, EDF, technical manager of the project	14.08.2015 10:00 – 11:30
E-Energy E-DeMa	Dr. Michael Laskowski, RWE, Project manager of E-DeMa	12.08.2015 09:00 – 09:40
E-Energy RegModHarz	Dipl.-Ing. Patrick Hochloff, Fraunhofer IWES, project employee in the area of VPP	12.08.2015 10:00 – 11:00

Source: Own compilation

Dr. Albert van den Noort, Head of Section Smart Energy since 2013, is an experienced consultant and project manager in various smart energy projects within DNV GL. As overall project manager of PowerMatching City, he gained knowledge on electricity and gas markets, gas applications and smart implementation of sustainable energy.[9]

Dr. Regine Belhomme is Project Manager and Senior Engineer in the R&D Division of EDF SA. Her activities have concerned the integration of Distributed Generation and Renewables into the transmission and distribution grids. She is also involved in projects on demand side integration and on active demand. She was the Technical Manager of the ADDRESS European Project.[10]

Dr. Michael Laskowski, Head „Innovative Network Strategies", RWE AG, Dortmund

[9] http://s36.a2zinc.net/clients/pennwell/PGE2015/Public/SpeakerDetails.aspx?FromPage=Calendar.aspx&ContactID=61104 (visited at 21.08.2015)
[10] http://www.dream-smartgrid.eu/advisory-board/ (visited at 14.08.2015)

Dipl.-Ing. Patrick Hochloff, Group manager VPP, Division Energy economy and grid operation, Fraunhofer Institut für Windenergie und Energiesystemtechnik (IWES)[11]

Fields of expertise:

- Use optimization of decentralized systems (CPLEX)
- Energy Economics simulations
- Matlab programming
- Energy market and trade
- Business model analysis
- economic analysis
- Renewable Energy Sources Act
- Virtual power plants
- Storage, biomass, biogas, cogeneration plants

[11] http://www.energiesystemtechnik.iwes.fraunhofer.de/en/personal/bereich-i/virtual-power-plants/hochloff-patrick.html (visited at 14.08.2015)